BAUER KOMPRESSOREN

Quality. Our DNA

BAUER B-DETECTION THE NEXT GENERATION

SENSOR CALIBRATION

SPORTS & SAFETY

75 1946 – 2021 BAUER KOMPRESSOREN

BASICS

SENSOR BASIC KNOWLEDGE: BASIC PRINCIPLE AND AGING

Gas sensors output a measurement signal (e.g. voltage) depending on the gas concentration. The measurement signal output at a given gas concentration changes due to various internal and external influences on the sensors. These include, for example, sensor aging and shocks.

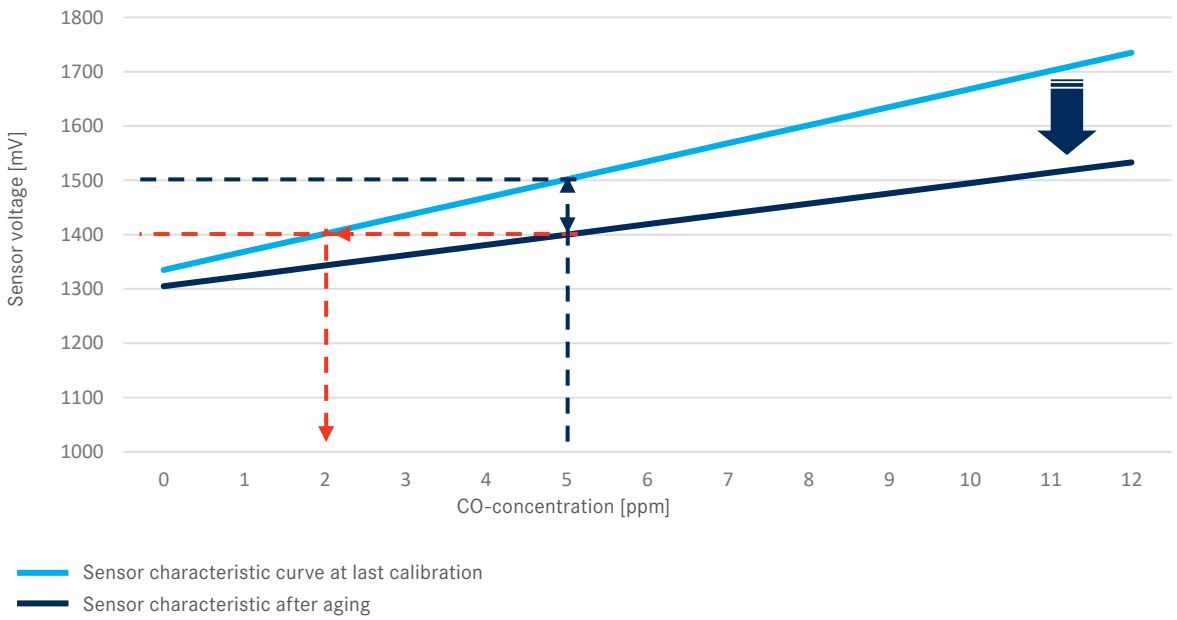
The assignment of the sensor voltage to the measured signal is done by an adjustment. Due to sensor changes, this assignment is no longer correct after a while. Accordingly, this requires regular checking and adjustment.

CO sensor example: At the time of the last calibration, a CO sensor output a voltage of about 1500 mV at 5 ppm CO. After sensor aging, the CO sensor only outputs a voltage of around 1400 mV. If the measuring device compares this value with the sensor characteristic curve of the last adjustment, a lower CO value is incorrectly output, in the case shown about 2 ppm CO.

EXPLANATION OF TERMS

- The term **calibration** describes the adjustment of a measurement against a known relationship of measured value and measurement signal. The results of a calibration allow statements about the measurement accuracy. Commonly, the term calibration is often used for an alignment of the sensor characteristic curve. However, this correctly falls under the term adjustment.
- **Adjustment** describes the adaptation of the sensor characteristic curve based on the results of a calibration. In this process, measurement deviations are rectified so that measured values correspond as closely as possible to the actual conditions.

CO-SENSOR OUTPUT UND SENSOR AGING



THE EXAMPLES IN THIS FLYER REFLECT EXTREME CHANGE AND ARE FOR ILLUSTRATIVE PURPOSES ONLY. IN REAL BEHAVIOR, CHANGES ARE LESS PRONOUNCED.

BUMP TEST

In a bump test, a gas with a precisely defined composition is measured in the gas measurement system and it is checked whether the correlation between the gas concentration and the resulting voltage value lies within a specified tolerance range.

Bump tests are performed for a variety of reasons:

- Validation of an adjustment that has just been made to rule out errors
- Checking the measurement accuracy during operation - independent of an adjustment

One point on the sensor characteristic curve is tested as an example, which serves as an indicator for the sensor accuracy. The calibration gas is selected according to the respective application or corresponding circumstances.

- For threshold value monitoring according to the standard EN 12021 (breathing air): Bump test at the threshold values according to the standard
- For all other applications: Bump test at a point far enough from the adjustment point so that deviations can be reliably detected.

With the B-DETECTION PLUS gas measurement systems, a bump test can be carried out either manually or automatically.

MANUAL BUMP TEST

By manually connecting a calibration gas cylinder to the gas inlet of the B-DETECTION PLUS gas measurement system, calibration gas will flow through its sensors. After a reaction phase of around three minutes, the measured values can be compared with the data of the known gas concentrations on the calibration gas cylinder.

AUTOMATIC BUMP TEST

With the automatic bump test, the new B-DETECTION PLUS gas measurement systems (available from production status F02) optionally determine independently and regularly the deviations of the sensor characteristic curve stored in the system compared to the actual sensor behavior. In the default setting, the bump tests are carried out weekly.

The bump test results are intuitively displayed using colored dots:

- Green: Small deviations, within specified tolerance
- Yellow: Deviations exceed warning tolerance
- Red: Deviations exceed the alarm limit

The respective threshold values for the tolerance ranges are to be determined by the users themselves and weighed according to the application. The threshold values for the tolerance ranges preset by BAUER are only recommendations.

PRESET WARNING AND ALARM LIMITS FOR THE AUTOMATIC BUMP TEST

Gas components	Warning tolerance	Alarm tolerance	Target value (calibration gas according to EN 12021)
CO	± 0.8 ppm	± 1.2 ppm	5.0 ppm
CO_2	± 40.0 ppm	± 80.0 ppm	500.0 ppm
O_2	± 0.8 %	± 1.0 %	21.0 %
VOC	± 85 ppb	± 125 ppb	214 ppb[1]

1 Corresponds to 0.5 mg/m³

If the result of a bump test is outside the tolerance range, it is recommended to adjust the sensor characteristics so that the purge valve opens and the compressor shuts down at the correct threshold values.

SENSOR ADJUSTMENT

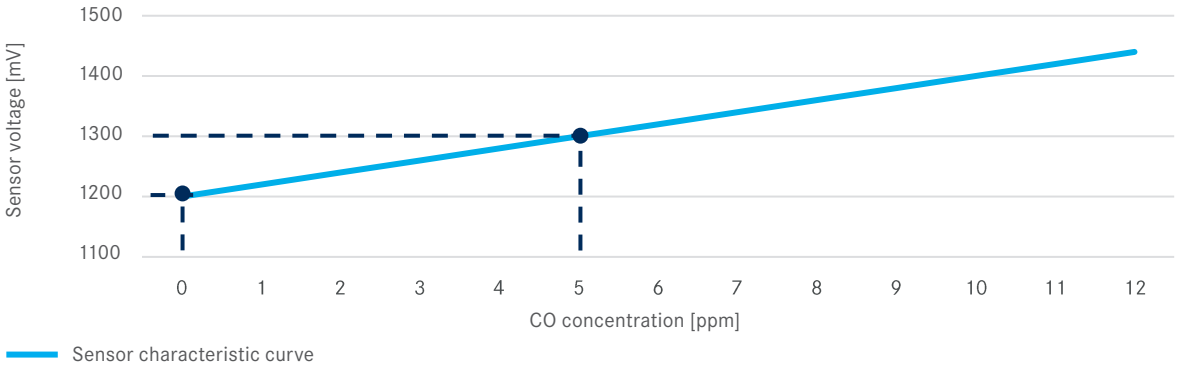
Two known points are required to define a sensor characteristic curve. Calibration gases contain precisely defined gas concentrations for this purpose. To obtain a point on the sensor characteristic curve, a known gas concentration is assigned the corresponding voltage signal output.

CO sensor two-point adjustment example

- With calibration gas C[1] (low-gas, 0 ppm CO), the CO sensor outputs a voltage of 1200 mV. This corresponds to the first (lower) point of the sensor characteristic curve.
- With calibration gas B[1] (high-gas, 5 ppm CO), the CO sensor outputs a voltage of 1300 mV. This corresponds to the second (upper) point of the sensor characteristic curve.

1 See calibration gases section

SENSOR CHARACTERISTIC CURVE WITH CALIBRATION POINTS



NEED FOR ADJUSTMENT

Adjustments to the sensor characteristics are necessary or recommended in a number of different cases.

- Measurements are out of tolerance. (Result of manual or automatic bump test)
- It is recommended to carry out a two-point adjustment of the sensor characteristic curves once a year.
- Additionally, adjustments are recommended if the operating conditions change permanently and significantly.
  Example: If the ambient temperature changes permanently from 15°C to 35°C, the sensor should be adjusted at 35°C in order to obtain maximum sensor accuracy.

CALIBRATION AND ADJUSTMENT METHODS

For the new B-DETECTION PLUS gas measurement systems, there are two methods for adjusting the sensor characteristic curve, which can be used in different applications.

NEW! Adjustment through single-point calibration

Single-point calibrations allows for a cheaper, faster, and easier adjustment process. As the name of the method suggests, only one of the two points required for the sensor characteristic curve is calibrated. This point is chosen so that it exactly reflects the threshold values of the **EN 12021** (breathing air) standard. As the second point for the definition of the sensor characteristic curve, the lower point of the last adjustment is used. The sensor curve is then adjusted using these two points.

Since the accuracy of the measured values with this adjustment method is only improved at the threshold values according to the breathing air standard, it is only suitable for **threshold monitoring** according to the standard **EN 12021** (breathing air)! For all other applications (including threshold monitoring for nitrox applications), the adjustment through two-point calibration must be selected.

The single-point calibration does not completely replace the two-point calibration, but solely allows an improvement of the accuracy of the threshold values of the **EN 12021** (breathing air) standard. Since only one of the two points is calibrated, the slope of the adjusted characteristic curve does not correspond to the actual sensor behaviour. Since one of the two points is not changed, mathematically a very extreme or even negative slope could occur. To prevent this, a tolerance range was introduced, which leads to a termination of the adjustment in case of extreme deviations. For this reason, regular two-point calibration with adjustment of the sensor characteristic curve (e.g. during the annual system check by a BAUER service technician) is still strongly recommended.

EVERY B-DETECTION PLUS GAS MEASUREMENT SYSTEM IS FACTORY-ADJUSTED USING A TWO-POINT CALIBRATION

Summary of the single-point calibration with adjustment of the sensor characteristic curve:

- Only one gas is required.
- The adjustment through a single-point calibration increases the accuracy only at the threshold values according to EN 12021 (breathing air).
- For the following reasons, it is highly recommended that every operator orders a calibration gas according to EN 12021 (breathing air) for every B-DETECTION PLUS gas measurement system:
  - For verifying measurement results. For example, in the case of display values that are unusual or difficult to explain.
  - Possibility of readjusting the threshold values according to EN 12021 (breathing air) without requiring BAUER service.
  - To potentially prove any discrepancies between different measuring devices.
- If required, the single-point adjustment can always be carried out by expert personnel at the unit operator’s premises.

Adjustment through two-point calibration

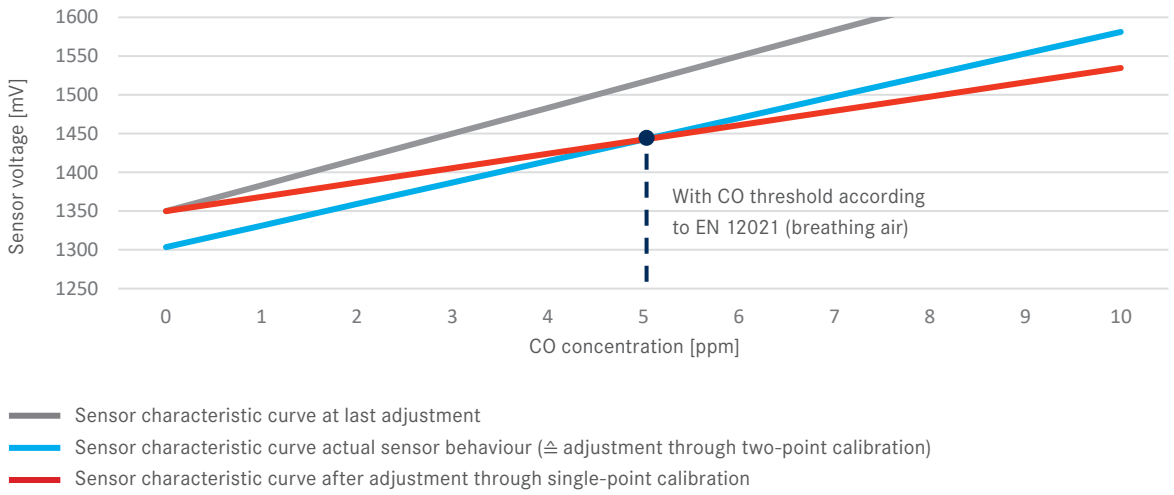
The two-point calibration is the standard option of the adjustment methods. It is suitable for **all applications** and increases the accuracy over the **entire sensor measuring range.**

With this adjustment method, both the lower calibration point and the upper calibration point are determined using gases with known gas concentrations.

Summary of the two-point calibration with adjustment of the sensor characteristic curve:

- Three gases are required to calibrate all sensors.
- The adjustment through a two-point calibration increases the accuracy over the entire measuring range.
- To be performed as required, but at least once a year or at an annual system check.
- Must be selected for all applications that **do not** comply with threshold monitoring according to EN 12021 (breathing air). These include nitrox applications and applications requiring accurate measurements over the entire measuring range.
- This adjustment method is usually performed by BAUER service technicians.

COMPARISON OF ADJUSTMENT METHODS



B-DETECTION PLUS SENSOR ADJUSTMENT

B-DETECTION PLUS gas sensors can be adjusted in two different ways.

Manual calibration with adjustment

With manual sensor adjustment, each sensor is adjusted individually. This expert mode also enables settings that go deeper into the system.

- Usually used by BAUER service technicians when required.

NEW! Semi-automatic calibration with adjustment

The semi-automatic calibration with adjustment is an aid that carries out most of the actions automatically. Flow monitoring ensures that sufficient gas flows through the sensors during the process. If desired, all sensors or

only selected sensors can be adjusted. The selected sensors are calibrated one after the other and the sensor characteristic curve is then automatically adjusted.

- Can usually be carried out by qualified personnel at the unit operator's premises.
- Saves up to 56% calibration gas (approx. 15 liters) compared to manual expert adjustment if all four sensors (CO, CO_2 , O_2 , VOC) are adjusted at once.
- Available for both adjustment methods.

CALIBRATION GASES

The calibration gases are gases that contain precisely defined gas concentrations. The exact concentrations are also determined in the laboratory and noted on the respective gas cylinders. They can be used both for regular sensor checking and for sensor adjustment. However, it must be noted that the gases intended for the correct area of application are selected with the appropriate gas concentrations.

The single-point calibration is carried out with a high-gas for all sensors (CO, CO_2 , VOC and O_2), which precisely reflects the gas concentrations according to the standard EN 12021 (breathing air).

In the two-point calibration, two low-gases are required in addition to the high-gas, since the CO, CO_2 and VOC sensors are to be adjusted at an oxygen concentration that corresponds to the general ambient condition. If the oxygen concentration deviates strongly from the usual ambient air concentration, the accuracies of the CO, CO_2 and VOC sensors will be negatively influenced.

OVERVIEW OF CALIBRATION GASES B-DETECTION PLUS (F02)

Calibration gases	CO	CO_2	VOC	O_2	Two-point calibration	Single-point calibration	Bump test suitability
	ppm	ppm	ppb	(%)			
A: High – CO, CO_2, O_2, VOC	6	550	500	18	(x)[1]		x
B: High – CO, CO_2, O_2, VOC (According to EN 12021)	5	500	214[2]	21	x	x	x
C: Low – CO, CO_2, VOC	0	0	0	21	x		
D: Low – O_2	0	0	0	5	x		

1 For devices with production status F01, calibration gas A is used to calibrate the upper point of the VOC sensor.

2 Corresponds to 0.5 mg/m³.

A calibration gas cylinder in accordance with EN 12021 (breathing air) is strongly recommended for each B-DETECTION PLUS gas measurement system in order to enable bump tests and the adjustment of sensor characteristics promptly on site if necessary.

SELECTION OF THE APPROPRIATE CALIBRATION GASES

If the gas measurement system is used to **monitor the entire measuring range** or for **nitrox applications** (or other applications that do not explicitly monitor the threshold values of the standard EN12021 (breathing air)), the sensors must deliver precise measurement results over the **entire measuring range.** In this case, calibration gas A should be selected for bump tests. With this gas, the correct slope of the sensor characteristics can be validated.

Monitoring of the entire measuring range (and nitrox applications):

› Bump tests: Calibration Gas A or B
› Adjusting the sensor characteristics: Calibration gases B, C and D
› Validation of sensor adjustments: Calibration gas A

If a gas measurement system is used to **monitor threshold values** according to the standard EN 12021 (breathing air), it is sufficient to only adjust the sensor at the threshold value. Since this point is particularly relevant when monitoring the breathing air threshold values, this point must also be checked during bump tests. For this purpose, the calibration gas B according to EN 12021 (breathing air) contains the gas concentrations, which are based **exactly** on the **threshold values of the standard EN 12021** (breathing air).

Monitoring of the threshold values according to the standard EN 12021 (breathing air)

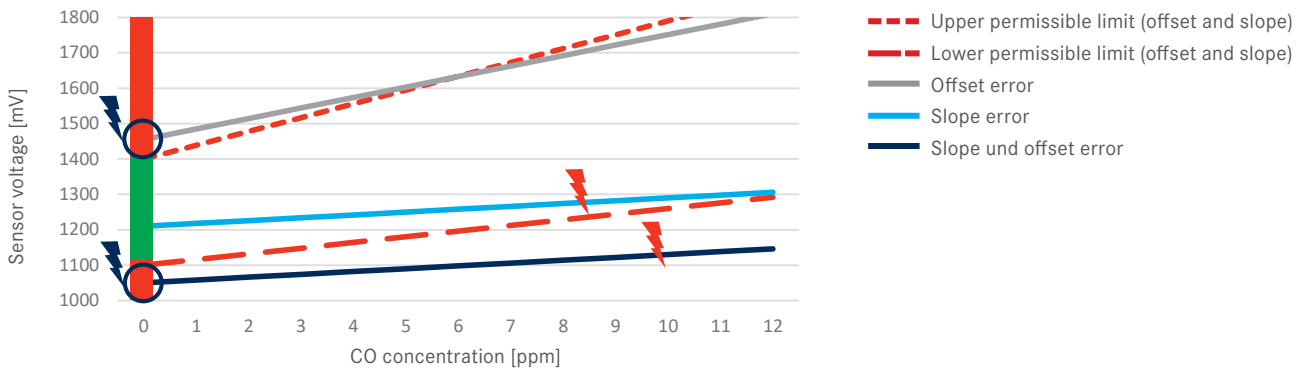
› Bump tests: Calibration gas B
› Adjusting the sensor characteristics: Calibration gas B (additionally C and D if required)
› Validation of sensor adjustments: Calibration gas B

IT IS RECOMMENDED TO PERFORM A BUMP TEST AFTER EACH SENSOR ADJUSTMENT TO VALIDATE A CORRECT CALCULATION OF THE SENSOR CHARACTERISTIC CURVE IN THE SYSTEM.

POSSIBLE ERROR MESSAGES

When adjusting sensors, certain limits of the sensor characteristics must be complied with for an adjustment to be successful. If these limits are not complied with, an adjustment cannot be completed.

ADJUSTMENT LIMITS AND ERRORS

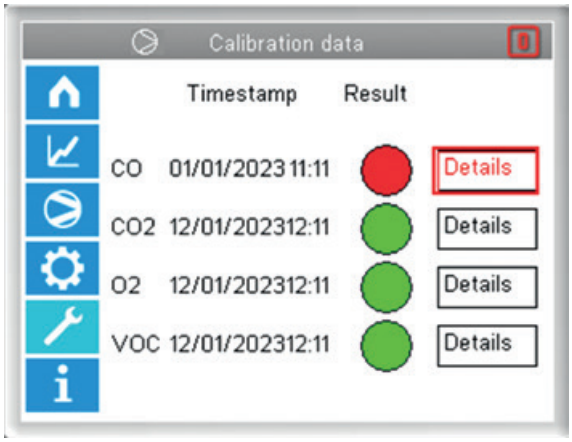


SLOPE ERROR

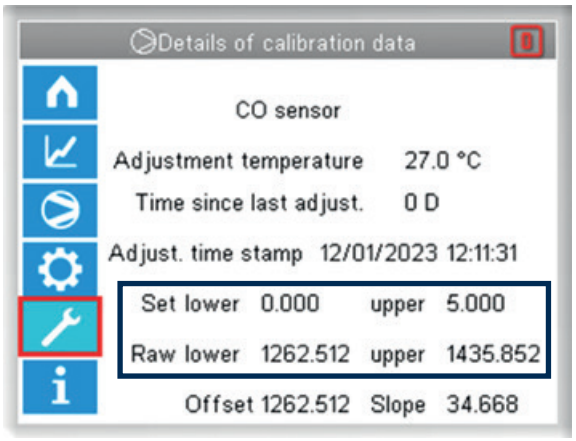
The slope error means that the slope of the adjusted characteristic curve is too steep or too flat. This can happen, for example, if the sensor‘s sensitivity is too low due to aging. Additionally, monitoring the slope of the sensor characteristic curve prevents the use of an incorrect calibration gas with a strongly deviating gas concentration.

OFFSET ERROR

If the measured value (e.g. sensor voltage) at the lower end of the measuring range (0 ppm/0 ppb/0% gas concentration) is outside the permissible range, the offset error is output.



CO sensor calibration error



CO sensor calibration data

WHETHER AN ERROR IS A SLOPE OR OFFSET ERROR IS ONLY DISPLAYED DURING MANUAL EXPERT ADJUSTMENT.

THE „SET“ & „RAW“ VALUES OF THE SENSOR CALIBRATION DATA (HIGHLIGHTED IN THE BLUE BOX) REPRESENT THE LAST CALIBRATION. THE OTHER INFORMATION DERIVES FROM THE LAST SENSOR ADJUSTMENT.

POSSIBLE CAUSES FOR SLOPE AND/OR OFFSET ERRORS

- Sensor aging
  - As the sensor ages, its sensitivity decreases.
- Impurities or leaks in the gas measurement system that distort the calibration result.
- Further influencing conditions during the adjustment:
  - Temperature, flow rate, gas composition, etc.

SOLUTION APPROACHES

There are a number of different approaches to rectifying adjustment errors that can help. The solution approaches for slope and offset error are identical. For some of the solution approaches, a distinction can be made between the locations of occurence:

1) Single-point adjustment
2) Two-point adjustment

1)	2)	Solutions
x	x	Check whether the correct calibration gas has been used
x	x	Check whether the gas concentrations stored in the controller match the gas concentrations specified on the calibration gas cylinder.
x	x	Especially in case of VOC sensor errors: Check the calibration equipment for contamination. › Hoses › Pressure reducer › Particle filter › Gas paths in sensor box
x	x	Purge the B-DETECTION PLUS gas measurement system with non-contaminated gas until the values no longer change continuously.
x	x	Repeat the sensor adjustment.
x		If the error occurs repeatedly: Perform a two-point adjustment.
	x	After unsuccessful troubleshooting measures and repeated adjustment: › For CO and O_2 sensors: Since these are electrochemical sensors that wear out with use, replace the affected sensors if necessary. › For CO_2 and VOC sensors: Contact Customer Support and provide the raw values of the sensor calibration to find the cause. If necessary, replace the affected sensors.

TIPS AND HINTS

There are a few tips and hints for the successful use of the B-DETECTION PLUS gas measurement system:

I) Tips and hints for the bump test
II) Tips and hints for adjusting the sensor characteristics

I)	II)	Tips and hints
x	x	Before and during bump tests and adjustment of the sensor characteristics, make sure not to touch connections, pressure reducers, hoses, etc. with greasy or creamy hands. This particularly affects the sensitive VOC measurement.
x	x	Switch on the gas measurement device at least 30 minutes before bump tests and adjustments to the sensor characteristics. › For optimal accuracy, bump tests and especially the adjustment of the sensor › The sensors are affected by temperature. › The gas measurement system heats up during operation for up to two hours after being switched on. › Sensors need some time to stabilize after being switched on.
x		The option automatic bump test can be started no earlier than 30 minutes after the system has started or the auto-standby mode has ended.
x	x	In the case of manual bump tests or manual adjustments of the sensor characteristics (expert mode): injection time per gas at least 3 minutes.
x	x	Use the same flow rate for all gases when feeding.
x	x	Deactivate auto-standby mode before bump tests and adjustment of the sensor characteristics and reactivate it afterwards if required. If no flow is detected during the warm-up phase, the B-DETECTION PLUS gas measurement system switches off. The default setting for the auto-standby timer is 45 minutes.
x		The preset tolerances for automatic bump tests are only recommendations and can be adjusted as required depending on the application.

Case with calibration gases

ARE YOU INTERESTED IN OUR PRODUCTS?

CONTACT US – WE ARE HAPPY TO PROVIDE INFORMATION AND ASSISTANCE.

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