Dimensioning mass flow in hot gas defrost lines

Using Coolselector®2

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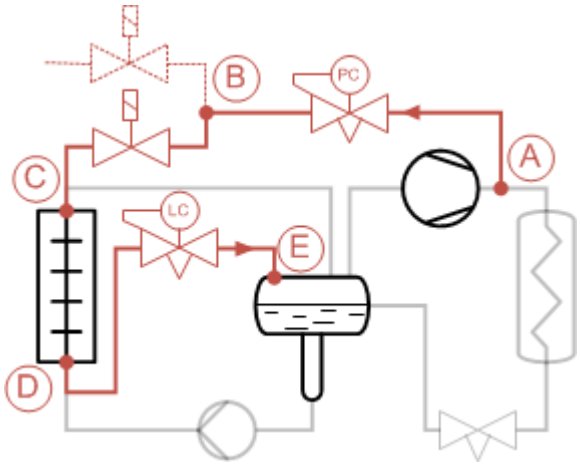
Determining the dimensioning mass flow required for selecting the right pipes, fittings and components in hot gas defrost lines in Coolselector2.

1 Introduction

Hot gas defrost calculations in Coolselector®2 are implemented for pump and gravity systems, i.e. systems where there is typically more than one evaporator.

Coolselector®2 supports 3 different types of hot gas defrost lines:

1. **Main hot gas defrost line**. Line that runs from compressor discharge to distribution point where line is split into separate lines for each evaporator (from A to B in diagram below).
2. **Hot gas defrost line**. Hot gas defrost supply line to each evaporator (from B to C in diagram below).
3. **Hot gas defrost drain line**. Line out of evaporator and back to separator (from D to E in diagram below).



The main functionality included in the three lines is often:

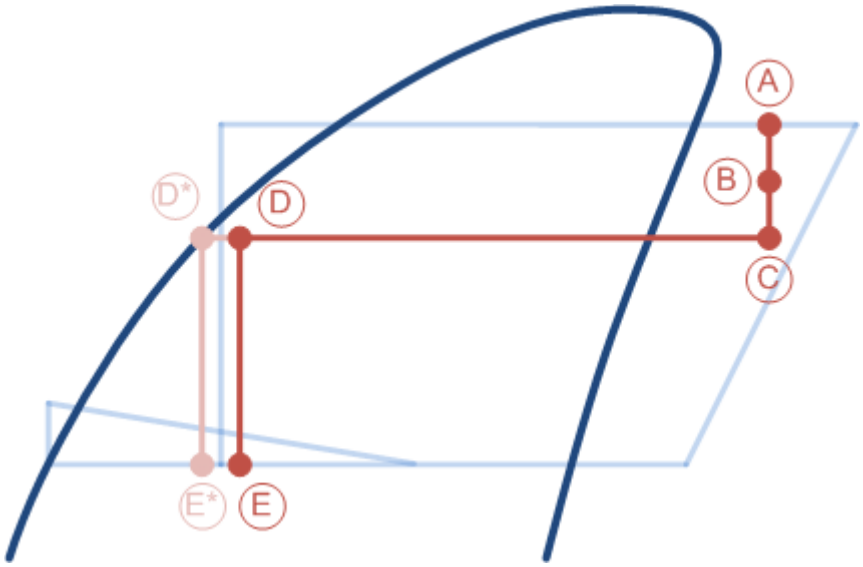
1. The main hot gas line is equipped with a control valve (ICS + CVC pilot) keeping the supply pressure at point B constant (“regulated hot gas”).
2. The hot gas defrost line is equipped with a solenoid valve, enabling start/stop of hot gas to the evaporator.
3. The defrost drain line is equipped with either:
    a. A control valve (ICS + CVP pilot) keeping the defrost pressure constant – this is called “Pressure controlled drain”
    b. A float valve, which simply lets condensed liquid generated during defrost back to the separator – this is called “Liquid drain”

2 Inputs

To define the condition of the hot gas used for defrost the following inputs are needed:

- **Condensing temperature**. The condensing temperature determines the pressure in point A in diagram below
- **Main hot gas supply temperature**. The temperature in point A. It can be equal to the compressor discharge temperature, but normally it is somewhat reduced due to heat loss from the discharge line.
- **Reduced hot gas supply pressure**. The pressure (or saturation temperature) corresponding to point B. This pressure is equal to the set point of the control valve in the main hot gas line.
- **Defrost pressure**. The pressure (or saturation temperature) corresponding to point D. This pressure is equal to the set point of the control valve (for pressure controlled drain) in the defrost drain line.
- **Dimensioning quality**. This will be treated separately below, but it is used to determine the density of the refrigerant flowing into the components placed in the defrost drain line – i.e. the dimensioning quality determines the position of point D.
- **Evaporating temperature**. The evaporating temperature determines the pressure in point E

The location of the points is illustrated in the following log(p)-h diagram:



Note: The pressure in point C is not defined. It is calculated based on components selected in to the hot gas defrost line. Point C is illustrated as having same pressure as point D above, but that is not automatically the case.

Note: For liquid drain, the pressure in point D still needs to be defined (even though the pressure is not actually controlled). For liquid drain, the pressure in point D will in reality be a function of valves in the hot gas defrost line and the evaporator pressure drop. But for dimensioning purposes, a reasonable value a few degrees lower than point B will be sufficient.

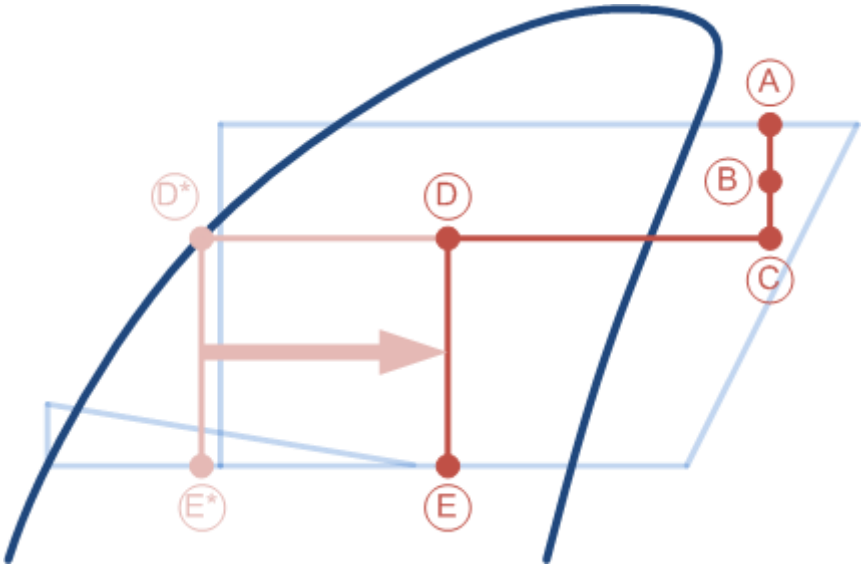
2.1 Dimensioning quality

The dimensioning quality is used to determine position of point D at the inlet to the defrost drain line.

The term “quality” is a measure of the mass of gas compared to the total mass of refrigerant.

The dimensioning quality will be quite different based on the drain control method you select:

- For liquid drain the dimensioning quality should always be 0.0 – i.e. the refrigerant in point D is saturated liquid. The function – or the purpose – of a float valve in the defrost drain line is exactly to avoid (as far as possible) gas to pass through the float valve, but only let liquid pass through.
- For pressure controlled drain, the defrost process will be quite different. Initially, all hot gas supplied to the evaporator will condense and the valve will only see liquid at the inlet. Later in the process, some gas will not condense in the evaporator and the valve will see a mixture of liquid and gas. This process is illustrated below (from D* to D):



Selecting the right dimensioning quality for pressure controlled drain is very important for selecting the right valve size:

- If a dimensioning quality of 0.0 is selected (saturated liquid) then the resulting valve will be relatively small, which could mean that defrost will be prolonged at the end of the defrost cycle (gas cannot efficiently be passed through the valve)
- If a dimensioning quality of 1.0 is selected (saturated gas) then the resulting valve will be relatively large, meaning that a lot of gas will be bypassed (equals larger energy consumption), plus the valve can become unstable when pure liquid enters the valve in beginning of the defrost cycle.

In Coolselector®2 we recommend using a relatively low value of dimensioning quality equal to 0.05. This ensures that the valve is stable when liquid enters it and that the amount of bypassed gas is minimized.

2.2 Dimensioning capacity

Determining the hot gas capacity in the defrost lines is a question of defining the necessary hot gas mass flow in the selected line.

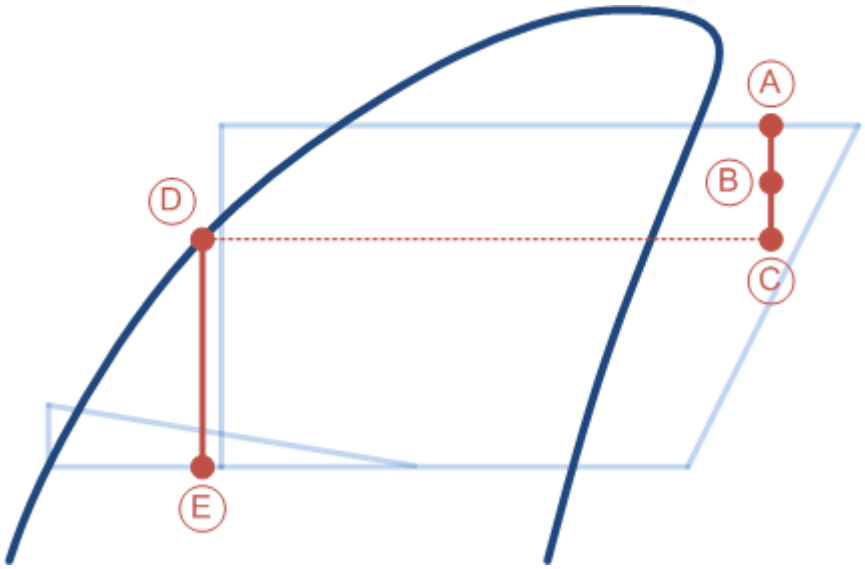
Normally some rules of thumb are used, which relates to the dimensioning cooling capacity of the evaporator (or evaporators) the selected hot gas line connects to.

In Coolselector®2 the following equation for determining the hot gas mass flow is used:

$$\dot{m}_{hot\,gas} = Defrost\ capacity\ factor \cdot \frac{Dimensioning\ cooling\ capacity}{Defrost\ enthalpy\ difference}$$

The *Dimensioning cooling capacity* is the cooling capacity of the evaporator(s) being defrosted. This value indirectly tells the size of the evaporator.

The *Defrost enthalpy difference* equals the energy content of the hot gas – it is equal to the enthalpy difference between point C and D in the diagram below:



The *Defrost capacity factor* is a value selected based on experience. A default value of 2.0 is used in Coolselector®2 but it is normally chosen between 1 and 3.

The larger *Defrost capacity factor* the larger the valves will be, and the shorter the defrost time will be. The smaller *Defrost capacity factor* the smaller the valves will be, and the longer the defrost time will be.

In general, you can say that the penalty of choosing too small valves is a longer defrost time.

Note: the equation above is also used when dimensioning the main hot gas defrost line. In this case, the dimensioning cooling capacity is the sum of the cooling capacity of the evaporators, which will be defrosted simultaneously.

3 Pressure in evaporator during defrost

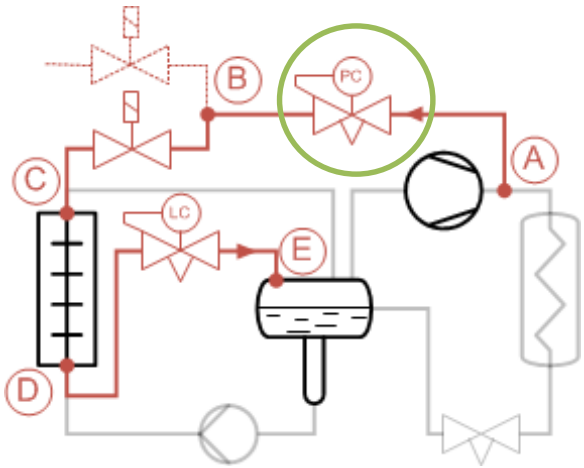
If the hot gas supply is coming directly from the compressor discharge, then there is a risk of the pressure in the evaporator raising to condensing pressure. This might be a problem if the evaporator is not dimensioned for high pressure.

If a pressure controlled drain valve is selected using a dimensioning quality of 0.05, then the pressure inside the evaporator can rise to condensing pressure at the end of the defrost process. Simply because the capacity of the pressure controlled drain valve will be too low to allow all uncondensed gas to pass.

For a float controlled drain valve, the pressure will always approach condensing pressure at the end of the defrost process if there is no valve to reduce the hot gas pressure.

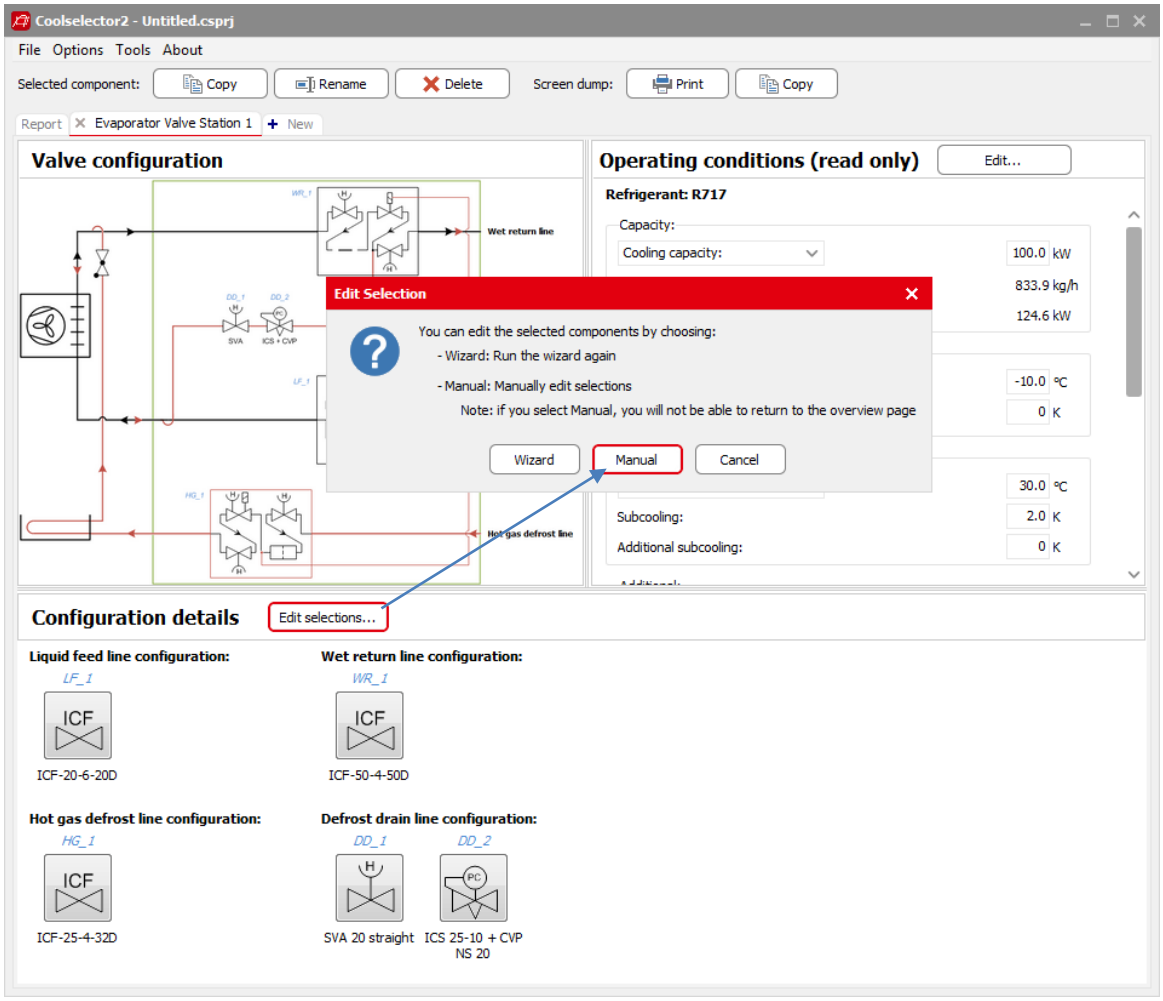
If a pressure controlled drain valve on the other hand is selected using a high value for the dimensioning quality, then this valve will have a capacity high enough to let the uncondensed gas pass, but it will:
- operate unstable in the beginning of the defrost process
- be associated with substantial energy losses (bypassed gas is essentially a loss)

If condensing pressure is not allowed in the evaporator, then the solution for both pressure controlled and float controlled drain valve is to install a valve to reduce the hot gas pressure as shown in the PI diagram:

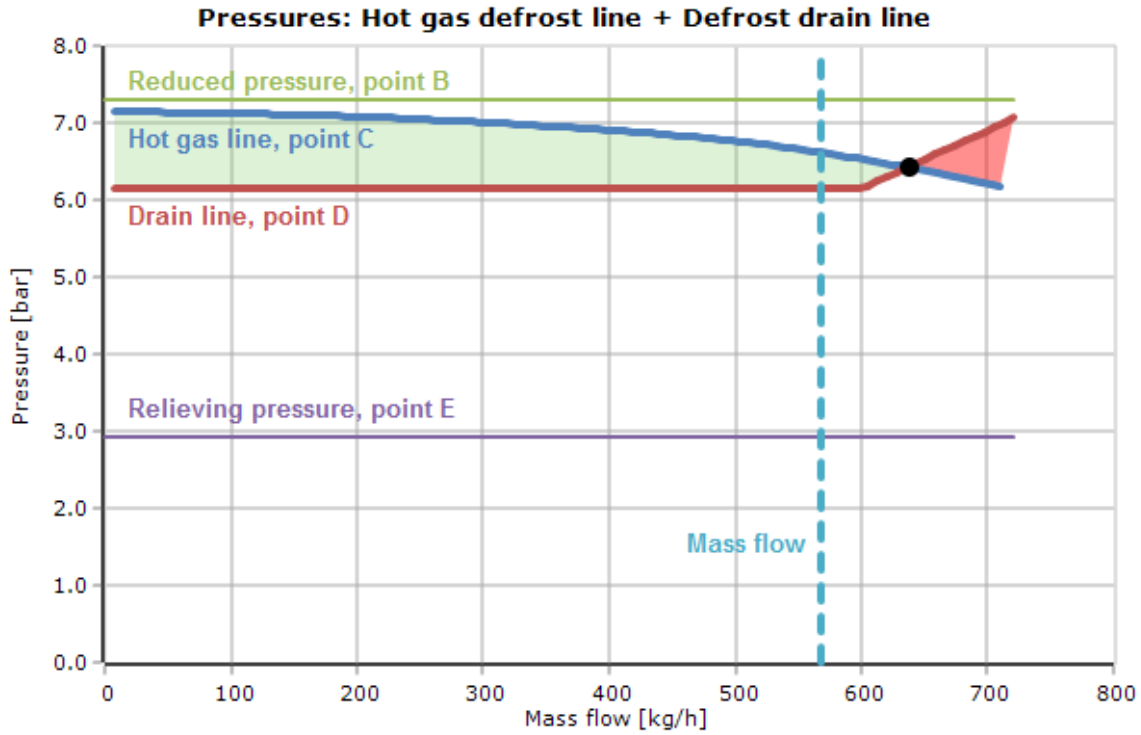


4 Defrost pressure graph

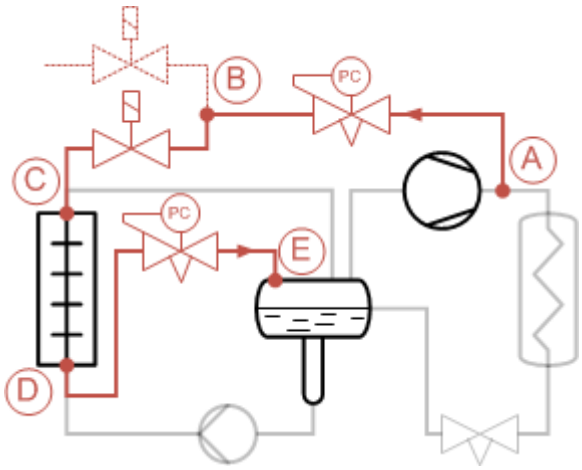
When you select the Evaporator Valve Station application in Coolselector2, you will be able to (when the selection is done) switch to manual mode:



In Manual mode you will be able to change the components in the 4 lines as you want, but you will not be able to return to the overview page. Also in manual mode, you will be able to review the selections you've made in detail using the Defrost pressure graph:



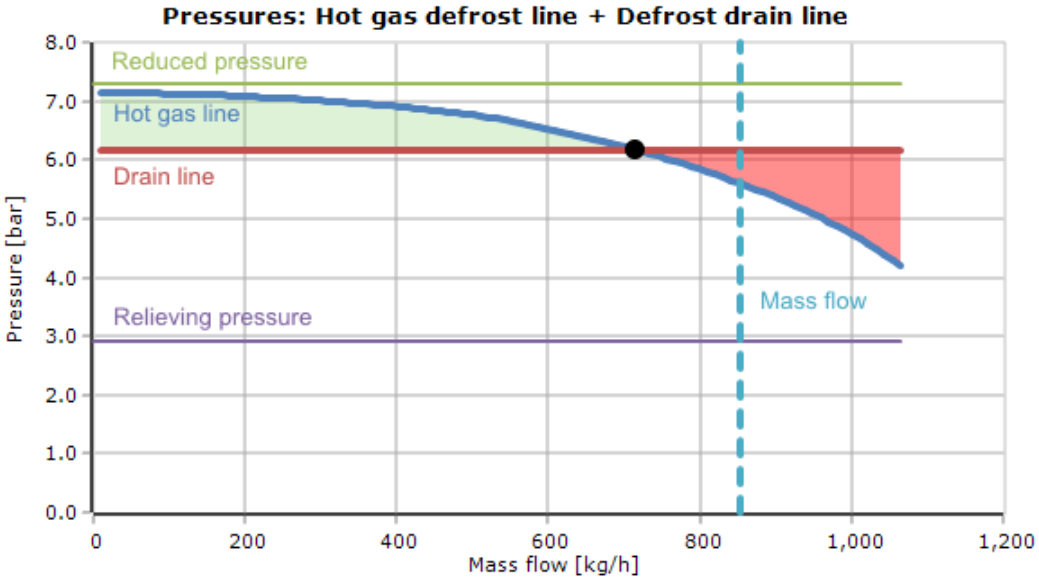
The Defrost pressure graph shows a combination of the pressure at the end of the hot gas line (point C), and the pressure at the beginning of the drain line (point D):



If you haven't added components to the end of the hot gas line which simulate the pressure drop in the evaporator, then the curves show the pressures at the evaporator inlet and the evaporator outlet. The difference between the two lines then illustrate the pressure drop available for the evaporator.

In the example above, the design mass flow (drawn as a vertical dotted line) is selected so that there is about 0.4 bar left for the evaporator (the difference between the two curves)

If you include the evaporator in the hot gas line (for example by adding a constant Δp or a pipe component), then the mass flow should be selected so that it approximately crosses the curves where they cross each other – as illustrated by the black dot below:

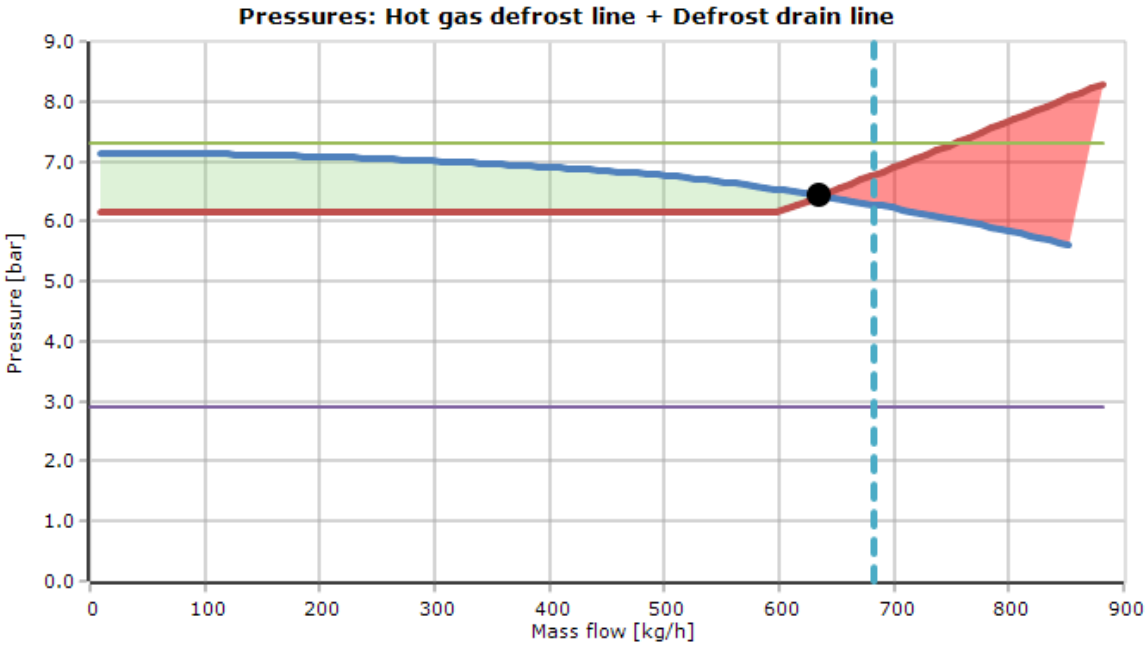


If you select the mass flow so that it crosses the red area (instead of the green or exactly through the black dot), then you expect the pressure in the hot gas line to be lower than the pressure in the drain line, which is clearly not possible.

To fix this situation, you can do one of the following:

1. Raise the reduced pressure (and check against the condensation pressure – especially in systems with floating head).
2. Lower the hot gas mass flow – at the price of a slower defrost.
3. Lower the defrost pressure (drain line pressure) – again at the price of a slower defrost.

If you increase the dimensioning quality (i.e. specify that the drain valve shall be able to handle more gas) so that the pressure controlled drain valve is too small and will be fully open, then you will see the following graph:



The graph illustrates that the defrost pressure (red curve) will no longer be constant but will increase when the mass flow increases above the maximum capacity of the pressure controlled drain valve. In the graph above, the maximum capacity of the drain valve is about 600 kg/h, but the crossing point between the hot gas and the drain curves is at about 640 kg/h.

This illustrates what will happen at the end of a defrost period where the refrigerant entering the drain valve will have an increasing share of gas. The defrost pressure will increase if the valve is too small, until the system settles at the point indicated by the black dot (assuming that the pressure drop in the evaporator is included in the hot gas line).