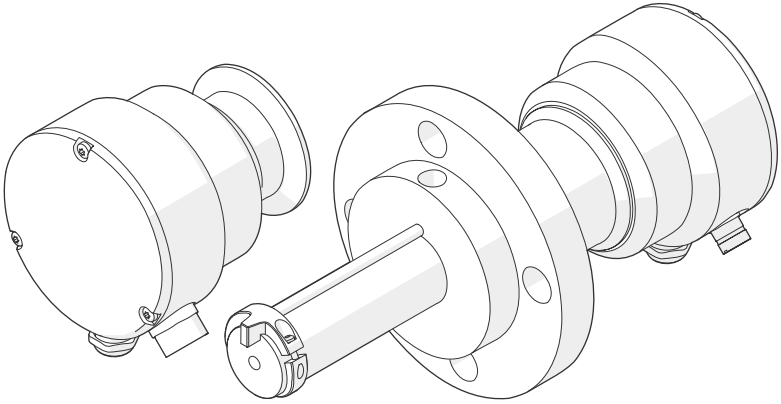
M212898EN-A

User Guide

Vaisala Polaris Process Refractometer

PR53 Series



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1. About this document

1.1 Version information

This document provides instructions for using and maintaining PR53 process refractometers.

Table 1 Document versions (English)

Document code	Date	Description
M212898EN-A	May 2023	First version

1.2 Related manuals

For the latest versions of these documents, see docs.vaisala.com.

Table 2 Related manuals

Document code	Name
B212610EN	Vaisala Polaris Process Refractometer PR53AC Installation Guide
B212613EN	Vaisala Polaris Process Refractometer PR53GP Installation Guide
M212808EN	Vaisala Polaris Process Refractometer PR53 Prism Wash System User Guide
M212287EN	Vaisala Indigo500 Series Transmitters User Guide

1.3 Documentation conventions

WARNING! Warning alerts you to a serious hazard. If you do not read and follow instructions carefully at this point, there is a risk of injury or even death.

CAUTION! Caution warns you of a potential hazard. If you do not read and follow instructions carefully at this point, the product could be damaged or important data could be lost.

Note highlights important information on using the product.

Tip gives information for using the product more efficiently.

Lists tools needed to perform the task.

Indicates that you need to take some notes during the task.

1.4 Trademarks

Vaisala®, Polaris™, and Indigo™ are trademarks of Vaisala Oyj.

All other product or company names that may be mentioned in this publication are trade names, trademarks, or registered trademarks of their respective owners.

1.5 Patent notice

This product is protected by the following patents and patent applications and their corresponding national rights:

- US2019391074A1

2. Product overview

2.1 Safety

This product has been tested for safety according to IEC 61010-1. Note the following precautions:

WARNING! Only licensed experts may install electrical components. They must adhere to local and state legislation and regulations.

2.1.1 ESD protection

Electrostatic discharge (ESD) can damage electronic circuits. Vaisala products are adequately protected against ESD for their intended use. However, it is possible to damage the product by delivering electrostatic discharges when touching, removing, or inserting any objects in the equipment housing.

To avoid delivering high static voltages to the product:

- Handle ESD-sensitive components on a properly grounded and protected ESD workbench or by grounding yourself to the equipment chassis with a wrist strap and a resistive connection cord.
- If you are unable to take either precaution, touch a conductive part of the equipment chassis with your other hand before touching ESD-sensitive components.
- Hold component boards by the edges and avoid touching component contacts.

2.2 Product nomenclature

Table 3 Product nomenclature

Item	Name
CCD element	Charge Couple Device element, camera element in the refractometer's prism
LA	Light area, sector of an optical image that corresponds to the light that is reflected
RI	Refractive index, number that indicates how much the path of light is bent, or refracted, when entering a material
QF	Quality factor, value that depicts the optical properties of the process medium. The value is monitored with Indigo520. Changes in the value may indicate the prism becoming coated.

2.3 PR53 product overview

The PR53 inline refractometer is an instrument for measuring liquid concentration in the process line. The measurement is based on the refraction of light in the process medium, an accurate and safe way of measuring liquid concentration.

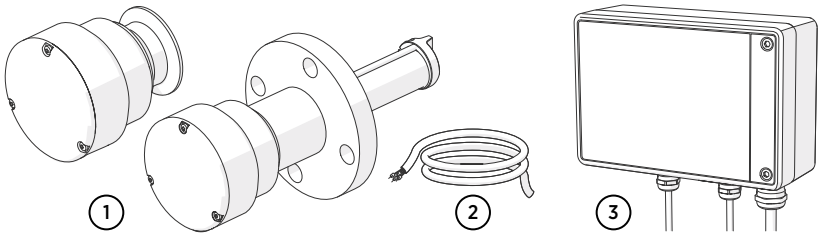


Figure 1 Refractometer equipment

1 Vaisala Polaris™ Process Refractometers
2 Interconnecting cables
3 Vaisala Indigo520 Transmitter (optional)

The inline process refractometer (1) measures the refractive index RI and the temperature of the process medium. This information is sent through the interconnecting cable (2) to the Indigo520 Transmitter (3, optional), or to an automation system. The refractometer calculates the concentration of the process liquid based on the refractive index and temperature, taking predefined process conditions into account. The output of the refractometer or optional transmitter is a 4 to 20 mA analog output proportional to process solution concentration. Process data can also be downloaded to a computer using the Indigo520 web interface.

2.4 PR53 refractometer models

There are different PR53 refractometer models. Each model is adapted for different process requirements.

- **The Vaisala Polaris PR53AC** sanitary compact process refractometer is designed to measure liquid concentrations, such as Brix.
- **The Vaisala Polaris PR53AP** sanitary probe process refractometer is designed for food and beverage, dairy and brewery industry customers, and OEMs to measure liquid concentrations, such as Brix, in applications such as jam cookers and mixing tanks.
- **The Vaisala Polaris PR53GC** general-purpose compact process refractometer is designed for measuring concentrations of acids, alkaline solutions, alcohols, hydrocarbons, solvents, and various other solutions.
- **The Vaisala Polaris PR53GP** general-purpose probe process refractometer is designed for measuring concentrations of sugars/Brix, acids, alkaline solutions, hydrocarbons, solvents, and various other solutions.

- **The Vaisala Polaris PR53M** PTFE-body process refractometer is designed to measure concentrations of aggressive chemicals, such as hydrochloric acid (HCl), sodium hydroxide (NaOH), sodium chloride (NaCl), and sulfuric acid (H2SO4) in the chemical and semiconductor industries.
- **The retractable Vaisala Polaris PR53SD** Safe-Drive process refractometer is designed for safety-critical measurements in pulp mills, such as firing liquor concentration. The Safe-Drive system with a PR53SD refractometer enables safe sensor insertion and removal also when the process line is in full operation.
- **The Vaisala Polaris PR53W** valve-body process refractometer is designed to measure concentrations of aggressive chemicals, such as sulfuric acid, hydrochloric acid (HCl), and sodium hydroxide (NaOH) in production pipelines such as in the chemical, biochemical, and pharmaceutical industries.

PR53AC and PR53AP have been designed to be used in food contact applications and meet the 3-A and EHEDG sanitary standard requirements.

2.5 Refractometer structure

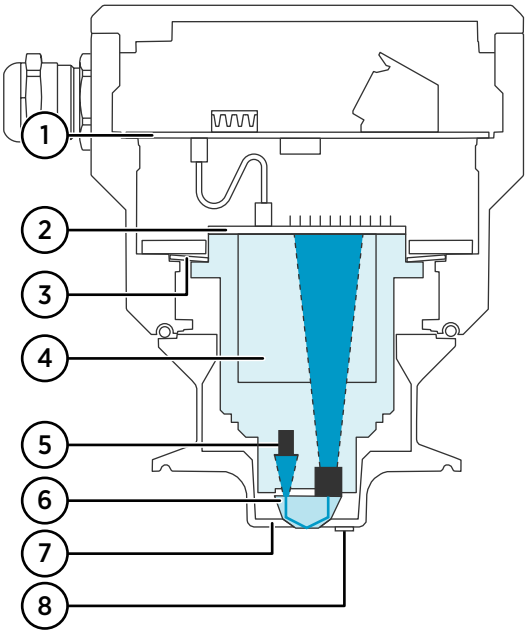


Figure 2 PR53 refractometer structure

1 Main circuit board
2 CCD camera
3 Disc springs
4 CORE-Module
5 Light source
6 Prism
7 Integrated temperature sensor (Pt-1000)
8 Prism gasket

The measurement prism (6) is flush-mounted to the surface of the probe tip. The prism (6) and all the other optical components are fixed to the solid CORE-Module (4), which is springloaded (3) against the prism gasket (8). The light source (5) is a yellow LED, and the receiver is a Charge Couple Device (CCD) element (2). The main circuit board (1) receives the raw data from the CCD element (2) and the Pt-1000 process temperature sensor (7), and then calculates the refractive index RI, the process temperature T, and process concentration according to a predefined concentration curve. This information is transmitted to the user with Indigo520 or Insight.

2.6 Storing and transporting

Soft shell packaging prevents damage to the components of the refractometer. Transport the device in its original packaging.

Before storing, remove any dirt and grease from the refactometer and make sure that it is dry.

Storage conditions:

- Temperature: −40 ... +40 °C (−40 ... +104 °F)
- Humidity: No condensation

3. Refractometer connections

3.1 Refractometer connections

For digital communications, see Modbus RTU (page 20).

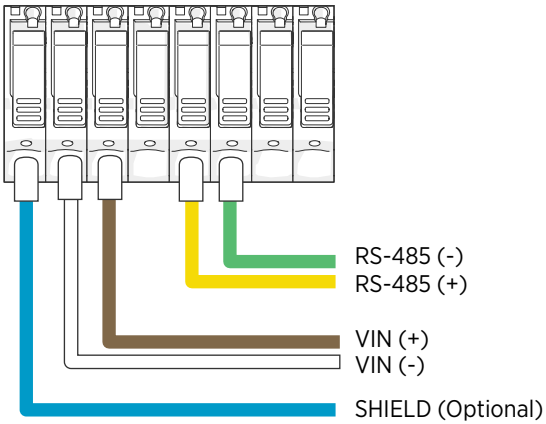


Figure 3 Connecting wires inside the refractometer (Modbus RTU or Indigo520)

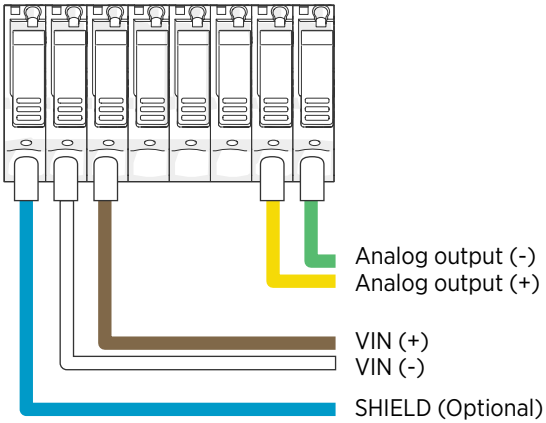


Figure 4 Connecting wires inside the refractometer (analog output)

When to use cable shield

- Voltage supply and signal output are connected to different grounds. Connect the shield to analog output ground to avoid ground loop currents.
  - Chassis ground and ground terminal are electrically connected. Grounding can be done either by connecting the cable shield to the respective terminal in the wiring header, or alternatively by connecting the cable shield to the cable gland.
- Operating voltage ground is galvanically isolated from the analog output, but not from the RS-485 port.
- Consider the grounding especially when the refractometer chassis is connected to non-conductive pipelines.

CAUTION! The PR53 series refractometer is an extra-low voltage device. Adhere to local and state legislation and regulations when installing the electrical components.

4. User interfaces

4.1 Refractometer LED indicators

The LED indicators are the refractometer's stand-alone user interface.

When using a stand-alone refractometer, connect the refractometer's service port to the Vaisala Insight PC software to do the following:

- Interpreting user input needs
- Configuring the refractometer
- Data logging

When the refractometer is disconnected from the process line, you can use Insight to calibrate and adjust the refractometer and create a blank image.

You can also use Indigo520 and Modbus to interpret user input needs. If the refractometer is connected to Indigo520, the service port is disconnected.

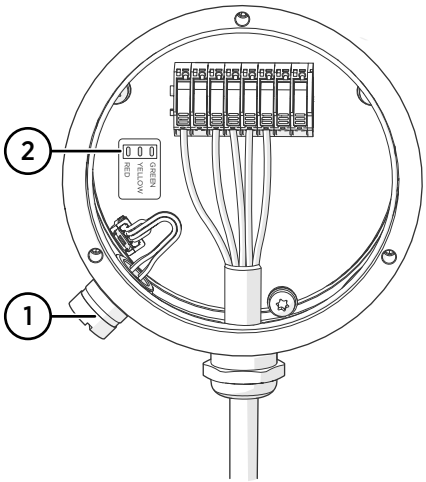


Figure 5 PR53 main circuit board

1 Service port
2 LED indicators

4.2 Indigo520 user interfaces

Vaisala Indigo520 is a transmitter that accommodates maximum of two PR53 refractometers for liquid measurements. The transmitter can display measurements on the spot as well as transmit them to automation systems through analog signals, control relays, or Modbus TCP/IP protocol.

Indigo520 can be used with two interfaces:

- Touch screen display
- Web interface

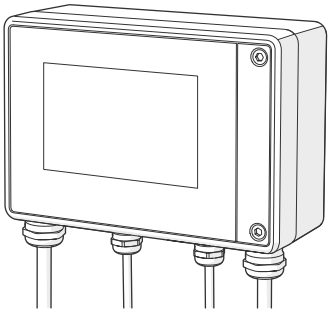


Figure 6 Indigo520 transmitter

Indigo520 provides:

- an easy-to-use touch panel display
- a web-based user interface
- data logging
- status and diagnostics info
- optical image diagnostics
- wash system control

The PR53 prism wash system is controlled by Indigo520. In most applications the prism keeps clean due to the self-cleaning effect. If coating occurs, your application may require a wash system.

For more information on the use of Indigo520, see Vaisala Indigo500 Series Transmitters User Guide.

4.3 Vaisala Insight PC software

Vaisala Insight PC software is a configuration software for Indigo-compatible probes and other supported devices. Insight is available for Microsoft Windows® operating systems (64-bit only).

With the Insight software, you can:

- See device information and status.

- See real-time measurement data.
- Manage concentration curves
- Calibrate and adjust the device.

Download Vaisala Insight software at www.vaisala.com/insight.

The refractometer can be connected to Insight using a Vaisala Indigo USB adapter (item code USB2).

4.4 Modbus RTU

The Modbus variant used in PR53 series refractometers is Modbus RTU.

The following table lists the default communication settings used when Modbus is enabled at the factory (chosen when ordering).

Table 4 Default Modbus communication settings

Description	Default value
Baudrate	19200
Parity	No parity
Number of data bits	8
Number of stop bits	2

See
- Configuring Modbus communication settings with Insight (page 51)
- Modbus registers (page 73)

.

4.5 Analog output

PR53 process refractometers provide one scalable analog output channel with 4 ... 20 mA current output.

When PR53 is connected to Indigo520, Indigo provides more analog output channels. The integrated analog output channel and the Indigo520 analog outputs are independent from each other, and can also be used simultaneously.

For configuring analog output with Indigo520, see Vaisala Indigo500 Series Transmitters User Guide.

For configuring analog output with Insight, see Configuring analog output (page 47).

Error state levels

PR53 process refractometers have two configurable error state levels.
- Default: 3.4 mA

- Secondary error state: Enabled, 3.2 mA

There are 4 error state messages, in rising severity order:

1. Info
2. Warning
3. Error
4. Critical

See Diagnostic message priorities (page 59).

5. Start-up

5.1 Start-up

At the start-up of the refractometer, check that it is connected to power and/or the graphical user interface.

If you have the optional prism wash system installed, you need to perform a prism wash test. See Vaisala Polaris Process Refractometer PR53 Prism Wash System User Guide.

Refractometer LED UI

The green LED light is on. The refractometer is powered.

Vaisala Indigo520

You see the "<Name of the refractometer> connected" pop-up window on the screen.

If the Main view is empty, you need to configure the view. See Vaisala Indigo500 Series Transmitters User Guide.

Vaisala Insight software

You see the "Device detected" text on the screen. The view representing the device is shown.

5.1.1 Connecting to Insight software

CAUTION! When connecting several devices at the same time, note that your computer may not be able to supply enough power through its USB ports. Use an externally powered USB hub that can supply >2 W for each port.

Insight can be coupled with 6 devices. The refractometer can be powered through USB, but an external power source can also be used.

Insight is meant for configuring a standalone refractometer. If you have Indigo520 connected to the refractometer, disconnect it before connecting to Insight.

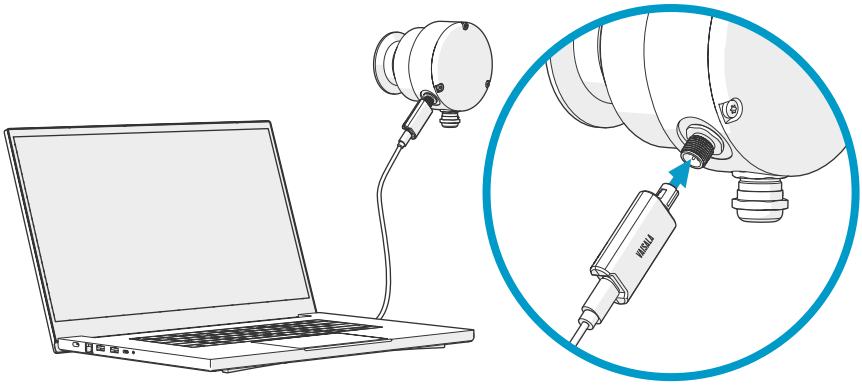


Figure 7 Connecting refractometer to Insight

1. Open the Insight software on your PC.
2. Connect the USB cable to a free USB port on the PC.

6. Using the refractometer LED UI

6.1 Using the refractometer LED indicators

The LED lights can convey the following information:

- **Green**:
  - When the green LED is on, the power is on.
  - When the green LED blinks, there are Modbus transactions going on.
- **Yellow**: When the yellow LED blinks, user input is required. To interpret user input needs, you need to attach the refractometer to Modbus, the Indigo520 transmitter or the Insight software.
- **Red**: When the red LED is on, the refractometer may need to be sent to Vaisala for service. Contact helpdesk@vaisala.com.

7. Using the Vaisala Indigo520

7.1 Using the Vaisala Indigo520

With Vaisala Indigo520 Transmitter, you can:

- View the refractometer status
- Adjust concentration measurement
- RI calibration
- Configure analog output channel
- Configure analog output signal damping
- Configure refractometer prism washes

For the full user guide, see Vaisala Indigo500 Series Transmitters User Guide.

7.2 General settings

You can edit the general settings of the refractometer as follows: **Main view > Select the refractometer > General settings**.

In general settings, you can give a custom name to the refractometer.

7.3 Diagnostics view

Diagnostics is the last screen in the main view. In the **Diagnostics** view, you can view various diagnostic and measurement values. You can also perform the following actions:

- Take a **Field sample**
  - A sample of the calculated average of 10 consequent measurements
  - Shown in a window so that they can be registered for later use.
- Start a **Prism wash**
  - Activate a configured prism wash
  - See diagnostics of the previous wash.

7.3.1 Viewing refractometer status

The refractometer status is shown in the **Diagnostics** view. The status **Normal operation** is shown when there are no active errors.

7.4 Concentration measurement

Adjustment of the raw concentration value may be required to compensate for some process conditions or to fit the measurement to the laboratory results.

There are four presets that each have their own C and F parameters that can be stored in their memory slots.

7.4.1 Overview of concentration measurement

The concentration measurement is organized in 6 layers.

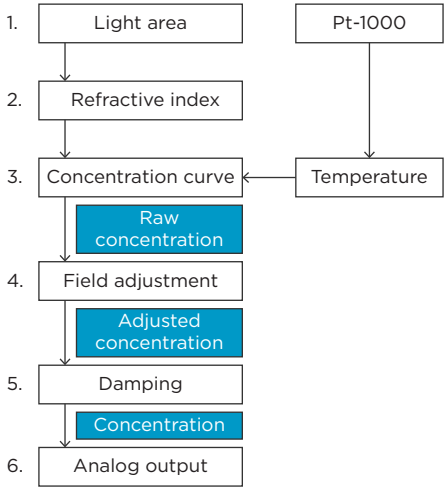


Figure 8 Concentration measurement layers

1 Light area information comes from the CCD element and temperature information from Pt-1000 temperature element. The position of the shadow edge is light area and scaled 0 ... 100 %. For more information, see Principle of measurement (page 82).
2 RI adjustment: The actual refractive index RI is calculated from the light area. The temperature is calculated from the Pt-1000 resistance. The RI measurement of each refractometer can be verified using standard nominal reference liquids.
3 Concentration curve: The refractometer calculates raw concentration from RI and temperature according to the chemical curve. The result is a temperature-compensated raw concentration value.
4 Field adjustment: Adjustment of the raw concentration value may be required to compensate for some process conditions or to fit the measurement to the laboratory results. The field adjustment parameters are used to convert raw concentration into adjusted concentration. The adjusted concentration is called concentration. If there is no adjustment, raw concentration and adjusted concentration are equal.
5 Damping: You can apply signal damping to diminish the influence of process noise.
6 Output signal: The range of the 4 ... 20 mA signal is defined by its 2 endpoints on the concentration scale. For more information, see Analog output (page 20).

7.4.2 Concentration curve

Concentration curve consists of the chemical curve (C parameters) and field adjustment parameters (F parameters).

7.4.2.1 Chemical curve

Chemical curve is the theoretical concentration curve based on RI and temperature. It is defined by a set of 16 parameters.

A chemical curve is specific to the given process medium, for example, sucrose or sodium hydroxide. The set of parameters is given by Vaisala. Do not alter the chemical curve parameters, except if you are changing to another process medium.

There are 4 parallel chemical curves in the refractometer internal memory. They can be changed via Indigo520, Insight or Modbus.

Table 5 Chemical curve parameters

C_{00}	C_{01}	C_{02}	C_{03}
C_{10}	C_{11}	C_{12}	C_{13}
C_{20}	C_{21}	C_{22}	C_{23}
C_{30}	C_{31}	C_{32}	C_{33}

7.4.2.2 Field adjustment parameters

The field adjustment can be calculated with the following pattern: **Adjusted concentration = Raw concentration × Field gain + Field offset**

Each concentration curve has its own field adjustment. If you change the concentration curve, field adjustment is no longer the same.

To edit the field gain and field offset,

1. Go to **Menu > Concentration curves**.
2. Select the concentration curve and **Modify adjustment**.
3. Modify **Offset** and **Gain**.

To check which concentration curve is active, see Managing concentration curves (page 28).

Accurate calibration is only achieved if the sample is taken correctly. Pay special attention to following details:

- Field adjustment using the process liquid must always be made inline.
- The sampling valve and the refractometer should be installed close to each other in the process.

WARNING! Wear protective clothing appropriate to your process when operating the sampling valve and handling the sample.

- Run the sample before starting to collect data points to avoid sampling old process liquid that has remained in the sampling valve.

- Read the raw concentration value at exactly the same time with sampling.
  The easiest way of doing this is to use the Field sample feature. The value of each sample is the average of 10 consequent measurements to increase accuracy and reduce possible process noise.
- Use a tight container for the sample to avoid evaporation.

Offline calibration using process liquid very seldom gives reliable results, as problems are caused by:
- Low flow which makes sample to form an unrepresentative film on the prism
- Sample evaporation at high temperature or undissolved solids at low temperature giving deviations from laboratory determinations
- An ageing sample which is not representative
- Outside light reaching the prism

7.4.2.3 Calculating field adjustment

To calculate field gain and field offset, you need to take samples from the process liquid.

1. Take samples from the process liquid and take a field sample. See Field sample (page 42).
2. Repeat as many times as needed.

   To calculate offset and gain you need at least two points. Take samples from process conditions with a wide span in the measurement range.
3. Calculate field gain and field offset from the data points.
4. Type the values to **Offset** and **Gain**.

If there is already a previous field calibration, before entering a new field calibration, clear it by setting values as follows:
- **Offset**: 0
- **Gain**: 1

7.4.2.4 Managing concentration curves

There are 1-4 concentration curves in the refractometer that have been defined when ordering the device.

Do not alter the concentration curve parameters, except if you are changing to another process medium. If you are unsure what to do, contact helpdesk@vaisala.com.

A concentration curve is specific to the given process medium, for example, sucrose or sodium hydroxide. The set of parameters is given by Vaisala. Do not alter the concentration curve parameters, except in case of changing to another process medium.

1. You can select the concentration curve in **Menu > Concentration curves**.

2. You can change the C parameters in **Menu > Concentration curves > View parameters > Modify parameters**.

   Changing from one concentration curve to another changes the way concentration is calculated from monitored liquids. The refractometer will restart to apply the change.

   If any concentration limit warnings have been set, they may be triggered by the change.

7.4.3 Field sample

A field sample is a measurement taken from the process that has the calculated average of 10 consequent measurements. A field sample is usually taken when a snapshot of the process condition is needed.

To take a field sample, browse to the Diagnostics view and select **Field sample**.

7.4.4 Field calibration service

Vaisala provides a field calibration service that adapts the calibration to the factory laboratory determinations based on the data supplied. The field calibration procedure should be made under normal process conditions using standard laboratory determinations of sample concentration.

Email the data to your local Vaisala representative. Vaisala makes a computer analysis of the data and sends optimal calibration parameters to be entered in the Indigo520 transmitter or Insight PC software.

Record the calibrating data in **Configure device > Concentration curve N > Field offset** and **Field gain**. For a complete report, 10 ... 15 valid data points (see below) are needed. A data point is of use for calibration only when there are no active errors or warnings. If prism wash is employed, do not take samples during the wash. Each data point consists of:

- LAB%: Sample concentration determined by the user.
- Raw concentration value: Calculated concentration value.

In addition to the calibration data, write down the refractometer serial number.

7.5 RI calibration

RI calibration ensures that the measurement of the refractometer is accurate.

The refractometer comes with a calibration certificate which ensures that it has fulfilled the measurement criteria when sent from the factory. RI calibration is needed when the optics of the device is serviced and RI adjustment needs to be performed.

Calibration is done to find out if there is measurement error in the device in the defined measurement area; adjustment is performed to fix the error.

RI adjustment can only be performed with Insight.

In order to perform RI calibration, you need:

- Indigo520 transmitter or Vaisala Insight software
- Sample holder
- Cleaning solution
- Tissues
- Nominal reference RI liquids, see below
- Protective clothing
- Environment with a good ventilation

Nominal reference RI liquids

There are two prism types, each of which have their own nominal reference RI liquid sets. You can check which prism your refractometer has from the configuration code by the side of the refractometer.

- H72
- H73

CAUTION! Each liquid has their own safety instructions with them. Read the instructions carefully before you start RI calibration.

7.5.1 Preparing RI calibration

Before you begin RI calibration, you must perform preparatory actions.

1. Remove the refractometer from the process and place it on a table, prism pointing upwards.
2. Clean the prism and the sample holder with ethanol cleaning solution. Make sure by looking closely that the prism is clean.
3. Mount the sample holder on the prism.
4. Prepare the necessary refractive index reference liquids and de-ionized water (sample liquids) and place them near the refractometer.
5. Let the refractometer and sample liquid temperature settle to room temperature, 20 ... 30 °C. Calibration must be done within this temperature range.

   The cooling of the refractometer may take several hours.

7.5.2 Performing RI calibration

1. Go to **Menu** and select the refractometer.
2. Select **RI calibration > Calibrate**.

   RI calibration can be done using either the touch screen or web interface. When calibration is being performed on one user interface, the other cannot be used at the same time.

3. Read the instructions on the screen and select **OK**.

   From this point onwards, the process is semi-automated and you will guided through the process on the screen.

4. Add a calibration point by pressing **+** and selecting the reference RI you want to calibrate against.
   - When calibrating, the refractometer waits for the temperature measurement to stabilize. This may take up to 4 minutes.
   - After nominal RI is selected, the refractometer calculates the correct reference RI at the measured temperature.

   Do not hold the refractometer or sample liquid container in your hand or near external heat sources during calibration. Changes in the refractometer or sample liquid temperature may decrease the measurement quality of the point or cause the calibration of the point to fail.

5. Once temperature measurement has stabilized, the UI will request you to apply sample liquid onto the sample holder and place the light cover on top.

   The calibration process will happen automatically from this point on with the following steps:
   a. Detecting sample
   b. Waiting for the sample to stabilize
   c. Calibrating

6. Once the calibration process is ready, results are displayed in the results screen.

   You can later view the results of a calibrated point by selecting a calibration point tile from the calibration view.

   You can now choose the following:
   - **Close**: Closes the summary screen and returns to calibration view
   - **Recalibrate**: Calibrates the point again
   - **Delete**: Removes the calibrated point.
7. Repeat the process for other available points as needed.
8. Finalize calibration by selecting **Complete calibration**. This will replace old calibration data with the new data.

   You can also do the following:
   - **Optical image**: View refractometer status, diagnostic values and both optical and slope image.
   - **Abort**: Quit the calibration process. Old calibration data is not replaced.

The result screen shows the difference between reference value and measured value, some diagnostic values, and the status of a single calibration point.

7.6 Configuring analog output signal damping

To configure analog output, see Vaisala Indigo500 Series Transmitters User Guide.

You can apply signal damping to diminish the influence of process noise. Damping is applied to the concentration value (and therefore the output signal) of the selected refractometer.

You can select the type of signal damping in **Main menu > Select the refractometer > Damping**.

There are 3 types of signal damping:
- Exponential signal damping
- Linear signal damping
- Slew rate

7.6.1 Exponential damping

Exponential damping works for most processes and is the standard choice for slow and continuous processes. The factory setting is always exponential damping.

Select **Damping type** to switch between different damping algorithms.

In the exponential damping, the damping time is the time it takes for the concentration measurement to reach half of its final value at a step change. For example, if the concentration changes from 50 % to 60 % and damping time is 10 s, it takes 10 s for the Indigo520 to display concentration 55 %. A damping time of 5 ... 15 s works best in most cases, the factory setting is 5 s.

Select **Damping time** to set the damping time.

The following figure shows how exponential damping time affects the measurement.

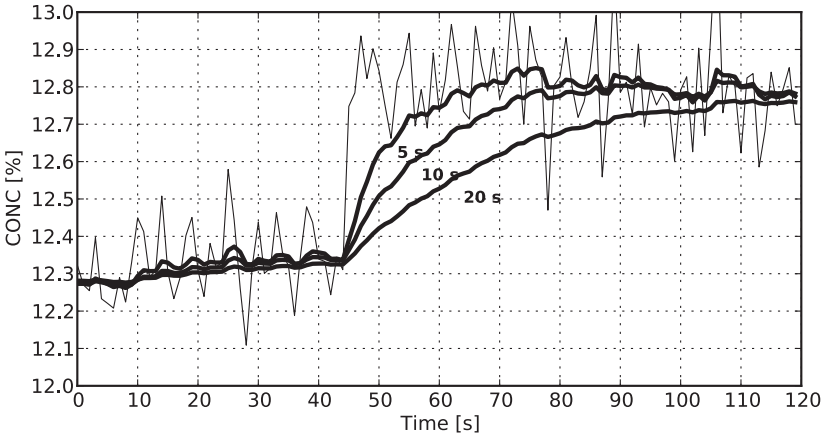


Figure 9 Exponential damping

7.6.2 Linear damping

If the process has fast step changes, linear (fast) damping gives shorter settling time.

In the linear damping, the output is the running average of the signal during the damping time. After a step change the signal rises linearly and reaches the final value after the damping time. The linear damping gives the best trade-off between random noise suppression and step change response time.

Select **Damping time** to set the damping time.

For similar noise suppression, you have to specify a longer damping time than for exponential damping.

The following figure shows how linear damping time affects the measurement.

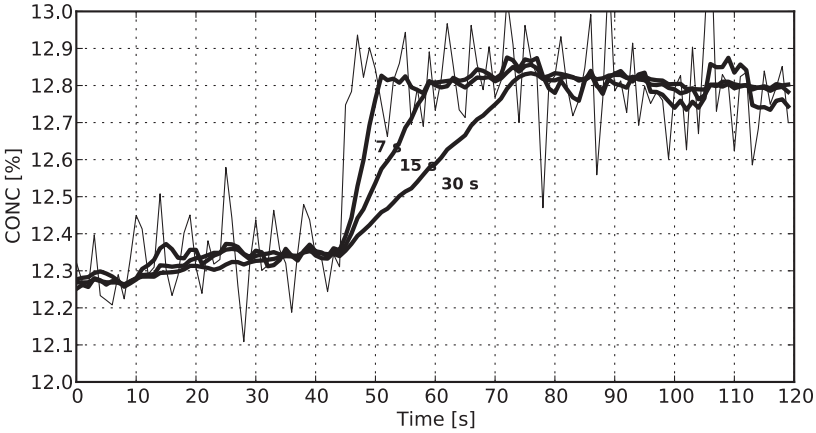


Figure 10 Linear damping

7.6.3 Slew rate limit

If the process signal has short erroneous high or low peaks, the slew rate limiting can be used to cut their effects.

The slew rate damping limits the maximum change for the output signal in 1 s. The slew rate limit damping is recommended for random noise suppression as it is non-linear.

Select **Slew rate** to set the slew rate limit. Typical values depend on the concentration unit but are typically 0.05 % to 1 % when the concentration is measured in %.

The following figure gives an example of different slew rate limits.

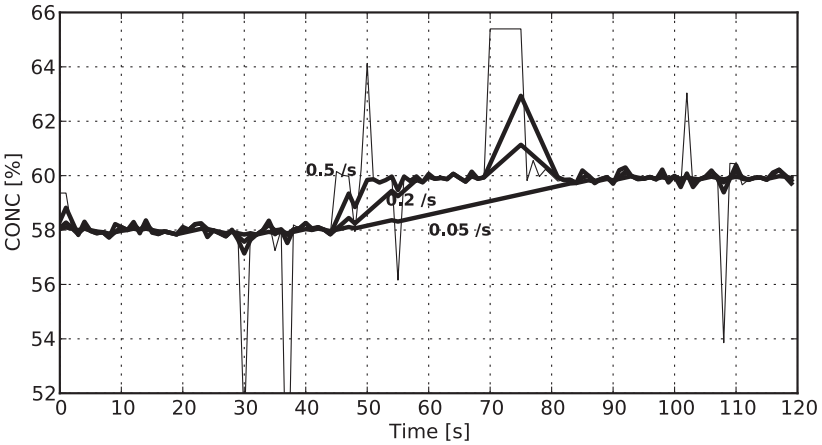


Figure 11 Slew rate damping

To avoid overdamping, do not make the signal insensitive.

8. Using the Vaisala Insight software

8.1 Using the Vaisala Insight software

With Vaisala Insight PC software, you can:

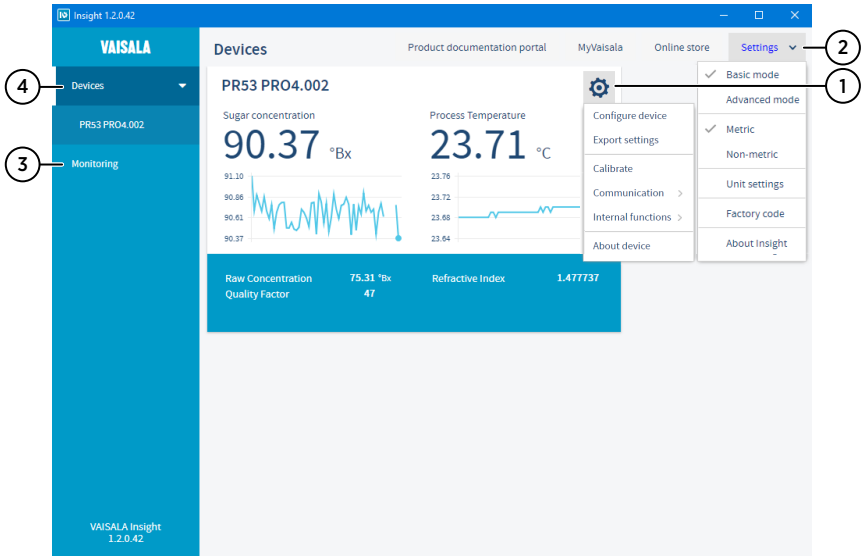
- Configure analog output channel
- Configure signal damping
- Adjust concentration curves
- Calibrate the RI measurement
- Reset factory RI adjustment parameters

Advanced mode features:

- Adjusting the RI measurement
- Creating blank image
- Overwriting factory RI adjustment parameters

Insight is the only tool to adjust the RI and analog output channel of the refractometer.

8.2 Insight main view



1 Select ⚙ to access Insight main menu.
   - **Configure Device**: environmental compensation settings, analog output 1 and 2 settings, filtering factor and general settings.
   - **Export Settings**: creates a text file export of the device settings.
   - **Calibrate**: options for calibrating and adjusting RI and T output, testing and adjusting current (analog) output levels, and restoring factory adjustments.
   - **Communication**: contains a quick access selection for restarting the device.
   - **Factory default settings**: restores the device back to default settings, clears any user adjustments and restores the latest factory calibration.
   - **About Device**: general device information such as serial number and software version.
2 Select **Settings** to switch between the **Basic Mode** and **Advanced Mode** user modes, change the units of parameters (metric/non-metric), enter a factory code to access restricted functionalities, or view information about the Insight software.
3 **Monitoring** provides options for monitoring and recording selected parameters, and exporting the monitoring data as a CSV (comma-separated values) file.
4 Device information menu with the following tabs:
   - **Measurements**: measurement graph view with parameter drop-down selection.
   - **Calibration information**: read-only information about the latest stored calibration.
   - **Diagnostics**: troubleshooting and administrative information about the device status.

8.2.1 Basic and Advanced user modes

You can switch between the **Basic Mode** and **Advanced Mode** user modes with the selections in the **Settings** menu.

Certain functionalities are only available in **Advanced Mode**. The options enabled by switching to **Advanced Mode** are often intended for administrative users: set the user mode according to the requirements of the personnel that use the device.

8.3 Concentration measurement

Adjustment of the raw concentration value may be required to compensate for some process conditions or to fit the measurement to the laboratory results.

There are four presets that each have their own C and F parameters that can be stored in their memory slots.

8.3.1 Overview of concentration measurement

The concentration measurement is organized in 6 layers.

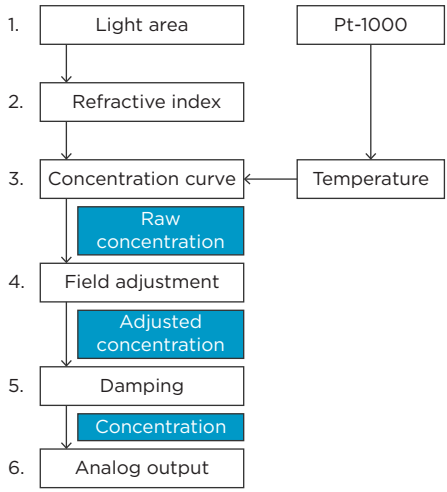


Figure 12 Concentration measurement layers

1 Light area information comes from the CCD element and temperature information from Pt-1000 temperature element. The position of the shadow edge is light area and scaled 0 ... 100 %. For more information, see Principle of measurement (page 82).
2 RI adjustment: The actual refractive index RI is calculated from the light area. The temperature is calculated from the Pt-1000 resistance. The RI measurement of each refractometer can be verified using standard nominal reference liquids.
3 Concentration curve: The refractometer calculates raw concentration from RI and temperature according to the chemical curve. The result is a temperature-compensated raw concentration value.
4 Field adjustment: Adjustment of the raw concentration value may be required to compensate for some process conditions or to fit the measurement to the laboratory results. The field adjustment parameters are used to convert raw concentration into adjusted concentration. The adjusted concentration is called concentration. If there is no adjustment, raw concentration and adjusted concentration are equal.
5 Damping: You can apply signal damping to diminish the influence of process noise.
6 Output signal: The range of the 4 ... 20 mA signal is defined by its 2 endpoints on the concentration scale. For more information, see Analog output (page 20).

8.3.2 Concentration curve

Concentration curve consists of the chemical curve (C parameters) and field adjustment parameters (F parameters).

8.3.2.1 Chemical curve

Chemical curve is the theoretical concentration curve based on RI and temperature. It is defined by a set of 16 parameters.

A concentration curve is specific to the given process medium, for example, sucrose or sodium hydroxide. The set of parameters is given by Vaisala. Do not alter the concentration curve parameters, except in case of changing to another process medium.

There are 4 parallel chemical curves in the refractometer internal memory. They can be changed via Indigo, Insight or Modbus.

Table 6 Chemical curve parameters

C_{00}	C_{01}	C_{02}	C_{03}
C_{10}	C_{11}	C_{12}	C_{13}
C_{20}	C_{21}	C_{22}	C_{23}
C_{30}	C_{31}	C_{32}	C_{33}

8.3.2.2 Field adjustment parameters

Field adjustment can be calculated with the following pattern: **Adjusted concentration = Raw concentration × Field gain + Field offset**

Each concentration curve has its own field adjustment. If you change the concentration curve, field adjustment is no longer the same.

To edit the field gain and field offset,

1. Go to > **Configure device**.
2. Select the concentration curve you want to modify.
3. Scroll to the end of the screen to modify the **Field gain** and **Field offset**.

To check which concentration curve is active, see Managing concentration curves (page 41).

Accurate adjustment is achieved only if the sample is taken correctly. Pay special attention to following details:

- Field adjustment using the process liquid must always be made inline.
- The sampling valve and the refractometer should be installed close to each other in the process.

> **WARNING!** Wear protective clothing appropriate to your process when operating the sampling valve and handling the sample.

- Run the sample before starting to collect data points to avoid sampling old process liquid that has remained in the sampling valve.
- Read the raw concentration value at exactly the same time with sampling.
  The easiest way of doing this is to use the Field sample feature, see Field sample (page 42). The value of each sample is the average of 10 consequent measurements to increase accuracy and reduce possible process noise.
- Use a tight container for the sample to avoid evaporation.

Offline adjustment using process liquid very seldom gives reliable results, as problems are caused by:
- Low flow which makes sample to form an unrepresentative film on the prism.
- Sample evaporation at high temperature or undissolved solids at low temperature giving deviations from laboratory determinations.
- An aging sample which is not representative.
- Outside light reaching the prism.

8.3.2.3 Calculating field adjustment

To calculate field gain and field offset, you need to take samples from the process liquid.

1. Take samples from the process liquid and take a field sample. See Field sample (page 42).
2. Repeat many enough times.

   To calculate offset and gain you need at least two points. Take samples from process conditions with a wide span in the measurement range.
3. Calculate field gain and field offset from the data points.
4. Type the values to **Field gain** and **Field offset**.

If there is already a previous field calibration, before entering a new field calibration, clear it by setting values as follows:
- **Offset**: 0
- **Gain**: 1

8.3.2.4 Managing concentration curves

There are 1-4 concentration curves in the refractometer that have been defined when ordering the device.

Do not alter the concentration curve parameters, except in case of changing to another process medium. If you are unsure what to do, contact helpdesk@vaisala.com.

A concentration curve is specific to the given process medium, for example, sucrose or sodium hydroxide. The set of parameters is given by Vaisala. Do not alter the concentration curve parameters, except if you are changing to another process medium.

1. You can select the concentration curve in **> Configure device > Active concentration curve > Select curve**.

2. You can change the C parameters in **> Configure device > Concentration curve 1/2/3/4**.

   Changing from one concentration curve to another changes the way concentration is calculated from monitored liquids. The refractometer will restart to apply the change.

   If any concentration limit warnings have been set, they may be triggered by the change.

8.3.2.5 Field calibration service

Vaisala provides a field calibration service that adapts the calibration to the factory laboratory determinations based on the data supplied. The field calibration procedure should be made under normal process conditions using standard laboratory determinations of sample concentration.

Email the data to your local Vaisala representative. Vaisala makes a computer analysis of the data and sends optimal calibration parameters to be entered in the Indigo520 transmitter or Insight PC software.

Record the calibrating data in **Configure device > Concentration curve N > Field offset** and **Field gain**. For a complete report, 10 ... 15 valid data points (see below) are needed. A data point is of use for calibration only when there are no active errors or warnings. If prism wash is employed, do not take samples during the wash. Each data point consists of:

- LAB%: Sample concentration determined by the user.
- Raw concentration value: Calculated concentration value.

In addition to the calibration data, write down the refractometer serial number.

8.3.3 Field sample

A field sample is a measurement taken from the process that has the calculated average of 10 consequent measurements. A field sample is usually taken when a snapshot of the process condition is needed.

To take a field sample, select the refractometer > **Diagnostics > Field sample**.

8.4 RI calibration

RI calibration ensures that the measurement of the refractometer is accurate.

The refractometer comes with a calibration certificate which ensures that it has fulfilled the measurement criteria when sent from the factory. RI calibration is needed when the optics of the device is serviced and RI adjustment needs to be performed.

Calibration is done to find out if there is measurement error in the device in the defined measurement area; adjustment is performed to fix the error.

RI adjustment can only be performed with Insight.

In order to perform RI calibration, you need:

- Indigo520 transmitter or Vaisala Insight software
- Sample holder
- Cleaning solution
- Tissues
- Nominal reference RI liquids, see below
- Protective clothing
- Environment with a good ventilation

Nominal reference RI liquids

There are two prism types, each of which have their own nominal reference RI liquid sets. You can check which prism your refractometer has from the configuration code by the side of the refractometer.

- H72
- H73

CAUTION! Each liquid has their own safety instructions with them. Read the instructions carefully before you start RI calibration.

8.4.1 Preparing RI calibration

Before you begin RI calibration, you must perform preparatory actions.

1. Remove the refractometer from the process and place it on a table, prism pointing upwards.
2. Clean the prism and the sample holder with ethanol cleaning solution. Make sure by looking closely that the prism is clean.
3. Mount the sample holder on the prism.
4. Prepare the necessary refractive index reference liquids and de-ionized water (sample liquids) and place them near the refractometer.
5. Let the refractometer and sample liquid temperature settle to room temperature, 20 ... 30 °C. Calibration must be done within this temperature range.

   The cooling of the refractometer may take several hours.

8.4.2 Performing RI calibration

1. Select the refractometer.
2. Select > **Calibrate**.
3. If you want to enter Calibration mode, select **Yes**.

   When in calibration mode, concentration calculation is paused and analog output 1 returns to error output level.

4. Select the **RI calibration** menu.
5. Apply sample liquid onto the sample holder and place the light cover on top.

   Do not hold the refractometer or sample liquid container in your hand or near external heat sources during calibration. Changes in the refractometer or sample liquid temperature may decrease the quality of the measurement point or cause it to fail.

6. From the available points, starting with Measure, point 1, press **Measure, point 1**.

   Calibration of a point may take a few minutes. The calibration progress can be seen at the top half of the screen.
   Before calibration, the refractometer waits for the measurement to stabilize and then proceeds to calibrate.
7. Select the used reference sample liquid from the **Nominal RI** dropdown menu.

   After nominal RI is selected, the refractometer calculates the correct reference RI at the measured temperature. It is not recommended to modify the reference RI value.
8. View the calibration results below in the result block.
9. Repeat the process for other available points as needed.

The result block shows the difference between reference value and measured value, some diagnostic values, and the status of a single calibration point.

Status tells if the calibration was within specified accuracy limits.

8.4.3 Completing RI calibration

1. Once all necessary points have been calibrated, press **Store calibration** at the bottom of the register list. Pressing this button completes the calibration and stores current calibration results in the refractometer memory.

   You can only access the most recent calibration result. Older results are not stored.

8.5 RI adjustment

Each refractometer has their own unique RI adjustment curve that has been calculated at the Vaisala factory. These are the A parameters.

RI adjustment should be performed only as a service procedure by trained personnel. Adjusting how the refractive index is calculated changes the way concentration is measured. If adjustment is done wrong, the refractometer can start measuring concentration incorrectly.

In order to perform RI calculation adjustment, at least five calibration points that all have a different Nominal RI must be calibrated. This can be done in the **RI calibration** menu. It is recommended that RI adjustment is done based on a recent calibration.

1. Perform RI calibration in the **RI calibration** menu. Alternatively, retrieve calibration data from a previously stored calibration by selecting **Retrieve stored calibration**.
2. Verify from the retrieved calibration date that the RI calibration data is available and recent.
3. Select **Start adjustment**.

   Refractometer calculates new RI calculation parameters. New parameters and maximum difference are shown on the top half of the screen.
   Maximum difference is the greatest refractive index difference value calculated from the available calibration points when using new RI calculation parameters.
4. If you are satisfied with the new RI calculation parameters and maximum difference result, select **Yes**.

   The new calculation parameters are applied immediately. The refractometer reboots after the new parameters are applied.

8.5.1 Restoring factory adjustment

1. Select **Restore factory adjustment**.

   Once restoration has been started, all RI calculation parameters will be reverted to the last factory set.

   If the prism of the refractometer has been replaced, the factory adjustment parameters may no longer be valid. Contact Vaisala for support.

8.6 Temperature adjustment

The reference value needs to be known.

Temperature adjustment does not affect concentration calculations.

1. Insert your device in the reference environment for the first calibration point.
2. Wait for the measurement to stabilize fully. The graph shows readings of the last 60 minutes.
3. When the measurement has stabilized, select the **Reference value, point 1** text box and enter the temperature of calibration point 1. Select **ENTER** or click outside the field when done.
4. Check that the measured value for point 1 is automatically inserted.
5. Check the difference between each reference and measured value. Very large differences may be due to insufficient stabilization time or unsuitable calibration setup.

   If you want to adjust the device, select **Activate adjustment** and verify the result from the message that appears at the top of the screen..
   To exit without taking the adjustment in use, select **Close**.
6. After calibrating your device, update the information in the **Calibration information** tab.

8.6.1 Adjusting temperature using previously measured value

If the device allows the field for measured value to be edited and you have a list of previously collected calibration readings (for example, from a third party laboratory calibration), you can adjust the device without having to generate the calibration conditions and wait for stabilization.

1. Select the **Reference value, point 1** field and enter the temperature of calibration point 1. Press **ENTER** or click outside the field when done.
2. Replace the automatically inserted measured value for point 1 with your previously measured value.
3. Repeat the procedure for all desired calibration points.

4. Select **Activate adjustment** and verify the result from the message that appears at the top of the screen.

8.7 Creating blank image

This is a maintenance operation only.

The procedure should only be done if the prism has been replaced, for example.

To create a blank image,

1. Remove the refractometer from the process line.
2. Clean the prism with ethanol cleaning solution.
3. Protect the prism from outside light.
4. Select **Create image**.

8.8 Configuring analog output

The PR53 process refractometer has one built-in 4 ... 20 mA output.

For the electrical properties of the analog output, see Refractometer connections (page 16).

To configure analog output, go to **> Configure device > Analog output 1**.

To adjust the analog outputs, see Adjusting output level for analog output 1 (page 48).

- **Scale low end** sets the value when the signal is 4 mA. The default zero value is 0.00, the unit depends on the source and display unit set for the sensor in question (and can thus be for example 0 Bx or 0 °F).
- **Scale high end** sets the range, which is the value given when the signal is 20 mA.
- **Error output level** sets an analog default output value that the instrument returns to in certain malfunction situations. The factory setting for default output is 3.4 mA. For a list of malfunctions that are affected, see Diagnostic message priorities (page 59).
  - NAMUR NE 43 uses the 3.8 ... 20.5 mA signal range for measurement information. With PR53 process refractometers, you can configure ≤3.6 mA to indicate diagnostic failures. With that information, it is easier to detect a failure condition on a refractometer, for example, it clearly tells you whether you have an empty pipe or a failed instrument.
- **No sample error output** and **No sample error output level** allow you to set a secondary mA output value for empty pipe (message **No liquid detected**) to differentiate it from the other messages that cause the measurement to revert to default mA. By default the secondary mA output is disabled.

8.8.1 Adjusting output level for analog output 1

In test mode, you can test the current output level of the analog output with a multimeter, and adjust the output level (2-point adjustment) if necessary.

> Always switch **Test mode** off after testing to return the analog outputs to normal operating mode. The analog output does not output measurement data when analog outputs are in test mode.

To test and adjust the current output level of the analog output:

1. Connect a multimeter to the analog output wiring (connect in series to measure the current output).
2. Go to ⚙ **> Calibrate > Yes**.
3. Enable the **Test mode** (switch to **ON** position).

   > Selecting **Disabled** turns off the selected output.

4. Enter a low output value in mA (for example, **5**) in the **Test output level** field. The analog output starts to output current at this level.
5. Check the multimeter reading and enter the measured value (for example, **4.95**) in the **Measured value, low point** field.
6. Enter a high mA value (for example, **19**) in the **Test output level** field, check the multimeter reading, and enter the value of the multimeter reading to the **Measured value, high point** field if it differs from the test output value.
7. Select **Activate adjustment** to save the correction to the output level.
8. To verify that the current level of the output is now accurate, enter a new value (for example, **12**) in the **Test output level** field and check that the multimeter reading matches the test output value you entered.
9. Record the gain and offset values for later use: you can enter the gain and offset directly to achieve the same adjustment later.
10. Disable the **Test mode** (switch to **OFF** position) and select **Close** to exit the calibration mode.
11. Replace the original analog output wiring.

8.8.2 Configuring analog output signal damping

You can apply signal damping in ⚙ **> Configure device > Damping** to diminish the influence of process noise. Damping is applied to the concentration value (and therefore the output signal) of the selected refractometer.

There are 3 types of signal damping:

- Exponential signal damping
- Linear signal damping
- Slew rate

You can select the type of signal damping in **Damping type**.

You can edit the following:

- **Damping time**
- **Tolerance time**
- **Slew rate**

8.8.2.1 Exponential damping

Exponential (standard) damping works for most processes and is the standard choice for slow and continuous processes. The factory setting is always exponential damping.

Select **Damping type** to switch between different damping algorithms.

In the exponential damping, the damping time is the time it takes for the concentration measurement to reach half of its final value at a step change. For example, if the concentration changes from 50 % to 60 % and damping time is 10 s, it takes 10 s for Insight to display concentration 55 %. A damping time of 5 ... 15 s works best in most cases, the factory setting is 5 s. Use the **Damping time** menu item to set the damping time.

The following figure shows how exponential damping time affects the measurement.

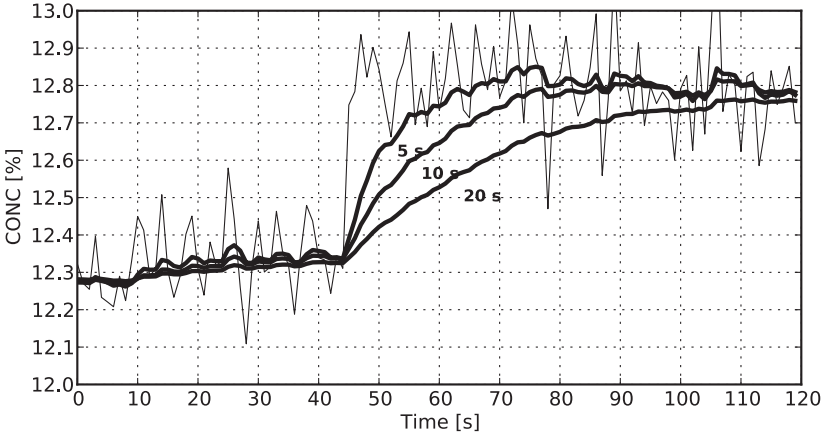


Figure 13 Exponential damping

8.8.2.2 Linear damping

If the process has fast step changes, linear (fast) damping gives shorter settling time.

In the linear damping, the output is the running average of the signal during the damping time. After a step change the signal rises linearly and reaches the final value after the damping time. The linear damping gives the best trade-off between random noise suppression and step change response time.

Select **Damping time** to set the damping time.

For similar noise suppression a longer damping time has to be specified than for the exponential damping.

The following figure shows how linear damping time affects the measurement.

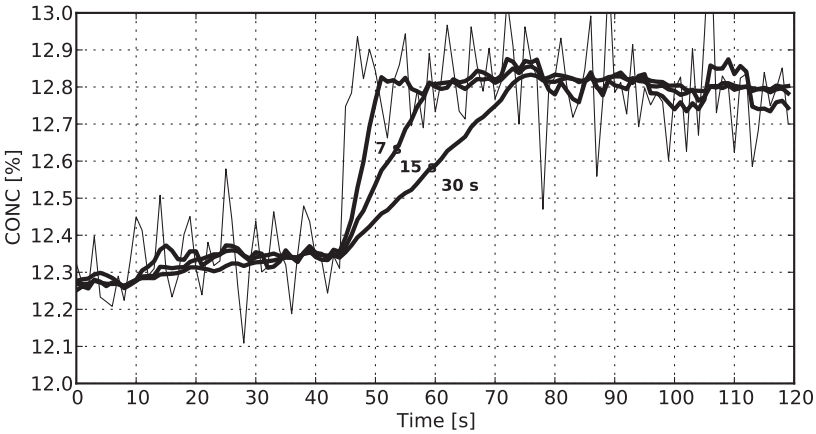


Figure 14 Linear damping

8.8.2.3 Slew rate limit

If the process signal has short erroneous high or low peaks, the slew rate limiting can be used to cut their effects.

The slew rate damping limits the maximum change for the output signal in 1 s. The slew rate limit damping is recommended for random noise suppression as it is non-linear.

Select **Slew rate** to set the slew rate limit. Typical values depend on the concentration unit but are typically 0.05 % to 1 % when the concentration is measured in %.

The following figure gives an example of different slew rate limits.

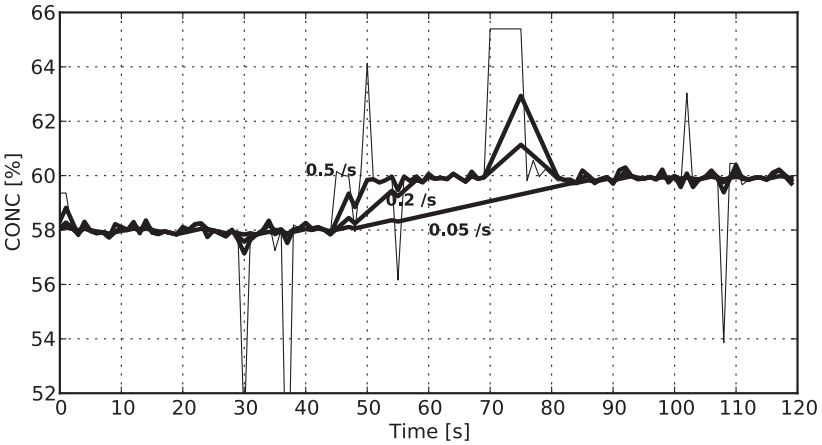


Figure 15 Slew rate damping

To avoid overdamping, do not make the signal insensitive.

8.9 Configuring Modbus communication settings with Insight

You can configure the following Modbus communication settings with the Insight PC software:

- Device address
- Communication bit rate
- Parity, data bits, and stop bits
- Response delay

To configure the Modbus communication settings with Insight:

1. Connect to Insight and select > **Configure Device > Communication**.
2. Enter the communication values as needed: see the instructions in the Insight interface for allowed ranges and additional information.
3. Select **Save** to store the settings.

8.10 Restoring factory settings

The **Restore default settings** function restores the refractometer to the latest saved settings and parameters.

1. Select **Factory default settings > Restore default settings > Yes**.

9. Preventive maintenance

9.1 Preventive maintenance

PR53 process refractometers do not have wearing parts or periodically changeable parts. Depending on the process conditions, PR53 process refractometers may never need to be serviced.

There a few things that should be monitored:

Table 7 Preventive maintenance

Part	Action
Prism	Make sure that the prism is clean by monitoring the following: • Optical image diagnostics. See Analyzing the optical image (page 84). • Change in the Quality Factor value. Change in the value usually indicates that the prism is dirty. See Vaisala Polaris Process Refractometer PR53 Prism Wash System User Guide.
Prism gasket	Visually check that the prism gasket is intact. This is especially important with the hygienic devices' wetted parts.
Refractometer's internal humidity level	Relative humidity indicates if any liquid has leaked inside the refractometer or if the internal drying capsule needs replacement. Typically the internal relative humidity should be < 50 %RH.

10. Troubleshooting

10.1 Troubleshooting messages

Table 8 Hardware troubleshooting

Problem	Severity level	Cause	Corrective action
Message **Internal humidity too high**	Error	The humidity measured at the refractometer's processor card exceeds 60 %RH relative humidity. The reason may be moisture leaking in through the prism seal or the cover being open.	Make sure that the prism seal is intact and the cover is closed. If necessary, replace the prism seal.
Message **Internal temperature too high**	Error	The temperature on the sensor processor card exceeds +65 °C (+150 °F). To read this temperature, • Indigo520: Browse to the fourth screen on the Main view to see the **Diagnostics**. • Insight: Select the refractometer > **Diagnostics**.	Make sure you are using the device in the right temperature. See the ambient and process temperature in the model-specific specifications.
Indigo520: No devices connected / Disconnected Insight: No connected devices in the start screen	n/a	The cables are not properly connected. The refractometer is connected to both Indigo520 and Insight.	Make sure that cables are properly connected at both ends. If the refractometer is connected to both Indigo520 and Insight, it prioritizes Indigo520 and is not visible to Insight. If you are able to open the refractometer cover, make sure that the green LED is on. This means that the refractometer is powered.

Problem	Severity level	Cause	Corrective action
Relays not working	n/a	Relays may be in test mode. Make sure using Indigo520 that the test mode is inactive in **Menu > Inputs and outputs > Relays > Test mode**. For testing the wash function, see Vaisala Polaris Process Refractometer PR53 Prism Wash System User Guide.	
Analog output signal is not working as expected	n/a	Check wiring, see the model-specific installation guide. If the analog output signal does not correspond to the concentration display, check output signal configuration, see **Diagnostics**. For possible correction, configure the analog output. • Indigo520: See Vaisala Indigo500 Series Transmitters User Guide. • Insight: See Configuring analog output (page 47). A low analog output signal can also be caused by high resistance in the external current loop, see Refractometer connections (page 16). A noisy signal can be damped, see • Indigo520: Configuring analog output signal damping (page 32) • Insight: Configuring analog output signal damping (page 48)	

Table 9 Measurement troubleshooting

Problem	Severity level	Cause	Corrective action
Message **No optical image**	Critical	To see the optical image, you need to use Indigo520. On the Main screen, browse to the **Diagnostics** view. There are several possible causes: 1. The prism is heavily coated. Perform prism wash if available, see Vaisala Polaris Process Refractometer PR53 Prism Wash System User Guide. If prism wash is not available, remove the refractometer from process line and clean the prism manually. 2. There is moisture condensation in the refractometer head. 3. The refractometer head temperature is too high. 4. The light source is faulty. When the refractometer is removed from the process, the yellow flashing light can be seen through the prism. The light is only visible at an oblique angle. Also check the LED value in the **Diagnostics** view; if the value is clearly below 100, LED fault is not likely. 5. There are negative spikes in the optical image. The probable cause is dust or fingerprints on the optical element. 6. The CCD card in the refractometer is faulty.	
Message **Blank image corrupted**	Critical	Blank image is missing or corrupted.	A trained person can create a blank image. Contact helpdesk@vaisala.com.
Message **External light level too high**	Error	The measurement is not possible because too much outside light reaches the camera.	Identify the light source (for example sun shining into an open tank or a translucent pipe) and block the light from getting to the prism at the sensor tip.

Problem	Severity level	Cause	Corrective action
Message **Prism coating detected**	Error	The optical surface of the prism is coated by the process medium or impurities in the process medium.	Perform prism wash if available, see Vaisala Polaris Process Refractometer PR53 Prism Wash System User Guide. If prism wash is not available, remove the refractometer from process line and clean prism manually. If the problem is recurrent, consider improving the flow conditions, see model-specific installation guide. If prism wash is available, adjust the wash parameters, see Vaisala Polaris Process Refractometer PR53 Prism Wash System User Guide.
Message **Temperature measurement error**	Error	A temperature element is faulty.	Replace the temperature element. Note that a difference to some other process temperature measurement is not a fault. PR53 measures the true temperature of the prism surface.
Message **Invalid calculation parameters**	Error	The A parameters are incorrect.	Perform RI adjustment or contact helpdesk@vaisala.com.

Problem	Severity level	Cause	Corrective action
Message **C measurement out of concentration curve range**	Warning	Concentration measurement is outside of the configured range. The measurement may not be reliable.	1. Make sure that the measurement is correct. If yes, consider if the used concentration curve is suitable for the process. Contact your sales representative or helpdesk@vaisala.com. 2. If you know that the measurement does not correspond to the true concentration value, the refractometer needs to be serviced. Contact helpdesk@vaisala.com.
Message **T measurement out of concentration curve range**	Warning	Temperature measurement is outside of the configured range. The measurement may not be reliable. If temperature measurement is wrong, concentration measurement will be unreliable.	1. Make sure that the measurement is correct. If yes, consider if the used concentration curve is suitable for the process. Contact your sales representative or helpdesk@vaisala.com. 2. If the temperature error is notably big, the refractometer needs to be serviced. Contact helpdesk@vaisala.com.
Message **External light level high**	Warning	Some light from the outside reaches the sensor and may disturb the measurement.	Identify the light source (for example sun shining into an open tank or a translucent pipe) and block the light from getting to the prism at the sensor tip.

Problem	Severity level	Cause	Corrective action
Message **Image quality low**	Warning	The most likely cause for this message is scaling on the prism. There still is an optical image available, but the measurement quality may not be optimal.	Clean the prism.
Message **No liquid detected**	Warning	The operation of the equipment is OK but there is no process liquid on the prism.	
Message **Calibration mode active**	Warning	When calibration mode is active, the refractometer will not calculate the concentration.	Make sure that the calibration mode is off in all used user interfaces.
Unexpected concentration drift	n/a	For drift upward, suspect prism coating, see Vaisala Polaris Process Refractometer PR53 Prism Wash System User Guide. Otherwise make sure calibration is correct, see RI calibration (page 29), as well as RI adjustment, see RI adjustment (page 45). The latter can only be done with Insight.	

10.2 Diagnostic message priorities

The messages are listed in descending order of priority. For example, if both **No optical image** and **Temperature measurement error** are activated, only **No optical image** is displayed.

Certain malfunctions cause the mA measurement to return to the error output level, see Configuring analog output (page 47). For more information, see the following table.

Table 10 Diagnostic message priorities

Message	Error output level
Image quality low	
External light level high	
Prism coating detected	x
No liquid detected	x
No optical image	x

Message	Error output level
External light level too high	x
Temperature measurement error	x
C measurement out of concentration curve range	
T measurement out of concentration curve range	
Invalid calculation parameters	x
Calibration mode active	x
Internal temperature too high	
Internal humidity too high	
Blank image corrupted	

Invalid calculation parameters: RI adjustment parameters are invalid. Perform RI adjustment or contact helpdesk@vaisala.com.

Blank image corrupted: Blank image for IDS image detection algorithm is corrupted. Create blank image or contact helpdesk@vaisala.com.

10.3 Calibration check

Wait until normal process conditions occur. The concentration reading is precalibrated at delivery and a copy of the calibration certificate is delivered with the process refractometer. If the diagnostic message is **Normal operation** but the concentration reading does not agree with the laboratory results, see

- Indigo520: Performing RI calibration (page 31)
- Insight: Performing RI calibration (page 44).

10.4 RI calibration failure

It is recommended to recalibrate any failed points at least once more. Something external may have caused the calibration failure.

- Temperature related failures:
  - There is a difference between the sample temperature and the refractometer temperature.
  - Measured temperature is out of the specified 20 ... 30 °C calibration range.

If the calibration failure is caused by temperature, both refractometer and sample liquid temperature should be allowed to stabilize to be in the calibration range. Retry calibration after a little while.

- Reference liquid related failures:
  - There is coating on the prism.
    Clean the prism and the sample holder, and then recalibrate.
  - There are impurities in the sample liquid.
    Clean the prism and the sample holder. Replace the sample liquid and then recalibrate.
  - Reference liquid has expired.
    Check the expiration date and use another reference liquid if needed. Notice that the liquids may expire quicker if the containers are left open for extended periods of time.

See Analyzing the optical image (page 84).

11. Technical data

11.1 Compatibility

PR53 refractometer is mechanically compatible with most PR-23 and PR-43 refractometers. The communication and electronic system has to be updated with the refractometer change.

11.2 PR53AC specifications

Table 11 Measurement performance

Refractive index	
Measurement range	1.32 ... 1.53 nD (Corresponds to 0 ... 100 °Bx)
Accuracy	±0.00014 nD (0.1 °Bx) [1]
Repeatability	±0.00002 nD [2]
Resolution	±0.000015 nD
Response time T_{63} with default damping	10 s [3]
Measurement cycle	1 / s
Long-term stability	Max. 0.1 % full scale / a
Temperature	
Accuracy at 20 °C (68 °F)	±0.3 °C (0.54 °F) [1]
Sensor class	F0.15 IEC 60751
Temperature coefficient	±0.002 °C / C

1) *Accuracy specified with respect to calibration reference, including non-linearity, hysteresis at +20 °C.*
2) *Repeatability, confidence level k=2, including random noise, at Ta = +20 °C, with standard low-pass filtering.*
3) *With standard low-pass filtering.*

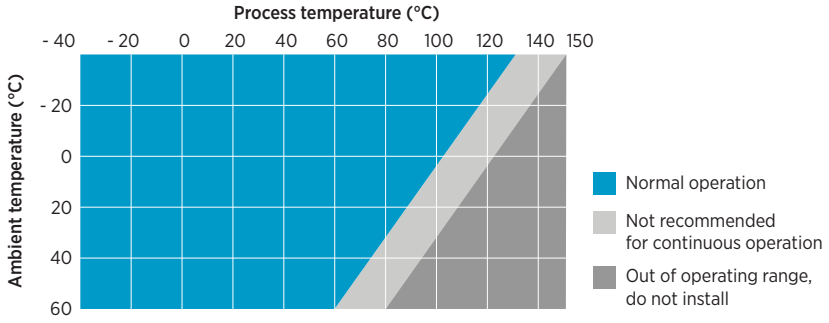


Figure 16 PR53AC process temperature, options Sanitary 2.5″ and Type N (indicative)

Table 12 Operating environment

Process parameters	
Process temperature	–40 ... +150 °C (–40 ... +302 °F) [1]
Design temperature	+180 °C (356 °F) [2]
Design pressure	40 bar [3]
Operating environment	
Storage temperature	–40 ... +65 °C (–40 ... +149 °F)
Operating temperature	–40 ... +60 °C (–40 ... +140 °F)
Maximum operating altitude	2000 m (approx. 6500 ft)
Operating humidity	0 ... 100 %RH
Storage humidity	0 ... 100 %RH, non-condensing
UL 50E (NEMA) rating	Type 4X
IP rating	IP66 IP67

1) *-40 ... +130 °C (-40 ... 266 °F) EPDM gasket, -40... +150 °C (–40 ... +302 °F) PTFE gasket.*
2) *Maximum momentary temperature peak.*
3) *Maximum at +20 °C, operating pressure to the clamp rating pressure.*

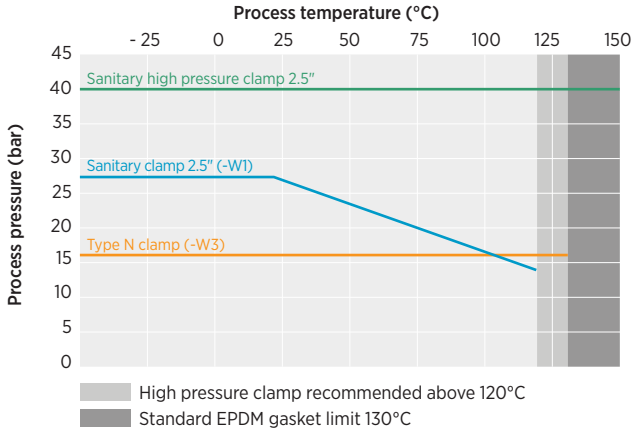


Figure 17 PR53AC process pressure

Table 13 Inputs and outputs

Supply	
Operating voltage	24 V DC nominal (9 ... 30 V DC)
Power consumption	Less than 1 W
Protection class	3, PELV
Outputs	
Output parameters	RI, temperature, concentration, quality factor
Analog outputs	
mA	Sourcing, isolated, NAMUR NE 43, configurable
mA range	3.8 ... 20.5 mA
Loop impedance	Max. 600 Ω
Accuracy of analog outputs at +20°C	±0.1 % of full scale (±0.00002 RI)
Digital outputs	
Digital output	RS-485, non-isolated
Maximum cable run	300 m (approx. 1000 ft) (digital)
Supported protocol	Modbus RTU
Connectors	

External connectors	1 × M12 F 4 pins, A-coded [1)] 2 × M16×1.5 cable gland, Cable D 5 ... 10 mm / Adapter for conduit entry M16×1.5 / NPT ½″

1) *For USB2 adapter and Insight software. See www.vaisala.com/insight.*

Table 14 Compliance

Electromagnetic compatibility (EMC)	EN 61326-1, industrial environment
Safety	IEC/EN/UL 61010-1
Pressure	CRN all territories, ASME BPVC Sec VIII Div. 1 Ed. 2021
Material compliance	FDA 21 CFR 177.150, 177.2600, 177.1550 EC 1935/2004 EC 2023/2006, GMP EU 10/2011
Compliance marks	CE, China RoHS, RCM, UKCA

Table 15 Sanitary compliance

Hygienic design	3-A 46-04 EHEDG
Compliance marks	3-A, EHEDG [1)]
Biocompatibility	USP Class VI <88>, 70 °C
ADI free (Animal Derived Ingredients)	Yes

1) *For EHEDG compliant installation, use 2.5″ / 4″ sanitary gasket.*

Table 16 Mechanical specifications

Wetted parts	
Sensor head	EN 1.4435 BN2 (AISI 316L) [1)]
Surface roughness	Ra 0.8 µm
Prism	Sapphire monocrystalline, 99.996 % Al_2O_3 [2)]
Prism gasket	Modified PTFE [3)]
Sanitary 2.5″ gasket	EPDM [2)]
Type N gasket	EPDM [2)]

Welding ferrule	EN 1.4435 (AISI 316L) [1) 4)] ASME BPE-2019 (DIN 32676-C)
Non-wetted parts	
Housing	EN 1.4404 (AISI 316L)
Screws TX20, torque 2.0 Nm	EN 1.4404 (AISI 316L)
Cable gland, dummy plug	EN 1.4305 (AISI 303)
Conduit hub	EN 1.4404 (AISI 316L)
M12 connector	Gland, EN 1.4305 (AISI 303) Contacts, CuZn with Ni/Au plating Carrier, PA 6.6
Sanitary 2.5″ clamp	EN 1.4301 (AISI 304) [2)]
Type N Clamp	EN 1.4301 (AISI 304) [2)]
Cable	4×22 AWG PUR, gray 10 m multistrand, with ferrules Flame-retardant acc. to IEC 60332-1-2, FT1, VW1
Weight	2.7 kg (5.95 lb)

1) EN 10204 / 3.1 certificate included.
2) Manufacturer's declaration included.
3) ADI free, FDA 21 C.F.R 177.1550, 3A Sanitary Standard, USP Class VI <88>, 70 °C.
4) 3-A certificate, EHEDG certificate.

11.3 PR53GP specifications

Table 17 Measurement performance

Refractive index	
Measurement range	1.32 ... 1.53 nD (Corresponds to 0 ... 100 °Bx)
Accuracy	±0.00014 nD (0.1 °Bx) [1)]
Repeatability	±0.00002 nD [2)]
Resolution	±0.000015 nD
Response time T_{63} with default damping	10 s [3)]
Measurement cycle	1 / s
Long-term stability	Max. 0.1 % full scale / a

Temperature	
Accuracy at 20 °C (68 °F)	±0.3 °C (0.54 °F) [1]
Sensor class	F0.15 IEC 60751
Temperature coefficient	±0.002 °C / C

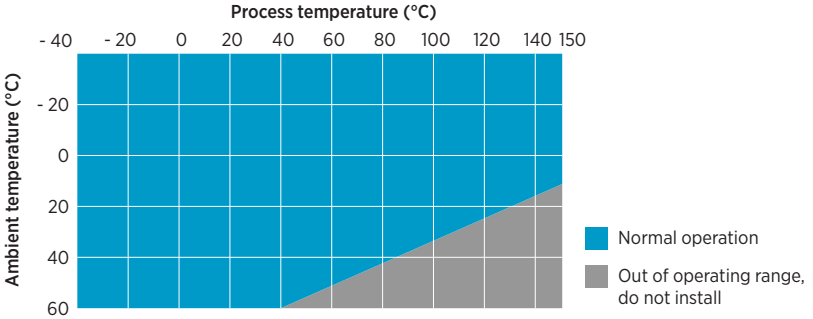


Figure 18 PR53GP process temperature (indicative)

Table 18 Operating environment

Process parameters	
Ambient temperature	–40 ... +60 °C (–40 ... +140 °F)
Process temperature	–40 ... +150 °C (–40 ... +302 °F) [1]
Design temperature	+180 °C (356 °F) [2]
Design pressure	40 bar [3]

1) *-40 ... +130 °C EPDM gasket, -40... +150 °C EHEDG gasket.*
2) *Maximum momentary temperature peak.*
3) *Maximum at +20 °C, operating pressure to the clamp rating pressure.*

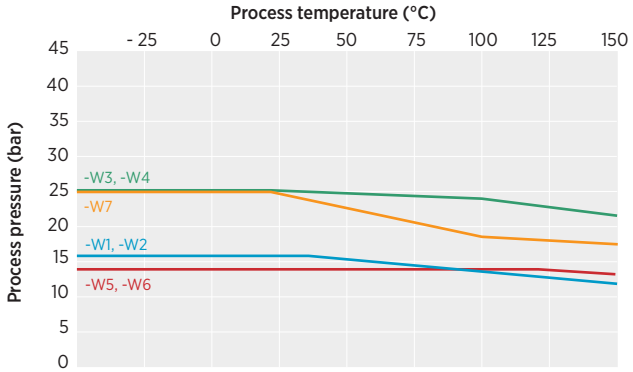


Figure 19 PR53GP process pressure

Table 19 Inputs and outputs

Supply	
Operating voltage	24 V DC nominal (9 ... 30 V DC)
Power consumption	Less than 1 W
Protection class	3, PELV
Outputs	
Output parameters	RI, temperature, concentration, quality factor
Analog outputs	
mA	Sourcing, isolated, NAMUR NE 43, configurable
mA range	3.8 ... 20.5 mA
Loop impedance	Max. 600 Ω
Accuracy of analog outputs at +20°C	±0.1 % of full scale (±0.00002 RI)
Digital outputs	
Digital output	RS-485, non-isolated
Maximum cable run	300 m (approx. 1000 ft) (digital)
Supported protocol	Modbus RTU
Connectors	
External connectors	1 × M12 F 4 pins, A-coded [1)] 2 × M16×1.5 cable gland, Cable D 5 ... 10 mm / Adapter for conduit entry M16×1.5 / NPT ½"

Table 20 Compliance

Electromagnetic compatibility (EMC)	EN 61326-1, industrial environment
Safety	IEC/EN/UL 61010-1
Pressure	CRN all territories, ASME BPVC Sec VIII Div. 1 Ed. 2021
Material compliance	FDA 21 CFR 177.150, 177.2600, 177.1550 EC 1935/2004 EC 2023/2006, GMP EU 10/2011
Compliance marks	CE, China RoHS, RCM, UKCA

Table 21 Mechanical specifications

Wetted parts	
Sensor head	EN 1.4404 (AISI 316L) [1)]
Surface roughness	Ra 0.8 µm
Prism	Sapphire monocrystalline, 99.996 % Al_2O_3 [2)]
Prism gasket	Modified PTFE [2)]
L coupling gasket	PTFE [2)]
L coupling welding ferrule	EN 1.4404 (AISI 316L)[1)]
Wash nozzle parts	EN 1.4404 (AISI 316L) [1)]
Non-wetted parts	
Housing	EN 1.4404 (AISI 316L)
Screws TX20, torque 2.0 Nm	EN 1.4404 (AISI 316L)
Cable gland, dummy plug	EN 1.4305 (AISI 303)
Conduit hub	EN 1.4404 (AISI 316L)
M12 connector	Gland, EN 1.4305 (AISI 303) Contacts, CuZn with Ni/Au plating Carrier, PA 6.6
Flange	EN 1.4404 (AISI 316L) Dimensioning and tolerances as per ASME B16.5, DIN 2543, JIS B2220
L coupling clamp, 88.9 mm	EN 1.4301 (AISI 304)

Cable	4×22 AWG PUR, gray 10 m multistrand, with ferrules Flame-retardant acc. to IEC 60332-1-2, FT1, VW1
Weight	PR53GP 2″ flange 7.2 kg (15.87 lb) - 7.7 kg (16.98 lb) PR53GP 3″ flange 10.5 kg (23.15 lb) - 11.7 kg (25.79 lb) PR53 L coupling 5.1 kg (11.24 lb)

1) *Material certificate included.*
2) *Manufacturer's declaration included.*

11.4 Spare parts and accessories

When in need of spare parts, contact your local distributor.

11.4.1 Interconnecting cable specifications

Table 22 Interconnecting cable specifications

Property	Specification
Maximum cable run	300 m (approx. 1000 ft)
Type	Shielded, multistrand
Dimensions	OD 5 ... 10 mm [0.20 ... 0.39 in], 0.2 ... 2.5 mm2 (AWG 24 ... 14), stripping length 10-12 mm
Circuit breaker	1 A (slow)

11.5 Recycling instructions

These recycling instructions guide you on the end-of-life treatment of this Vaisala product. As waste regulations and infrastructure vary in each country, these instructions only indicate the different components to be separated and common ways to handle them. Always follow local requirements when disposing of the product. Vaisala encourages to use the best available recycling practices to minimize related environmental impacts.

Vaisala is committed to meeting the requirements of the EU Waste Electrical and Electronic Equipment (WEEE) Directive. This directive aims to minimize the impact of electrical and electronic goods on the environment, by increasing reuse and recycling, and reducing the amount of WEEE going to landfill. This symbol indicates that the product should be collected separately from other waste streams and treated appropriately.

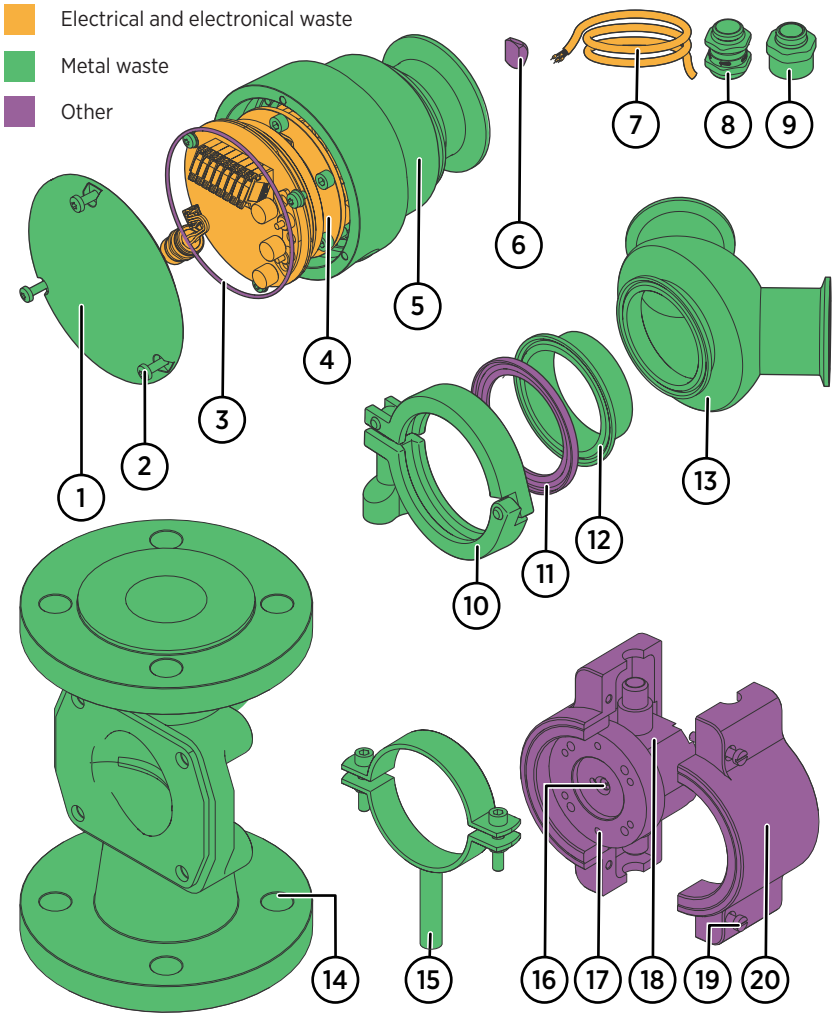


Figure 20 Materials for recycling

Table 23 Materials for recycling

	Part	Material	Recycling
1	Cover	Stainless Steel	Metal waste

	Part	Material	Recycling
2	Screws and washers	Stainless steel	Metal waste
3	O-rings	FPM	Other
4	Electronics	Various	Eletrical and electronical waste
5	Enclosure	Stainless Steel	Metal waste
6	Prism	Sapphire	Other
7	cables	Various	Eletrical and electronical waste
8	Cable gland	Various	Metal waste
9	Conduit hub	Various	Metal waste
10	Clamps	Stainless steel	Metal waste
11	Gasgets	Various	Other
12	Ferrule	Stainless steel	Metal waste
13	Flowcells	Stainless steel	Metal waste
14	Saunders body	SG iron	Metal waste
15	PR53M support	Stainless steel	Metal waste
16	PR53M sapphire plate	Sapphire	Other
17	PR53M headring	PVDF	Other
18	PR53M flowcell	PTFE	Other
19	PR53M screws	PEEK	Other
20	PR53M lightcover	PP-C	Other

12. Modbus registers

12.1 Modbus registers

Table 24 Measurement data registers (read-only)

Register number (decimal)	Address (hexadecimal)	Register description	Data format	Unit
3	0002_{hex}	Concentration	32-bit float	*
	0003_{hex}			
5	0004_{hex}	Temperature	32-bit float	°C
	0005_{hex}			
7	0006_{hex}	Raw concentration	32-bit float	*
	0007_{hex}			
9	0008_{hex}	Refractive index	32-bit float	
	0009_{hex}			
11	$000A_{hex}$	Quality factor	16-bit integer	

* Depends on the active concentration curve

Table 25 Measurement diagnostic registers (read-only)

Register number (decimal)	Address (hexadecimal)	Register description	Data format	Unit/ Valid range /Writable
529	0210_{hex}	Light area	32-bit float	%
	0211_{hex}			
531	0212_{hex}	Ambient light	32-bit integer	
	0213_{hex}			
533	0214_{hex}	Internal temperature	32-bit float	°C
	0215_{hex}			
535	0216_{hex}	Internal relative humidity	32-bit float	%RH
	0217_{hex}			

Register number (decimal)	Address (hexadecimal)	Register description	Data format	Unit/ Valid range /Writable
537	0218_{hex}	Light exposure	32-bit float	%
	0219_{hex}			
539	$021A_{hex}$	Analog output 1 output level	32-bit float	mA
	$021B_{hex}$			
541	$021C_{hex}$	Adjusted concentration	32-bit float	*
	$021D_{hex}$			
543	$021E_{hex}$	Adjusted temperature	32-bit float	°C
	$021F_{hex}$			
545	0220_{hex}	Raw temperature	32-bit float	°C
	0221_{hex}			
547	0222_{hex}	Measurement number	32-bit integer	
	0223_{hex}			
553	0228_{hex}	Temperature stable	16-bit integer	0 = not stable 1 = stable

* Depends on the active concentration curve

Table 26 Status registers (read-only)

Register number (decimal)	Address (hexadecimal)	Register description	Data format
515	0202_{hex}	Error code	32-bit integer
	0203_{hex}		
517	0204_{hex}	Error subcode	32-bit integer
	0205_{hex}		

Error subcode is meant to be sent to Vaisala service along with error code.

Table 27 Error code encoding

MSB	30	29	28	27	26	25	24	...	17	16	15	14	13	12	11	10	...	6	5	4	3	2	1	LSB
System									Environment				Calculation					Temperature			Image			

Error code register value	Corresponding error
Image detection status	
1	Image quality low.
2	External light level high.
3	Prism coating detected.
4	No liquid detected.
5	No optical image.
6	External light level too high.
Temperature measurement status	
1	Temperature measurement error.

Measurement statuses are listed in priority order. Higher values are prioritized.

Error code register value	Corresponding error
Calculation errors	
01_{hex}	Concentration out of concentration curve range.
02_{hex}	Temperature out of concentration curve range.
04_{hex}	Invalid calculation parameters.
08_{hex}	Calibration mode active.
Environmental errors	
01_{hex}	Internal temperature too high.
02_{hex}	Internal humidity too high.
System errors	
01_{hex}	Blank image corrupted.

If several errors are active at the same time, the Modbus error code register contains the sum of currently active error codes.

Table 28 Device information registers (read-only)

Register number (decimal)	Address (hexadecimal)	Register description	Data format	Example output
7425	$1D00_{hex}$ ... $1D07_{hex}$	VendorName	text	“Vaisala Oyj”

Register number (decimal)	Address (hexadecimal)	Register description	Data format	Example output
7433	$1D08_{hex}$ ... $1D0F_{hex}$	ProductCode	text	“PR53”
7441	$1D10_{hex}$ ... $1D17_{hex}$	SerialNumber	text	“J1140501”
7449	$1D18_{hex}$ ... $1D1F_{hex}$	FirmwareVersion	text	“1.0.0”

Table 29 Configuration registers

Register number (decimal)	Address (hexadecimal)	Register description	Data format	Unit / Valid range
Damping				
771	0302_{hex}	Damping type	16-bit integer	0 = Exponential 1 = Linear 2 = Slew rate
772	0303_{hex}	Damping time	16-bit integer	s
773	0304_{hex}	Slew rate	32-bit float	*
	0305_{hex}			
775	0306_{hex}	Tolerance time	16-bit integer	s
Concentration curve management				
776	0307_{hex}	Number of concentration curves	16-bit integer	Read-only
778	0309_{hex}	Select curve	16-bit integer	0 = concentration curve 1 1 = concentration curve 2 2 = concentration curve 3 3 = concentration curve 4
Communication				
1537	0600_{hex}	Address	16-bit integer	1 ... 247

1538	0601_{hex}	Bit rate (b/s)	16-bit integer	0 = 300 1 = 600 2 = 1200 3 = 2400 4 = 4800 5 = 9600 6 = 19200 7 = 28800 8 = 38400 9 = 57600 10 = 76800 11 = 115200
1539	0602_{hex}	Parity, data, stop bits	16-bit integer	0 = None, 8, 1 1 = None, 8, 2 2 = Even, 8, 1 3 = Even, 8, 2 4 = Odd, 8, 1 5 = Odd, 8, 2
1540	0603_{hex}	Response delay	16-bit integer	0 ... 1000 ms
1541	0604_{hex}	Restart device	16-bit integer	When writing to register: 1 = Restart the device
Analog output 1				
1794	0701_{hex}	Scale low end	32-bit float	*
	0702_{hex}			
1796	0703_{hex}	Scale high end	32-bit float	*
	0704_{hex}			
1798	0705_{hex}	Error output level	32-bit float	0.0 ... 20.5 mA
	0706_{hex}			
1800	0707_{hex}	No sample error output	16-bit integer	0 = Disabled 1 = Enabled
1801	0708_{hex}	No sample error output level	32-bit float	0.0 ... 20.5 mA
	0709_{hex}			
Temperature offset				
8967	2306_{hex}	T offset	32-bit float	°C

* Depends on the active concentration curve

Table 30 Concentration curve configuration registers

Register number (decimal)	Address (hexadecimal)	Register description	Data format	Unit	Writable
0 + base	0000_{hex} ... 0004_{hex} + base	Identifier	text		No
5 + base	0005_{hex} + base	Solvent type	16-bit integer	0 = Other 1 = Water-based	No
6 + base	0006_{hex} + base	Concentration minimum	32-bit float	*	No
	0007_{hex} + base				
8 + base	0008_{hex} + base	Concentration maximum	32-bit float	*	No
	0009_{hex} + base				
10 + base	$000A_{hex}$ + base	Temperature minimum	32-bit float	°C	No
	$000B_{hex}$ + base				
12 + base	$000C_{hex}$ + base	Temperature maximum	32-bit float	°C	No
	$000D_{hex}$ + base				
14 + base	$000E_{hex}$ ... $002D_{hex}$ + base	Description	text		No
95 + base	$005F_{hex}$ + base	Chemical coefficients, C00	32-bit float		Yes
	0060_{hex} + base				
97 + base	0061_{hex} + base	Chemical coefficients, C01	32-bit float		Yes
	0062hex + base				
99 + base	0063_{hex} + base	Chemical coefficients, C02	32-bit float		Yes
	0064_{hex} + base				
101 + base	0065_{hex} + base	Chemical coefficients, C03	32-bit float		Yes
	0066_{hex} + base				
103 + base	0067_{hex} + base	Chemical coefficients, C10	32-bit float		Yes
	0068_{hex} + base				

Register number (decimal)	Address (hexadecimal)	Register description	Data format	Unit	Writable
105 + base	0069_{hex} + base $006A_{hex}$ + base	Chemical coefficients, C11	32-bit float		Yes
107 + base	$006B_{hex}$ + base $006C_{hex}$ + base	Chemical coefficients, C12	32-bit float		Yes
109 + base	$006D_{hex}$ + base $006E_{hex}$ + base	Chemical coefficients, C13	32-bit float		Yes
111 + base	$006F_{hex}$ + base 0070_{hex} + base	Chemical coefficients, C20	32-bit float		Yes
113 + base	0071_{hex} + base 0072_{hex} + base	Chemical coefficients, C21	32-bit float		Yes
115 + base	0073_{hex} + base 0074_{hex} + base	Chemical coefficients, C22	32-bit float		Yes
117 + base	0075_{hex} + base 0076_{hex} + base	Chemical coefficients, C23	32-bit float		Yes
119 + base	0077_{hex} + base 0078_{hex} + base	Chemical coefficients, C30	32-bit float		Yes
121 + base	0079_{hex} + base $007A_{hex}$ + base	Chemical coefficients, C31	32-bit float		Yes
123 + base	$007B_{hex}$ + base $007C_{hex}$ + base	Chemical coefficients, C32	32-bit float		Yes
125 + base	$007D_{hex}$ + base $007E_{hex}$ + base	Chemical coefficients, C33	32-bit float		Yes
127 + base	$007F_{hex}$ ... $009E_{hex}$ + base	Name	text		Yes
159 + base	$009F_{hex}$ + base $00A0_{hex}$ + base	Field offset	32-bit float	*	Yes

Register number (decimal)	Address (hexadecimal)	Register description	Data format	Unit	Writable
131 + base	$00A1_{hex}$ + base	Field gain	32-bit float		Yes
	$00A2_{hex}$ + base				
Concentration curve bases					
3073	$0C00_{hex}$	Concentration curve 1			
3329	$0D00_{hex}$	Concentration curve 2			
3585	$0E00_{hex}$	Concentration curve 3			
3841	$0F00_{hex}$	Concentration curve 4			

* Depends on the active concentration curve

Table 31 Test value registers

Register number (decimal)	Address (hexadecimal)	Register description	Data format	Test value
7937	$1F00_{hex}$	Signed integer test	16-bit integer	-12345
7938	$1F01_{hex}$	Floating point test	32-bit float	-123.45
	$1F02_{hex}$			
7940	$1F03_{hex}$	Text string test	text	Text string “-123.45”
	$1F04_{hex}$			
	$1F05_{hex}$			
	$1F06_{hex}$			

Table 32 Device identification objects

Object ID	Object ID (hexadecimal)	Object name	Example contents
0	00_{hex}	VendorName	“Vaisala”
1	01_{hex}	ProductCode	“PR53”
2	02_{hex}	MajorMinorVersion	”1.0.0”
3	03_{hex}	VendorUrl	“https://www.vaisala.com”
4	04_{hex}	ProductName	“Polaris™ process refractometer”
5	05_{hex}	ModelName	“PR53AC”

128	80_{hex}	SerialNumber [1)]	“J1140501”
129	81_{hex}	CalibrationDate [1)]	”2023-04-21” Calibration date in YYYY-MM-DD format. Empty string if not set/valid.
130	82hex	CalibrationText [1)]	”Vaisala/HEL” Calibration information text. Empty string if not set/valid.

1) Vaisala-specific device information object

Appendix A. Principle of measurement

The Vaisala K-PATENTS® inline process refractometer determines the refractive index (RI) of the process solution. It measures the critical angle of refraction using a yellow LED light source with the same wavelength (589 nm) as the sodium D line. Light from the light source (L) in the following figure is directed to the interface between the prism (P) and the process medium (S). Two of the prism surfaces (M) act as mirrors bending the light rays so that they meet the interface at different angles.

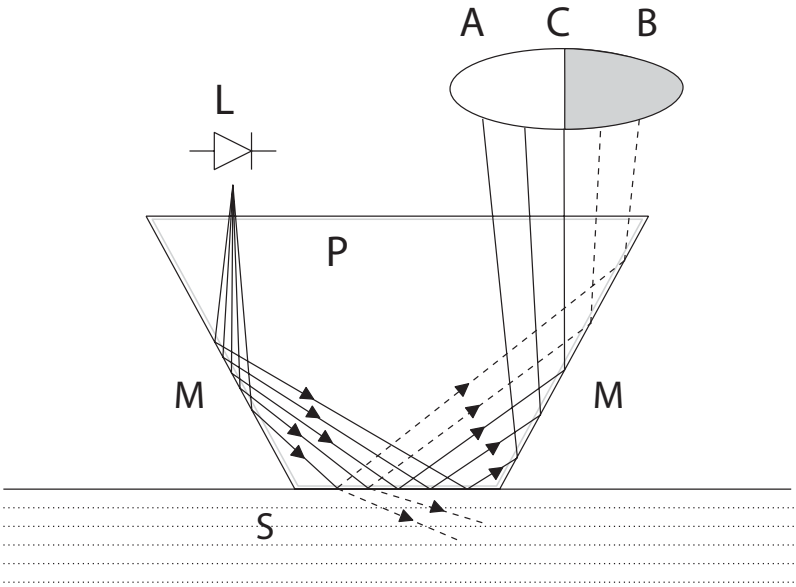


Figure 21 Refractometer principle

The reflected rays of light form an image (ACB), where (C) is the position of the critical angle ray. The rays at (A) are totally internally reflected at the process interface, the rays at (B) are partially reflected and partially refracted into the process solution. In this way the optical image is divided into a light area (A) and a dark area (B). The position of the shadow edge (C) indicates the value of the critical angle. The refractive index can then be determined from this position.

The refractive index changes with the process solution concentration and temperature. For most solutions the refractive index increases when the concentration increases. At higher temperatures the refractive index is smaller than at lower temperatures. From this follows that the optical image changes with the process solution concentration as shown in the following figure. The color of the solution, gas bubbles or undissolved particles do not affect the position of the shadow edge (C).

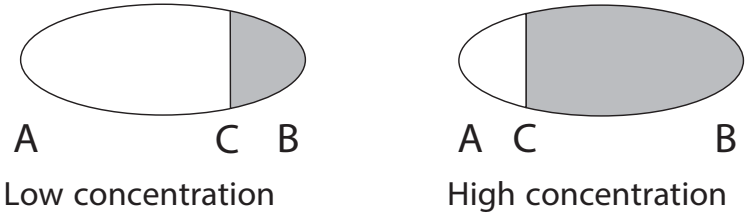


Figure 22 Optical images

The position of the shadow edge is measured digitally using a CCD element and is converted to a refractive index value by a processor inside the instrument. This value is used together with the measured process temperature to calculate the concentration.

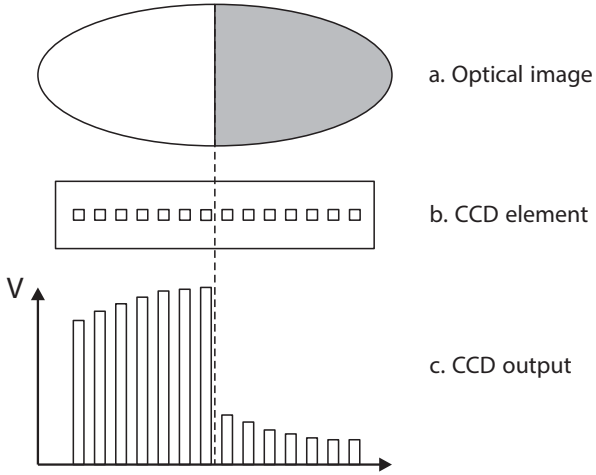


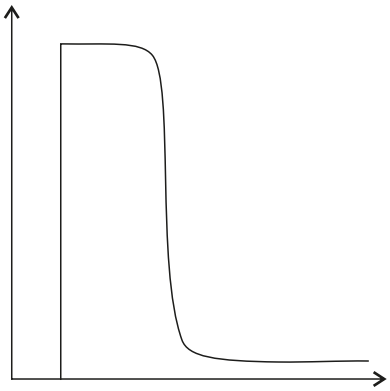
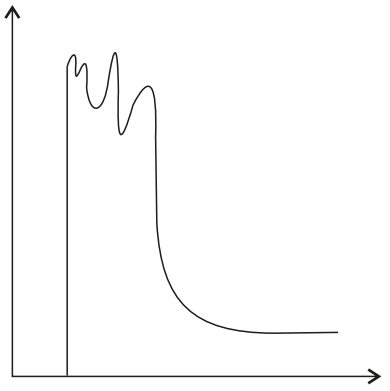
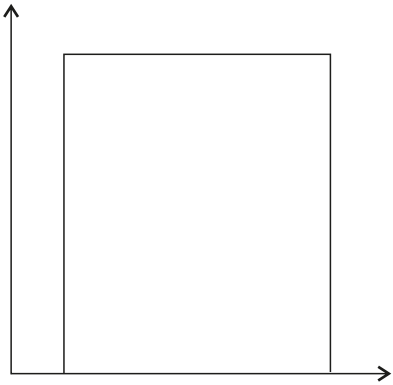
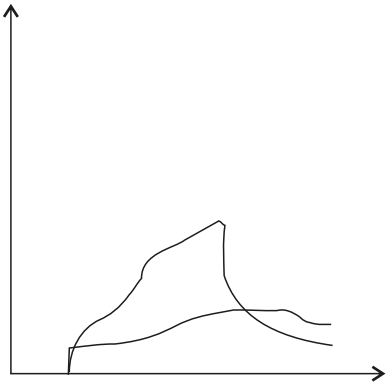
Figure 23 Optical image detection

Appendix B. Analyzing the optical image

The optical image can tell you about problems, for example, with the condition of the prism.

Y-axis is light intensity and X-axis the position of the shadow edge. RI calibration follows the X-axis. The position of RI measurement on X-axis is at the steepest curve drop, being the highest angle at the corner.

Table 33 Analyzing the optical image

Optical image with a reference RI liquid 	Erosion of the prism 
No sample 	Process liquid is leaking into the refractometer 

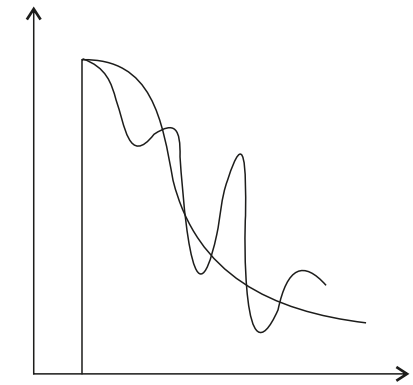
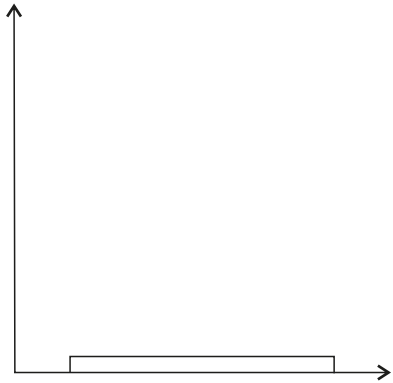
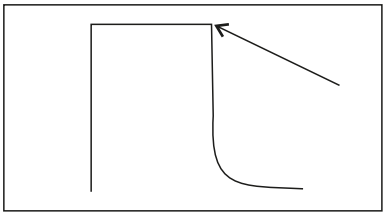
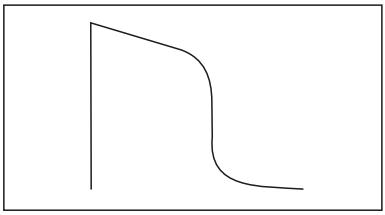
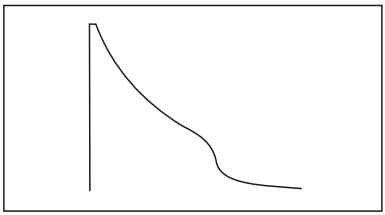
Prism coated 	CCD card is disconnected or faulty, or LED card is disconnected or faulty, or the optical fiber is broken 

Table 34 Prism scaling

	**Good** • Measurement status **Normal operation**. • Observe the angle, drop from high intensity light to low light intensity should be as steep as possible.
	**Compromized** • Measurement status **Normal operation**. • Scaling has started • Measurement starts to drift up • Perform manual cleaning
	**Heavy scaling** • Measurement status **No liquid detected** or **Prism coating detected**. • Measurement 0% • Immediate manual wash needed. See Vaisala Polaris Process Refractometer PR53 Prism Wash System User Guide.

Maintenance and calibration services

Vaisala offers comprehensive customer care throughout the life cycle of our measurement instruments and systems. Our factory services are provided worldwide with fast deliveries. For more information, see www.vaisala.com/calibration.

- Vaisala Online Store at store.vaisala.com is available for most countries. You can browse the offering by product model and order the right accessories, spare parts, or maintenance and calibration services.
- To contact your local maintenance and calibration expert, see www.vaisala.com/contactus.

Warranty

For standard warranty terms and conditions, see www.vaisala.com/warranty.
Please observe that any such warranty may not be valid in case of damage due to normal wear and tear, exceptional operating conditions, negligent handling or installation, or unauthorized modifications. Please see the applicable supply contract or Conditions of Sale for details of the warranty for each product.

Technical support

Contact Vaisala technical support at helpdesk@vaisala.com. Provide at least the following supporting information as applicable:

- Product name, model, and serial number
- Software/Firmware version
- Name and location of the installation site
- Name and contact information of a technical person who can provide further information on the problem

For more information, see www.vaisala.com/support.

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