VAPOR QUALITY

Energy Efficient

Evaporator Control

HB Products

VAPOR QUALITY

Contents

INTRODUCTION

• This presentation is about Vapor Quality Control, focusing on the technical aspect of Vapor Quality

• Please note that we constantly improve and modify our presentations. This is our latest version, 2022.

• If you have comments or suggested improvements, please contact:
Henrik Kudsk, product manager, hk@hbproducts.dk

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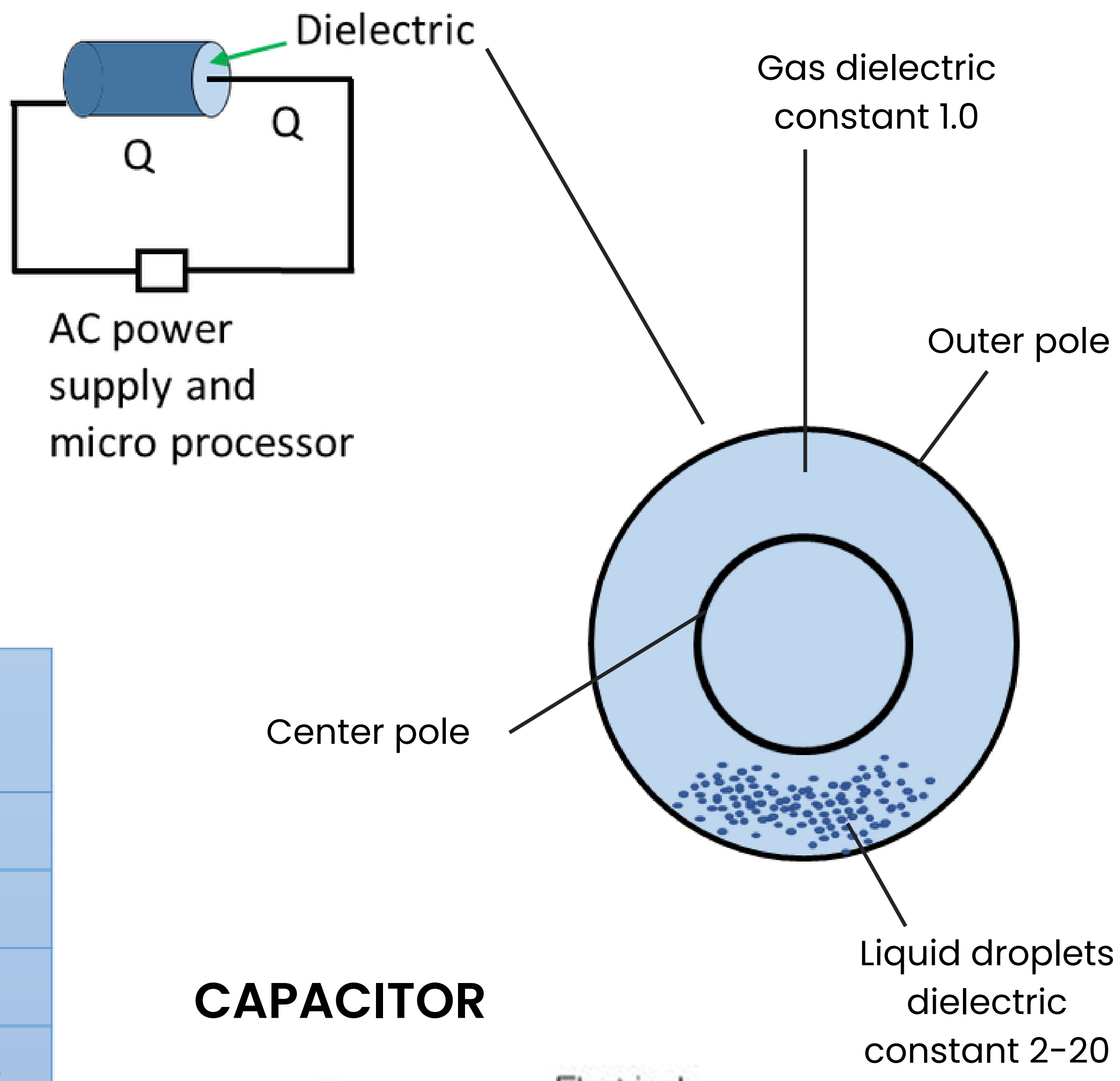
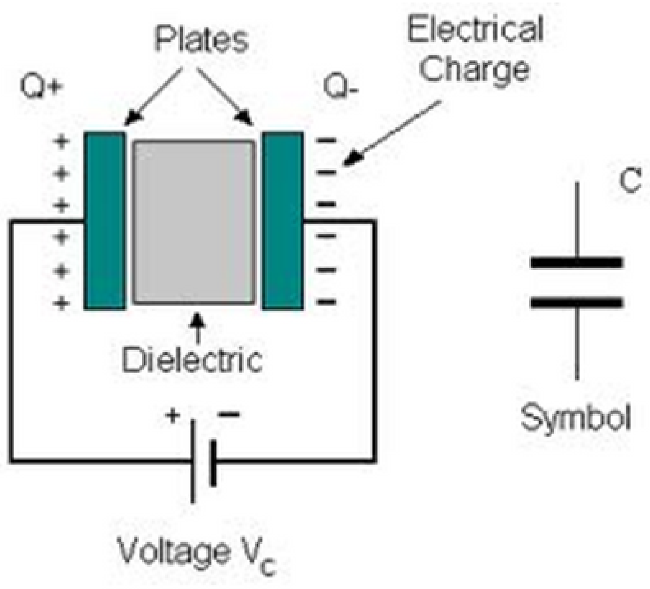
MEASUREMENT PRINCIPLE

SENSOR



Dielectric Constant:	Temperature 20°C
Water/brine	80 (0°C is 88)
Ammonia	17 (-40°C is 22)
CO2	1.5 (-40°C is 2.0)
Oil type PAO, PEO Oil type PAG	2.2 Mineral and synthetic types 3.5 Synthetic types
R134a	9.24
R22	6.35
R410A	7.78
R507	6.97
R1234ze	7.7
Air and gas	1.0

CAPACITOR



THE SENSOR

The sensor uses the capacitive measurement principle like most of the sensors from HB Products.
In principle, the sensor acts as a large capacitor where the liquid droplets and gas are the dielectric that fills the gap between the two poles.

The capacitance is based on the dielectric constant of the fluid between the center pole and the outer pole. Different liquids have different dielectric constants, some of which are shown in the blue box.

The electronic unit applies a low voltage high-frequency AC to the sensor element to measure the capacitance. The measured capacitance and base dielectric parameters allow the sensor to calculate the volumetric percentage of gas in the gas-liquid mix.

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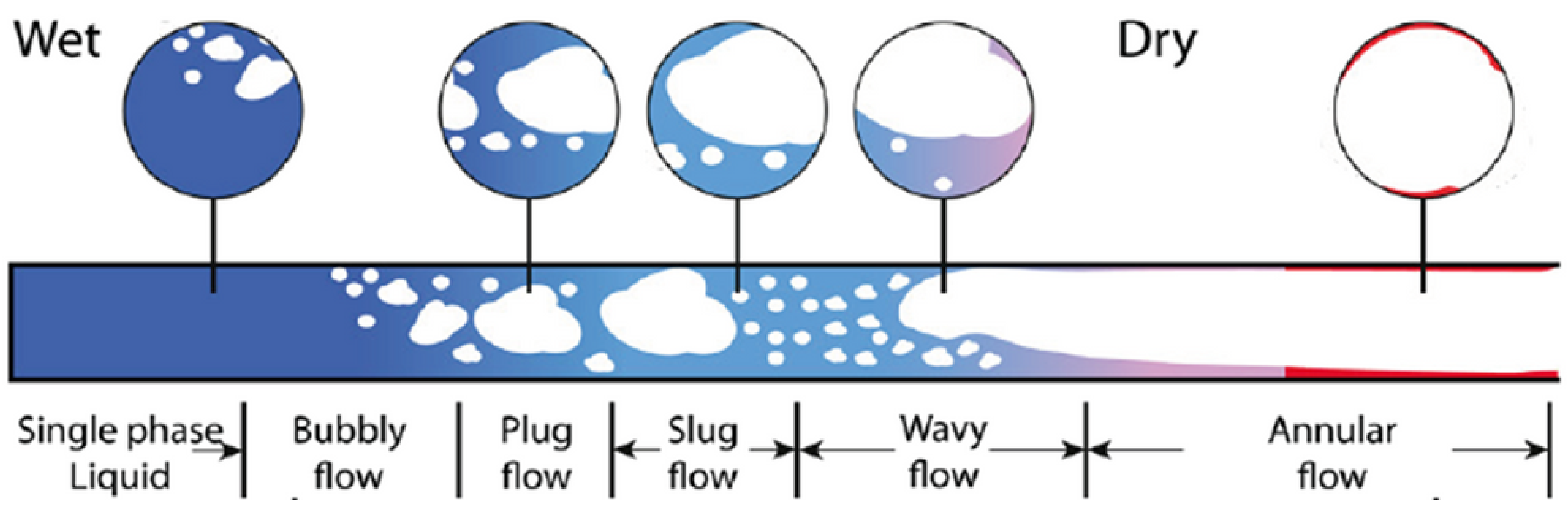
FUNCTIONALITY

- Measures the volumetric content of gas in a gas/liquid mix named X.
- Measures the vapor quality output from an evaporator

In an evaporation process, you typically start with liquid or bubbles and a lot of liquid. In this area, the sensor will not provide a reliable output, but as soon as the flow reaches the plug and slug flow the sensor becomes linear with the volumetric percentage of gas.

The output from an evaporator is mainly gas and in this area, the sensor is linear and is suitable for both DX and overfed systems with a circulation ratio of up to 5.



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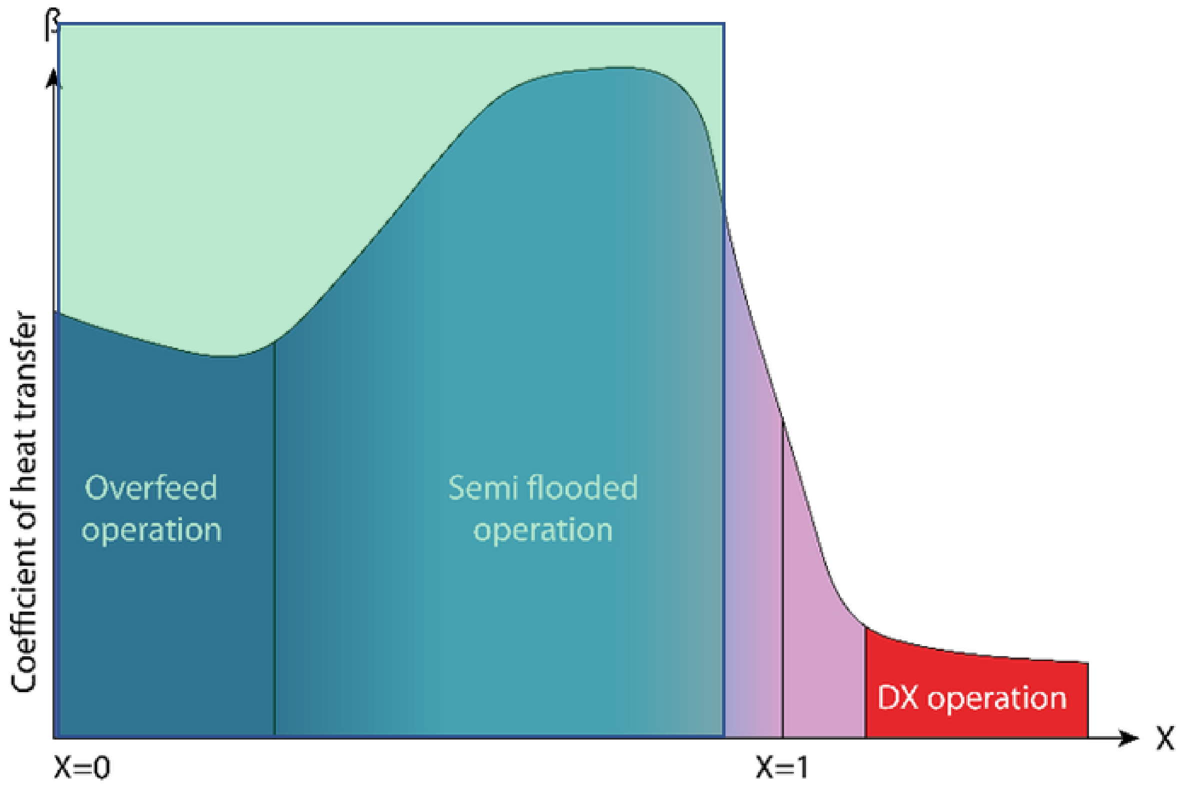
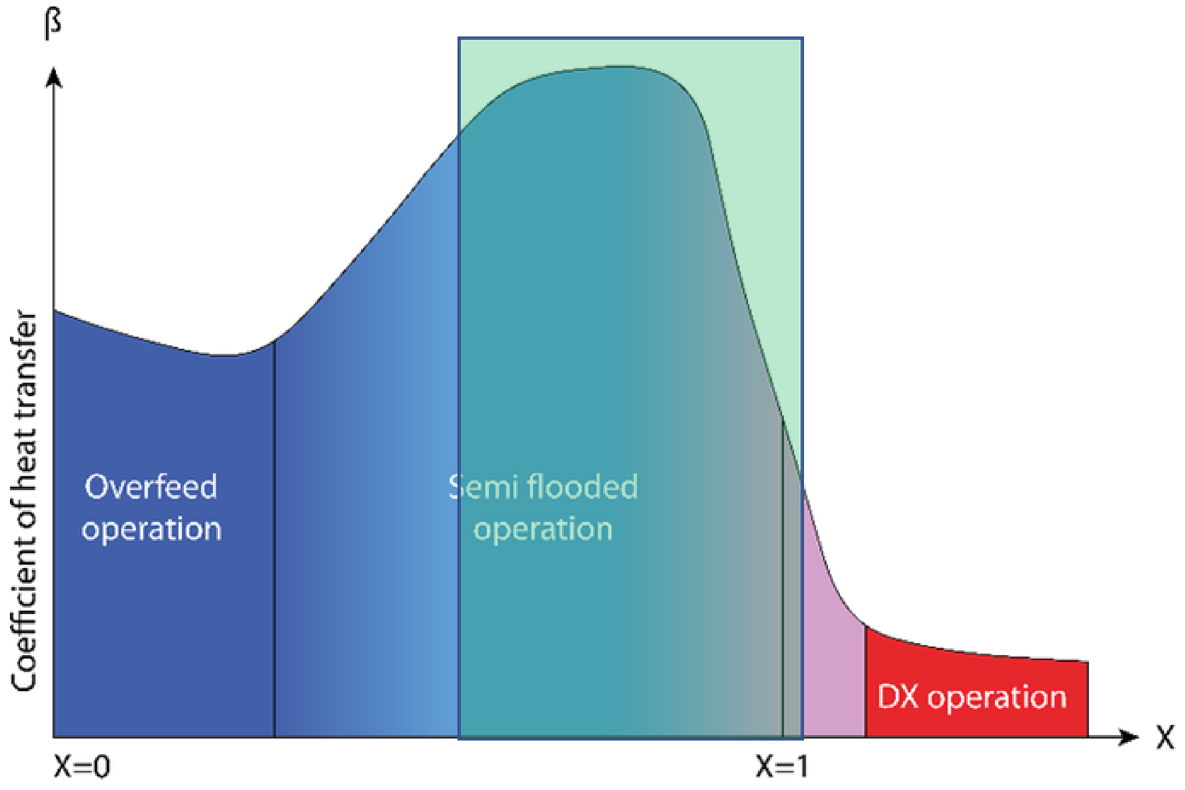
HEAT TRANSFER OPTIMIZATION

The evaporator efficiency depends on the liquid content of the substance and the flow rate. The figure shows that the efficiency depends on the vapor quality from X=0 wet to X=1 dry gas.

The highest efficiency is achieved in the semi-flooded operation area from an X value of 0.5 to 0.9. In this area, the substance is a mix between a small amount of liquid and a lot of gas.

As soon as the gas becomes dry beyond 0.9 the efficiency drops dramatically and at the same time, the gas is superheated. In a conventionally DX (direct expansion) system the gas is heated up to 5-10 K superheat and that creates a loss in efficiency in the evaporator as 20-30 % of the area is used for superheating. At the same time superheating is a waste of energy and should be avoided.





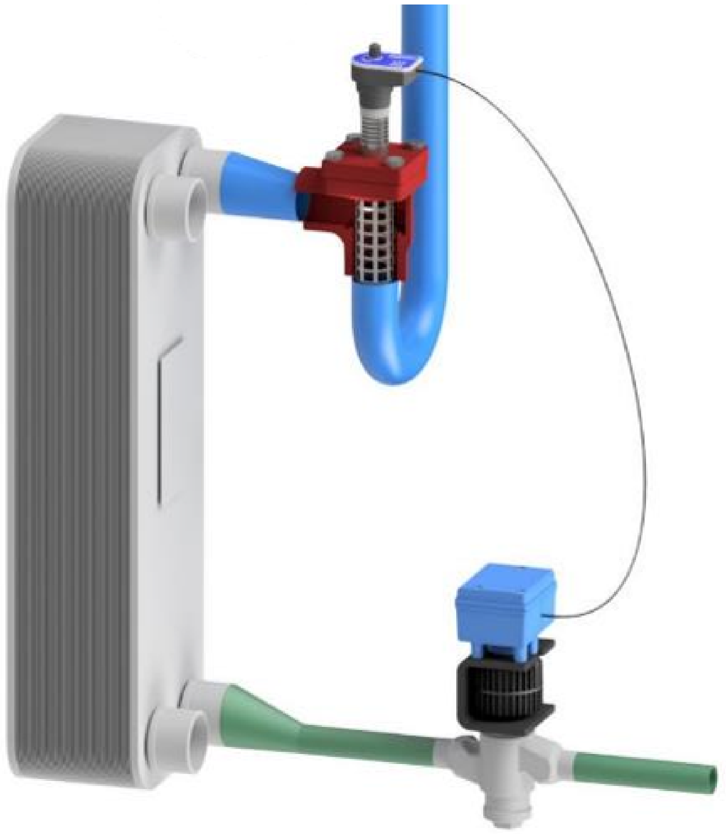
DX APPLICATION

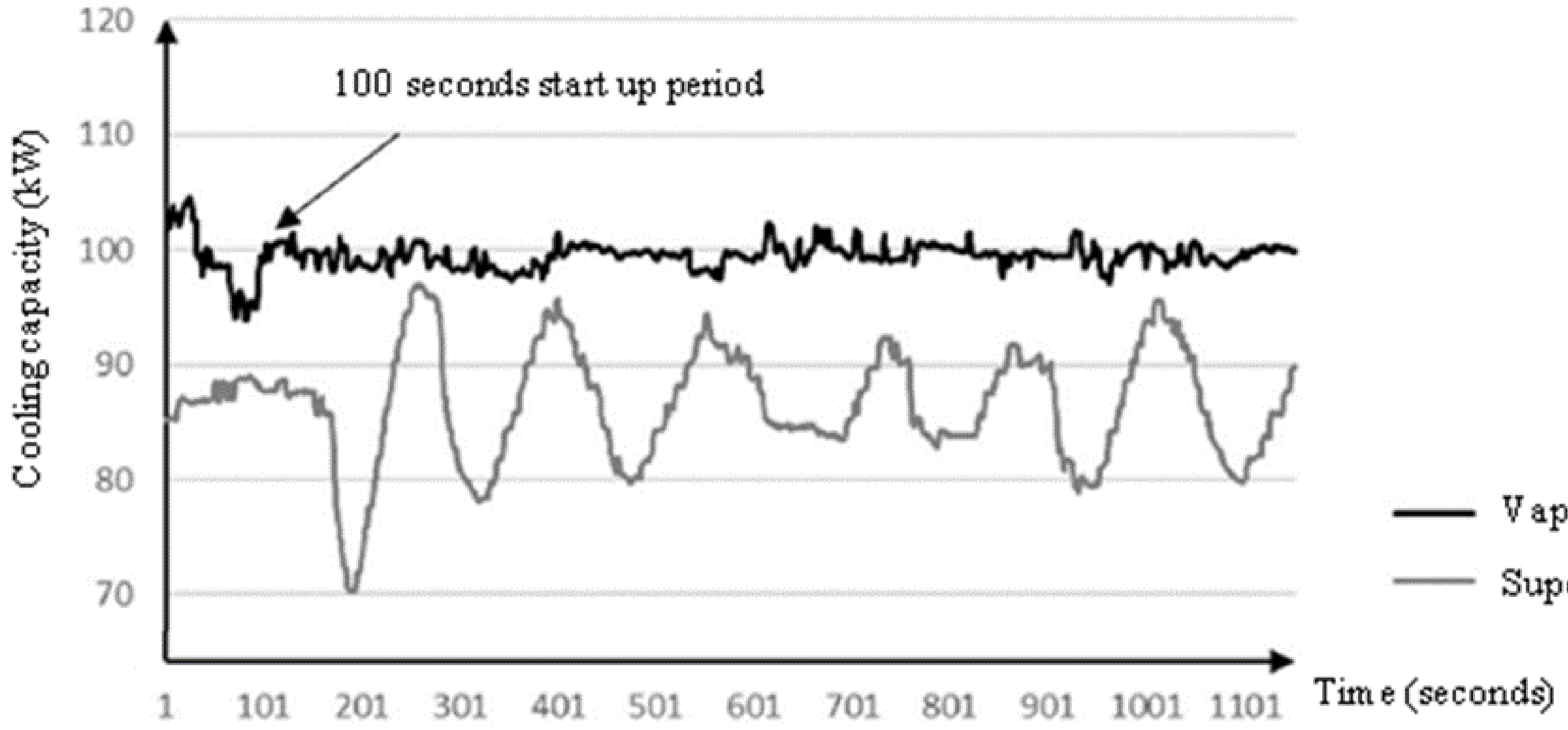
The vapor quality sensor is perfectly suited for DX control. Compared to the conventional superheat control it is significantly faster and the variations in cooling capacity are reduced and the average capacity is increased.

Superheat can be reduced to a minimum which both increases capacity and improves the COP.

The expansion valve can be controlled directly without the use of a PLC and with significantly less cabling.

- Replace superheat control with vapor quality control
- Faster control loop compared to superheat control
- Reduce superheat to a minimum
- Increased evaporator capacity
- Improved COP
- Direct control of the expansion valve





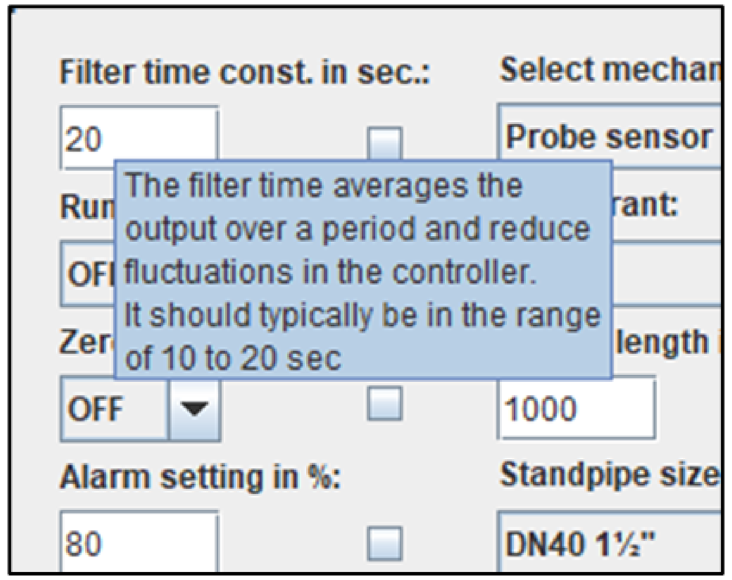
SENSOR SETUP WITH THE HB TOOL

The sensor is normally delivered in a plug-and-play version which means it will be operational without further modifications.

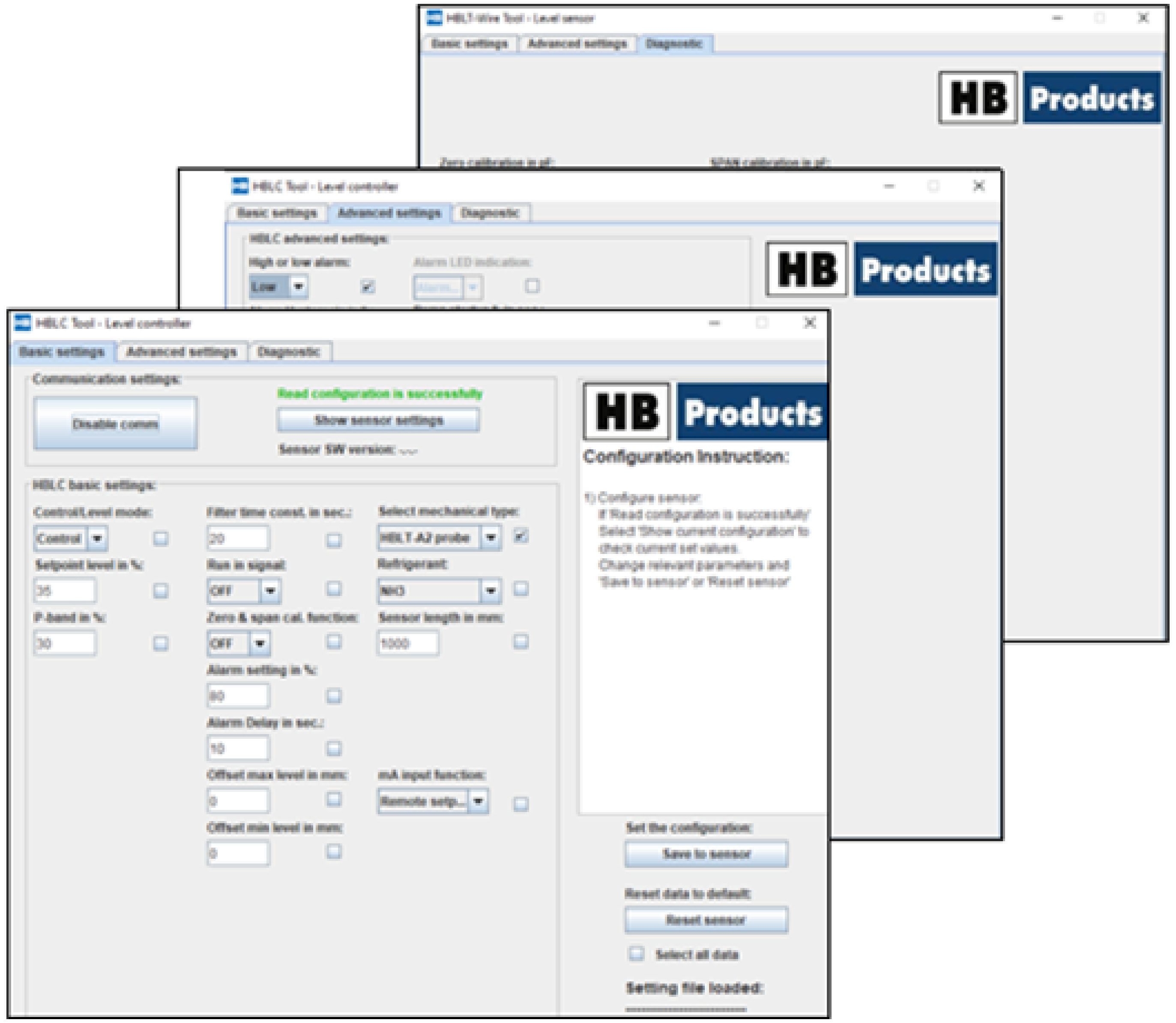
If the sensor must control a valve or if high accuracy is needed a calibration in the HB-tool is recommended.

The HB-tool is available for free download on **www.hbproducts.dk**

To setup the sensor a special USB/M12 cable is needed – the same cable can be used for all HB Products.



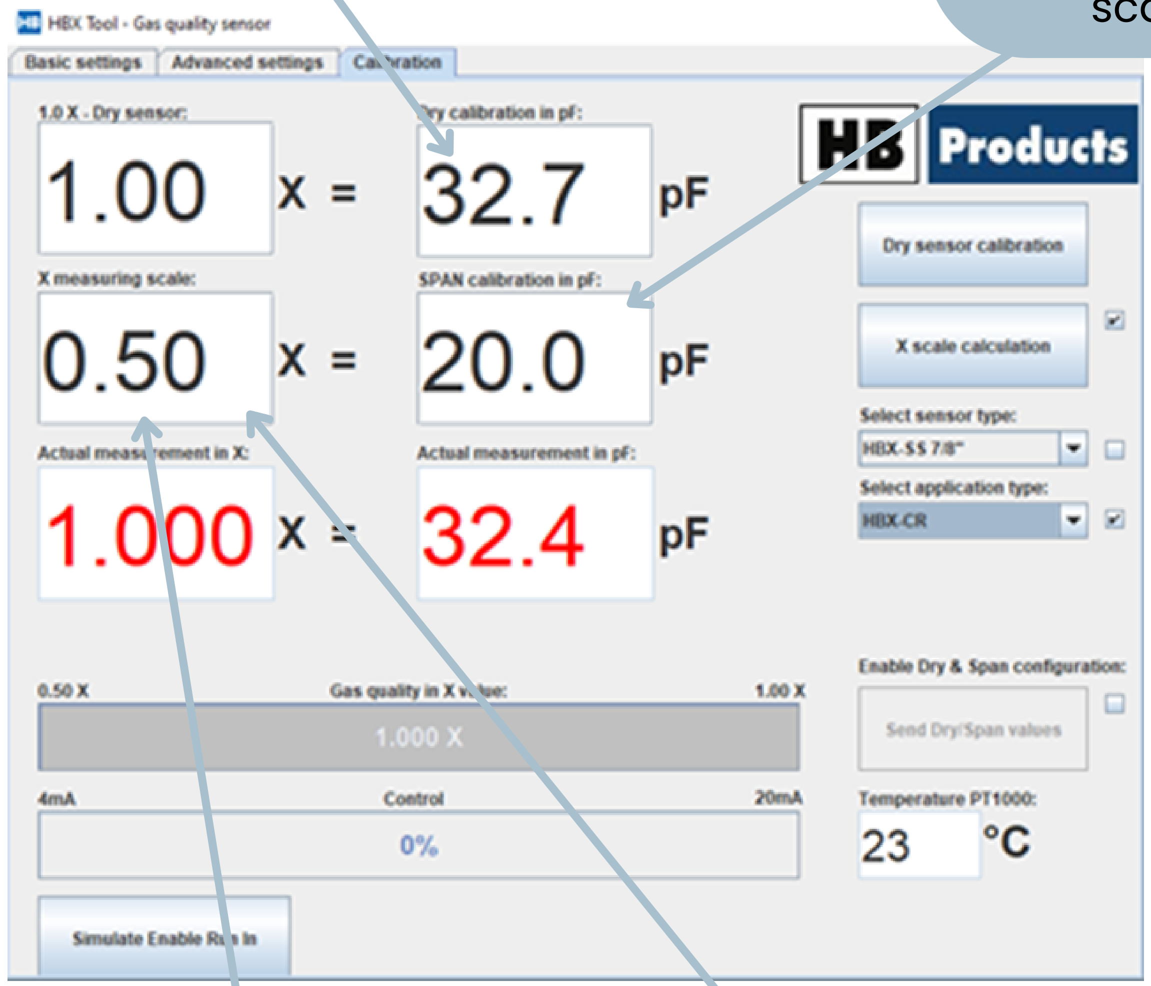
USB/M12 cable for setting up the sensor

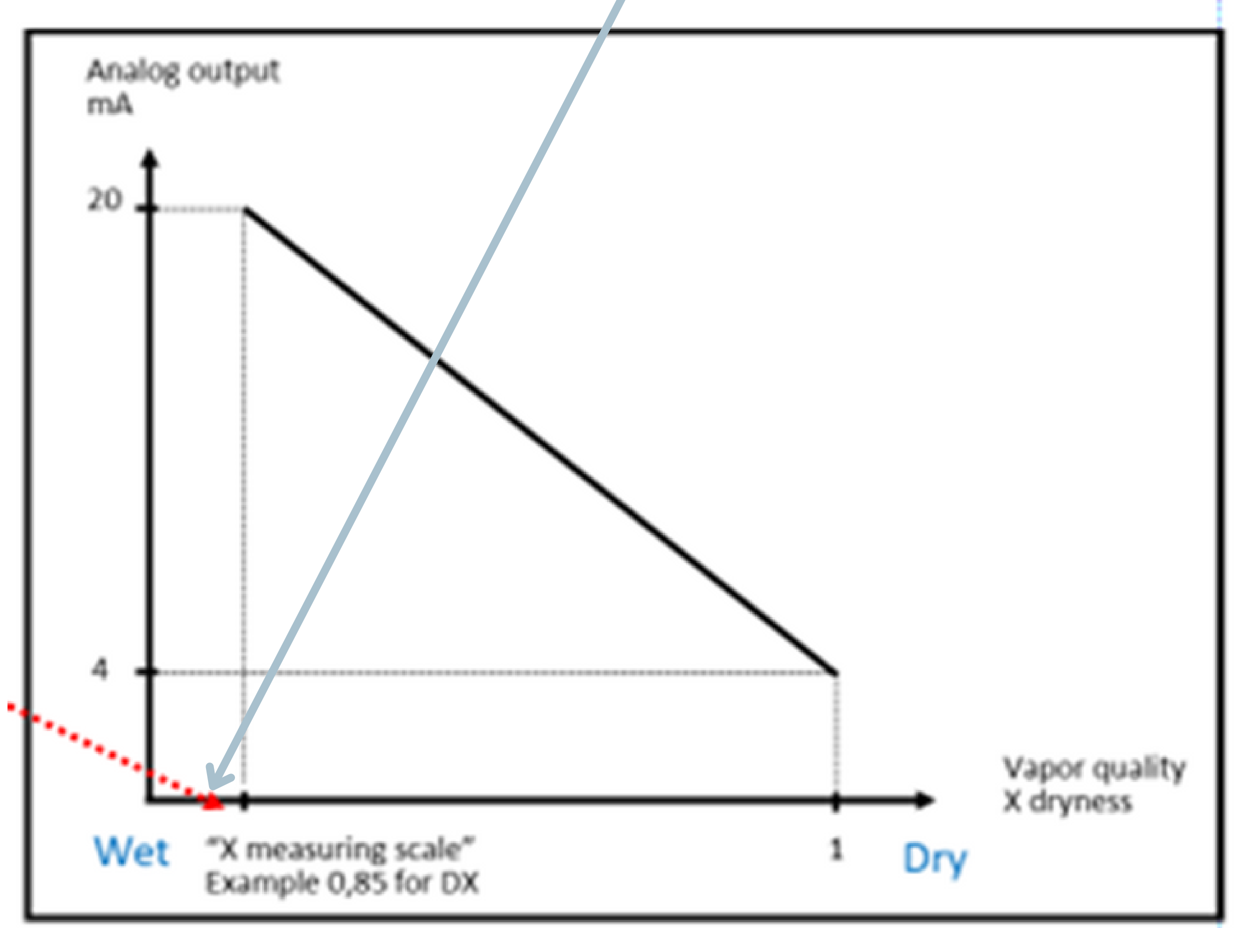


THE ANALOG OUTPUT

Dry calibration is minimum pF

SPAN is the range which must fit the scale pF





Numbers predefined by HB products in settings file

Scale is typically 0,85 for DX 0,5 for CR

The "X measuring scale" can be changed in the calibration tab

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DIFFERENT TYPES OF SENSORS WITH SAME FUNCTIONALITY

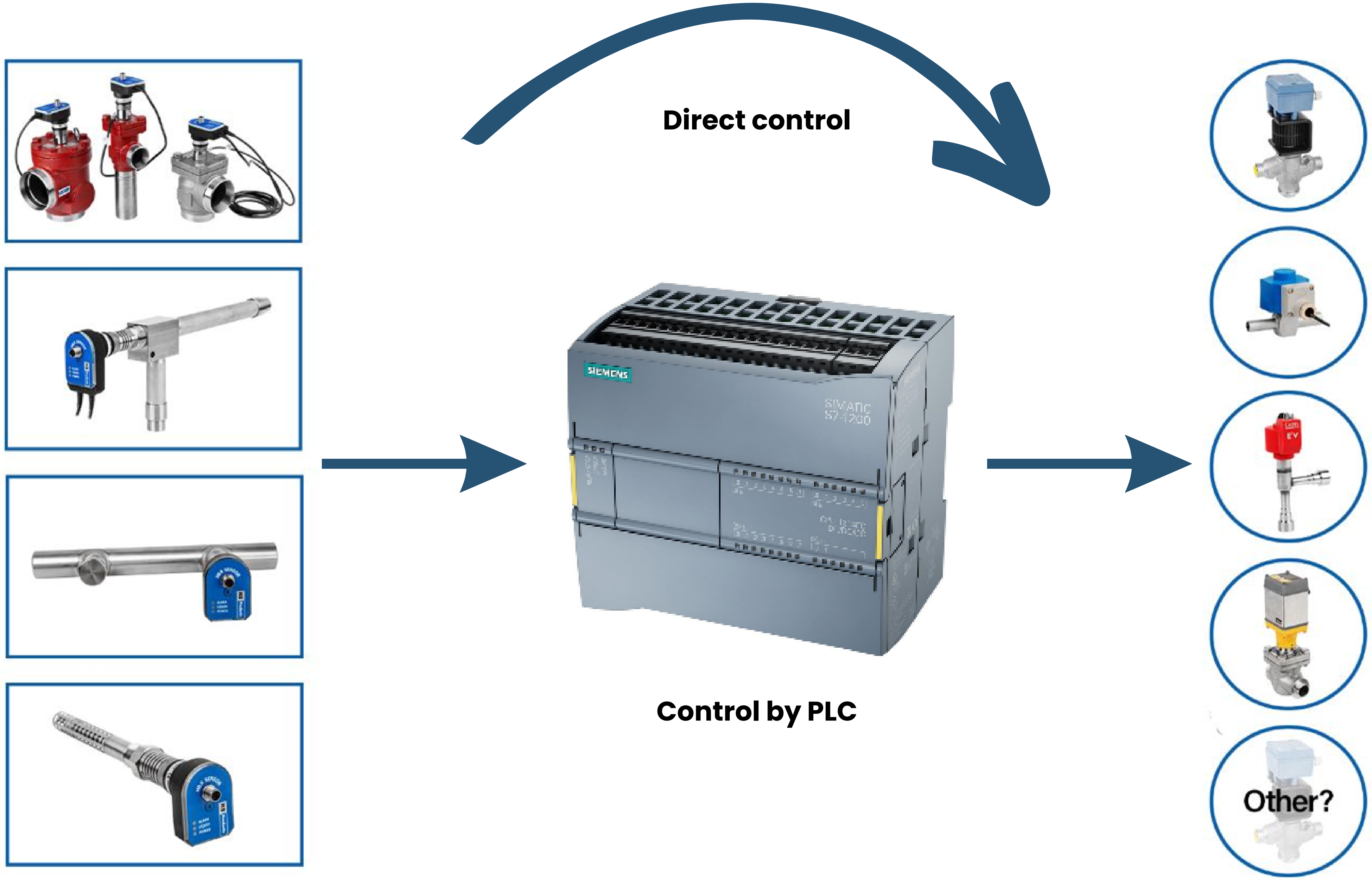
The HBX Vapor Quality Sensor comes in different versions for different pipe sizes and in both straight and elbow versions.

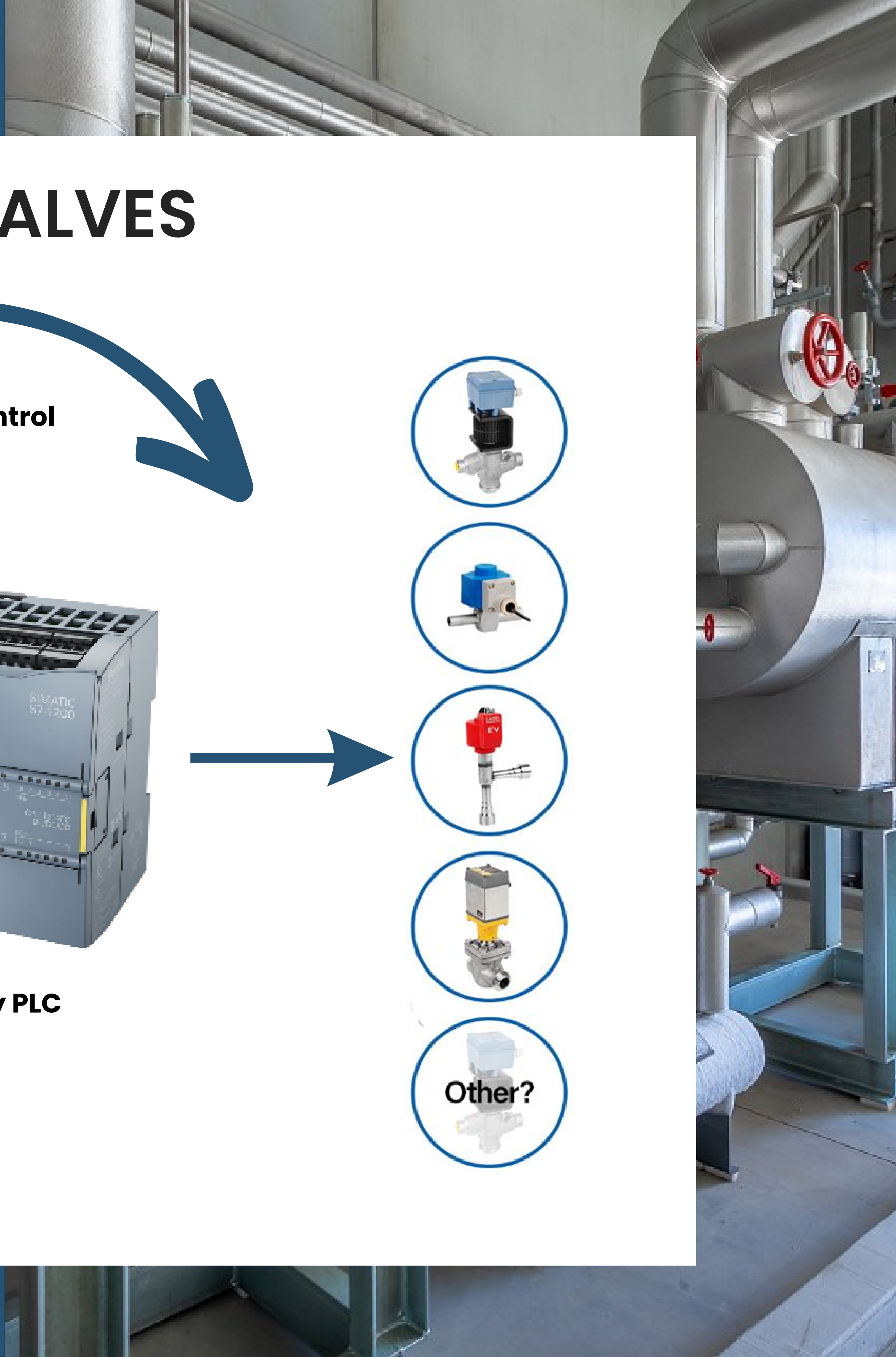
- Straight and elbow versions
- From ½” to DN300
- With or without a direct valve control cable
- With and without housing

CONTROL OF ELECTRONIC EXPANSION VALVES

The HBX Vapor Quality Sensor can deliver an analog signal for a PLC which can control an electronic expansion valve. However, the sensor has a built-in controller, which can both supply and control most expansion valves directly.

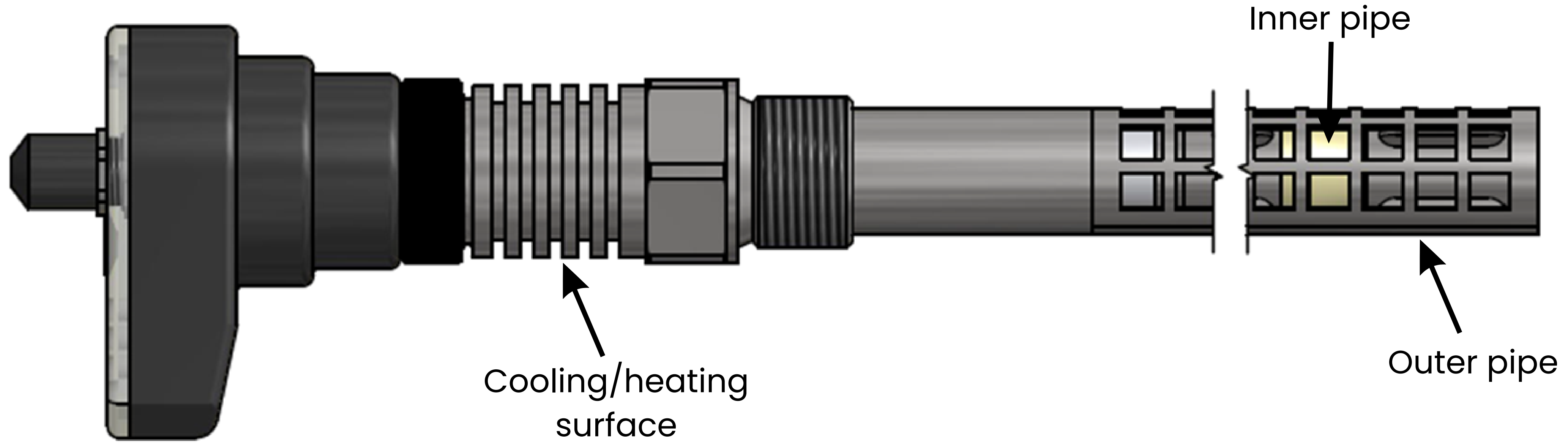
This option makes it possible to make large savings on the cabling cost and reduce the PLC programming work





THE MECHANICAL ELEMENT
– ROD STYLE TYPE

The rod-style sensor is the universal solution for many applications, but the mounting is difficult. The sensor must be installed at the bottom of a pipe to be effective as it only measures the liquid flowing between the inner and outer pipe.



Mechanical element

- PTFE used as insulator and tightening
- Stainless steel sensor element
- Measures between the inner and outer pipe
- Multi-purpose suited for all pipe dimensions

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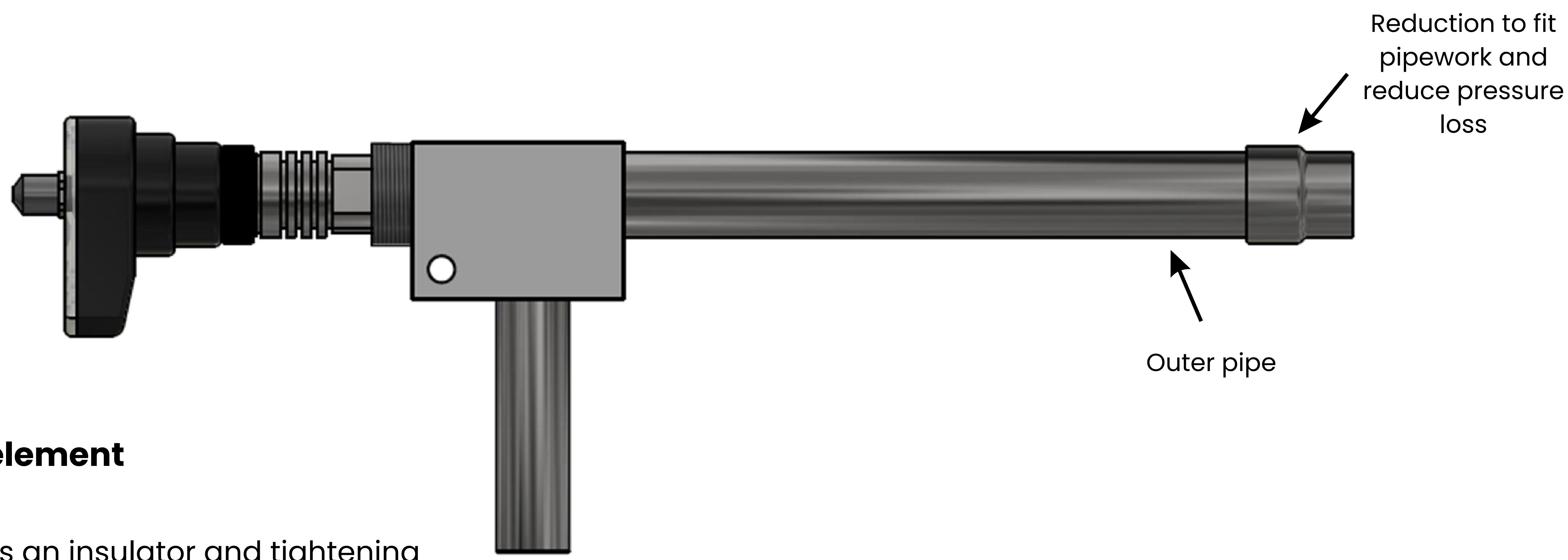
THE MECHANICAL ELEMENT
– ANGLE ROD TYPE

The angle rod version is the smallest version. The sensor comes with reductions as standard which means a larger sensor pipe is used in order to reduce the pressure loss.



Mechanical element

- PTFE used as an insulator and tightening
- Stainless steel sensor element
- Measures between an inner rod and the outer pipe surface
- Suited for CO_2
- Available from ½" to 1"

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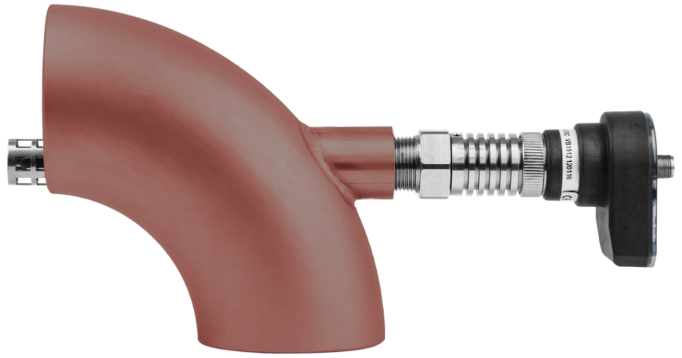
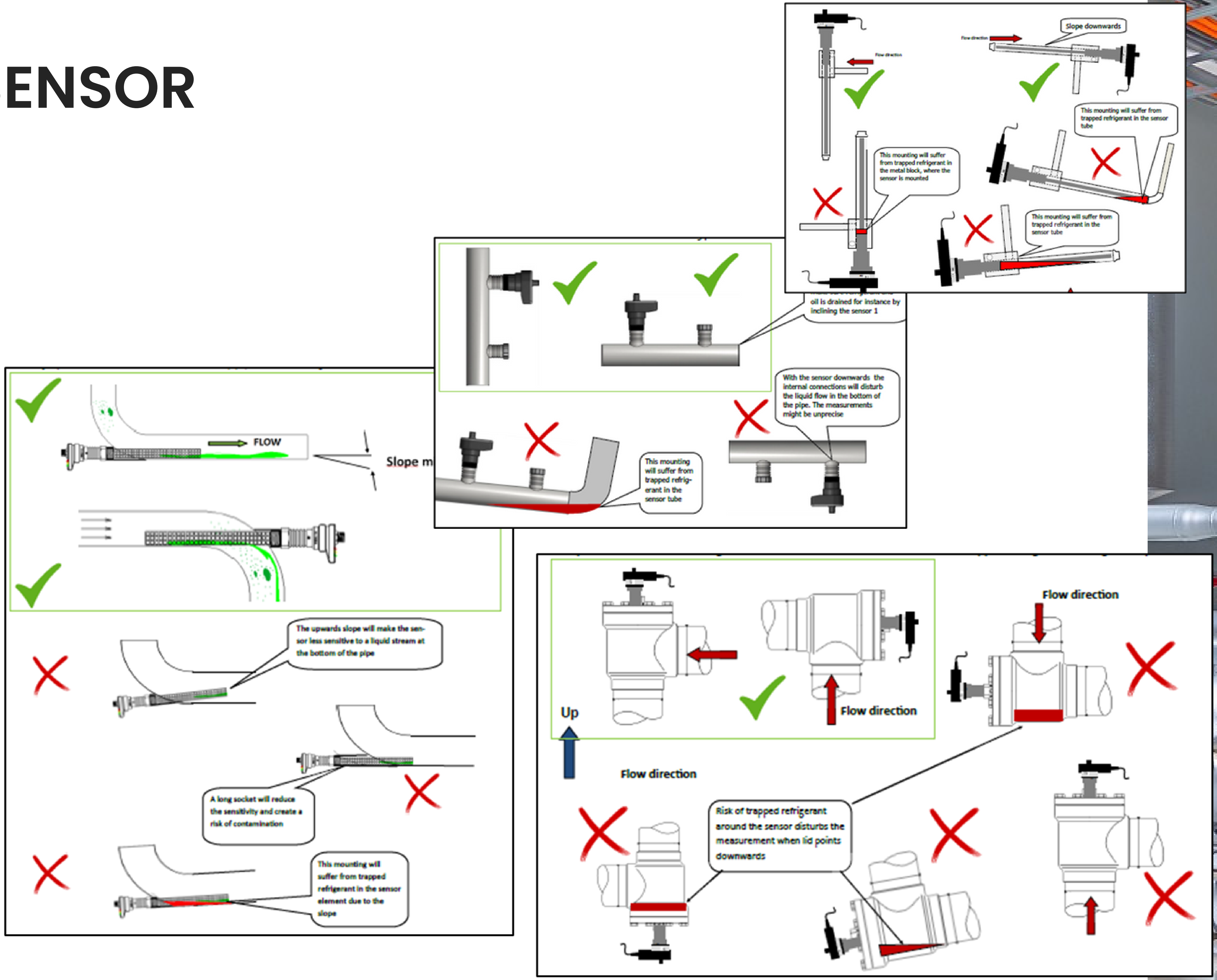
HOW TO INSTALL THE SENSOR

It is very important to install the sensor so all liquid and oil will be drained from the sensor during a stop.

If liquid is trapped in the sensor it will be disturbed during startup and startup will be difficult.

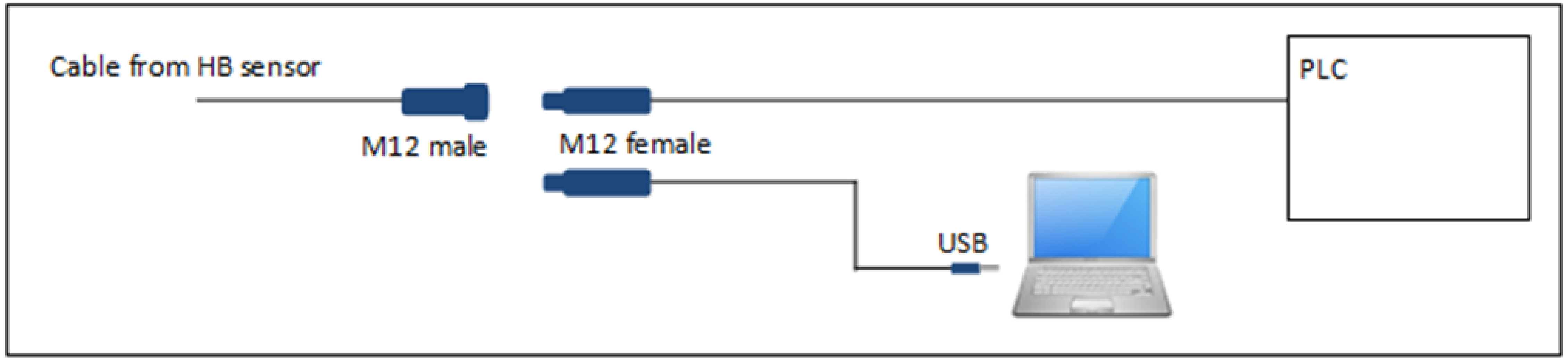
The manual describes this for all types of sensors – but it is mainly common sense and avoiding trapped liquid.





WHERE TO INSTALL

- Typically, at roof level
- At evaporator output level
- Not on the roof
- Not on top of a riser



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COP IMPROVEMENT ON DX CHILLER

46% improvement in SEPR was obtained by replacing the conventional control operating with superheat with a control based on vapor quality control. The system is a 100-kW chiller operating with R717 using direct expansion. The test was made on Hochschule Karlsruhe as a bachelor and master project.

Most chillers and heat pumps constructed as direct expansion plants use conventional control based on the temperature and pressure of the gas leaving the evaporator. An alternative to the conventional approach is to use a vapor quality sensor, which can measure the content of the liquid in the gas leaving the evaporator. When controlling the expansion valve based on the vapor quality, superheat can be eliminated and the heat transfer improved, which improves the COP.

For unique plants, it is difficult to compare the different control methods, but at Hochschule Karlsruhe, they have built and tested a chiller with the two different control systems. The chiller can be operated with both control systems and it is easy to switch between the two systems and measure the difference.

•21% COP improvement at full load
•51% COP improvement at part load

The DX chiller:
•100 kW ammonia chiller 7/12°C
•4 kg ammonia charge
•Tested at Hochschule Karlsruhe, Germany
•Designed by Fischer Kälte, Germany

COP IMPROVEMENT ON DX CHILLER

Improvement obtained by replacing superheat control by vapor quality control.

The chiller is designed with two plate heat exchangers operating as evaporator and condenser both liquid heated/cooled. The charge is 4 kg ammonia (R717) and the capacity is 100 kW. The temperature settings are made to match 2016/2281 regulation following the EU Ecodesign directive making it comparable to other chillers. The output of the chiller is 12/7 °C according to the standard. The chiller is tested at different capacities matching the SEPR (Seasonal Energy Performance Ratio) specifications both running with superheat control and with vapor quality-based control and the differences are significant. SEPR can be seen as a specific COP value, where the boundaries reflect the temperature variation over a year, making it a much better measurement.

Measured values for ammonia-based chiller					
	SEPR	Full load COP	Part load COP	unit	Yearly energy consumption
Superheat 8K control	5.6	3.9	6.9	kW/kW	91.086 kWh
Vapor Quality control	8.2	4.7	10.5	kW/kW	63.140 kWh
Improvement	46	21	51	%	27.946 kWh

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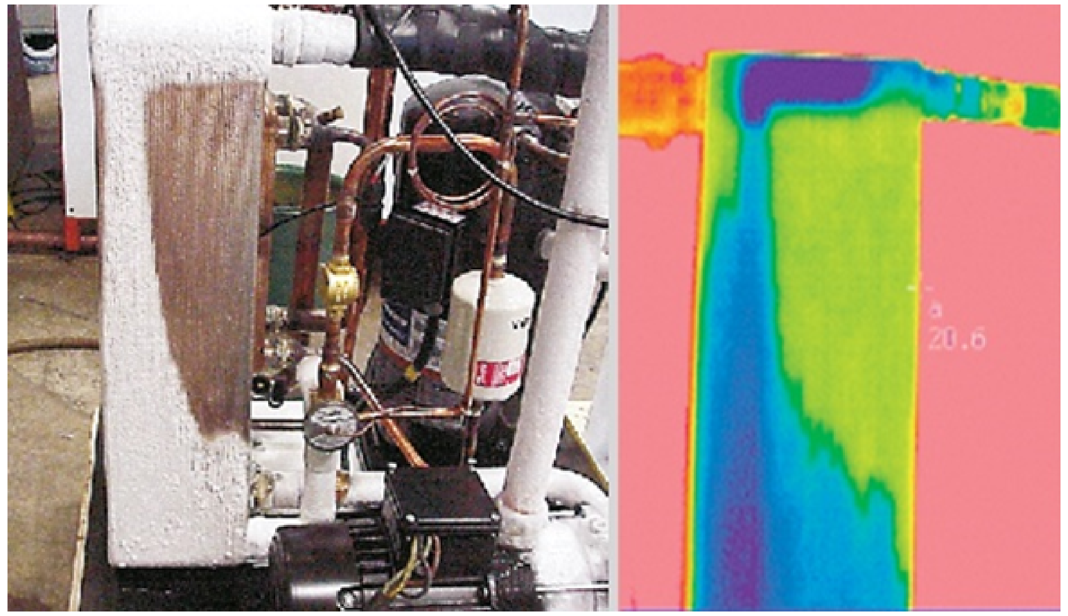
SPECIAL EVAPORATORS DESIGNED FOR DX

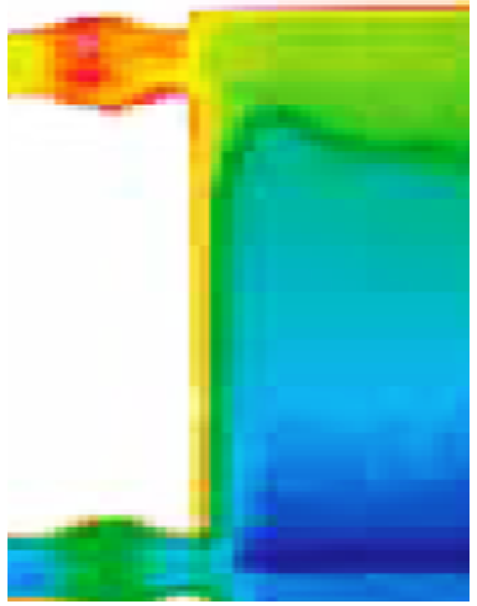
The evaporator needs to have a distributor to utilize the complete evaporator area

Ammonia has a bad reputation in connection with DX systems. This is mainly due to the challenges such as poor liquid distribution, high latent heat, water content, and oil accumulation, which can occur in a DX ammonia system. These challenges can be met by installing an optimal DX evaporator, which has a parallel flow and a distributor that makes sure the liquid is distributed evenly and secures the oil transport.

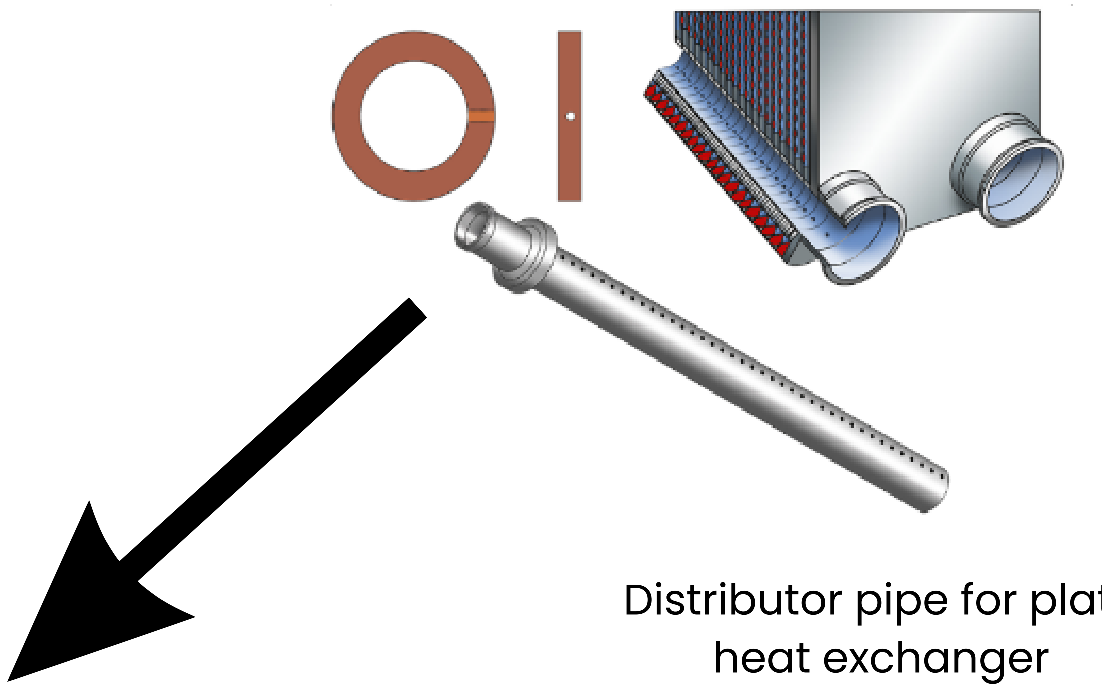
For plate heat exchangers a distributor pipe can optimize the utilization significantly. The left picture is without a distributor pipe the rig picture is when using the distributor shown to the right.



Heat distribution for heat exchanger without distributor pipe



Heat distribution for heat exchanger using a distributor pipe



Distributor pipe for plate heat exchanger

LOW CHARGE AMMONIA SYSTEMS

WITH REDUCED REGULATORY BURDENS

In some countries, the regulatory burden is a challenge if the charge is above a certain level.

•USA 5 tons
•Germany 3 tons
•France 150 kg

The DX ammonia systems typically have less than a quarter of the charge used in pump-circulated ammonia systems. This inventory reduction applies to systems using hot gas for defrosting.

Charge is reduced by at least 75 %

VAPOR QUALITY IN OVERFEED SYSTEMS

In overfeed systems, the Vapor Quality sensor is used for controlling the circulation ratio. The measurement is used to control the circulation ratio depending on the type of system. The advantage of controlling the circulation ratio is a reduced pressure loss which derives from a larger part of the heat exchanger operating in the semi-flooded area where the heat transfer is highest.

- Use the sensor for measuring the vapor quality and calculate the circulation ratio
- Control the circulation ratio
- Control of level in the separator in thermo siphon systems by controlling the pump in pump-circulated systems
- Increased COP due to reduced pressure loss

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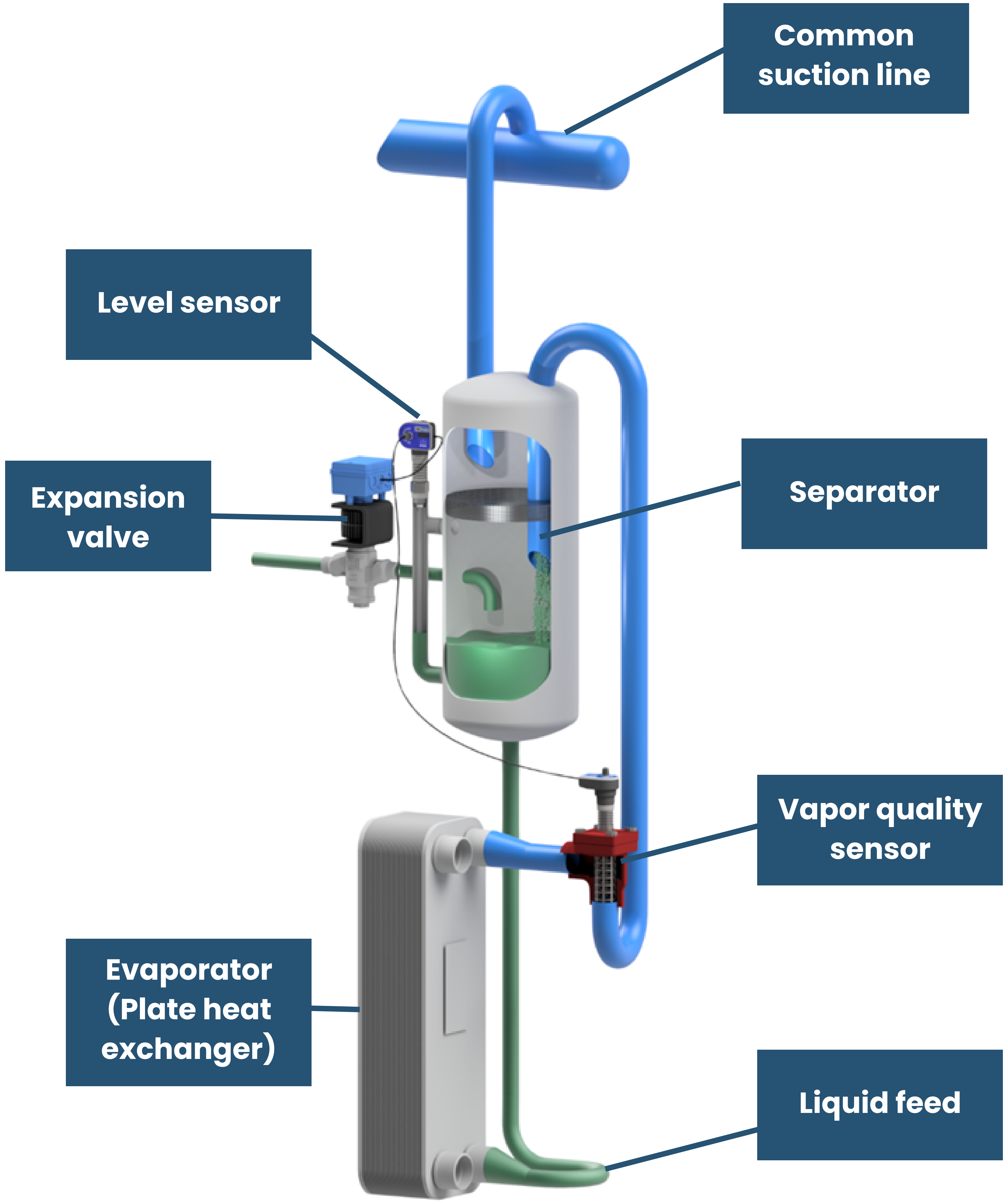
VAPOR QUALITY IN COMBINATION WITH OTHER SENSORS

In a thermosiphon system, the liquid height in the separator is used to control the flow and this type of system can be controlled effectively by a Vapor Quality sensor and a liquid level sensor.

The principle is that the Vapor Quality sensor measures the output from the heat exchanger and controls the circulation ratio via the level sensor. The level sensor controls the expansion valve and the reference is set by the Vapor Quality sensor.

- The level sensor used in combination with Vapor Quality sensor for controlling a thermosiphon system
- The Vapor Quality sensor provides a remote setpoint for the level sensor
- The level sensor controls the capacity by controlling the liquid level in the separator
- The expansion valve is controlled directly by the level sensor



CONTROLLING A BATCH PROCESS USING AN HBX VAPOR QUALITY SENSOR

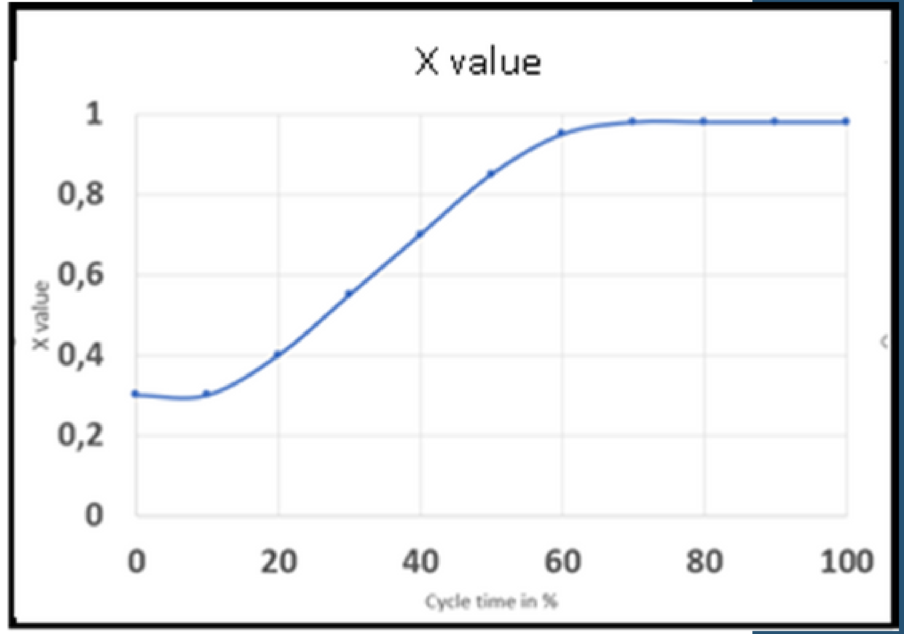
Batch processes are characterized by a cyclic load going very high to very low during a cycle. This is normally a challenge to control and results in poor performance in the last part of the cycle where the evaporator is filled up with liquid refrigerant and the pressure loss is large. If riser pipes are used, they normally start slugging which creates a large pressure loss.

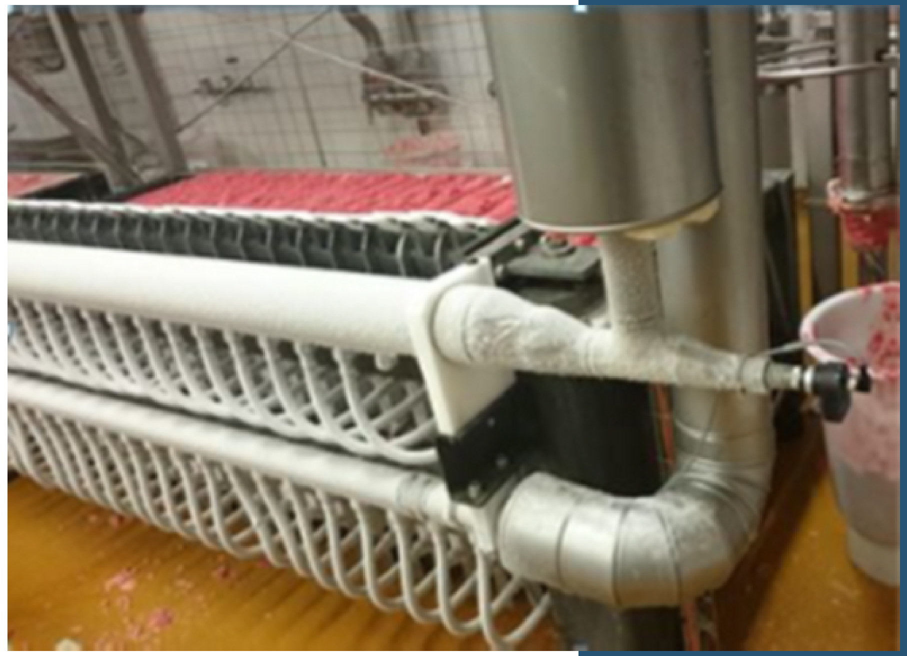
A smart way to control a batch process is to use the Vapor Quality to measure the output of the evaporator and then control the x value so it starts with an X value of 0.3 equal to a circulation ratio of 3 and then gradually increases the target for X to 0.99 equal to a circulation ratio of 1.

The control must be implemented in a PLC or similar and will increase both COP and capacity.

Starts as flooded ends as DX

- Increased capacity
- Increased COP
- No slugging in risers
- Start cycle with CR=3 and end with CR=1





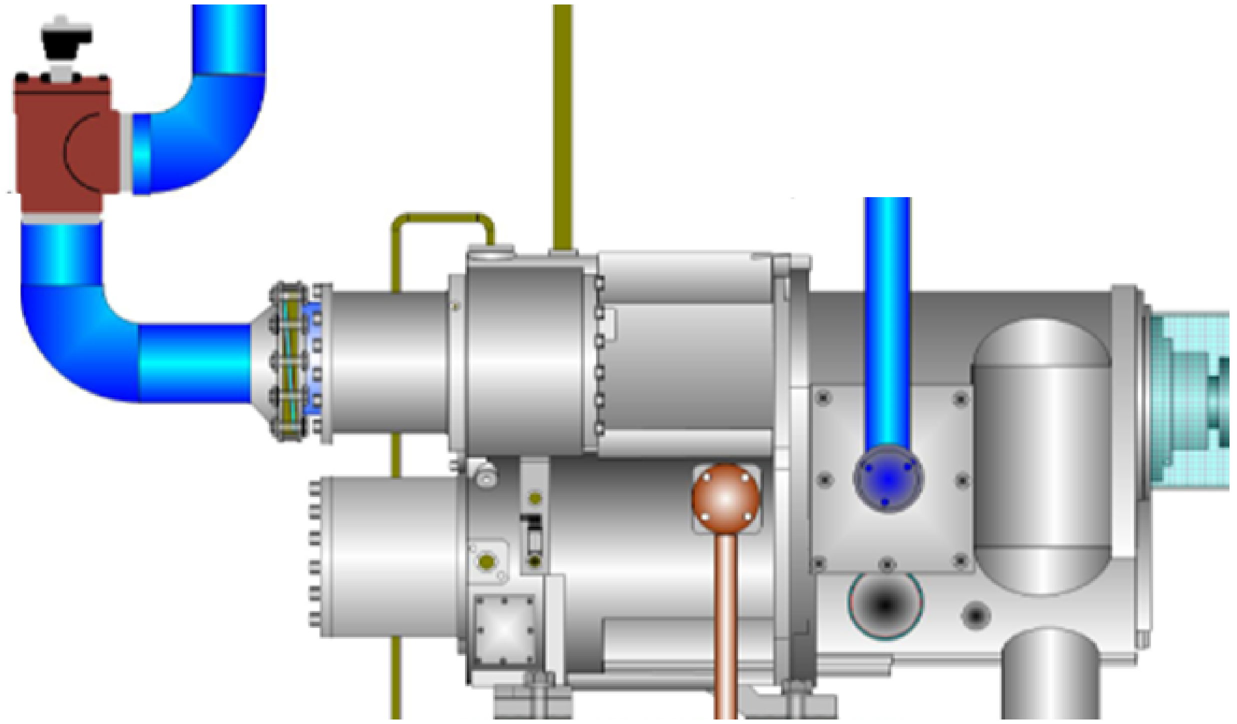
SPECIAL APPLICATIONS FOR VAPOR QUALITY

- The sensor is perfect for compressor protection by detecting liquid in the suction line before the compressor.
- It is installed on the compressor and detects liquid to prevent liquid hammering.
- Suited for large systems with multiple evaporators.

The sensor can also be used in cascade systems with ammonia and CO2 where it detects ammonia carbamate which is created when CO2 leaks into ammonia. Ammonia carbamate is the salt shown in the picture and it is very corrosive. If a plant is not stopped in time the salt formation will cause severe damage.

Compressor protection

- Detects liquid in the suction line
- Prevents liquid hammering



CO2 leakage into ammonia

- Suited for leakage detection in cascade systems with ammonia and CO2
- Can operate both as Vapor Quality sensor and as leakage alarm
- Detects ammonia carbamate

KEY SELLING POINTS

• Instant measurement of liquid in gas
• Replace superheat-based evaporator control
• 20-50% documented COP improvement for DX chiller
• Direct expansion valve control possible
• Split design electronic head can be replaced without evacuating the system
• Suited for aggressive liquids like ammonia
• No moving parts

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IF YOU LIKE MORE INFORMATION, FIND OUR INSTRUCTION MANUALS AND PRODUCT SPECIFICATIONS AVAILABLE ON OUR WEBSITE

WWW.HBPRODUCTS.DK

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