

# User Guide

Sanitary OEM Refractometer

**PR-33-AC**



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# 1. About this document

## 1.1 Version information

This document provides instructions for installing, using and maintaining the Vaisala K-PATENTS® Sanitary OEM Refractometer PR-33-AC.

Table 1 Document versions (English)

Document Code	Date	Description
M212411EN-B	February 2020	Manual updated to new format, template, and document code. Minor changes to content.
IM-EN-PR33AC-A	September 2019	First version.

## 1.2 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.

## 1.3 Trademarks

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## 2. Product overview

### 2.1 Vaisala Sanitary OEM Refractometer PR-33-AC

The inline Sanitary OEM Refractometer PR-33-AC measures the refractive index  $n_D$  and the temperature of the process medium. The concentration of the process liquid is calculated from these values when the main components of the process medium are known.

The output values of the sensor are transmitted through a 4 ... 20 mA output and an Ethernet connection by using a UDP/IP protocol. For more information, see [Ethernet protocol specification \(page 47\)](#). An optional mA output unit is also available, if more than one current output is required.



Figure 1 Sanitary OEM Refractometer PR-33-AC

### 2.2 Safety

This product has been tested for safety. Note the following precautions:



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

The process medium may be hot or otherwise hazardous. Use shields and protective clothing adequate for the process medium. Do not rely on avoidance of contact with the process medium.



Wear protective eyewear.



Wear protective gloves.

Precautions when removing a sensor from the process line :

- Check that the process line is depressurized and drained
- Loosen the flowcell screws cautiously; be prepared to tighten again
- Ensure you are clear of any possible spillage and you have a clear emergency escape path

## 2.3 Regulatory compliances

This product complies with the following performance and environmental test standards:

- 3-A
- EHEDG

## 3. Instrument connections

The instrument has three different connections: power supply (+24 Vdc), 4 ... 20 mA current output, and an Ethernet connection for digital data acquisition and configuration.

These connections are grouped into two connectors so that one of the connectors carries both the power supply and the current output. The other connector is an Ethernet connection.

Both connections use the industrial M12 connector. The Ethernet connector has the industry standard M12-Ethernet pin-out. The power supply and current output use an A-coded M12 male on the instrument side. The Ethernet connection uses a D-coded female connector on the instrument side.

For the wiring details, see [Refractometer wiring \(page 18\)](#).

### 3.1 Power supply

The Sanitary OEM Refractometer requires a 24 V DC power supply (allowable tolerance is  $\pm 10\%$ ). The current consumption of the refractometer is less than 100 mA. Shield the power supply from external voltage surges.

### 3.2 mA output

The mA output of the refractometer supplies voltage and it is galvanically isolated. The compliance (maximum resistive load) for the output is 1000  $\Omega$ .

### 3.3 Ethernet connection

The Ethernet connection enables data download from a Sanitary OEM Refractometer to a computer. Any type of computer (PC, Mac, PDA, mainframe) with a compatible network connection can be configured to view and download data from the refractometer.

The Sanitary OEM Refractometer can be configured and monitored without any special software by using a standard web browser. [Ethernet protocol specification \(page 47\)](#) gives all the specifications necessary to write a data acquisition program.

#### 3.3.1 Ethernet specification

The Sanitary OEM Refractometer is designed to be connected to a network with a standard Ethernet cable. The cable supplied with the instrument has an industrial M12 connector in the instrument and a RJ-45 connector in the other end. The maximum communication speed of the refractometer is 100 Mbit/s (Ethernet 100BASE-T). In the simplest form the network consists of one refractometer and one computer. The following figure shows the configuration.

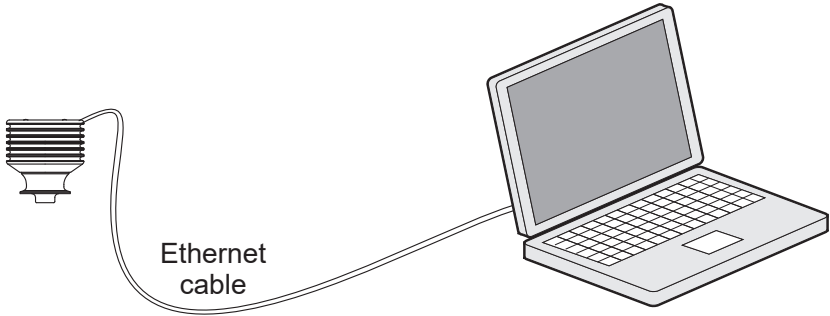


Figure 2 Simple network configuration

Several refractometers can be connected to the same Ethernet network. The Sanitary OEM Refractometer also has an automatic function (known as Auto MDI/MDIX) to detect the polarity of the network so that the network may utilize either cross-over or straight interconnecting cables.

The following figure shows an example of how to connect three refractometers to an existing LAN with a switch.

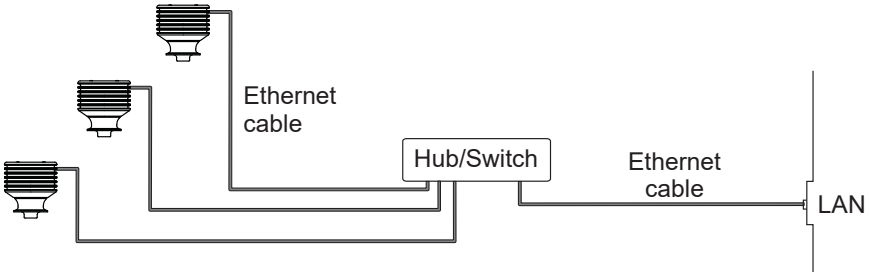


Figure 3 Three refractometers in the same network

It is possible to use a WLAN access point to decrease the number of cables.

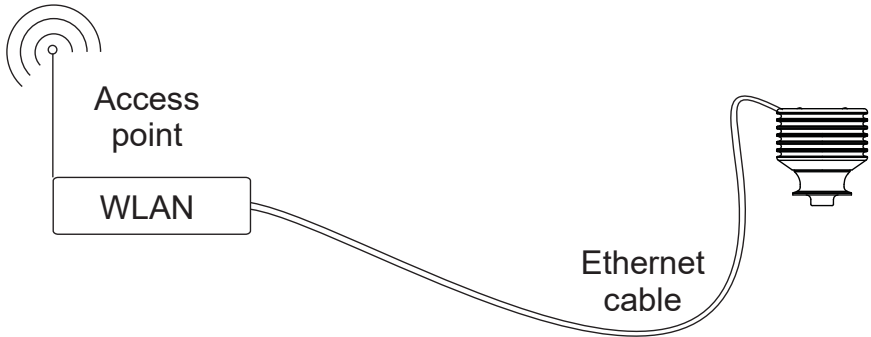


Figure 4 Connecting refractometer(s) via wireless

The maximum distance of a single Ethernet connection is 100 m (incl. one joint adapter/coupler), but if longer distances are required, a fiber link may be used to extend the range as shown in the following figure. The range may be up to several kilometers with a suitable fiber connection.

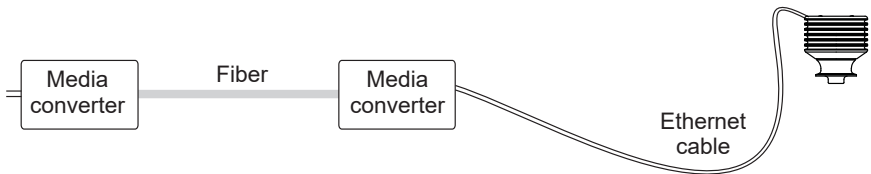


Figure 5 Using fiber link to connect refractometer(s)

### 3.3.2 IP settings for Sanitary OEM Refractometer

All Sanitary OEM Refractometers are shipped with the factory default IP address of 169.254.23.33. This address belongs to the Zeroconf addresses (as defined in IETF standard RFC 3927) so that it can easily be reached from a stand-alone computer, usually without changing the network settings of the computer.

This address remains in the instrument even after a different IP address has been set. The sensor answers in the address that is first called up after startup.



If there is more than one Sanitary OEM Refractometer in the same network, this address cannot be used. For more information, see [Configuring refractometer network \(page 13\)](#).

Change the IP address of the instrument through the instrument homepage. For more information, see [Instrument homepage \(page 21\)](#).

### 3.3.3 IP settings for stand-alone computer

When a computer with automatic IP settings (DHCP enabled) is turned on in a network with only the refractometer, the computer automatically obtains the IP address 169.254.x.x. In this case the factory default address of the refractometer can be used for connecting without any further changes in settings. If this does not work, make sure that the WLAN (Wireless network connection) is not active on the computer that is connected to the refractometer. If the WLAN is active, the computer's Ethernet connection may not function as expected. Obtaining the 169.254.x.x. address may take up to a minute.

If you still have difficulties connecting to the refractometer, check the computer's IP address by opening the command window (command prompt) and by typing the command **ipconfig** (press **ENTER** to give the command). In Mac OS X and Linux the same command is called **ifconfig**. The information given includes the computer's IP address. If the address does not start with 169.254, configure the IP address of the computer manually to 169.254.23.34, netmask 255.255.0.0.

For further troubleshooting, see [Troubleshooting connection \(page 13\)](#).

The following figure shows an example IP configuration for a stand-alone laptop when connected to the refractometer. The laptop wireless (WLAN) is turned off.

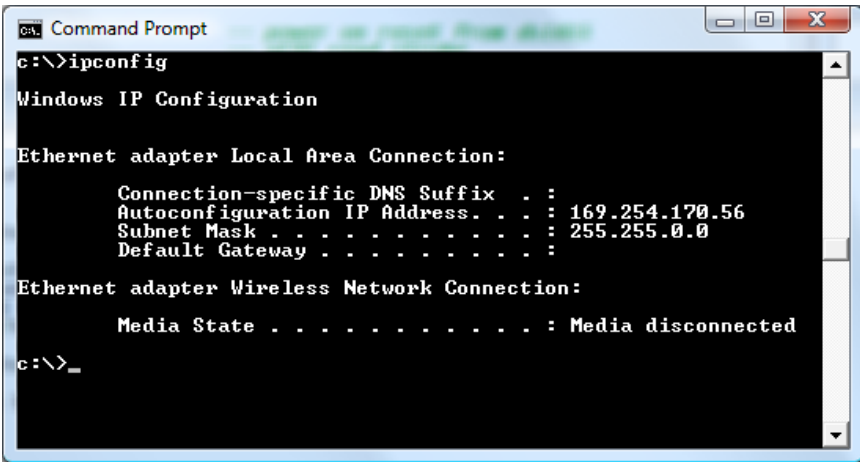


Figure 6 Typical stand-alone IP configuration



The connection does not work if the computer and the refractometer have exactly the same IP address.

When the network settings of the instrument (and/or the computer) have been configured according to the instructions above, the next step is to test the connection as instructed in [Testing Ethernet connection \(page 13\)](#).

### 3.3.4 Configuring refractometer network

If there is more than one Sanitary OEM Refractometer in a network, configure their IP addresses manually as the factory defaults do not work.

If the Sanitary OEM Refractometer is to be connected to a factory network, consult the network administrator for the correct settings.

If the network is a stand-alone network with only one Sanitary OEM Refractometer and one or more computers with no connection to any other network, then the IP addresses can be chosen rather freely. One possibility is to number the instruments so that they all have 192.168.33.x addresses so that every computer and instrument has a different number x between 1. 254. The subnet mask (or netmask) is in this case 255.255.255.0.

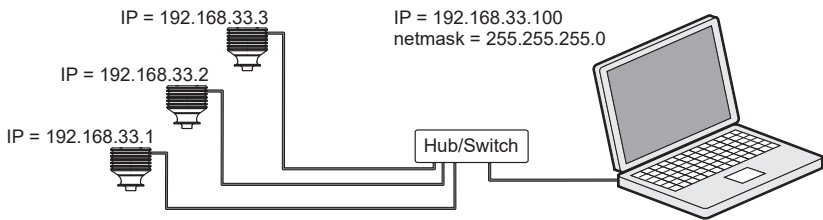


Figure 7 A network of Sanitary OEM Refractometers



There are no settings for subnet mask, default gateway or name servers in the Sanitary OEM Refractometer, as these settings are not required.

### 3.3.5 Testing Ethernet connection

When the Sanitary OEM Refractometer is connected to a switch, the corresponding link light illuminates in the switch.

Once the refractometer is powered up, it is reachable from any correctly configured computer. Typing the IP address of the instrument to the address bar of a web browser should bring up the instrument homepage. For more information, see [Instrument homepage \(page 21\)](#).



The factory-default IP address of the Sanitary OEM Refractometer is 169.254.23.33. This address always responds. For more information, see [IP settings for Sanitary OEM Refractometer \(page 11\)](#).

### 3.3.6 Troubleshooting connection

If the instrument cannot be reached through the network, check the following:

- The instrument receives power; the ethernet switch link light is lit.

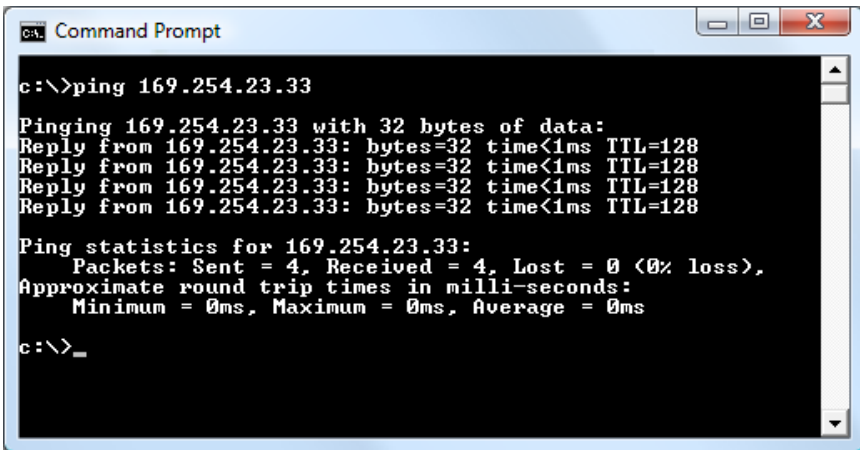
- The network settings of the computer are compatible with those of the instrument; for more information, see [IP settings for stand-alone computer \(page 12\)](#).
- If the instrument should be at IP address 169.254.23.33, but cannot be reached, check that there is only one Sanitary OEM Refractometer in the same network, as otherwise there is an address conflict.
- Check that the software firewall of the computer does not block the connections.

A useful test to determine whether the problem is in network settings is to set up a small network. Perform the following steps:

- Set up a network of only one Sanitary OEM Refractometer and one computer.
- Check that the computer has suitable network settings and that its WLAN connection is turned off; for more information, see [IP settings for stand-alone computer \(page 12\)](#).
- Use the ping utility of the computer to try and reach the refractometer.

The ping utility is available in Windows systems by using the Command Prompt (usually found in the Accessories; or open **Run**, type **cmd** in the empty line and press **ENTER** to open Command Prompt).

To use ping go to the command interface, type the name of the command and the IP address you want to check and press **ENTER**. If the Ethernet connection is physically working and the address given to ping is correct, the refractometer answers the ping and returns any data packets sent to it.

A screenshot of a Windows Command Prompt window. The title bar reads "C:\> Command Prompt". The command prompt shows the user entering the command "c:\>ping 169.254.23.33". The output shows four successful replies from 169.254.23.33, each with 32 bytes of data, a time of less than 1ms, and a TTL of 128. Below the replies, it shows "Ping statistics for 169.254.23.33:" followed by "Packets: Sent = 4, Received = 4, Lost = 0 (0% loss)," and "Approximate round trip times in milli-seconds: Minimum = 0ms, Maximum = 0ms, Average = 0ms". The prompt ends with "c:\>\_" indicating the user is ready for another command.

```
C:\>ping 169.254.23.33

Pinging 169.254.23.33 with 32 bytes of data:
Reply from 169.254.23.33: bytes=32 time<1ms TTL=128
Reply from 169.254.23.33: bytes=32 time<1ms TTL=128
Reply from 169.254.23.33: bytes=32 time<1ms TTL=128
Reply from 169.254.23.33: bytes=32 time<1ms TTL=128

Ping statistics for 169.254.23.33:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 0ms, Average = 0ms

c:\>_
```

Figure 8 Pinging address 169.254.23.33



## 4. Refractometer mounting

Choose the Sanitary OEM Refractometer mounting location with care to ensure reliable readings from the process.

### 4.1 Choosing refractometer mounting location

The mounting location must be such that sediments or gas bubbles cannot accumulate by the refractometer. Good flow velocity is essential in keeping the prism clean.



**CAUTION!** If the process pipe vibrates, support the pipe. A vibrating pipe can damage the in-line refractometer mounted on it.

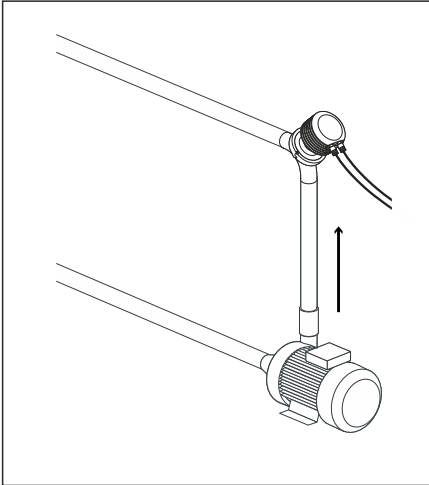
The refractometer cover should not be exposed to high temperature radiation. In most cases, draft and natural convection provide sufficient air cooling if the air gets to flow freely around the refractometer head.



**CAUTION!** Always mount the refractometer so that the interconnecting cable points downwards from the refractometer head.

### 4.2 Checklist for pipe mounting

Most Sanitary OEM Refractometers are mounted in a pipe. The recommended flow velocity is between 1 and 3 m/s (3 ... 10 ft/s). If the flow velocity exceeds 6 m/s (20 ft/s), there is a risk of cavitation. Cavitation may damage the sensor and the piping. Too slow a flow velocity may cause erroneous measurement readings due to coating or stratification (layering) of the sample on the prism.



- Upper pipe bend
- Cable downwards
- High velocity (>1.5 m/s [5 ft/s])
- High temperature
- High pressure
- Easy access

The diameter and form of the pipe and the process temperature all affect the measurement and need to be taken into account.

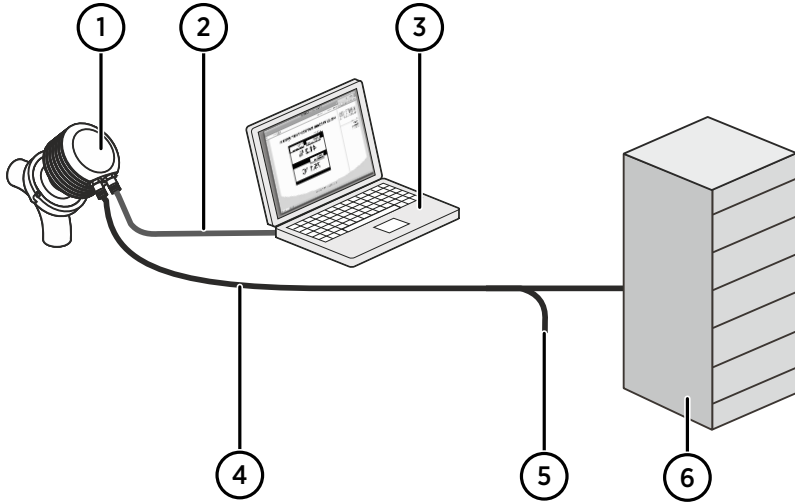


Figure 9 Sensor configuration

- 1 IP: 169.254.23.33
- 2 Ethernet
- 3 Computer with Ethernet and browser
- 4 4 ... 20 mA
- 5 24 VDC
- 6 PLC

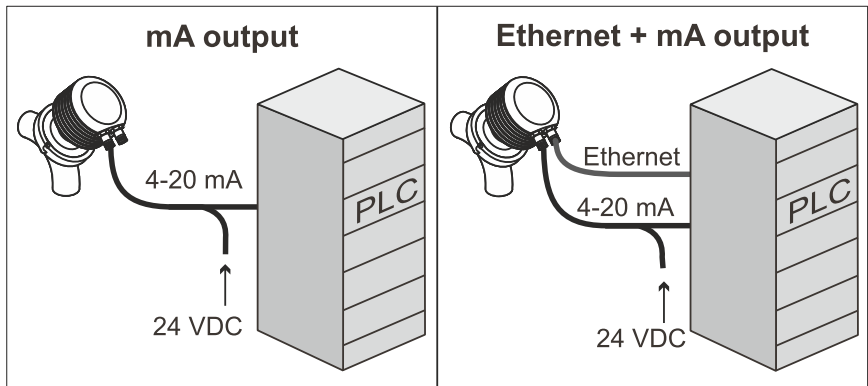


Figure 10 Output options

1. If the process pipe diameter varies, select the position with the smallest diameter (and accordingly highest velocity) to ensure the prism stays clean better.

2. If the refractometer is used in a feedback control loop, make the time lag short. For example, when a dilution valve is controlled, mount the refractometer close to the dilution point. However, make sure complete mixing has occurred at mounting location.
3. If the temperature varies along the process pipe, select the position with the highest process temperature. That minimizes the risk of coating, because higher temperature means higher solubility and also lower viscosity.
4. Often the position with the highest process pressure (= after pump + before valve) has favorable flow conditions without sedimentation or air trapping risks.
5. Position the refractometer so it is conveniently accessible for service.

## 4.3 Refractometer wiring

The Sanitary OEM Refractometer sensor has two M12 connectors. The A-coded male sensor is for power supply and milliamp output signals. The D-coded female connector is for the Ethernet connection.



Figure 11 Sanitary OEM Refractometer connectors

The following figure shows the wiring layout.

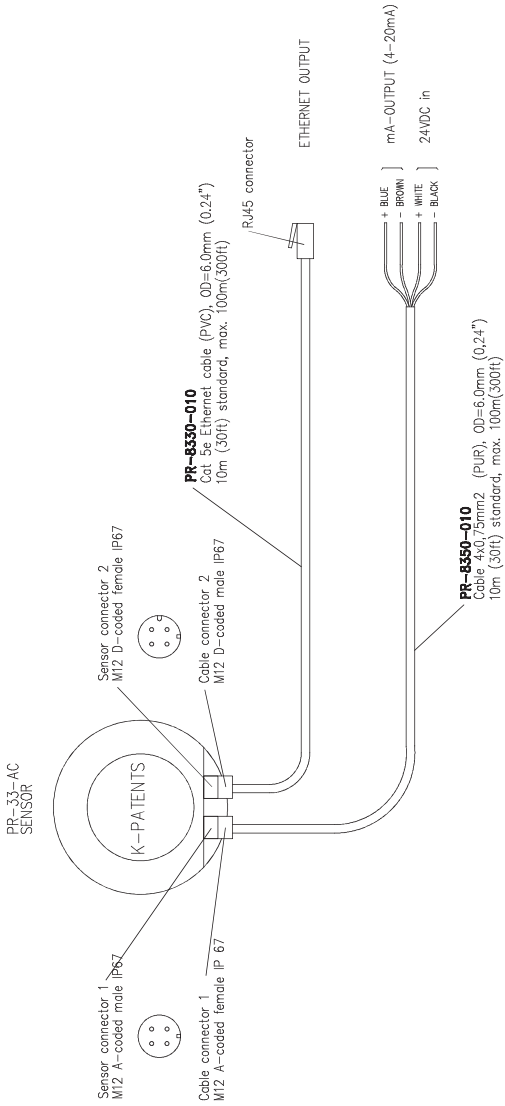


Figure 12 Wiring drawing

## 5. Startup and use

### 5.1 Startup

Startup of the Sanitary OEM Refractometer consists of the following checks:

- Initial check
- Calibration check

#### 5.1.1 Initial check

Connect the Sanitary OEM Refractometer to a 24 V DC supply. For more information, see [Power supply \(page 9\)](#) and [Refractometer wiring \(page 18\)](#).

Check that the instrument powers up properly. This is easiest to check by measuring the milliamp output, which should be at 4 mA after the first startup. It is also possible to see a faint blinking amber light when viewing the prism at an oblique angle.

Connect the instrument to a computer with an Ethernet cable (RJ-45 to M12 type). After the instrument has powered up, use a web browser to open the instrument homepage. For more information, see [Ethernet connection \(page 9\)](#).

On the homepage, check that the serial number of the page corresponds to that on the instrument nameplate. If you have difficulties connecting to the instrument, see [Troubleshooting connection \(page 13\)](#).

#### 5.1.2 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 refractometer. If the diagnostic message is **Normal operation** but the concentration reading does not agree with the laboratory results, see [Calibrating concentration measurement \(page 29\)](#).

### 5.2 Viewing refractometer status

The basic information on the measurements is shown on the **Main** page of the instrument. For more information, see [Main page \(page 21\)](#). More information is shown on the **Diagnostics** page. For more information, see [Parameters \(page 25\)](#).

The measurement result is calculated from the refractive index ( $n_D$ ) and process temperature (T) values. Both of these values are available on the main page.

In addition to these measurements, the refractometer monitors its internal temperature and humidity, which both are available on the **Diagnostics** page. The internal temperature should not be above 65 °C, and the humidity should be below 60 %. High humidity is an indication of leaking seals, and high temperature may deteriorate the measurement performance and/or shorten the lifetime of the unit.

## 6. Instrument homepage

Every Sanitary OEM Refractometer has a built-in web server with an instrument homepage. The homepage offers facilities to configure, monitor, verify and diagnose the instrument.

Once there is a functional Ethernet connection between the instrument and the computer, access the instrument's homepage by entering the instrument's IP address into the address bar of the computer's web browser.

The recommended browsers are Firefox 15.0 (or later) or Internet Explorer 8.0 (or later), but most functionality is accessible using any modern web browser.

Opening the instrument homepage:

1. Establish a functioning Ethernet connection to the instrument. For more information, see [Ethernet connection \(page 9\)](#).
2. Open your preferred web browser (for example Mozilla Firefox, Internet Explorer, Safari, Chrome or Opera).
3. The address (URL) to access the instrument's homepage is the refractometer's IP address, which for a factory default set Sanitary OEM Refractometer is **http://169.254.23.33/**. Insert this address into the browser address bar, then **ENTER**, just as you would enter any other web address.
4. Wait until the homepage is loaded, this may take a few seconds.  
The page looks approximately as shown in [Main page \(page 21\)](#); the exact appearance of the page depends on the browser and screen settings you are using.
5. Access more extensive instrument information using the links in the link bar at the left side of the page.



The JavaScript support must be enabled in the browser, in order for the web pages to function as intended.

### 6.1 Main page

Once the instrument homepage has loaded, it displays all the essential information regarding the instrument.

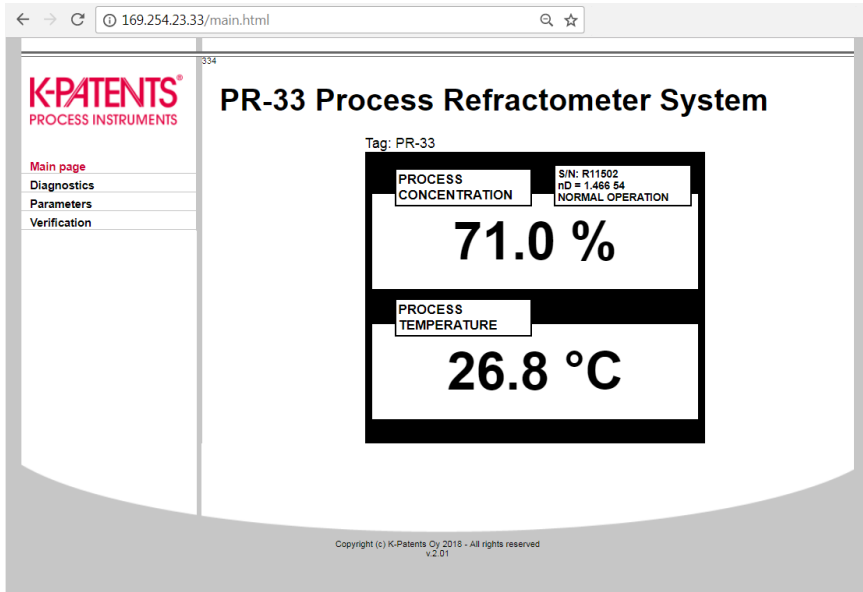


Figure 13 Main page

This page shows the measurement values, serial number and the tag for the instrument. The small numeric display in the top left-hand corner of the page indicates the number of measurement cycles (one per second) since the last login to the sensor.

## 6.2 Diagnostics

The **Diagnostics** page displays the diagnostic values produced by the refractometer. In addition to the measurement results, the page shows several intermediate results and other diagnostic values.

The optical images produced by the refractometer can be seen on this page. Both the images and the diagnostic values are live values, updated with an interval of a few seconds.



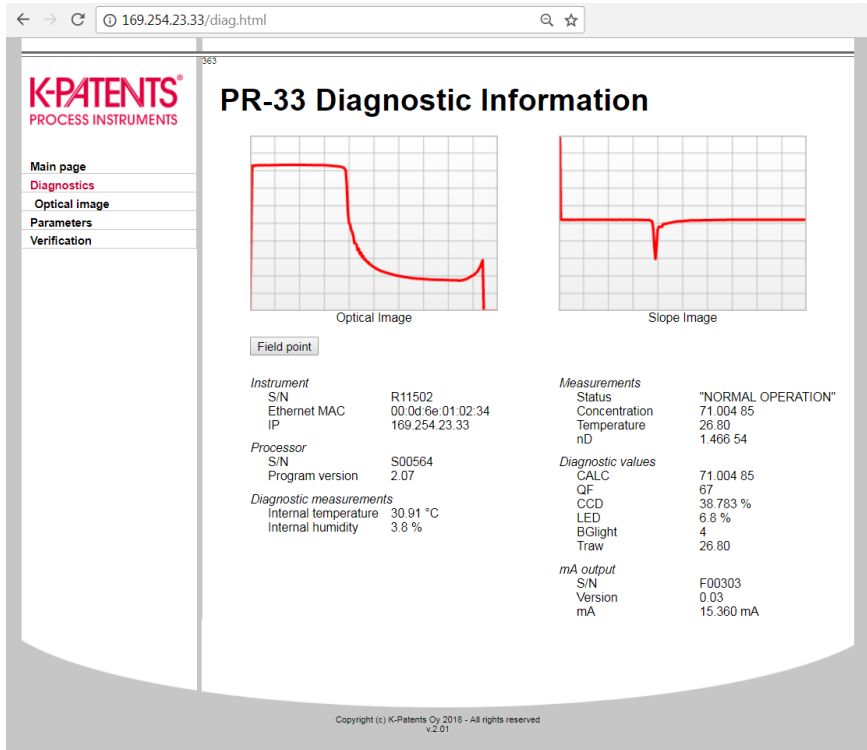


Figure 14 Diagnostics page

## 6.2.1 Measuring field samples

The **Diagnostics** page offers a possibility to measure samples for field calibration purposes. For more information, see [Field calibration \(page 31\)](#).

Measure a sample by clicking the **Field point** button on the page. After clicking the button the instrument measures ten measurement results and shows the average and deviation of the measurements. The measurement status is also shown, and if the status is not **Normal operation**, the point is not accepted.

Several points may be measured, and all the points display on the page until the page is reloaded. After measuring a sufficient amount of points, you can print the page.

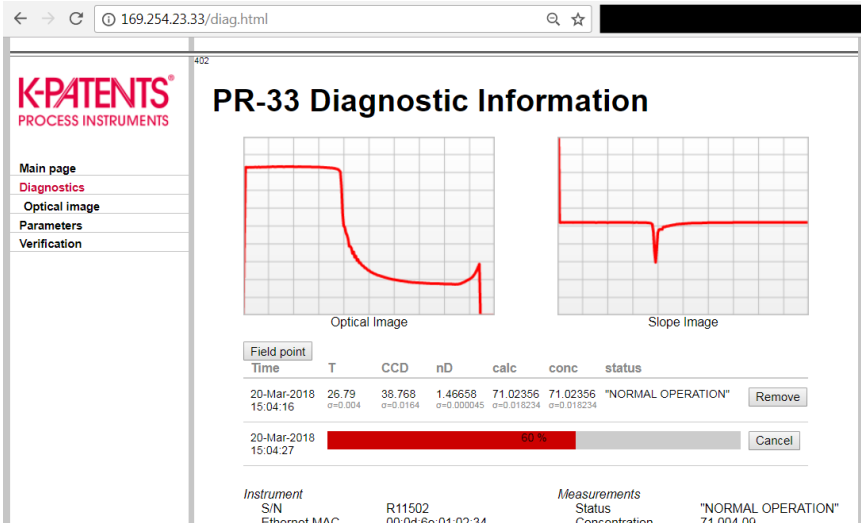


Figure 15 Measuring field samples

### 6.2.2 Optical image

View the raw optical image, which contains all optical information, by clicking on the **Optical image** link on the left panel on the **Diagnostics** page.

Download the optical image as a file by clicking on the caption (Raw optical image) of the image. This file can be used by Vaisala for troubleshooting purposes.

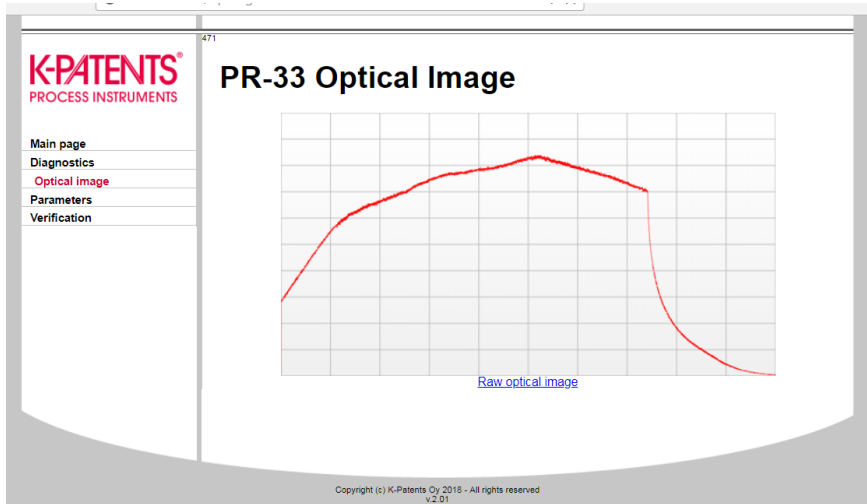


Figure 16 Optical image

## 6.3 Parameters

All the instrument's functional parameters can be changed using the **Parameters** page. The link to which is located in the menu displayed on the left-hand side of the computer display.

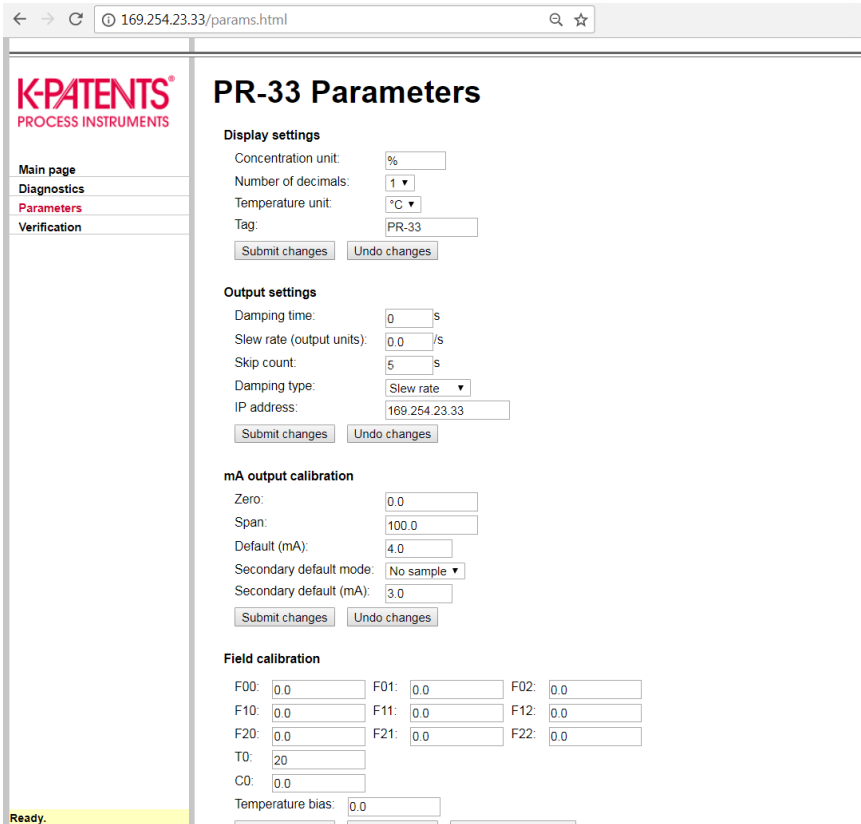



Figure 17 Parameters page

New parameters can be entered into the input fields. Once parameter editing is complete, clicking on the **Submit changes** button applies the designated parameters following their confirmation. The parameter update may take a few seconds to apply.

## 6.4 Verification

Perform instrument verification on the **Verification** page. For more information on the verification procedure, see [Refractometer verification \(page 34\)](#).



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## Instrument verification

The instrument verification can be carried out by using standard refractive index liquids (available from K-Patents). The procedure consists of measuring a number of these liquids one-by-one and verifying the reading of the instrument.

Before starting the verification, please read through the following checklist:

- The verification requires the instrument to be removed from the process and placed onto a table prism pointing up.
- Depending on the instrument model, a sample holder may be needed.
- To carry out an acceptable verification, at least three R.I. standard liquids have to be measured successfully. The verification is valid only within the range of these liquids.
- The instrument must reach a stable temperature before verification. This temperature must be between 20 °C and 30 °C. The nominal temperature for the liquids is 25 °C, but there is an automatic temperature compensation which enables a wider temperature range.

To carry out the verification, do the following for each standard R.I. liquid:

1. Make sure the prism (and sample holder) is clean and dry before placing the liquid on the prism.
2. Keep an eye on the optical image; it will help in determining the sufficient amount of liquid on the prism; if there is too little liquid, the shape of the optical image will change.
3. Once the liquid is on the prism, click the "New verification point" button. A progress indicator will show the progress. Once the point is measured, the measured values are reported.
4. Clean the prism and repeat the procedure for each standard liquid.

You may remove a failed point by clicking the "Remove" button on the line. If you use the same liquid several times, only the newest result will be recorded.

Once you have carried out the measurement for all points, click the "Save verification" button. This will save the verification results into the instrument and show the verification report. The latest verification report can always

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Figure 18 Verification page

## 7. Configuration and calibration

### 7.1 Configuring refractometer

In PR-33, all parameter changes are made with a web browser through the **Parameters** page. For more information, see [Parameters \(page 25\)](#).

#### 7.1.1 Signal damping

The system provides the possibility to enter signal damping to diminish the influence of process noise. The damping is applied to the CONC value (and thus the output signal).

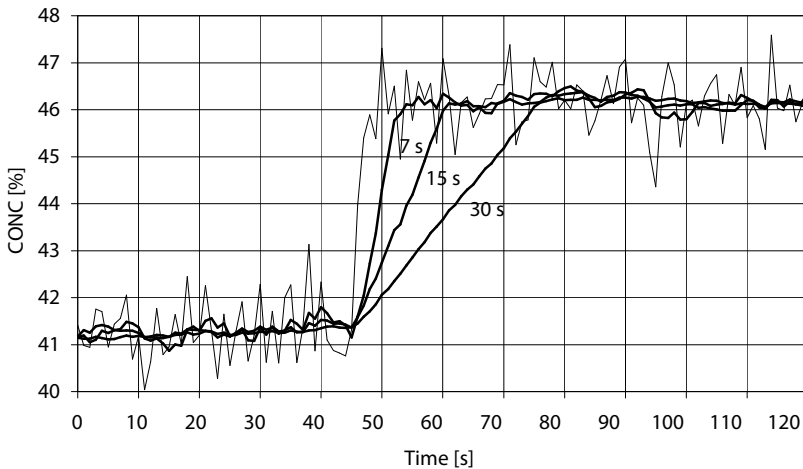


Figure 19 Effect of damping time on measurement with linear damping

There are three different damping types available in the Sanitary OEM Refractometer:

- Linear damping
- Exponential damping
- Slew rate limit damping

Linear damping is a sliding average, and it is recommended for most cases. The damping time represents the averaging time. For fast damping, use 0–2 s damping, for minimal noise, use a value of 10 s or more.

Exponential damping is a single time constant (one pole) low-pass filter. If this option is chosen, the damping time represents the half-time of the filter. The damping time recommendation is the same as for the linear damping.

With both linear and exponential damping the residual random noise is inversely proportional to the square root of the damping time. In practice, using a damping time of more than 30 seconds does not improve the noise performance. It should also be noted that increasing the damping time will deteriorate the response speed of the instrument.

If the process signal has short erroneous high or low peaks, slew rate limit damping can be used to cut their effects. Slew rate limit damping limits the maximum change for the output signal in one second. Slew rate limit damping is recommended for random noise suppression as it is non-linear.

The slew rate parameter is presented in output units. For example when the concentration is measured in percentages, typical slew rate value is 0.05

### 7.1.2 Skip count

When the sample is removed, the refractometer goes to NO SAMPLE state. However, if skip count is greater than 0, the CONC is frozen to its last value for the number of measurement cycles (one per second) indicated by skip count. Typically skip count is used when there are large voids in the process liquid. For example a setting of 10 measurement cycles ensures that any NO SAMPLE state shorter than 10 seconds will not make a dip in the output signal.

Skip count is set in the **Output settings** section of the parameter page.

## 7.2 Calibrating concentration measurement

The concentration calibration of the inline refractometer PR-33 is organized in six layers.

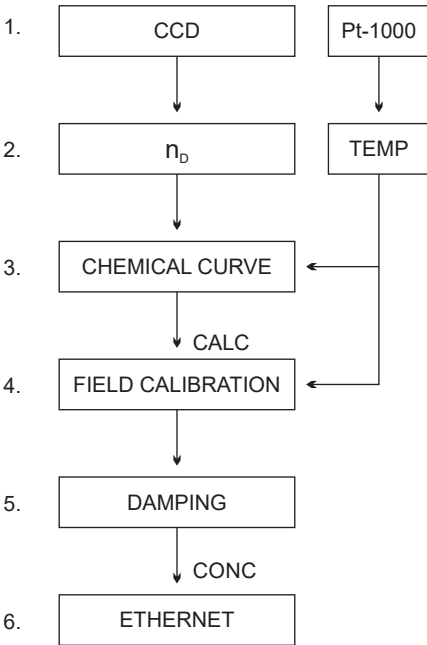


Figure 20 Calibration layers

- 1 The information from the CCD element and the Pt- 1000 temperature element. The position of the shadow edge is described by a number called CCD and scaled from 0 to 100 %.
- 2 The refractometer calibration: The actual refractive index  $n_D$  is calculated from the CCD value. The process temperature is calculated from the Pt-1000 resistance. The refractometer output is  $n_D$  and temperature TEMP in Centigrade. The calibrations of all PR-33 refractometers are identical, which makes the refractometers interchangeable. The calibration of each refractometer can be verified using standard refractive index liquids.
- 3 The chemical curve: The refractometer calculates the Brix value based on  $n_D$  and TEMP. The result is a temperature compensated calculated concentration value CALC.
- 4 Field calibration: Adjustment of the calculated concentration value CALC may be required to compensate for some process conditions or to fit the measurement to the laboratory results.
- 5 Damping.
- 6 Output signal: The output signal is transmitted through the Ethernet connection.

The calibration of each refractometer can be verified using standard refractive index liquids, see [Refractometer verification \(page 34\)](#).

[Field calibration \(page 31\)](#) determines the appropriate adjustment to CALC. The adjusted concentration is called CONC. If there is no adjustment, CALC and CONC are equal. Thus the chemical curve is kept intact as a firm base for the calculation, the adjustment is merely additional terms.

For more information on damping, see [Signal damping \(page 28\)](#).



The output signal can also be transmitted over the 4 ... 20 mA current output.



## 7.2.1 Chemical curve

The chemical curve is a model of the refractive index behavior of the process medium. It is used in calculating the Brix value from the measured  $n_D$  and TEMP. The curve is defined by a set of 16 parameters.

Table 2 Chemical curve parameters

C <sub>00</sub>	C <sub>01</sub>	C <sub>02</sub>	C <sub>03</sub>
C <sub>10</sub>	C <sub>11</sub>	C <sub>12</sub>	C <sub>13</sub>
C <sub>20</sub>	C <sub>21</sub>	C <sub>22</sub>	C <sub>23</sub>
C <sub>30</sub>	C <sub>31</sub>	C <sub>32</sub>	C <sub>33</sub>

The Sanitary OEM Refractometer is shipped with a chemical curve to show the temperature compensated Brix value of the process medium. The set of parameters is given by Vaisala and should not be altered, except in case of changing to another process medium.

## 7.2.2 Field calibration

Vaisala provides a field calibration service that adapts the calibration to the factory laboratory determinations based on the data supplied. This field calibration corrects the instrument reading to show the same values as the laboratory measurements.

Perform the field calibration procedure under normal process conditions only, using standard laboratory determinations of sample concentration.

Measure the calibrating data by using the Field point functionality on the on the Sanitary OEM Refractometer homepage. For more information, see [Measuring field samples \(page 23\)](#).

Record the data either on the [Refractometer field calibration form \(page 54\)](#), or print out the field points on the web page.

If you have a constant offset, you can perform a bias adjustment, see [Direct BIAS adjustment \(page 32\)](#). For a more detailed field calibration, send the completed calibration form to either [helpdesk@vaisala.com](mailto:helpdesk@vaisala.com) or your local representative. A computer analysis of the data will be made at Vaisala and optimal calibration parameters will be sent to be entered in the system.

For a complete report, 10 - 15 valid data points (see below) are needed. A data point is of use for calibration only when the diagnostic message is **Normal operation**. Each data point consists of:

- LAB%: Sample concentration determined by the user
- CALC: Calculated concentration value
- T: Process temperature measurement in Centigrade
- nD: Actual refractive index  $n_D$
- CONC: Measurement in concentration units, the large size number

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

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

- 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 values CALC, T(emp), nD and CONC at exactly the same time with sampling
- Use a tight container for the sample to avoid evaporation



**CAUTION!** 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

Calibration using the process liquid must always be made inline.

### 7.2.3 Direct BIAS adjustment

The concentration measurement value can also be directly adjusted by changing the field adjustment parameter f00. The bias adjustment is well-suited to situations where the difference between the refractometer and the laboratory readings is small, and where there is no clear temperature or concentration dependence of the correction.

Also, if the field calibration points are from a narrow concentration and temperature range, the bias adjustment is usually the best option.

The value of the bias parameter f00 is added to the concentration value:

NEW CONC = OLD CONC + f00.

## 7.3 Default mA output value

Since sensor program version 2.05, it is possible to set in the mA output settings a mA default output value that the instrument returns to in certain malfunction situations. The value can be set to a low or high mA value, e.g. 3.0 mA or 22 mA. The mA measurement always returns to the mA default output value when error message is **SHORT-CIRCUIT, NO SIGNAL, TEMP MEASUREMENT FAULT** or **NO SENSOR**. When mA output source is configured to concentration, also **NO OPTICAL IMAGE, NO SAMPLE** and **PRISM COATED** cause the mA measurement to return to the default mA output value.

NAMUR is an international association of users of automation in process industries. The association recommendation NE 43 promotes a standardization of the signal level for failure information. The goal of NE 43 is to set a basis for proactively using transmitter failure signals in process control strategies. Using these failure signals, instrument faults are separated from process measurements.

NAMUR NE 43 uses the 3.8 - 20.5 mA signal range for measurement information, with  $\geq 21$  mA or  $\leq 3.6$  mA to indicate diagnostic failures. For more information, see the figure below. 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.

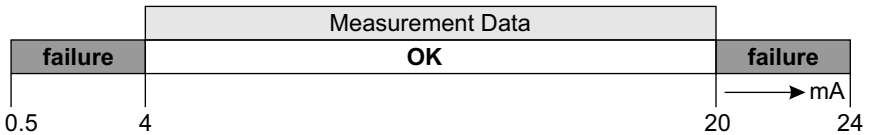


Figure 21 NAMUR NE 43 signal ranges

An optional secondary mA output default can be set for the **NO SAMPLE** state to differentiate it from the other messages that cause the measurement to revert to default mA.

The factory setting for secondary mA default is **Disable**. To implement secondary mA default, go to the mA output calibration section on the parameter page and set secondary default mode to **NO SAMPLE** and then set the mA output value desired. For more information, see [Parameters \(page 25\)](#).

## 8. Instrument verification

### 8.1 Refractometer verification

The refractometer calibration is verified using a set of standard refractive index liquids. In order to perform a valid verification, at least three liquids need to be used. The verification is valid only within the refractive index range defined by these three liquids.

The instrument automatically recognizes the following refractive index standard liquids (the values are stated at +25 °C):

- 1.3200
- 1.3300
- 1.3400
- 1.3500
- 1.3600
- 1.3700
- 1.3800
- 1.3900
- 1.4000
- 1.4100
- 1.4200
- 1.4300
- 1.4400
- 1.4500
- 1.4600
- 1.4700
- 1.4800
- 1.4900
- 1.5000
- 1.5100
- 1.5200

The accuracy of the certified standard refractive index liquids is  $\pm 0.0002$  and they can be traced back to NIST standards #1823 and #1823 II. As the specified accuracy of the refractometer is  $\pm 0.0002$ , then the representative level is the sum of the two accuracy specifications, that is  $\pm 0.0004$ .

Vaisala provides a set of standard R.I. liquids, PR-2300, containing five selected liquids (1.3300, 1.3700, 1.4200, 1.4700, 1.5200). The set can be ordered from Vaisala. Other liquids are available on request.

#### 8.1.1 Handling R.I. liquids

Use gloves and safety glasses or goggles. Make sure the ventilation is good, local ventilation is preferable. Review the safety instructions and the MSDS shipped with the liquids (valid inside R.I. range 1.30-1.57, safety markings valid in EU/EEA areas). Do not put tissues or liquid bottles in household waste, dispose of waste according to local regulations for chemical waste.

## 8.2 Verification procedure

Perform instrument verification using the web interface. On the instrument homepage, go to the **Verification** page. The standard liquids are placed on the prism as instructed by the instructions on the screen. Once the liquid has settled, sample is measured by clicking the **New verification point** button.

The liquids are automatically detected, and the quality of the measurement is constantly monitored throughout the process. If the same liquid is measured several times, the new result replaces the older one. To remove a single measurement point, click the **Remove** button.


The verification result displays on the page. Reloading the page removes all points. After measuring a sufficient number of points the verification can be saved by clicking the **Save verification** button.

In order to avoid verification errors, please make sure:

- The temperature has settled, i.e., the refractometer is in the ambient temperature
- The temperature of the refractometer is between 20 °C and 30 °C
- The prism is cleaned properly before placing the sample
- The test liquid wets the prism properly

Check the temperature of the refractometer by following the temperature measurement on the **Verification** page. The temperature should be constant.

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- [Main page](#)
- [Diagnostics](#)
- [Parameters](#)
- [Verification](#)
- [Verification report](#)

## Instrument verification

The instrument verification can be carried out by using standard refractive index liquids (available from K-Patents). The procedure consists of measuring a number of these liquids one-by-one and verifying the reading of the instrument.

Before starting the verification, please read through the following checklist:


- The verification requires the instrument to be removed from the process and placed onto a table prism pointing up.
- Depending on the instrument model, a sample holder may be needed.
- To carry out an acceptable verification, at least three R.I. standard liquids have to be measured successfully. The verification is valid only within the range of these liquids.
- The instrument must reach a stable temperature before verification. This temperature must be between 20 °C and 30 °C. The nominal temperature for the liquids is 25 °C, but there is an automatic temperature compensation which enables a wider temperature range.

To carry out the verification, do the following for each standard R.I. liquid:

- Make sure the prism (and sample holder) is clean and dry before placing the liquid on the prism.
- Keep an eye on the optical image; it will help in determining the sufficient amount of liquid on the prism; if there is too little liquid, the shape of the optical image will change.
- Once the liquid is on the prism, click the "New verification point" button. A progress indicator will show the progress. Once the point is measured, the measured values are reported.
- Clean the prism and repeat the procedure for each standard liquid.

You may remove a failed point by clicking the "Remove" button on the line. If you use the same liquid several times, only the newest result will be recorded.

Once you have carried out the measurement for all points, click the "Save verification" button. This will save the verification results into the instrument and show the verification report. The latest verification report can always be seen by clicking the "Verification report" link in the menu.



S/N: R11502  
 NORMAL OPERATION  
 nD 1.362 15  
 T 26.71  
 CCD73.895  
 LED 6.7

STANDARD LIQUID	MEASUREMENT		VERIFICATION RESULT	
@ 25°C    @ T	T	nD	CCD	nD error    Status
<div style="display: flex; align-items: center; justify-content: center;"> <div style="width: 100px; height: 15px; background-color: red; margin-right: 10px;"></div> <span>50 %</span> </div>				

Measurement in progress...

Figure 22 Verification page

The sample holder keeps the sample on the prism surface and also blocks the ambient light from reaching the prism. Universal sample holder PR-1012 can be used with any Vaisala K-PATENTS® refractometer.

The optical image displayed on the page helps determining whether the prism is wetted completely. The image should have a sharp corner as in the figure above. The position of the corner depends on the refractive index. A soft image may indicate improper cleaning of the prism. If there is not enough liquid on the prism, the image tends to flatten. If the image changes its shape during the measurement of a single liquid, redo the measurement. The most likely reason is that the liquid leaks from the sample holder.



Figure 23 Universal sample holder PR-1012

After measuring a sample, remove the sample and clean the prism and the sample holder. The prism can be cleaned by soft tissue and ethanol or other suitable solvent. Repeat the procedure (cleaning, replacing the sample, measuring) for each  $n_D$  liquid. In case you perform the procedure more than once for a single sample, the latest measurement will replace earlier measurements.

The table on the verification page keeps a real time record of the points measured and the status (pass/fail) of the verification. If you have a failed point, either remove it or remeasure it.

Once all liquids have been measured, save the verification by clicking the **Save verification** button. The button is only available after a sufficient number of points has been measured.

The limit for acceptance is that all measurements must be within  $\pm 0.0004$  of the nominal values.



The refractometer verification concerns only the refractive index  $n_D$  measurement. The calculation of concentration from  $n_D$  and process temperature TEMP is not included.

## 8.3 Verification report

The last saved verification data can be accessed by clicking the Verification report link on the left panel. This verification report includes all measurement data and the PASS/FAIL status of the verification. The report can be printed out or saved as a reference for the quality system.

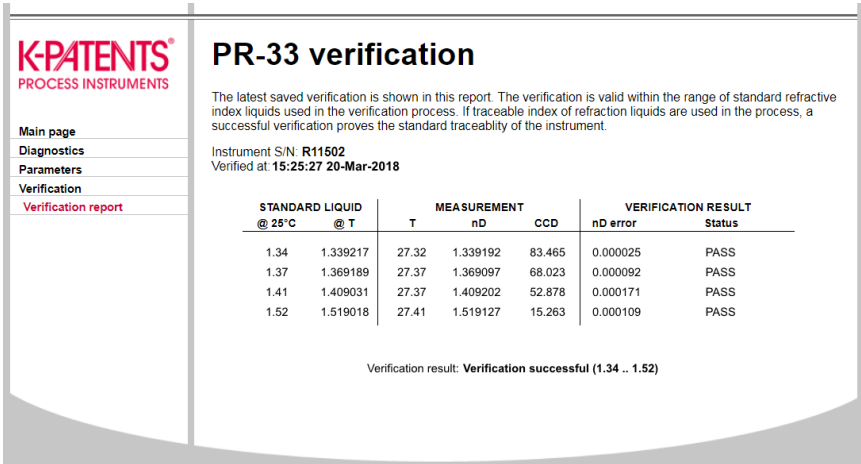


Figure 24 Verification report

## 8.4 Corrective action

If the verification is not passed, first check that both the prism and the sample holder are absolutely clean and the sample holder sits tightly on the refractometer tip before a standard liquid is applied. Make sure the standard liquids are in good condition and not past their expiration date. Also, inspect the prism surface, checking that it is flat and shiny without any scratches, digs or deposition on it.

Repeat the verification procedure. If the verification still fails, print out the verification report, send the data to [helpdesk@vaisala.com](mailto:helpdesk@vaisala.com) or your nearest representative, and wait for further instructions.



## 9. Maintenance

Ensure that the refractometer is not a source of contamination to product due to damaged or worn product contact surfaces. Such surfaces may not stay clean in processing and so do not fulfill 3-A requirements. Vaisala offers 3-A Standard Accepted repair and maintenance package, performed by a 3-A authorized service center. In the repair process all wetted parts, prism, gaskets and dryer are replaced and the sensor is calibrated, all according to 3-A Sanitary standards.



If a sensor is repaired by using old wetted metal parts (replacing only prism and gaskets), the repair may result in a non-sanitary condition of the surfaces.

# 10. Troubleshooting

## 10.1 Diagnostic message priorities



The messages are listed in descending order of priority. For example, if both **NO OPTICAL IMAGE** and **TEMP MEASUREMENT FAULT** are activated, only **NO OPTICAL IMAGE** displays.

- **OUTSIDE LIGHT ERROR**
- **NO OPTICAL IMAGE**
- **TEMP MEASUREMENT FAULT**
- **HIGH SENSOR HUMIDITY**
- **HIGH SENSOR TEMP**
- **NO SAMPLE**
- **PRISM COATED**
- **OUTSIDE LIGHT TO PRISM**
- **LOW IMAGE QUALITY**
- **Normal operation**

The following sections list the diagnostic messages, their causes and corrective actions.

## 10.2 Hardware

The following table describes the hardware messages and their related actions.


Table 3 Hardware messages


Message	Description	Corrective action
<b>HIGH SENSOR HUMIDITY</b>	Tells that humidity measured inside the instrument exceeds 60 % relative humidity. The reason may be moisture leaking in through prism seal or the cover being open.	Contact Vaisala.
<b>HIGH SENSOR TEMP</b>	The temperature inside the instrument exceeds 65 °C (150 °F). To read this temperature, go to the diagnostics page. For more information, see <a href="#">Diagnostics (page 22)</a> .	See <a href="#">Choosing refractometer mounting location (page 15)</a> .

## 10.3 Measurement

The following table describes the measurement messages and their related actions.

Table 4 Measurement messages

Message	Description	Corrective action
<b>OUTSIDE LIGHT ERROR</b> or <b>OUTSIDE LIGHT TO PRISM</b>	The measurement is not possible or is disturbed because outside light reaches the camera.	Identify the light source and block the light from getting to the prism at the sensor tip. The amount of outside light can be seen at <b>BGlight</b> on the <b>Diagnostics</b> page.
<b>NO OPTICAL IMAGE</b>	The prism is heavily coated.	Remove sensor from line and clean prism manually.
	There is moisture condensation in the sensor.	See <a href="#">Hardware (page 40)</a> .
	The sensor temperature is too high.	
	The light source is faulty. When the sensor is removed from the process, the yellow flashing light can be seen through the prism.	Check the LED value on the <b>Diagnostics</b> page. For more information, see <a href="#">Diagnostics (page 22)</a> .
	 The light is only visible at an oblique angle.	If the value is clearly below 100, LED fault is not likely. If the value is above 100, contact Vaisala.
	There are negative spikes in the optical image. The probable cause is dust or fingerprints on the CCD window.	Contact Vaisala.
	The CCD card in the sensor is faulty.	
<b>PRISM COATED</b>	The optical surface of the prism is coated by the process medium or impurities in the process medium.	Remove sensor from line and clean prism manually.
<b>LOW IMAGE QUALITY</b>	The most likely cause for this message is coating on the prism. There still is an optical image available, but the measurement quality may not be optimal.	If the problem is recurrent, consider improving the flow conditions. For more information, see <a href="#">Choosing refractometer mounting location (page 15)</a> .
<b>NO SAMPLE</b>	The operation of the equipment is OK but there is no process liquid on the prism. In some cases this message may also be caused by coating on the prism.	

Message	Description	Corrective action
<p><b>TEMP MEASUREMENT FAULT</b></p>	<p>Indicates faulty temperature element.</p>	<p>Contact Vaisala.</p> <div data-bbox="628 247 958 512" style="background-color: #f0f0f0; padding: 10px; border: 1px solid #ccc;">  <p>A difference to some other process temperature measurement is not a fault. The Sanitary OEM Refractometer shows the true temperature of the prism surface.</p> </div>
<p>Concentration drift during <b>Normal operation</b></p>	<p>For drift upward or downwards to zero, cause is likely the prism coating.</p>	<p>Remove sensor from line and clean prism manually.</p> <p>If the problem is recurrent, consider improving the flow conditions. For more information, see <a href="#">Choosing refractometer mounting location (page 15)</a>.</p>

# 11. Specifications

## 11.1 PR-33-AC model code

Table 5 SANITARY OEM REFRACTOMETER for pipelines (3-A Sanitary Standard 46-04 Certified)

Model and description	Model
PR-33 = Refractometer	PR-33
<b>Refractometer type</b>	
-AC = Compact type for pipeline installation, 3-A certified	-AC
<b>Refractive Index range limits</b>	
-73 = R.I. 1.320-1.530 nD (0-100 Brix) Sapphire prism	-73
<b>Process connection</b>	
-H = for Sanitary 3A-clamp, 2½ inch <sup>1)</sup>	-H
-E = for Varivent® in-line access unit clamp DN65 <sup>1)</sup>	-E
<b>Wetted parts material</b>	
SS = AISI 316 L	SS
<b>Electrical classification</b>	
-GP = General purpose	-GP
<b>Housing material</b>	
-RS = Stainless steel AISI 304	-RS
<b>Electrical connections</b>	
-A = 1 x 4–20 mA, 1 x Ethernet UDP/IP, power supply +24 VDC	-A
<b>Sensor wetted parts surface treatment option</b>	
-EP = Electropolished sensor wetted parts (Ra 0.38 µm, 15 µ inch)	-EP

1) Sensor only without clamp, gasket and ferrule.

Example: PR-33-AC-73-HSS-GP-RS-A-EP

Table 6 SANITARY OEM REFRACTOMETER for pipelines (3-A Sanitary Certified and EHEDG certified)

Model and description	Model
PR-33 = Refractometer	PR-33

Model and description	Model
<b>Refractometer type</b>	
-AC = Compact type for pipeline installation, 3-A certified	-AC
<b>Refractive Index range limits</b>	
-73 = R.I. 1.320-1.530 nD (0-100 Brix) Sapphire prism	-73
<b>Process connection</b>	
-H = for Sanitary 3A-clamp, 2½ inch <sup>1)</sup>	-H
-E = for Varivent® in-line access unit clamp DN65	-E
<b>Wetted parts material</b>	
SS = AISI 316 L	SS
<b>Electrical classification</b>	
-GP = General purpose	-GP
<b>Housing material</b>	
-RS = Stainless steel AISI 304	-RS
<b>Electrical connections</b>	
-A = 1 x 4-20 mA, 1 x Ethernet UDP/IP, power supply +24 VDC	-A
<b>EHEDG</b>	
-EH = EHEDG Type EL Class I Certified model	-EH
<b>Sensor wetted parts surface treatment option</b>	
-EP = Electropolished sensor wetted parts (Ra 0.38 µm, 15 µ inch)	-EP

1) Complete with clamp, gasket and ferrule.

Example: PR-33-AC-73-HSS-GP-RS-A-EH

Table 7 Elbow Flow Cells for PR-33-AC

Model and description	Model
AFC = Elbow flow cell	AFC
<b>Sensor connection</b>	
-H = Sanitary 3A-clamp, 2½ inch	-H
<b>Material of construction</b>	
SS = AISI 316 L	SS
<b>Process connection</b>	

Model and description	Model
-H = Sanitary 3A clamp	-H
<b>Pipe section diameter</b>	
10 = 25 mm (1 inch)	10
15 = 40 mm (1½ inch)	15
20 = 50 mm (2 inch)	20
25 = 65 mm (2½ inch) <sup>1)</sup>	25
<b>Flow cell inlet type</b>	
-SI = Straight pipe	-SI
-RI = Reduced pipe (cone)	-RI

1) With -SI option only.

Table 8 EHEDG Certified Elbow Flow Cells, connection Sanitary 3A-clamp 2½ inch

Model and description	Model
AFC = Elbow flow cell	AFC
<b>Sensor connection</b>	
-H = Sanitary 3A-clamp, 2½ inch	-H
<b>Material of construction</b>	
SS = AISI 316 L	SS
<b>Process connection</b>	
-H = Sanitary 3A clamp	-H
<b>Pipe section diameter</b>	
20 = 50 mm (2 inch)	20
<b>Flow cell inlet type</b>	
-SI = Straight pipe	-SI
<b>EHEDG</b>	
-EH = EHEDG Type EL Class I Certified Model	
<b>Polishing option</b>	
-EP = Electropolished process wetted parts (Ra 0.38 µm, 15 µ inch)	-EP

Table 9 Mounting hardware for PR-33-AC

Model and description	Model
MFC = Mini Flow Cell	MFC
<b>Sensor connection</b>	
-H = Sanitary 3A-clamp, 2½ inch	-H
<b>Material of construction</b>	
SS = AISI 316 L	SS
<b>Process connection</b>	
-H = Sanitary 3A clamp	-H
<b>Pipe section diameter</b>	
05 = 15 mm (½ inch)	05

## 11.2 Mounting specifics for EHEDG certified PR-33-AC configuration

Vaisala offers certain PR-33-AC configurations which have been certified to fulfill the sanitary requirements published by EHEDG (European Hygienic Engineering & Design Group) organization. During this certification the hygienic characteristics of both the refractometer and the process connection were evaluated against the applicable requirements.

To ensure EHEDG compliant installation, follow the mounting specifics provided on the mounting drawing supplied by Vaisala with each PR-33-AC refractometer sensor ordered with the -EH option.



## 12. Ethernet protocol specification

The main purpose of the Ethernet connection is to collect measurement data from the instrument. For this data acquisition, you need suitable software on your computer. You can program a data acquisition program yourself following the specifications listed in the following sections.

For examples and ready-made applications, contact Vaisala.

### 12.1 Communication protocol

The communications protocol is based on UDP/IP to port 50023. It is a client/server protocol, where the sensor is the server and thus only sends information when the client (i.e. your computer) requests it. The server should answer to all requests within 100 ms.

#### 12.1.1 Request format

The client to server communication, i.e. the requests sent from your computer to the refractometer, is in binary format. The request packets contain the following binary data (all integers are in the network order, MSB first):

- 32-bit integer: packet number
- 32-bit integer: request ID
- (any): request data (depends on the request)
- (any): fill-in data



The maximum size of the message is 1472 octets (bytes).

The packet number is echoed back by the refractometer, but not processed in any way. The packet numbers do not have to be sequential, any 32-bit value is valid.

The request ID is a 32-bit value that identifies the requested function, for example refractometer information. See [Request-response pair specification \(page 49\)](#) for request IDs.

The request data consists of 0 to 1464 octets of additional data associated with the request.

The fill-in data can be used to increase the number of octets in a message. Any number of NULL characters (0x00) may be added to the end of the request as long as the total size of the message does not exceed the maximum of 1472 octets. This may be useful, for example, if the client implementation uses fixed-length packets.

#### 12.1.2 Response format

The response data sent by the instrument is in ASCII format. With the exception of the packet number, the data is human-readable. The data structure is very simple:

- Packet number (32-bit integer)
- Zero or more lines of ASCII (text) keys and values associated with these keys (for example temperature key and process temperature in Celsius)

The **packet number** is echoed back without change. The client (software on computer) can use the packet number to check the response against the packet number of the request.

The **message text** consists of lines of text, each line a single key (of one word) and its value or values. The values are separated from the key by an equal sign (=) and multiple values are separated by a comma. White space (space or tabulator) is allowed anywhere except within a single value or key name.

If the response consists of a character string, it is enclosed in double quotes ("). For example, all these are valid message text lines:

```
ok
```

```
temp = 23.45
```

```
headhum = 13.32
```

```
LEDcnt = 8341
```

```
ChemCurve = 1.234, 3.21, 0.00, 4.37, 1.11, 0.00002, 2.1345
```

```
StatusMessage = "Normal Operation"
```



All the key identifiers are case-insensitive. For more information, see [Request-response pair specification \(page 49\)](#). However, the recommendation is that they are written as in this specification.

The server (refractometer) may send the response keys in any order. It sends the mandatory keys of the specific request, but may omit any other keys. The mandatory keys are marked with an asterisk in [Request-response pair specification \(page 49\)](#).

The server may also send keys that are not specified in this document, but the client (computer) may ignore them.

### 12.1.3 Request and response errors

When the server (refractometer) detects an error, it responds with an error message. For more information, see [Error message specification \(page 50\)](#).

An error message can be caused, for example, by an unknown request or inability to collect data for the mandatory keys of a response.

## 12.2 Request-response pair specification

The following table describes the query messages, i.e. request-response pairs, used for data collection using the Ethernet connection.



Those response keys that are always sent are preceded by an asterisk (\*).

Table 10 Request-response pair specification

Specification	Description	Request ID	Request data	Response key
NULL message	Included in query messages for debugging purposes as it can be used to check whether the server is listening. The message gives a high-level 'ping' functionality.	0x00000000 0	(none)	<ul style="list-style-type: none"> <li>• IP: IP address</li> <li>• MAC: Ethernet MAC address</li> </ul>
Protocol version	Responded to with a value representing the server (refractometer) protocol version.	0x00000001	(none)	*Version: integer, the server protocol version (currently 3)
Refractometer information	Gives the basic information of the refractometer.	0x00000003	0x00000000 0: always zero	<ul style="list-style-type: none"> <li>• *SensorSerial: string, refractometer serial number</li> <li>• *SProcSerial: string, processor card serial number</li> <li>• *SensorVersion: string, version number of the refractometer software</li> </ul>

Specification	Description	Request ID	Request data	Response key
Measurement results	Gives the measured and calculated measurement values from the refractometer.	0x00000004	0x00000000 0: always zero	<ul style="list-style-type: none"> <li>• Status: string, refractometer status message</li> <li>• PTraw: integer, PT1000 value</li> <li>• LED: float, LED value</li> <li>• RHsens: float, internal humidity</li> <li>• nD: float, calculated n<sub>D</sub> value</li> <li>• CONC: float, final concentration value</li> <li>• Tsens: float, internal temperature</li> <li>• T: float, process temperature</li> <li>• CCD: float, image shadow edge</li> <li>• CALC: float, calculated concentration value</li> <li>• QF: float, quality factor</li> <li>• BGlight: integer, background light</li> </ul>

### 12.3 Error message specification

If the server (refractometer) does not recognize the request or cannot fulfill it, it responds with an error message. The error message has the following keys:

- \*Error: integer, error code 0x00000000: Unknown request
- \*Error: integer, error code 0x00000001: Invalid request (request recognized, invalid request data)
- \*Error: integer, error code 0x00000002: Invalid sensor number
- ErrorMessage: string, error details

There may also be error-dependent extra keys. Other error codes may be returned. 0x00000003 is handled as an unknown request. Codes with higher numbers refer to internal errors; contact Vaisala for more information.

## 13. Principle of measurement

The Vaisala K-PATENTS® inline refractometer determines the refractive index  $n_D$  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 (hence  $n_D$ ). Light from the light source (L) in the figure below 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.

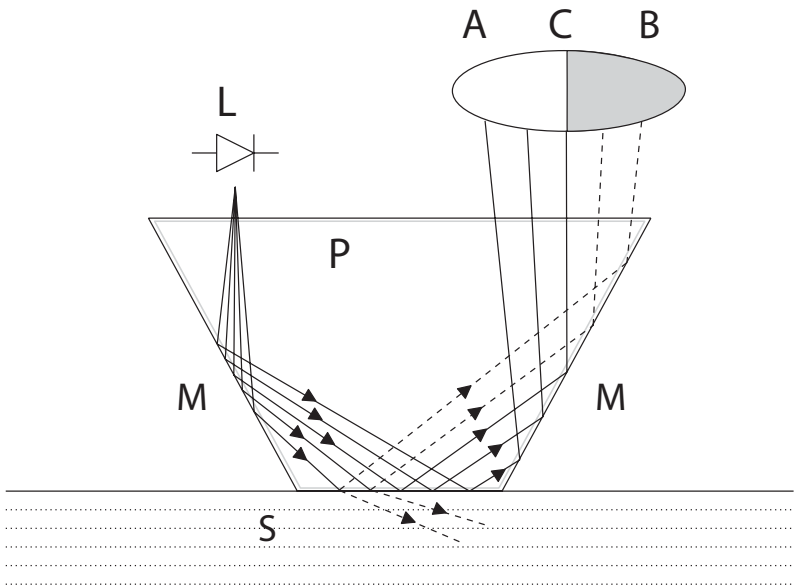


Figure 25 Refractometer principle

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  $n_D$  can then be determined from this position.

The refractive index  $n_D$  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 figure below. The color of the solution, gas bubbles or undissolved particles do not affect the position of the shadow edge (C).

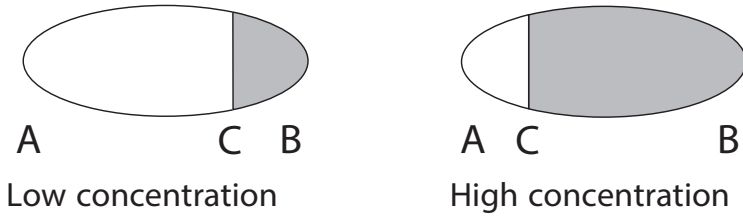


Figure 26 Optical images

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

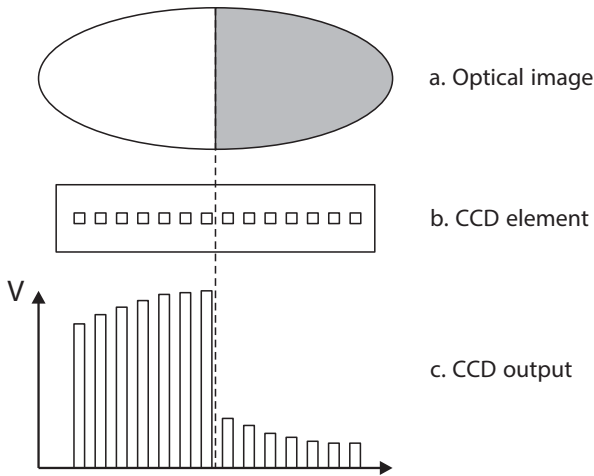


Figure 27 Optical image detection

# Appendix A. EU declaration of conformity

**VAISALA**

2019-09-01H/JAMO

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## EU DECLARATION OF CONFORMITY

Manufacturer: Vaisala Oyj  
Mail address: P.O. Box 26, FI-00421 Helsinki, Finland  
Street Address: Vanha Nurmiyarventie 21, Vantaa, Finland

This declaration of conformity is issued under the sole responsibility of the manufacturer.

Object of the declaration:

### **K-Patents Process Refractometer PR-33 series**

The object of the declaration described above is in conformity with Directives:

RoHS Directive (2011/65/EU)  
EMC Directive (2014/30/EU)

The conformity is declared using the following standards:

**EN 50581:2012** Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

**EN 61010-1:2010** Safety requirements for electrical equipment for measurement, control and laboratory use – Part 1: General requirements

**EN 61326-1:2013** Electrical equipment for measurement, control and laboratory use – EMC requirements – intended for use in industrial locations

Signed for and on behalf of Vaisala Oyj, in Vantaa, on 1<sup>st</sup> September 2019



Jukka Lyömiö  
Standards and Approvals Manager





## Warranty

For standard warranty terms and conditions, see [www.vaisala.com/warranty](http://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](mailto: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](http://www.vaisala.com/support).

## Recycling



Recycle all applicable material.



Follow the statutory regulations for disposing of the product and packaging.





**VAISALA**

[www.vaisala.com](http://www.vaisala.com)

