

General safety considerations

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.



Precautions when removing a sensor from the process line :

- Make positively sure that the process line is not under pressure.
- Loosen the flowcell screws cautiously, be prepared to tighten again.
- Be out of the way of any possible splash and ensure the possibility of escape.



Warranty

K-Patents warrants that all products made by K-Patents shall be free of defects in material and workmanship. K-Patents agrees to either replace or repair free of charge, any such product or part thereof which shall be returned to the nearest authorized K-Patents repair facility within two (2) years from the date of delivery.

Important: The warranty is void if the sensor has been opened.

Before returning a defective product for service or replacement, please contact K-Patents or your nearest K-Patents representative (see <http://www.kpatents.com/> for contact information) for packing and shipping information.

Disposal

When disposing of an obsolete instrument or any parts of an instrument, please observe the local and national requirements for the disposal of electrical and electronic equipment.

Table of contents

1	Introduction	1
2	Instrument connections	2
2.1	Power supply	2
2.2	mA output	2
2.3	Ethernet connection	2
2.3.1	Ethernet specification	3
2.3.2	IP settings for the Sanitary OEM Refractometer	5
2.3.3	IP settings for a stand-alone computer	6
2.3.4	Configuring a network of refractometers	7
2.3.5	Testing the Ethernet connection	7
2.3.6	Troubleshooting the connection	8
3	Refractometer mounting	10
3.1	Choosing the refractometer mounting location	10
3.2	Check list for pipe mounting	10
3.3	Refractometer wiring	12
4	Startup and use	14
4.1	Startup	14
4.1.1	Initial check	14
4.1.2	Calibration check	14
4.2	Viewing refractometer status	14
5	Instrument homepage	16
5.1	Main page	16

5.2	Parameters	18
5.3	Diagnostics	20
5.3.1	Measuring field samples	21
5.3.2	Optical image	21
5.4	Verification	22
6	Configuration and calibration	24
6.1	Configuring the refractometer	24
6.1.1	Signal damping	24
6.2	Calibrating the concentration measurement	25
6.2.1	The chemical curve	26
6.2.2	Field calibration	26
6.2.3	Direct bias adjustment	28
7	Instrument verification	29
7.1	Refractometer verification	29
7.2	Refractive index n_D verification	29
7.3	Verification procedure	30
7.4	Verification report	33
7.5	Corrective action	33
8	Troubleshooting	35
8.1	Hardware	35
8.1.1	Message HIGH SENSOR HUMIDITY	35
8.1.2	Message HIGH SENSOR TEMP	35
8.2	Measurement	35
8.2.1	Message OUTSIDE LIGHT ERROR or OUTSIDE LIGHT TO PRISM	35
8.2.2	Message NO OPTICAL IMAGE	35
8.2.3	Message PRISM COATED	36
8.2.4	Message LOW IMAGE QUALITY	36
8.2.5	Message NO SAMPLE	36
8.2.6	Message TEMP MEASUREMENT FAULT	36
8.2.7	Concentration drift during NORMAL OPERATION	36
8.3	Diagnostic messages table	37
9	Ethernet protocol specification	38
9.1	Communication protocol	38
9.1.1	Request format	38
9.1.2	Response format	39
9.1.3	Request and response errors	40

9.2	Request-response pair specification	40
9.2.1	NULL message	40
9.2.2	Protocol version	40
9.2.3	Refractometer information	41
9.2.4	Measurement results	41
9.3	Error message specification	42
10	Principle of measurement	43
11	Sanitary OEM refractometer field calibration form	45

1 Introduction

The inline K-Patents Sanitary OEM Refractometer PR-33-AC (figure 1.1) 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 (see chapter 9). An optional mA output unit is also available, if more than one current output is required.

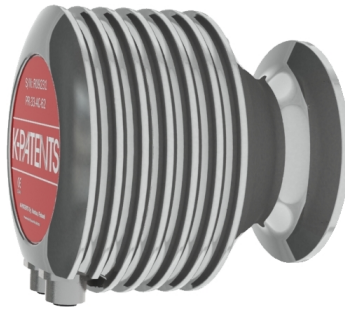


Figure 1.1 K-Patents Sanitary OEM Refractometer PR-33-AC.

2 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, please see figure 3.3.

2.1 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. The power supply should be shielded from external voltage surges.

2.2 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 Ω .

2.3 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. Chapter 9 gives all the specifications necessary to write a data acquisition program.

2.3.1 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. This configuration is shown in figure 2.1.

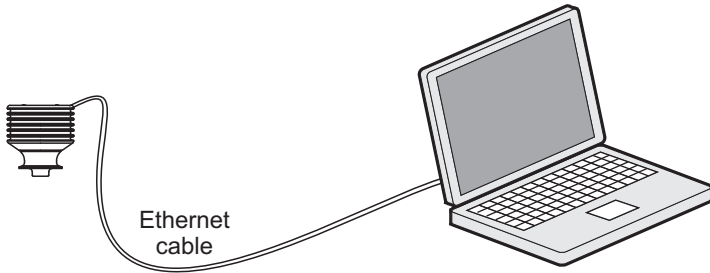


Figure 2.1 Simple network configuration.

Several refractometers can be connected to the same Ethernet network. Also, the Sanitary OEM Refractometer 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.

Figure 2.2 shows an example of how to connect three refractometers to an existing LAN with a switch.

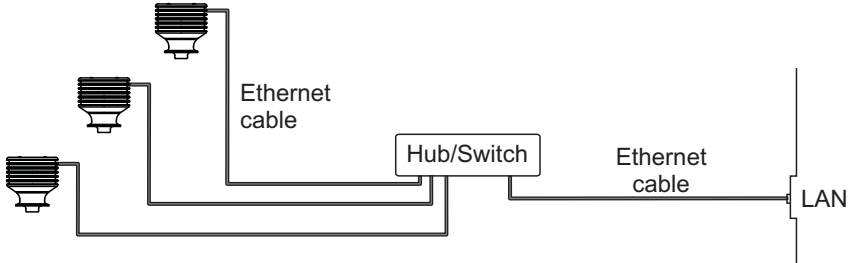


Figure 2.2 Three refractometers in the same network.

It is possible to use a WLAN access point to decrease the number of cables (figure 2.3).



Figure 2.3 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 (see figure 2.4). The range may be up to several kilometers with a suitable fiber connection.

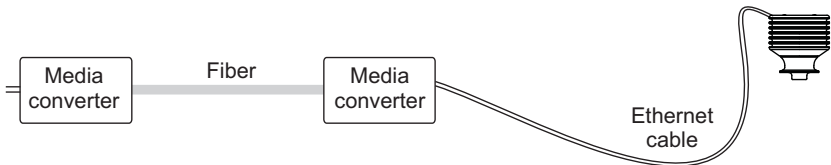


Figure 2.4 Using fiber link to connect refractometer(s).

2.3.2 IP settings for the 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 (figure 2.1), usually without changing the network settings of the computer. *This address will remain 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.*

Note: If there are more than one Sanitary OEM Refractometers in the same network, this address cannot be used (section 2.3.4).

The IP address of the instrument can be changed through the instrument homepage (see chapter 5).

2.3.3 IP settings for a stand-alone computer

When you start up a computer with automatical IP settings (DHCP enabled) in a network with only the Sanitary OEM Refractometer, the computer should automatically obtain an IP address 169.254.x.x. In this case you can connect to the factory default address of the refractometer without any further changes in settings. If this does not work, please make sure that your WLAN (Wireless network connection) is not active when you connect to the refractometer. If the WLAN is active, the computer's Ethernet connection may not function as expected. Also, obtaining the 169.254.x.x. address may take up to a minute.

If you still have difficulties in connecting to the instrument, you may check the IP address of the computer by opening the command window (command prompt) and by typing the command `ipconfig` at the command prompt (press Enter to give the command), see figure 2.5 (in Mac OS X and Linux the same command is called `ifconfig`). The result will give you your computer's IP address. If the address does not start by 169.254, you will have to manually configure the IP address of the computer to 169.254.23.34, netmask 255.255.0.0.

For further troubleshooting, see section 2.3.6.

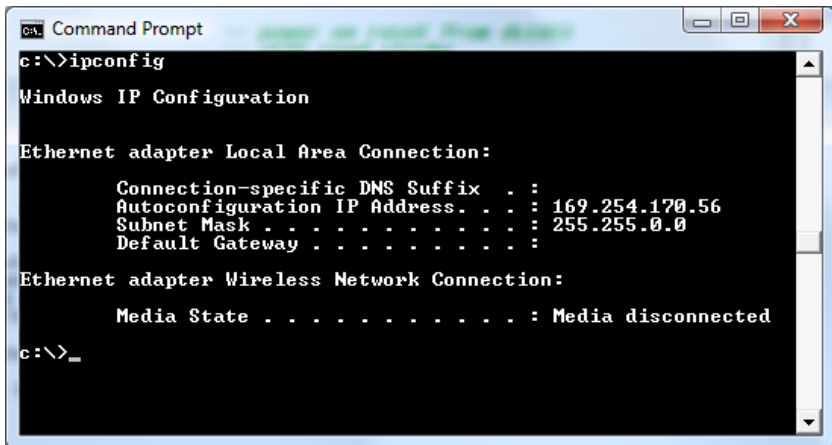


Figure 2.5 Typical IP configuration for a stand-alone laptop when connected to a Sanitary OEM Refractometer; laptop wireless (WLAN) is turned off

Note: The connection will not work if the computer and the refractometer have exactly the same IP address.

When you have configured the network settings of the instrument (and/or the computer) according to the instructions above, you can proceed to test the connection as instructed below in Section 2.3.5.

2.3.4 Configuring a network of refractometers

In case you have more than one Sanitary OEM Refractometer in a network, their IP addresses have to be configured, as the factory default will not work.

If you are connecting an Sanitary OEM Refractometer to a factory network, please 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 (see figure 2.6).

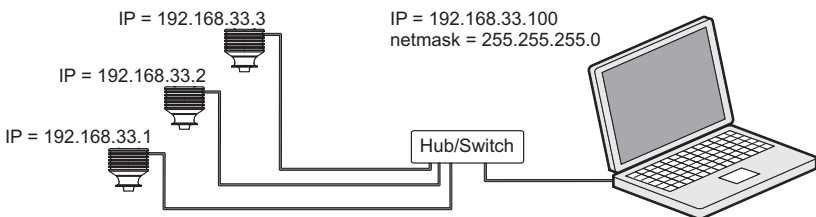


Figure 2.6 A network of Sanitary OEM Refractometers.

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

2.3.5 Testing the Ethernet connection

When you connect the Sanitary OEM Refractometer to a switch, the corresponding link light should light up in the switch.

Once the refractometer is powered up, it should be 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 (see chapter 5).

Note: The factory-default IP address of the Sanitary OEM Refractometer is 169.254.23.33. This address should always respond (see section 2.3.2).

2.3.6 Troubleshooting the connection

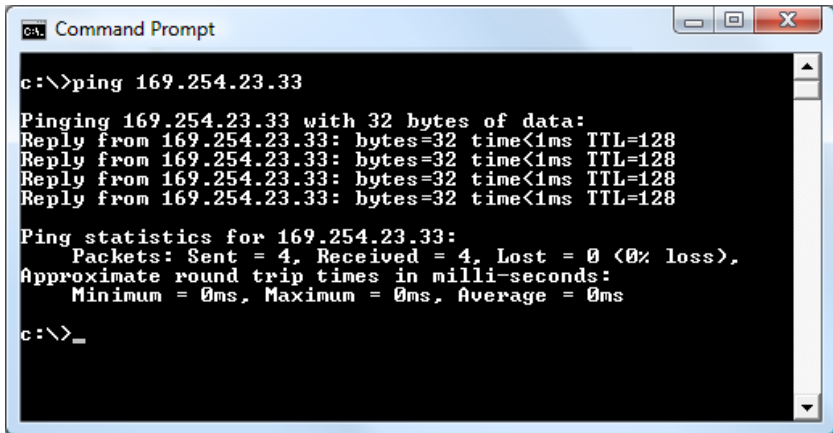
In case you are unable to reach the instrument through the network, please check the following things:

- the instrument receives power; the ethernet switch link light is lit.
- the network settings of the computer are compatible with those of the instrument (section 2.3.3)
- if you try to reach the instrument at IP address 169.254.23.33, 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 (figure 2.1)
- check that the computer has suitable network settings and that its WLAN connection is turned off (section 2.3.3)
- use the ping utility of the computer to try and reach the refractometer

The ping utility mentioned above is in Windows systems available 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). The usage of ping is very simple: 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 Sanitary OEM Refractometer will answer to ping and return any data packets sent to it, see figure 2.7.

A screenshot of a Windows Command Prompt window titled "Command Prompt". The window has a standard Windows title bar with minimize, maximize, and close buttons. The command prompt shows the following text:

```
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 2.7 Pinging address 169.254.23.33, ping returned fully and connection ok.

3 Refractometer mounting

The Sanitary OEM Refractometer mounting location should be chosen with care to ensure reliable readings from the process.

3.1 Choosing the refractometer mounting location

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

Important: If the process pipe vibrates, support the pipe. A vibrating pipe might 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.

Important: Always mount the refractometer so that the interconnecting cable points downwards from the refractometer head.

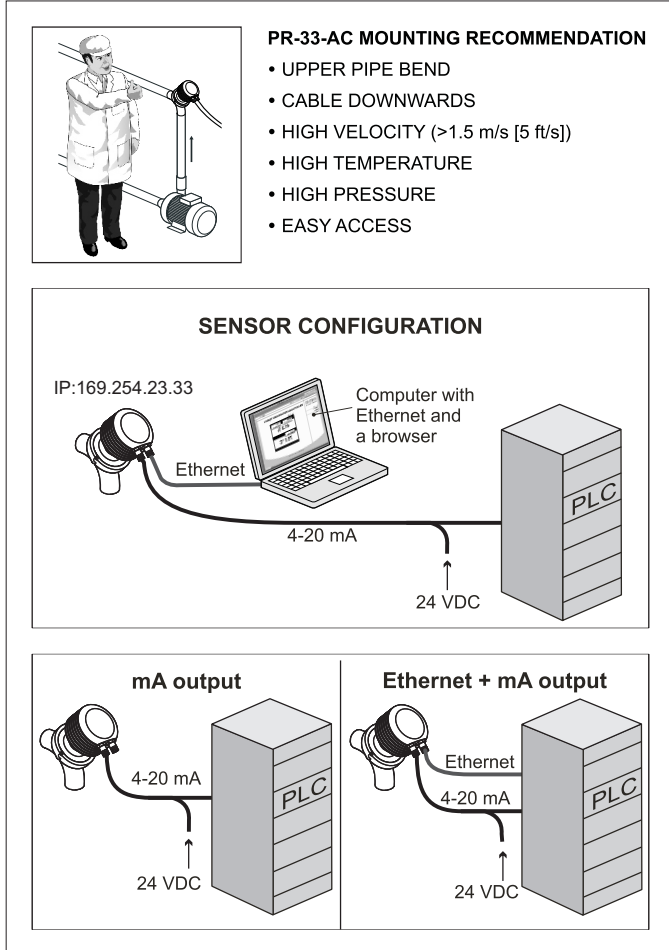
3.2 Check list for pipe mounting

Most Sanitary OEM Refractometers are mounted in a pipe. K-Patents recommends a flow velocity 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.

The diameter and form of the pipe and the process temperature all affect the measurement and need to be taken into account. (See figure 3.1)

1. If the process pipe diameter varies, select the *position with the smallest diameter* (and accordingly highest velocity). Then the prism stays clean better.
2. If the refractometer is used in a feed-back control loop, *make the time lag short*. E.g. when a dilution valve is controlled, mount the refractometer close to the dilution point. However, make sure complete mixing has occurred at mounting location.

PR-33-AC SENSOR INSTALLATION



MTG-512

<http://www.kpatents.com/>

Figure 3.1 Pipe mounting of Sanitary OEM Refractometer

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. The refractometer should be conveniently accessible for service.

3.3 Refractometer wiring

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



Figure 3.2 Connectors on the Sanitary OEM Refractometer

Please see the wiring drawing (figure 3.3) for wiring instructions.

4 Startup and use

4.1 Startup

4.1.1 Initial check

Connect the Sanitary OEM Refractometer to a 24 V dc supply (see section 2.1 and section 3.3), and 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 start-up. It is also possible to see a faint blinking amber light when the prism is looked at 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 (see section 2.3) and check that the serial number of the page corresponds to that on the instrument nameplate. In case you have difficulties connecting to the instrument, please see section 2.3.6.

4.1.2 Calibration check

Wait until normal process conditions occur. The concentration reading is precalibrated at delivery and a copy of the Calibration certificate is shipped with the refractometer. If the diagnostic message is NORMAL OPERATION but the concentration reading does not agree with the laboratory results, consult Section 6.2, "Calibrating the concentration measurement".

4.2 Viewing refractometer status

The basic information on the measurements is shown on the main page of the instrument (section 5.1). More information is shown on the Diagnostics page (section 5.3).

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.

5 Instrument homepage

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

Once there is a functional Ethernet connection between the instrument and the computer, the homepage can be opened by typing the instrument's IP address to the address bar of a web browser. K-Patents recommends using Firefox 2.0 (or newer) or Internet Explorer 8.0 (or newer), but most functionality is available with any modern web browser.

Opening the instrument homepage:

1. Establish a working Ethernet connection to the instrument. For more instructions, see section 2.3.
2. Start your preferred web browser (for example Mozilla Firefox, Internet Explorer, Safari, Chrome or Opera).
3. The address (URL) of the instrument homepage is the refractometer's IP address, for a factory set Sanitary OEM Refractometer it is `http://169.254.23.33/`. Give the address to the browser just like you'd enter any other address (for example `http://www.kpatents.com/`)
4. Wait until the homepage is loaded, this may take a few seconds. The page looks approximately like in Figure 5.1; the exact look of the page depends on your browser and screen settings so slight variation can be expected.
5. Use the links in the link bar on the left side of the page to find more extensive information on the instrument.

Important: In order for the web pages to function as designed, the JavaScript support has to be enabled in the browser.

5.1 Main page

Once the instrument homepage is loaded, the most important information is visible on the main page (figure 5.1). This page shows the measurement values, serial number and the tag of the instrument.

The small number on the top left corner of the page shows the number of measurement cycles (one per second) since the last startup of the sensor.

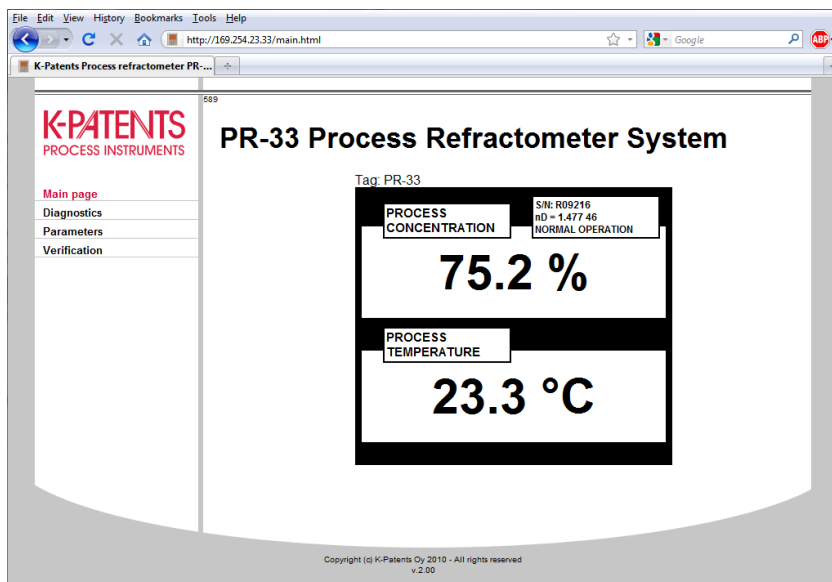


Figure 5.1 Main page

5.2 Parameters

All functional parameters of the instrument can be changed on the Parameters page of the instrument (figure 5.2). New parameters may be typed into the input fields.

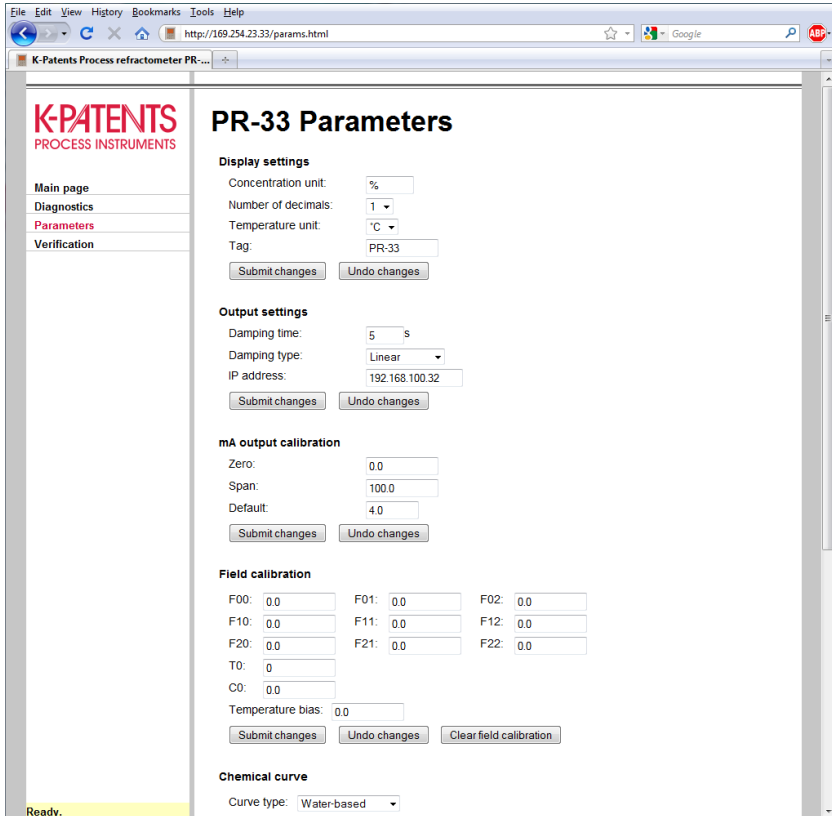


Figure 5.2 Parameter page

Once the parameter editing is done, pressing the Submit changes button will send the parameters to the instrument after asking for a confirmation. Updating the parameters may take a few seconds.

Note: If you change the IP address of the instrument, you will have to enter the new address to the address bar of the browser, as the instrument will no longer respond to the old address.

5.3 Diagnostics

On the diagnostics page (figure 5.3) you may see 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.

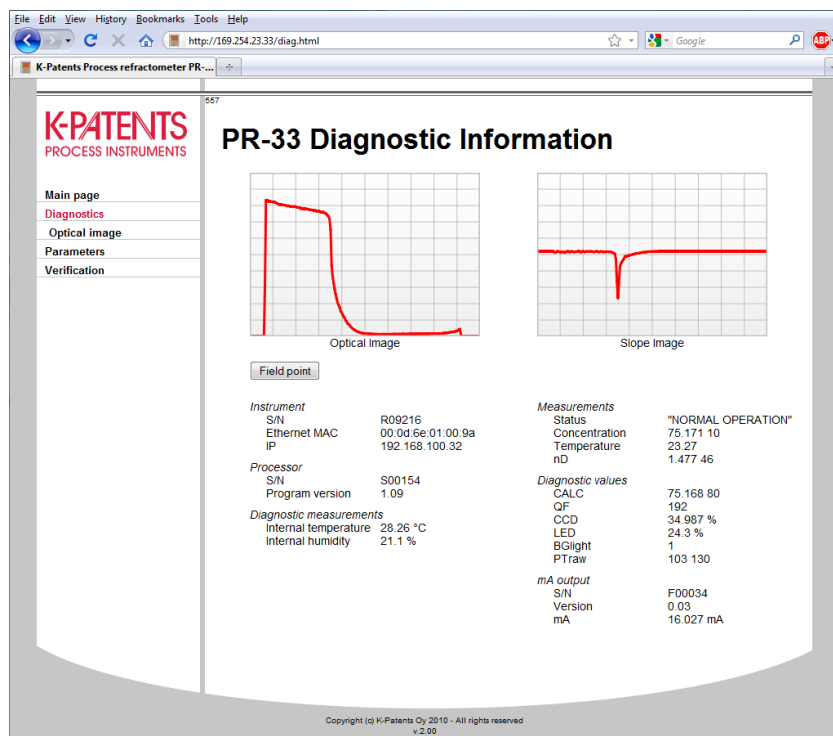


Figure 5.3 Diagnostics page

5.3.1 Measuring field samples

The diagnostics page offers a possibility to measure samples either for field calibration purposes (see section 6.2.2).

A sample can be measured by clicking the `Field point` button on the page. After clicking the button the instrument will measure ten measurements and shows the average and deviation of the measurements. Also the measurement status is shown, and if the status is not `Normal operation`, the point is not accepted.

Several points may be measured, and all the points are shown on the page until the page is reloaded. After measuring a sufficient amount of points the page may be printed.

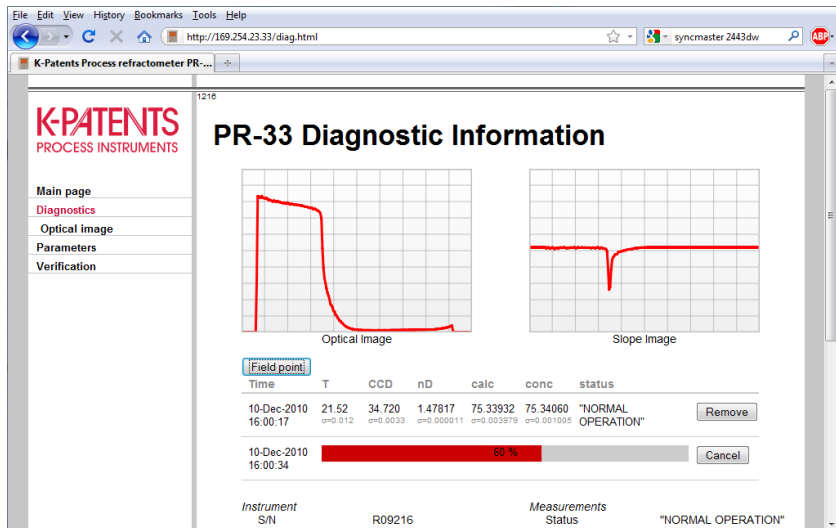


Figure 5.4 Measuring field samples

5.3.2 Optical image

The raw optical image (figure 5.5) which contains all optical information can be seen by clicking on the `Optical image` link on the left panel on the Diagnostics page.

The optical image can be downloaded as a file by clicking on the caption (Raw optical image) of the image. This file can be used by K-Patents for troubleshooting purposes.

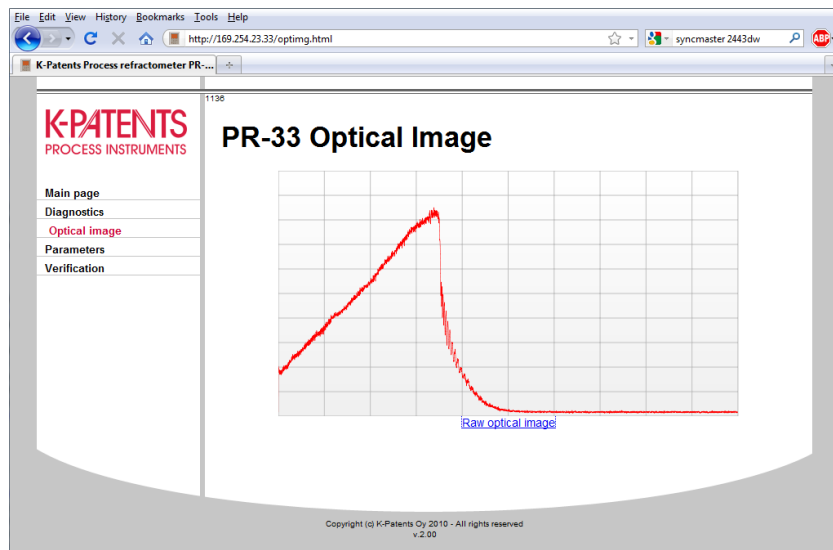
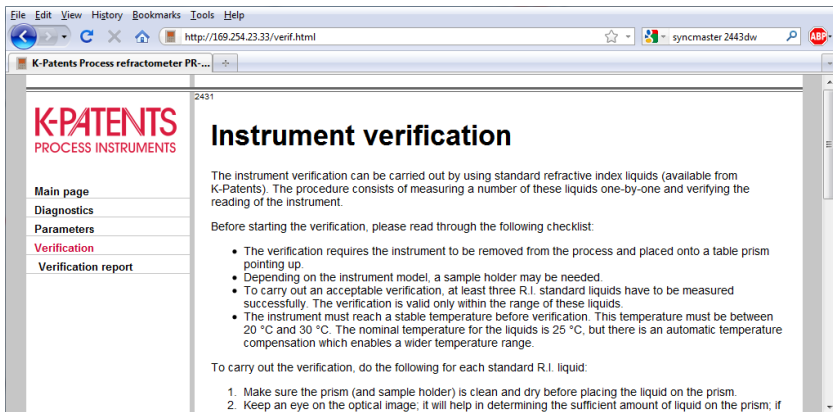


Figure 5.5 Raw optical image

5.4 Verification

The instrument verification can be performed on this page (figure 5.6). For more information on the verification procedure, please see chapter 7.



The screenshot shows a web browser window with the address bar displaying `http://169.254.23.33/verif.html`. The browser's title bar reads "K-Patents Process refractometer PR-...". The page content is as follows:

K-PATENTS
PROCESS INSTRUMENTS

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

The left sidebar contains a navigation menu with the following items: Main page, Diagnostics, Parameters, Verification (highlighted in red), and Verification report.

Figure 5.6 Verification page

6 Configuration and calibration

6.1 Configuring the refractometer

In the Sanitary OEM Refractometer, all parameter changes are made with a web browser through the parameters page, see Section 5.2.

6.1.1 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).

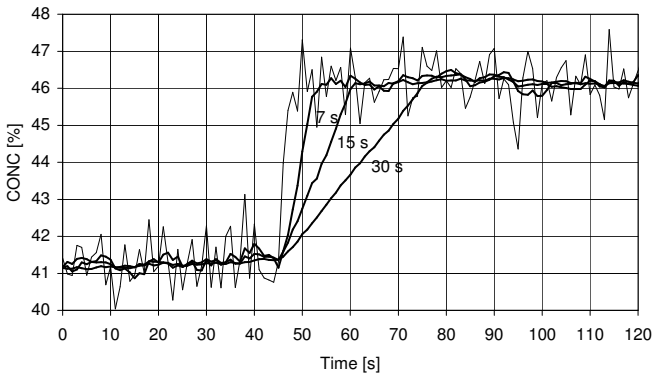


Figure 6.1 Effect of damping time on measurement

There are two different damping types available in the Sanitary OEM Refractometer. The *linear damping* is a sliding average, and it is recommended for most cases. The damping time represents the averaging time. For fast damping, use 0–2s damping, for minimal noise, use a value of 10s or more.

The *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 types of 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 s does not improve the noise performance. It should also be noted that increasing the damping time will deteriorate the response speed of the instrument. Figure 6.1 shows how the damping time affects the measurement.

6.2 Calibrating the concentration measurement

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

1. *The information from the CCD element and the Pt-1000 temperature element.* The position of the shadow edge (Figure 10.3, "Optical image detection") is described by a number called CCD and scaled from 0-100 %.
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. Hence, the calibrations of all Sanitary OEM Refractometers are identical, which makes the refractometers interchangeable. Furthermore, the calibration of each refractometer can be verified using standard refractive index liquids, see chapter 7.
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.

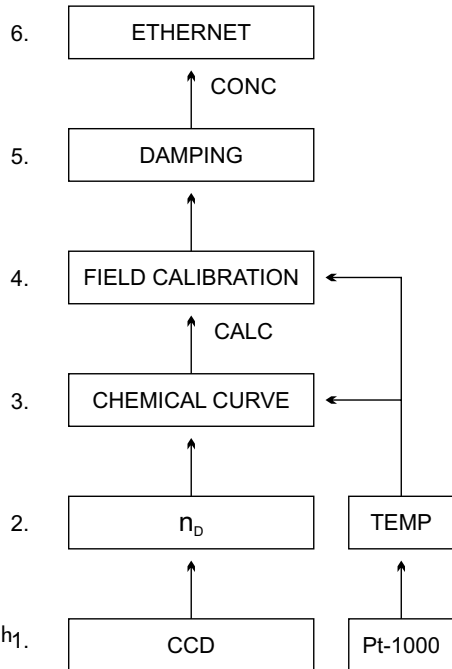


Figure 6.2 Calibration layers

- 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. The Field calibration procedure, section 6.2.2, 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.
- 5. *Damping:* See Section 6.1.1.
- 6. *Output signal:* The output signal is transmitted over the 4–20 mA current output or through the Ethernet connection (see chapter 9).

6.2.1 The chemical curve

The chemical curve is a model of the refractive index behaviour 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 6.1).

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}

Table 6.1 The chemical curve parameters

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 K-Patents and should not be altered, except in case of changing to another process medium.

6.2.2 Field calibration

K-Patents 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.

The field calibration procedure should be made under normal process conditions 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 (see section 5.3.1). Record the data either on the field calibration form (found in the end of this manual or at <http://www.kpatents.com/>) or print out the field points on the web page.

In case you have a constant offset, you can perform a bias adjustment, see section 6.2.3. For a more detailed field calibration, send the completed calibration form to either K-Patents headquarters <info@kpatents.com> or your local K-Patents representative. A computer analysis of the data will be made at K-Patents 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
n _D	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), n_D and CONC at exactly the same time with sampling.
- Use a tight container for the sample to avoid evaporation.

Important: 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

Thus *calibration using the process liquid should always be made inline.*

6.2.3 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 $f00$ will be added to the concentration value:

$$\text{NEW CONC} = \text{OLD CONC} + f00.$$

7 Instrument verification

7.1 Refractometer verification

A company maintaining quality system according to ISO 9000 quality standards must have defined procedures for controlling and calibrating its measuring equipment. Such procedures are needed to demonstrate the conformance of the final product to specified requirements. The company should

- Identify the required accuracy and select appropriate equipment for measurements.
- Establish calibration procedures including a check method and acceptance criteria.
- calibrate the equipment at prescribed intervals against certified equipment having a known valid relationship to nationally recognized standards. In cases where no such standards exist, the basis used for calibration must be documented.

K-Patents verifies the calibration of all delivered instruments according to a procedure similar to the one described below. The K-Patents quality system is ISO 9001 certified by Det Norske Veritas.

7.2 Refractive index n_D verification

The verification of the Sanitary OEM Refractometer calibration is made 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 recognizes automatically the following refractive index standard liquids (the values are stated at $+25^\circ\text{C}$):

- 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 ± 0.0002 and they can be traced back to NIST standards # 1823 and # 1823 II. As the specified accuracy of the Sanitary OEM Refractometer is ± 0.0002 , then the representative level is the sum of the two accuracy specifications, that is ± 0.0004 .

K-Patents 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 K-Patents. Other liquids are available on request.

7.3 Verification procedure

The instrument verification can be performed by using the web interface (see chapter 5) on the instrument verification page (figure 7.1). 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, new result will replace the older one. A single measurement point can be removed by clicking the Remove button.

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PROCESS INSTRUMENTS

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 be seen by clicking the "Verification report" link in the menu.

S/N: R09216
NORMAL OPERATION
nD 1.477 45
T 23.28
CCD 34.991
LED 24.3

STANDARD LIQUID @ 25 °C	@ T	MEASUREMENT			VERIFICATION RESULT	
		T	nD	CCD	nD error	Status

94%

Cancel

Measurement in progress...

Figure 7.1 Verification page

The verification result is shown on the page. Please note that reloading the page removes all points. After measuring a sufficient number of points the verification may 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

The temperature of the refractometer can be checked by following the temperature measurement on the Verification page. The temperature should be constant.

The sample holder keeps the sample on the prism surface and also blocks the ambient light from reaching the prism. The K-Patents universal sample holder PR-1012 (Figure 7.2) can be used with any K-Patents refractometer.



Figure 7.2 The K-Patents universal sample holder PR-1012

The optical image displayed on the page helps determining whether the prism is wetted completely. The image should have a sharp corner as in figure 7.1. Note that the position of the corner depends on the refractive index. A soft image may indicate improper cleaning of the prism. Also, 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, please redo the measurement. The most likely reason is that the liquid leaks from the sample holder.

After a sample has been measured, 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, you may either remove it or remeasure it.

Once all liquids have been measured, the verification can be saved by clicking the **Save verification** button. Please note that 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 ± 0.0004 of the nominal values.

Note: 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, see Section 6.2, "Calibrating the concentration measurement".

7.4 Verification report

The last saved verification data can be accessed by clicking the **Verification report** link on the left panel. This verification report (figure 7.3) 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.

7.5 Corrective action

If the verification is not passed, first check that 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, fill in the form **Sanitary OEM Refractometer verification form**, found in the end of this manual. You may also print out the verification report, it carries the same information. Send the data to K-Patents <info@kpatents.com> or your nearest K-Patents representative and wait for further instructions.

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PR-33 verification

The latest saved verification is shown in this report. The verification is valid within the range of standard refractive index liquids used in the verification process. If traceable index of refraction liquids are used in the process, a successful verification proves the standard traceability of the instrument.

Instrument S/N: **R09216**
Verified at: **16:48:22 6-Sep-2010**

STANDARD LIQUID		MEASUREMENT			VERIFICATION RESULT	
@ 25°C	@ T	T	nD	CCD	nD error	Status
1.34	1.339217	27.32	1.339192	83.465	0.000025	PASS
1.37	1.369189	27.37	1.369097	68.023	0.000092	PASS
1.41	1.409031	27.37	1.409202	52.878	0.000171	PASS
1.52	1.519018	27.41	1.519127	15.263	0.000109	PASS

Verification result: **Verification successful (1.34 .. 1.52)**

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v.2.00

Figure 7.3 The verification report

8 Troubleshooting

8.1 Hardware

8.1.1 **Message** HIGH SENSOR HUMIDITY

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.

Action: Please contact K-Patents.

8.1.2 **Message** HIGH SENSOR TEMP

The temperature inside the instrument exceeds 65 °C (150 °F). To read this temperature, go to the diagnostics page (section 5.3). For action, see Section 3.1, "Choosing the refractometer mounting location".

8.2 Measurement

8.2.1 **Message** OUTSIDE LIGHT ERROR **or** OUTSIDE LIGHT TO PRISM

Cause: The measurement is not possible or is disturbed because outside light reaches the camera.

Action: 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 BGLight on the diagnostics page (section 5.3).

8.2.2 **Message** NO OPTICAL IMAGE

There are several possible causes to this message:

1. The prism is heavily coated. Remove sensor from line and clean prism manually.
2. There is moisture condensation in the sensor, see Section 8.1.1.
3. The sensor temperature is too high, see Section 8.1.2.

4. The light source is faulty. When the sensor is removed from the process, the yellow flashing light can be seen through the prism. **Note:** The light is only visible at an oblique angle. Also check the LED value on the Diagnostics page (section 5.3); 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 CCD window. Please contact K-Patents.
6. The CCD card in the sensor is faulty. Please contact K-Patents.

8.2.3 Message PRISM COATED

Cause: The optical surface of the prism is coated by the process medium or impurities in the process medium.

Action: Remove sensor from line and clean prism manually.

If the problem is recurrent, consider improving the flow conditions.

8.2.4 Message LOW IMAGE QUALITY

Cause: The most likely cause for this message is coating on the prism. There still is a optical image available, but the measurement quality may not be optimal.

Action: Clean the prism, see Section 8.2.3 above.

8.2.5 Message NO SAMPLE

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.

8.2.6 Message TEMP MEASUREMENT FAULT

Indicates faulty temperature element. Please contact K-Patents.

Note: A difference to some other process temperature measurement is not a fault. The Sanitary OEM Refractometer shows the true temperature of the prism surface.

8.2.7 Concentration drift during NORMAL OPERATION

For drift upward or downwards to zero, suspect prism coating and clean the prism.

8.3 Diagnostic messages table

Important: The messages are listed in descending order of priority. *Example:* If both NO OPTICAL IMAGE and TEMP MEASUREMENT FAULT are activated, only NO OPTICAL IMAGE will be shown.

Message	Section
OUTSIDE LIGHT ERROR	8.2.1
NO OPTICAL IMAGE	8.2.2
TEMP MEASUREMENT FAULT	8.2.6
HIGH SENSOR HUMIDITY	8.1.1
HIGH SENSOR TEMP	8.1.2
NO SAMPLE	8.2.5
PRISM COATED	8.2.3
OUTSIDE LIGHT TO PRISM	8.2.1
LOW IMAGE QUALITY	8.2.4
NORMAL OPERATION	

9 Ethernet protocol specification

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

For examples and ready-made applications, please contact K-Patents.

9.1 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.

9.1.1 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

Important: 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 Section 9.2 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.

9.1.2 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"
```

Note: All the key identifiers (see Section 9.2 for additional information) are case-insensitive. However, K-Patents recommends that they are written as in this specification.

The server (refractometer) may send the response keys in any order. It will send the mandatory keys (marked with an asterisk in Section 9.2) of the specific request, but it may omit any other keys. The server may also send keys that are not specified in this document, but the client (computer) may ignore them.

9.1.3 Request and response errors

When the server (refractometer) detects an error, it responds with an error message (for more information see Section 9.3). An error message can be caused for example by an unknown request or inability to collect data for the mandatory keys of a response.

9.2 Request-response pair specification

The list below describes the *query messages*, i.e. request-response pairs, used for data collection via Ethernet. **Those response keys that are always sent are preceded by an asterisk (*)**.

9.2.1 NULL message

The null message is included in the 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.

Request ID	0x00000000
Request data	(none)
Response key	IP : IP address
	MAC : Ethernet MAC address

9.2.2 Protocol version

The version query is responded with a value representing the server (refractometer) protocol version.

Request ID	0x00000001
Request data	(none)
Response key	*Version : integer, the server protocol version (currently 3)

9.3 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 0x00000001 : Unknown request
*Error : integer, error code 0x00000002 : Invalid request (request recognized, invalid request data)
*Error : integer, error code 0x00000003 : Invalid sensor number
ErrorMsg : string, error details

There may also be error-dependent extra keys.

10 Principle of measurement

The 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 Figure 10.1 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.

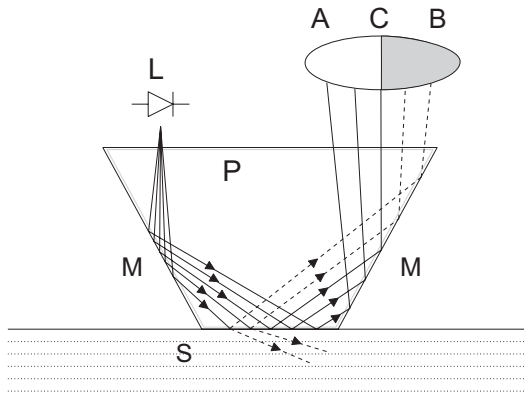


Figure 10.1 Refractometer principle

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 Figure 10.2. The color of the solution, gas bubbles or undissolved particles do not affect the position of the shadow edge (C).

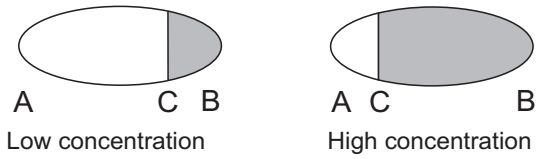


Figure 10.2 Optical images

The position of the shadow edge is measured digitally using a CCD element (Figure 10.3) 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.

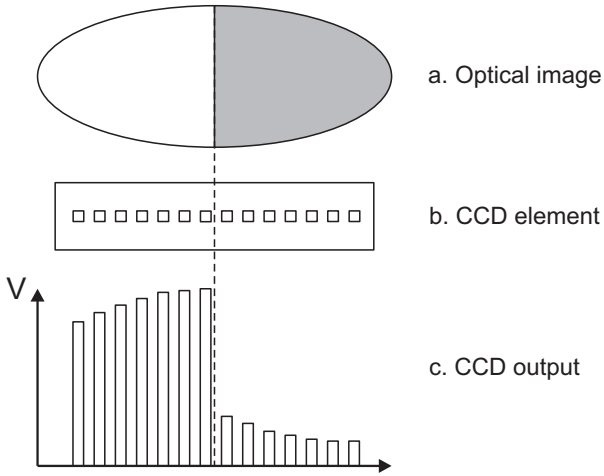


Figure 10.3 Optical image detection

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