

Installation and configuration guide

HBX Vapor Quality Sensor - for evaporator control and compressor protection based on analog output. (Does not cover direct valve control)

Introduction

The Vapor Quality Sensor can measure small and more significant amounts of liquid in a gas. It constantly measures the volumetric % of liquid and delivers an analog signal. The sensitivity can be adjusted from being very sensitive for DX and compressor protection to less sensitive and suited for pump-circulated systems.

The sensors are different and suited for applications but use the same principle. The pipe size, application, and refrigerant drive the sensor type selection.

The different sensor designs.

The angle rod is used mainly for small systems with CO₂ and HFC/HFO refrigerants. The largest pipe size is 7/8" for CO₂. All liquid in the pipe is detected.



The inline sensor can be installed both vertically and horizontally, and it can be used with all refrigerants. It is available for pipe sizes from 25 to 100 mm. All liquid in the pipe is detected.



A sensor is built into a strainer house. It must be installed in a downward elbow. This sensor detects all liquid in the pipe but is only suited for ammonia and HFC/HFO. Available for pipes from 25 to 200 mm.



Rod-style sensors are the universal type for all refrigerants. It must be installed in an elbow with the sensing element at the bottom of a horizontal pipe. This sensor can be used in pipe sizes from 50 to 200 mm. This sensor will only detect the liquid inside the perforated pipe and **not** all liquid in the pipe.



Controlling the liquid feed

The evaporator is supplied with liquid refrigerant or a mix of gas and liquid, depending on the type of system. You get the optimal evaporator performance for all these systems if most of the refrigerant is evaporated.

For pump-circulated systems, the limit for how much you can evaporate is typically given by the evaporator design in general and the distribution of liquid between the parallel passes. For most evaporators, a circulation rate of 1.5:1 to 2:1 can be achieved with a good liquid distribution, providing the best performance and lowest energy consumption. In part-load, this sensor controls the circulation rate and maintains the low circulation rate by controlling the liquid feed.

The liquid line is typically half the diameter of the suction pipe, and the velocity is much higher in the suction pipe. This means the liquid should fill less than 10% of the suction line cross-section when the evaporator works and isn't blocked. The liquid will run at the bottom horizontal suction pipe, which will be measured to control the liquid feed.

The liquid leaving the evaporator should be shallow but detectable for DX systems.

Any liquid should be detected for compressor protection, and the result should be fed back to the control system.

What does the Vapor Quality Sensor do?

The Vapor Quality Sensor detects the amount of liquid in a suction line. The 4-20 mA output is typically used for controlling the liquid feed to an evaporator or for compressor protection. The sensor can be used both for DX and pumped systems, but the sensitivity must be higher. This means the sensor needs to have the correct settings for the application.

All Vapor Quality Sensors can be used for different refrigerants/liquids, but for CO2 and hydrocarbons, the strainer house versions can't be used.

The liquid leaving the evaporator will typically be on the pipe's walls and for a horizontal pipe at the bottom. The rod-style sensor version must be installed at the bottom of a horizontal pipe, whereas the other versions will detect liquid on all surfaces.

In DX systems, the sensor output controls the expansion valve, replacing the conventional superheat control. It is common practice to start the system using superheat control and switch to vapor quality control as soon as the system is in operation, as this is easier to implement.

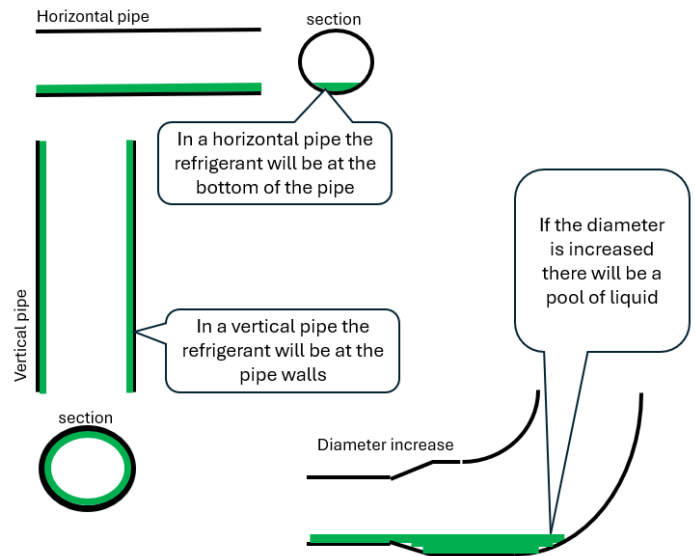
The liquid feed is controlled based on the vapor quality measurement for pump circulated and other overfeed systems. This can be done by a liquid valve or by controlling the pumps for simple systems where all evaporators see the same load.

Where is the liquid located?

Most of the liquid should have evaporated at the outlet of an evaporator, and the remaining liquid is found at the bottom or where the velocity is lowest. This means the sensor must detect the liquid at the bottom of a horizontal pipe. In a vertical pipe, the fluid will flow on the walls where the boundary layer secures the lowest velocity.

If the diameter of the suction pipe increases, the velocity will drop, and the liquid will typically remain where the diameter increases. Typically, this is where you like to measure the vapor quality, but that is a bad idea because the sensor will be constantly in liquid.

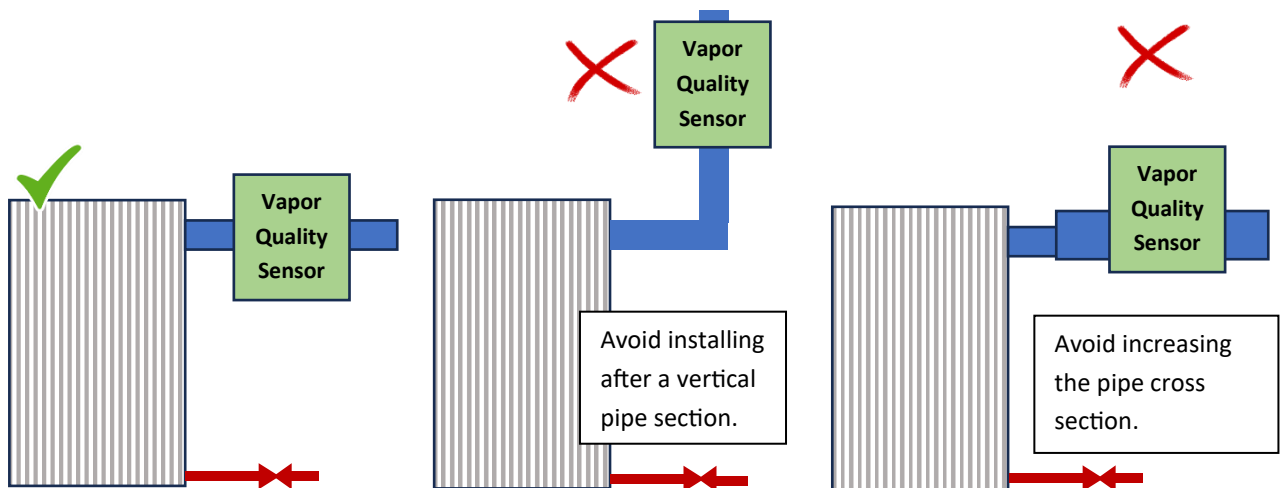
If the sensor is installed after a section increase where a pool of liquid can exist, the measurement will be delayed or disturbed by the pool of liquid.



How and where to install.

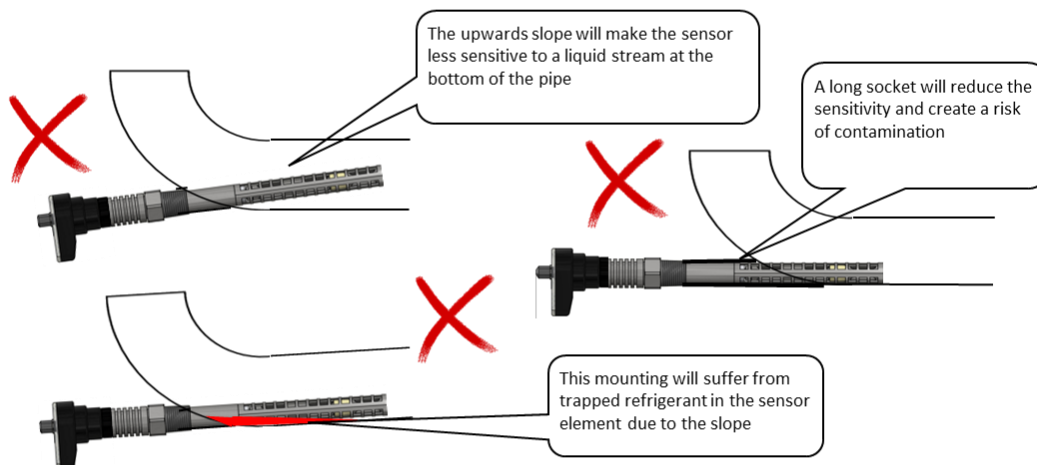
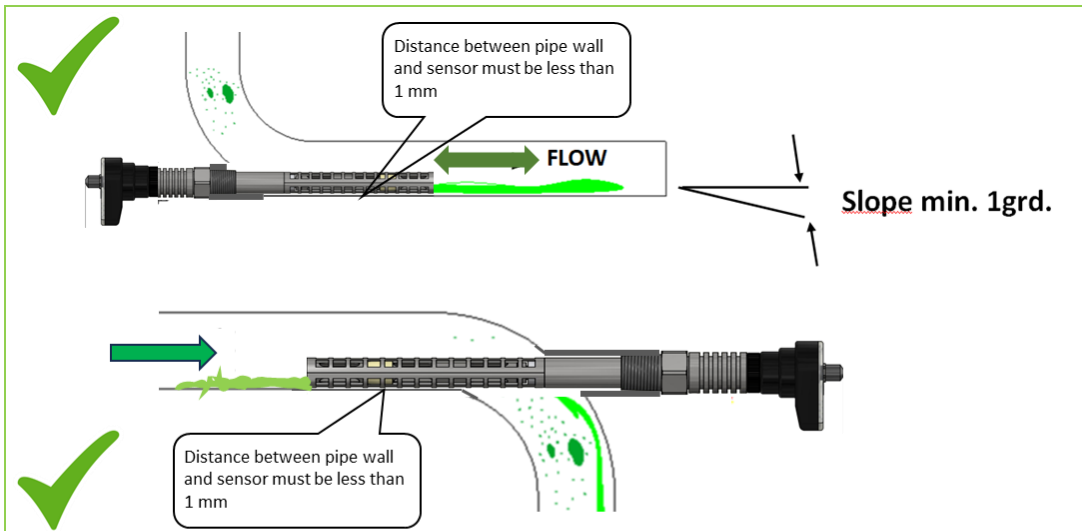
For evaporator control, installing the sensor just after the evaporator is essential. If the suction pipe between the evaporator and the sensor is vertical or is increased in cross-section, there is a risk of liquid accumulation during part load. This liquid accumulation will disturb the measurement and typically result in a plug flow. If the sensor is installed after a couple of meters of a horizontal pipe it will still work, but the measurement will be delayed and provide not as good feedback for the control system.

For compressor protection, the sensor must be installed close to the compressor to avoid condensation between the sensor and the compressor.

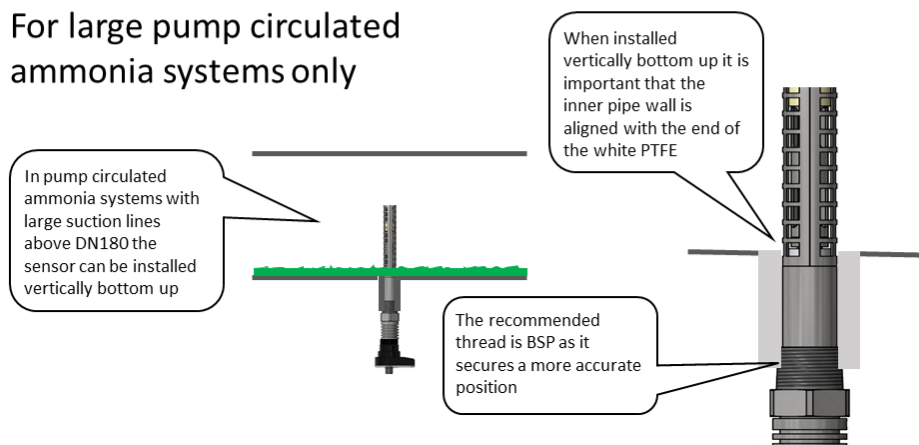


How to install the rod-style versions

This sensor is installed with the perforated part at the bottom of a horizontal pipe. The nonperforated part is not active. **The sensor will not detect any liquid outside the perforated pipe.** The sensor can be installed vertically in large pump-circulated ammonia systems with large suction pipes. This installation method can't be used for DX systems and other refrigerants.

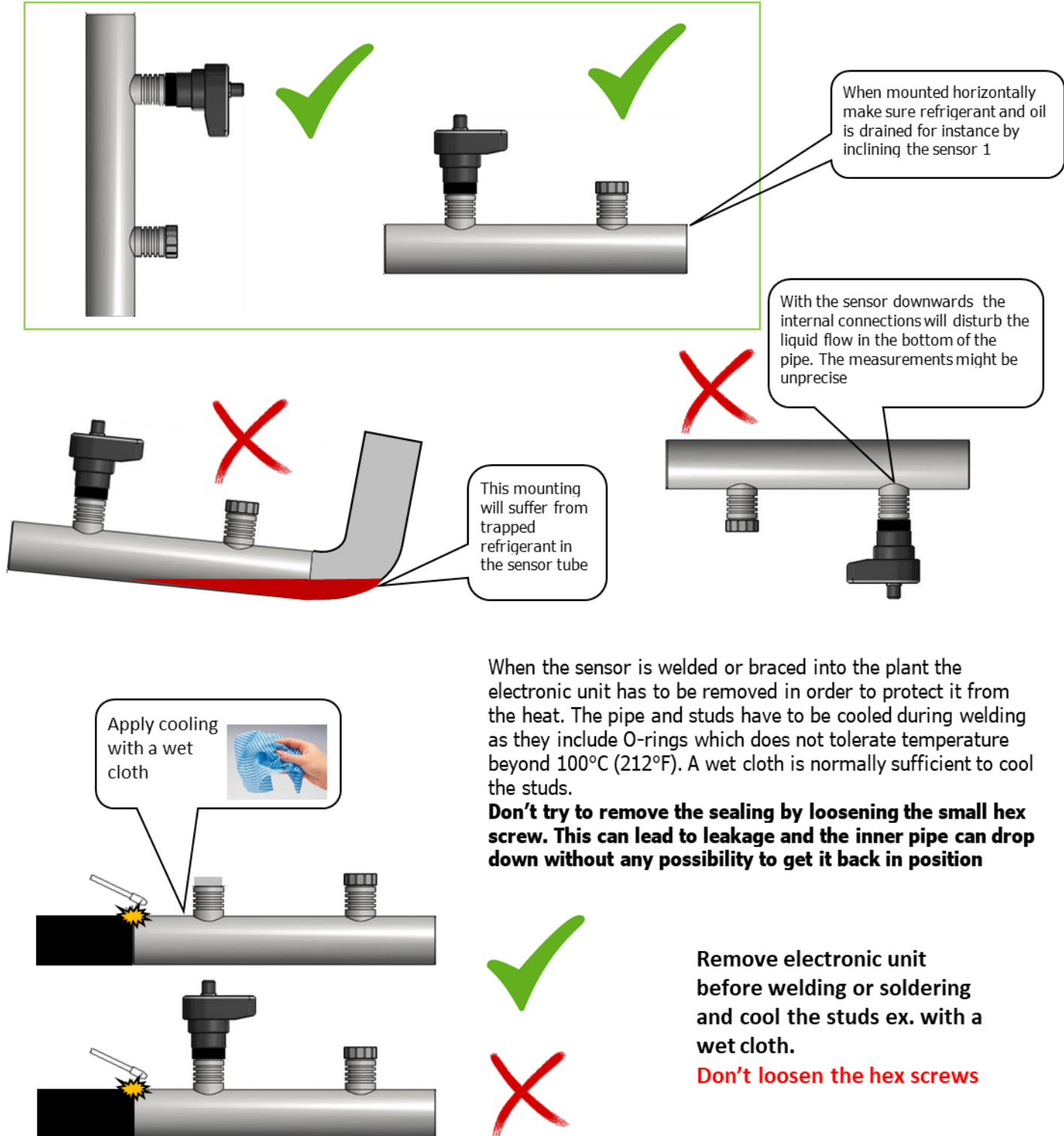


For large pump circulated ammonia systems only



How to install the in-line versions

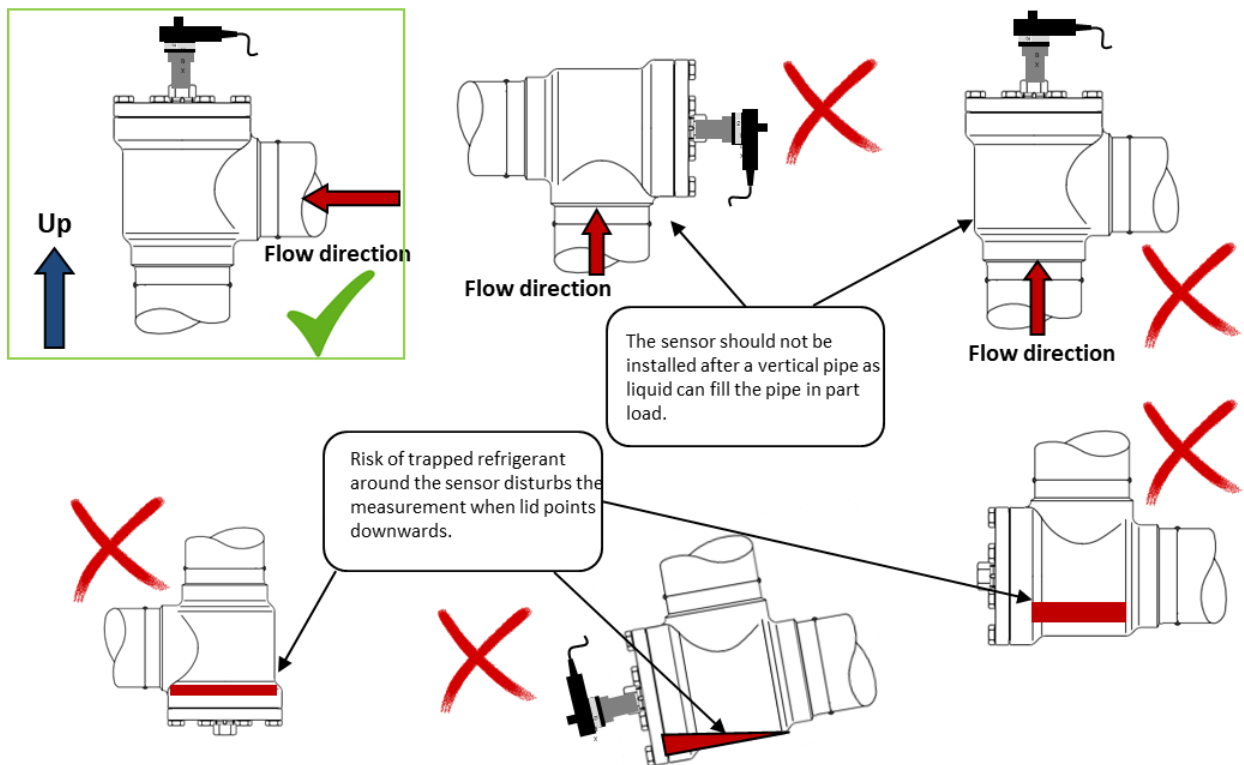
This sensor is built into a straight pipe and can be used in horizontal and vertical applications. This sensor version can be used for all refrigerants.



How to install the strainer house versions

This sensor utilizes a standard strainer house, and a unique sensing element is installed. This sensor version can be used for ammonia, HFOs, and HFCs but **not for CO2 and hydrocarbons**.

The sensor is installed in an elbow, and securing drainage from the sensor is essential. Without drainage, you will get a signal upon startup, which must be dealt with.

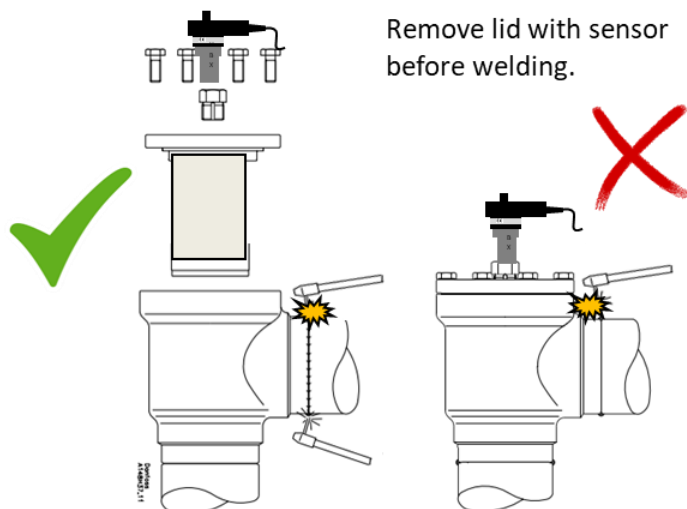


When the sensor is welded into the plant the lid and sensor must be removed. After the welding the piping must be checked for welding debris and deformations which might disturb the measurement. The distance between the sensor element and the wall must be uniform.

The lid with sensor is reassembled and the bolts are tightened according to the table.

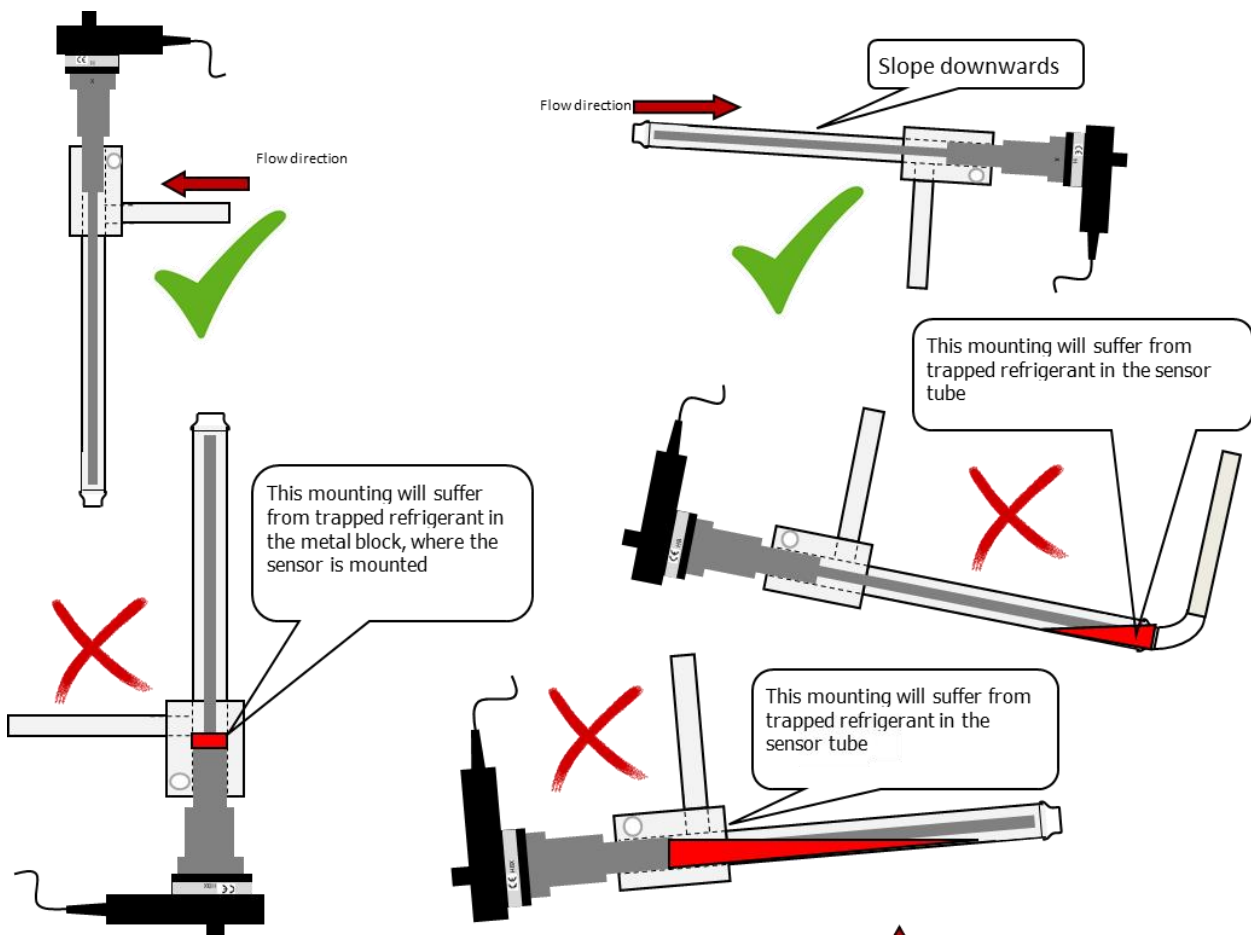
Max torque for bolts

	Nm	LB-ft
DN 15-20	21	15
DN 25-32-40-50	44	32
DN 65	74	54
DN 80	44	32
DN 100	75	53
DN 125-150	183	135
DN 200-300	370	272



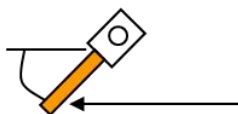
How to install the angle rod versions

This sensor is designed mainly for CO2 and small systems in general. The sensor has a high sensitivity but also a potential significant pressure loss. The sensor is delivered with reductions and expansion adaptors to either stainless steel or copper pipe sizes. All sensors and adaptors are stainless steel and must be brazed/soldered into the system. The sensor accepts flow from both directions, and all refrigerants can be used.

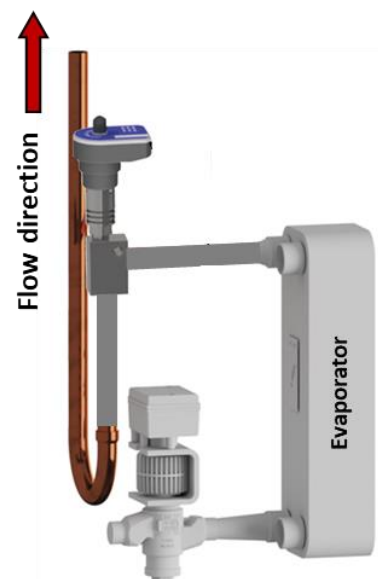


Workarounds for low mounted evaporator outlets

It is important to secure drainage of liquid refrigerant and oil as this could affect the sensor and especially oil is difficult to remove with a low velocity gas. Especially in small systems without oil separator, it is important to keep the sensor free from oil to avoid it disturbing the measurement. Both pipes should be angled minimum downwards 1 degree or designed with a P-trap/drop-leg to secure drainage.

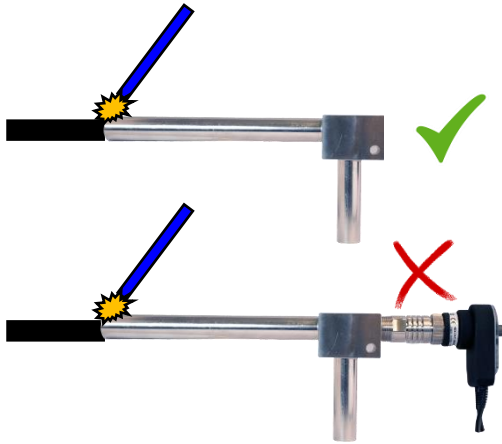


Angle minimum 30° downwards



Welding or brazing in the sensor to the system.

When installing the angle rod or strainer house sensor, you need to remove the electronic part and the parts which includes nonmetallic parts. Soldering connection, fittings and pipes are made of stainless steel. The sensor part itself must be removed by unscrewing it from the steel block/base part before soldering. The inline sensor needs different treatment as described under the installation method.



Remove the entire sensor component before soldering.

Use two wrenches when dismantling and installing the HBX sensor: One to turn the sensor and one to stabilize the steel block to avoid stress to the soldering.

Use thread sealant. We recommend using liquid thread sealant when installing the sensor.

Temperature sensor installation

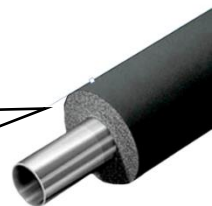
Refrigeration systems working with CO₂, can benefit from temperature measurement. The temperature measurement is used for offsetting the zero calibration point and makes the measurement more accurate. If the system is operating continuously a temperature sensor is not needed.

The sensor normally has a cable with a temperature sensor which must be mounted to the pipework using cable ties. The mounting on the outside of the pipe provides sufficient accuracy. The temperature sensor compensates for the change in the dielectric constant with the temperature and makes the measurement more accurate when starting the system.

The temperature sensor should be mounted to a pipe in position 3 or 9 o'clock with cable ties as shown.



Insulate the entire mechanical sensor part with insulation foam.



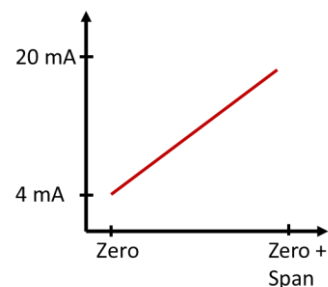
Electronic unit

The electronic unit is the same used across all the different versions, but the settings are different. These settings must match the mechanical part, application, and refrigerant. This means you can replace the electronic unit, but it needs to have the correct settings file. HB Products has the proper settings, and we recommend you contact support@hbproducts.dk if you need a different settings file.

Output and calibration

The sensor measures the capacity in pF and converts the output to an analog signal used in the control system. All gasses have approx. the same dielectric constant, and the measurement will be the same for all refrigerants. This means the zero calibration will only depend on the type of mechanical unit, and the zero calibration can be made in the air. When the sensor is in air or dry gas, it will deliver 4 mA.

The sensor has a measurement window depending on the application and refrigerant. The measurement window is named span and is the number of pF, increasing the analog output from 4 mA to 20 mA. This means that when the pF measurement reaches the zero calibration + span, the sensor will emit 20 mA.



The span will depend on the sensor type, application, and refrigerant. Sensitive sensors adjusted for DX systems will have a small span, whereas those used for overfeeding systems will have a large one. Sensors for CO₂ and hydrocarbons will have small span. The sensor is usually delivered with a settings file with the right span according to the specifications we receive.

Temperature sensor

Sensors used for CO₂ will typically have a temperature sensor, which can compensate for the change in dielectric constant with temperature. This feature improves the accuracy, especially for CO₂ systems working at different temperatures. Sensors operating in ammonia and HFC/HFOs should not use temperature compensation.

Sensors with direct valve control

The sensors can be delivered with a direct valve control cable, simplifying the cabling and system. The challenge is that all modifications must be made in the sensor directly connected to a PC. So, if the sensor is installed remotely, you must go there to modify or optimize the control.

For larger systems and systems where you like remote access, we recommend using the standard sensor and making the valve control in a PLC or controller.

The setup of the controller is described in a separate manual.

Getting started

Installation in existing systems

Suppose you install the sensor in an existing system. In that case, the general recommendation is to install the sensor and look at the output while running with the old control system because it will provide valuable information. In pumped systems, 20 mA output in part load indicates too much liquid in the suction line. You will typically see a constant output of 4 mA for DX systems with some peaks where the analog output increases. That is due to dry superheated gas, so the energy consumption and capacity are poor. The system should be run with minimal liquid leaving the evaporator but not reaching the compressor.

Installation in new systems

For pump-circulated systems

In a pump-circulated system, the sensor measures the amount of liquid leaving the evaporator. The system should continuously operate with the same circulation ratio to achieve the best COP, so the liquid feed should be reduced when the required capacity is diminished. This means the output from the sensor should be the same in full and part load. The highest COP is achieved with the lowest circulation rate possible for the actual system. The best evaporators can operate with rates down to 1.2:1, but they are rare 1.5:1 up to 2:1 is more common and should be a good compromise. If the circulation rate is too low, you will see poor liquid distribution and reduced capacity.

When a sensor is installed, it must be suited for the application, and that usually means it should have a setting suited for circulation control, typically named "CR" type and not "DX." The measurement window of the CR version is larger, and it will return 20 mA when the CR is higher than approx. 5:1. When the gas is dry, 4 mA is returned.

If the system is designed to operate optimally at full load, the measurement (mA signal) should be used as a target in the liquid feed controller. This means you start the system and run it with maximum load, then read the measurement and expect it to be between 10 and 20 mA. This number should be the target for the controller. A liquid valve can make the control for large systems with more than one evaporator or with frequency control of the pumps for single evaporator systems.

This setpoint will be a good starting point, but it might not be optimal for all systems. It would be best to aim for the lowest circulation rate while maintaining an excellent liquid distribution and a high capacity to get the highest COP.

For DX systems

In a DX system, the sensor will replace the superheat control entirely or partly. Many users of vapor quality control use the standard superheat controller to start the system and then use the sensor as soon as the system is started. This makes the programming easier as the standard procedures are used for starting and stopping, and you still get the savings during regular operation.

When a sensor is installed, it must be suited for the application, and that typically means it should have a setting suited for direct expansion "DX." The sensor is very sensitive and will return 4 mA when the gas is dry. The system without any liquid separator should operate with a mA signal of around 5 mA, and systems with a separator should operate with a higher mA. Higher setpoints will give higher COP but also a higher risk of liquid reaching the compressor. That means if you would like to optimize your system, you must increase the setpoint without killing the compressor.

Zero calibration is essential for DX systems and should represent the tool's lowest measured value in pF. If the zero calibration is too high, you cannot measure small amounts of liquid.

Using the Vapor Quality Sensor for compressor protection

When using the sensor for compressor protection, you need to find the delicate balance between detecting liquid and not getting unnecessary alarms. Systems are different, and both oil and refrigerant will be detected. In principle, this is just a Vapor Quality Sensor for DX applications where you utilize either an alarm output or the mA signal.

Alarm output: You can have an alarm providing 24V on pin3 when you reach the calculated X value. To change the X alarm value, you need a USB cable and a pc with the HB tool.

mA signal: You will get a mA signal on pin4 linear to the liquid content. You can set up and optimize the PLC using the method shown below. The HB tool is normally not needed.

Using the sensor alarm signal (Trial and error method)

1. Install the sensor according to the installation guide.
2. Use the standard setting for a DX sensor and connect the sensor to a PC. Look at the zero calibration and compare it to the actual measurement. These two numbers should be approximately the same within ± 1 pF. If that is not the case, the sensor is continuously fed with oil, or you have some liquid returned to the compressor. Watch the level for a period when the system runs typically. If this level is stable, you can make a new zero calibration.
3. The standard settings will not provide you with an alarm. Start by increasing the alarm setting to 0.95, then gradually increase the alarm level until you get an alarm. Then, decrease the setting again to reach stable operation. The standard alarm range is between 0.95 and 0.98.

The scientific method uses the mA signal.

If you follow this method of optimizing, you can reach the balance relatively fast, but the complete process is longer.

1. Install the sensor according to the installation guide.
2. Use the standard setting for a DX sensor, connect the sensor to a PLC with a data logger, and start logging the mA signal from the sensor. After a week of representative use, you can look at the variations in the mA signal.
3. Then, you adjust the alarm limit in the PLC to just above the maximum level (mA signal) you have seen in the logging. With this setting, you will get an alarm if the liquid increases above the usual level.

Connecting the sensor to a PC

The Vapor Quality Sensor can be connected to a PC with the HB tool installed. With this tool, you can read the pF measurement and change the measurement window. You can also set alarms and make a direct valve control.

The connection is done with a special USB/M12 cable. When the cable is connected, the sensor is powered by the PC. You can get a special box that splits the signal and makes it possible to read the pF measurement while still getting the mA signal to the PLC. This box is named "splitter box," it is only used for setup and fault finding.



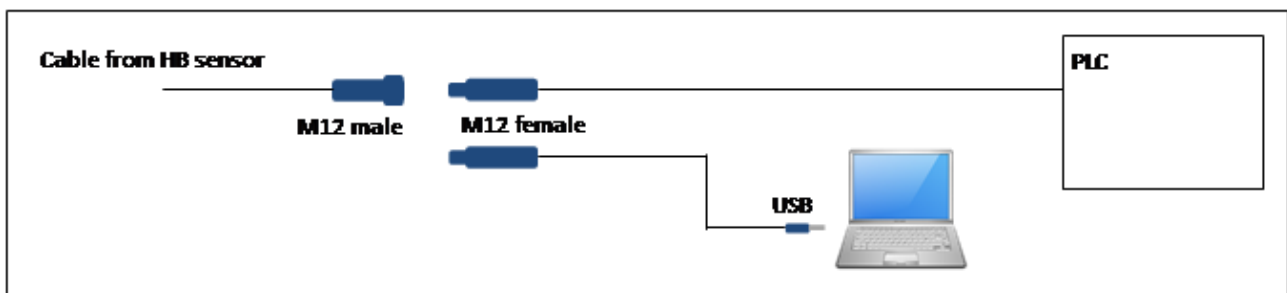
Using the HB tool

When you connect the tool to the sensor, there will be some calculated X values for guidance. These values are not exact measurements and should only be used for guidance. The sensor measures the capacitance, which is converted into an X value, but the installation and type of sensor will affect the accuracy of the calculations.

The mA signal is used for evaporator control with a PLC or controller, and that signal is scaled in the tool linear to the measurement. This means the calculated X values are only for guidance and should not be used for optimizing a refrigeration system.

Connection to the sensor when installed where access is difficult.

If the sensor is installed on an evaporator in a cold room where access is difficult or similar, you can use an extension cable to the roof or another location where you have access. At the end of the extension cable, you can connect your PC if you need access to the sensor settings, etc.



Calibration

The most crucial calibration point for the Vapor Quality Sensor is the dry calibration. The dry calibration is done in gas, and it must be the lowest value that the sensor can detect. In this situation, the sensor must deliver 4 mA.

Zero calibration

The sensor is usually delivered with a zero-calibration made in air. You can check the calibration by ensuring that the measurement in dry gas is equal to the dry calibration value.

The two numbers ringed in the picture must be almost identical. ± 0.2 pF for all CO₂ and DX applications and ± 1 pF for other applications

If the number is wrong, you can calibrate by clicking the “dry sensor calibration” button or typing the correct number into the “Dry calibration in pF” field. To change the values, you need to click on the small box next to “send dry/span values” and save the values by clicking on the to “send dry/span values” button.

Span calibration

The span defines the measuring window, and the sensor is delivered with a span calibration that suits the application. When the measurement reaches the dry calibration + span calibration, the sensor output will be 20 mA.

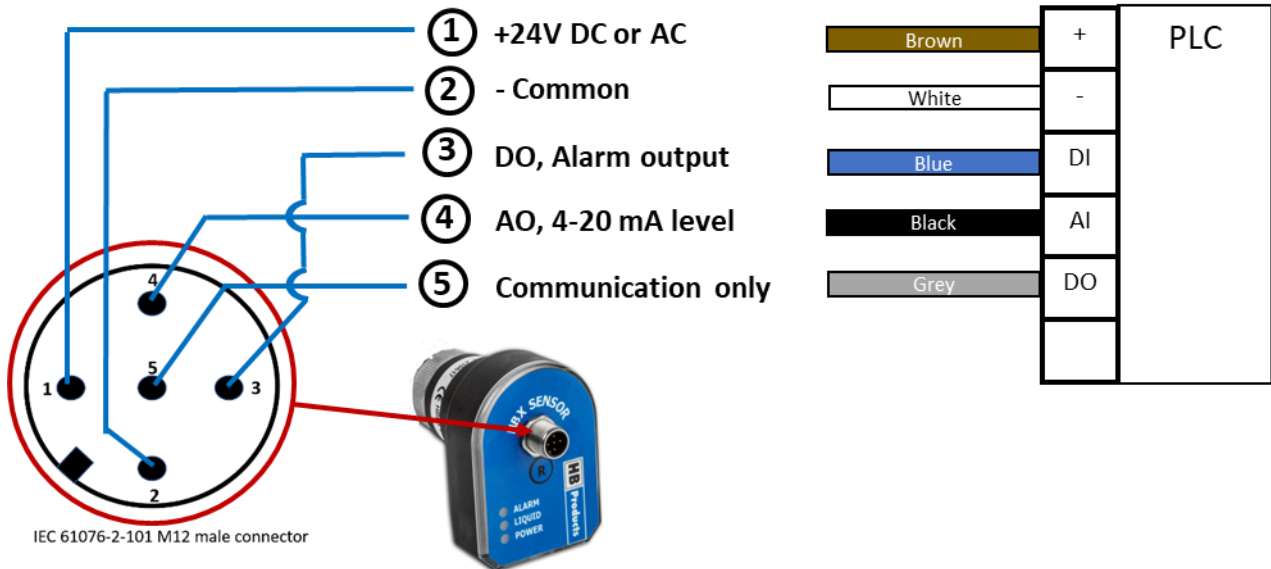
You can change the span calibration if needed. Change is necessary if your maximum output in mA is minimal or if it often is 20 mA for a more extended period.

Change will also be needed if the sensor or electronic unit is moved to another application than initially intended.

Alarm output

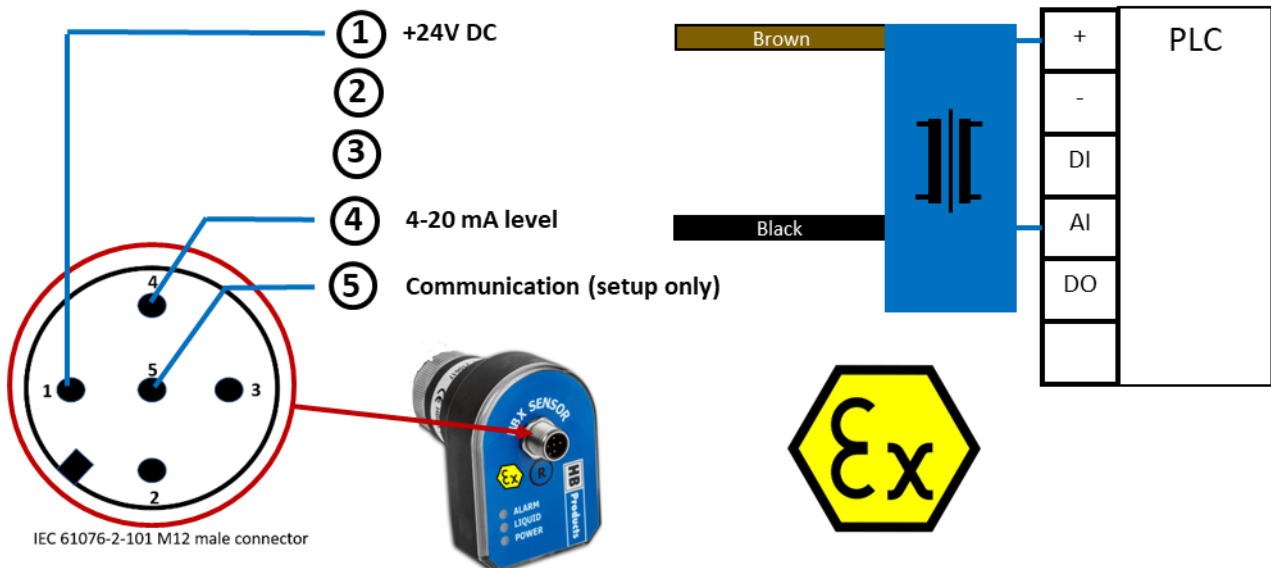
The sensor can provide an alarm output if needed. This is done in the tool, and it is based on an “X” calculation. The alarm will be provided on pin3

Electrical connections for standard sensors without direct valve control.



Electrical connections for Ex, ATEX, and two wire sensors without direct valve control.

The ATEX and Ex products are always two-wire products. To comply with the certifications, the sensor should be connected through a barrier that limits the current to the sensor. All the 2-wire sensors can be used directly with a PLC or similar but uses only two wires. They can be connected to a PC like a standard multi-wire sensor for setup.



LED indication

For the simple sensor without direct valve control, the LED indications are:

LED light	Appearance	Functionality
Green	Flashing	The sensor is on.
	OFF	The sensor is not receiving power.
Red	ON	Measurement is outside the measurement window
	Flashing (one pr. sec)	The sensor detects a liquid. The sensor will give 22 mA.
	Flashing (two pr. sec.)	The sensor is connected to a USB cable
Red, yellow, and green	All flashing	The sensor is connected to a USB cable

Contact HB products support if you need more information.

Email: support@hbproduct.dk

Telephone: +45 8747 6200

Where to install the vapor quality sensor?

The vapor quality sensor detects the liquid content in the output from an evaporator. This output is used for controlling the liquid feed and securing a constant dryness. The sensor is used both in overfeed systems and in DX systems - just with different targets for the liquid content. The vapor quality sensor can have different shapes, but for all it is important to install it as close to the evaporator as possible to get the best feedback for the control system.

