SEMICON PROCESS REFRACTOMETER PR-33-S

K-PATENTS
PROCESS INSTRUMENTS

K-PATENTS
PROCESS INSTRUMENTS

INSTRUCTION MANUAL

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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.

8 PR-33 field calibration form

Fill in this form and fax it to K-Patents Oy or to your local service representative. For contact information, please see <*http://www.kpatents.com/*>.

Sensor serial no: ____________________
Customer: ____________________
Address: ____________________
Fax: ____________________
Email: ____________________
Sample description: ____________________
Solvent (water/other): ____________________
Laboratory method: ____________________
Date: ____________________
Data collected by: ____________________

Sample no	LAB%	CALC	T	n_D	CONC

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7.3 Error message specification

If the server (sensor) 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`	: No sensor (sensor(s) not connected to sensor)
`ErrorMsg`	: string, error details		

There may also be error-dependent extra keys.

1 Introduction

The inline refractometer sensor PR-33-S (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 composition of the process medium is known.

The output values of the sensor are transmitted through its Ethernet connection by using a UDP/IP protocol (see chapter 2). An optional mA output unit is also available.

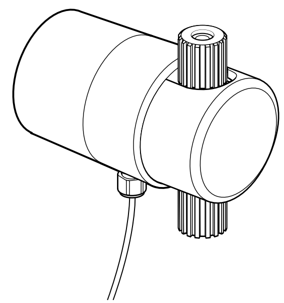


Figure 1.1 PR-33 sensor

1.1 Principle of measurement

The K-Patents inline refractometer sensor 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 1.2 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.

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.

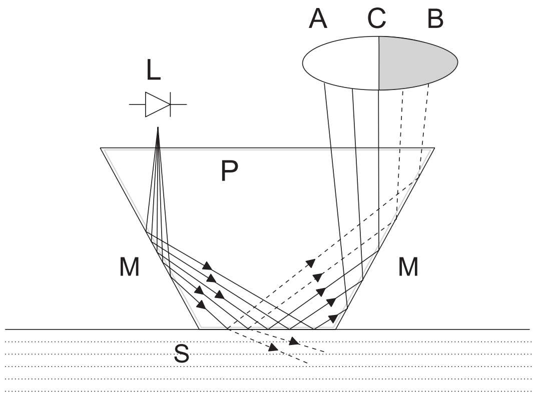


Figure 1.2 Refractometer principle

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

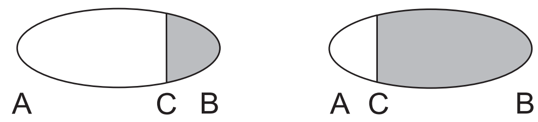


Figure 1.3 Optical images

7.2.3 Sensor information

The sensor information query gives the basic information of the sensor.

Request ID	`0x00000003`	
Request data	`0x00000000`	: always zero
Response keys	`*SensorSerial`	: integer, sensor serial number
	`*SProcSerial`	: integer, sensor processor card serial number
	`*SensorVersion`	: integer, version number of the sensor software

7.2.4 Measurement results

The measurement result query gives the measured and calculated measurement values from the chosen sensor.

Request ID	`0x00000004`	
Request data	`0x00000000`	: always zero
Response keys	`Status`	: string, sensor status message
	`PTraw`	: integer, PT1000 value
	`LED`	: float, sensor led value
	`RHsens`	: float, sensor internal humidity
	`nD`	: float, calculated n_D value
	`CONC`	: float, final concentration value
	`Tsens`	: float, sensor internal temperature
	`T`	: float, process temperature
	`CCD`	: float, image shadow edge
	`CALC`	: float, calculated concentration value
	`QF`	: float, quality factor
	`BGlight`	: integer, background light

7.1.3 Request and response errors

When the server (sensor) detects an error, it responds with an error message (for more information see Section 7.3). An error message can be caused for example by an unknown request or inability to collect data for the mandatory keys of a response.

7.2 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 (*).**

7.2.1 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

7.2.2 Protocol version

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

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

The position of the shadow edge is measured digitally using a CCD element (Figure 1.4) and is converted to a refractive index value n_D by a processor inside the sensor. This value is used together with the measured process temperature to calculate the concentration.

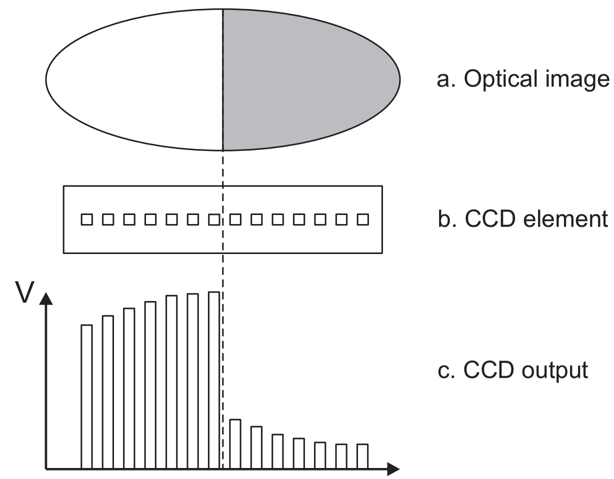


Figure 1.4 Optical image detection

2 Ethernet connection

The Ethernet connection enables data download from a PR-33 sensor 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 sensor. Sensor configuration and monitoring can be carried out without special software by using a standard web browser. Section 7.1 gives all the specifications necessary to write a data acquisition program.

2.1 Ethernet specification

The sensor is designed to be connected to a network with **PoE** (Power over Ethernet, IEEE-802.3af) **mode A support**, as it receives its operating power through the Ethernet. The sensor is equipped with an integrated Ethernet cable, 10 meter long. The cable can be connected to any standard RJ45 Ethernet equipment. Additional length can be gained by using a UTP joint adapter/coupler with a standard Ethernet cable, length up to 90 meters. The maximum communication speed of the sensor is 100 Mbit/s (Ethernet 100BASE-T).

In the simplest form the network consists of a sensor, a computer, and a PoE switch. This configuration is shown in figure 2.1.

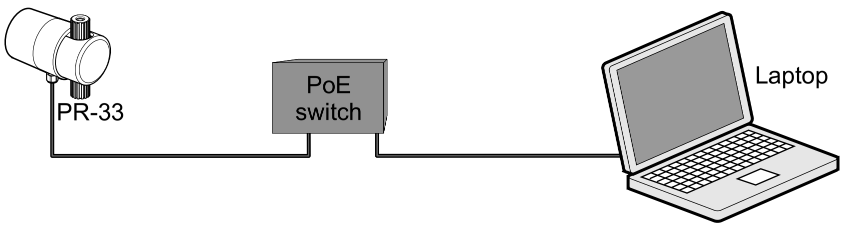


Figure 2.1 Simple network configuration.

Several sensors can be connected to the same Ethernet network. Also, the sensors have an automatic function 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 sensors to an existing LAN with no PoE functionality. A single PoE switch will suffice in this case.

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.

7.1.2 Response format

The response data sent by the sensor 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 7.2 for additional information) are case-insensitive. However, K-Patents recommends that they are written as in this specification.

The server (sensor) may send the response keys in any order. It will send the mandatory keys (marked with an asterisk in Section 7.2) 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.

7 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.

7.1 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.

7.1.1 Request format

The client to server communication, i.e. the requests sent from your computer to the sensor, 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 sensor, 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 sensor information. See Section 7.2 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

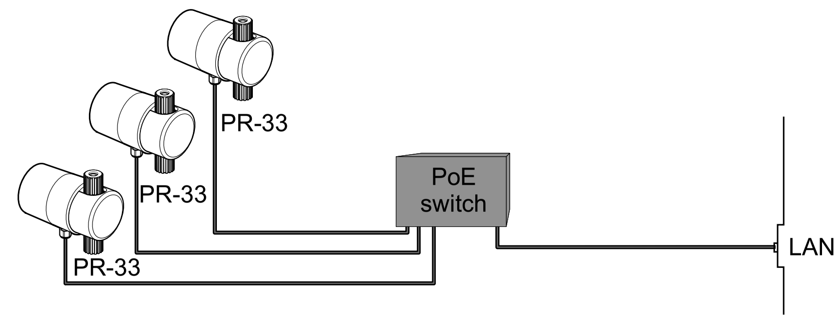


Figure 2.2 Three sensors in the same network.

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

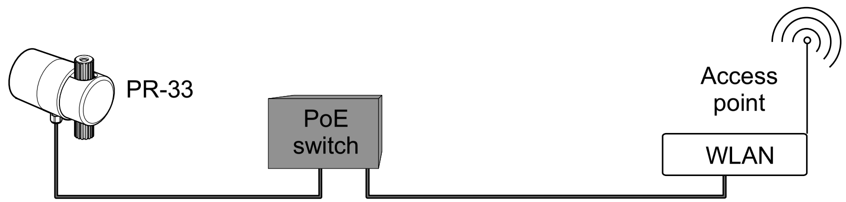


Figure 2.3 Connecting sensor(s) via wireless.

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).

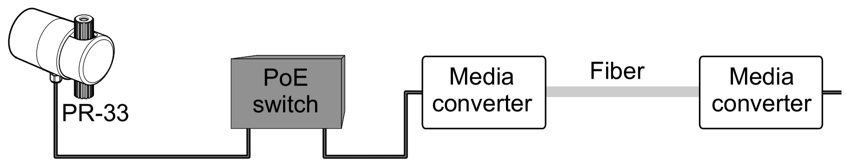


Figure 2.4 Using fiber link to connect sensor(s).

2.2 Connection settings

2.2.1 IP settings for sensor

All sensors 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 sensor 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 PR-33 in the same network, this address cannot be used (section 2.2.3).

The IP address of the sensor can be changed through the instrument homepage (section 2.4).

2.2.2 IP settings for stand-alone computer

When you start up a computer with automatical IP settings (DHCP enabled) in a network with only the PR-33 sensor, 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 sensor 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 sensor. 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 sensor, 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 2.3.1.

6.3 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	6.2.1
NO OPTICAL IMAGE	6.2.2
TEMP MEASUREMENT FAULT	6.2.6
HIGH SENSOR HUMIDITY	6.1.1
HIGH SENSOR TEMP	6.1.2
NO SAMPLE	6.2.5
PRISM COATED	6.2.3
OUTSIDE LIGHT TO PRISM	6.2.1
LOW IMAGE QUALITY	6.2.4
NORMAL OPERATION	

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 2.4.3); 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.

6.2.3 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 (see Section 3.1, "Mounting the sensor").

6.2.4 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 6.2.3 above.

6.2.5 Message NO SAMPLE

The operation of the equipment is OK but there is no process liquid on the prism.

6.2.6 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 PR-33 measures the true temperature of the prism surface.

6.2.7 Concentration drift during NORMAL OPERATION

For drift upward, suspect prism coating.

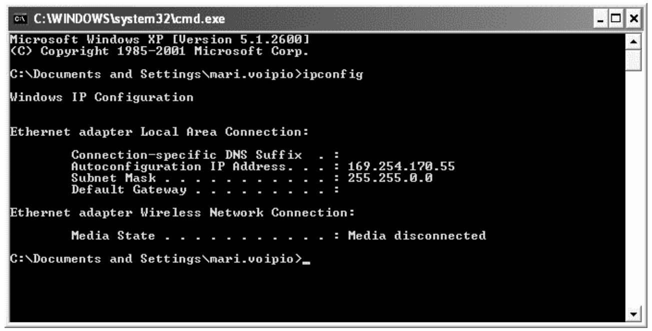


Figure 2.5 Typical IP configuration for a stand-alone laptop when connected to a sensor; laptop wireless (WLAN) is turned off

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

When you have configured the network settings of the sensor (and/or the computer) according to the instructions above, you can proceed to test the connection as instructed below in Section 2.3.

2.2.3 Configuring a network of sensors

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

If you are connecting the sensor to a factory network, please consult the network administrator for the correct settings.

If the network is a stand-alone network with only PR-33's 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).

Note: There are no settings for subnet mask, default gateway or name servers in PR-33, as these settings are not required.

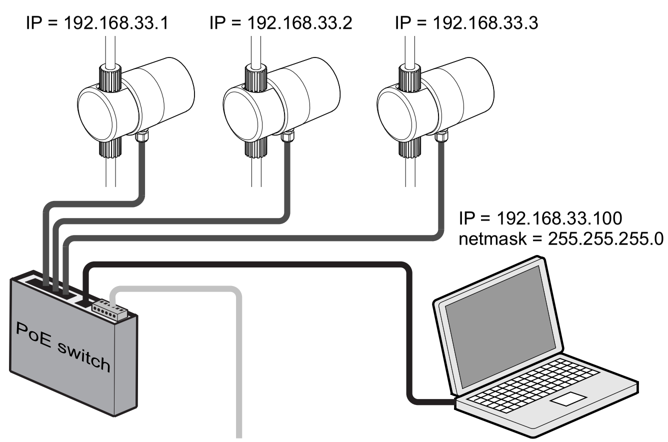


Figure 2.6 A network of PR-33 sensors.

2.3 Testing the Ethernet connection

When you connect the sensor to a powered PoE switch, the indicator lights should light up. The actual position and function of the lights depend on the switch, but figure 2.7 shows the indicators on a typical PoE switch. There's one indicator showing that the instrument is drawing power, another indicator (next to the Ethernet connector) shows the connection status. In this case a 100 Mbit/s connection is formed between two instruments at the switch ports 1 and 3 (a sensor per port), and there is a PoE device connected in these ports, 1 and 3.

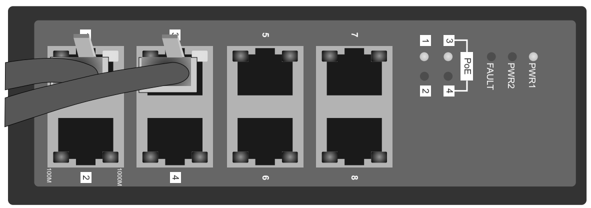


Figure 2.7 An example of PoE switch indicator lights

Note: It is typical that, e.g., 8-port PoE switches only have 4 ports supplying power.

6 Troubleshooting

6.1 Hardware

6.1.1 Message HIGH SENSOR HUMIDITY

Tells that humidity measured inside the sensor exceeds 60 % relative humidity. The reason may be moisture leaking in through prism seal or the cover being open.

Action: Please contact K-Patents.

6.1.2 Message HIGH SENSOR TEMP

The temperature inside the sensor exceeds 65 °C (150 °F). To read this temperature, go to the diagnostics page (section 2.4.3). For action, see Section 3.1.1, "Choosing sensor mounting location".

6.2 Measurement

6.2.1 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 2.4.3).

6.2.2 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 6.1.1.
3. The sensor temperature is too high, see Section 6.1.2.

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 sensor 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.

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*.

5.2.2 Direct BIAS adjustment

The concentration measurement value can also be directly adjusted by changing the field adjustment parameter f00.

The value of the bias parameter f00 will be added to the concentration value:
NEW CONC = OLD CONC + f00.

If you keep the sensor in a dimly lit space, you should see the flashing of the processor indicator lights on the instrument cover (see figure 2.8). If the lights are flashing, the instrument receives power from the PoE connection.

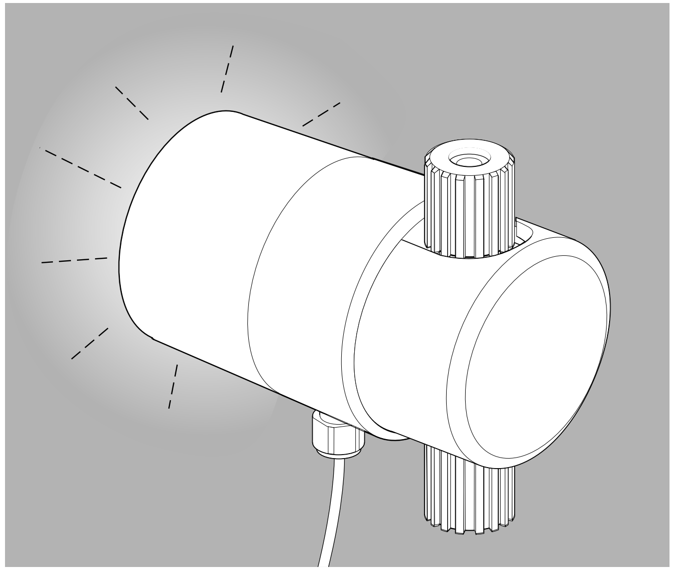


Figure 2.8 Process indicator lights in the sensor

Once the sensor is powered up, it should be reachable from any correctly configured computer connected to the same Ethernet network by typing the IP address of the instrument to a web browser (see section 2.4).

Note: The factory-default IP address of the sensor is 169.254.23.33. This address should always respond (see section 2.2.1).

2.3.1 Troubleshooting the connection

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

- the instrument receives power; there is a faint flashing light on the cover of the instrument (figure 2.8) or the PoE switch indicates 'power OK'.(see figure 2.7).

- the network settings of the computer are compatible with those of the instrument (section 2.2.2)
- if you try to reach the instrument at IP address 169.254.23.33, check that there is only one PR-33 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 sensor, PoE switch, and a computer (figure 2.1)
- check that the computer has suitable network settings and that its WLAN connection is turned off (section 2.2.2)
- use the ping utility of the computer to try and reach the sensor

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 sensor will answer to ping and return any data packets sent to it, see figure 2.9.

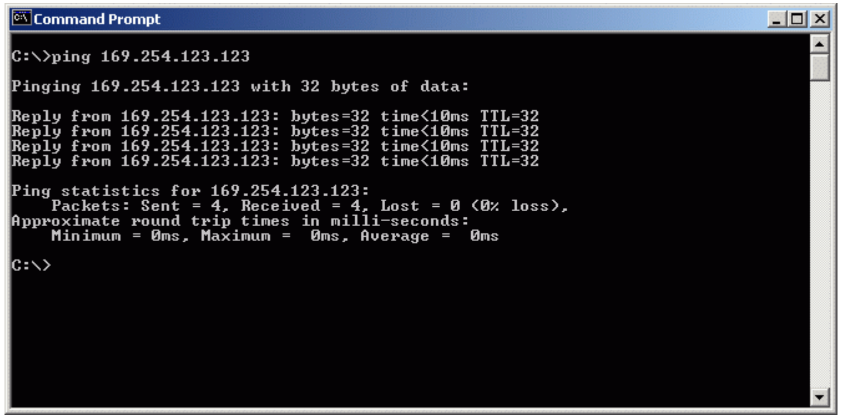


Figure 2.9 Pinging address 169.254.123.123, ping returned fully and connection ok.

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 5.1.1.
6. *Output signal*: The output signal is transmitted over the Ethernet connection. By adding an optional mA output unit, the Ethernet signal can be converted into mA output.

5.2.1 The chemical curve

The chemical curve is the theoretical concentration curve based on n_D and TEMP. It is defined by a set of 16 parameters (Table 5.1, one set for each sensor).

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 5.1 The chemical curve parameters

A chemical curve is specific to the given process medium, e.g. sucrose or sodium hydroxide. The set of parameters is given by K-Patents and should not be altered, except in case of changing to another process medium.

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

Record the calibrating data on the PR-33 field calibration form (found in the end of this manual), also available at <*http://www.kpatents.com/*> and by emailing a request to <*info@kpatents.com*>. Fax the completed Field calibration form to either K-Patents headquarters 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:

5.2 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 1.4, “Optical image detection”) is described by a number called CCD and scaled from 0-100 %.

2. *The sensor calibration*: The actual refractive index n_D is calculated from the CCD value. The process temperature is calculated from the Pt-1000 resistance. The sensor output is n_D and temperature TEMP in Centigrade. Hence, the calibrations of all PR-33 sensors are identical, which makes sensors interchangeable. Furthermore, the calibration of each sensor can be verified using standard refractive index liquids.

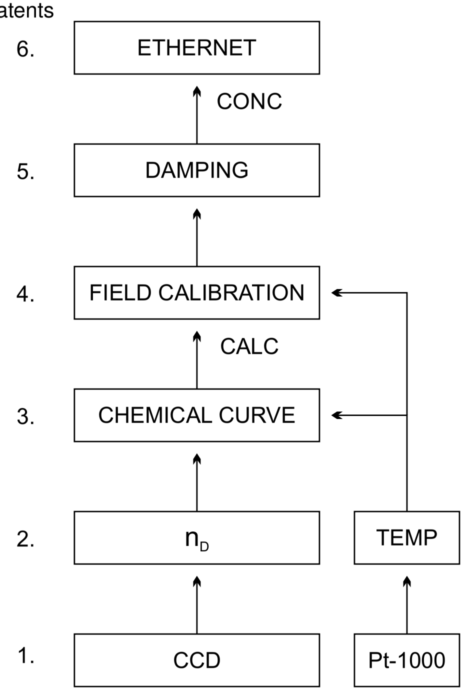


Figure 5.2 The layers of concentration calibration

3. *The chemical curve*: The sensor calculates the concentration value based on n_D and TEMP according to chemical curves derived from available chemical literature and K-Patents expertise. 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. The Field calibration procedure determines the appropriate adjustment to CALC. The adjusted concentration is called CONC. If there is no adjustment,

2.4 Instrument homepage

Every PR-33 sensor 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, but most functionality is available with any modern web browser.

Opening the instrument homepage:

1. Establish a working Ethernet connection (see above) to the sensor.

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 sensor’s IP address, for a factory set sensor it is http://192.168.23.33/. 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 2.10; 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.

2.4.1 Main page

Once the instrument homepage is loaded, the most important information is visible on the main page (figure 2.10). This page shows the measurement values, serial number and the tag of the instrument.

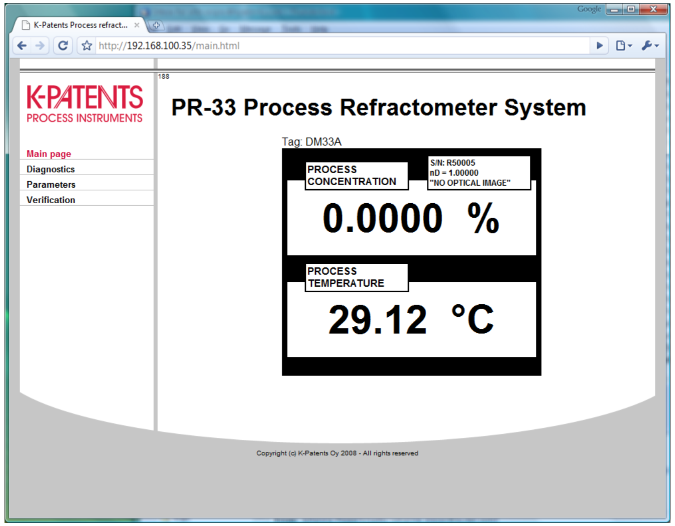


Figure 2.10 Main page (sensor not in process)

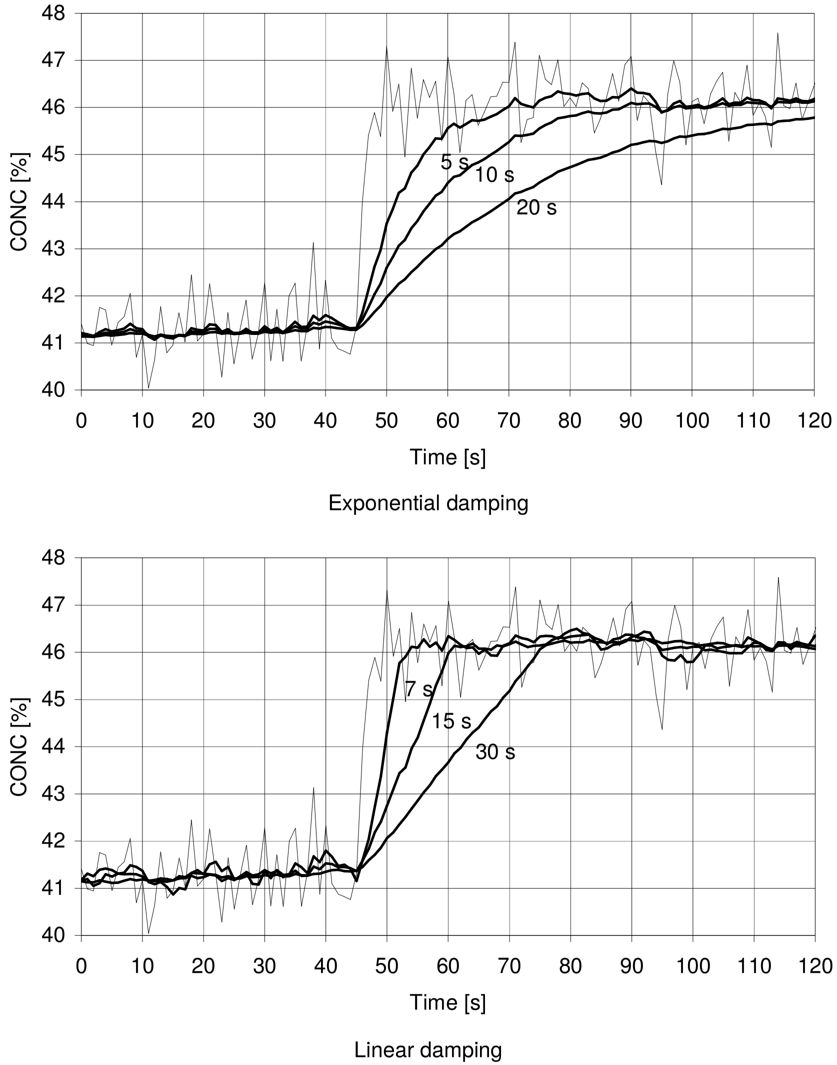


Figure 5.1 Effect of damping time on measurement

5 Configuration and calibration

5.1 Configuring the refractometer

In PR-33, all parameter changes are made with a web browser through the parameters page, see Section 2.4.2.

5.1.1 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).

The PR-33 offers two types of signal damping. **Exponential (standard) damping** works for most processes and is the standard choice for slow and continuous processes. However, if the process has fast step changes, **linear (fast) damping** gives shorter settling time.

The damping time is set separately. What the damping time means in practice, depends on the damping type:
In the *exponential damping*, the damping time is the time it takes for the concentration measurement to reach half of its final value at a step change. For example, if the concentration changes from 50 % to 60 % and damping time is 10 s, it takes 10 seconds for the sensor to display concentration 55 %. A damping time of 5–15 seconds seems to work best in most cases.
In the *linear damping* (fast damping), the output is the average of the signal during damping time. After a step change the signal rises linearly and reaches the final value after the damping time. Figure 5.1 shows how the damping time affects the measurement.

Note: The factory setting for damping in PR-33-S is **5 s linear**. Avoid overdamping, the signal should not be made insensitive.

2.4.2 Parameters

All functional parameters of the instrument can be changed on the Parameters page of the instrument (figure 2.11). New parameters may be typed into the input fields.

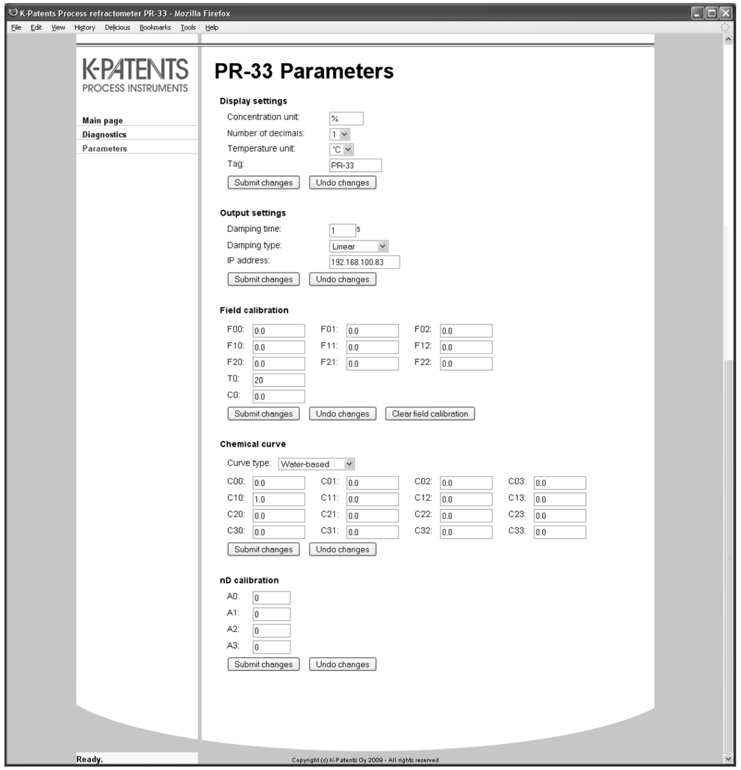


Figure 2.11 Parameter page

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 sensor will no longer exist in the old address.

2.4.3 Diagnostics

On the diagnostics page (figure 2.12) you may see the diagnostic values produced by the sensor. There is also a link to the optical image. The diagnostic values are updated live, but the optical image is only loaded on request.

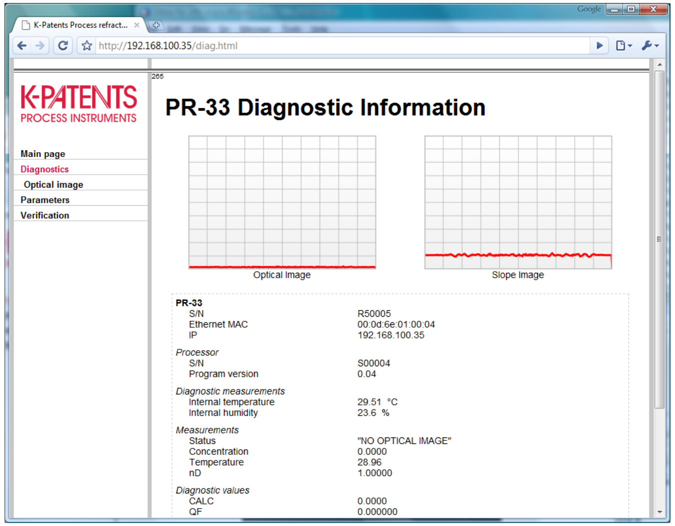


Figure 2.12 Diagnostics page

4 Startup and use

4.1 Startup

4.1.1 Initial check

Connect the sensor to a PoE enabled network, and check that the instrument powers up properly (see section 2.3). Use a web browser to open the instrument homepage and check that the serial number of the instrument corresponds to that on the instrument nameplate. In case you have difficulties connecting to the sensor, please see section 2.3.1.

4.1.2 Calibration check

Wait until normal process conditions occur. The concentration reading is precalibrated at delivery and a copy of the Sensor calibration certificate is shipped with the sensor. If the diagnostic message is NORMAL OPERATION but the concentration reading does not agree with the laboratory results, consult Section 5.2, "Calibrating the concentration measurement".

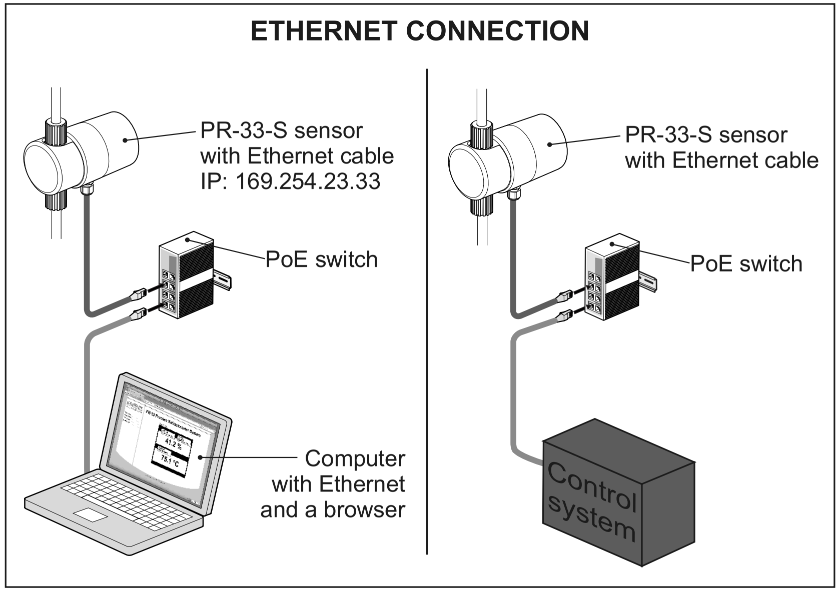
4.2 Viewing sensor status

The basic information on the measurements is shown on the main page of the instrument (section 2.4.1). More information is shown on the Diagnostics page (section 2.4.3).

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 sensor monitors its internal temperature and humidity, which both are available on the Diagnostics page. The internal temperature should not be above 55 °C, and the humidity should be below 30 %.

3.2 Connecting the sensor



3 Inline refractometer sensor

3.1 Mounting the sensor

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

3.1.1 Choosing sensor mounting location

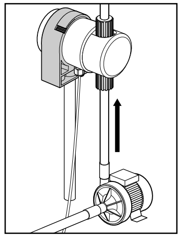
The mounting location needs to be such that sediments or gas bubbles cannot accumulate by the sensor. Good flow velocity is essential in keeping the prism clean.

Important: If the process pipe vibrates, support the pipe. A vibrating pipe might damage the in-line sensor mounted on it.

The sensor 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 sensor head.

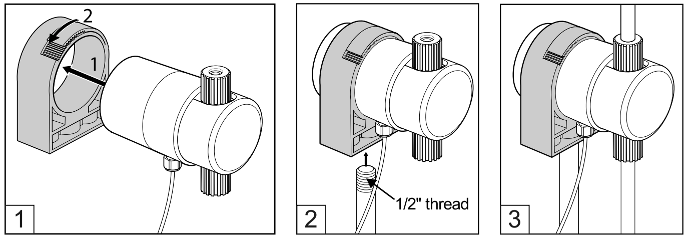
Important: Always mount the sensor so that the interconnecting cable points downwards from the sensor head.

3.1.2 PR-33 mounting guide

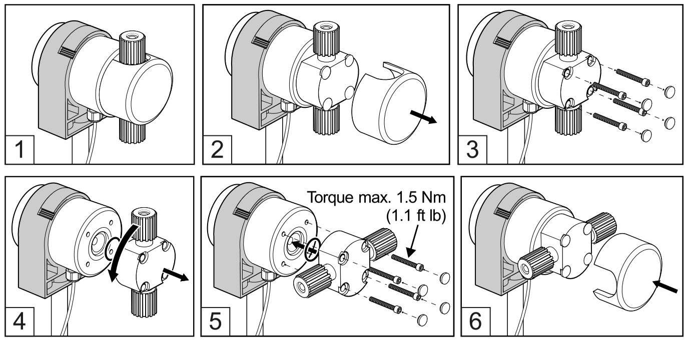


PR-33-S MOUNTING RECOMMENDATION
- SENSOR HORIZONTAL
- CABLE DOWNWARDS
- SENSOR SUPPORT
- HIGH VELOCITY (>1.5 m/s [5 ft/s])
- HIGH TEMPERATURE
- HIGH PRESSURE

SENSOR SUPPORT



CHANGE OF FLOW CELL ORIENTATION



3.1.3 Check list for pipe mounting

Most K-Patents inline refractometer models are mounted in a pipe. K-Patents recommends a minimum flow velocity of 1.5 m/s (5 ft/s). The diameter and form of the pipe and the process temperature all affect the measurement and need to be taken into account.

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.
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 sensor should be conveniently accessible for service.