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sensor technology

Optical pH Sensors

USER MANUAL
OPERATING INSTRUCTIONS

pH

Optical pH Sensors

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1 INTRODUCTION

PyroScience offers fiber-based and contactless optical pH sensors, as well as a number of combined sensors such as sensor vials for simultaneous measurements of temperature, oxygen and pH.

These sensors can be read-out with the following fiber-optic meters from **PyroScience**

- the multi-channel PC-operated **FireSting-PRO** (with **Pyro Workbench** software)
- the compact OEM module **Pico-pH** (with **Pyro Workbench**)
- the underwater **AquapHOx** Loggers and Transmitters (with **Pyro Workbench** software)

All software versions are available for free download from the **PyroScience** website and must be installed on a Windows PC/laptop before connecting the respective meter for the first time. For details on the read-out devices and their software, please see their respective manuals and handling guidelines.

This manual is intended to provide all necessary information on standard application of optical pH sensors from **PyroScience**.

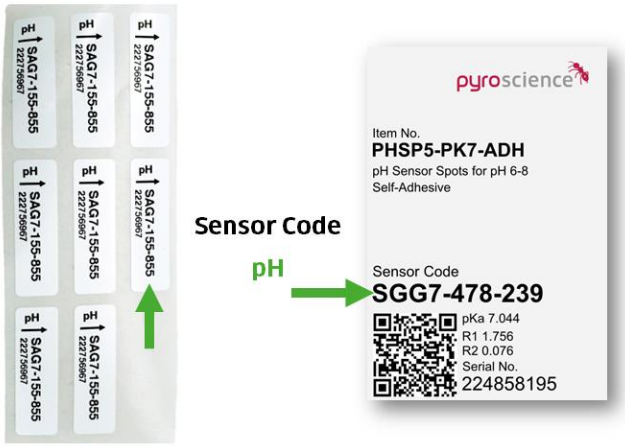
For more information concerning advanced applications, please contact us at info@pyroscience.com.

Your **PyroScience** Team

2 SENSOR SETTINGS

Each optical pH sensor comes with an individual Sensor Code, containing important information on adjustments for optimal sensor performance and pre-calibration of the respective sensor type. Therefore, it is important to enter the Sensor Code of the connected sensor into the Sensor Settings of the Pyro Workbench software. For multi-channel **FireSting-PRO**, the number of the channel tab must correspond with the channel number at the **FireSting-PRO** read-out device.

> **Important:** Enter the correct **Sensor Code** for sensors connected to a channel at a **FireSting-PRO** read-out device. The sensor code can be found on the label attached to the cable (fiber-based sensors) or on the bag of contactless sensors (see example below).



The sensor code contains the following information:

Example Code: **SAE7 -532-205**

SA: Sensor Type. Factory calibration values of the sensor types (PK7, PK8….)

E: LED Intensity of the device

7: Amplification of the measurement signal

532 – 205: Pre-calibration values

2.1 Conditions in the Sample

When entering the sensor settings, the **Conditions in the Sample** during the measurements have to be determined. There are two important parameters to be taken into account and which can be automatically compensated:

- Temperature
- Salinity

2.1.1 Temperature

Several options for **Automatic Temperature Compensation** of optical pH sensors are available:

- External Temperature Sensor (Pt100, temperature port)
- Fixed Temperature (must be entered, kept constant and controlled)
- Optical Temperature sensor connected to a channel connector (its channel number must be selected) of a multi-channel **FireSting-PRO**

If External Temperature Sensor or Optical Temperature Channel is selected, automatic compensation of temperature changes on the respective pH sensor readings is activated. The compensation temperature will be displayed in the corresponding channel row of the main window.

FireSting-PRO: If External Temperature Sensor or Optical Temperature Channel is selected, automatic compensation of temperature changes on the respective pH sensor readings is activated. The compensation temperature will be displayed in the corresponding channel row of the main window.

AquapHOx: The AquapHox devices have a temperature sensor included for automatic temperature compensation. The temperature sensor is factory 2-point calibrated.

Pico-pH: The Pico-pH OEM module does not include an Pt100 temperature sensor. This sensor (Item No. TSUB21-NC) needs to be soldered on the device. Please refer to the Pico-pH manual for more information.

NOTE: The Pt100 temperature sensor may have an offset which needs to be determined manually and calibrated first. To calibrate the Pt100 sensor please see the Appendix.

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2.1.2 Salinity

The optical pH sensors show a cross sensitivity to the ionic strength of the medium. Ionic strength is a function of the concentration and charge of all the ions in a solution and is an important parameter for pH measurements. Theoretically, the ionic strength of a sample can be calculated, but from a practical point of view, other indicators can provide a rough estimate of the ionic strength, such as using the concentration of all compounds or conductivity data.

The sensors are specified for measurements between 20-500 mM ionic strength. Response time and accuracy at lower or higher salinities may differ from the specified value which was determined at 150mM Ionic strength.

For compensation of the effect, the salinity [g/l] must be entered in the sensor settings and during a pH calibration (please note that the ionic strength can differ between the calibration buffer and the medium of the measurements).

There are several general categories of salinity ranges to select in the **Pyro Workbench** software:

Category	Salinity [g/l]	Conductivity [mS/cm]	Ionic Strength [mM]
Wastewater	0.5 - 1.5	1 - 3	10 - 30
Intermediate	1.5 - 5	3 - 10	30 - 100
Physiological	5 - 15	10 - 30	100 - 300
Seawater	15 - 40	30 - 80	300 - 800

For more accurate measurements it is possible to enter a known salinity [g/l] of the sample in the software. For salt solutions based on NaCl the salinity value can be calculated by a simplified approach:

Salinity [g/l] = Conductivity [mS/cm] /2
Salinity [g/l] = Ionic Strength [mM] / 20

For experiments with strongly changing ionic strength, it is recommended to update the settings and perform a new calibration in order to acquire accurate results.

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3 SENSOR CALIBRATION

3.1 General Informations

For single use applications, pre-calibrated pH sensors can be used once without manual calibration ("pre-calibration measurement") in combination with pre-calibration ready **FireSting-PRO** devices (SN>23360000 and labeled devices). Older **FireSting-PRO** meters can be upgraded for pre-calibration pH measurements. Please contact info@pyroscience.com for further information. Pre-calibration measurements only work in combination with the bare optical fiber **SPFIB-BARE** (NOT **SPFIB-LNS**).

Following initial use, regular manual calibration is required to ensure reliable continued operation of the pH sensor.

For maximum accuracy and precision, manual calibration is recommended over the pre-calibration option.

pH calibration must be **repeated periodically**, depending on the **individual application** (e.g. required accuracy, temperature of the sample, lifetime of the sensor, substances in sample). It is advisable to perform a 2-point calibration before every measurement using freshly prepared buffer solutions.

The calibration of optical pH sensor differs from other measurements methods, as the calibration points are NOT in the dynamic range of the sensor. This is due to the function principle.

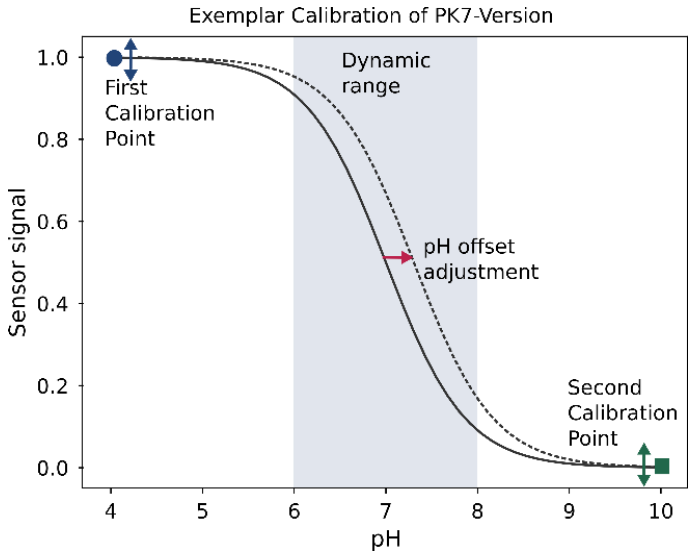
Depending on the applied equipment and requirements, the following calibration modes are possible:

- **Calibration free measurements:** pre-calibrated pH sensors (SN>231450494) enable calibration free measurements in combination with **SPFIB-BARE** (NOT **SPFIB-LNS**) and with pre-calibration ready **FireSting-PRO** devices (SN>23360000 and labeled devices). To achieve higher accuracy and precision a manual calibration is advised.

- **1-point calibration:** Calibration of the completely protonated sensor at highly acidic conditions (pH must be lower than pH 3). This calibration is required for the continued use of the pH sensors, for readout devices which do not support pre-calibrated sensors, and for measurements in combination with **SPFIB-LNS**. Recommended before every measurement.

- **2-point calibration (recommended for maximum accuracy and precision):** Additional calibration of the completely deprotonated sensor at highly basic conditions. Recommended before every measurement. pH has to be higher than pH 10. The 2-point calibration is **required** for the pH Minisensor.

- **pH-offset adjustment (for complex medium):** Adjustment of the turning point of the sensor in highly complex medium (individual sample, see image below). This offset pH has to be in the dynamic range (e.g. between pH 6.5 and 7.5 for a pH 7 sensor).



Please do **NOT** use commercially available buffer solutions and certified reference materials (CRMs, except TRIS buffer solution in synthetic seawater (Dr. A. Dickson)) used for pH electrodes. These buffers (colored and uncolored) contain anti-microbial agents that will affect the sensor performance irreversibly. It is important to only use **PyroScience** buffer capsules or self-made buffers with known pH and ionic strength for calibration (with advice from **PyroScience**).

3.1.1 Temperature

It is crucial to determine exactly the temperature of the pH calibration buffer during the calibration process via one of the following possibilities:

- Manual adjustment of a Fixed Temperature (needs to be determined and kept constant)
- Temperature Compensation with an External (Pt100) Temperature Sensor connected to the temperature port of a **FireSting-PRO** or **Pico-pH**, or

- Optical Temperature Sensor (calibrated) connected to a channel at a multi-channel **FireSting-PRO** (its respective channel number needs to be entered at Optical Temp. Channel).

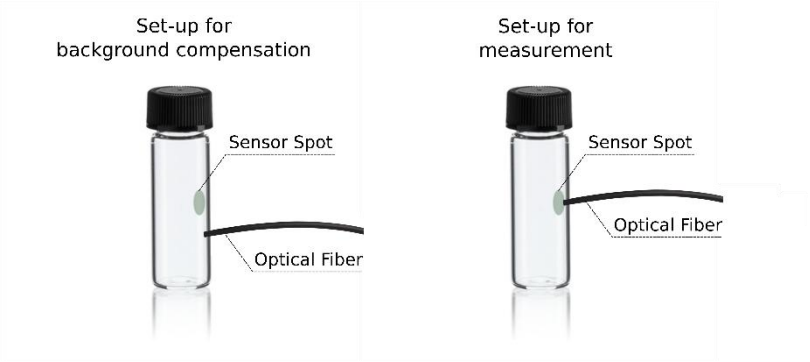
For **AquapHOx**, the integrated temperature sensor can be used.

3.1.2 Background Compensation

For pH Robust Screw Cap Probes, Sensor Vials, Flow-Through Cells and Sensor Spots the **fiber length** needs to be entered into the software for an automatic background compensation. This is recommended and sufficient for most applications.

Sensor Spots and Sensor Vials used in applications with low signal intensities (e.g. thick glass) and for measurements in colored media, the option **MANUAL background compensation** should be used to determine the individual luminescence background of the sample.

For more information, please refer to the **Workbench Software Manual** Chapter 7.



3.2 Preparation of Calibration Standards

For the calibration it is strongly recommended to use **PyroScience pH** buffer capsules with pH 2 (item no. **PHCAL2)** and pH 11 (item no. P**HCAL11**)

- pH 2 buffer are used for the first calibration point
- pH 11 is used for the second calibration point

For this, open the capsule by holding both ends and pulling them apart. Dissolve the powder of the capsule in 100 mL deionized water. Mix well and insure, that the contents are completely dissolved.

> **Note:** Always prepare a fresh buffer for calibration. The buffers are not stabilized against microbial growth.

Alternatively, it is possible to perform a Custom Calibration. Prepare a buffer with known pH value and known ionic strength. For the first calibration point the pH must be <3 and for the second calibration point the pH must be >10. The respective pH value and salinity must be entered in the custom calibration menu in the software.

3.3 First Calibration Point (acidic pH)

Ensure that the correct **Sensor Code** has been entered into the settings and a calibration standard has been prepared correctly.

For the first calibration point, prepare a pH 2 buffer solution based using the **PyroScience** buffer capsules (item no. **PHCAL2**) **or a custom calibration buffer.**

It is recommended to perform the calibration at the same **temperature** of the actual pH measurements.

It is strongly recommended to perform calibration at conditions close to the environmental conditions during measurements. Ensure constant conditions during calibration.

> **IMPORTANT**: If the sensor was previously **stored under dry conditions**, let the sensor condition in deionized water for at least **60 min** to achieve wetting of the sensor membrane. This step is necessary to achieve high accuracy. For the best result, let the sensor soak in deionized water overnight (do not use tap water!). The equilibration can be reduced to 5 minutes for the **pH Minisensor**.

After completing the Settings Wizard for all channels, open the **Calibration Wizard** by clicking the "Cal." button in the respective row ("Ch. 1" to "Ch. 4") of the table in the main window. The software will guide you through the complete calibration procedure.

Insert the pH and temperature sensor into the stirred buffer, and ensure that the sensor tips are completely immersed into the buffer and free of air bubbles. Let the sensor equilibrate and perform the calibration. Wait for a **stable sensor signal** as this is substantial for correct pH measurements (this can take several minutes depending on the temperature and stirring rate). For best result, wait at least for 15 minutes.

With increasing stability of the sensor signal the color will change from red to orange to yellow to green. Although a calibration is possible in the orange state, we strongly recommend to wait until **Take Value** and the frame of the graph have turned to **green**.

After setting the first calibration point, wash the sensor with deionized water and submerse the sensor in the next calibration buffer without letting the sensor dry.

> **IMPORTANT**: The sensor membrane should not dry out between calibration and your measurement.

3.4 Second Calibration Point (basic pH)

It is highly recommended to perform a 2-point calibration before every measurement. For pH Minisensor it is necessary to perform a 2-point calibration.

For the second calibration point, prepare a pH 11 solution based on the **PyroScience buffer capsule (item no. PHCAL11) or a custom calibration buffer**.

Insert the pH and temperature sensor into the stirred buffer, and ensure that the sensor tips are completely immersed in the buffer and free of air bubbles. Let the sensor equilibrate (15 minutes for best result) and perform the calibration.

Wait for a **stable sensor signal** as this is substantial for correct pH measurements (this can take several minutes depending on the temperature and stirring rate).

3.5 pH Offset Adjustment (Advanced Applications)

This will perform a pH offset adjustment to a buffer with exactly known pH value. The pH of the solution has to be in the dynamic range of your sensor version (e.g. between pH 6.5 – 7.5 for PK7 sensors). This can be used for measurements in highly complex

media (e.g. cell culture media) or for seawater measurements using a suitable reference pH value (spectrophotometric pH measurement). Please contact **PyroScience** for support.

To undo the pH offset, please click on **Delete calibrations** in the calibration wizard. This will delete all current calibration values and set the sensor back to factory calibration. A 2-point calibration has to be performed afterwards to start a measurement.

3.6 Common Warnings during Calibration

During the calibration various errors can occur, resulting in different warnings.

3.6.1 "Signal Intensity too low, refer to the manual"

The Sensor Signal Intensity can be too low for several reasons:

1. The end of the sensor lifetime is reached and the sensor needs to be replaced.
2. The sensor is connected to the wrong channel at the multi-channel **FireSting-PRO**
3. In case of sensor spots: the positioning of the optical fiber on the sensor spot is not correct.
4. The vessel wall is too thick in the case of sensor spots.

In this case, please try to increase the LED intensity as maybe the vessel wall is too thick or the sensor is altered to a high extend.

To do this, go back to the **Settings** and increase the LED Intensity.

A higher LED intensity leads to a higher sensor signal. If the warning still shows up after setting the LED intensity up, please increase it further until the calibration is possible.

3.6.2 "Warning: Sensor signal out of range"

The reason for this can be:

1. The end of the sensor lifetime is reached and the sensor or sensor screw cap needs to be replaced.
2. The calibration buffer does not exhibit the correct pH value.
3. The pH of the sample is out of the dynamic range of the sensor.

Be sure that you use the correct pH buffer. The allowed pH buffers are: pH <3 for the first calibration point, pH >10 for the second calibration point, pH of the pKa value of the sensor for offset adjustment (pH 7 for a PK7 sensor, pH 8 for a PK8 sensor).

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3.6.3 "Warning: Wait for steady state"

The reason for this can be:

1. The sensor is not equilibrated yet. Wait for a few minutes longer.
2. The temperature of the sample is changing.

3.6.4 "Warning: Bad temperature measurement"

The reason for this can be:

1. No temperature sensor is connected
2. In case of optical temperature spots: The fiber is not located at the sensor spot anymore.

3.7 Advanced Calibration of Sensor Spots

If sensor calibration is not possible due to a too large vessel for the pH buffer to reach the spot, it is possible to use a smaller vessel with a second spot from the same product batch for calibration. Use the identical optical fiber and the same optical channel from the **FireSting-PRO** as your measurement will be performed. It is possible that the accuracy of the measurement will be influenced due to this calibration method.

4 STERILIZATION, CLEANING AND STORAGE

4.1 Cross Sensitivities

Do not use any organic solvents, surfactant solutions or antimicrobial agents (which can be a compound commercial calibration buffers used for pH electrode). The sensor may have cross-sensitivity to substances in your sample. The sensors should not be kept in solutions with pH<2 or pH>11 for long time. Please note that chlorinated and fluorinated tap water can interfere with the sensors. Please contact us in doubt as irreversible damage of the sensor can occur with some compounds (e.g. surfactants).

4.2 Sterilization

Ethylene Oxid: **PyroScience** optical pH sensors can be sterilized with Ethylene Oxid (EtO or EO). After sterilization a recalibration of the sensors is required. Further details are available on request.

2% Glutaraldehyde: For disinfection, 2% Glutaraldehyde can be used. After disinfection a recalibration of the sensors is required.

Autoclave sterilization (with restrictions): Non-sterilized sensor spots, screw caps (without fiber and packaging) and sensor vials (without lid) can be autoclaved once for 20 minutes at 121°C in the gas phase (Caution: Autoclaving in aqueous solution will damage the sensor irreversibly). Autoclaving the pH sensors leads to premature aging of the pH sensors and reduces the sensor lifetime. A recalibration is required after autoclaving. PHCAPs, PHFTC-MF and pH Minisensor cannot be autoclaved. Further details are available on request.

Disclaimer:

PyroScience optical pH sensors cannot be sterilized using beta or gamma radiation.

Do not use bleach, hydrogen peroxide, ethanol, acetone or any solvent for sterilization or disinfection.

Please note that we offer a variation of pre-sterilized pH sensor products.

Re-sterilisation of pre-sterilized products is not possible.

4.3 Cleaning and Storage

After a measurement, the pH sensor should be rinsed carefully with deionized water and let dry. The sensor has to be stored in a dry and dark place at room temperature. For all sensors and fibers, put the black caps on the plug of the fiber to prevent that light is entering the fiber possibly causing photo-bleaching of the indicator. Storage at high humidity or in sunlight will destroy the sensor over time.

> Store the sensor in a **dry, dark** and secure place at room temperature.

5 RELATED DOCUMENTS

Related documents for more detailed instructions on fiber-optic read-out devices, software and optical sensors are available:

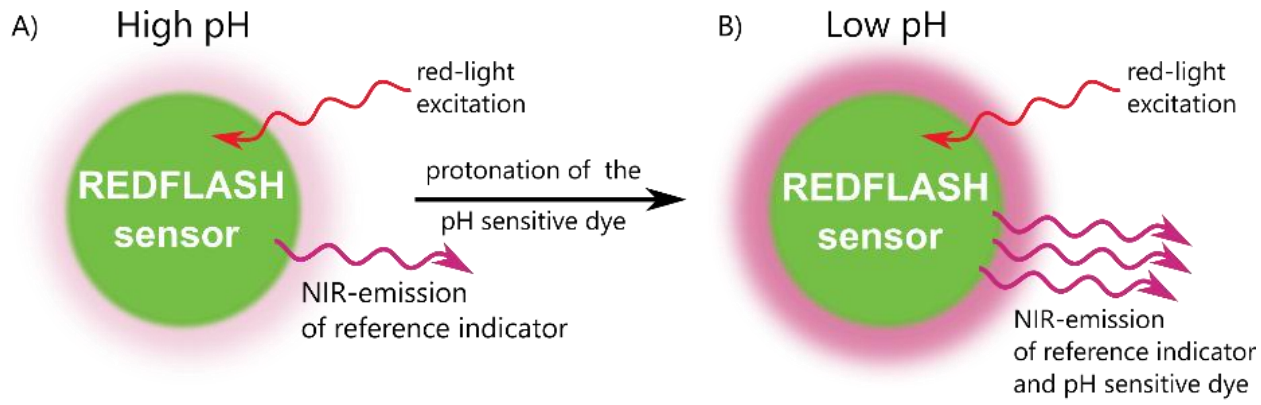
- manual for logger software "**Pyro Workbench**" (Windows)
- manual for multi-analyte meter **FireSting-PRO**
- manual for the **AquapHOx** Loggers or Transmitters
- manual for the OEM module **Pico-pH(-SUB)**
- manual for optical temperature sensors
- manual for optical oxygen sensors

6 APPENDIX

6.1 pH Measuring Principle

The optical pH sensor is based on the successful **PyroScience REDFLASH technology**. The sensor consists of a pH insensitive reference indicator and a pH sensitive luminescent dye. Both are excited with red-light (more precisely: orange-red at a wavelength of 610-630 nm) and show bright luminescence in the near infrared (NIR, 760-790 nm).

If the pH indicator is de-pronated at high pH, its fluorescence is quenched and only the NIR emission of the reference indicator is measured. If the pH gets more acidic, the pH indicator is protonated and emits bright NIR luminescence and the emission of both indicators is detected.



Principle: red light excited REDFLASH sensor shows luminescence in the near infrared (NIR). The REDFLASH sensor consists of a pH insensitive reference indicator and a pH sensitive dye.**A)** low NIR emission from just the reference indicator and **B)** high NIR emission from the protonated dye and the reference indicator.

The **REDFLASH technology** impresses by its high accuracy, high reliability and low power consumption.

The red-light excitation of the **REDFLASH indicators** significantly reduces interferences caused by autofluorescence and reduces background fluorescence from biological samples / media.

The measuring principle is based on a sinusoidally modulated red excitation light. This results in a phase-shifted sinusoidally modulated emission in the NIR. The **PyroScience** read-out device measures this phase shift, which is then calculated into pH.

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6.2 Explanation of the Sensor Code

The pH sensors are delivered with an attached sensor code which must be entered in the Settings (refer to chapter 2). The following chapter gives a short explanation of the sensor code.

Example Code: SGG7-505-638

Sensor Type

pH range

LED Intensity

Amplification

Pre-Calibration pKa

Pre-Calibration R1 (acid calibration point)

Pre-Calibration R2 (basic calibration point)

Sensor Type

F	pH Sensor Cap
N	pH Fiber Sensor
S	pH Sensor Spot
X	pH Screw Caps and pH Flow Through Cells

pH range

G	pH 6-8 (pK7)
H	pH 7-9 (pK8)
I	pH 7-9 on total scale (pK8T)
J	pH 4-6 (pK5)
K	pH 5-7 (pK6)
L	pH5.5-7.5 (pK6.5)

LED Intensity

A	10%	E	40%
B	15%	F	60%
C	20%	G	80%
D	30%	H	100%

Amplification

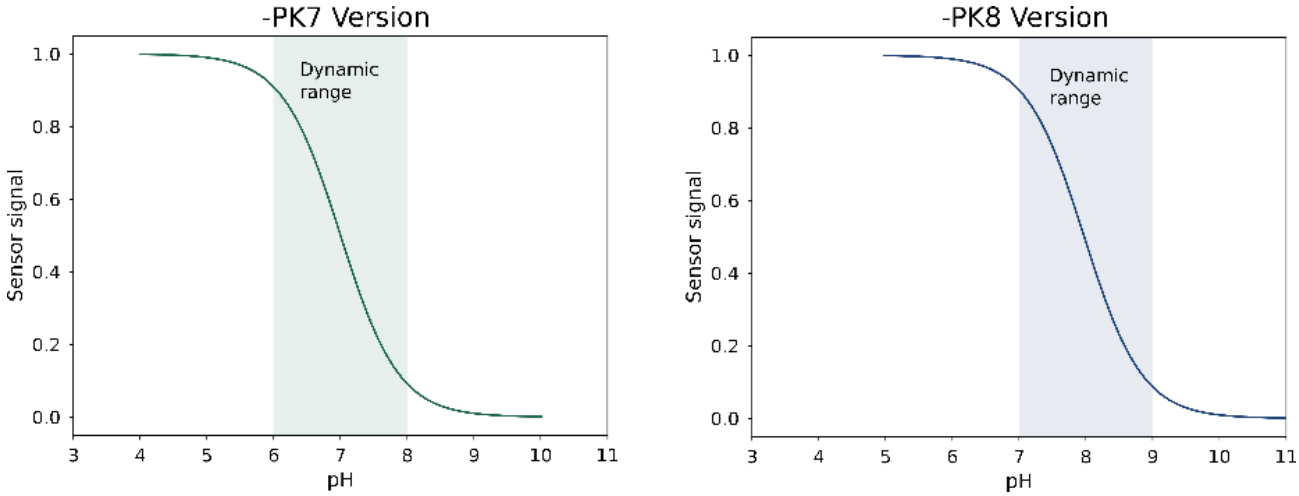
4	40x
5	80x
6	200x
7	400x

6.3 Explanation of the Different pH Ranges

Optical pH sensors are sensitive to a pH range of 2-3 pH units. Sensors are offered for 5 different ranges for pH measurements.

pH range (optimum)	pH range (maximum)	Item No.
4.0-6.0	3.5-6.5	**…-PK5**
5.0-7.0	4.5-7.5	**…-PK6**
5.5-7.5	5.0-8.0	**…-PK6.5**
6.0-8.0	5.5-8.5	**…-PK7**
7.0-9.0	6.5-9.5	**…-PK8**
7.0-9.0 on pH total scale for seawater measurements	6.5-9.5 on pH total scale for seawater measurements	**…-PK8T**

Depending on the application it is important to choose the right version.



Calibration of both versions is performed at low pH values (completely protonated indicator dye) and at high pH values (completely de-protonated indicator dye). For this reason, it is possible to use the same pH buffer capsules (**PHCAL2** and **PHCAL11**) for both pH sensor versions.

6.4 Available sensors and read-out devices

Sensor Type	Compatible read-out devices						
	FireSting-PRO	OEM-Module PICO-PH	PICO-PH-SUB	APHOX-LX	APHOX-TX	APHOX-L-PH	APHOX-T-PH
PHROBSC-PKx	✓						
PHROBSC-PKx-SUB			✓	✓	✓	✓	✓
PHCAP-PKx-SUB			✓	✓	✓	✓	✓
PHSP5-PKx	✓	✓	✓	✓	✓	✓	✓
PHSP5-PKx-ADH	✓	✓	✓	✓	✓	✓	✓
PHFLOW- PKx	✓	✓					
PHTOVIAL20-PKx	✓	✓					
PHTVIAL20-PKx	✓	✓					
PHF500-PKx	✓						
PHIMP500-PKx	✓						

6.5 Pt100 Temperature Sensor Calibration

For precise absolute temperature readings, an optional **1-point calibration of the external temperature sensor** is recommended (except for **AquapHOx** devices).

For this, check the reading of the external temperature Pt100 probe periodically in stirred water/water bath/incubator of known temperature at steady state. It is also possible to prepare a water-ice-mixture giving 0°C, where at least 50 mm of the Pt100 temperature probe tip is submerged.

In the **Pyro Workbench** software please click on the calibrate button "Cal." to perform the Pt100 calibration.

IMPORTANT: After calibration of the Pt100, a new optical sensor calibration must be performed.

7 WARNINGS AND SAFETY GUIDELINES

Before using PyroScience pH sensors, carefully read the instructions and user manuals for the respective PyroScience read-out device. The manuals are available for download on www.pyroscience.com

Prevent mechanical stress (e.g. scratching) to the sensing surface at the tip of the temperature sensor! Avoid strong bending of the fiber-optic cables and the pH Minisensor. They might break!

Ensure that the complete sensing surface at the tip is always covered by the sample and is free of air bubbles, and that liquid samples are stirred.

Calibration and application of the temperature sensors is on the user's authority, as well as data acquisition, treatment and publication!

PyroScience **pH sensors and read-out devices are not intended for medical or military purposes or any other safety-critical applications.** They must **not** be used for applications in humans; **not** for in vivo examination on humans, not for human-diagnostic or therapeutic purposes. The sensors **must not** be brought in direct contact with foods intended for consumption by humans.

The sensors must be used in the laboratory by qualified personnel only, following the user instructions and the safety guidelines of the manual, as well as the appropriate laws and guidelines for safety in the laboratory!

Keep the PyroScience pH sensors and read-out devices out of reach of children! Store the temperature sensors in a secure, dry and dark place at room temperature.

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