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Operating Instructions
Turbimax CUS51D

Sensor for turbidity and solids content

Endress+Hauser
People for Process Automation

Table of contents

1 About this document

1.1 Warnings

Structure of information	Meaning
DANGER **Causes (/consequences)** If necessary, Consequences of non-compliance (if applicable) ▶ Corrective action	This symbol alerts you to a dangerous situation. Failure to avoid the dangerous situation **will** result in a fatal or serious injury.
WARNING **Causes (/consequences)** If necessary, Consequences of non-compliance (if applicable) ▶ Corrective action	This symbol alerts you to a dangerous situation. Failure to avoid the dangerous situation **can** result in a fatal or serious injury.
CAUTION **Causes (/consequences)** If necessary, Consequences of non-compliance (if applicable) ▶ Corrective action	This symbol alerts you to a dangerous situation. Failure to avoid this situation can result in minor or more serious injuries.
NOTICE **Cause/situation** If necessary, Consequences of non-compliance (if applicable) ▶ Action/note	This symbol alerts you to situations which may result in damage to property.

1.2 Symbols

- Additional information, tips
- Permitted
- Recommended
- Forbidden or not recommended
- Reference to device documentation
- Reference to page
- Reference to graphic
- Result of a step

1.2.1 Symbols on the device

- Reference to device documentation
- Do not dispose of products bearing this marking as unsorted municipal waste. Instead, return them to the manufacturer for disposal under the applicable conditions.

2 Basic safety instructions

2.1 Requirements for the personnel

- Installation, commissioning, operation and maintenance of the measuring system may be carried out only by specially trained technical personnel.
- The technical personnel must be authorized by the plant operator to carry out the specified activities.
- The electrical connection may be performed only by an electrical technician.
- The technical personnel must have read and understood these Operating Instructions and must follow the instructions contained therein.
- Faults at the measuring point may only be rectified by authorized and specially trained personnel.

Repairs not described in the Operating Instructions provided must be carried out only directly at the manufacturer's site or by the service organization.

2.2 Intended use

The sensor is used to measure turbidity and solids content in water and wastewater.

The sensor is particularly suited for use in the following applications:
- Turbidity measurement in the outlet
- Solids content in activated sludge and recirculation
- Solids content in sludge treatment
- Filterable matter in outlet of WWTPs

Use of the device for any purpose other than that described, poses a threat to the safety of people and of the entire measuring system and is therefore not permitted.

The manufacturer is not liable for damage caused by improper or non-designated use.

2.3 Workplace safety

As the user, you are responsible for complying with the following safety conditions:
- Installation guidelines
- Local standards and regulations
- Regulations for explosion protection

Electromagnetic compatibility
- The product has been tested for electromagnetic compatibility in accordance with the applicable international standards for industrial applications.
- The electromagnetic compatibility indicated applies only to a product that has been connected in accordance with these Operating Instructions.

2.4 Operational safety

Before commissioning the entire measuring point:

1. Verify that all connections are correct.
2. Ensure that electrical cables and hose connections are undamaged.
3. Do not operate damaged products, and protect them against unintentional operation.
4. Label damaged products as defective.

During operation:

- If faults cannot be rectified:
  products must be taken out of service and protected against unintentional operation.

2.5 Product safety

The product is designed to meet state-of-the-art safety requirements, has been tested, and left the factory in a condition in which it is safe to operate. The relevant regulations and international standards have been observed.

3 Product description

3.1 Product design

The sensor is designed for continuous in-situ determination of turbidity and solids content.

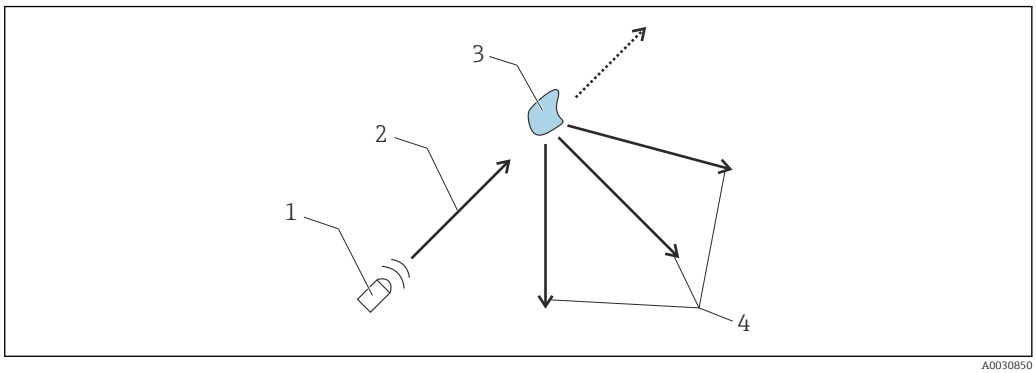
The sensor with the 40 mm (1.57 in) diameter can be operated directly and completely in the process without the need for further sampling (in-situ).

The sensor includes all necessary modules:
- Power supply
- Light sources
- Detectors
  Detectors record the measuring signals, digitize them and process them into a measured value.
- Sensor microcontroller
  This is responsible for controlling internal processes and transmitting data.

All data - including the calibration data - are stored in the sensor. The sensor can be precalibrated and used at a measuring point, calibrated externally, or used for several measuring points with different calibrations.

3.1.1 Measuring principle

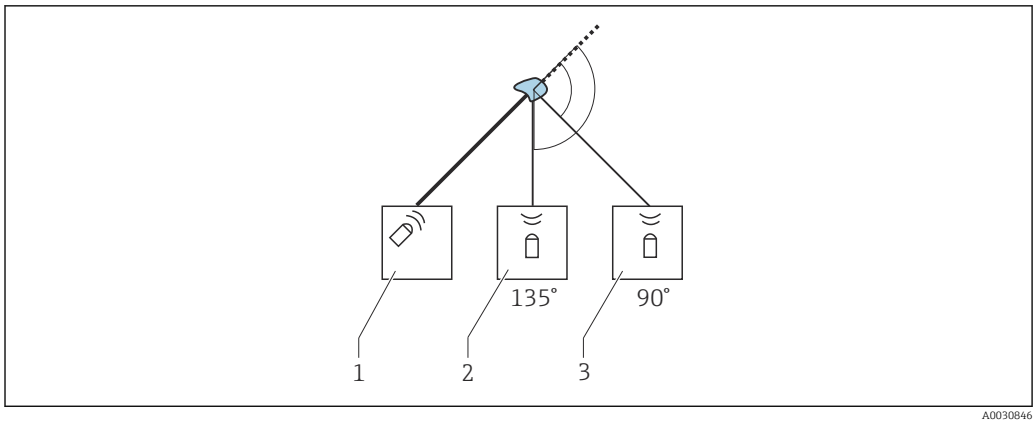
For turbidity measurement a light beam is directed through the medium and is deflected from its original direction by optically denser particles, e.g. particles of solid matter. This process is also called scattering.



1 Deflection of light

1 Light source
2 Light beam
3 Particle
4 Scattered light

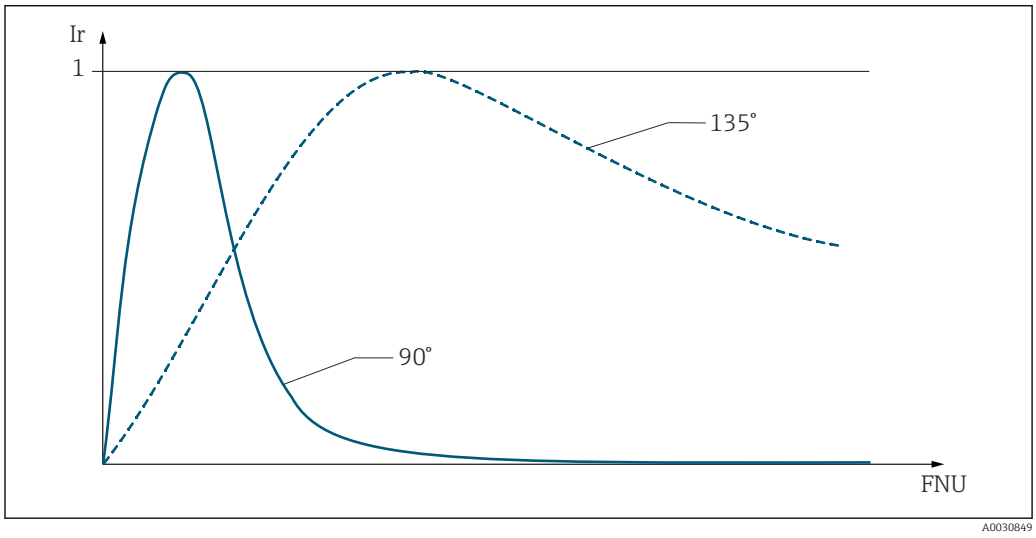
The incident light is scattered in many directions, i.e. at different angles to the direction of propagation. 2 angle ranges are of particular interest here:
- Light scattered at a 90° angle is used primarily for turbidity measurement in drinking water.
- Light scattered at a 135° angle extends the dynamic range for high particle densities.



2 Principle mode of operation of turbidity sensor

1 Light source
2 135° light receiver
3 90° light receiver

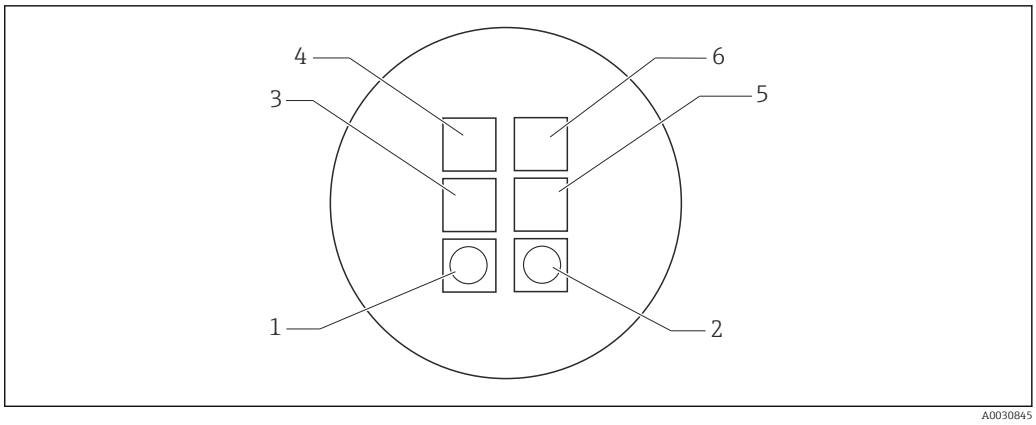
If the particle density in the medium is low, most of the light is scattered in the 90°channel and a small amount of light is scattered in the 135° channel. As the particle density increases, this ratio shifts (more light in the 135° channel, less light in the 90° channel).



3 Signal distribution as a function of the particle density

Ir Relative intensity
FNU Turbidity unit

The CUS51D turbidity sensor has 2 sensor units, which are independent of each other and arranged in parallel. The application-dependent evaluation of both signals leads to stable measured values.



4 *Arrangement of light sources and light receivers*

1, 2 Light sources 1 and 2
3, 5 135° light receiver
4, 6 90° light receiver

The sensor covers a broad range of turbidity and solids measurements thanks to the optical arrangement with 2 light sources, each with 2 light receivers placed at different angles (90° and 135°).

- As soon as the customer selects an application, e.g. **Activated sludge**, the optical method best suited for the particular measuring task is automatically activated in the sensor (e.g. 90° measurements with both light sources).
- The double sensing system (2 light sources with 2 receivers per source) largely compensates for measurement errors caused by fouling (4-beam pulsed light method → 9).

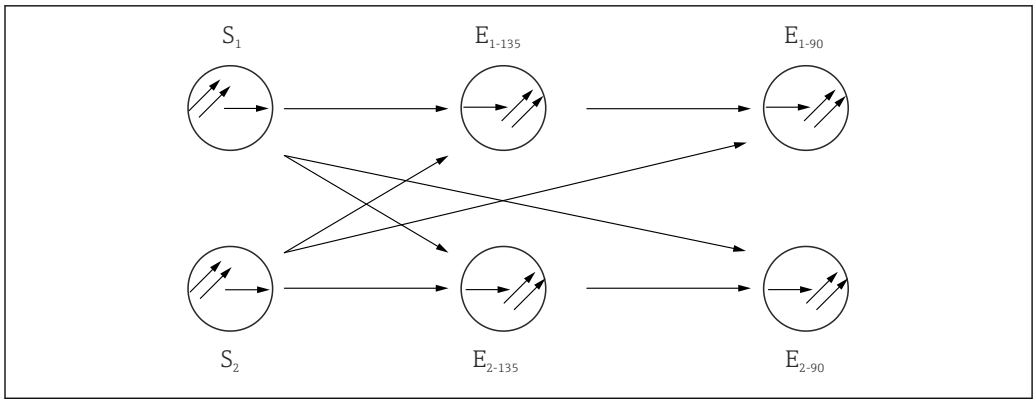
The sensor types available vary in terms of their measuring ranges and therefore the range of available applications.

3.1.2 Measuring methods

4-beam pulsed light method

The method is based on 2 light sources and 4 light receivers. Long-life LEDs are used as monochromatic light sources. These LEDs are pulsed alternately and generate 4 scattered light signals per LED pulse at the receivers.

This offsets interference influences such as extraneous light, LED aging, fouling of windows and absorption in the medium. Depending on the chosen application, different scattered light signals are processed. The signal type, number and calculation are stored in the sensor.



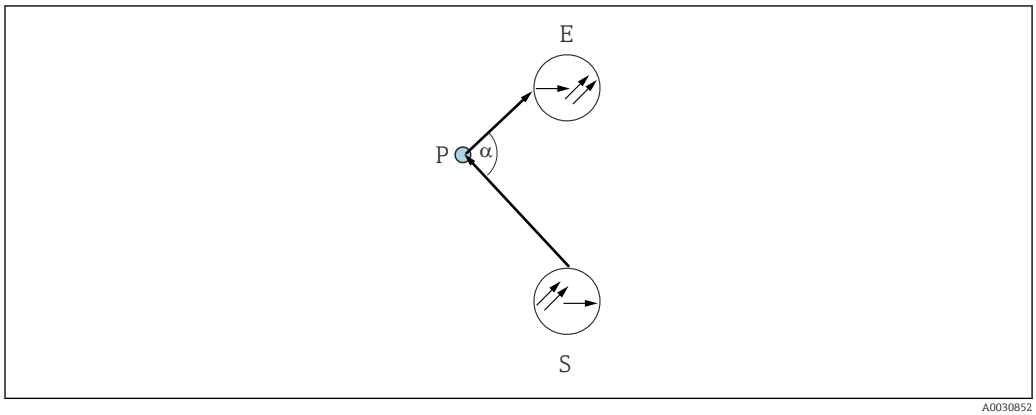
5 4-beam pulsed light method

S_1 S_2 Light source
E_{90} Light receiver for 90° scattered light
E_{135} Light receiver for 135° scattered light

90° scattered light method

Measurement is performed with a wavelength of 860 nm, as described in ISO 7027/EN 27027.

The emitted light beam is scattered by the solid particles in the medium. The scattered radiation generated in this way is measured by scattered light receivers, which are arranged at an angle of 90° to the light sources. The turbidity of the medium is determined by the amount of scattered light.

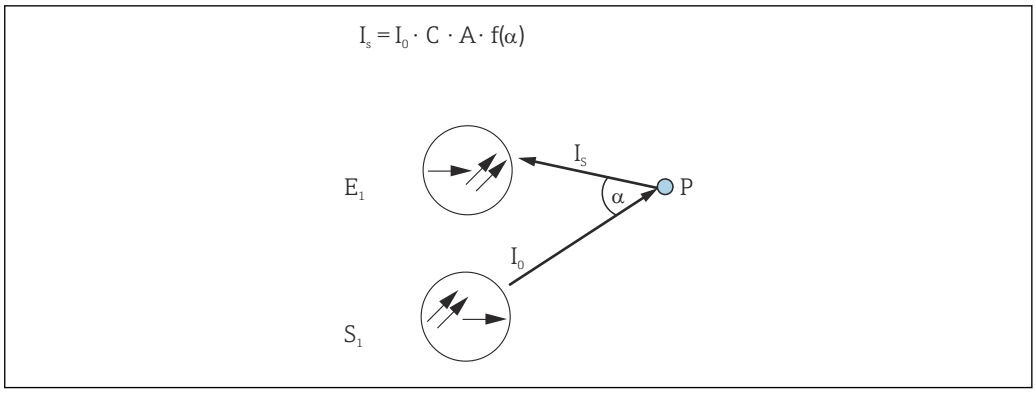


6 90° scattered light method

S Light source
E Receiver
P Particle

135° backscattered light method

The emitted light beam is scattered by the solid particles in the medium. The backscattering generated is measured by scattered light receivers, which are arranged next to the light sources. The turbidity of the medium is determined based on the quantity of back-scattered light. It is possible to measure very high turbidity values with this type of scattered light measurement.



7 *Principle of backscattered light method*

I_o Intensity of transmitted light
I_s Intensity of scattered light
A Geometric factor
C Concentration
P Particle
f(a) Angle correlation

4 Incoming acceptance and product identification

4.1 Incoming acceptance

1. Verify that the packaging is undamaged.
   ↳ Notify the supplier of any damage to the packaging.
   Keep the damaged packaging until the issue has been resolved.
2. Verify that the contents are undamaged.
   ↳ Notify the supplier of any damage to the delivery contents.
   Keep the damaged goods until the issue has been resolved.
3. Check that the delivery is complete and nothing is missing.
   ↳ Compare the shipping documents with your order.
4. Pack the product for storage and transportation in such a way that it is protected against impact and moisture.
   ↳ The original packaging offers the best protection.
   Make sure to comply with the permitted ambient conditions.

If you have any questions, please contact your supplier or your local Sales Center.

4.2 Product identification

4.2.1 Nameplate

The nameplate provides you with the following information on your device:
- Manufacturer identification
- Order code
- Extended order code
- Serial number
- Safety information and warnings

▶ Compare the information on the nameplate with the order.

4.2.2 Product identification

Product page

www.endress.com/cus51d

Interpreting the order code

The order code and serial number of your product can be found in the following locations:
- On the nameplate
- In the delivery papers

Obtaining information on the product

1. Go to www.endress.com.
2. Page search (magnifying glass symbol): Enter valid serial number.
3. Search (magnifying glass).
   ↳ The product structure is displayed in a popup window.
4. Click the product overview.
   ↳ A new window opens. Here you fill information pertaining to your device, including the product documentation.

4.2.3 Manufacturer address

Endress+Hauser Conducta GmbH+Co. KG
Dieselstraße 24
D-70839 Gerlingen

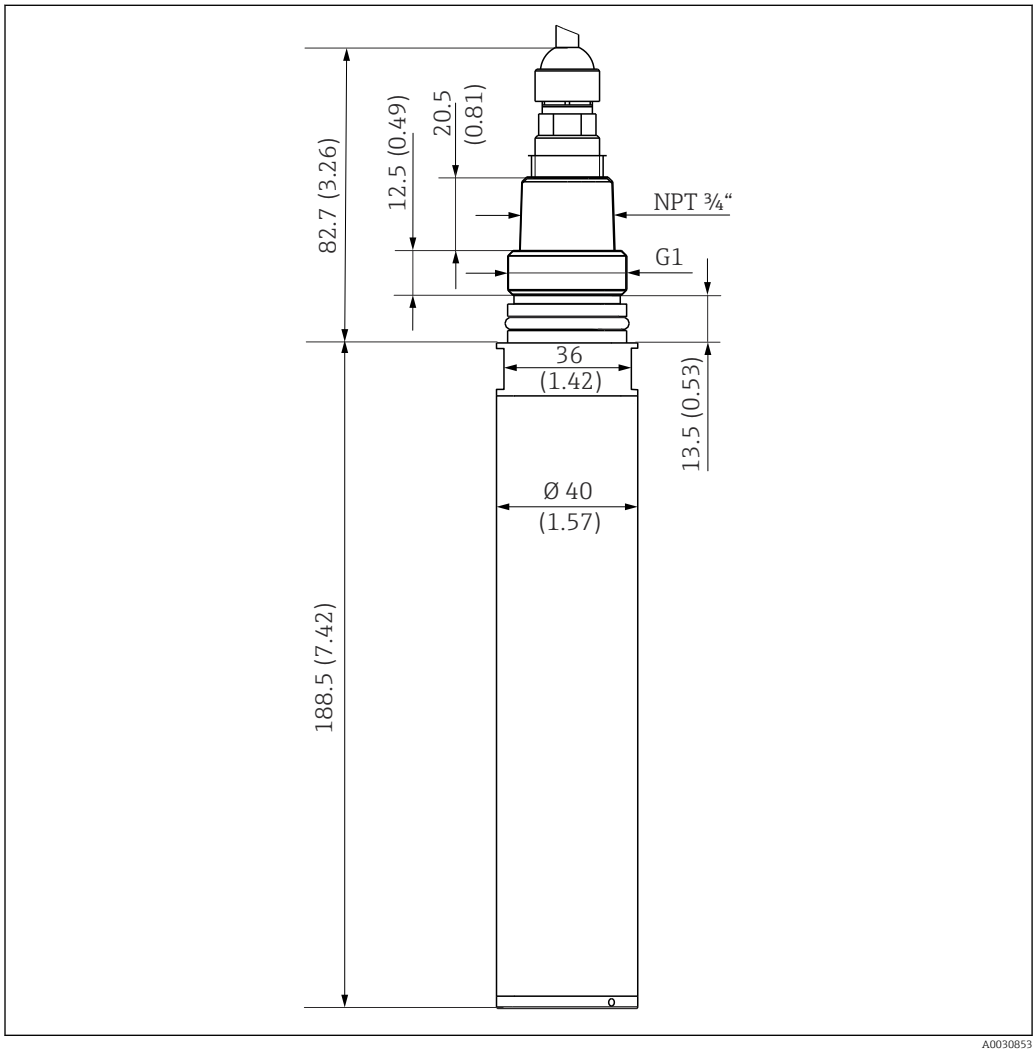
4.3 Scope of delivery

The delivery comprises:
- 1 Turbimax CUS51D sensor, version as ordered
- 1 Operating Instructions BA00461C

5 Mounting

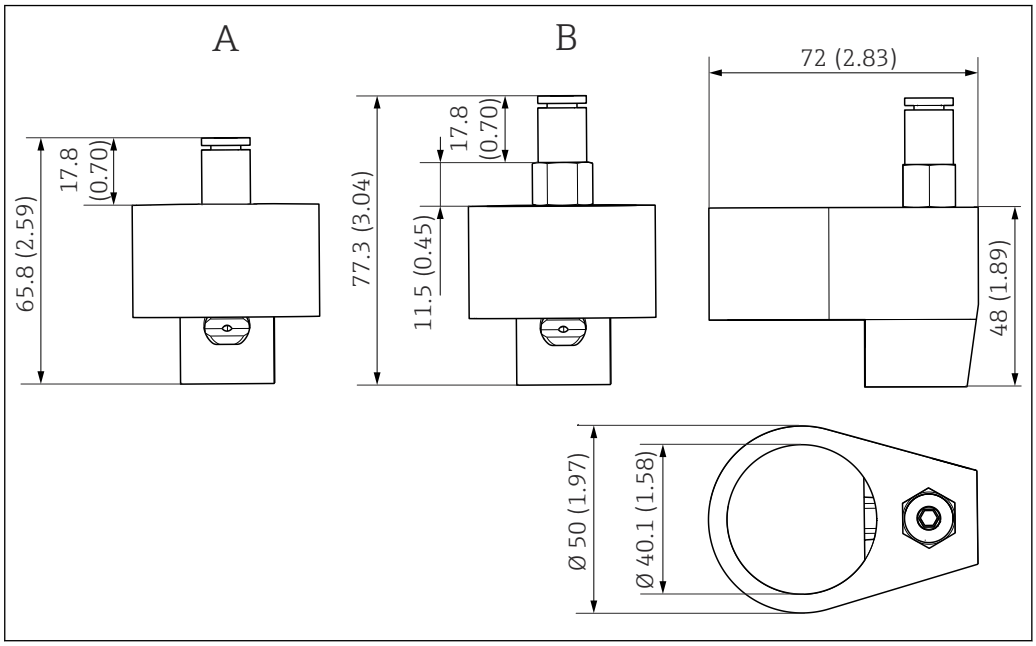
5.1 Mounting requirements

5.1.1 Dimensions



8 Dimensions. Engineering unit: mm (in)

Compressed air cleaning



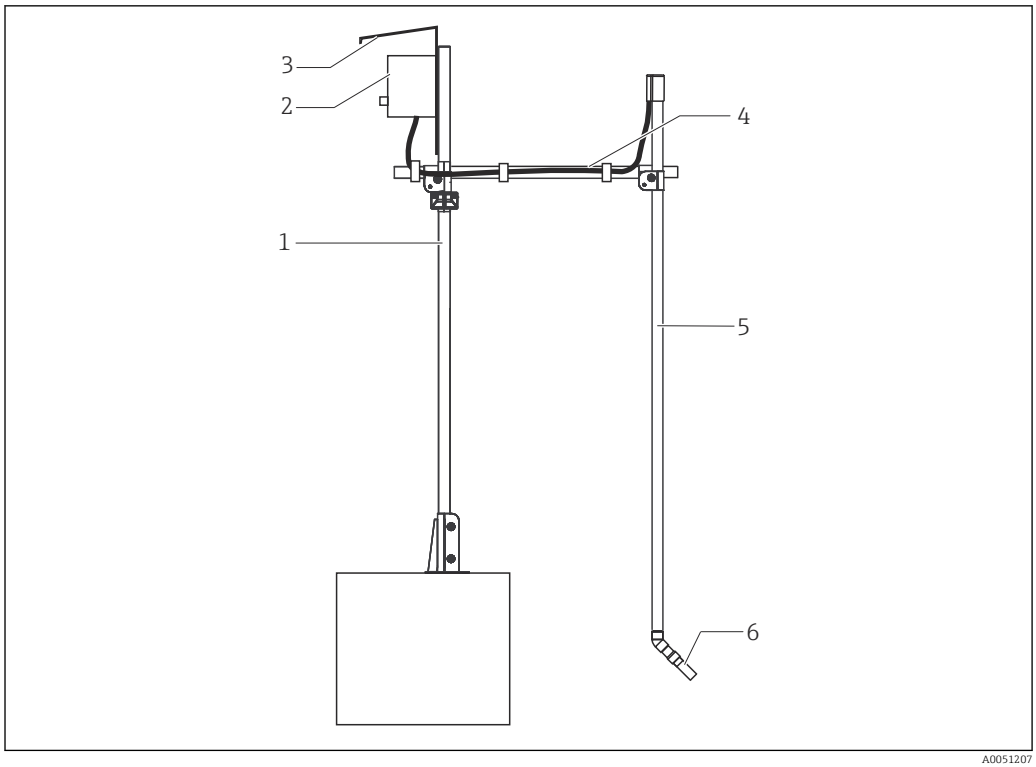
9 *Compressed air cleaning. Engineering unit: mm (in)*

A Version 6 mm (0.24 in)
B Version 6.35 mm (0.25 in)

5.2 Mounting the sensor

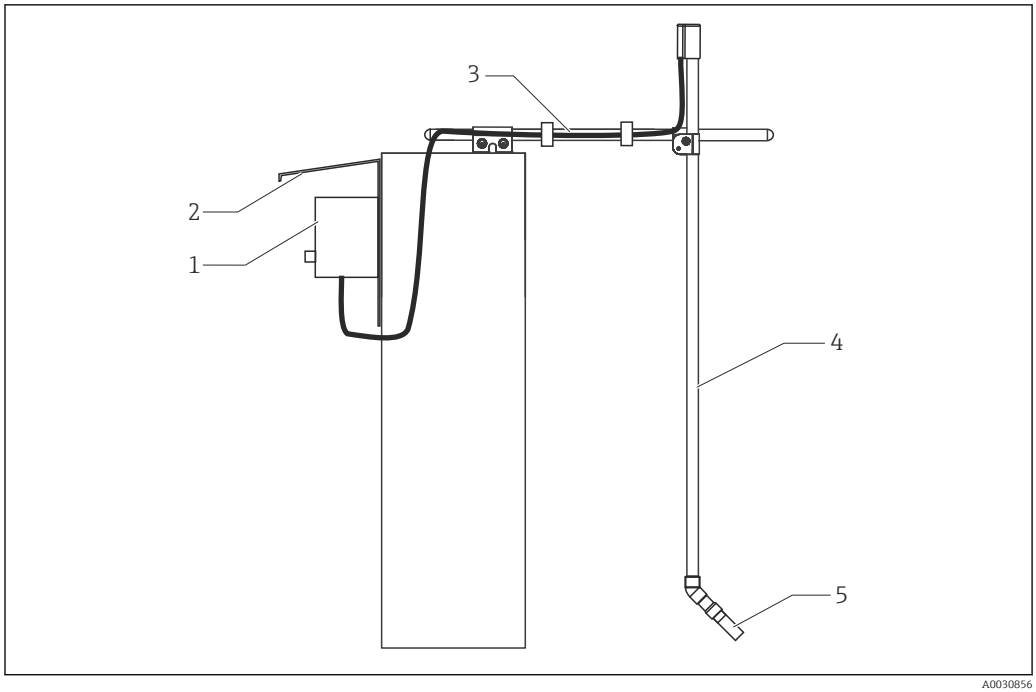
5.2.1 Measuring system

A complete measuring system comprises:
- Turbimax CUS51D turbidity sensor
- Liquiline CM44x multi-channel transmitter
- Assembly:
  - Flexdip CYA112 assembly and Flexdip CYH112 holder or
  - Retractable assembly, e.g. Cleanfit CUA451



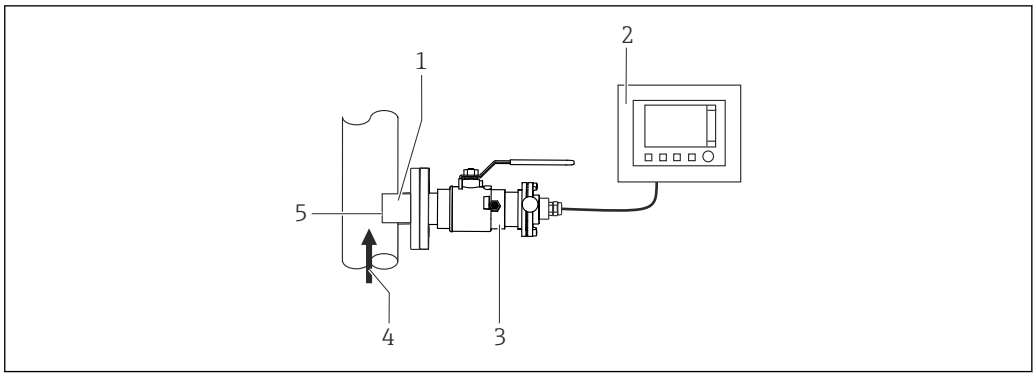
10 Measuring system with immersion assembly (example)

1 *Main pipe, Flexdip CYH112 holder*
2 *Liquiline CM44x multi-channel transmitter*
3 *Weather protection cover*
4 *Transverse pipe, Flexdip CYH112 holder*
5 *Wastewater assembly Flexdip CYA112*
6 *Turbimax CUS51D turbidity sensor*



11 Measuring system with immersion assembly (example)

1 *Liquiline CM44x multi-channel transmitter*
2 *Weather protection cover*
3 *Transverse pipe, Flexdip CYH112 holder*
4 *Wastewater assembly Flexdip CYA112*
5 *Turbimax CUS51D turbidity sensor*

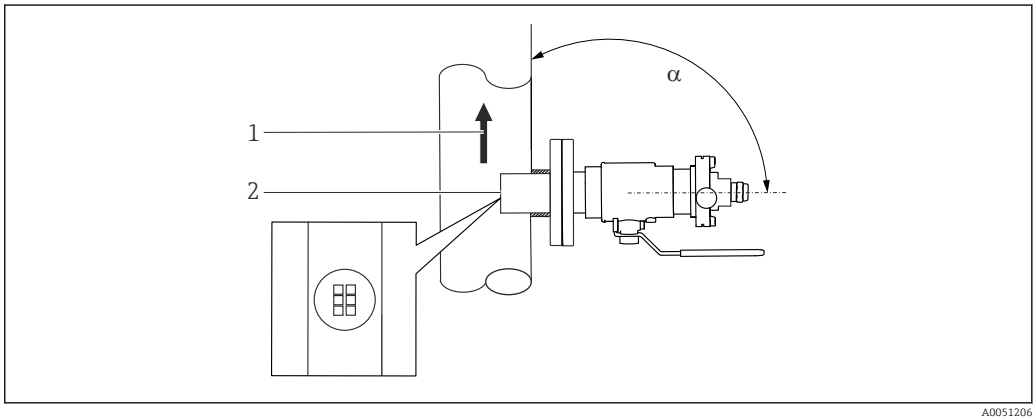


12 *Measuring system with retractable assembly (example)*

1 *Turbimax CUS51D turbidity sensor*
2 *Liquiline CM44x multi-channel transmitter*
3 *Cleanfit CUA451 retractable assembly*
4 *Flow direction*
5 *Optical windows*

5.2.2 Installation examples

Pipe installation

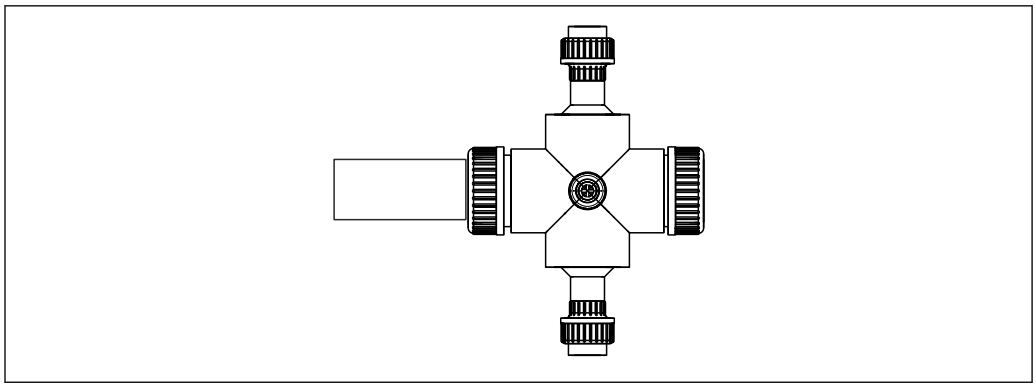


13 *Installing with retractable assembly*

1 *Flow direction*
2 *Optical windows*

The installation angle α must not exceed 90° → 13, 17. The recommended installation angle is 75°. The optical windows of the sensor must be aligned along the flow direction.

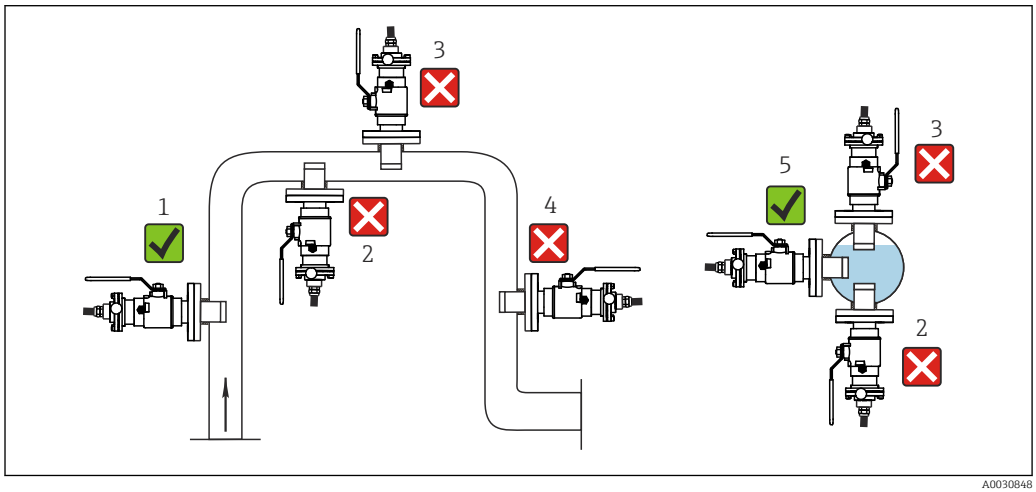
The medium pressure may not exceed 2 bar (29 psi) for manual assembly retraction.



14 *Installing with CYA251 flow assembly*

The installation angle is 90°. For turbidity measurements < 200 FNU, the backscattering of the internal surfaces of the assembly causes distortions in the measured values.

The following diagram shows different installation scenarios in pipes, indicating whether or not they are permitted.

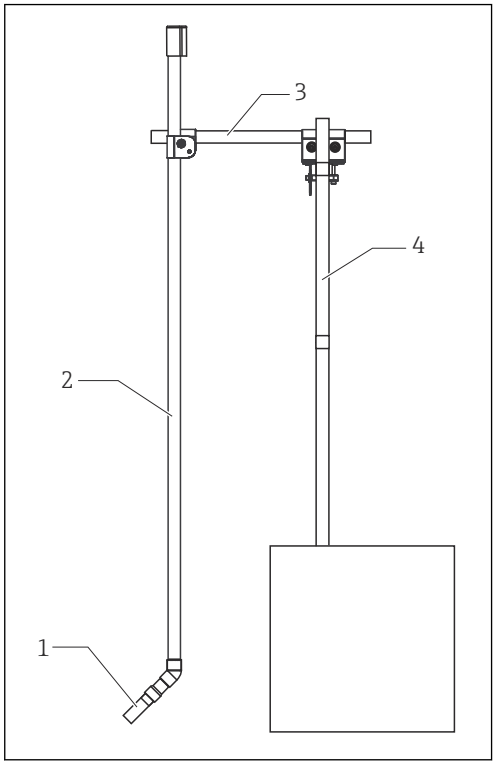


15 *Orientations and positions (with CUA451 retractable assembly)*

- When using reflective materials (e.g. stainless steel), the pipe diameter must be at least 100 mm (3.9 in). An onsite calibration is recommended.
- Install the sensor in places with consistent flow conditions.
- The best installation location is in the ascending pipe (item 1). Installation is also possible in the horizontal pipe (item 5).
- Do not install in places where air spaces or bubbles occur (item 3) or where sedimentation may occur (item 2).
- Avoid installation in the down pipe (item 4).
- When measuring turbidity < 200 FNU, the backscattering of the pipe wall causes distortions in the measured values. For this reason, measured value adjustment with an offset is recommended here.
- Avoid fittings downstream from pressure reduction stages which can lead to outgassing.

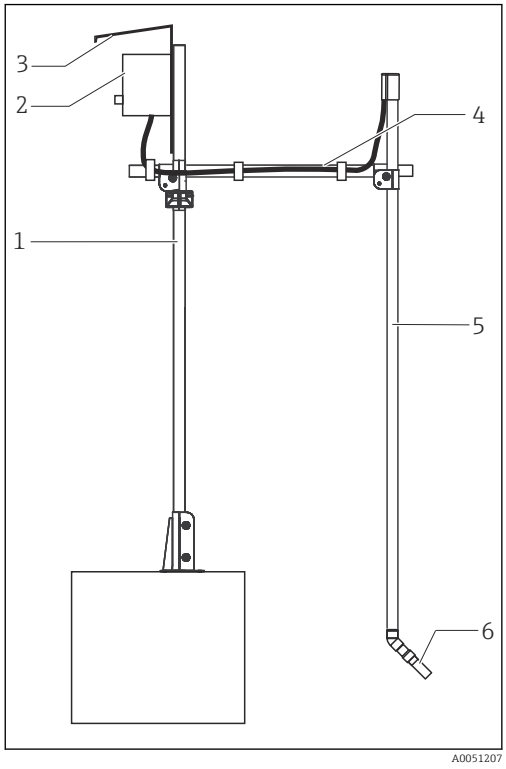
Immersion operation

Fixed installation with wastewater assembly



16 *Installation on railing*

1 *Turbimax CUS51D turbidity sensor*
2 *Wastewater assembly Flexdip CYA112*
3 *Transverse pipe, Flexdip CYH112 holder*
4 *Main pipe, Flexdip CYH112 holder*

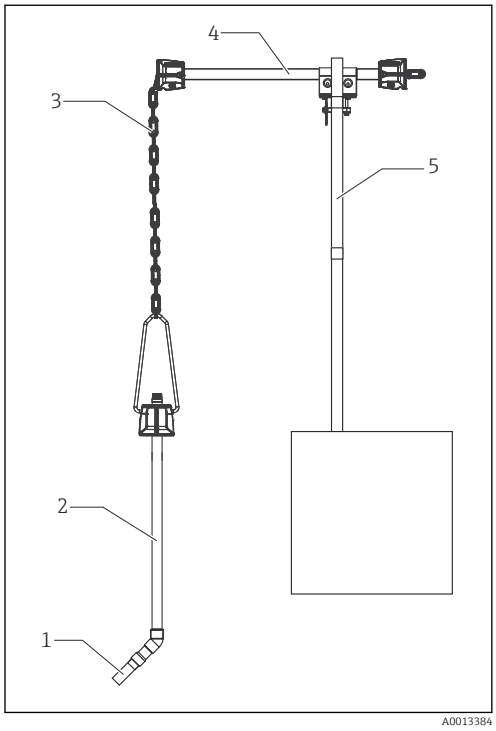


17 *Installation with upright post*

1 *Main pipe, Flexdip CYH112 holder*
2 *Liquiline CM44x multi-channel transmitter*
3 *Weather protection cover*
4 *Transverse pipe, Flexdip CYH112 holder*
5 *Wastewater assembly Flexdip CYA112*
6 *Turbimax CUS51D turbidity sensor*

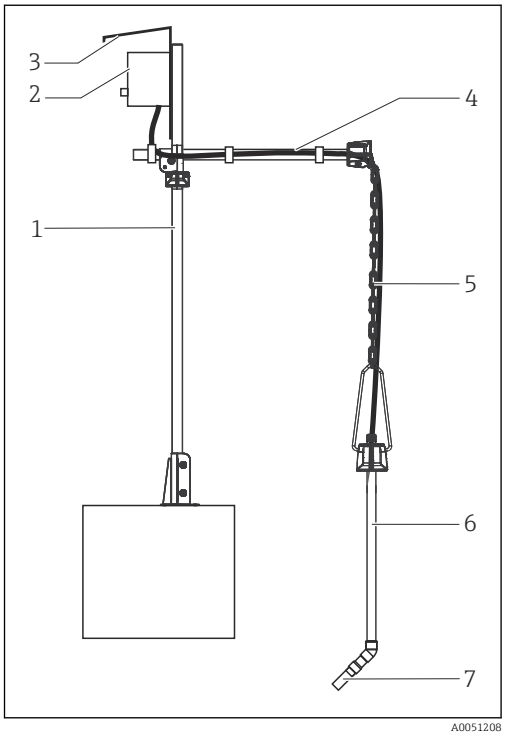
This type of installation is particularly suitable for strong or turbulent flow (> 0.5 m/s (1.6 ft/s)) in basins or channels.

Installation with chain retainer



18 *Chain retainer on railing*

1 *Turbimax CUS51D turbidity sensor*
2 *Wastewater assembly Flexdip CYA112*
3 *Chain of Flexdip CYH112 holder*
4 *Transverse pipe, Flexdip CYH112 holder*
5 *Main pipe, Flexdip CYH112 holder*



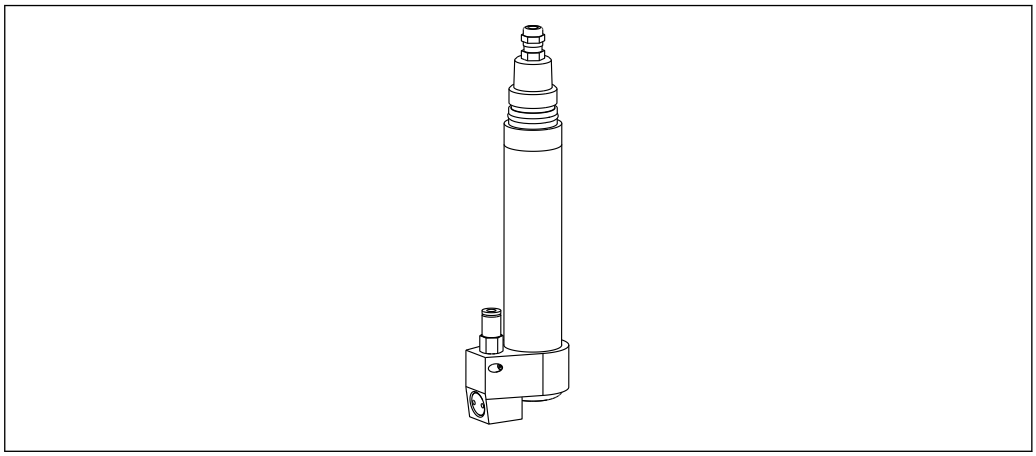
19 *Chain retainer on upright post*

1 *Main pipe, Flexdip CYH112 holder*
2 *Liquiline CM44x multi-channel transmitter*
3 *Weather protection cover*
4 *Transverse pipe, Flexdip CYH112 holder*
5 *Chain of Flexdip CYH112 holder*
6 *Wastewater assembly Flexdip CYA112*
7 *Turbimax CUS51D turbidity sensor*

The chain retainer is particularly suitable for applications that require a sufficient distance between the mounting location and the wall of the aeration basin. As the assembly is freely suspended, any vibration of the upright post is avoided. The swinging of the chain enhances the self-cleaning effect of the optics.

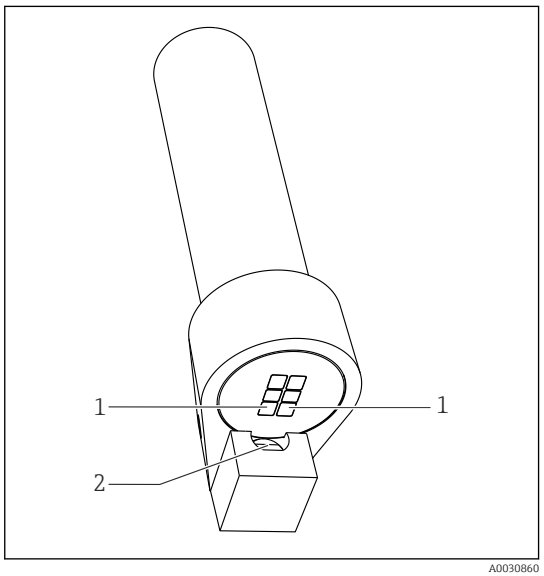
For detailed information on mounting with the wastewater assembly, see the Operating Instructions BA00432C

Mounting the cleaning unit



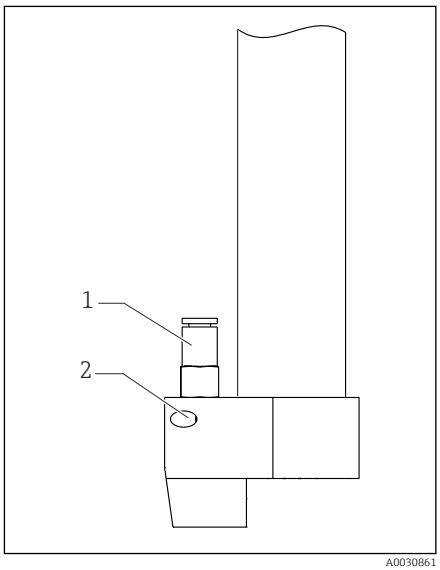
20 Turbimax CUS51D sensor with cleaning unit

The cleaning unit is particularly suitable for clear water or media with a high fat content that tend to cause heavy buildup.



21 Aligning the cleaning unit

1 LEDs
2 Nozzle



22 Fixing the cleaning unit

1 Hose connection
2 Fixing screw

Mount the cleaning unit as follows:

1. Fit the cleaning unit onto the sensor as far as possible.
2. Locate the two LEDs (they are installed at an angle and have a bright background).
3. Position the cleaning unit in such a way that the nozzle is located at the side of the two LEDs (→ 21).
4. Fix the cleaning unit in place with the securing screw using an Allen key 2.5 mm (0.1 in) (max. torque: 0.5 Nm (0.37 lbf ft).
5. Insert the compressed air hose of the compressor into the hose connection.

5.3 Post-mounting check

Put the sensor into operation only if the following questions can be answered with "yes":
- Are the sensor and cable undamaged?
- Is the orientation correct?
- Has the sensor been installed in the process connection, and does not suspend freely from the cable?

6 Electrical connection

⚠ WARNING

Device is live!

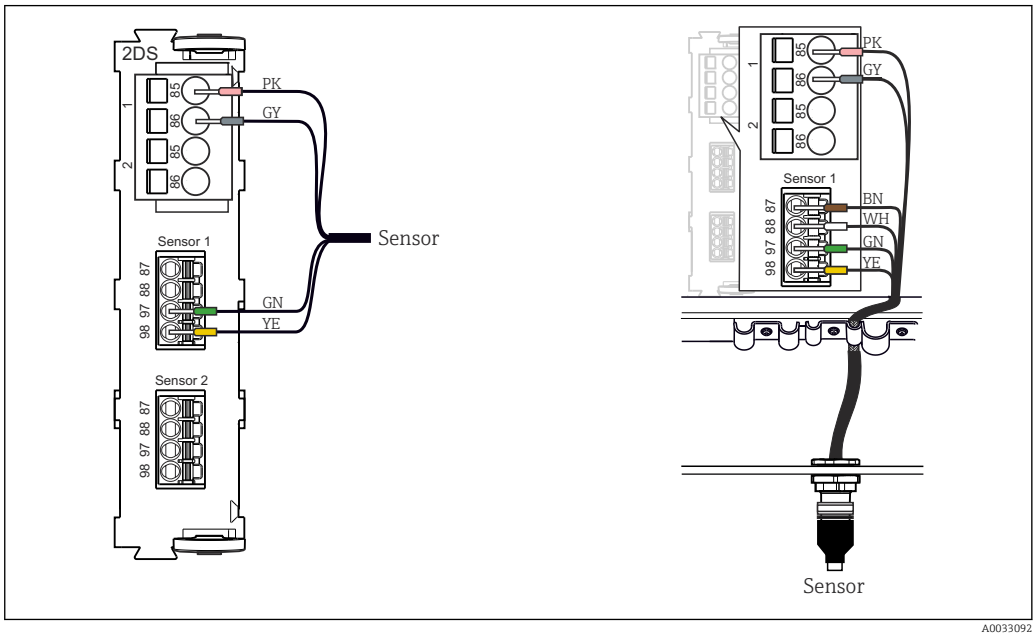
Incorrect connection may result in injury or death!

- ▶ The electrical connection may be performed only by an electrical technician.
- ▶ The electrical technician must have read and understood these Operating Instructions and must follow the instructions contained therein.
- ▶ **Prior** to commencing connection work, ensure that no voltage is present on any cable.

6.1 Connecting the sensor

The following connection options are available:

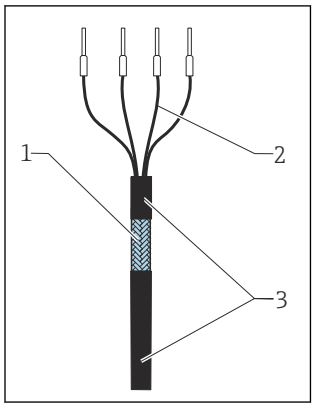
- via M12 connector (version: fixed cable, M12 connector)
- via sensor cable to the plug-in terminals of a sensor input on the transmitter (version: fixed cable, end sleeves)



23 Sensor connection to sensor input (left) or via M12 connector (right)

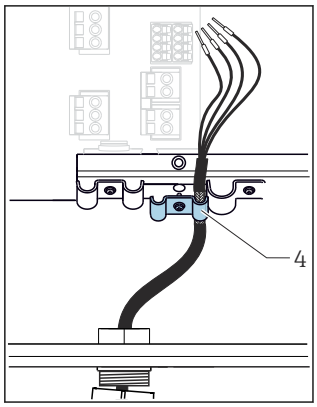
Connecting the cable shield

Cable sample (does not necessarily correspond to the original cable supplied)



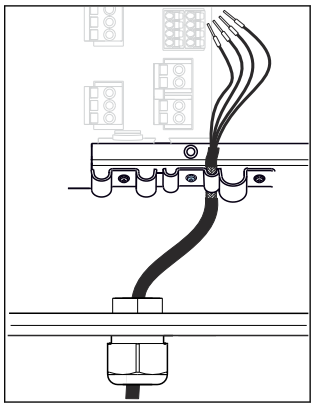
24 Terminated cable

1 Outer shield (exposed)
2 Cable cores with ferrules
3 Cable sheath (insulation)



25 Inserting the cable

4 Grounding clip



26 Tightening the screw (2 Nm (1.5 lbf ft))

The cable shield is grounded by the grounding clip

The maximum cable length is 100 m (328.1 ft).

6.2 Ensuring the degree of protection

Only the mechanical and electrical connections which are described in these instructions and which are necessary for the required, designated use, may be carried out on the device delivered.

► Exercise care when carrying out the work.

Individual types of protection permitted for this product (impermeability (IP), electrical safety, EMC interference immunity) can no longer be guaranteed if, for example :
- Covers are left off
- Different power units to the ones supplied are used
- Cable glands are not sufficiently tightened (must be tightened with 2 Nm (1.5 lbf ft) for the permitted level of IP protection)
- Unsuitable cable diameters are used for the cable glands
- Modules are not fully secured
- The display is not fully secured (risk of moisture entering due to inadequate sealing)
- Loose or insufficiently tightened cables/cable ends
- Conductive cable strands are left in the device

6.3 Post-connection check

Device health and specifications	**Action**
Is the outside of the sensor, assembly or cable free from damage?	► Perform a visual inspection.
Electrical connection	**Action**
Are the mounted cables strain-relieved and not twisted?	► Perform a visual inspection. ► Untwist the cables.
Is a sufficient length of the cable cores stripped, and are the cores positioned in the terminal correctly?	► Perform a visual inspection. ► Pull gently to check they are seated correctly.
Are the power supply and signal lines connected correctly?	► Use the transmitter wiring diagram.
Are all screw terminals tightened?	► Tighten the screw terminals.

Device health and specifications	Action
Are all cable entries mounted, firmly tightened and leak-tight?	▶ Perform a visual inspection. In the case of lateral cable entries:
Are all cable entries mounted on the side or pointing downwards?	▶ Point cable loops downward so that water can drip off.

7 Commissioning

7.1 Function check

Prior to initial commissioning, ensure that:
- The sensor is correctly installed
- The electrical connection is correct

8 Operation

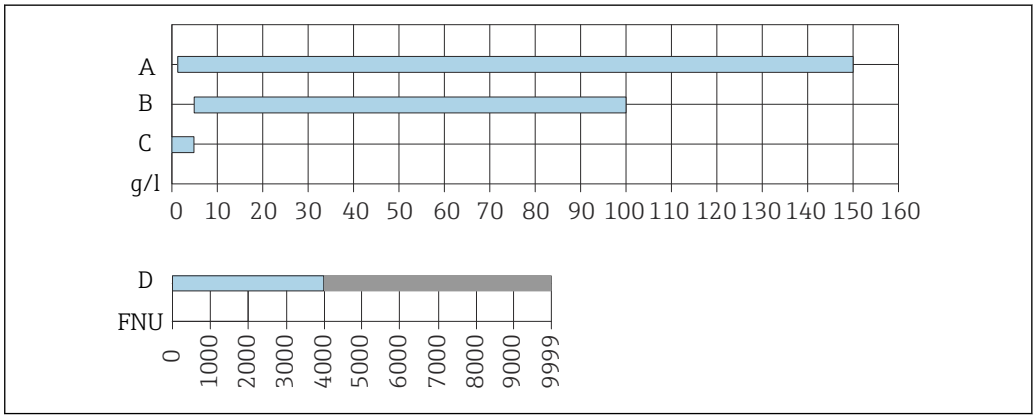
8.1 Adapting the measuring device to the process conditions

8.1.1 Applications

The sensor permits measurements in a wide variety of applications. The measuring method is set automatically by selecting the relevant application.

Clear water *application type*

Application	Method	Measuring range
Formazine	135° - single-channel measurement	0 to 4000 FNU Display range up to 9999 FNU
Kaolin	135° - single-channel measurement	0 to 5 g/l
TiO2	135°, 4-beam pulsed light	0.2 to 150 g/l
SiO2	135°, 4-beam pulsed light	5 to 100 g/l

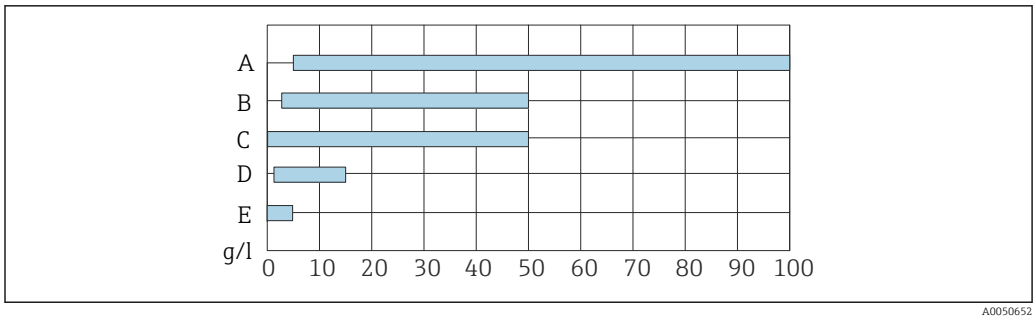


27 **Clear water** *application type*

A TiO2
B SiO2
C Kaolin
D Formazine

Solid *application type*

Application	Method	Measuring range
Thin sludge	135° turbidity, single-channel	0 to 5 g/l
Activated sludge	90°, 4-beam pulsed light	2 to 15 g/l
Excess sludge	135°, 4-beam pulsed light	3 to 50 g/l
Sludge, general	135°, single-channel (for low TS content)	0 to 50 g/l
	135°, 4-beam pulsed light (for high TS content)	
Digested sludge	135° turbidity, single-channel	5 to 100 g/l / 300 g/l



28 **Solid** *application type*

A *Digested sludge*
B *Excess sludge*
C **Sludge, general** *(mainly for SBR applications)*
D **Activated sludge** *(only for TS ranges > 2 g/l)*
E *Thin sludge*

The **Thin sludge** application enables measurements in any sludge applications from 0 to 5 g/l (0 to 0.04 lb/gal). Measurements in numerous sludge applications from 0 to 50 g/l (0 to $^{0}.^{4}$/lb/ga) (e.g. SBR) are possible with the **Sludge, general** application. These applications can be calibrated at a single point in the process during operation.

Fields of use and associated applications → 28

NOTICE

Multiple scattering in the following applications: formazine, kaolin and thin sludge
If the specific operational range is exceeded, the measured value displayed by the sensor can decrease despite increasing turbidity or increasing TS content. The indicated operational range is reduced in the case of highly absorbing (e.g. dark) media.

- In the case of highly absorbing (e.g. dark) media, determine the operational range experimentally beforehand.

8.1.2 Calibration

The sensor is precalibrated on leaving the factory. As such, it can be used in a wide range of applications (e.g. clear water measurement) without any further calibration. The factory calibrations are based on a three-point calibration in each case. The **Formazine** application is already fully calibrated and can be used without any further calibration.

All other applications are precalibrated with reference samples and require calibration to the corresponding application.

In addition to the factory calibration data, which cannot be modified, the sensor has five other data records to be used for storing process calibrations.

Application selection

- During initial commissioning or calibration at the transmitter, select the appropriate application for your field of application and measuring range.

Application: Wastewater

Field of application	Range	Application	Recommended type of calibration
Inlet	< 5 g/l	**Thin sludge [mg/l, g/l]** Formazine [FNU, NTU]	Single-point (in the process)
	> 5 g/l	**Excess sludge [g/l, %TS]**	Two-point (outside the process)

Field of application	Range	Application	Recommended type of calibration
Primary sludge extraction, primary clarification	3 to approx. 50 g/l	**Excess sludge [g/l, %TS]**	Two-point (outside the process)
	> approx. 50 g/l	**Digested sludge[g/l, %TS]**	Two-point (outside the process)
Aeration basin	0 to 5 g/l	**Thin sludge [mg/l, g/l]**	Single-point (in the process)
	2 to 15 g/l	**Activated sludge [mg/l, g/l]** Excess sludge [g/l, %Ts]	Two-point (outside the process)
Sequencing batch reactors	0 to approx. 50 g/l	**Sludge, general [mg/l, g/l, %TS]** For applications with wide dynamic range, from clear water to high solids content	Single-point (in the process)
Recirculation pipe	3 to approx. 50 g/l	**Excess sludge [g/l, %TS]**	Two-point (outside the process)
Waste activated sludge extraction	3 to approx. 50 g/l	**Excess sludge [g/l, %TS]**	Two-point (outside the process)
	> approx. 50 g/l	**Digested sludge [g/l, %TS]**	Two-point (outside the process)
Sludge thickener (primary sludge)	3 to approx. 50 g/l	**Excess sludge [g/l, %TS]**	Two-point (outside the process)
	> approx. 50 g/l	Digested sludge [g/l, %TS]	Two-point (outside the process)
Digester inlet	3 to approx. 50 g/l	**Excess sludge [g/l, %TS]**	Two-point (outside the process)
	> approx. 50 g/l	Digested sludge [g/l, %TS]	Two-point (outside the process)
Digester outlet (sludge)	> 5 g/l	**Digested sludge [g/l, %TS]**	Two-point (outside the process)
	3 to maximum 50 g/l	Excess sludge [g/l, %TS]	Two-point (outside the process)
WWTP outlet	0 to 5 g/l	**Formazine [FNU, NTU], Thin sludge [mg/l, g/l]** Kaolin [mg/l, g/l]	Single-point (in the process)
Sand filter monitoring	0 to 5 g/l	**Formazine [FNU, NTU], Thin sludge [mg/l, g/l]**	Single-point (in the process)

Preferred applications are highlighted in bold.

Application: process water

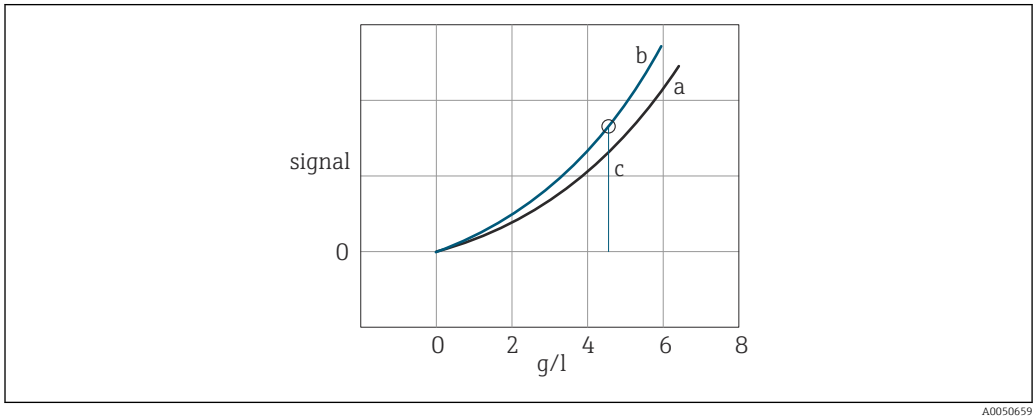
Field of application	Range	Application	Recommended type of calibration
Silicon dioxide process water	0 to 5 g/l	**Formazine [FNU, NTU],** Thin sludge [mg/l, g/l], **Kaolin [mg/l, g/l])**	Single-point (in the process)
Silicon dioxide process sludges	5 to 100 g/l	**SiO2 [ppm, g/l]**	Two-point (outside the process)
Titanium dioxide process water	0 to 1 g/l	**Formazine [FNU, NTU]**, Thin sludge (mg/l, g/l), **Kaolin [mg/l, g/l])**	Single-point (in the process)

Field of application	Range	Application	Recommended type of calibration
Titanium dioxide process sludges	1 to 150 g/l	**TiO2 [ppm, g/l]**	Two-point (outside the process)
Kaolin process water/ process water sludges	0 to 5 g/l	**Kaolin [mg/l, g/l]**	Single-point (in the process)

Preferred applications are highlighted in bold.

Type of calibration (number of calibration points)

Single-point calibration

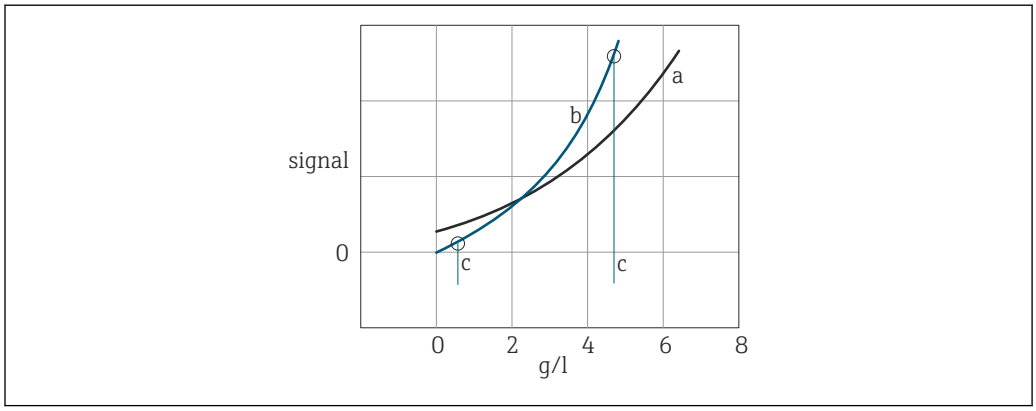


29 *Single-point calibration*

a *Factory calibration curve*
b *New calibration curve*
c *Calibration point*

A single-point calibration causes a change in the slope of the factory calibration curve programmed into the device.

Two-point calibration



30 *Two-point calibration*

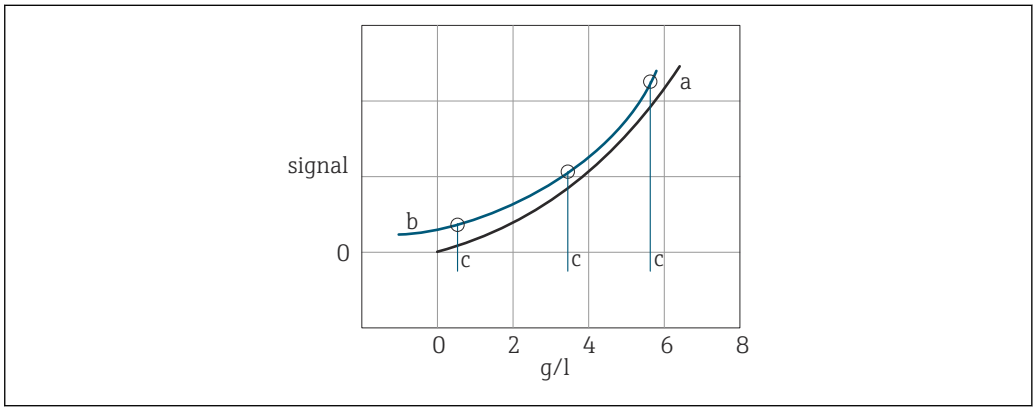
a *Factory calibration curve*
b *New calibration curve*
c *Calibration points*

A two-point calibration causes a change in the slope and zero point of the factory calibration curve programmed into the device. This type of calibration is recommended as

the standard method as it produces robust calibration curves and good measurement results with minimum calibration effort.

1. Select the two calibration points at the limits of the expected measuring range.
2. Do not select any calibration points outside the specified measuring range for the application.

Three-point calibration



31 *Three-point calibration*

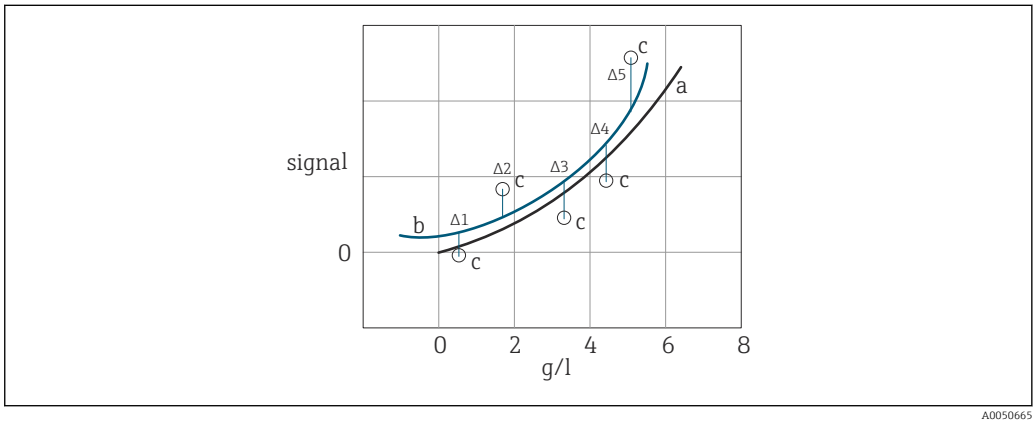
a *Factory calibration curve*
b *New calibration curve*
c *Calibration points*

With a three-point calibration, a new calibration curve is plotted through all 3 calibration points, resulting in a high level of accuracy in the calibrated range.

1. Within the measuring range, select calibration points that are as far apart as possible.
2. Do not select any calibration points outside the specified measuring range for the application.

If the calibration points selected are inappropriate, the curve profile will be distorted to an extent that could result in implausible measured values.

Five-point calibration



32 *Five-point calibration*

a *Factory calibration curve*
b *New calibration curve*
c *Calibration points*

With a four- or five-point calibration, the calibration curve is plotted between the calibration points. Avoid this type of calibration if possible, as it does not significantly improve accuracy.

Explanations regarding the type of calibration

Single-point and two-point calibrations are based on the factory data record stored internally in the device. In the case of a calibration at 3 points or more, the original factory calibration curve is always rejected and a completely new calibration curve is calculated.

For multipoint calibrations, the calibration points should always cover the complete measuring range of the application.

A calibration with zero water (0 g/l) will result in unusable calibrations for the following applications:
- Activated sludge
- Excess sludge
- Digested sludge
- SiO2
- TiO2

Procedure for single-point calibration

With 1-point calibration, the sensor can remain immersed in the process medium.

1. For the laboratory measurement, take a sample of the medium in the direct vicinity of the sensor.
2. Give the sample to the laboratory so that the turbidity or solids content can be determined.
3. Select a data record on the CM44x transmitter.
4. If possible, start the calibration at the same time as the sampling procedure and enter the laboratory value of the sample as the set point.
5. Enter an approximate value as the set point if no laboratory value is available during calibration.
   ↳ As soon as the laboratory value is available, amend the set point on the transmitter.

Procedure for multipoint calibration

⚠ CAUTION

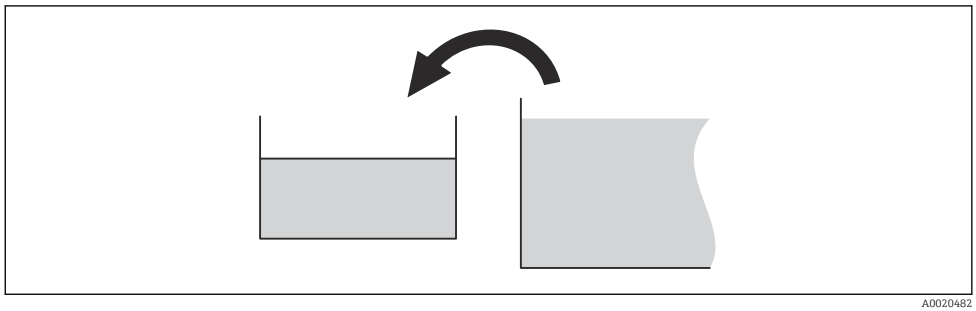
Acid or medium

Risk of injury, damage to clothing and the system!

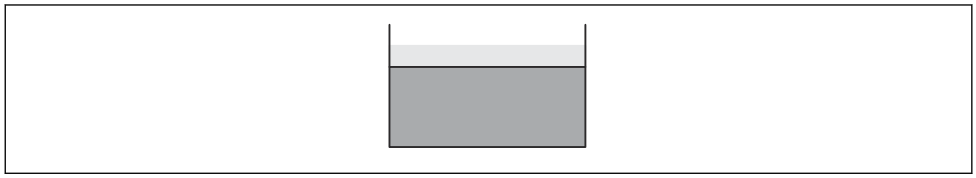
- ▶ Switch off the cleaning unit before removing the sensor from the medium.
- ▶ Wear protective goggles and safety gloves.
- ▶ Clean away splashes on clothes and other objects.

Sample preparation of the calibration solutions:

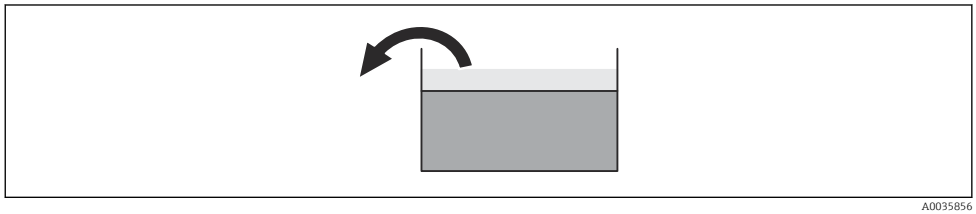
In the case of multipoint calibrations, the calibration takes place outside the process. For this, a sample is taken from the process and prepared accordingly.

1. 
A0020482

Take a sample from the process (e.g.10 l (2.6 gal) bucket).

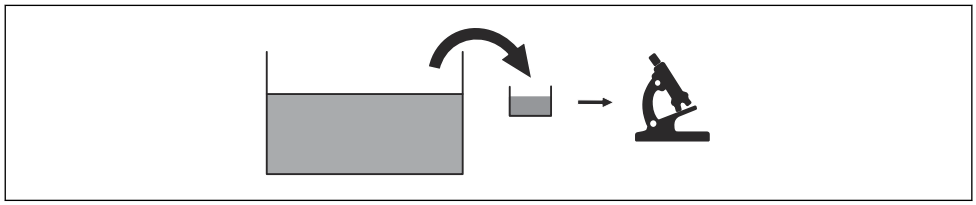
2. 
A0035855

Wait until the sludge components have settled.

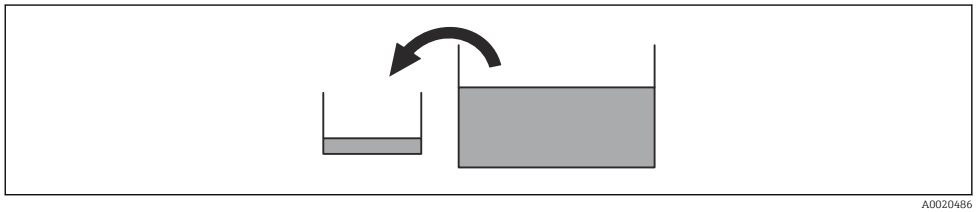
3. 
A0035856

Siphon off the excess water (if possible) in order to increase the concentration of the sample.

4. Stir the sample to make it more homogeneous.

5. 
A0020485

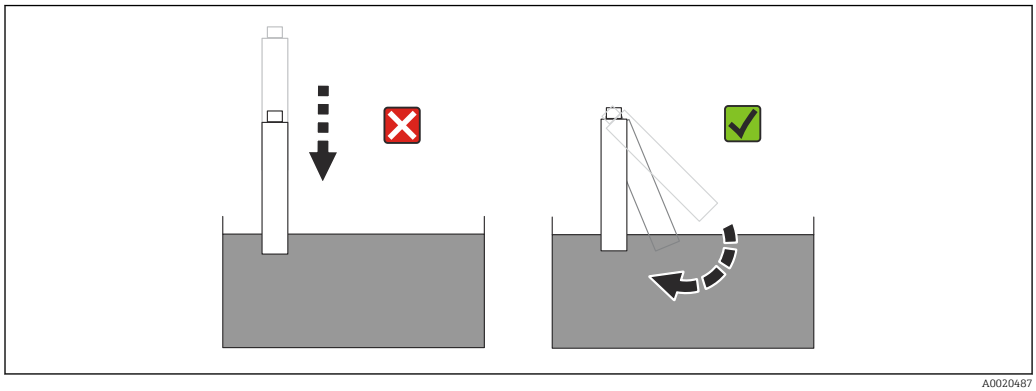
Remove a portion of the sample for laboratory analysis.

6. 
A0020486

Transfer a defined amount of the sample (e.g.2 l (0.5 gal)) to the calibration vessel (bucket).

7. Continue stirring the sample to maintain homogeneity.

Sensor calibration



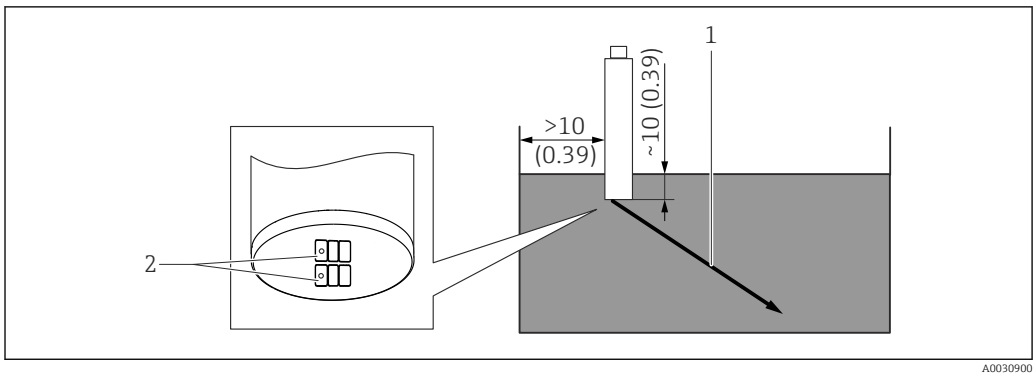
33 *Immersing the sensor*

Preparing the sensor for calibration:

1. Clean the optical components (windows) of the sensor with water and a brush or sponge.
2. Place the sensor into the calibration vessel.
3. The sensor must be placed in the sample at an angle, not vertically. → 33, 34
   ↳ This prevents air bubbles from adhering to the windows.

Observe the following:
- Sensor LEDs are directed at the center of the calibration vessel.
- The minimum distance of the sensor to the vessel wall is 10 mm (0.4 in).
- The distance to the vessel floor is as large as possible. The sensor must be immersed in at least 10 mm (0.4 in) of the medium, however.

▶ Secure the sensor in this position (ideally using a laboratory stand).



34 *Positioning the sensor. Dimensions: mm (in)*

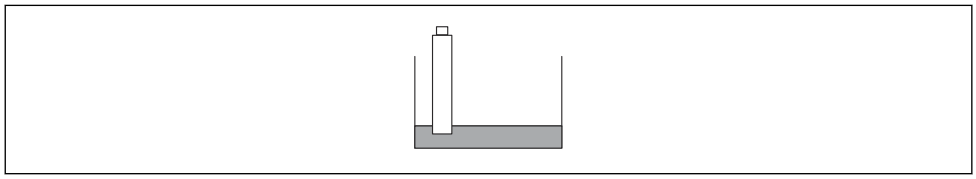
1 Beam direction of LEDs
2 LEDs

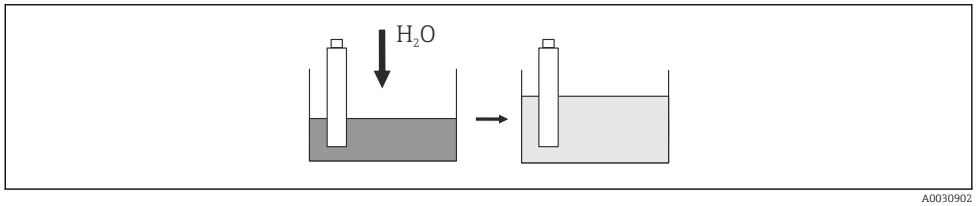
Note the following during calibration:
- The calibration points should cover the complete measuring range.
- During calibration, ensure that the medium is well homogenized (use a magnetic stirrer).
- Determine the laboratory measured values with utmost care (the quality of the laboratory measurement has a direct influence on the accuracy of the sensor).
- Apply maximum precision when dosing volumes for the sample and the dilution water (use a graduated cylinder).
- Air bubbles on optical components significantly interfere with the calibration result. For this reason, remove air bubbles before every calibration action.

- Make sure the medium is always well mixed (homogeneity).
- Avoid temperature changes during the calibration.
  Ensure that the temperatures of the dilution water and the medium are as identical as possible.
- Do not alter the position of the sensor during calibration.
- It is also possible to edit the calibration set points in the CM44x at a later stage (e.g. if the reference value of the laboratory measurement is not yet known at the time of calibration).

Performing a calibration:

Using the example of a two-point calibration in the expected measuring range 2 to 6 g/l.

1. At the CM44x transmitter, select a free data record and the suitable application.
2. Wait at least 1 minute (to stabilize).
3. 

   Start the calibration for measuring point 1 (e.g. 2 l (0.5 gal). Sample with a concentration of 6 g/l (0.05 lb/gal)).
4. Enter the value of the sample determined in the laboratory as the set point (e.g. 6 g/l (0.05 lb/gal)) or edit the value later.
5. 

   Perform a 1:3 dilution of the sample. Add water (4 l (1.1 gal)); in the example this results in 2 g/l (0.02 lb/gal).
6. Avoid air bubbles beneath the sensor.
7. Calibrate measuring point 2. Enter a third of the laboratory value as the set point.

The calibration can also be performed in increasing concentrations (less advisable).

Stability criterion

During calibration, the measured values provided by the sensor are checked to ensure they are constant. The maximum deviations that may occur in measured values during a calibration are defined in the stability criterion.

The specifications comprise the following:
- The maximum permitted deviation in temperature measurement
- The maximum permitted deviation in measured value as a %
- The minimum time frame in which these values must be maintained

The calibration resumes as soon as the stability criteria for signal values and temperature have been reached. If these criteria are not met in the maximum time frame of 5 minutes, no calibration is performed - a warning is issued.

The stability criteria are used to monitor the quality of the individual calibration points in the course of the calibration process. The aim is to achieve the highest possible calibration quality in the shortest possible time frame while taking external conditions into account.

For calibrations in the field in adverse weather and environmental conditions, the measured value windows selected can be suitably large and the time frame selected can be suitably short.

8.1.3 Cyclic cleaning

For cyclic cleaning, compressed air is the most suitable option. The cleaning unit is either supplied or can be retrofitted, and is attached to the sensor head. The following settings are recommended for the cleaning unit:

Type of fouling	Cleaning interval	Cleaning duration
Severe fouling with rapid buildup of deposits	5 minutes	10 seconds
Low degree of fouling	10 minutes	10 seconds

9 Diagnostics and troubleshooting

9.1 General troubleshooting

When troubleshooting, the entire measuring point must be taken into account:
- Transmitter
- Electrical connections and cables
- Assembly
- Sensor

The possible causes of error in the following table refer primarily to the sensor.

Problem	Check	Remedial action
Blank display, no sensor reaction	▪ Line voltage at transmitter? ▪ Sensor connected correctly? ▪ Buildup on optical windows?	▸ Connect mains voltage. ▸ Establish correct connection. ▸ Clean sensor.
Display value too high or too low	▪ Buildup on optical windows? ▪ Sensor calibrated?	▸ Clean device. ▸ Calibrate device.
Display value fluctuating greatly	Is the mounting location correct?	▸ Select a different mounting location. ▸ Adjust measured value filter.

Pay attention to the troubleshooting information in the Operating Instructions for the transmitter. Check the transmitter if necessary.

10 Maintenance

⚠ CAUTION

Acid or medium

Risk of injury, damage to clothing and the system!

- ▶ Switch off cleaning before the sensor is removed from the medium.
- ▶ Wear protective goggles and safety gloves.
- ▶ Clean away splashes on clothes and other objects.

- ▶ You must perform maintenance tasks at regular intervals.

We recommend setting the maintenance times in advance in an operations journal or log.

The maintenance cycle primarily depends on the following:

- The system
- The installation conditions
- The medium in which measurement takes place

10.1 Maintenance tasks

10.1.1 Cleaning the sensor

Sensor fouling can affect the measurement results and even cause a malfunction.

- ▶ To ensure reliable measurements, clean the sensor at regular intervals. The frequency and intensity of the cleaning depend on the medium.

Clean the sensor:

- As specified in the maintenance schedule
- Before every calibration
- Before returning it for repairs

Type of fouling	Cleaning measure
Lime deposits	▶ Immerse the sensor in 1 to 5% hydrochloric acid (for several minutes).
Dirt particles on the optics	▶ Clean the optics with a cleaning cloth.

After cleaning:

- ▶ Rinse the sensor thoroughly with water.

11 Repair

11.1 General information

- Only use spare parts from Endress + Hauser to guarantee the safe and stable functioning of the device.

Detailed information on the spare parts is available at:
www.endress.com/device-viewer

11.2 Spare parts

For more detailed information on spare parts kits, please refer to the "Spare Part Finding Tool" on the Internet:

www.products.endress.com/spareparts_consumables

11.3 Return

The product must be returned if repairs or a factory calibration are required, or if the wrong product was ordered or delivered. As an ISO-certified company and also due to legal regulations, Endress+Hauser is obliged to follow certain procedures when handling any returned products that have been in contact with medium.

To ensure the swift, safe and professional return of the device:

- Refer to the website www.endress.com/support/return-material for information on the procedure and conditions for returning devices.

11.4 Disposal

The device contains electronic components. The product must be disposed of as electronic waste.

- Observe the local regulations.

If required by the Directive 2012/19/EU on waste electrical and electronic equipment (WEEE), the product is marked with the depicted symbol in order to minimize the disposal of WEEE as unsorted municipal waste. Do not dispose of products bearing this marking as unsorted municipal waste. Instead, return them to the manufacturer for disposal under the applicable conditions.

12 Accessories

The following are the most important accessories available at the time this documentation was issued.

Listed accessories are technically compatible with the product in the instructions.

1. Application-specific restrictions of the product combination are possible.
   Ensure conformity of the measuring point to the application. This is the responsibility of the operator of the measuring point.
2. Pay attention to the information in the instructions for all products, particularly the technical data.
3. For accessories not listed here, please contact your Service or Sales Center.

12.1 Device-specific accessories

12.1.1 Assemblies

FlowFit CUA120
- Flange adapter for mounting turbidity sensors
- Product Configurator on the product page: www.endress.com/cua120

Technical Information TI096C

Flexdip CYA112
- Immersion assembly for water and wastewater
- Modular assembly system for sensors in open basins, channels and tanks
- Material: PVC or stainless steel
- Product Configurator on the product page: www.endress.com/cya112

Technical Information TI00432C

Cleanfit CUA451
- Manual retractable assembly made of stainless steel with ball valve shut-off for turbidity sensors
- Product Configurator on the product page: www.endress.com/cua451

Technical Information TI00369C

Flowfit CYA251
- Connection: See product structure
- Material: PVC-U
- Product Configurator on the product page: www.endress.com/cya251

Technical Information TI00495C

12.1.2 Holder

Flexdip CYH112
- Modular holder system for sensors and assemblies in open basins, channels and tanks
- For Flexdip CYA112 water and wastewater assemblies
- Can be affixed anywhere: on the ground, on the coping stone, on the wall or directly onto railings.
- Stainless steel version
- Product Configurator on the product page: www.endress.com/cyh112

Technical Information TI00430C

12.1.3 Compressed air cleaning

Compressed air cleaning for CUS51D
- Connection: 6 mm (0.24 in) or 8 mm (0.31 in) (metric) or 6.35 mm (0.25 in)
- Materials: POM/V4A
- Consumption: 50 l/min (13.2 gal/min)
- 6 mm (0.24 in) or 8 mm (0.31 in) order number: 71110782
- 6.35 mm (0.25 in) Order number: 71110783

Compressor
- For compressed air cleaning
- 230 V AC, order number: 71072583
- 115 V AC, order number: 71194623

12.1.4 Cable

Memosens data cable CYK11
- Extension cable for digital sensors with Memosens protocol
- Product Configurator on the product page: www.endress.com/cyk11

Technical Information TI00118C

13 Technical data

13.1 Input

Measured variable

- Turbidity
- Solids content
- Temperature

Measuring range

CUS51D-**C1		Application
Turbidity	0.000 to 4000 FNU Display range up to 9999 FNU	Formazine
Solids content	0 to 5 g/l	Kaolin Filterable matter
Temperature	–20 to 80 °C (–4 to 176 °F)	

CUS51D-**D1		Application
Turbidity	0.000 to 4000 FNU Display range up to 9999 FNU	Formazine
Solids content	0 to 300 g/l (0 to 2.5 lb/gal) 0 to 30 %	Solids content depending on the selected application (see list)
Temperature	–20 to 80 °C (–4 to 176 °F)	

Measuring range with solids content:

For solids, the achievable ranges depend very much on the media that are actually present and may differ from the recommended operating ranges. Extremely inhomogeneous media may cause fluctuations in measured values, thus narrowing the measuring range.

13.2 Performance characteristics

Reference operating conditions

20 °C (68 °F), 1013 hPa (15 psi)

Maximum measurement error

Turbidity < 2% of measured value or 0.1 FNU (the greater value applies in each case).

Solids < 5% of the measured value or 1% of the upper range value (the greater value applies in each case); applies to sensors that are calibrated for the observed measuring range.

The measurement error encompasses all inaccuracies of the measuring chain (sensor and transmitter). However, it does not include the inaccuracy of the reference material used for calibration.

For solids, the achievable measurement errors depend very much on the media that are actually present and may differ from the specified values. Extremely inhomogeneous media cause the measured value to fluctuate and increase the measurement error.

Repeatability

< 0.2 % of reading

Factory calibration

FNU and NTU in accordance with application table

Standard: 3 points

Drift

Working on the basis of electronic controls, the sensor is largely free of drifts.

Detection limits

Application	Measuring range	Limit of detection
Formazine	0 to 50 FNU	0.006 FNU
	0 to 4000 FNU	0.4 FNU
Kaolin	0 to 5000 mg/l	0.85 mg/l

13.3 Environment

Ambient temperature range

−20 to 60 °C (−4 to 140 °F)

Storage temperature

−20 to 70 °C (−4 to 158 °F)

Degree of protection

IP 68 (test conditions: 1 m (3.3 ft) water column, 60 days, 1 mol/l KCl)

Electromagnetic compatibility (EMC)

Interference emission and interference immunity according to:
- EN 61326-1:2013
- EN 61326-2-3:2013
- NAMUR NE21: 2012

13.4 Process

Process temperature range

−5 to 50 °C (23 to 122 °F)

Up to 80 °C (176 °F) for a short period of time (1 h)

Process pressure range

0.5 to 10 bar (7.3 to 145 psi) (abs.)

Compressed air cleaning

Pressure: 1.5 to 2 bar (21.8 to 29 psi)

Minimum flow

No minimum flow required.

For solids which have a tendency to form deposits, ensure that sufficient mixing is performed.

13.5 Mechanical construction

Dimensions

→ Section "Installation"

Weight	Approx. 0.7 kg (1.5 lb)without cable	
Materials	Sensor	Stainless steel 1.4404 (AISI 316 L) Stainless steel 1.4571 (AISI 316 Ti)
	Optical windows	Sapphire
	O-rings	EPDM
Process connections	G1 and NPT ¾'	
	Compressed air cleaning	
	6 mm (0.24 in) or 8 mm (0.31 in) or 6.35 mm (0.25 in) (¼")	

Index

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