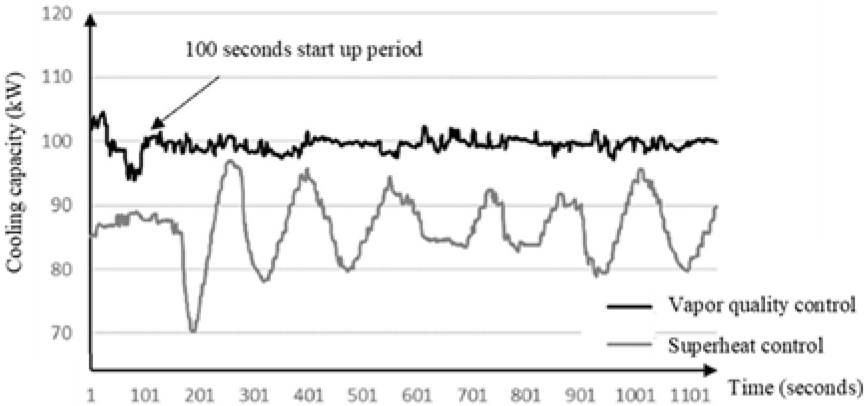
Controlling and optimizing a DX plant using the HBX Vapor Quality Sensor

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.



In direct expansion systems it is possible to replace the conventional superheat control by a vapor quality-based control. The vapor quality control has a significantly faster reaction time than a superheat control and this makes it possible to increase the capacity of a system without the risk of liquid hammering.

The graph shows that the variations in capacity are larger for the superheat control due to the relatively slow feedback from a temperature sensor used in superheat control. The Vapor Quality Sensor provides instant feedback and allows for frequent small actions.

The consequence is that for systems with frequent changes in capacity and a primarily part load operation the benefit is large, whereas for stabile systems the benefits are smaller when shifting to vapor quality control.

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 expansion valve and maintaining an X value typically around 0.985 which means 1.5 vol % liquid in the gas. This will secure dry gas reaching the compressor and a superheat around 2K.

The sensor has a build in controller which means it is possible to both supply and control the electronic expansion valve directly.

Start up

The superheat-based system typically has a starting program which opens the expansion valve to get the process started. The same behavior must be copied into the sensor. The built-in controller has a startup function called “Dry out function” which is in operation for a specified period after the run-in signal is applied. The run-in signal should be applied when the compressor starts. The reason for this functionality is that the Vapor Quality Sensor cannot provide any feedback before some liquid reach the sensor.

The startup process will be very different from system to system. Heat pumps typically need a lot of liquid to start up because the evaporator is hot after a stop and if the valve is not opened quickly the system will stop due to low pressure. Chillers with plate heat exchangers also need a relatively large amount of refrigerant to get started as the evaporator is relatively warm and has a lot of heating capacity. Normal refrigeration systems, where the evaporator is placed in a cold room, requires a softer startup, and do not need fast ramp up.

How to optimize evaporator control

The sensor has a filter time/integration time function which effects the analog output. This function also applies to the analog output even when the sensor operates in sensor mode. This filter time needs to be configured so it matches the dynamics of the system. If the system is slow you can set the filter time to 10-20 seconds whereas if you need to act fast it is better to set it low in the range from 0 to 10 seconds.

If you have a system with superheat control and you want to replace it with vapor quality control, you can start by monitoring the vapor quality to get familiar with the operation of the system. This is done in this way:

1. Connect the sensor to a pc where you have installed the HB-tool. (as described in the manual)
2. Check the zero calibration of the sensor and make a new calibration if it is off. (this is described in the manual)
3. Monitor the “Actual measurement in X” value calculated by the sensor - you find the value displayed under the calibration tab. This value will typically be 1 most of the time which indicate the superheat is higher than needed. You can also connect a measuring device to the analog output and track the output over a longer period.
4. Monitor the behavior of the control system. Pay special attention to how fast the expansion valve opens and how the X value vary especially during a startup situation.

Based on the observations you need either to set up the parameters in the controller in the sensor with values that match the observations or do the same thing in the PLC. Especially you need to pay attention to the startup procedure, so you are getting the process started in the best way.

The target for the X value is called “Degree of dryness “X”” and this value determines the liquid content in the gas and a good starting point would be 0.99.

There is a setting in the sensor called “Alarm setting in “X”” this is a safety function which can stop the system quickly if liquid is detected. If you use the controller in the sensor you need to consider where to set up this parameter. If you have a fast and lively system with a separator between the evaporator and the compressor, or a compressor type which tolerates some liquid you can set the value low which means 0.8. If you have a stabile system and no separator it should be set to 0.9.

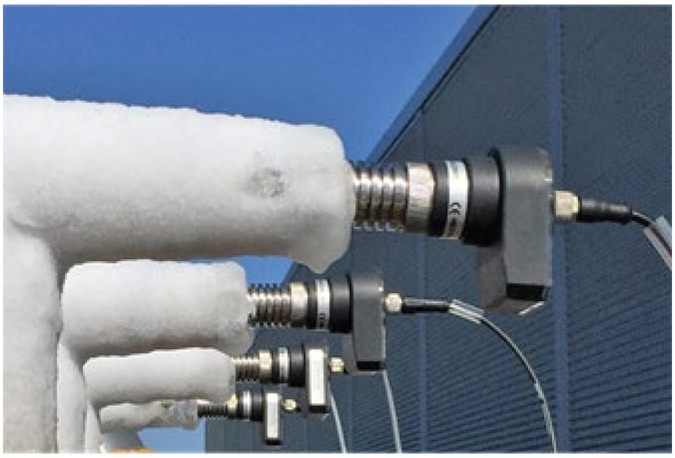
When all parameters have been set you connect the sensor to a power supply or the PLC and start the system. Make sure to provide a run-in signal if you use the built-in controller.

Then you can normally observe the superheat and see if you are satisfied. If not, you can connect the PC again and reduce the target “Degree of dryness “X”” gradually until you are satisfied. Systems are different but normally it should be possible to reach 2K in superheat.

Challenges

Oil flow through the sensor

The sensor will measure both the oil and the liquid. The impact of oil is smaller, because the dielectric constant of oil is only half of the dielectric constant of refrigerant, but it still disturbs the measurement. This means, if you maintain a constant flow of oil through the sensor and make a zero calibration with oil flow through the sensor you can measure the amount of liquid. If your flow varies a lot then your measurement will be unprecise. The best solution is to use an oil separator and reduce the oil flow.



When the sensor is used in gas containing oil you must make sure to have sufficient drainage from the sensor, so no oil gets trapped.

At our office and production building here at HB Products we have a small 20 kW heat pump in house operating on HFC gas and controlled by a Vapor Quality Sensor. In this system we have installed an oil separator to get an accurate measurement.

After the installation of the Vapor Quality Sensor we gained 11 % higher output and 18 % better COP compared to the superheat control. Some of the benefits could probably be due to a cleaner evaporator which works better and the fact that you do not need to have the oil in the evaporator- but of course a separator does not come for free.

Do not install after risers

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 can create a problem. 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 opens the expansion valve. The result is that the evaporator fills with liquid and the process stops with an error.

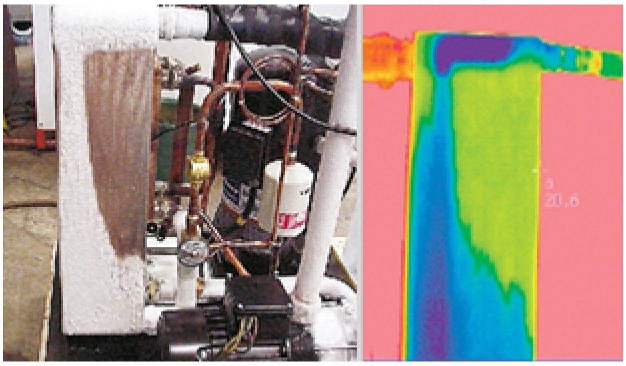
The conclusion is that the Vapor Quality Sensor must be as close to the evaporator as possible and the position on top of a riser only works for very stable processes were the Vapor Quality Sensor bring small value.

Heat pumps - get the startup sequence right

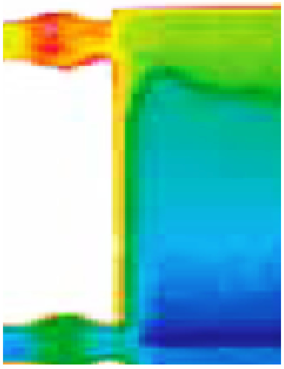
Heat pumps operate with hot evaporators and need a lot of liquid after a stop to get the process going and avoid stops due to low suction pressure on the compressor. You need to study the startup process carefully to get the right startup sequence. A challenge in this context is that the starting procedure might need to be different from summer to winter due to the temperature of the evaporator.

Evaporator design

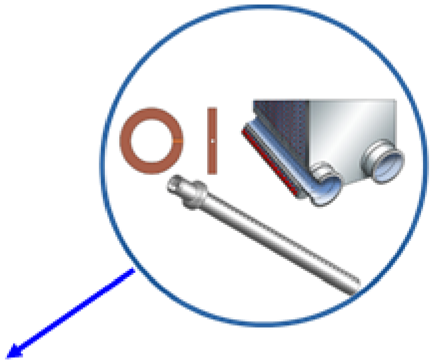
To benefit from the vapor quality control the evaporator must be designed for a DX-system. This means the evaporator has parallel flows and a distributer which ensures that all the parallel flows have the same load. For plate heat exchangers a distributer pipe is needed and for air cooled evaporators a suited distributer is needed. If the evaporator does not have a distributer the capacity will be lower. And if the heat exchanger does not have a parallel flow the pressure loss will be to large.



Heat distribution for heat exchanger without distributor pipe



Heat distribution for heat exchanger using a distributor pipe



Distributor pipe for plate heat exchanger

Typical benefits

When superheat control is replaced by vapor quality control there are typically a saving in energy of 10 % and an increase in capacity of 10 %. Systems with frequency-controlled compressors typically has a larger saving, when operating in part load. We have a show case with a 100 kW DX ammonia chiller a saving of 51 % was obtained in part load.