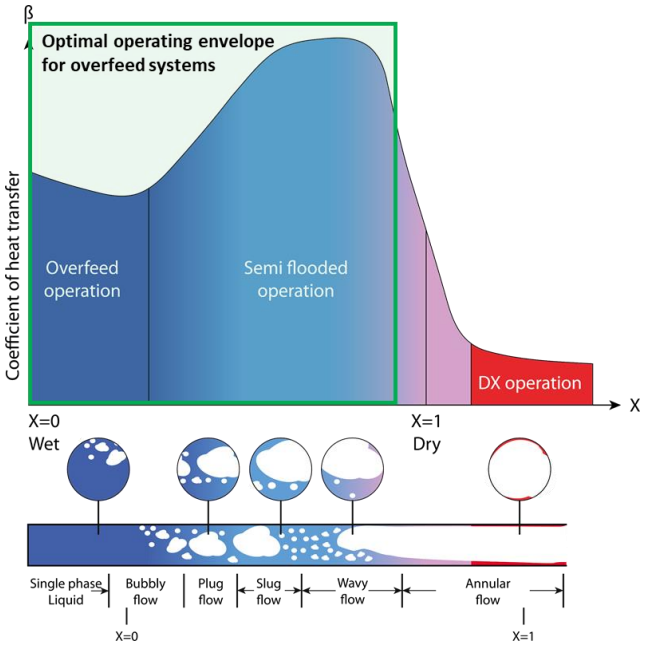
Optimizing an overfeed system using the HBX Vapor Quality Sensor

In overfeed systems it is possible to control the circulation ratio and secure an optimal heat transfer in the evaporator. The optimization is done by making sure to operate in the green envelope shown in the figure. It is important to keep a little liquid of liquid in the outlet and make sure not to get into the superheat area shown as red and purple, characterized by a poor heat transfer.

The evaporator should operate with X values from 0 to 0.9 depending on the evaporator design. Classic evaporators designed for pump circulated liquid might not have a distribution, which allows them to reach X=0.9 equal to CR=1.1 without part of the evaporator operating in superheat and they should be kept down to X= 0.7 equal to CR=1.5. More optimal evaporators can go all the way to X=0.9 equal to CR=1.1 and benefit from the high heat transfer.



How to get high energy efficiency

To get a high energy efficiency and high capacity it is important to keep the circulation rate constant and as low as possible to benefit from the high coefficient of heat transfer obtained above X=0.5 equal to CR=2. When the cooling demand is reduced the pump capacity have to be reduced, to maintain a low circulation ratio, otherwise the coefficient of heat transfer will drop and the pressure loss increase. Another factor is that the transport of a large amount of liquid back to the separator has a further cost of more energy used by the pumps and increased pressure loss.

The vapor quality sensor measures the liquid content.

The HBX Vapor Quality Sensor can measure the content of liquid in a gas flowing through the sensor. The measurement is instant and perfect for controlling an evaporator. The sensor uses the capacitive measurement principle and provide an output linear to the volumetric percentage of gas in a liquid gas mixture.

The signal from the sensor is used for controlling the liquid flow to the evaporator. This done by controlling pump capacity in pump circulated systems or the separator level in thermosiphon systems.

The Vapor Quality Sensor provides an analog signal, 20 mA when the gas is wet and 4 mA when it is completely dry. This signal can be used in a PLC for controlling the liquid flow and maintaining the optimal X value /circulation ratio typically around 0.7 to 0.9 equal to CR between 0.5 to 0.9.

The sensor also has a build in controller which means it is possible to both supply and control a liquid valve directly. This feature can reduce the cabling cost and make the programming of the PLC simpler.

Controlling flooded systems

In flooded systems without pump circulation like thermosiphon systems it is possible to use the vapor quality sensor signal as input to a level sensor controlling the level of liquid in the separator and thereby the flow rate through the evaporator.

The level sensor can then control an expansion valve either directly like it is shown in the figure or by using a PLC.

Where to install the sensor

The Vapor Quality Sensor must be placed immediately after the evaporator to avoid liquid built-up between the evaporator and the sensor. Some customers have installed the sensor at the top of a riser pipe, but that is far from optimal. They typically end up in a situation at low load where liquid built up in the riser pipe and does not reach sensor. This means the sensor measures dry gas and increase the liquid feed. The result is that the evaporator fills with liquid and the process stops with an error.

The conclusion is that the Vapor Quality Sensor must be as close to the evaporator as possible and the position on top of a riser only works for very stable processes where the Vapor Quality Sensor bring less value.

Oil flow through the sensor

The sensor will measure both the oil and the liquid. The impact of oil depends on the refrigerant. For ammonia systems it is not a problem due to limited oil amounts and for synthetic refrigerants the dielectric constant of oil is only half of the dielectric constant of refrigerant, but it still disturbs the measurement. However, oil will normally not be a problem for an overfeed system – only in the case that the gas gets dry it might be a concern and only in systems without an oil separator.

Typical benefits

The potential saving obtained by using a vapor quality measurement depends a lot in the system and the circulation rate is used. The largest benefit is obtained if the current circulation rate is high and not controlled during part load. Typical energy saving is 10 % or more. For systems with high CR numbers and cyclic loads or other types of part load operation the saving will be significantly larger. During part load it will not only be possible to reduce energy consumption the capacity will be increased as well.

Batch processes or other cyclic loads

If the cooling capacity is reduced it is important to reduce the circulation rate to avoid filling up the evaporator with liquid and with provide a lot of losses. A way to control a batch process is to move from overfeed in the high-capacity situation and ending the cycle in low-capacity in DX mode. Read more about this solution here: https://www.hbproducts.dk/en/knowledge/case-studies-and-articles/731-batch-freezing