ENGINEERING
TOMORROW

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Coolselector®2 Exercises

Exercises for Coolselector®2. Training material for use in courses and self-studies for both internal and external use. Not for use as a design guide. Always remember that selection software is only as good as the person using it.

We did complex – **you do awesome**

Contents

1 Introduction

This document contains a number of exercises designed to introduce you to Coolselector®2 and take you through the capabilities of the software. In these exercises, we will try to cover both the general aspects of Coolselector®2 and also some of the more challenging procedures where you should take extra care when designing your system.

The exercises in this document are not meant as a design guide. The exercises are designed for the sole purpose of taking you through the features of Coolselector®2. Please also read and accept the End-user license agreement in the next chapter before continuing with the exercises.

The document is structured so that each exercise is followed by a possible solution.

Coolselector®2 is designed so that it provides an optimized interface based on the application, user preferences and the type of components you want to calculate/select. Hence, we have tried to split the exercises into these main Coolselector®2 functionalities and cover the general aspects in the first chapter.

The exercises are divided into: general information and basic selection, commercial applications, industrial applications, CO_2 Systems, compressors and, finally, condensing-units; where each section is designed by an experienced Danfoss expert in the specific functionality. Users coming from the various application areas would benefit from the exercises in other functionality areas, despite the differences in the system setups, refrigerants, or other parameters. This is since the selection methods are similar, and the notes from different experts provide a more comprehensive understanding and cover more fine tips, all of which can help you to reach the best results.

All units used in this document are international units. Coolselector®2 supports many different units and supports switching back and forth between the units in an easy way, so you should be able to go through the exercises using your preferred units.

2 Coolselector®2 - end user license agreement and disclaimer

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3 General information and basic selection

Exercise 3.1 Installing and setting up Coolselector®2

a) We need to get Coolselector®2 up and running if you have not done so already. You can download and install Coolselector®2 from http://coolselector.danfoss.com.

b) Check if there are any updates available for Coolselector®2?

c) Change the country and language based on your preferences:

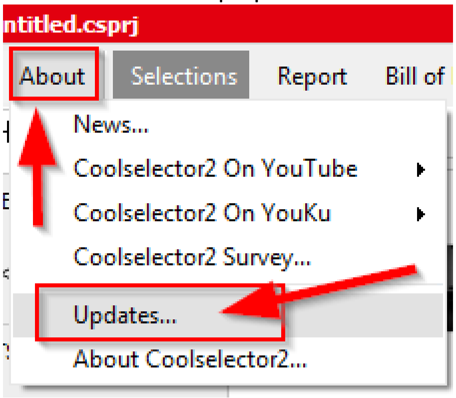
   1. Note, the type of components you can select on the “Valves and Line Components” page. Then, change the Country to USA (if your country is USA, change it to, for example, Denmark)
   2. Have the available components in “Valves and Line Components” changed?
   3. Change your Country back (or select to show all products)

d) What was the last change in this release of Coolselector®2?

Solution 3.1 Installing and setting up Coolselector®2

a) You can download and install Coolselector®2 from http://coolselector.danfoss.com.

b) Go to the "About | Updates" menu:

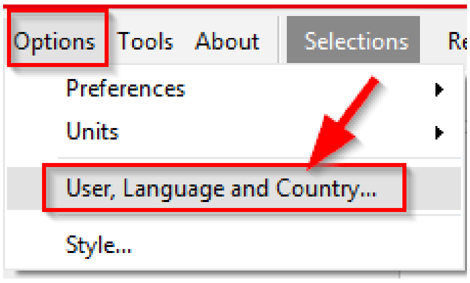


Once you see the 'Updates screen', click on the "Check for new version" button:

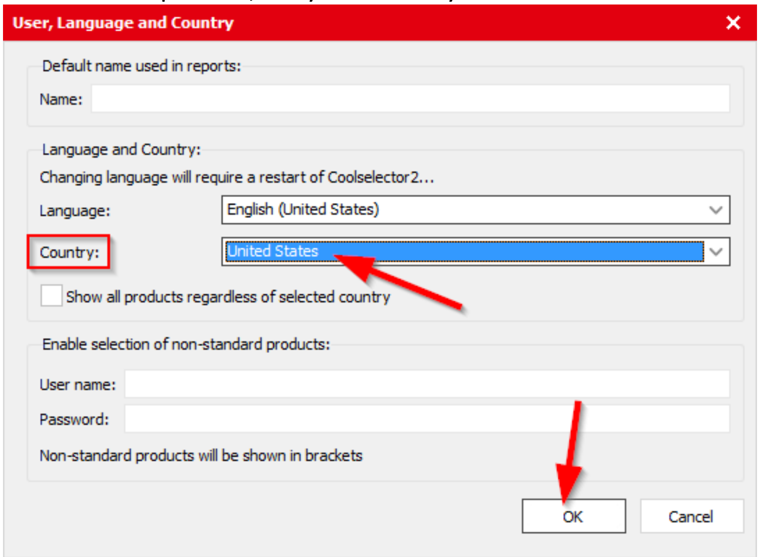
Note that, if you cannot update automatically (i.e. due to your company policies), it is possible to subscribe to an email service, which will notify you whenever a new version is released.

Once you have clicked the button, Coolselector®2 will notify you if there is a newer version available. If that is the case, you can install the new version directly from the prompt.

c) You can set the preferences for the country and language in “Options | User, Language, Country” menu. As an example, for this exercise, you can change your country to ‘USA’:



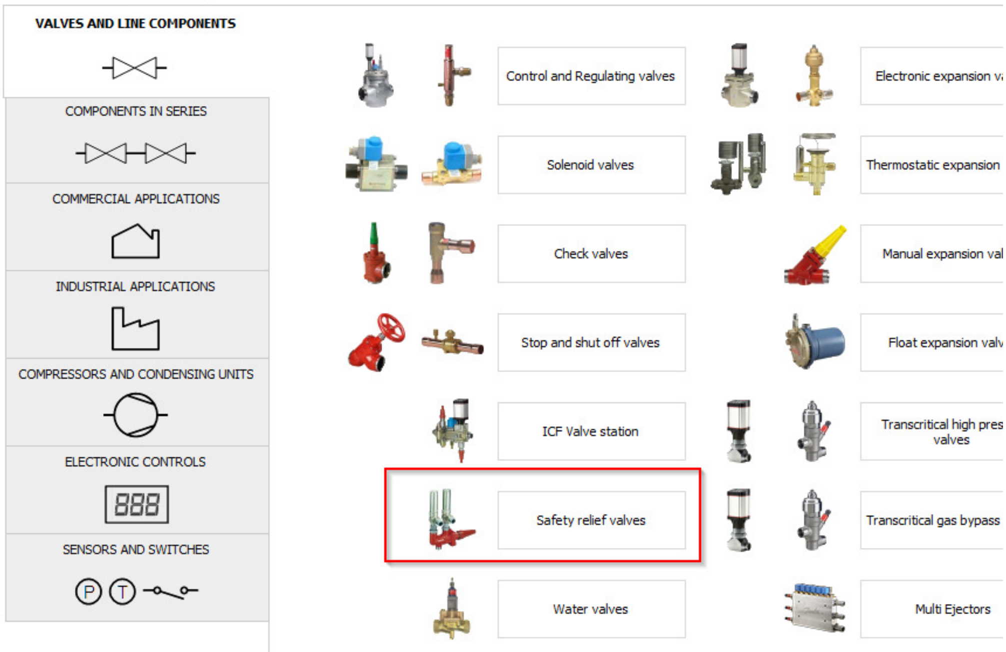
From the drop down, set your country to ‘United States’ and click OK:



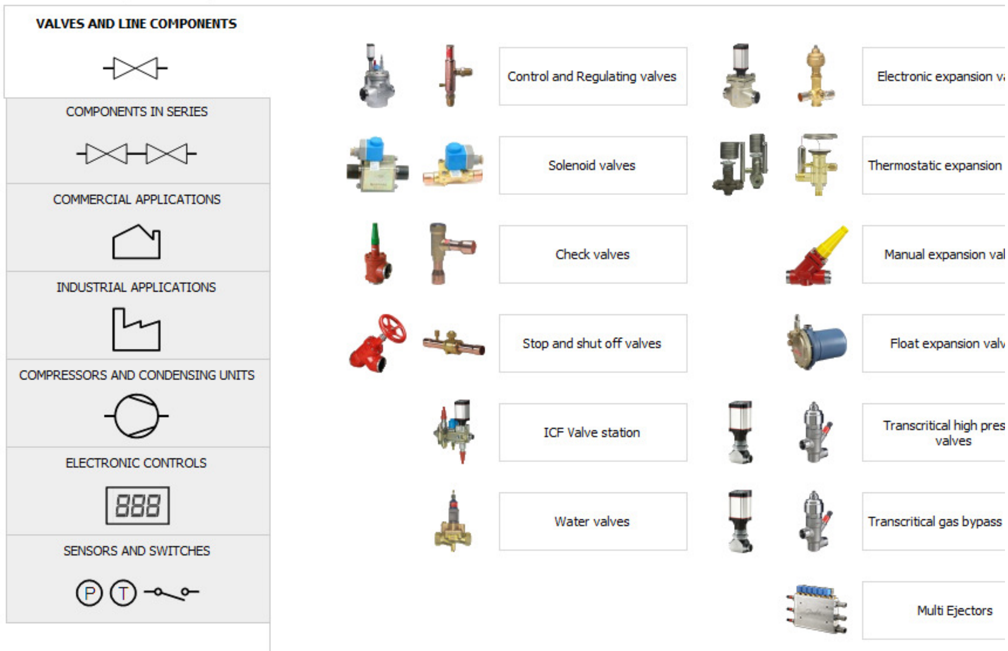
When you change your country to USA, you will see that the available components in “Valves and Line Components” have changed. You will no longer be able to select “Safety relief valves” – the reason being that Danfoss does not sell safety valves for the US market (this might change in the future).

The important thing to note here is that Coolselector®2 will use your country to display as relevant as possible information to you (this is even more pronounced for condensing units, where each unit has a specific sales region).

1. Country = Denmark (or any other EU country as an example):

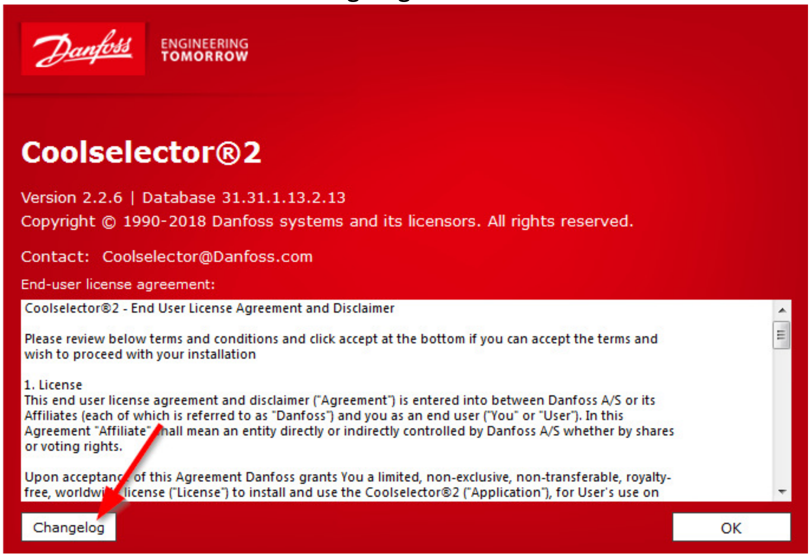


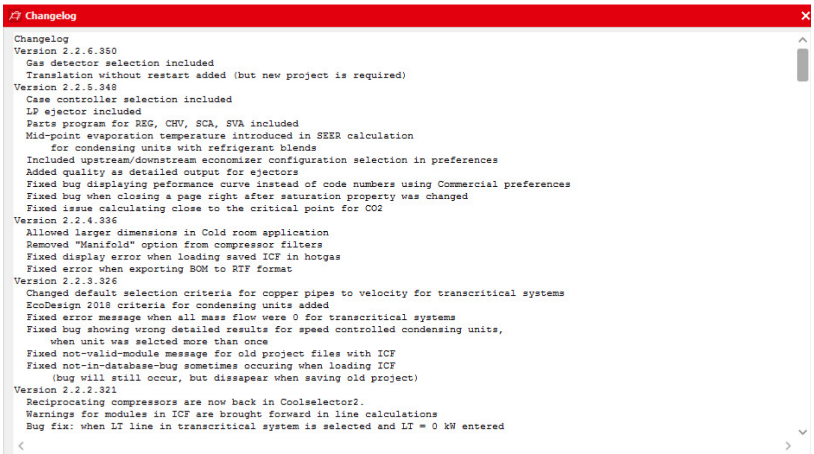
2. Country = United States:



3. Do not forget to revert back to your preferred settings.

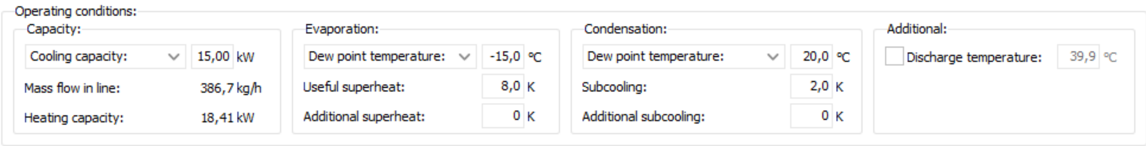
d) To see the latest changes in Coolselector®2, go to the “About | About Coolselector2” menu and click on the <Changelog> button:



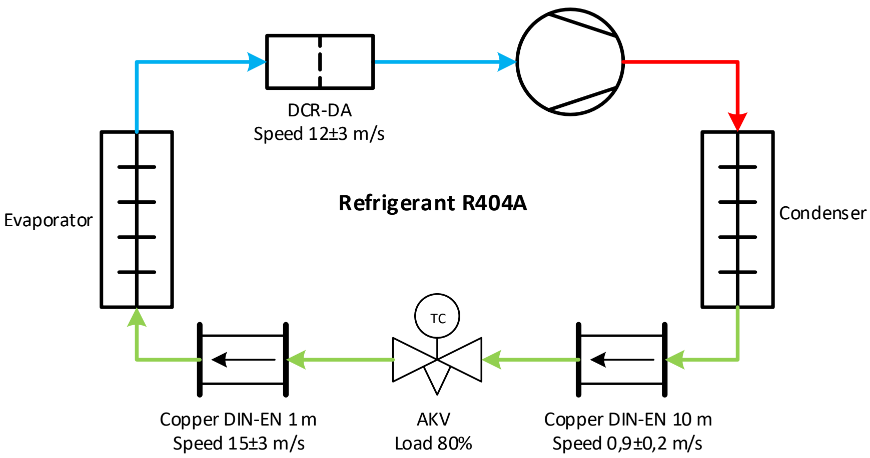


Also, check out the “About | News” menu item for new product releases.

In the following part of this section, we will go through creating a project in which we try selection and calculation for a few components in a very simplified refrigeration cycle as it can be seen in the following graph and properties snippet. Following this, we will discuss how to customize the project with your own name, how to get bill of materials and how to generate a report for this project. Make sure your preferences choice is set to all applications in "Options | Preferences | All applications" before you start the exercises.



System Properties 1



Cycle Diagram 1

Exercise 3.2 Starting a new project and basic component selection

Using information in System Properties 1 and Cycle Diagram 1:

a) Start Coolselector®2 and then in the option for "Valves and Line Components" start selecting a DCA-DA burnout filter for the suction line in a dry system with the default operating conditions. What is the Coolselector®2 suggestion?

b) Now, first change the refrigerant to R404A. Then, in three steps, change the capacity, evaporator dew-point temperature and condenser dew point temperature to those shown in the above snippet. Explain the effect of each step on the suggestion.

c) Can you explain the usage of the different segments of the screen?

d) How can you check the calculations done for the cycle and see calculation details for the selected component?

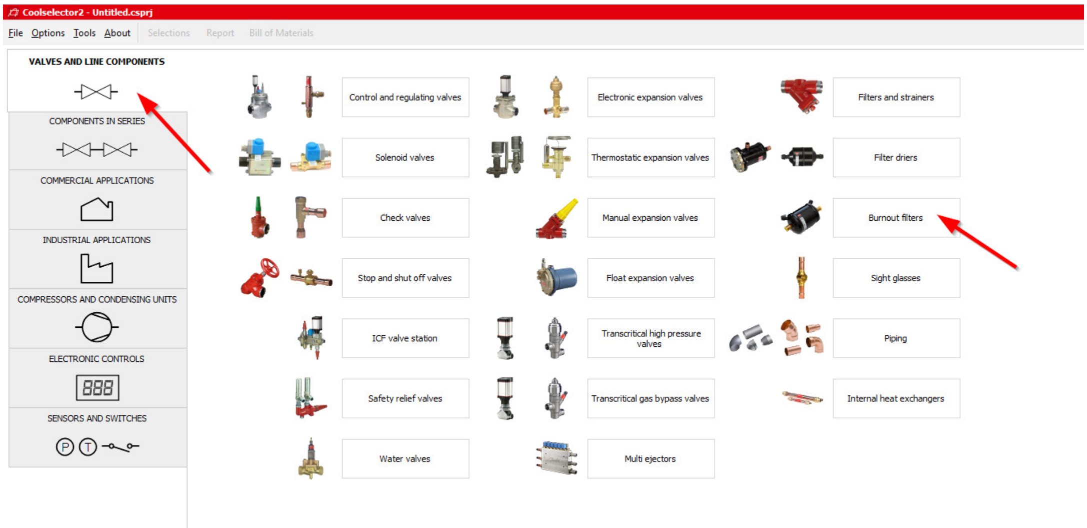
e) Save your project.

f) Now continue the selection for the components in the liquid line by creating new tabs and using the option for "Valves and Line Components" selection. What does Coolselector®2 suggest for each of the components?

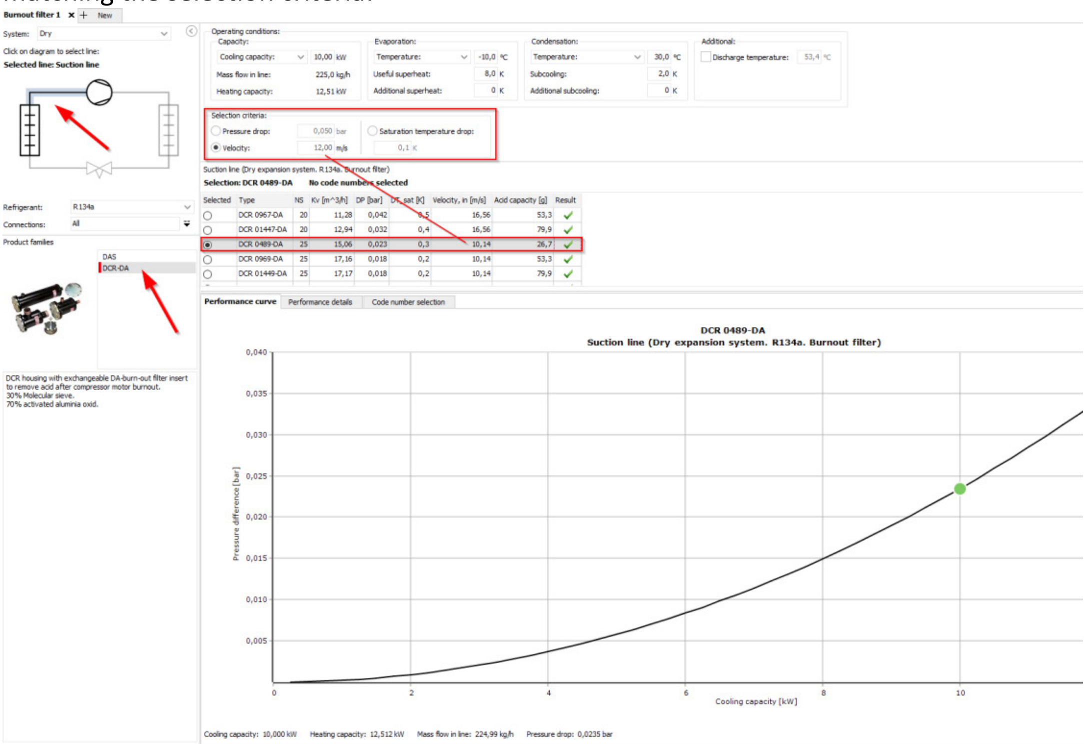
g) Check for possible warnings and the calculated inlet and outlet results for these components. Is there any problem in the selection results? Is this as it was expected for the cycle diagram?

Solution 3.2 Starting a new project and basic component selection

a) Open Coolselector®2; you will find that the program starts on the tab for ‘Valves and Line Components’. From this screen, among the different component functionalities choose “Burnout filters”.

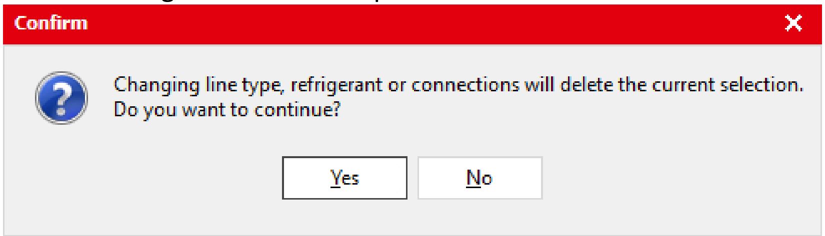


Coolselector®2 creates a dry system by default, select the suction line and then click on the DCR-DA in the product families. You will see the list of valid products and the best one matching the selection criteria:



Here you can also see the other parameters for the filter in the table, such as the acid capacity, as well as the pressure-drop as a function of changing the cooling capacity and keeping the other parameters constant.

b) When you change the refrigerant, Coolselector®2 asks for a confirmation, as this would mean creating a new selection procedure:

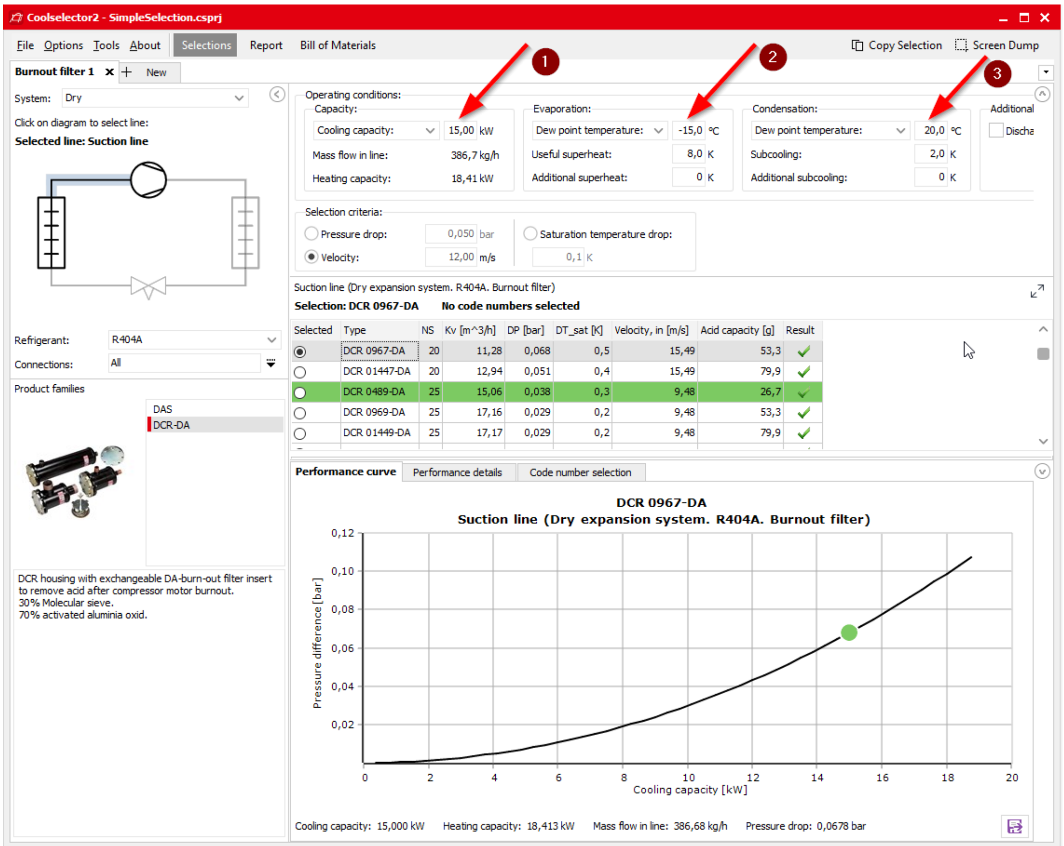


By clicking "Yes", a new selection will be made. Note that, the 'evaporation temperature' and 'condenser temperature' are now changed to 'dew point temperature'. This is since R404A is a glide-refrigerant and hence it is required to have a reference for the evaporator and condenser temperatures.

The current suggestion is "DCR 0967-DA", which is different from the suggestion made by the exact same properties in the system running with R134a; this is of course due to the different properties of the two refrigerants.

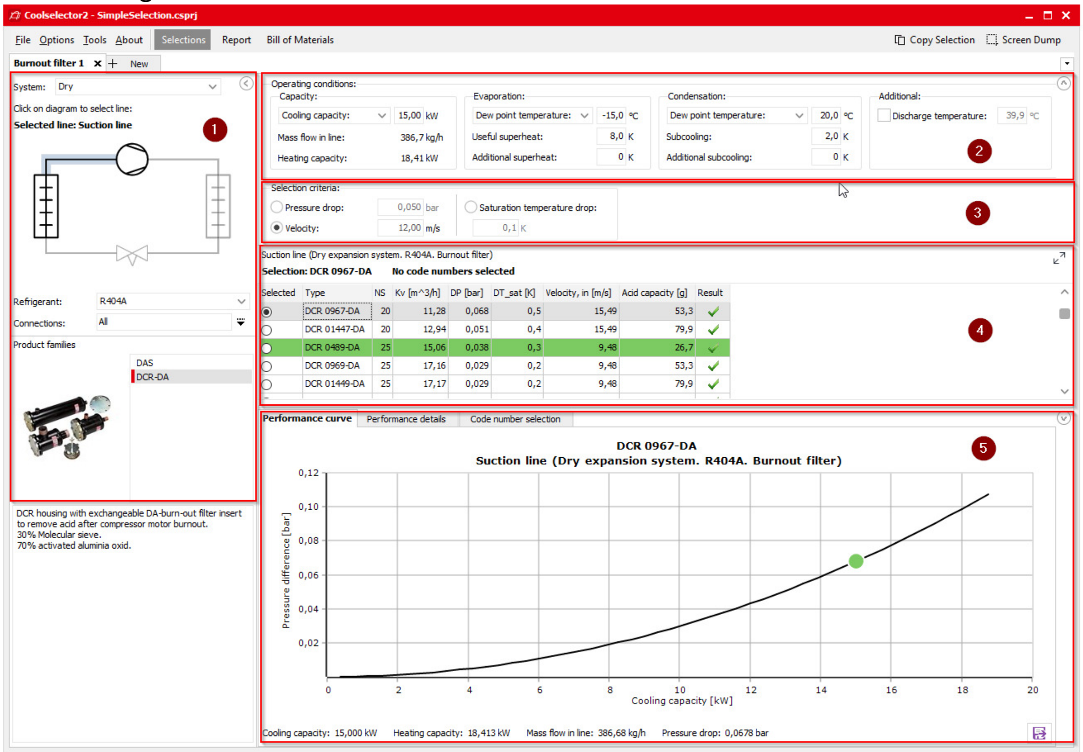
Now you can proceed to changing the system properties. If you change them in the order mentioned in the exercise, the suggestion will consequently be "DCR 01447-DA", "DCR 0969-DA" and "DCR 0489-DA".

Increasing the capacity would increase the mass flow in line and hence the speed in the component, which results in a larger component. Decreasing the evaporation temperature increases the mass flow-rate as the cycle COP would be lower. Decreasing the condensation temperature has the opposite effect, which is the cause of the changes in the suggestion.



As you noticed, the Coolselector®2 suggestion can change and can very easily be affected by the system properties.

c) Once in the calculation and selection interface, you will find that the screen is separated in different segments:



1. Segment “1” is dedicated to the application criteria for your selection. These criteria include, but are not exclusive to, system type, line, refrigerant, connection type, and product family.
2. Segment “2” is where you insert your system operating conditions, such as cooling capacity, evaporation and condensation temperature, and useful superheat. These operating conditions have significant impact on the calculations and a lack of due care when filling them in might lead to inapplicable results. Whereas great care has been taken to set meaningful default conditions, there is no guarantee that these will mirror the operating conditions for your system design.
3. Segment “3” is dedicated to the product selection criteria for the suggestion to be made in the next segment based on your inputs in functionality criteria and operating conditions segments.
4. In segment “4” you will find the selection table. In this area you will see the options matching the functionality criteria and operating conditions that you specified in the selected family. For each calculation, Coolselector®2 has a ‘suggestion’ which remains highlighted in green based on your input in the product selection criteria input. The selection table also includes some of the most relevant information for the product.
5. In segment “5”, you will find the performance details and information about the chosen product from the previous segment. This information updates as you choose other products from the list. The next part of this exercise gives some more information about this segment.

d) You can click on the performance details and check the system diagram calculations, system details and the performance of the selected product from the list in the corresponding tabs.

System diagram and different points calculations:

Suction line (Dry expansion system. R404A. Burnout filter)

Selection: DCR 0967-DA **No code numbers selected**

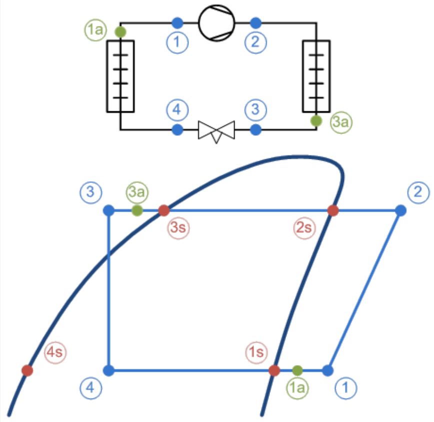
Selected	Type	NS	Kv [m^3/h]	DP [bar]	DT_sat [K]	Velocity, in [m/s]	Acid capacity [g]	Result
◉	DCR 0967-DA	20	11,28	0,068	0,5	15,49	53,3	✓
○	DCR 01447-DA	20	12,94	0,051	0,4	15,49	79,9	✓
○	DCR 0489-DA	25	15,06	0,038	0,3	9,48	26,7	✓
○	DCR 0969-DA	25	17,16	0,029	0,2	9,48	53,3	✓
○	DCR 01449-DA	25	17,17	0,029	0,2	9,48	79,9	✓

Performance cu… | **Performance details** | Code number selection

System diagram | System details | DCR 0967-DA

Mass flow in evaporator: 386,7 kg/h

		Temperature	Pressure	Density	Enthalpy	Entropy
Point	Description	[°C]	[bar]	[kg/m^3]	[kJ/kg]	[kJ/(kg·K)]
1	Compressor suction	-7,0	3,642	17,76	364,7	1,642
2	Compressor discharge (estimated)	39,9	10,89	49,04	396,5	1,67
2s	Condensation dew point	20,0	10,89	56,38	374,3	1,597
3s	Condensation bubble point	19,6	10,89	1070	228	1,097
3a	Condenser out	17,6	10,89	1079	225	1,087
3	Including additional subcooling	17,6	10,89	1079	225	1,087
4	After expansion valve	-15,4	3,642	68,81	225	1,1
4s	Evaporation bubble point	-15,6	3,642	1208	178,9	0,9214
1s	Evaporation dew point	-15,0	3,642	18,57	357,4	1,614
1a	Evaporator out	-7,0	3,642	17,76	364,7	1,642



System calculation details:

Suction line (Dry expansion system. R404A. Burnout filter)

Selection: DCR 0967-DA **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP [bar]	DT_sat [K]	Velocity, in [m/s]	Acid capacity [g]	Result
◉	DCR 0967-DA	20	11,28	0,068	0,5	15,49	53,3	✓
○	DCR 01447-DA	20	12,94	0,051	0,4	15,49	79,9	✓
○	DCR 0489-DA	25	15,06	0,038	0,3	9,48	26,7	✓
○	DCR 0969-DA	25	17,16	0,029	0,2	9,48	53,3	✓
○	DCR 01449-DA	25	17,17	0,029	0,2	9,48	79,9	✓

Performance curve | **Performance details** | Code number selection

System diagram | **System details** | DCR 0967-DA

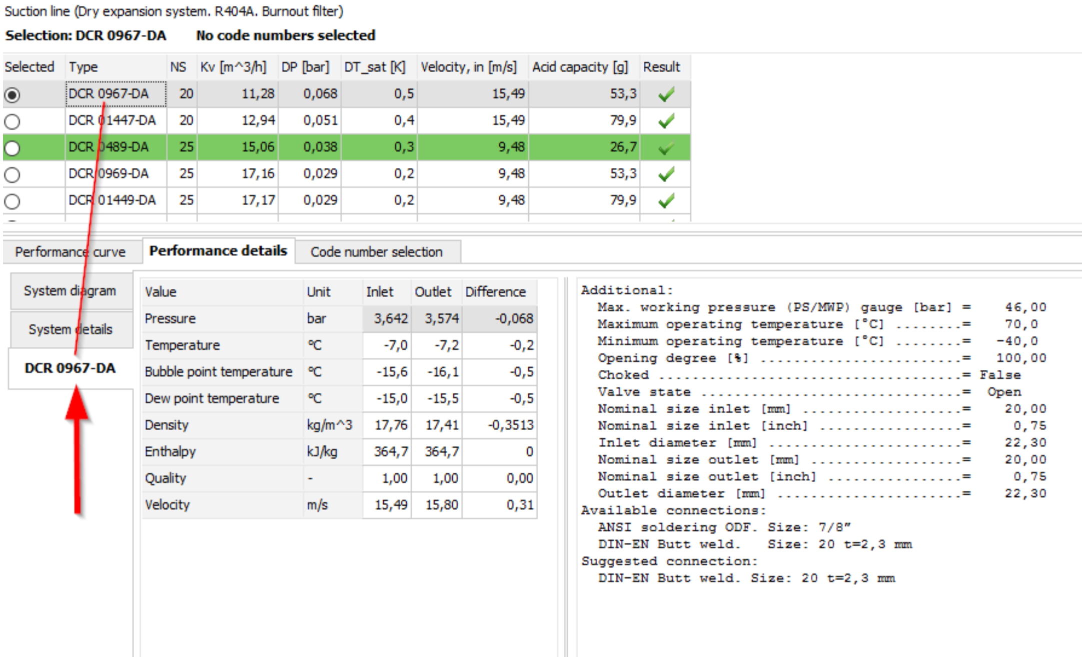
System:

```
Capacity
  Cooling capacity [kW] ................................= 15,00
  Specific cooling capacity [kJ/kg] ....................= 139,7
  Heating capacity [kW] ................................= 18,41
  Specific heating capacity [kJ/kg] ....................= 171,4
  Compressor mass flow [kg/h] ..........................= 386,7
  Evaporator mass flow [kg/h] ..........................= 386,7
Evaporation
  Evaporating temperature [°C] .........................= -15,0
  Evaporating dew point temperature [°C] ...............= -15,0
  Evaporating bubble point temperature [°C] ............= -15,6
  Evaporating pressure [bar] ...........................=   3,642
  Useful superheat [K] .................................=   8,0
  Additional superheat [K] .............................=   0
Compressor discharge
  Discharge temperature [°C] ...........................=  39,9
Condensation
  Condensing temperature [°C] ..........................=  20,0
  Condensing dew point temperature [°C] ................=  20,0
  Condensing bubble point temperature [°C] .............=  19,6
  Condensing pressure [bar] ............................=  10,89
  Subcooling [K] .......................................=   2,0
  Additional subcooling [K] ............................=   0
Additional
  Max liquid line pressure drop (before flashing) [bar] =   0,581
```

Line:

```
Total pressure drop [bar] ..............=   0,068
Total saturation temperature drop [K] ..=   0,5
Max available pressure difference [bar] =   3,642
Line mass flow [kg/h] ..................= 386,7
```

Product performance details:



Suction line (Dry expansion system. R404A. Burnout filter)

Selection: DCR 0967-DA **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP [bar]	DT_sat [K]	Velocity, in [m/s]	Acid capacity [g]	Result
◉	DCR 0967-DA	20	11,28	0,068	0,5	15,49	53,3	✓
○	DCR 01447-DA	20	12,94	0,051	0,4	15,49	79,9	✓
○	DCR 0489-DA	25	15,06	0,038	0,3	9,48	26,7	✓
○	DCR 0969-DA	25	17,16	0,029	0,2	9,48	53,3	✓
○	DCR 01449-DA	25	17,17	0,029	0,2	9,48	79,9	✓

Performance curve | **Performance details** | Code number selection

System diagram

System details

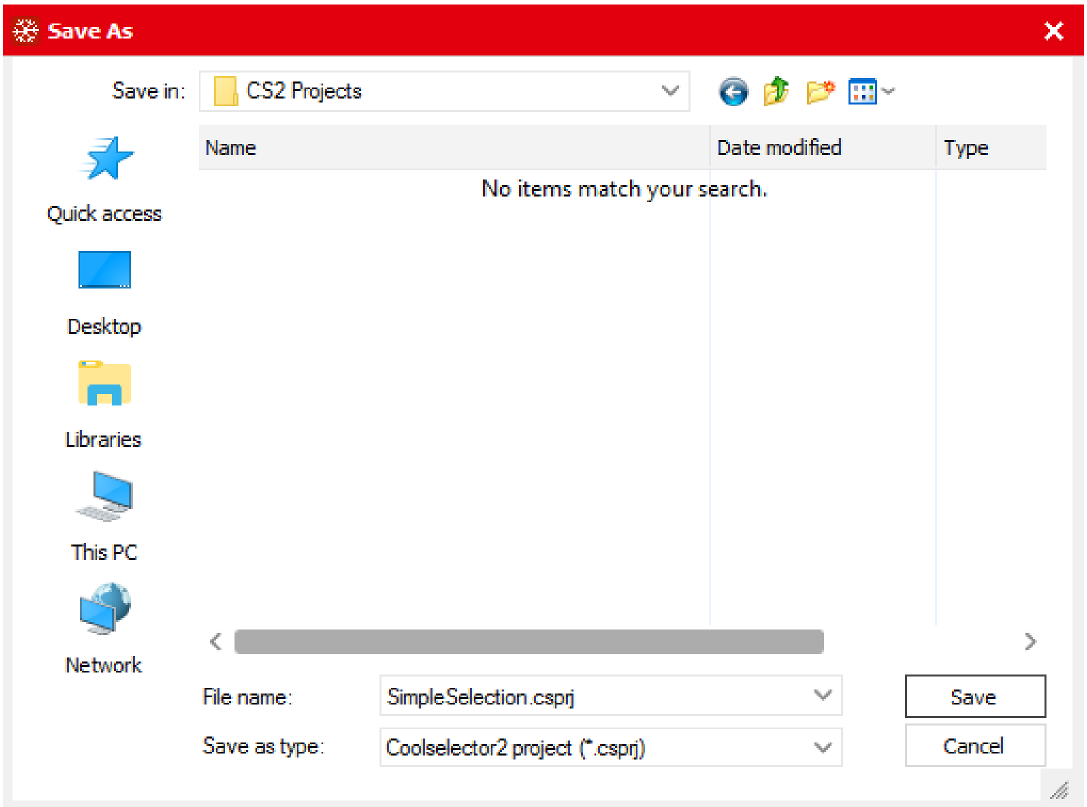
DCR 0967-DA

Value	Unit	Inlet	Outlet	Difference
Pressure	bar	3,642	3,574	-0,068
Temperature	°C	-7,0	-7,2	-0,2
Bubble point temperature	°C	-15,6	-16,1	-0,5
Dew point temperature	°C	-15,0	-15,5	-0,5
Density	kg/m^3	17,76	17,41	-0,3513
Enthalpy	kJ/kg	364,7	364,7	0
Quality	-	1,00	1,00	0,00
Velocity	m/s	15,49	15,80	0,31

```
Additional:
  Max. working pressure (PS/MWP) gauge [bar] =    46,00
  Maximum operating temperature [°C] ........=    70,0
  Minimum operating temperature [°C] ........=   -40,0
  Opening degree [%] ........................=   100,00
  Choked ....................................= False
  Valve state ...............................=  Open
  Nominal size inlet [mm] ...................=    20,00
  Nominal size inlet [inch] .................=     0,75
  Inlet diameter [mm] .......................=    22,30
  Nominal size outlet [mm] ..................=    20,00
  Nominal size outlet [inch] ................=     0,75
  Outlet diameter [mm] ......................=    22,30
Available connections:
  ANSI soldering ODF. Size: 7/8"
  DIN-EN Butt weld.   Size: 20 t=2,3 mm
Suggested connection:
  DIN-EN Butt weld. Size: 20 t=2,3 mm
```

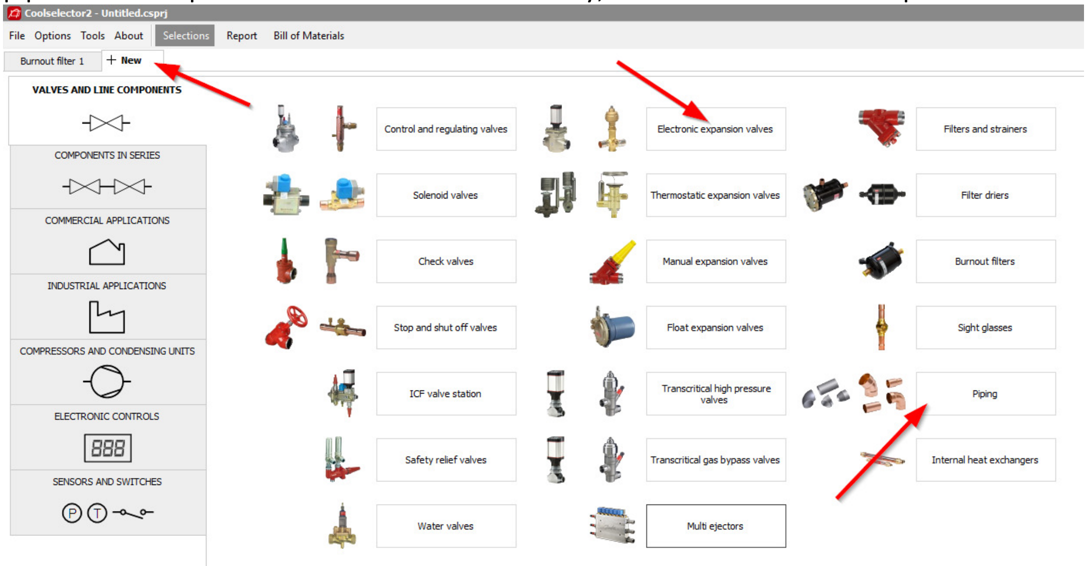
Notice, that the performance details are presented for any selected product and are not limited to the suggested product. You can click on any of the products in the list and see the calculations for the selected product.

e) To save the project, open File | Save Project… or click "Ctrl+S" on the keyboard. You will then be asked for the name and the location of the file:



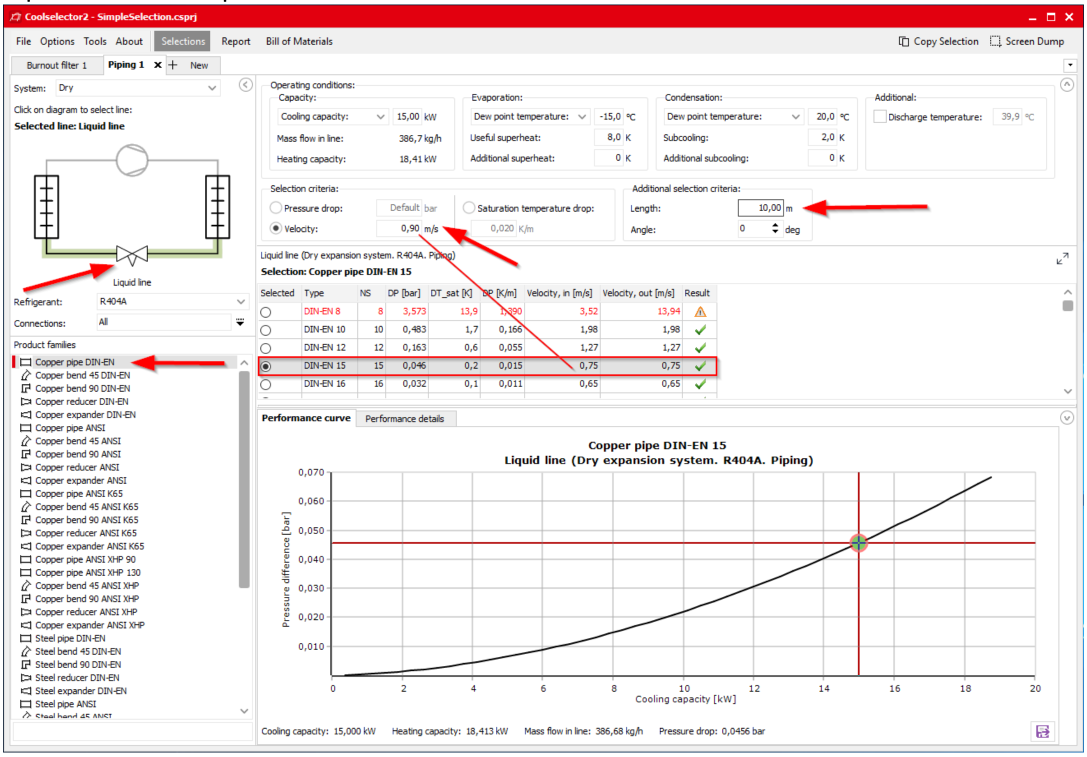
You can also use the "Save Project As…" option to save it with a different name or "Save and Send…" option to save and send it to a customer or a colleague.

f) You can add a new tab for your new selection by clicking the "+ New" tab at the top beside the tab for "Burnout filter 1". The components, we need for the liquid line, are two pipes and an expansion valve from the AKV family, which is an electronic expansion valve.



The suggested results would be:

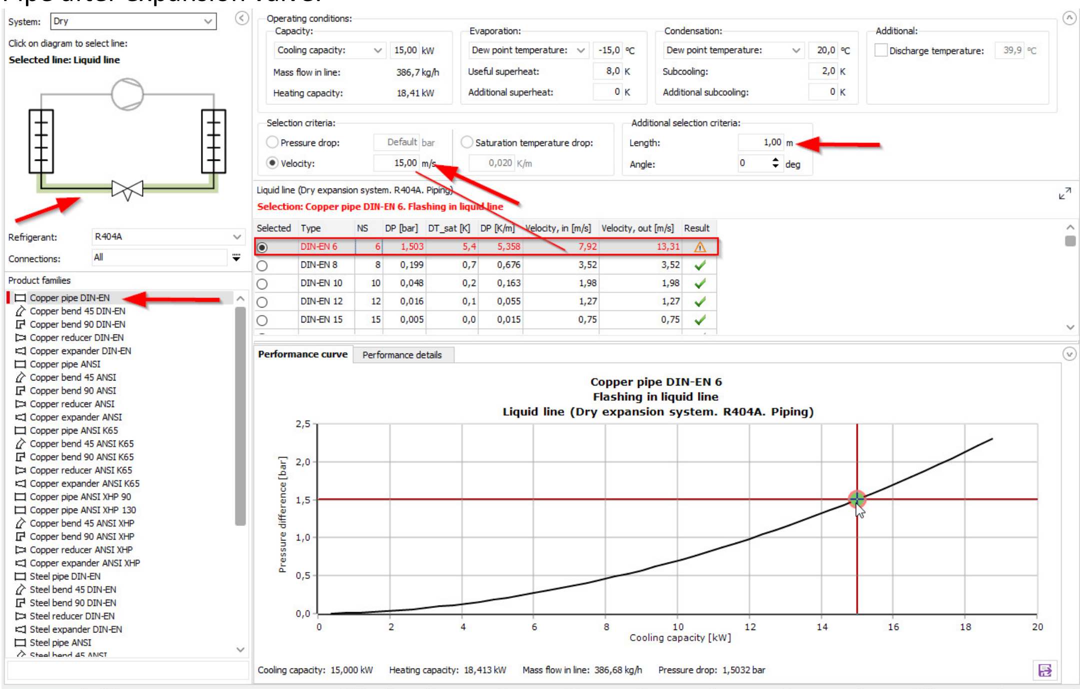
Pipe before the expansion valve:



Note, that Coolselector®2 keeps your operating conditions for the system based on your previous selection.

Electronic expansion valve:

Pipe after expansion valve:



g) As can be seen, the selected pipe to be placed after the expansion valve has a warning "Flashing in liquid line", which is due to flashing before the expansion valve. Coolselector®2 always calculates the outlet conditions based on the inlet conditions. Hence, by selecting a single component, which is going to be placed after other products, in a line, the effect of the previous components in the line would be neglected. This effect exists in every line; however, it is much more tangible in the liquid line since there is a phase change after the expansion valve.

   Comparing the product calculation results with the results from the system diagram calculations, you can see that the inlet condition for all products is the condenser outlet and the fact that the pipes cannot meet the outlet conditions required by the evaporator. To overcome this, the inlet of each component should be the outlet of the previous component. This is possible by using the components in series functionality, which we will discuss in the next exercise.

   Notice that the subcooling reference is the bubble-point temperature.

Exercise 3.3 Selecting components in series

Using information in System Properties 1 and Cycle Diagram 1:

a) Load the project you saved before selection of components in the liquid line in the previous exercise. (If you saved it after that, simply close the tabs for the liquid line components)

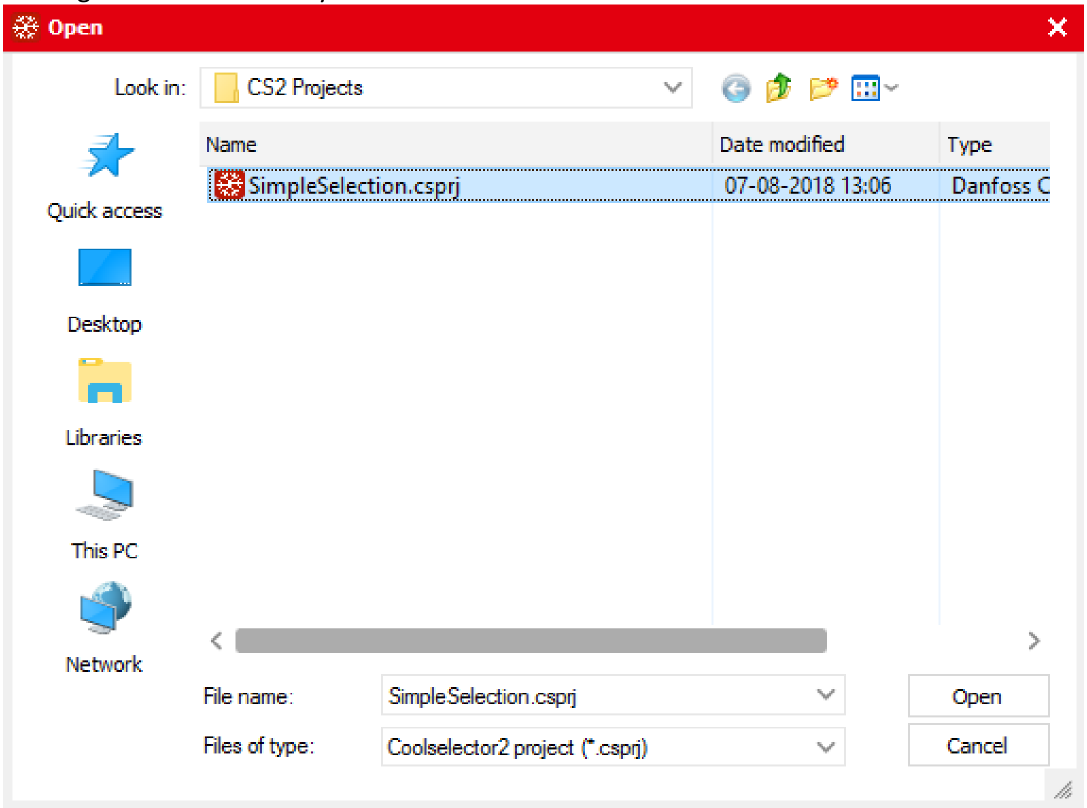
b) Create a new tab and repeat the selection process for all the components in the liquid line, using the option "Components in Series".

c) What is the difference between the two selection methods? Does the inlet and outlet calculation results for each component match what was expected for the cycle diagram?

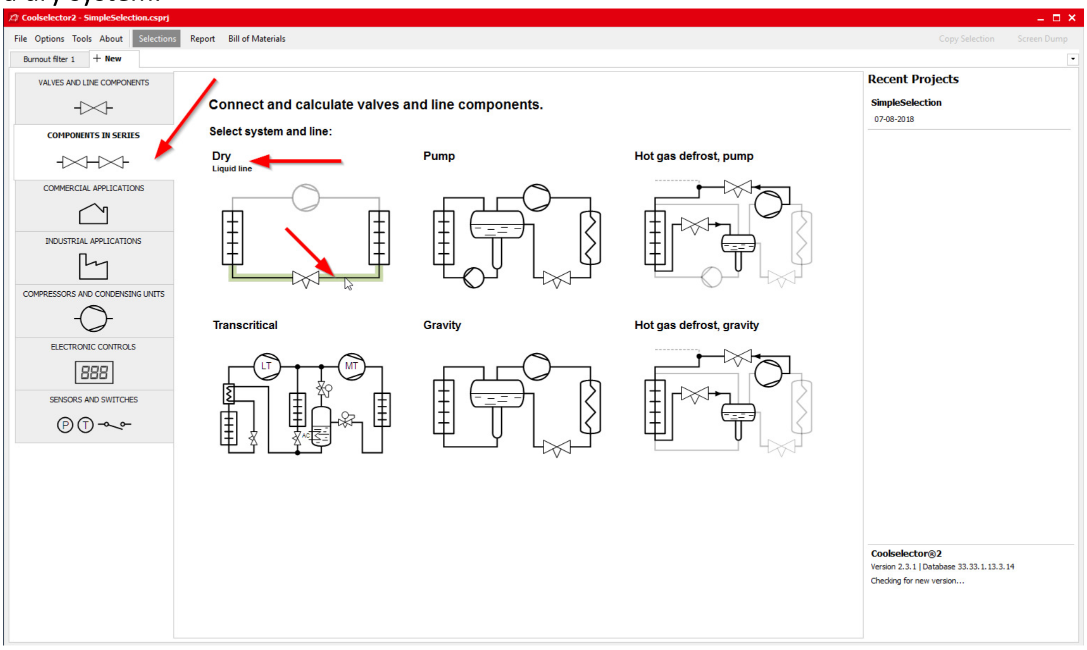
d) Can you change the selected component to improve the design? What is the share of each component in the pressure drop of the line? What is the minimum and maximum capacity which can be gained in this system using the selected expansion valve?
Save your project for the next exercises.

Solution 3.3 Selecting components in series

a) You can load the previously saved project from the menu File | Open Project… or by clicking “Ctrl+O” on the keyboard.

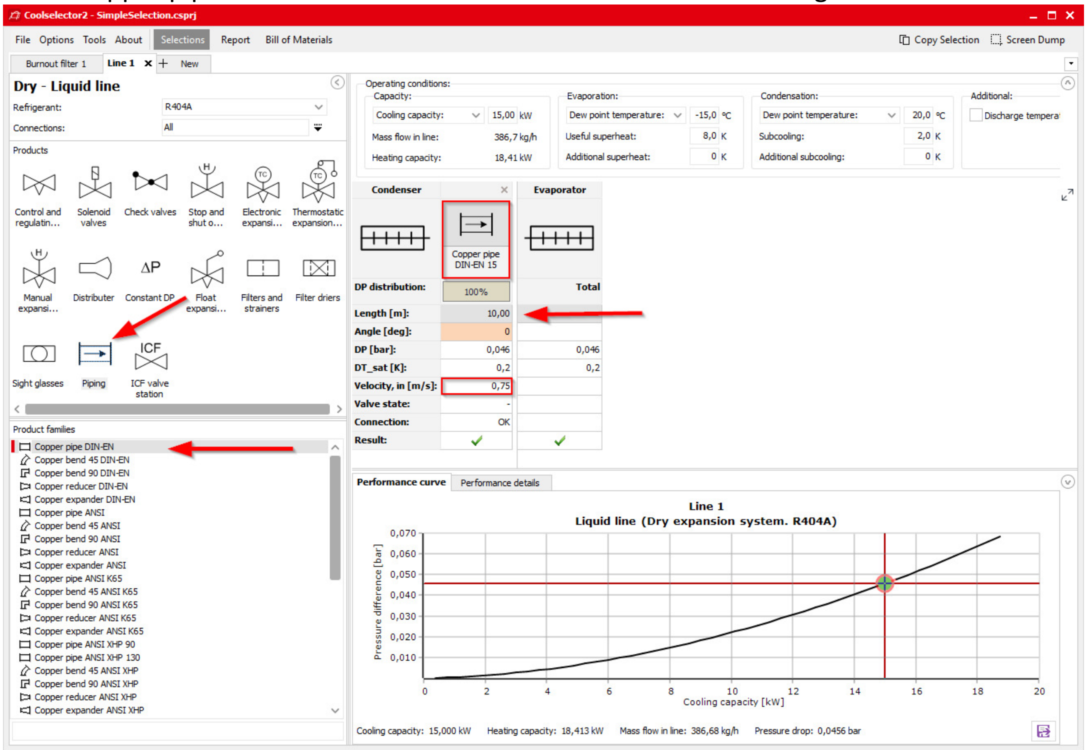


b) Create a new tab and select the option “Components in Series” and then the liquid line in a dry system:

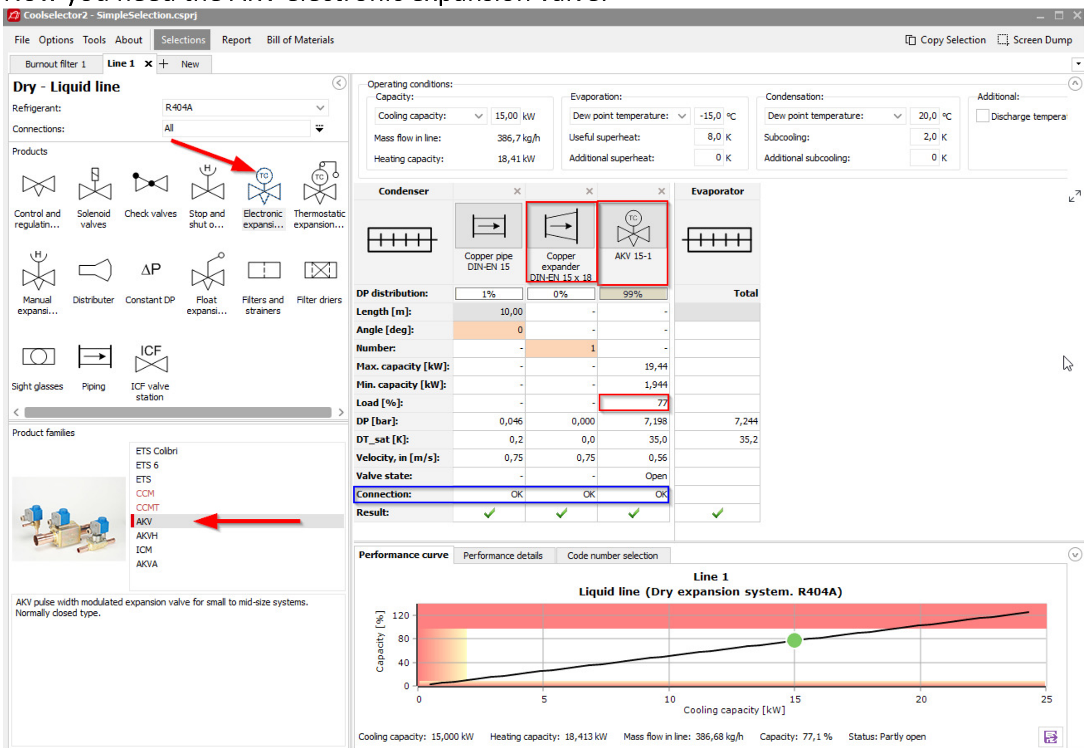


Now, you need to add the components to the line. To do so, first, you need to select the functionality you would like to add to the line, and then double click on the family or drag the family and drop it in the location that you need it.

Add a copper pipe with DIN-EN connection to the line and set its length to one meter:

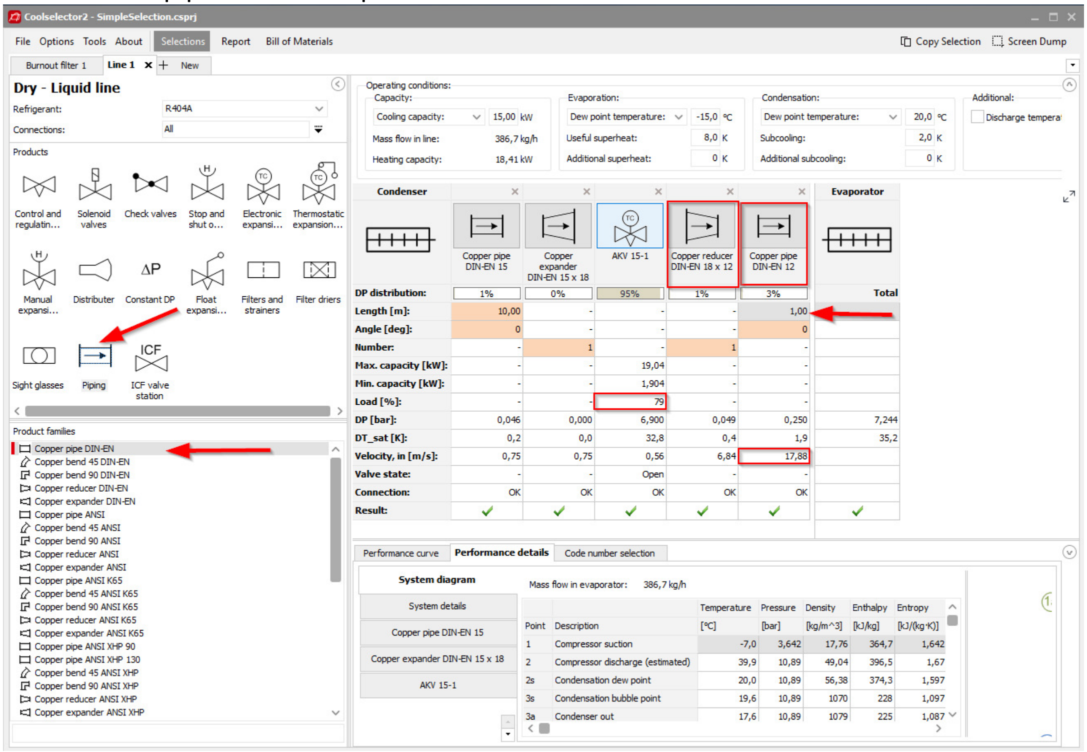


Now you need the AKV electronic expansion valve:



Notice that Coolselector®2 automatically added a “Copper expander DIN-EN 15 × 18” between the two components. The software recognizes the material of the piping as well as the connection sizes and standard between two components. When two connections do not match, it adds the required expander/reducer between the two componets for common cases, or informs you in the row shown by the blue triangle and you can fix the connection problem manually by adding an expander/reducer from the proper family in the piping function.

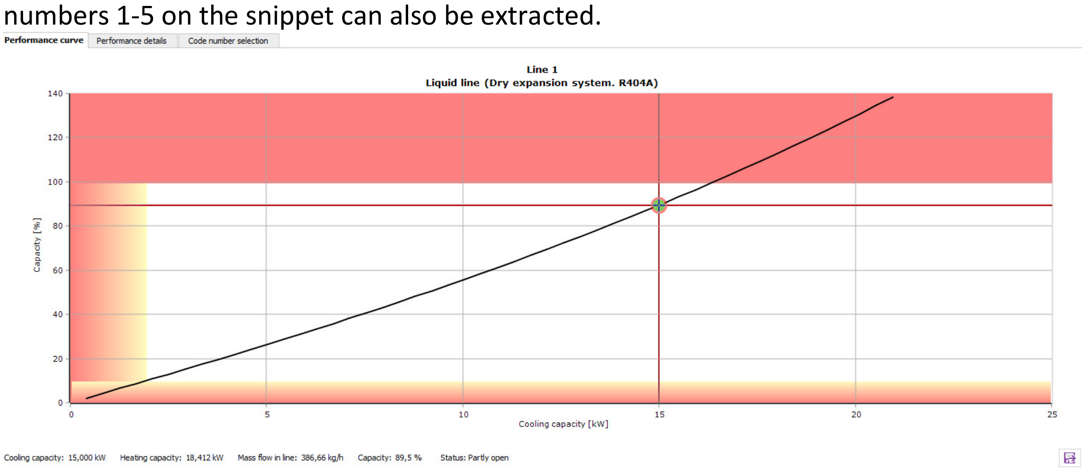
Now add the pipe after the expansion valve:

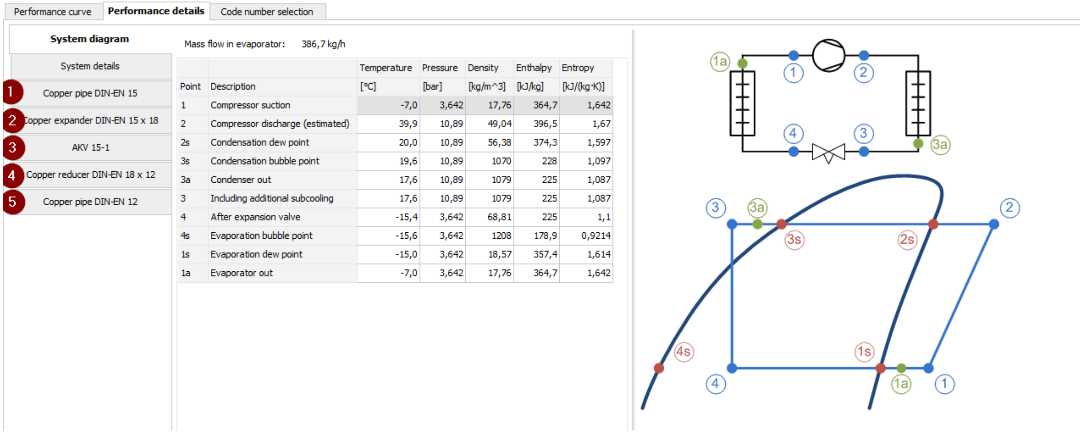


As can be seen, there are no warnings in the selected pipe anymore, since the expansion is now happening in the expansion valve. It is also interesting to notice, that the load for the AKV valve is increased. This is due to the fact that the added pipes after the valve increase the pressure drop and hence the opening load of the valve will also increase. Additionally, as can be seen, the target criteria for the pipe suggestion after the expansion valve are clearly different to the one before the expansion valve.

Proper selection of AKV valves requires extra care, which we will discuss later in detail in **Error! Reference source not found.**. Please be sure to check that before selecting an AKV v alve.

c) Here Coolselector®2 calculates components one after another. Furthermore, you can see the collective effect on the performance curve for the components in the liquid line and the need for an expander/reducer if you want to select the suggested components. The detailed calculation of each component with the right inlet condition as shown by numbers 1-5 on the snippet can also be extracted.

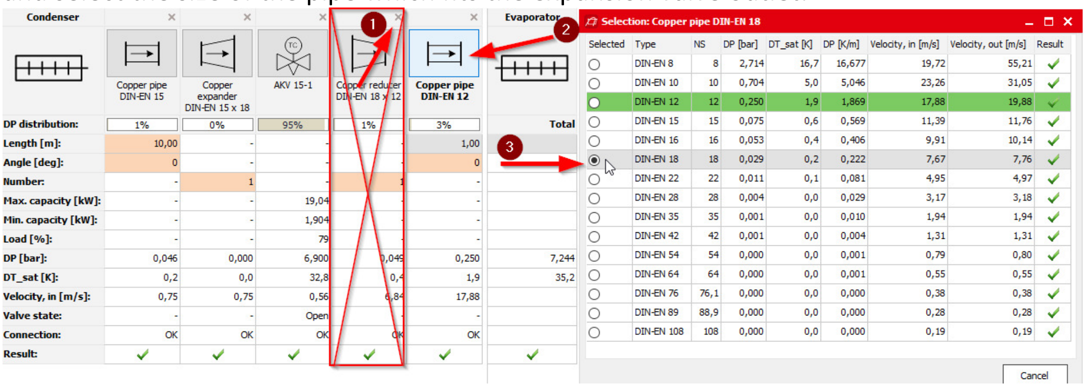




		Temperature	Pressure	Density	Enthalpy	Entropy
Point	Description	[°C]	[bar]	[kg/m^3]	[kJ/kg]	[kJ/(kg·K)]
1	Compressor suction	-7,0	3,642	17,76	364,7	1,642
2	Compressor discharge (estimated)	39,9	10,89	49,04	396,5	1,67
2s	Condensation dew point	20,0	10,89	56,38	374,3	1,597
3s	Condensation bubble point	19,6	10,89	1070	228	1,097
3a	Condenser out	17,6	10,89	1079	225	1,087
3	Including additional subcooling	17,6	10,89	1079	225	1,087
4	After expansion valve	-15,4	3,642	68,81	225	1,1
4s	Evaporation bubble point	-15,6	3,642	1208	178,9	0,9214
1s	Evaporation dew point	-15,0	3,642	18,57	357,4	1,614
1a	Evaporator out	-7,0	3,642	17,76	364,7	1,642

Note, that if you need to replace components in the line, you can do so by simply dragging the component to the preferred position and dropping it there.

d) The suggestions for components in series calculation use the default selection targets and values in Coolselector®2. However, if you want to select another component from the same family, you can do so by clicking on the icon of the component in the line and choosing the preferred one in the pop-up menu. In this case, as a good design practice, it is better to avoid having a reducer after the expansion valve. To avoid having this, you can simply remove the reducer using the close sign on the top right-hand side of the reducer and select the size of the pipe which fits the expansion valve outlet:

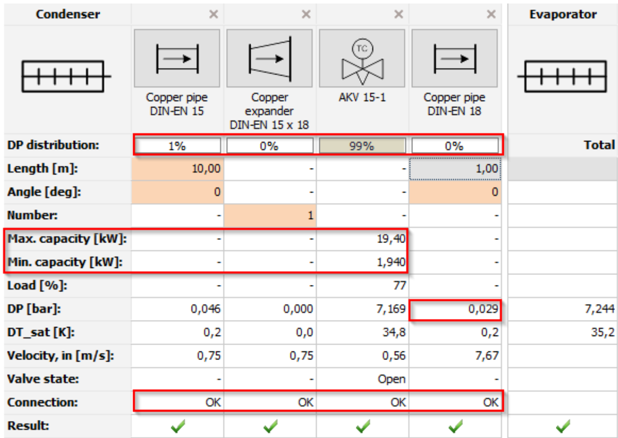


Condenser	Copper pipe DIN-EN 15	Copper expander DIN-EN 15 x 18	AKV 15-1	Copper reducer DIN-EN 18 x 12	Copper pipe DIN-EN 12	Evaporator
DP distribution:	1%	0%	95%	1%	3%	Total
Length [m]:	10,00	-	-	-	1,00	
Angle [deg]:	0	-	-	-	0	
Number:	-	1	-	1	-	
Max. capacity [kW]:	-	-	19,04	-	-	
Min. capacity [kW]:	-	-	1,904	-	-	
Load [%]:	-	-	79	-	-	
DP [bar]:	0,046	0,000	6,900	0,049	0,250	7,244
DT_sat [K]:	0,2	0,0	32,8	0,4	1,9	35,2
Velocity, in [m/s]:	0,75	0,75	0,56	6,84	17,88	
Valve state:	-	-	Open	-	-	
Connection:	OK	OK	OK	OK	OK	
Result:	✓	✓	✓	✓	✓	✓

Selection: Copper pipe DIN-EN 18

Selected	Type	NS	DP [bar]	DT_sat [K]	DP [K/m]	Velocity, in [m/s]	Velocity, out [m/s]	Result
○	DIN-EN 8	8	2,714	16,7	16,677	19,72	55,21	✓
○	DIN-EN 10	10	0,704	5,0	5,046	23,26	31,05	✓
○	DIN-EN 12	12	0,250	1,9	1,869	17,88	19,88	✓
○	DIN-EN 15	15	0,075	0,6	0,569	11,39	11,76	✓
○	DIN-EN 16	16	0,053	0,4	0,406	9,91	10,14	✓
◉	DIN-EN 18	18	0,029	0,2	0,222	7,67	7,76	✓
○	DIN-EN 22	22	0,011	0,1	0,081	4,95	4,97	✓
○	DIN-EN 28	28	0,004	0,0	0,029	3,17	3,18	✓
○	DIN-EN 35	35	0,001	0,0	0,010	1,94	1,94	✓
○	DIN-EN 42	42	0,001	0,0	0,004	1,31	1,31	✓
○	DIN-EN 54	54	0,000	0,0	0,001	0,79	0,80	✓
○	DIN-EN 64	64	0,000	0,0	0,001	0,55	0,55	✓
○	DIN-EN 76	76,1	0,000	0,0	0,000	0,38	0,38	✓
○	DIN-EN 89	88,9	0,000	0,0	0,000	0,28	0,28	✓
○	DIN-EN 108	108	0,000	0,0	0,000	0,19	0,19	✓

You can see the share of each component on the pressure drop on top of the calculation details. As you can see, the connections fit and, furthermore, the pressure drop after the expansion valve is reduced significantly and is happening properly in the AKV valve. You can also see the relevant calculation details such as min. and max. capacity in the details:



Condenser	Copper pipe DIN-EN 15	Copper expander DIN-EN 15 x 18	AKV 15-1	Copper pipe DIN-EN 18	Evaporator
DP distribution:	1%	0%	99%	0%	Total
Length [m]:	10,00	-	-	1,00	
Angle [deg]:	0	-	-	0	
Number:	-	1	-	-	
Max. capacity [kW]:	-	-	19,40	-	
Min. capacity [kW]:	-	-	1,940	-	
Load [%]:	-	-	77	-	
DP [bar]:	0,046	0,000	7,169	0,029	7,244
DT_sat [K]:	0,2	0,0	34,8	0,2	35,2
Velocity, in [m/s]:	0,75	0,75	0,56	7,67	
Valve state:	-	-	Open	-	
Connection:	OK	OK	OK	OK	
Result:	✓	✓	✓	✓	✓

Exercise 3.4 Understanding superheat and selecting a compressor

Using System Properties 1 and Cycle Diagram 1:

a) Select a compressor for the system using the following requirements. Which compressor does Coolselector®2 suggest as the best choice for this cycle?

   1. Application: Refrigeration
   2. Power supply: 50 Hz
   3. Refrigerant: R404A
   4. All compressor types
   5. Fixed speed

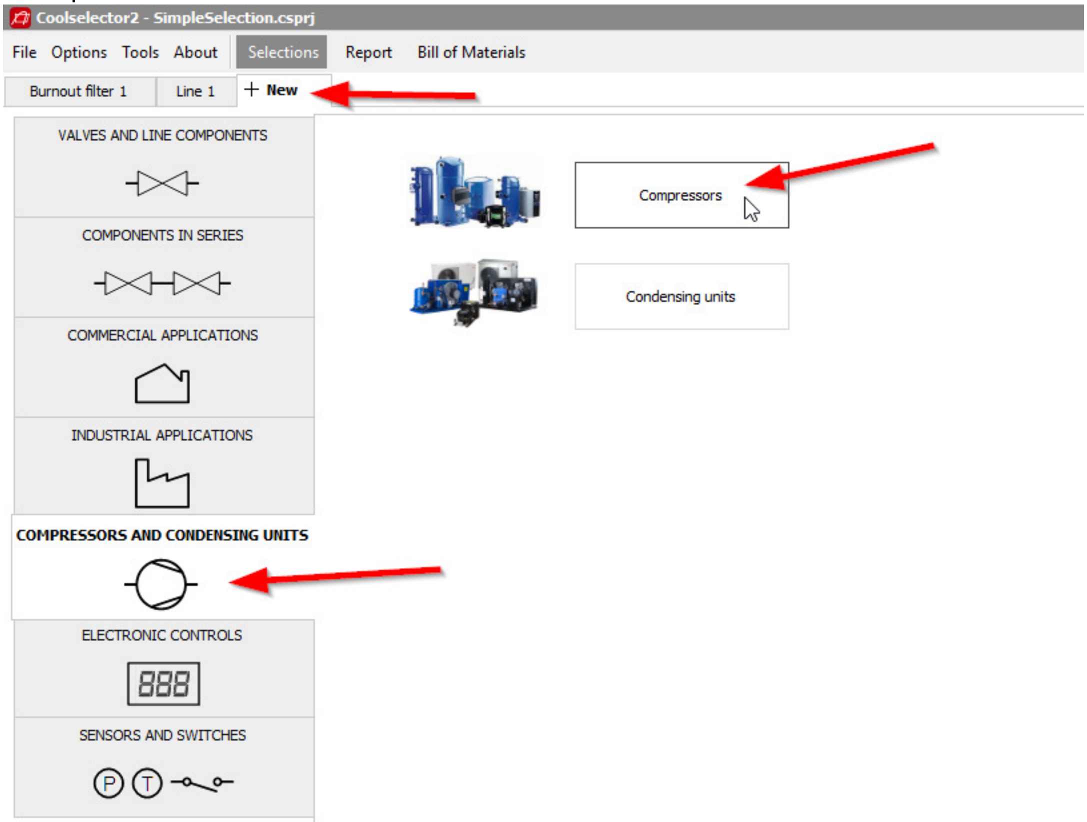
b) Can you explain the importance of superheat and the difference between useful and additional superheat?

c) Now, set the additional superheat to 5 K. Does it change the suggested compressor? Can you explain why it is important to provide the additional superheat correctly? Change the superheat back to the previous value.

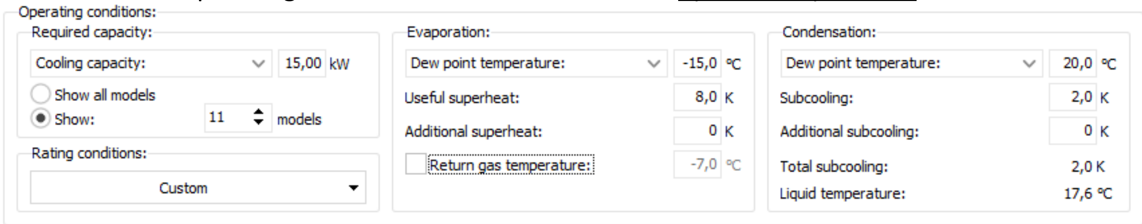
d) What is the COP of the suggested compressor at the working conditions? Save the project for the next exercise.

Solution 3.4 Understanding superheat and selecting a compressor

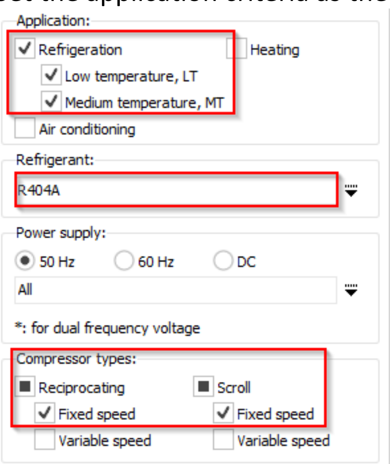
a) Create a new tab and choose the option compressors and condensing units. Then select “Compressors”:



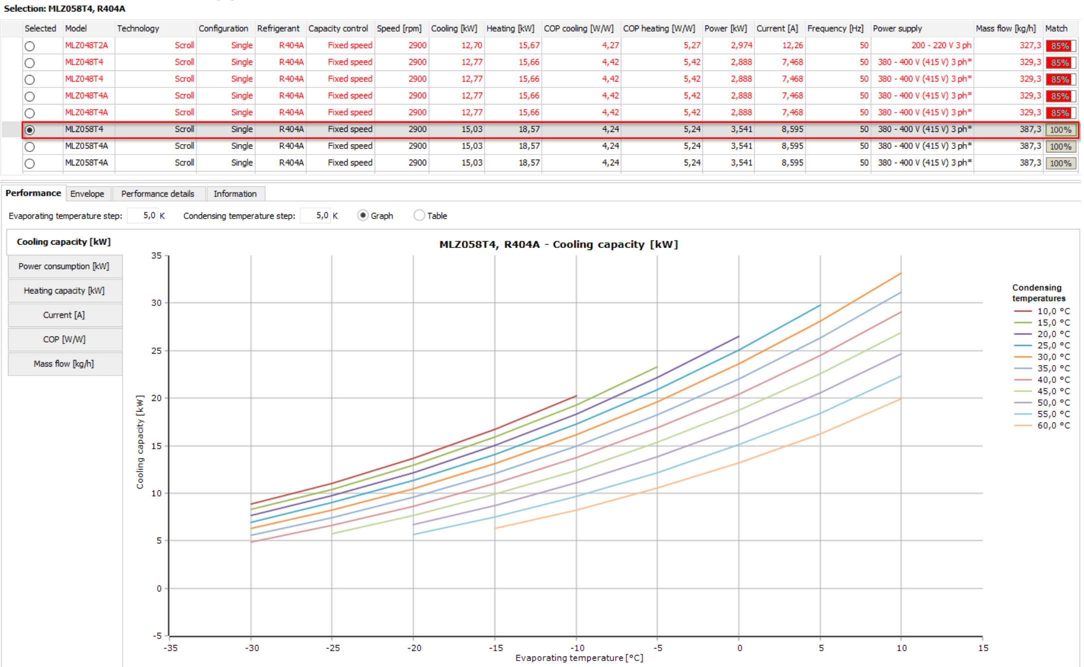
Check that the operating conditions are as mentioned in System Properties 1:



Set the application criteria as they were specified in the exercise:



Coolselector®2 suggests the MLZ058T4:



Selection: MLZ058T4, R404A

Selected	Model	Technology	Configuration	Refrigerant	Capacity control	Speed [rpm]	Cooling [kW]	Heating [kW]	COP cooling [W/W]	COP heating [W/W]	Power [kW]	Current [A]	Frequency [Hz]	Power supply	Mass flow [kg/h]	Match
○	MLZ048T2A	Scroll	Single	R404A	Fixed speed	2900	12,70	15,67	4,27	5,27	2,974	12,26	50	200 - 220 V 3 ph	327,3	85%
○	MLZ048T4	Scroll	Single	R404A	Fixed speed	2900	12,77	15,66	4,42	5,42	2,888	7,468	50	380 - 400 V (415 V) 3 ph*	329,3	85%
○	MLZ048T4	Scroll	Single	R404A	Fixed speed	2900	12,77	15,66	4,42	5,42	2,888	7,468	50	380 - 400 V (415 V) 3 ph*	329,3	85%
○	MLZ048T4A	Scroll	Single	R404A	Fixed speed	2900	12,77	15,66	4,42	5,42	2,888	7,468	50	380 - 400 V (415 V) 3 ph*	329,3	85%
○	MLZ048T4A	Scroll	Single	R404A	Fixed speed	2900	12,77	15,66	4,42	5,42	2,888	7,468	50	380 - 400 V (415 V) 3 ph*	329,3	85%
◉	MLZ058T4	Scroll	Single	R404A	Fixed speed	2900	15,03	18,57	4,24	5,24	3,541	8,595	50	380 - 400 V (415 V) 3 ph*	387,3	100%
○	MLZ058T4A	Scroll	Single	R404A	Fixed speed	2900	15,03	18,57	4,24	5,24	3,541	8,595	50	380 - 400 V (415 V) 3 ph*	387,3	100%
○	MLZ058T4A	Scroll	Single	R404A	Fixed speed	2900	15,03	18,57	4,24	5,24	3,541	8,595	50	380 - 400 V (415 V) 3 ph*	387,3	100%

The suggested compressor can achieve the requirement for this cycle and match the demand. You can check the match in the last column in the selection segment. To show the relevant details for this exercise, the columns shown for the selection segment are different from the default ones. If you want to know how you can change this, check out Exercise 1.1.

b) Some superheat is required for the refrigerant at the compressor inlet to ensure avoidance of liquid droplets in the compressor.

The useful superheat is the superheat inside the evaporator, which contributes to the cooling capacity. However, a very high useful superheat decreases the evaporator efficiency as well as the density at the evaporator outlet which results in higher compressor consumption. This value is set to 8 K by default in Coolselector®2.

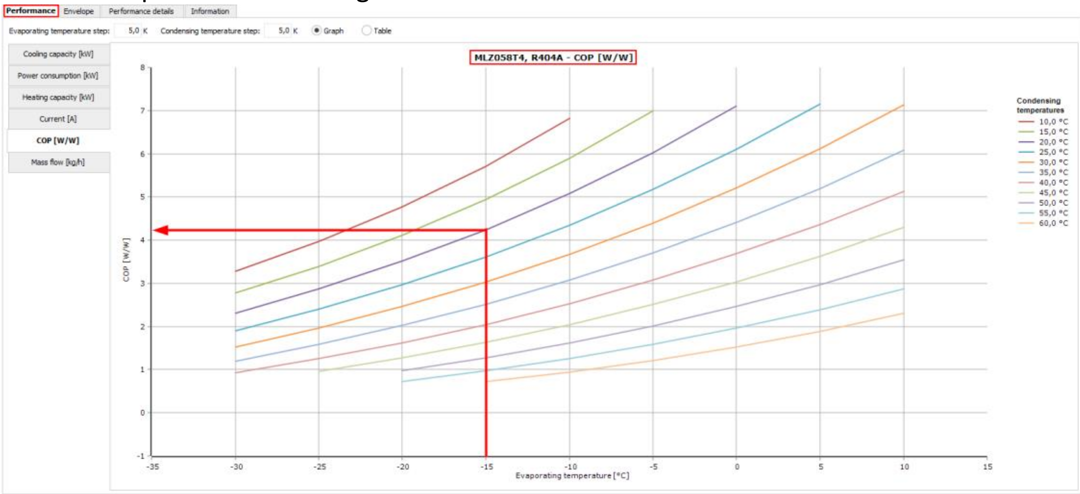
Additional superheat happens after the evaporator in the suction line. A longer length of the suction line would result in a higher additional superheat. This is set to zero by default, as it is highly affected by the length and size of the suction line, which is not provided in Coolselector®2. However, you should try to provide an accurate value or estimation for a good selection.

c) If you change the additional superheat to 5 K, the suggested compressor will change to MLZ058T2, which allows a slightly higher volumetric flow rate to support the given cooling capacity.

The reason is that increasing the useful superheat would result in a decrease of density after the suction line at the compressor inlet. The mass flow rate required for the cooling capacity would be the same (you can check that in the performance details tab), but a lower density means a higher volumetric flow rate, which results in demand for a slightly larger compressor. Another important aspect regarding additional superheat is the discharge temperature, which can be affected significantly, and which would affect selection of components in the discharge line, as well as compressors or condensing units.

Hence providing additional superheat correctly is important for proper selection and suggestion.

d) You can check the details of the compressors in the list in the performance tab in the product performance and information segment. To check the COP at the working conditions, choose the performance tab, then select the COP. Now you can check the COP for the compressor on working conditions:



You can also check the COP at the exact working condition in the selection segment:

Selected	Model	Technology	Configuration	Refrigerant	Capacity control	Speed [rpm]	Cooling [kW]	COP cooling [W/W]	Heating [kW]	COP heating [W/W]	Power [kW]	Current [A]	Frequency [Hz]	Power supply	Mass flow [kg/h]	Match
○	MLZ048T4A	Scroll	Single	R404A	Fixed speed	2900	12,77	4,42	15,66	5,42	2,888	7,468	50	380 - 400 V (415 V) 3 ph*	329,3	85%
○	MLZ048T4A	Scroll	Single	R404A	Fixed speed	2900	12,77	4,42	15,66	5,42	2,888	7,468	50	380 - 400 V (415 V) 3 ph*	329,3	85%
◉	MLZ058T4	Scroll	Single	R404A	Fixed speed	2900	15,03	4,24	18,57	5,24	3,541	8,595	50	380 - 400 V (415 V) 3 ph*	387,3	100%
○	MLZ058T4A	Scroll	Single	R404A	Fixed speed	2900	15,03	4,24	18,57	5,24	3,541	8,595	50	380 - 400 V (415 V) 3 ph*	387,3	100%
○	MLZ058T4A	Scroll	Single	R404A	Fixed speed	2900	15,03	4,24	18,57	5,24	3,541	8,595	50	380 - 400 V (415 V) 3 ph*	387,3	100%

Exercise 3.5 Selecting electronic controllers

Now, we would like to add a controller to our system. Our system, Cycle Diagram 1, is a single compressor system with an AKV expansion valve.

a) Select a case controller with the following requirements:

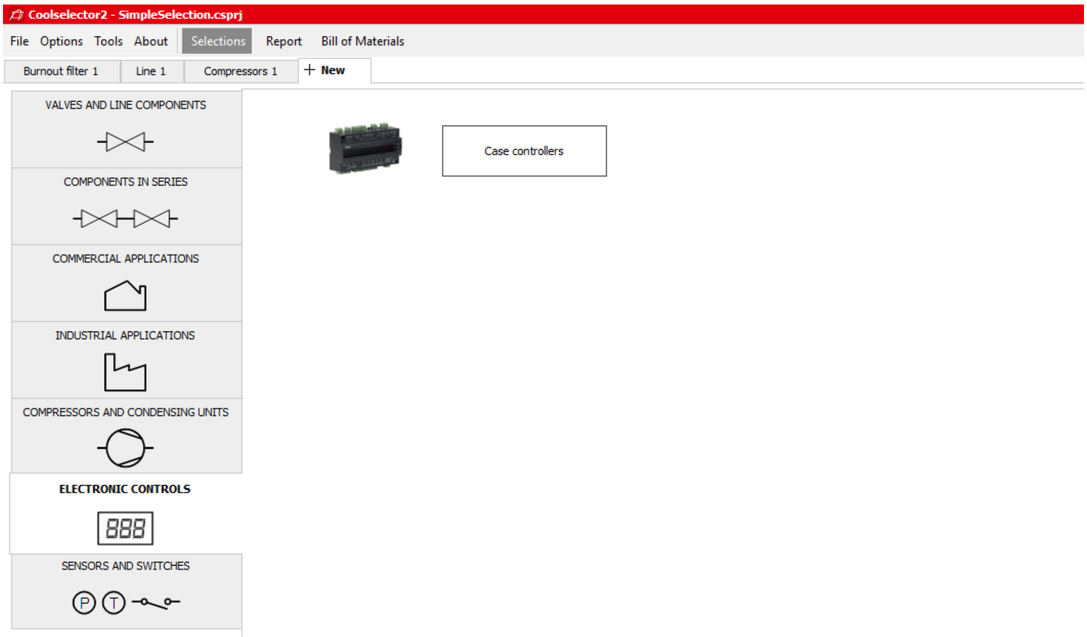
   1. Expansion Valve Type: EEV AKV
   2. Number of Compressors: Single compressor
   3. Communication: MOD bus

   Which controller(s) does Coolselector®2 suggest?

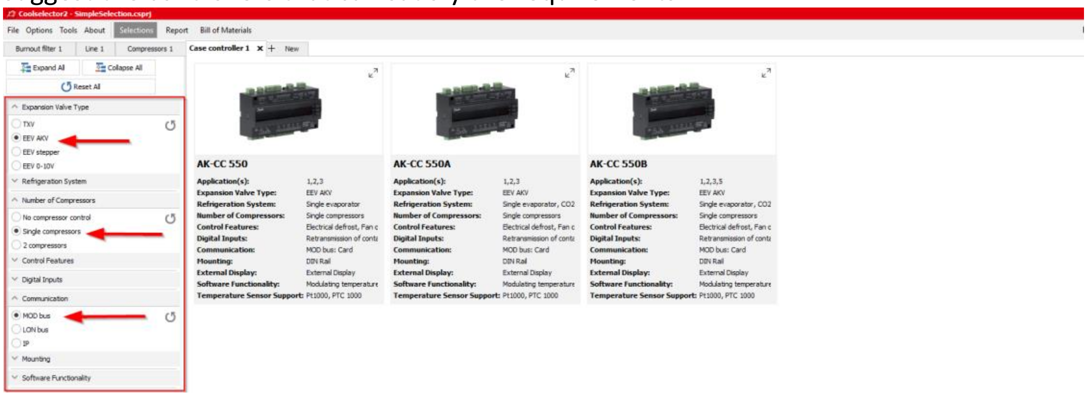
b) If we would like to have a system with "Dual case sections" as a future update, which controller(s) can you select?

Solution 3.5 Selecting electronic controllers

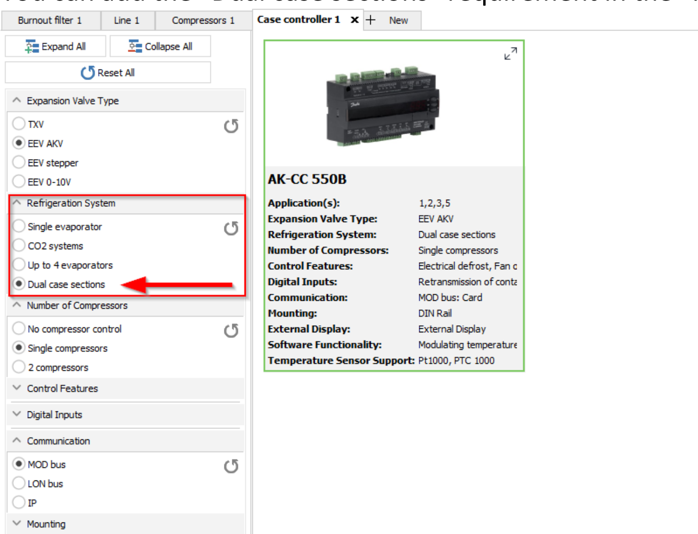
a) Create a new tab and choose the option “Electronic controls”. Then select “Case controllers”:



If you apply the requirements in the selection criteria segment, Coolselector®2 will suggest the controllers that can satisfy the requirements:



b) You can add the “Dual case sections” requirement in the “Refrigeration System” section:



Exercise 3.6 Creating a report, bill of materials and code numbers

Now, after going through the selections and calculation phase, we will create a report and get the bill of materials for our selections. For this exercise, load the project including burnout filter selection, the components in series selections for the liquid line, the compressor and the controller, then:

a) Check the report for your selections:

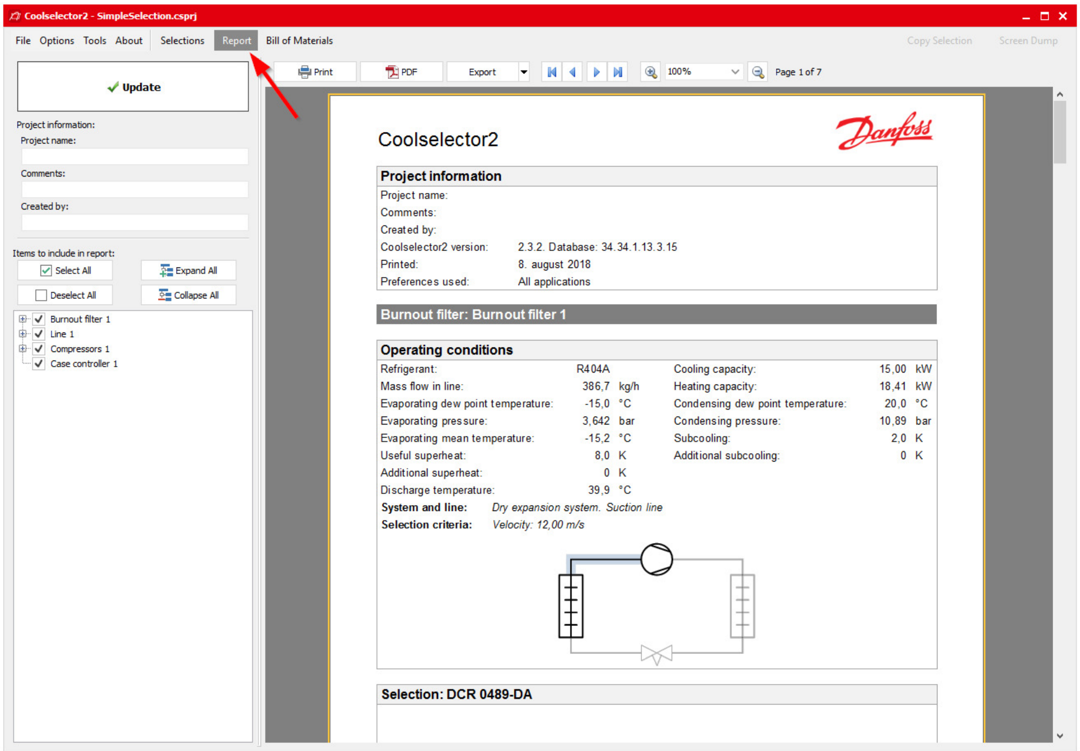
1. Then try adding your name to Coolselector®2, so it appears automatically on the reports. Add a project name to the report.
2. Add component performance details for the burnout filter and the cooling capacity curves for the compressor to your report.
3. Try exporting the report as a PDF file.

b) Select the code numbers for different components on each tab and then:

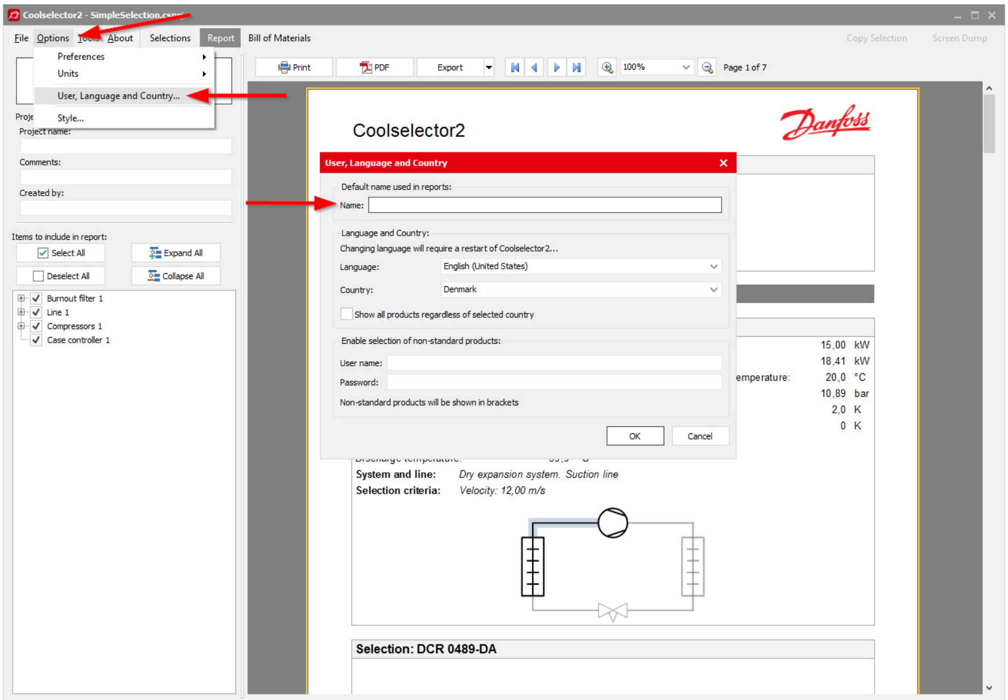
1. Check the bill of materials for your selections.
2. Include piping in your bill of materials.
3. Export your bill of materials as an Excel file.

Solution 3.6 Creating a report, bill of materials and code numbers

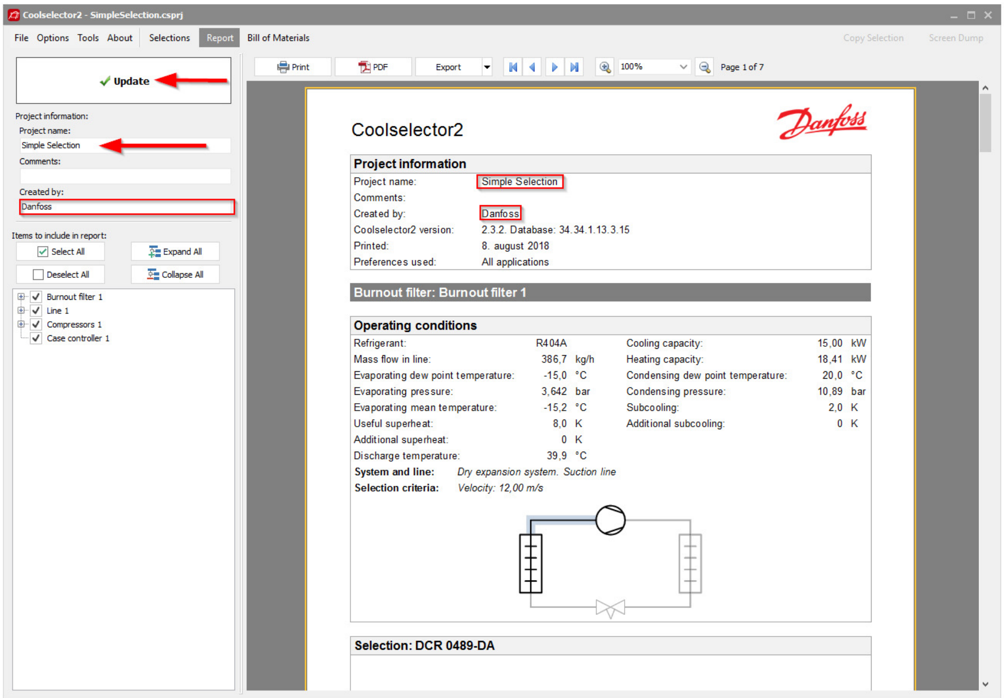
a) Check the report by clicking on the "Report" in the menu bar of Coolselector®2. This opens the report section. The segment for the project information will be blank if you did not enter this information before:



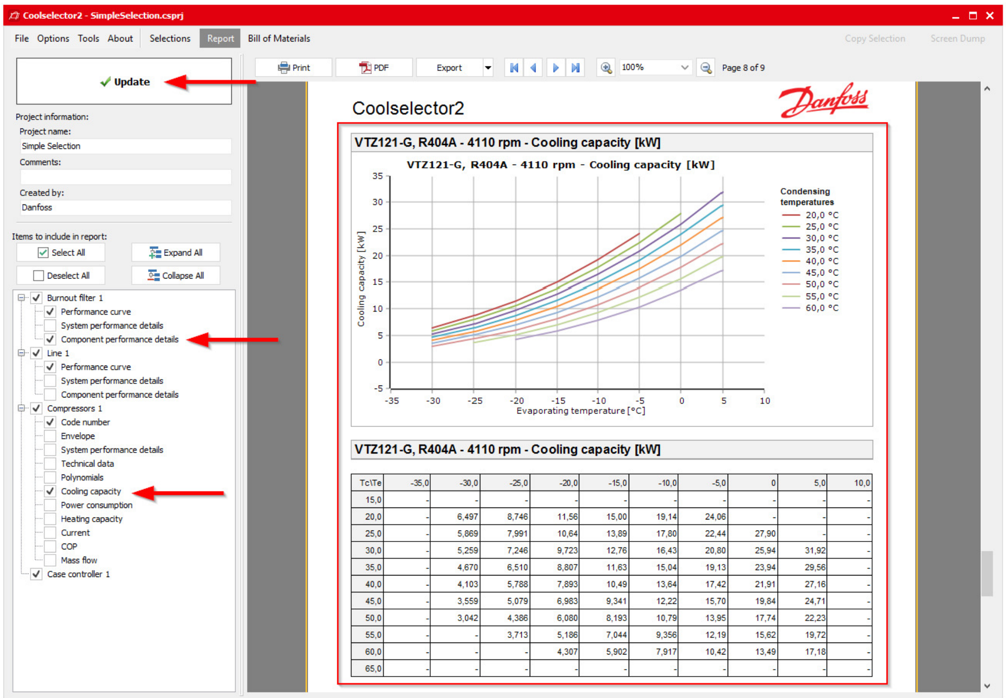
1. To add your name to Coolselector®2, open "Options | User, Language and Country …" and then add your name and click "OK"



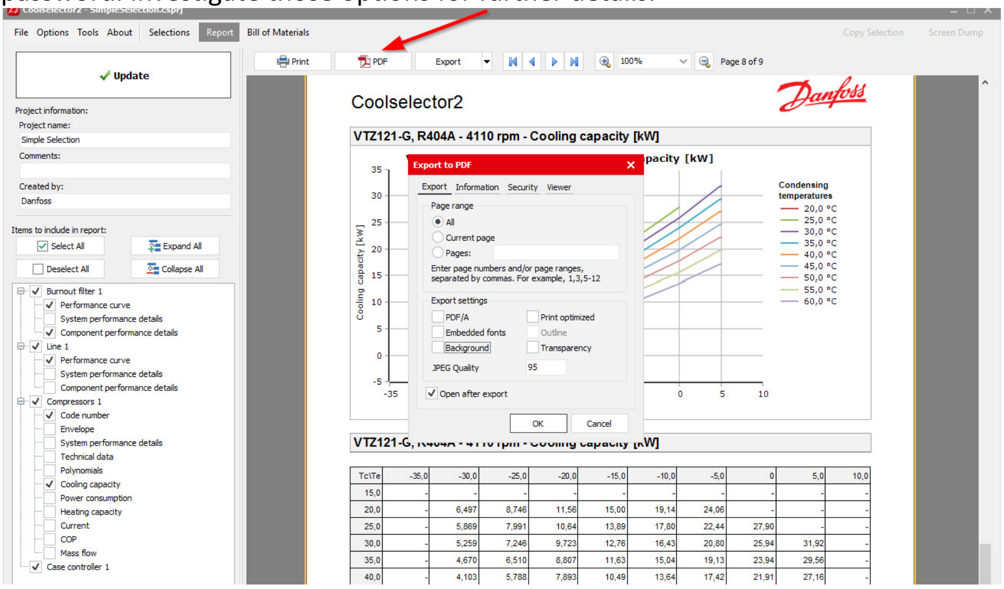
Now, your name should be on the report preview section. You can also add a project name. After that, click on "Update" to update the report preview:



2. You can add/remove included information in the report. To do so, click on the "+" sign beside each list to see the available options, or click on the "Collapse all button". Add the required fields requested by the exercise and click update and check the result. Note that each list belongs to one tab on your "Selections" section:



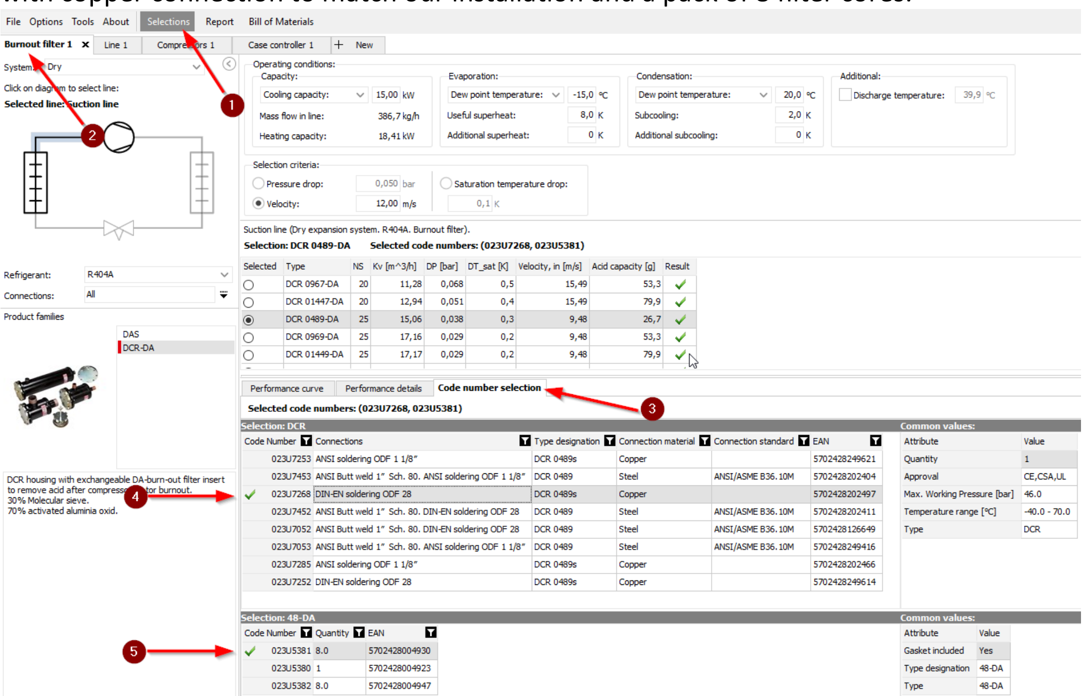
3. Click the “PDF” button at the top of the report preview to export your report as a PDF. You have multiple options for your exported PDF, such as printing specific pages in the report, adding extra information, or securing your pdf file with a password. Investigate those options for further details.



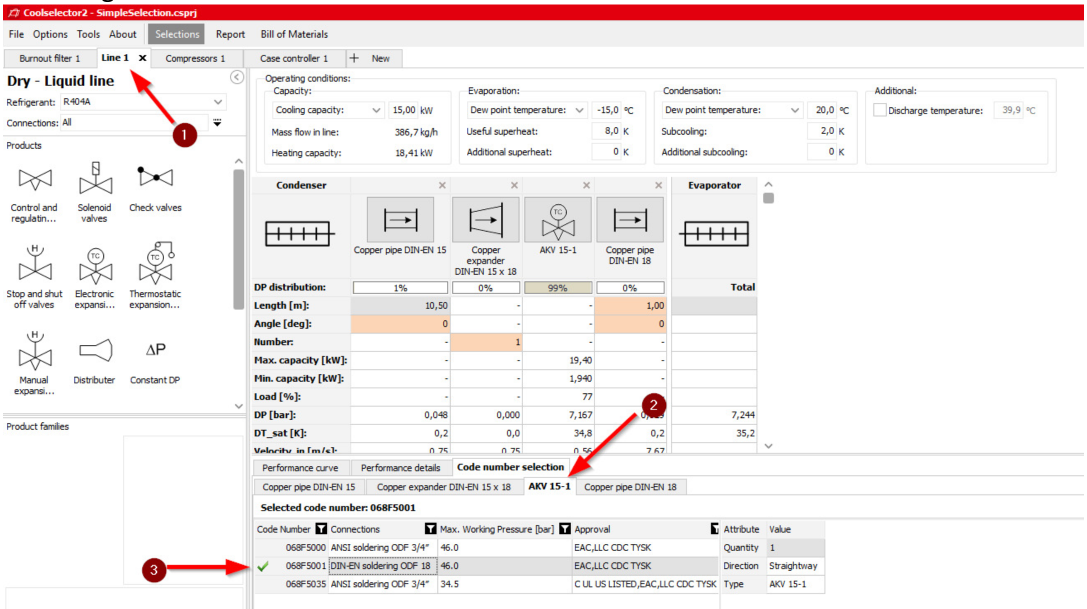
You will then be asked for the name and the location of the document and you can click “Save”. If you selected the option “Open after export”, the report will then automatically open.

b) Coolselector®2 enables you to select the relevant code numbers for the selected products. Depending on the product type, the code number(s) can be accessed/modified differently. In the current document, go to the “Selections” section by clicking on the “Selections” button in the menu bar.

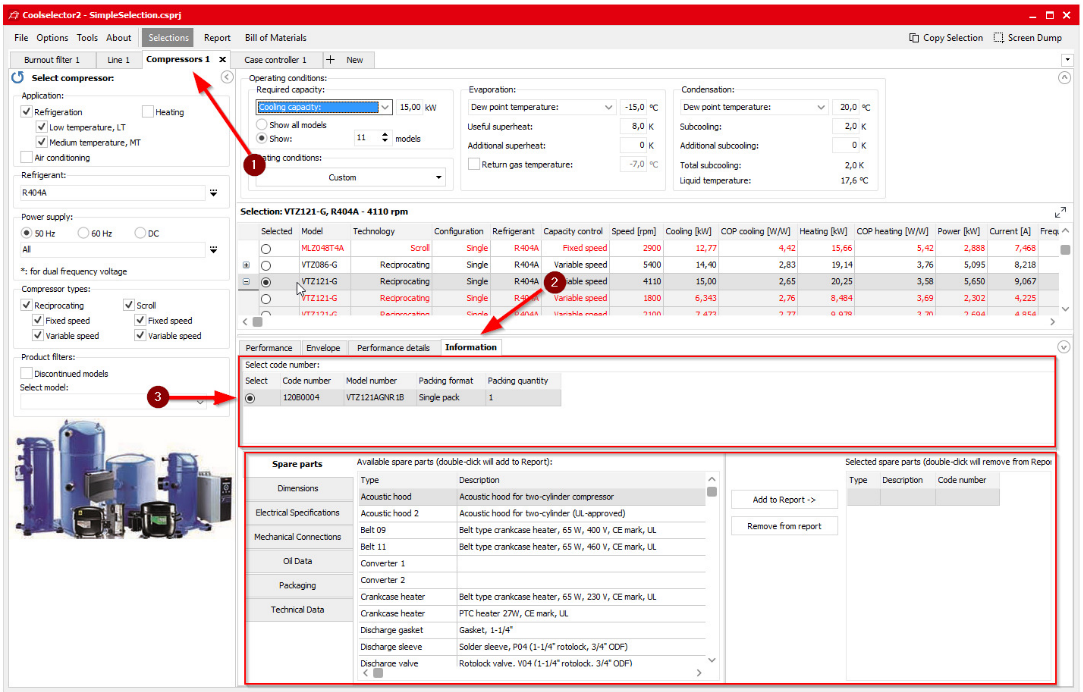
Go to the tab for “Burnout filter" and select the tab for “Code number selection” and select the proper casing and filters. E.g. we would like to have the DIN connection casing with copper connection to match our installation and a pack of 8 filter cores:



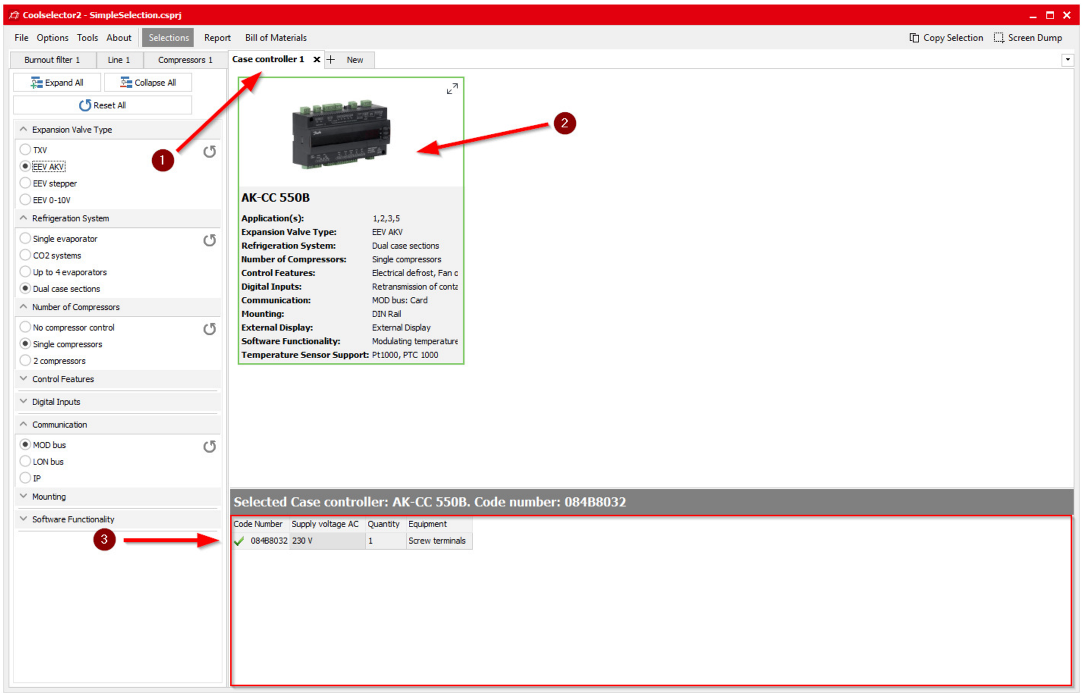
Then, go to the tab for liquid-line calculation and select the code number for the AKV valve. E.g. we select the one with DIN-EN connection to match our selection:



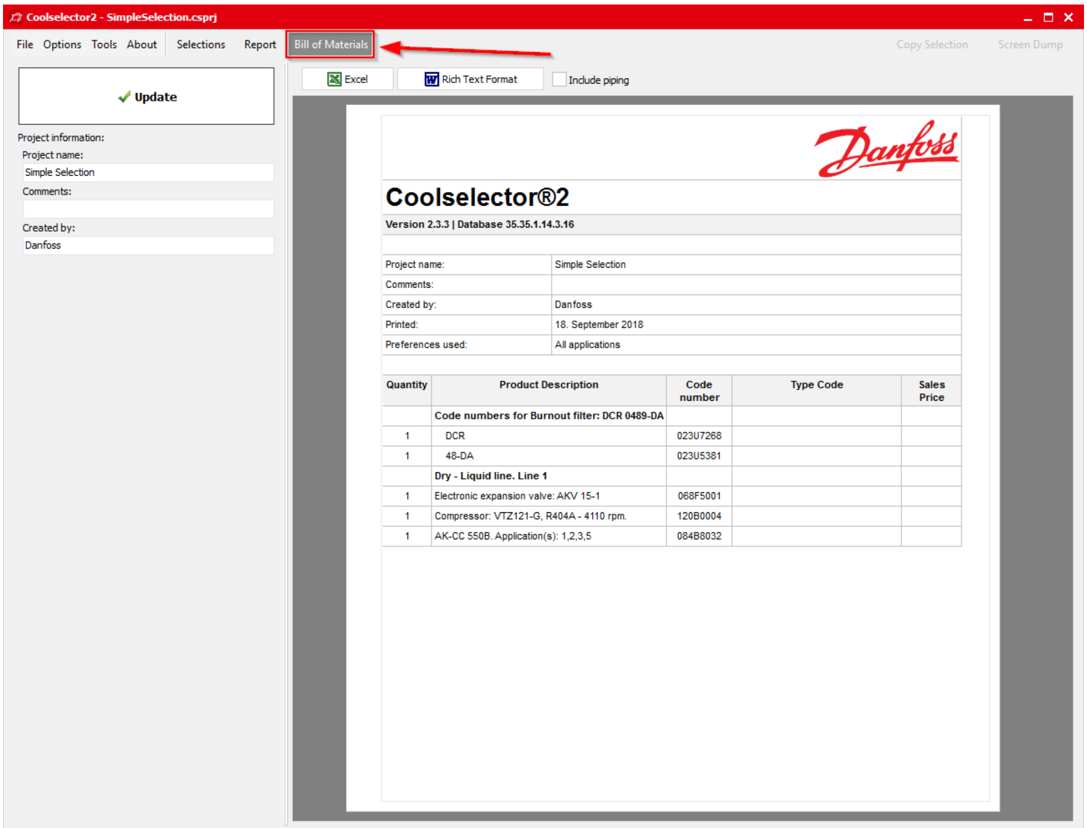
Now, for the compressor code number, you need to go the "Information" tab, where you can select the code number and also see other information about the compressor, including the available spare parts:



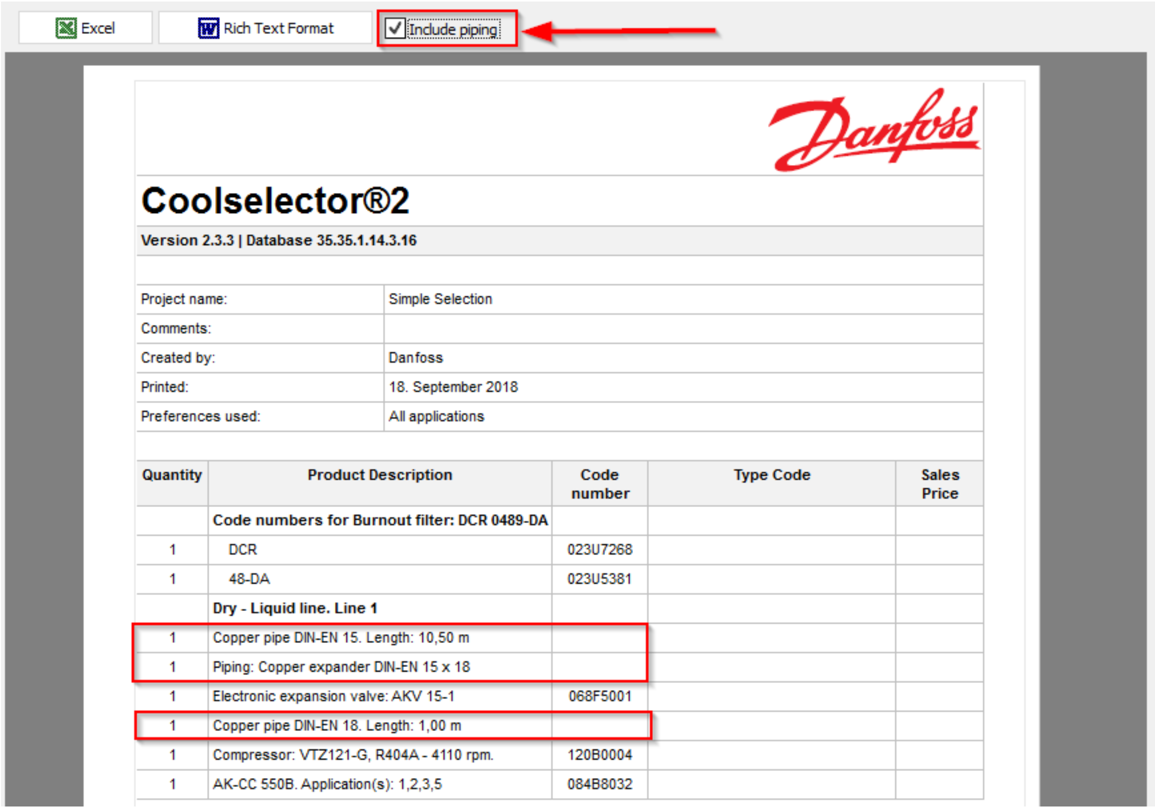
And for the case controller the code number is visible after you click on your selected controller:



1. To check the bill of materials after the selection of code numbers, you just need to click on the “Bill of materials” button in the menu bar:



2. To include the piping, just click on the option “Include piping”:



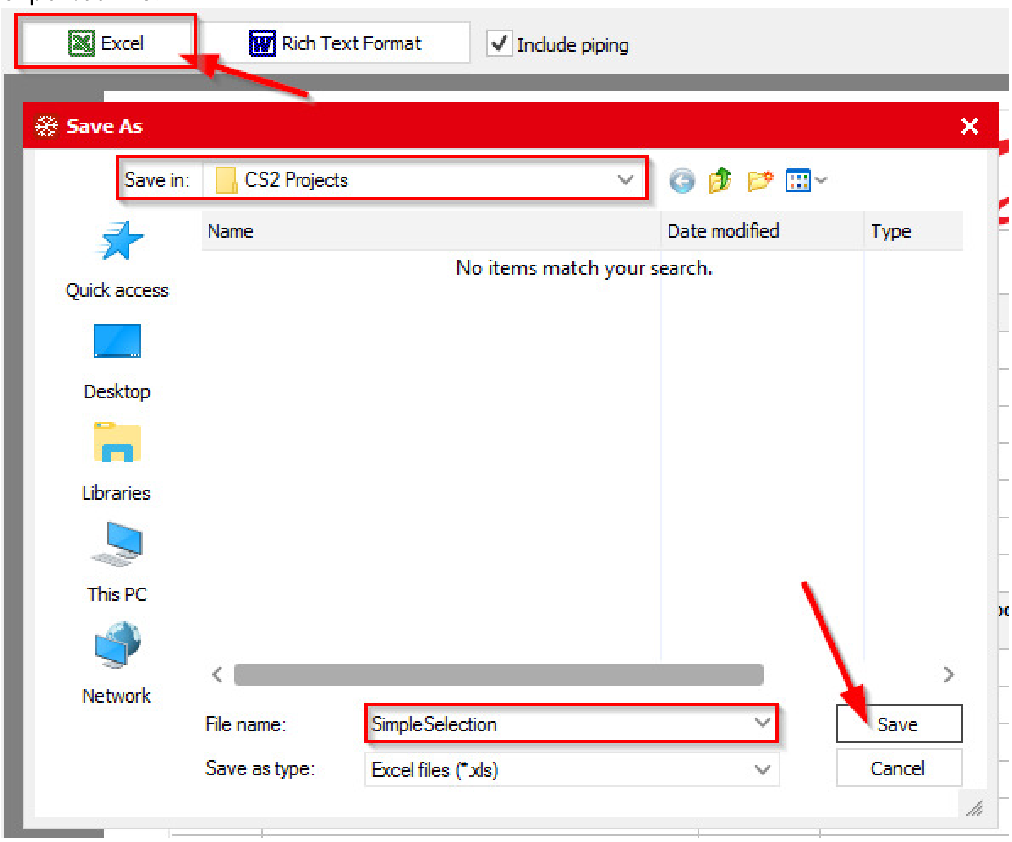
Coolselector®2

Version 2.3.3 | Database 35.35.1.14.3.16

Project name:	Simple Selection
Comments:	
Created by:	Danfoss
Printed:	18. September 2018
Preferences used:	All applications

Quantity	Product Description	Code number	Type Code	Sales Price
	Code numbers for Burnout filter: DCR 0489-DA			
1	DCR	023U7268		
1	48-DA	023U5381		
	Dry - Liquid line. Line 1			
1	Copper pipe DIN-EN 15. Length: 10,50 m			
1	Piping: Copper expander DIN-EN 15 x 18			
1	Electronic expansion valve: AKV 15-1	068F5001		
1	Copper pipe DIN-EN 18. Length: 1,00 m			
1	Compressor: VTZ121-G, R404A - 4110 rpm.	120B0004		
1	AK-CC 550B. Application(s): 1,2,3,5	084B8032		

3. To export the bill of materials as an Excel file, click on the “Excel” button at the top of the bill of materials preview. Then specify the destination and the name for the exported file:



Exercise 3.7 Changing predefined preferences and customizing the interface

a) What is the equivalent of operating conditions in different unit systems? Change the unit system to American units.

b) Set the preferences to commercial applications. Check the changes that happened in the default interface of the new tab. Is there any difference in the option for selection of "Valves and Line Components"? Then go back to all applications again.

c) Modify the selection table for compressors:

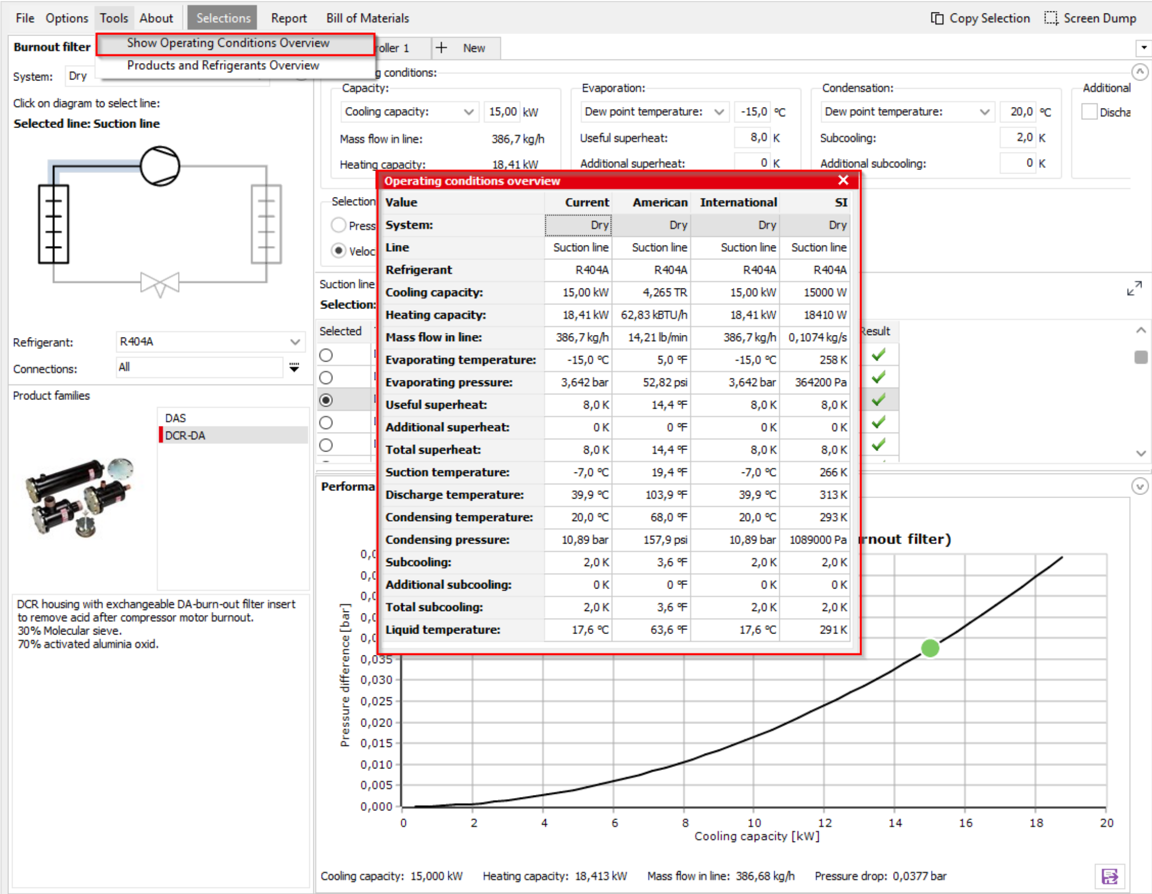
1. Remove the columns after "Mass flow".
2. Replace "Heating" column with COP cooling.

d) Resize the segments in the current session for the burnout filter:

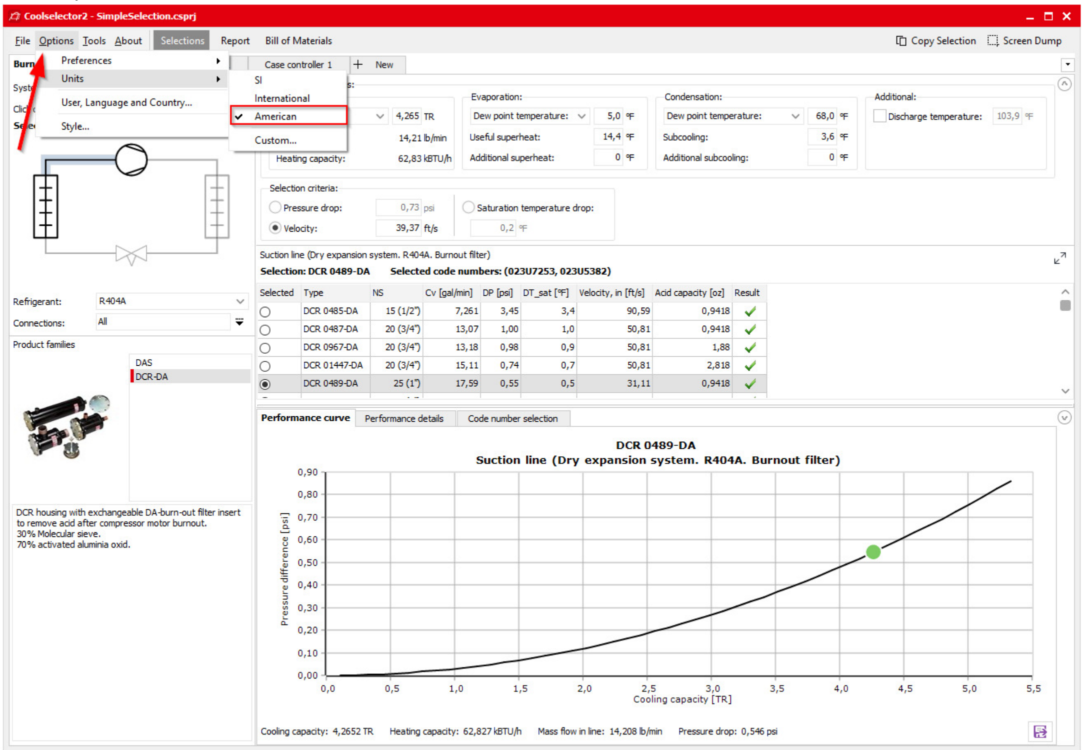
1. Minimize the operating conditions segment. Then maximize it again.
2. Resize the product performance and information section.
3. Expand the selection table and performance and information section to full screen.

Solution 3.7 Changing predefined preferences and customizing the interface

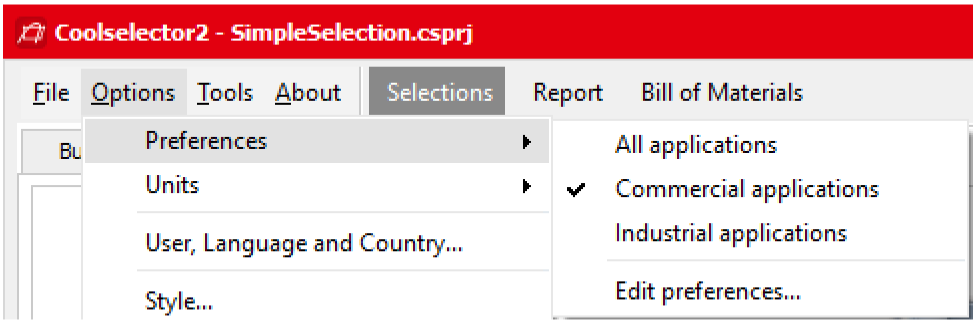
a) You can select the “Tools | Show operating conditions” menu and see the equivalent of your operating conditions in different unit systems:



To change the unit system to American units, you simply need to select it in “Options | Units | American”:

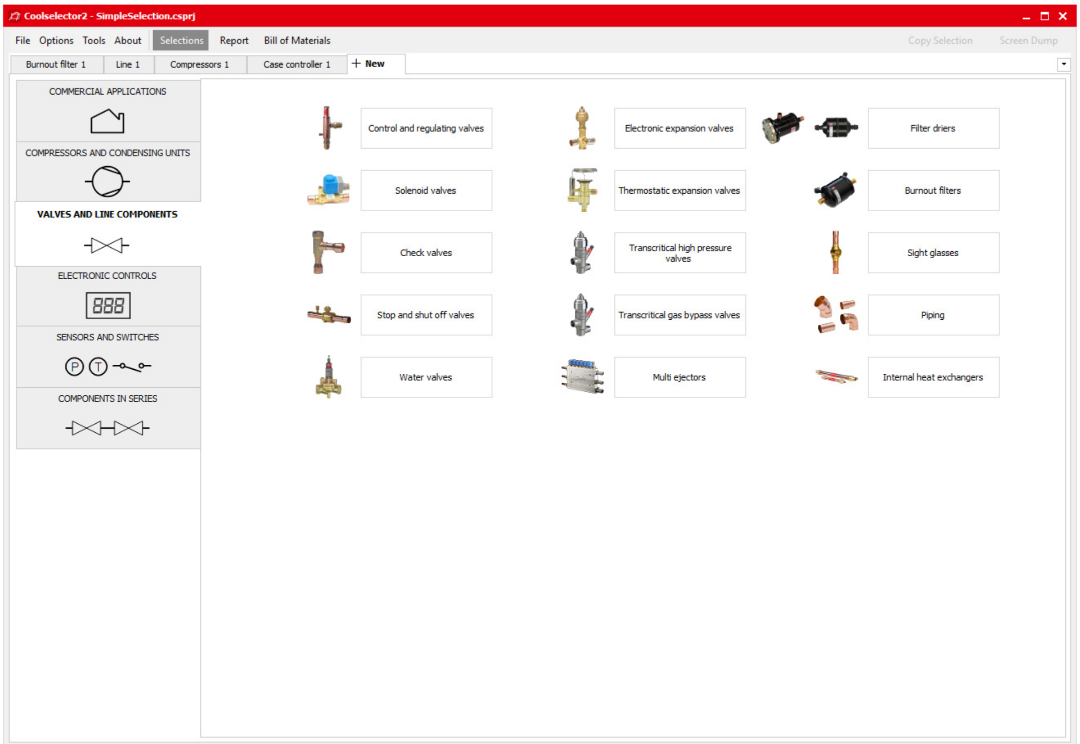


b) You can set the preferred application to commercial applications in “Options | Preferences | Commercial applications”:

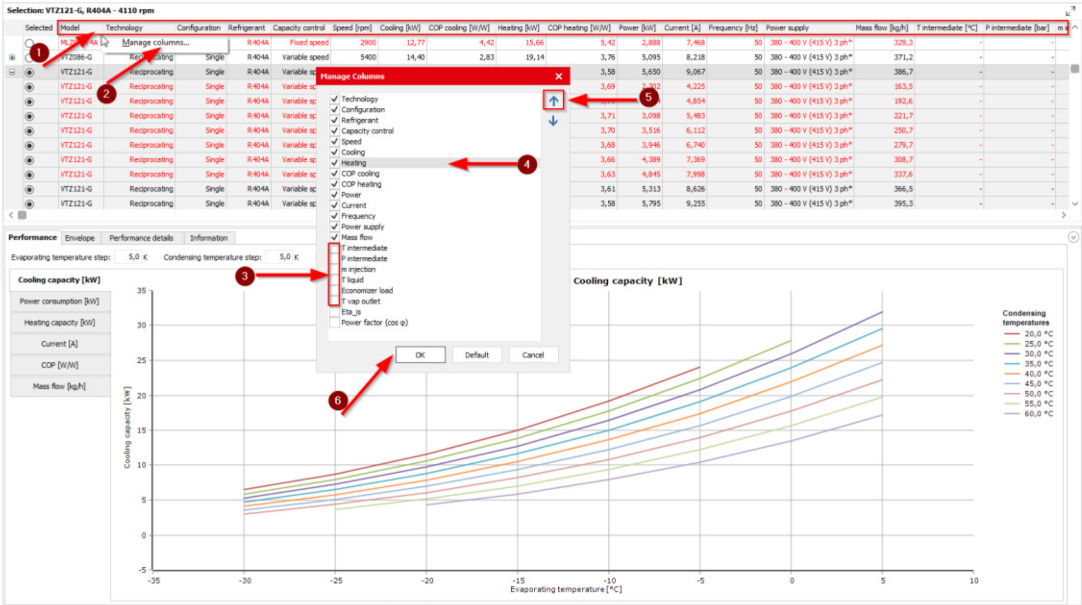


You will notice that the “+ New” tab interface has changed in terms of product sort order as well as the available options. This is to provide a better environment for you as the user. You can customize the options to further match your requirements, this is somethingwe will discuss that in the next exercise.

You can see that some of the options, which are more specific to industrial applications are now missing from the “+ New” tab interface, such as “ICF valve station”:



c) Go to the tab for your selected compressor. You can modify which columns you see in your selection table and also change the order of the calculations and selections made in the “Valve and Line Components” option as well as “Compressors”. To do so, right click on the table header and select “Manage Columns…”. This is step 1 and 2 in the following snippet:



1. To remove the columns after the “Mass flow”, you can simply uncheck them in the list as shown by step 3.
2. To replace “Heating” with “COP cooling”, you should click on “Heating” and then click on the top arrow as shown by steps 4 and 5.

Then you can click OK to update the table. Coolselector®2 will remember your modifications next time you run it, and you can always go back to the default table by clicking on the default setting:

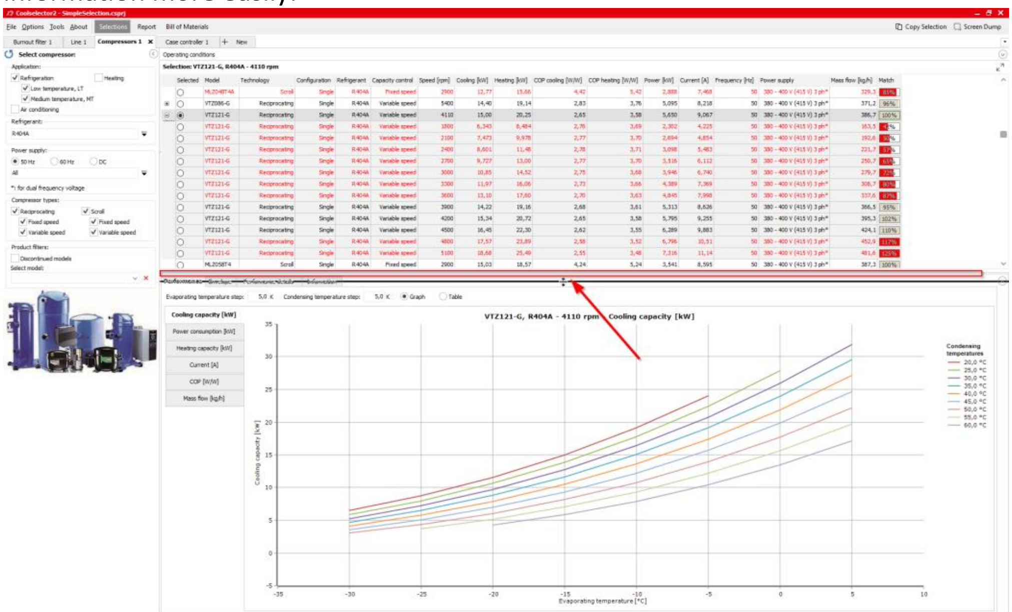
Selection: VTZ121-G, R404A - 4110 rpm

	Selected	Model	Technology	Configuration	Refrigerant	Capacity control	Speed [rpm]	Cooling [kW]	Heating [kW]	COP cooling [W/W]	COP heating [W/W]	Power [kW]	Current [A]	Frequency [Hz]	Power supply	Mass flow [kg/h]	Match
		MLZ048T4	Scroll	Single	R404A	Fixed speed	2900	12,77	15,66	4,42	5,42	2,888	7,468	50	380 - 400 V (415 V) 3 ph*	329,3	85%
		MLZ048T4	Scroll	Single	R404A	Fixed speed	2900	12,77	15,66	4,42	5,42	2,888	7,468	50	380 - 400 V (415 V) 3 ph*	329,3	85%
		MLZ048T4A	Scroll	Single	R404A	Fixed speed	2900	12,77	15,66	4,42	5,42	2,888	7,468	50	380 - 400 V (415 V) 3 ph*	329,3	85%
		MLZ048T4A	Scroll	Single	R404A	Fixed speed	2900	12,77	15,66	4,42	5,42	2,888	7,468	50	380 - 400 V (415 V) 3 ph*	329,3	85%
+		VTZ086-G	Reciprocating	Single	R404A	Variable speed	5400	14,40	19,14	2,83	3,76	5,095	8,218	50	380 - 400 V (415 V) 3 ph*	371,2	96%
−		VTZ121-G	Reciprocating	Single	R404A	Variable speed	4110	15,00	20,25	2,65	3,58	5,650	9,067	50	380 - 400 V (415 V) 3 ph*	386,7	100%
		VTZ121-G	Reciprocating	Single	R404A	Variable speed	1800	6,343	8,484	2,76	3,69	2,302	4,225	50	380 - 400 V (415 V) 3 ph*	163,5	42%
		VTZ121-G	Reciprocating	Single	R404A	Variable speed	2100	7,473	9,978	2,77	3,70	2,694	4,854	50	380 - 400 V (415 V) 3 ph*	192,6	50%
		VTZ121-G	Reciprocating	Single	R404A	Variable speed	2400	8,601	11,48	2,78	3,71	3,098	5,483	50	380 - 400 V (415 V) 3 ph*	221,7	57%
		VTZ121-G	Reciprocating	Single	R404A	Variable speed	2700	9,727	13,00	2,77	3,70	3,516	6,112	50	380 - 400 V (415 V) 3 ph*	250,7	65%
		VTZ121-G	Reciprocating	Single	R404A	Variable speed	3000	10,85	14,52	2,75	3,68	3,946	6,740	50	380 - 400 V (415 V) 3 ph*	279,7	72%
		VTZ121-G	Reciprocating	Single	R404A	Variable speed	3300	11,97	16,06	2,73	3,66	4,389	7,369	50	380 - 400 V (415 V) 3 ph*	308,7	80%
		VTZ121-G	Reciprocating	Single	R404A	Variable speed	3600	13,10	17,60	2,70	3,63	4,845	7,998	50	380 - 400 V (415 V) 3 ph*	337,6	87%

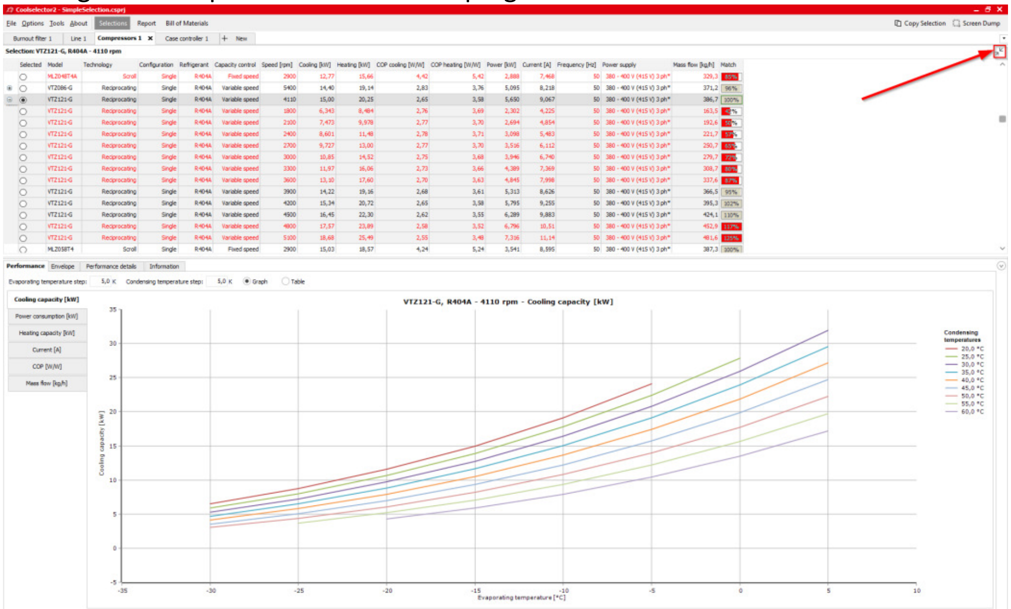
d) You can also resize different segments or minimize the segments to see the information more clearly. Coolselector®2 will remember previous modifications mentioned in this exercise, but sizes will reset to default when you start Coolselector®2 again.

1. You can minimize the “Operating conditions” segment by clicking on the button at the top right-hand side of the segment:

2. To resize any of the segments, you can click and drag on the border to see information more easily:



3. After setting the general criteria and operating conditions and the product suggestion criteria, sometimes, it is handy to expand the segments for the selection table and product performance and information to full-screen. You can do that by clicking on the expand button in the top right-hand corner of the selection table:



Exercise 3.8 Changing the advanced settings

Create a custom preference for the selection you made in this chapter by going to “Options | Preferences | Edit preferences” and then:

a) Select “Dry expansion system” as the default system for your custom preference. Then enable “Valves and Line Components”, “Components in series”, Compressors and Condensing Units” and “Electronic Controls” as the available product pages.

b) Go to the “Operating conditions" tab and change the refrigerant and default values for subcritical systems to match the information in System Properties 1.

c) Go to the “Valves and Line Components” and select “Commercial components”. Then remove all connections except for “Copper DIN-EN”.

d) Go to the “Compressors and condensing units” and change the number of models to show to 15.

e) Save your preferences to use them later.

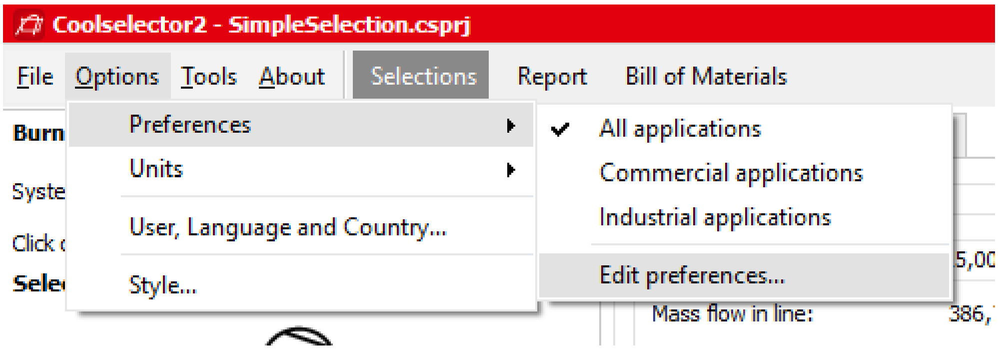
f) Can you change the default length of the pipes?

g) Can you change the default selection criteria for the “Copper pipes” in the discharge line to velocity?

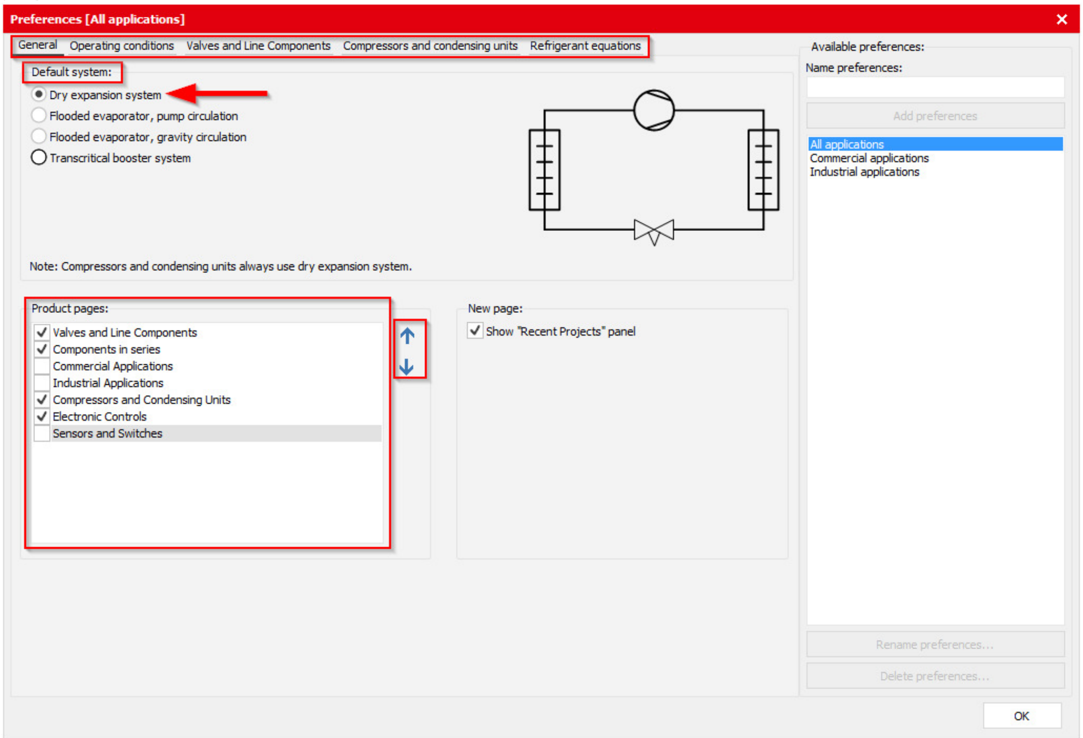
h) Can you create a custom unit system for your special needs based on American units but using kilowatts as the unit for the cooling and the heating capacity?

Solution 3.8 Changing the advanced settings

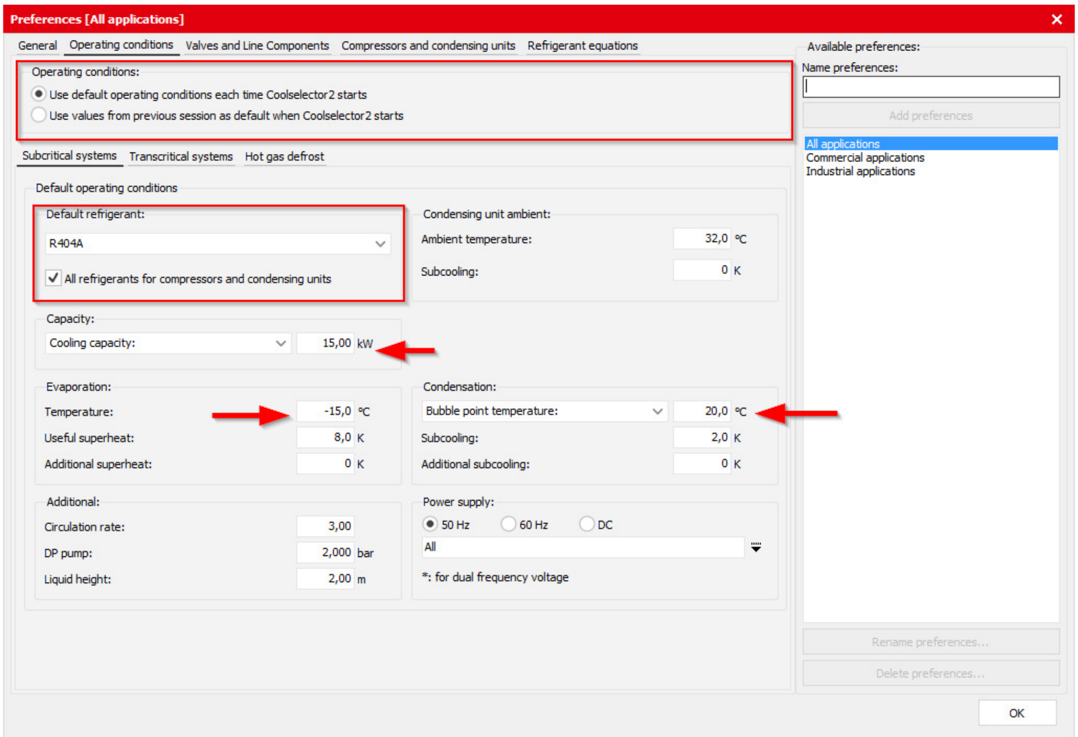
The settings we discuss in this exercise do not need to be modified in most cases, since we, in the Coolselector®2 team, constantly strive to optimize the default preferences based on our customers' requirements. However, the advanced settings enable you to customize and improve your experience and even modify the calculations if you see a necessity to do so. To create custom preferences, use "Options | Preferences | Edit preferences…":



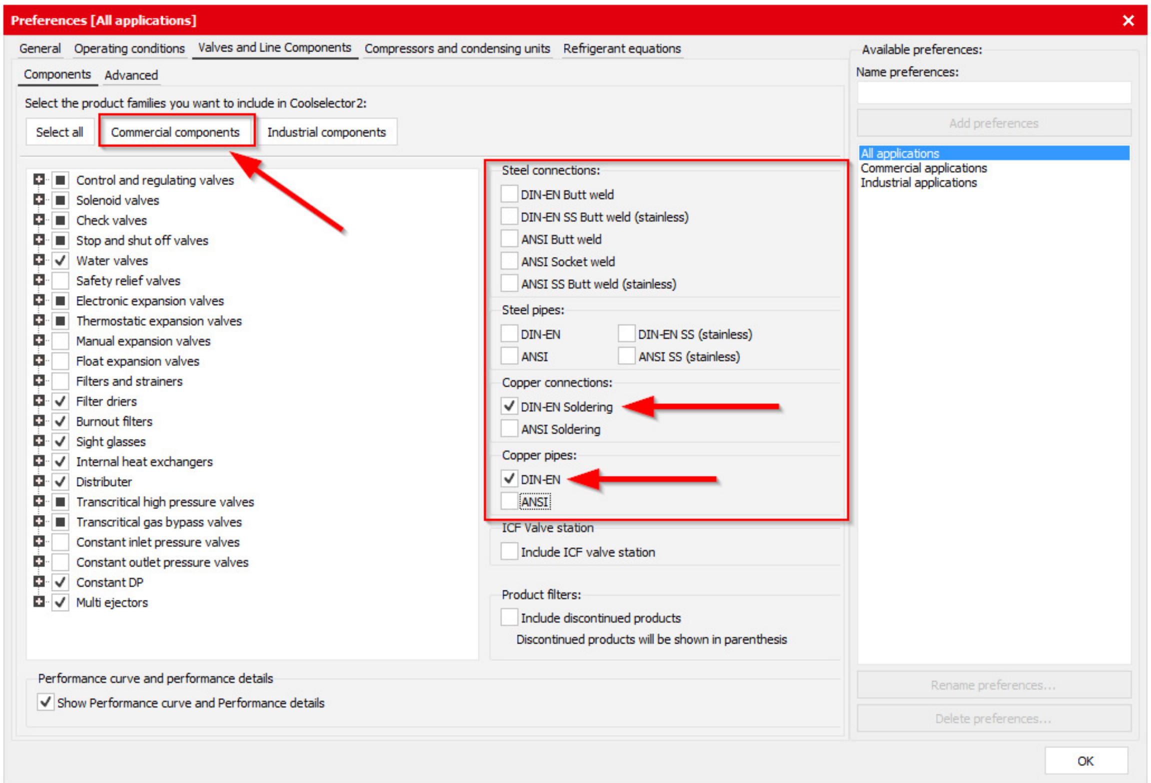
a) You will see the "Preferences" window. On top you have the different preferences that we will try to cover briefly in this exercise. Feel free to investigate further and explore your other options. You can select "Dry expansion systems" among the options for the "Default system" and add/remove options for your selection and calculations among the product pages and also sort their order in the interface:



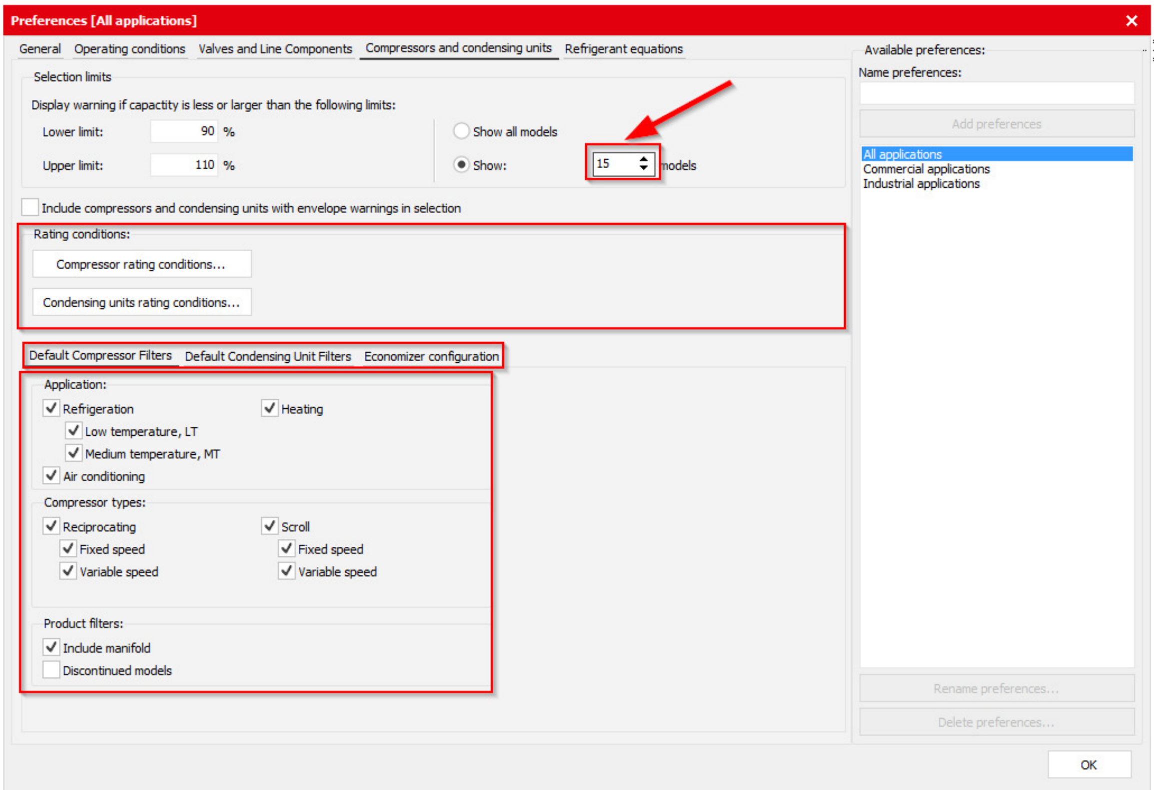
b) Then you can go to the “Operating conditions” tab by clicking on the top bar and changing the default operating conditions:



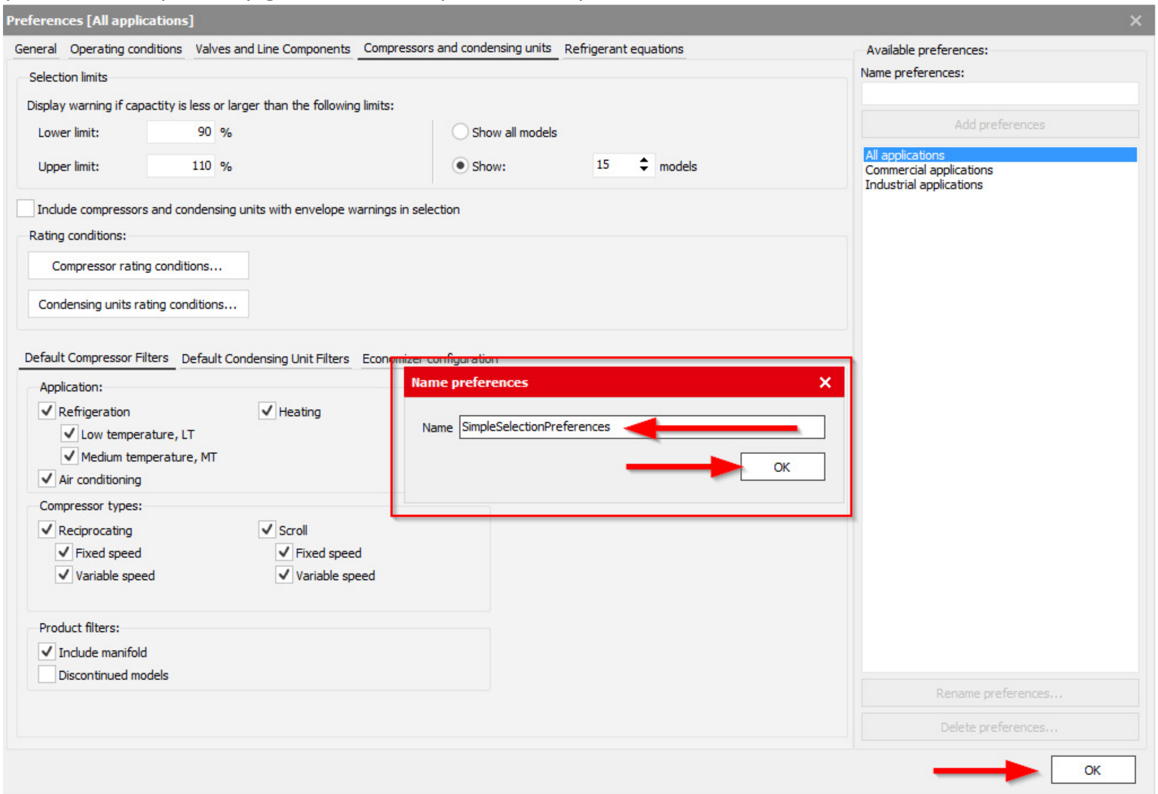
c) Now, you can go to the “Valves and Line Components” tab and select the type of components you would like to see for your selections/calculations and the families in each functionality, as well as connection sizes and some more options:



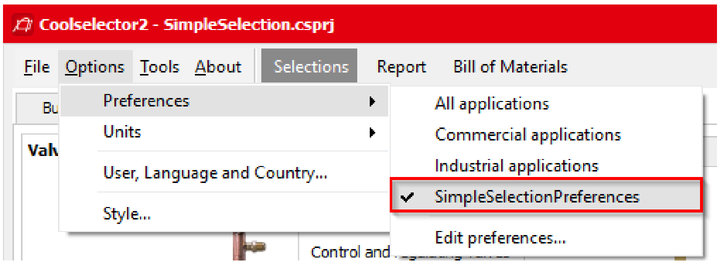
d) In the tab for compressors and condensing units, you will find the relevant settings for those products. You can choose which products to see and even see the rating conditions as well as create custom ones. You can also set the limits to those that you prefer. For this exercise, we just want to change the number of models to show in the selection table:



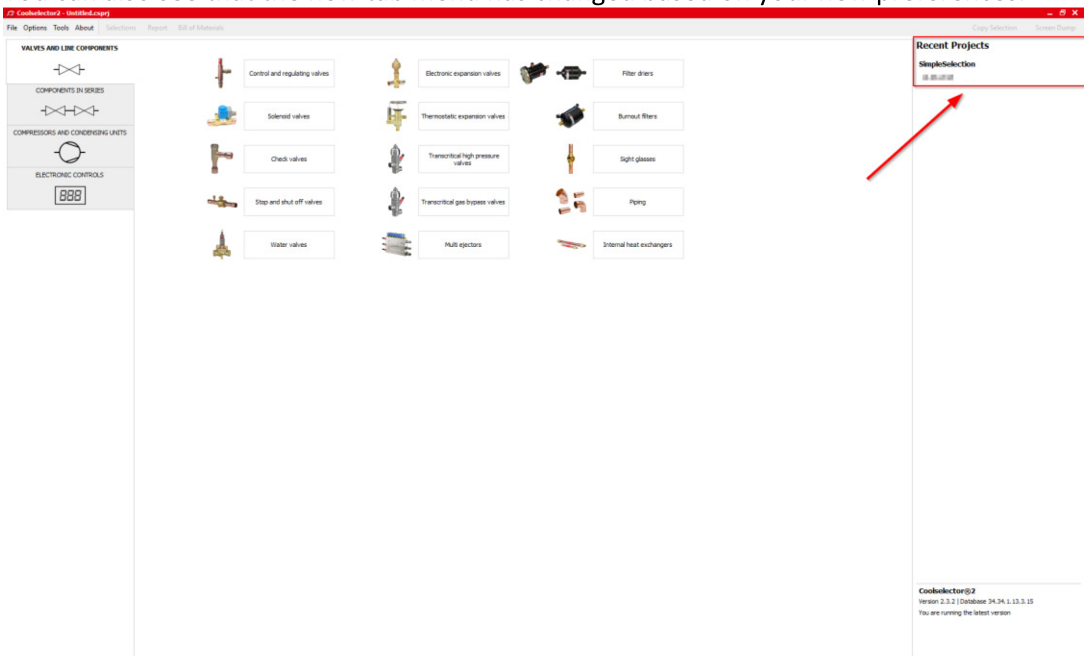
e) If you click the "OK" button to apply your settings, Coolselector®2 will ask you to name your preferences and save them. Coolselector®2 will keep the default settings intact so you can always easily go back to the predefined preferences:



Next time you open Coolselector®2, it will keep your preferences and you can see that in the list of the preferences. You can come back to this menu and edit, rename or delete your preferences at any time.



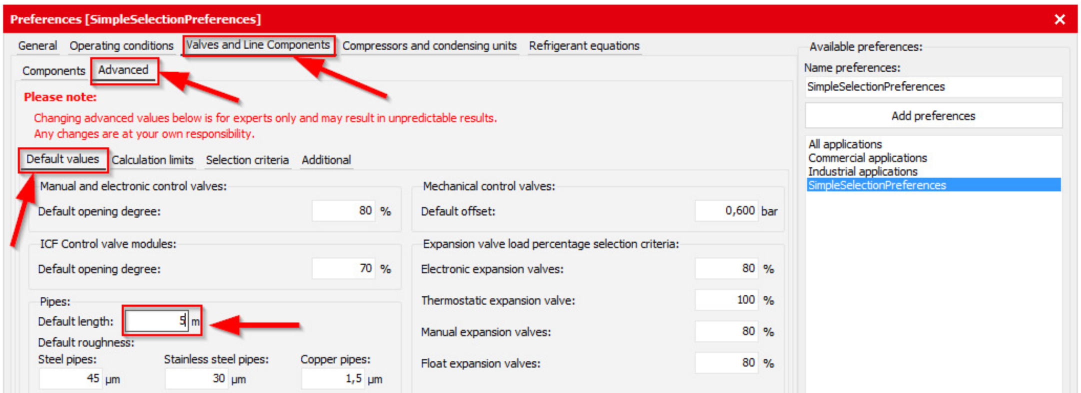
You can also see that the new tab menu has changed based on your new preferences.



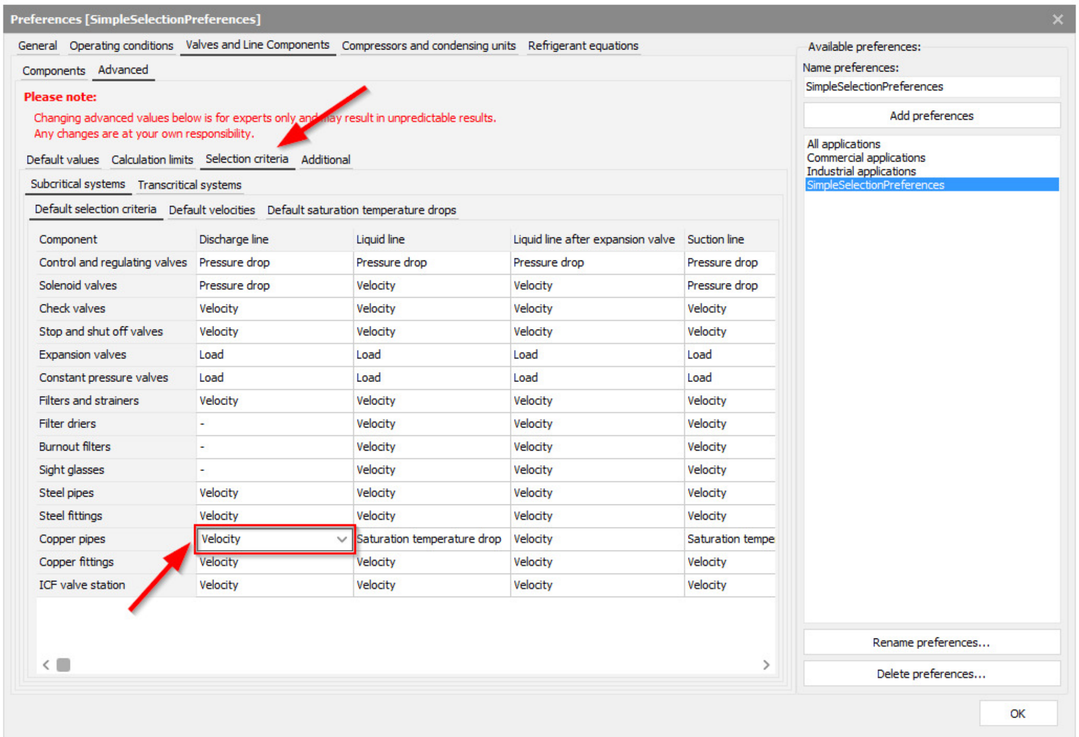
And on the top right-hand side of the window, you will be able to see the recent projects and load them easily.

Please note that changing the following settings can affect the results of the selection or calculation process and lack of due care can have a negative effect on the suggestions and default calculations. However, when necessary, the advanced settings can be changed, but it is suggested to avoid such changes and to revert them to the default values when there is no need to change them.

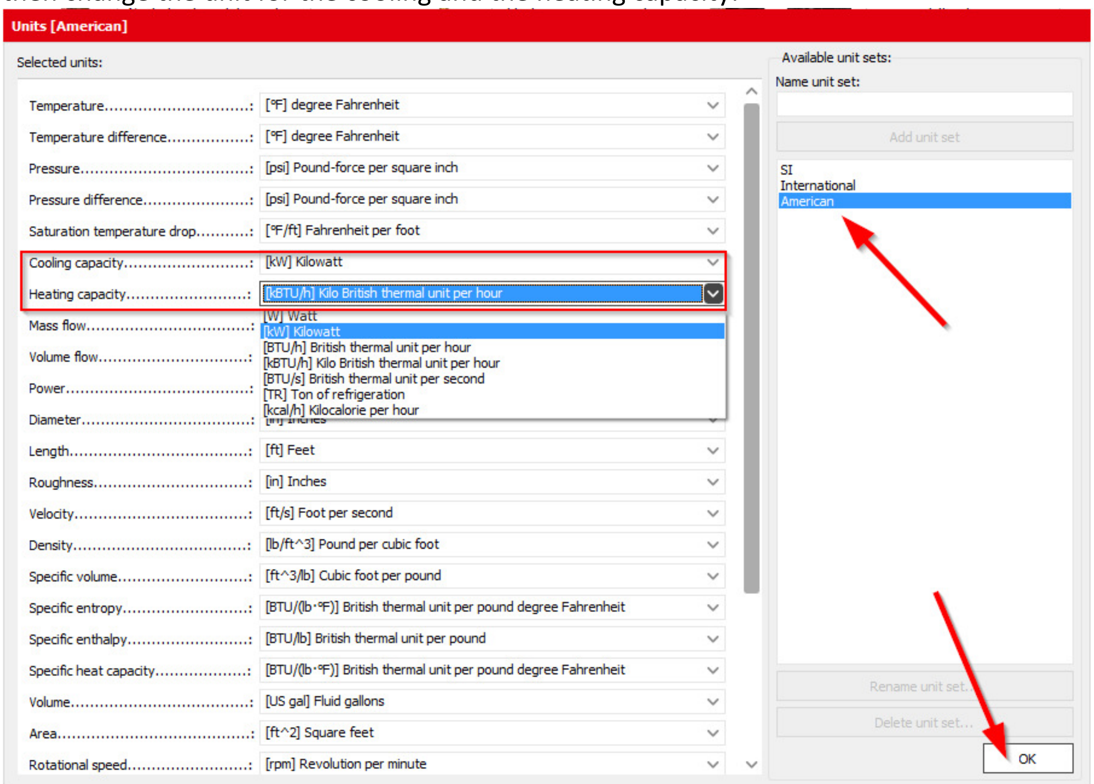
f) The default values for the calculations can be changed in "Valves and Line Components | Advanced | Default values" in the preferences window. For this exercise, we want to change the default length of the pipes to 5 meters instead of 10 meters:



g) The selection criteria for all the components supported by Coolselector®2 can be found in "Valves and Line Components | Advanced | Selection critera":



h) To create a custom unit system, you need to go to "Options | Units | Custom…". Then you will find the unit used for each of the default unit systems, and you can create your own. For the unit system for this exercise, we need to select the American unit system first and then change the unit for the cooling and the heating capacity:



By clicking OK, you will be asked to save your custom unit system and give it a name. It will then appear on the list of unit systems similar to your custom preferences.

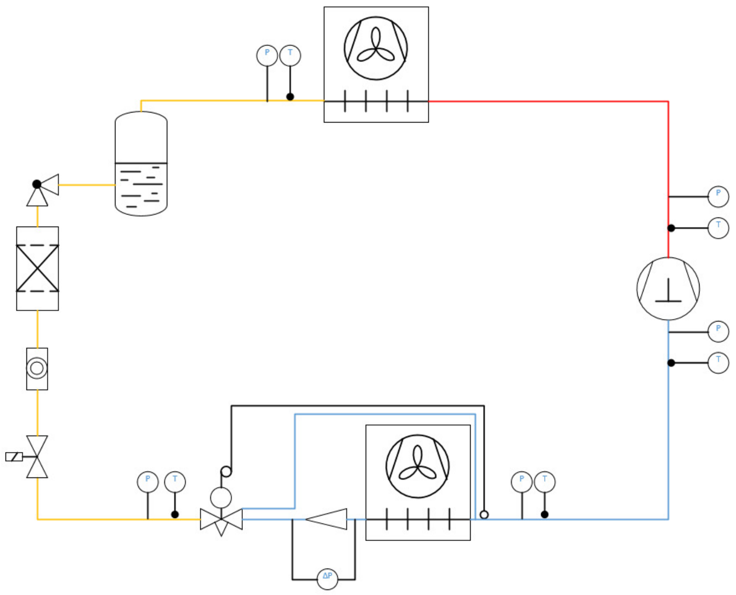
4 Commercial applications

For exercises in this chapter, you can set your preferences to commercial applications through "Options | Preferences | Commercial applications".

Exercise 4.1 Selecting a thermostatic expansion valve

Select a TU thermostatic expansion valve for a dry expansion system with R448A with the following operating conditions:

- Cooling capacity: 2.5 kW
- Evaporator dew point temperature: -8 °C
- Useful superheat: 8 K (Default)
- Condenser bubble point temperature: +45 °C
- Subcooling: 3 K
- Load: 100%
- Distributor pressure drop: 1.0 bar



a) Which valve is suggested by Coolselector®2?

b) What is the nominal capacity of the suggested valve?

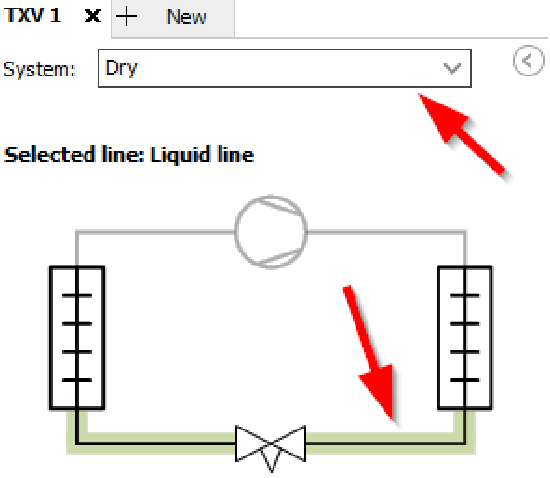
c) Is it possible to run the system at 20 °C condensation temperature with this valve size?

d) What is the load at 45 °C and 20 °C, respectively?

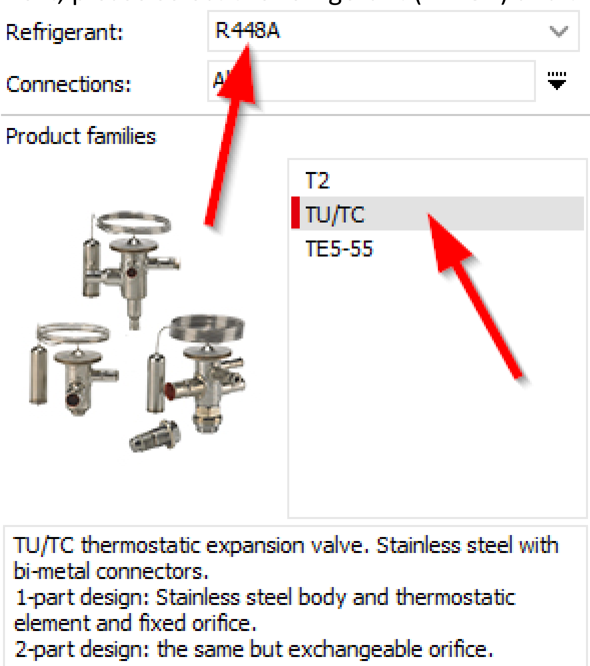
e) What is the load a TXV should typically be selected at?

Solution 4.1 Selecting a thermostatic expansion valve

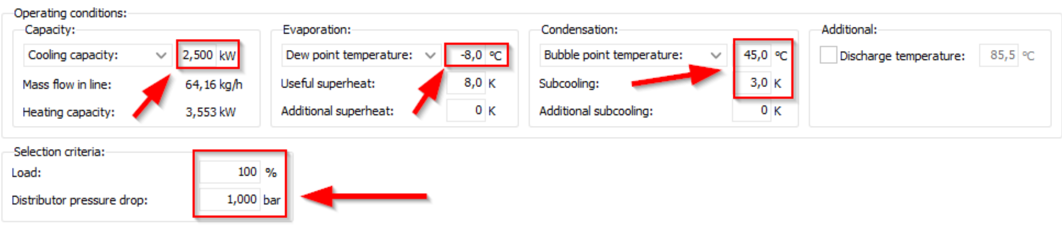
With a commercial refrigeration system, we usually talk about a dry expansion system. So, in Coolselector®2, you first set the System to 'Dry' and then select the Liquid line:



Next, please select the refrigerant (R448A) and the product family (TU/TC):



Afterwards, type in the operating conditions:



The operation (system) condition values are required to calculate the mass flow circulating through the expansion valve. Part of this information is the pressure losses between the condenser outlet and the valve inlet, as well as the pressure drop between the outlet and the evaporator inlet. Those pressure drops are reflected in the value of "Distributer dp". The pressure drop across the valve therefore is equal to pc – (pe + dp distributer).

a) The suggested valve is a TU orifice size 5 (TU - 5):

Liquid line (Dry expansion system. R448A. TXV)

Selection: TU - 5 **No code numbers currently available**

Selected	Type	NS	Range	Nominal capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	TU - 3	9,53	N	1,139	0,285	220	16,09	0,36	⚠
○	TU - 4	9,53	N	1,898	0,474	132	16,09	0,36	⚠
◉	TU - 5	9,53	N	2,541	0,635	98	16,09	0,36	✓
○	TU - 6	9,53	N	3,941	0,985	63	16,09	0,36	✓
○	TU - 7	9,53	N	5,203	1,301	48	16,09	0,36	✓

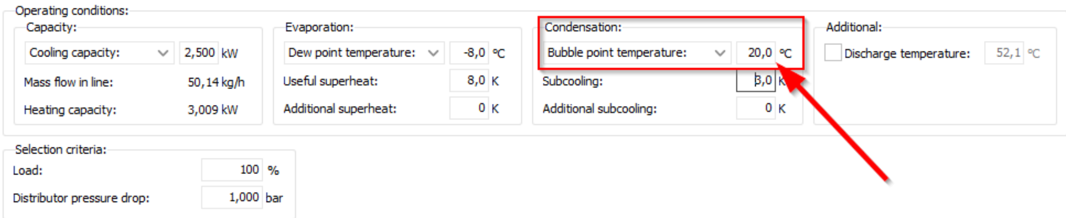
b) The suggested valve has a nominal capacity of 2.541 kW:

Liquid line (Dry expansion system. R448A. TXV)

Selection: TU - 5 **No code numbers currently available**

Selected	Type	NS	Range	Nominal capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	TU - 3	9,53	N	1,139	0,285	220	16,09	0,36	⚠
○	TU - 4	9,53	N	1,898	0,474	132	16,09	0,36	⚠
◉	TU - 5	9,53	N	2,541	0,635	98	16,09	0,36	✓
○	TU - 6	9,53	N	3,941	0,985	63	16,09	0,36	✓
○	TU - 7	9,53	N	5,203	1,301	48	16,09	0,36	✓

c) Yes, it is possible to run the valve at +20 °C condensation temperature. To prove this in Coolselector®2, change the bubble point temperature of condensation to +20 °C:



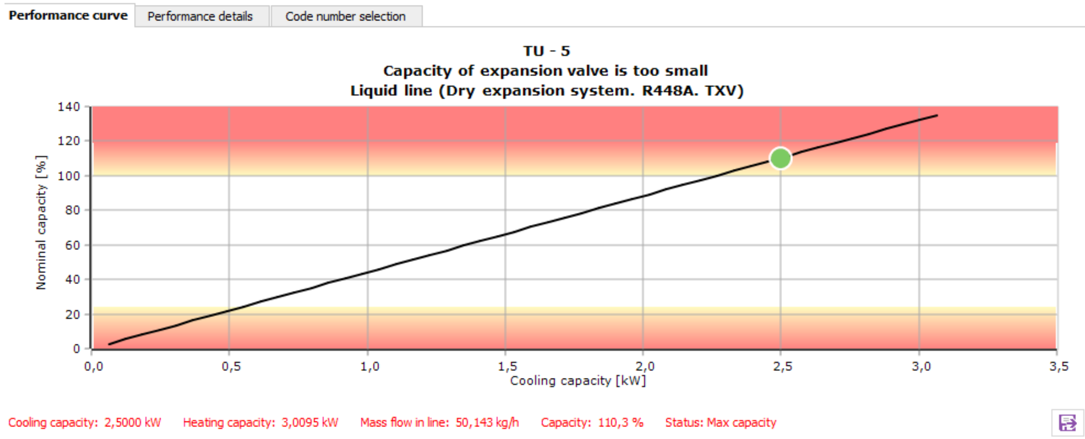
You will now see that TU – 5 is no longer the suggested best match by Coolselector®2, however, it is still in the list with a warning that the capacity of the expansion valve is too small:

Liquid line (Dry expansion system. R448A. TXV)

Selection: TU - 5. Capacity of expansion valve is too small **No code numbers currently available**

Selected	Type	NS	Range	Nominal capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	TU - 3	9,53	N	1,011	0,253	247	6,286	0,25	⚠
○	TU - 4	9,53	N	1,694	0,423	148	6,286	0,25	⚠
◉	TU - 5	9,53	N	2,266	0,566	110	6,286	0,25	⚠
○	TU - 6	9,53	N	3,513	0,878	71	6,286	0,25	✓
○	TU - 7	9,53	N	4,641	1,160	54	6,286	0,25	✓

A thermostatic expansion valve has a nominal capacity at a defined opening superheat, but with higher opening superheat a higher capacity is given. However, typically, such a valve can be used up to 150% of its nominal capacity. Due to that, a TXV has a so-called “over capacity”, which is indicated by the Performance diagram with a curve that does *not* end at 100% nominal capacity:



Since the valve, for a limited period of time, would run at the higher load, it is not the recommended selection in Coolselector®2. However, in reality, the valve is an option.

d) At 45 °C condensation the load is about 98% and at 20 °C condensation the load is about 110% of the nominal capacity.

45 °C:

Liquid line (Dry expansion system. R448A. TXV)

Selection: TU - 5 **No code numbers currently available**

Selected	Type	NS	Range	Nominal capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
	TU - 3	9,53	N	1,139	0,285	220	16,09	0,36	⚠
	TU - 4	9,53	N	1,898	0,474	132	16,09	0,36	⚠
●	TU - 5	9,53	N	2,541	0,635	98	16,09	0,36	✓
	TU - 6	9,53	N	3,941	0,985	63	16,09	0,36	✓
	TU - 7	9,53	N	5,203	1,301	48	16,09	0,36	✓

20 °C:

Liquid line (Dry expansion system. R448A. TXV)

Selection: TU - 5. Capacity of expansion valve is too small **No code numbers currently available**

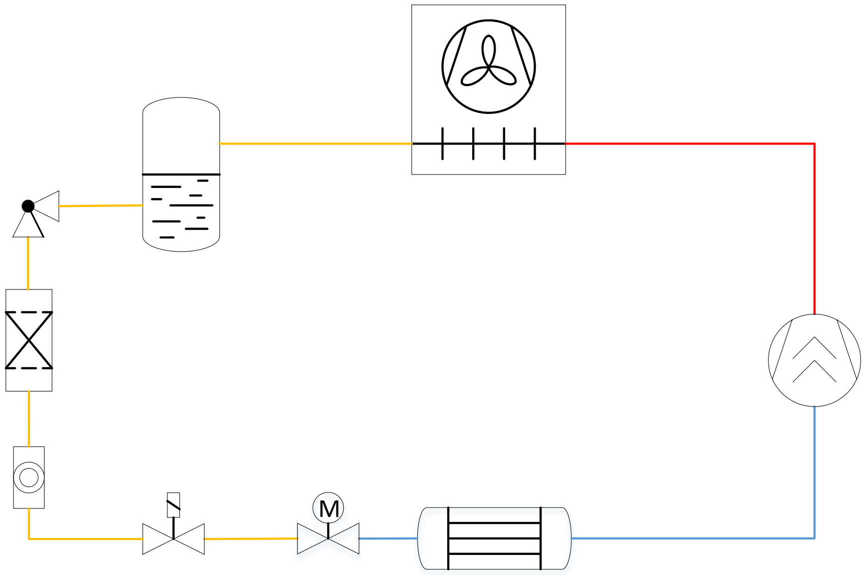
Selected	Type	NS	Range	Nominal capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
	TU - 3	9,53	N	1,011	0,253	247	6,286	0,25	⚠
	TU - 4	9,53	N	1,694	0,423	148	6,286	0,25	⚠
●	TU - 5	9,53	N	2,266	0,566	110	6,286	0,25	⚠
	TU - 6	9,53	N	3,513	0,878	71	6,286	0,25	✓
	TU - 7	9,53	N	4,641	1,160	54	6,286	0,25	✓

e) A TXV should never be oversized but should be selected at 100% of its nominal capacity. To reach the required working superheat built in to the system, the static superheat should be re-adjusted rather than oversizing the valve. In this way, the bandwidth will be utilized better and the valve will work with higher stability.

Exercise 4.2 Selecting an electronic expansion valve

Select an electronic expansion valve for a chiller, from the product family 'ETS Colibri®', with the following operating conditions:

- Refrigerant: R513A
- Cooling capacity: 90 kW
- Evaporator temperature: 3 °C
- Useful superheat: 8 K (Default)
- Condenser temperature: +40 °C
- Subcooling: 3 K



a) Which target load should be put in the selection criteria and why?

b) Which valve size will be recommended for that target load (if you have chosen a range for the load, use the upper limit of the range for this input)?

c) What is the velocity at the valve inlet for the suggested valve?

d) Is there an alternative to the valve suggested by Coolselector®2 in the selection list with the same load at nominal conditions? What is the difference between the two valves and why is there a difference? Please explain.

e) Please explain, what is the minimum possible capacity and opening degree for the valve suggested by Coolselector®2 in b)?

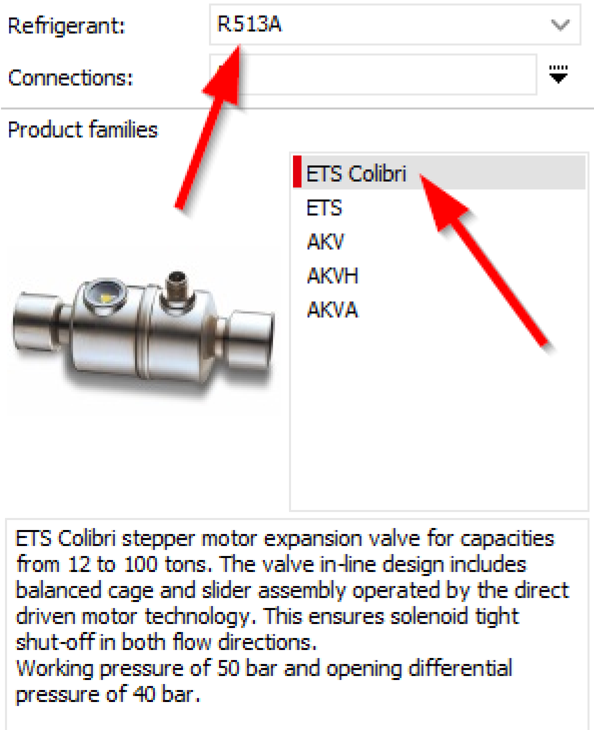
f) Would there be a risk if you select ETS Colibri 100C electronic expansion valve? Please explain using a chiller application as an example.

g) What would be the suggested valve if we want to replace the valve with one from the AKV family?

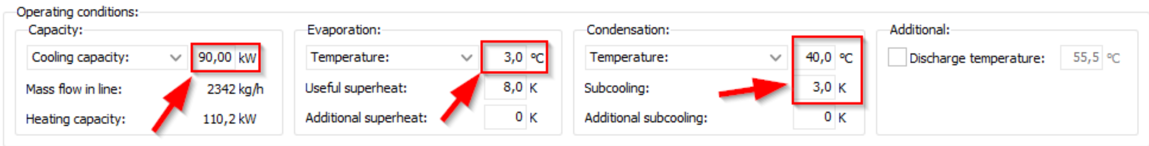
    1. What is the difference between the two families, ETS and AKV?
    2. What would be the actual speed at the inlet of the suggested expansion valve?

Solution 4.2 Selecting an electronic expansion valve

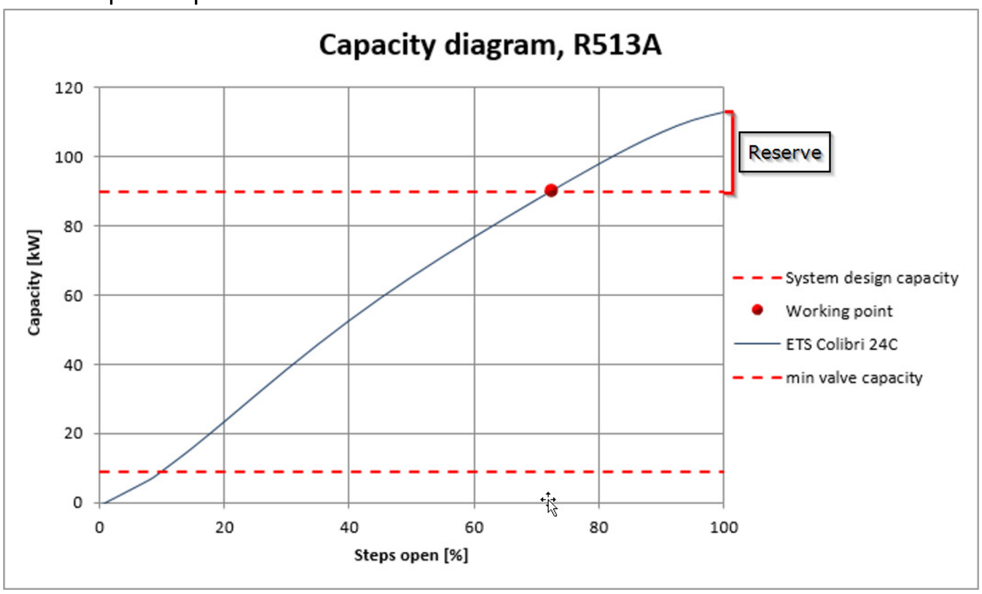
Similar to the previous exercise, set the system to 'Dry' and then select the liquid line. Next, please select the refrigerant (R513A) and the Product Family (ETS Colibri):



Afterwards, change the operating conditions as requested by the exercise:



a) For both air condition and refrigeration systems, the recommended selection criteria for 'load' is about 70% to 80%. By setting the load like this, there is 20% to 30% capacity left, for example for pull-down.



As is evident, the more over-capacity the system requires, the lower the load should be set in the selection criteria.

For low temperature applications it is recommended to size the electronic expansion valve at 50-60%. Otherwise, the pull-down capacity might be insufficient.

b) Based on the selection criteria and a load set to 80%, Coolselector®2 suggest the ETS Colibri 24C-22 as the best match:

Selection criteria:

Load: 80 %

Distributor pressure drop: 0 bar

Liquid line (Dry expansion system. R513A. Electronic expansion valve).

Selection: ETS Colibri 24C-22

Selected	Type	NS	Max. capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	ETS Colibri 24C-12	12	87,17	12,30	103	7,145	7,17	⚠
○	ETS Colibri 24C-16	16	92,79	12,64	97	7,145	3,60	✓
◉	ETS Colibri 24C-22	22	115,0	15,66	78	7,145	1,80	✓
○	ETS Colibri 25C	22	115,0	15,66	78	7,145	1,80	✓
○	ETS Colibri 50C	28	218,2	19,87	41	7,145	1,06	✓

c) The liquid velocity at the inlet connector is about 1.80 m/s. You can find the liquid velocity in the selection table:

Selection: ETS Colibri 24C-22

Selected	Type	NS	Max. capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	ETS Colibri 24C-12	12	87,17	12,30	103	7,145	7,17	⚠
○	ETS Colibri 24C-16	16	92,79	12,64	97	7,145	3,60	✓
◉	ETS Colibri 24C-22	22	115,0	15,66	78	7,145	1,80	✓
○	ETS Colibri 25C	22	115,0	15,66	78	7,145	1,80	✓
○	ETS Colibri 50C	28	218,2	19,87	41	7,145	1,06	✓

d) An alternative would be the ETS Colibri 25C, since this has the same load percentage (78%) as the ETS Colibri 24C-22:

Selected	Type	NS	Max. capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	ETS Colibri 24C-12	12	87,17	12,30	103	7,145	7,17	⚠
○	ETS Colibri 24C-16	16	92,79	12,64	97	7,145	3,60	✓
○	ETS Colibri 24C-22	22	115,0	15,66	78	7,145	1,80	✓
◉	ETS Colibri 25C	22	115,0	15,66	78	7,145	1,80	✓
○	ETS Colibri 50C	28	218,2	19,87	41	7,145	1,06	✓

The ETS Colibri 24c-22 and the ETS Colibri 25C valves are exactly the same in performance, which you can see in the calculation results. The only difference is that ETS Colibri 25C is equipped with a side glass, while ETS Colibri 24C-22 does not have the side glass.

You can contact Danfoss or your supplier for more information or if you have any questions regarding the products and you require assistance with your selection.

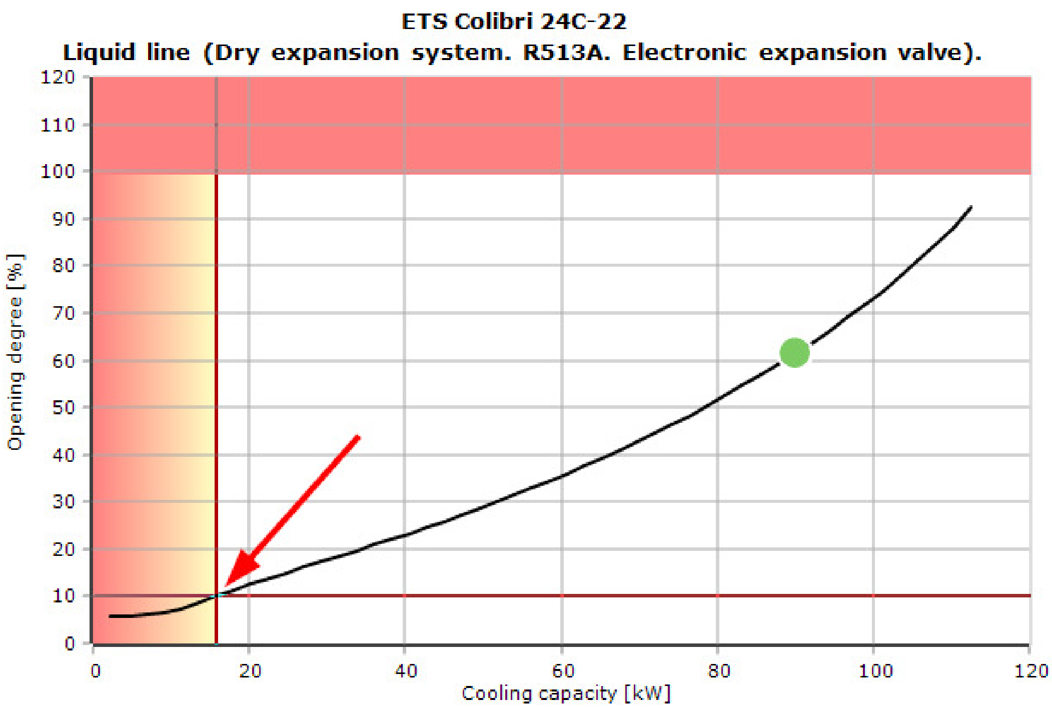
e) The minimum capacity for the ETS Colibri 24C-22 at the given operating conditions is 15.66 kW at around 10% opening of the valve. You can find the minimum capacity in the selection table.

Furthermore, you can see this in Coolselector®2 if you use the performance curve shown underneath the selection table. Move your mouse to the desired cooling capacity [kW] on the x-axis to see the corresponding opening degree [%] on the y-axis:

Selection: ETS Colibri 24C-22

Selected	Type	NS	Max. capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	ETS Colibri 24C-12	12	87,17	12,30	103	7,145	7,17	⚠
○	ETS Colibri 24C-16	16	92,79	12,64	97	7,145	3,60	✓
◉	ETS Colibri 24C-22	22	115,0	15,66	78	7,145	1,80	✓
○	ETS Colibri 25C	22	115,0	15,66	78	7,145	1,80	✓
○	ETS Colibri 50C	28	218,2	19,87	41	7,145	1,06	✓

Performance curve | Performance details



f) ETS Colibri 100C has a higher max capacity of about 428.5 kW, as is evident from the selection table in Coolselector®2:

Selection: ETS Colibri 100C

Selected	Type	NS	Max. capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	ETS Colibri 24C-16	16	92,79	12,64	97	7,145	3,60	✓
○	ETS Colibri 24C-22	22	115,0	15,66	78	7,145	1,80	✓
○	ETS Colibri 25C	22	115,0	15,66	78	7,145	1,80	✓
○	ETS Colibri 50C	28	218,2	19,87	41	7,145	1,06	✓
◉	ETS Colibri 100C	35	428,5	39,01	21	7,145	0,69	✓

This would be more than enough capacity for running the system under full load conditions as well as pull-down. However, in the event that the chiller runs into part load, the size of the ETS Colibri 100C might become an issue since its minimum possible capacity is 39.01 kW. Thus, the ETS Colibri 100C may be too large for this system.

As is evident from the example above, it is always recommended to verify if the valve is suitable for the whole envelope of the system, considering both loads and extreme conditions.

g) To replace the valve with one from the AKV family, we need to click on the AKV in the "Product families" list:

Product families

- ETS Colibri
- ETS
- AKV
- AKVH
- AKV 10P
- AKV 10PS
- ICM
- AKVA

AKV pulse width modulated expansion valve for small to mid-size systems. Normally closed type.

If you don't change the operating conditions, you will notice that Coolselector®2 keeps the previous inputs for operating conditions. The suggested valve would be AKV 20-2 in this case:

Selection criteria:

Load: 80 %

Distributor pressure drop: 0 bar

Liquid line (Dry expansion system. R513A. Electronic expansion valve).

Selection: AKV 20-2 **No code numbers selected**

Selected	Type	NS	Max. capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	AKV 15-4	28	78,33	7,833	115	7,145	1,15	⚠
○	AKV 20-1	32	79,27	7,927	114	7,145	0,52	⚠
◉	AKV 20-2	32	126,4	12,64	71	7,145	0,52	✓
○	AKV 20-3	32	196,1	19,61	46	7,145	0,52	✓
○	AKV 20-4	40	309,9	30,99	29	7,145	0,39	✓

1. AKV is a family of pulse width modulated expansion valves. This means the valve is either fully open or fully closed. As a result, while the valve is open, the capacity is the maximum capacity.
2. To calculate the actual velocity for AKV or any of the pulse width modulated expansion valves, you should replace the capacity to the maximum capacity of the valve. You will see that for AKV 20-2 the velocity at the inlet would be 0.73 m/s:

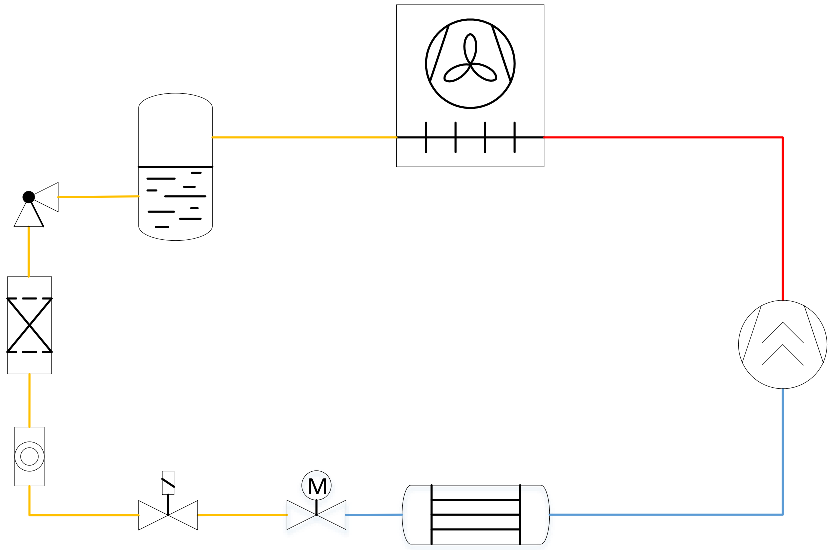
Selection: AKV 20-2 **No code numbers selected**

Selected	Type	NS	Max. capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	AKV 15-3	22	49,73	4,973	254	7,145	2,79	⚠
○	AKV 15-4	28	78,33	7,833	161	7,145	1,61	⚠
○	AKV 20-1	32	79,27	7,927	159	7,145	0,73	⚠
◉	AKV 20-2	32	126,4	12,64	100	7,145	0,73	✓
○	AKV 20-3	32	196,1	19,61	64	7,145	0,73	✓

Exercise 4.3 Selecting a solenoid valve

Please select an EVR v2 solenoid valve for a liquid line of a chiller application with an electronic expansion device. For safety reasons, a solenoid valve shall be installed in front of the expansion valve. Please use the following operating conditions:

- Refrigerant: R513A
- Max cooling capacity: 45 kW
- Evaporator temperature: 0 °C
- Useful superheat: 4 K
- Condenser temperature: +42 °C
- Subcooling: 2 K
- Cooling load: 40% to 100%



a) Which solenoid valve does Coolselector®2 suggest as the best fit for the system requirements under the given operating conditions?

b) What is the capacity range of the system using the suggested valve?

c) Please explain what should be considered in relation to the cooling load when selecting a failsafe component for a system matching these operating conditions.

d) Taking your conclusions from the previous parts into consideration, is the valve suggested by Coolselector®2, at these operating conditions, the best fit for the system requirements? If not, which valve should be chosen instead and why?

e) What is the pressure drop in the solenoid valve?

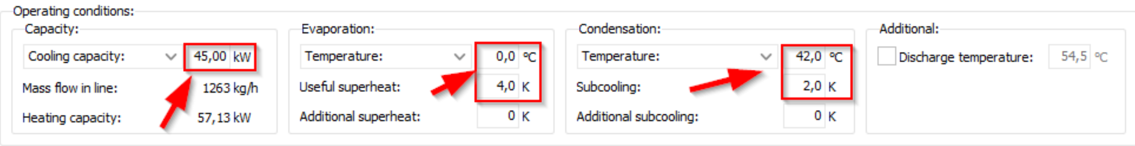
f) What is the maximum possible pressure drop without getting flash gas in front of the expansion device?

g) Please explain what the limits are for a solenoid valve placed in a liquid line.

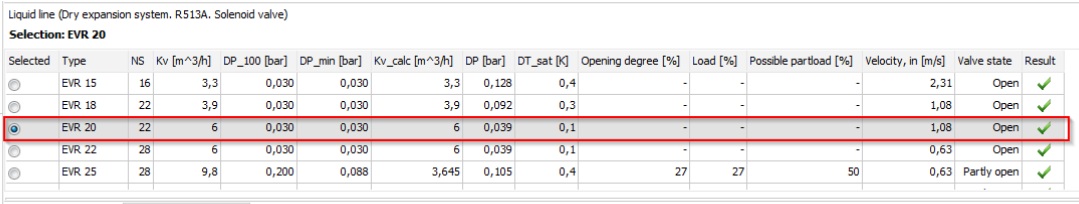
Solution 4.3 Selecting a solenoid valve

Select the solenoid valve from the “Valves and Line Components” and then set the System to ‘Dry’ and choose the Liquid line. Then select the refrigerant (R513A) and the product family (EVR v2).

Afterwards, type in the operating conditions:

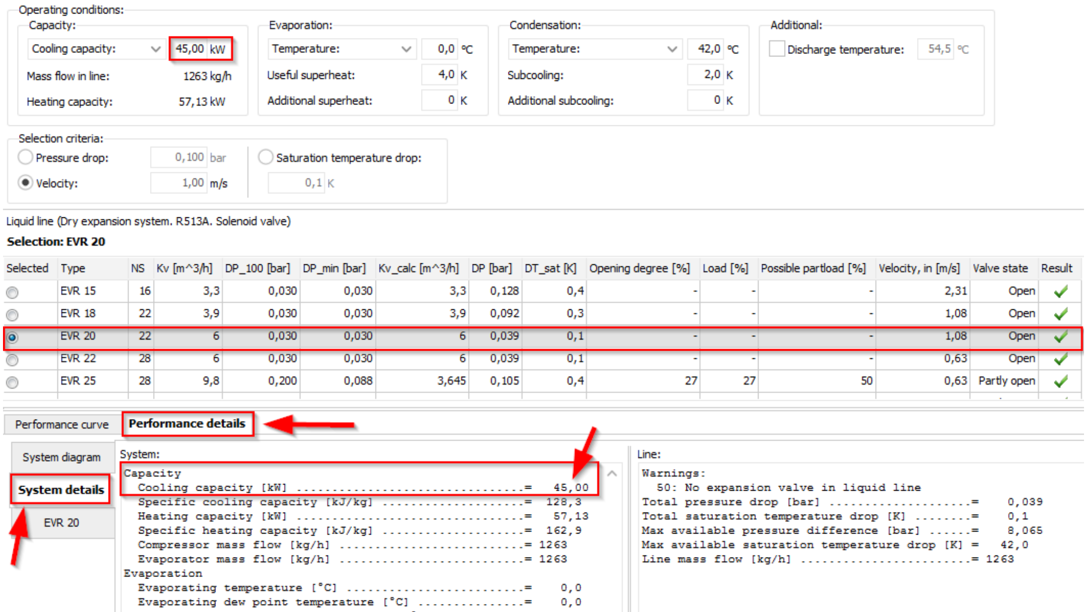


a) The solenoid valve suggested as the best match for the system under these operating conditions is the EVR 20:


Liquid line (Dry expansion system. R513A. Solenoid valve)
Selection: EVR 20

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	EVR 15	16	3,3	0,030	0,030	3,3	0,128	0,4	-	-	-	2,31	Open	✓
○	EVR 18	22	3,9	0,030	0,030	3,9	0,092	0,3	-	-	-	1,08	Open	✓
◉	EVR 20	22	6	0,030	0,030	6	0,039	0,1	-	-	-	1,08	Open	✓
○	EVR 22	28	6	0,030	0,030	6	0,039	0,1	-	-	-	0,63	Open	✓
○	EVR 25	28	9,8	0,200	0,088	3,645	0,105	0,4	27	27	50	0,63	Partly open	✓

b) At 100% cooling load the capacity is 45 kW, as specified in the operating conditions. You can also verify this in the “Performance details | System details”:



Liquid line (Dry expansion system. R513A. Solenoid valve)
Selection: EVR 20

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	EVR 15	16	3,3	0,030	0,030	3,3	0,128	0,4	-	-	-	2,31	Open	✓
○	EVR 18	22	3,9	0,030	0,030	3,9	0,092	0,3	-	-	-	1,08	Open	✓
◉	EVR 20	22	6	0,030	0,030	6	0,039	0,1	-	-	-	1,08	Open	✓
○	EVR 22	28	6	0,030	0,030	6	0,039	0,1	-	-	-	0,63	Open	✓
○	EVR 25	28	9,8	0,200	0,088	3,645	0,105	0,4	27	27	50	0,63	Partly open	✓

Thus, at 40% cooling load, the capacity will be 18 kW.

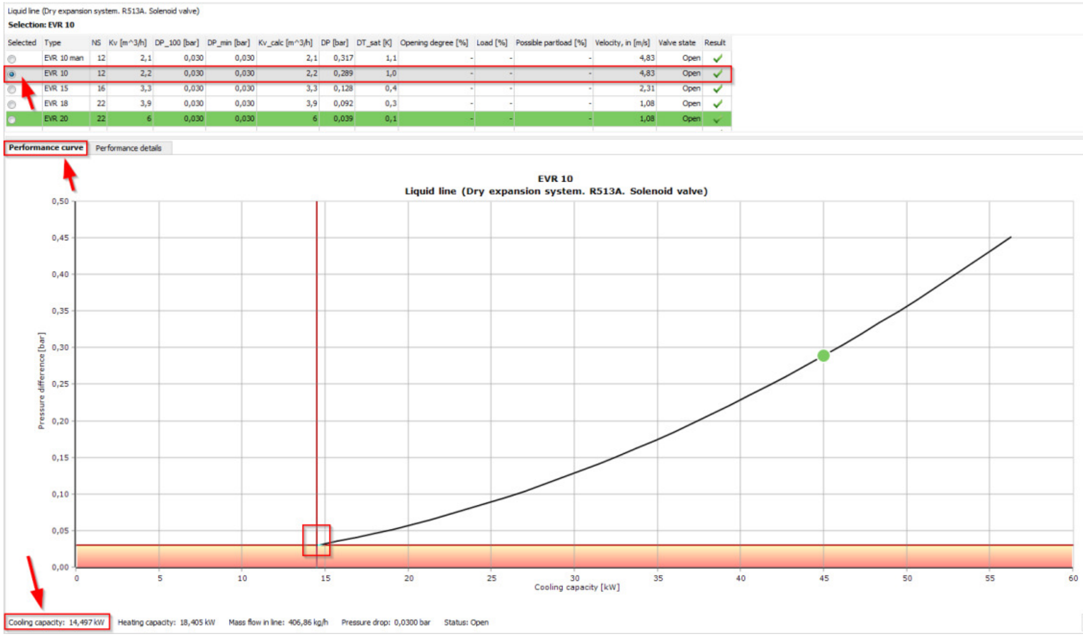
$$45kW * 0.4 = 18\ kW$$

c) In relation to the cooling load, it is important to consider that the system design supports a continuous change of cooling load from 100% down to 40% of its nominal capacity, as stated in the operating conditions. When selecting a component, please take this into careful consideration, in order to ensure that the solenoid valve will work failsafe across the entire application envelope.

d) Taking your previous conclusions into consideration, it is evident that the EVR 20, as suggested by Coolselector®2 for the full load condition, is not suited for the system with the given operating conditions.

Looking at the performance curve, the valve is poorly suited for cooling capacities of less than 39.547 kW:

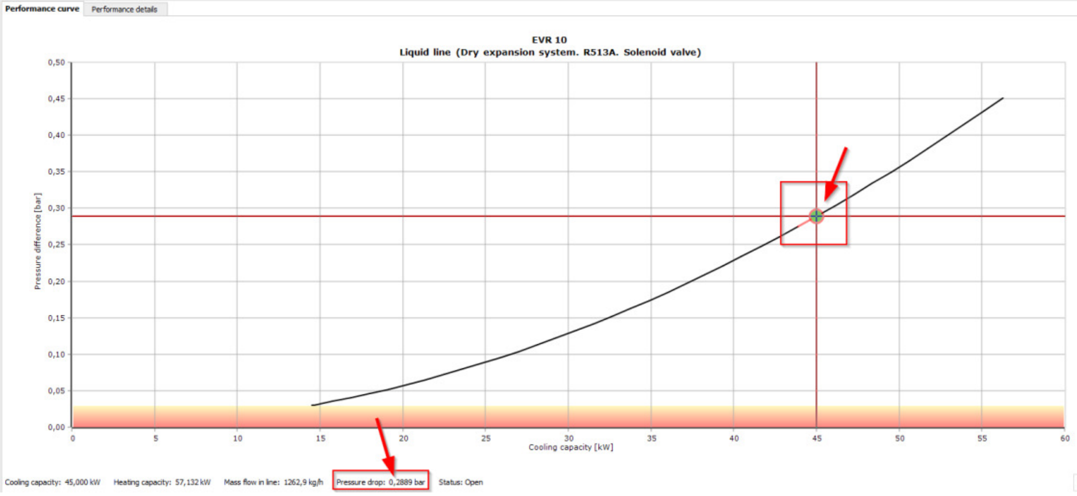
A better fit for the system with the given operating conditions and a continuous change of cooling load from 40-100% and thereby capacities ranging from 18 kW to 45 kW would be the EVR 10, which supports capacities starting as low as 14.497:



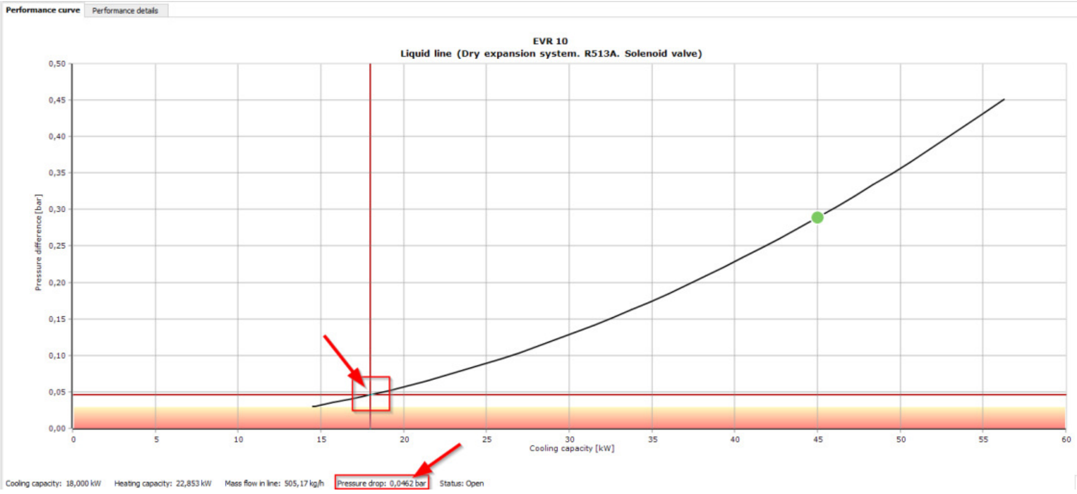
As is evident from the performance curve, the EVR 10 supports the entire application envelope of the proposed system. If you change the load to the minimum from the given operating conditions (18 kW) and check the suggested valve again, you will notice that Coolselector®2 suggests “EVR 10”. So, make sure you check the full range of capacity or other varying parameters to improve your selection.

e) From the performance curve we can conclude that for the EVR 10, at 45 kW the pressure drop is about 0.2889 bar, whilst at 18 kW the pressure drop is 0.0462 bar.

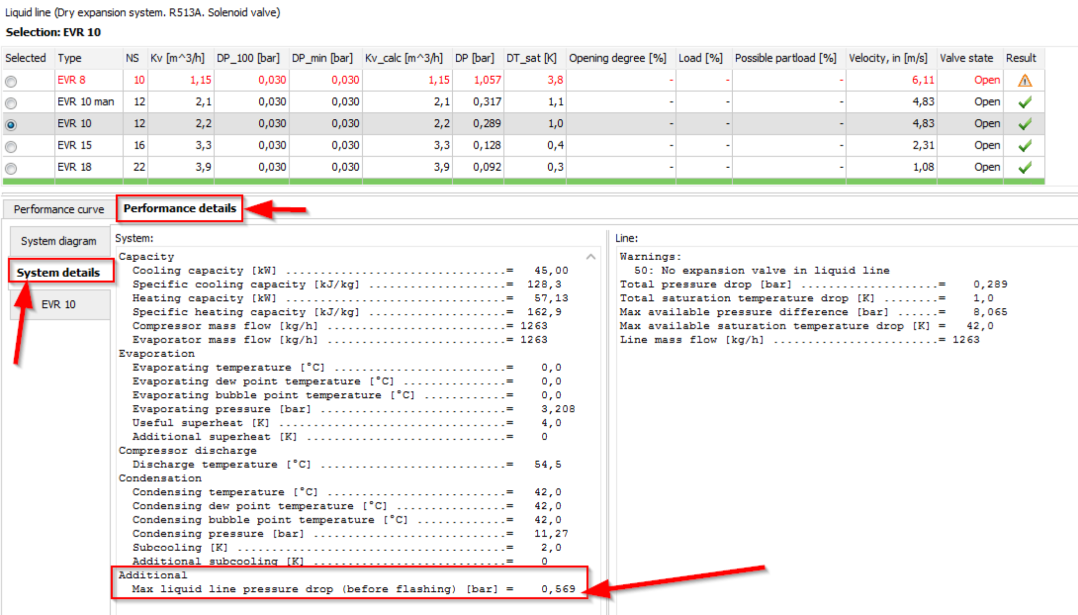
45 kW (0.2889 bar):



18 kW (0.0462 bar):



f) The maximum pressure drop without getting flash gas in front of the expansion device is 0.569 bar. The value can be found under 'Performance details | System details':



Liquid line (Dry expansion system. R513A. Solenoid valve)

Selection: EVR 10

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
	EVR 8	10	1,15	0,030	0,030	1,15	1,057	3,8	-	-	-	6,11	Open	⚠
	EVR 10 man	12	2,1	0,030	0,030	2,1	0,317	1,1	-	-	-	4,83	Open	✓
◉	EVR 10	12	2,2	0,030	0,030	2,2	0,289	1,0	-	-	-	4,83	Open	✓
	EVR 15	16	3,3	0,030	0,030	3,3	0,128	0,4	-	-	-	2,31	Open	✓
	EVR 18	22	3,9	0,030	0,030	3,9	0,092	0,3	-	-	-	1,08	Open	✓

Performance curve | **Performance details**

System diagram
System details
EVR 10

System:

```
Capacity
  Cooling capacity [kW] ................................=   45,00
  Specific cooling capacity [kJ/kg] ....................=  128,3
  Heating capacity [kW] ................................=   57,13
  Specific heating capacity [kJ/kg] ....................=  162,9
  Compressor mass flow [kg/h] ..........................= 1263
  Evaporator mass flow [kg/h] ..........................= 1263
Evaporation
  Evaporating temperature [°C] .........................=    0,0
  Evaporating dew point temperature [°C] ...............=    0,0
  Evaporating bubble point temperature [°C] ............=    0,0
  Evaporating pressure [bar] ...........................=    3,208
  Useful superheat [K] .................................=    4,0
  Additional superheat [K] .............................=    0
Compressor discharge
  Discharge temperature [°C] ...........................=   54,5
Condensation
  Condensing temperature [°C] ..........................=   42,0
  Condensing dew point temperature [°C] ................=   42,0
  Condensing bubble point temperature [°C] .............=   42,0
  Condensing pressure [bar] ............................=   11,27
  Subcooling [K] .......................................=    2,0
  Additional subcooling [K] ............................=    0
Additional
  Max liquid line pressure drop (before flashing) [bar] =    0,569
```

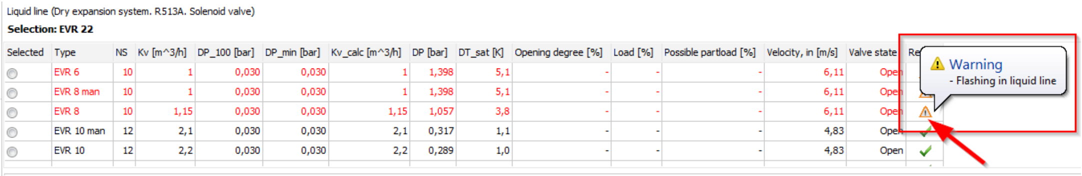
Line:

```
Warnings:
  50: No expansion valve in liquid line
Total pressure drop [bar] ....................=    0,289
Total saturation temperature drop [K] ........=    1,0
Max available pressure difference [bar] ......=    8,065
Max available saturation temperature drop [K] =   42,0
Line mass flow [kg/h] ........................= 1263
```

g) Most of the Danfoss solenoid valves are so-called “servo operated” and need a minimum pressure drop (by the mass flow through the valve) to be in a stable open position.

Thus, for a solenoid valve in a liquid line, the limits are: sub cooling, no creation of flash gas and minimum pressure drop. If one (or more) of those limits has been reached, it will turn the result in Coolselector®2 red and a warning will come up to inform you that the valve is not well suited for the system under the given operating conditions.

Exact warning texts can be read by resting the mouse pointer over the warning icon within Coolselector®2:


Liquid line (Dry expansion system. R513A. Solenoid valve)

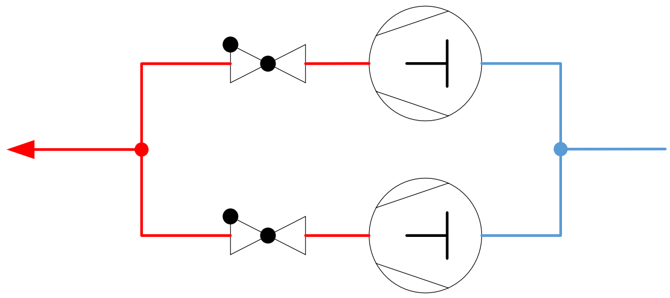
Selection: EVR 22

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Re
	EVR 6	10	1	0,030	0,030	1	1,398	5,1	-	-	-	6,11	Open	
	EVR 8 man	10	1	0,030	0,030	1	1,398	5,1	-	-	-	6,11	Open	
	EVR 8	10	1,15	0,030	0,030	1,15	1,057	3,8	-	-	-	6,11	Open	
	EVR 10 man	12	2,1	0,030	0,030	2,1	0,317	1,1	-	-	-	4,83	Open	
	EVR 10	12	2,2	0,030	0,030	2,2	0,289	1,0	-	-	-	4,83	Open	

Exercise 4.4 Selecting a check valve with reciprocating compressors

Using the following operating conditions for the discharge line of two circuits with semi-hermetic reciprocation compressors working in parallel and a small power pack. First, please explain which check valve version should be selected (NRV or NRVH)? Then check the exercises for the following operating conditions:

- Refrigerant: R513A
- Cooling capacity: 45 kW
- Evaporator temperature: -10 °C
- Superheat: 8 K
- Superheat suction line: 4 K
- Condenser temperature: +42 °C
- Sub cooling: 2 K



a) Which check valve version does Coolselector®2 suggest as the best match?

b) What is the pressure drop across the valve?

c) What is the minimum required pressure drop to fully open the valve?

d) What is the possible system part load?

e) What is the minimum capacity to keep the valve fully open?

f) What is the suggested connection size?

Solution 4.4 Selecting a check valve with reciprocating compressors

Selection of check valves at the discharge of a compressor needs very special attention. Depending on the compressor type and application, slightly different results may occur.

If a power pack's compressor is cut off, the check valve will protect against returning gas from the discharge line back into the cylinders of the compressor.

Due to mechanical vibrations, in this particular situation, it could happen that a check valve with a standard spring cannot keep the port tightly closed. If this happens, the refrigerant could return into the cylinder and in a worst-case scenario, it could condensate, thereby forming a liquid. When the compressor is next started, its valve place will be damaged, and it will break down.

Apart from mechanical vibrations, reciprocating compressors tend to create gas pulsations. The reason for this is the principal of compressing gas in one stack and releasing it into the discharge line within an extremely short time. With each release, a peak called a "gas pulse" will be generated. Depending on the design and number of cylinders in the compressor, the effect can vary. Generally speaking, the greater the number of cylinders, the smoother the running will be and fewer pulses will be generated.

As a result of the above, two types of Danfoss check valves are available:

- NRV with a standard spring
- NRVH with a stronger spring.

Since the compressors in question in this example are semi-hermetic, it can thus be concluded that to ensure the tight closure of the port, and to prevent the refrigerant from returning to the cylinder, the check valve with the stronger spring (namely the NRVH) should be selected.

Now, please set the proper system, refrigerant and operating conditions in check valve selections based on the given conditions and as explained in the previous exercises.

a) Based on the above input, Coolselector®2 suggests the NRVH 22:

Discharge line (Dry expansion system. R513A. Check valve)

Selection: NRVH 22 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRVH 16	16	3,6	0,300	0,280	3,6	5,150	22,0	-	297	7	53,18	Open	✓
○	NRVH 19	20	5,5	0,300	0,280	5,5	1,271	4,6	-	194	10	39,95	Open	✓
◉	NRVH 22	22	8,5	0,300	0,280	8,5	0,484	1,7	-	126	16	24,90	Open	✓
○	NRVH 28	28	16,5	0,300	0,280	10,96	0,284	1,0	-	65	31	14,38	Partly open	⚠
○	NRVH 35	35	29	0,300	0,280	11,03	0,281	1,0	-	37	54	8,78	Partly open	⚠

b) The pressure drop across the valve is 0.484 bar:

Discharge line (Dry expansion system. R513A. Check valve)

Selection: NRVH 22 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRVH 16	16	3,6	0,300	0,280	3,6	5,150	22,0	-	297	7	53,18	Open	✓
○	NRVH 19	20	5,5	0,300	0,280	5,5	1,271	4,6	-	194	10	39,95	Open	✓
◉	NRVH 22	22	8,5	0,300	0,280	8,5	0,484	1,7	-	126	16	24,90	Open	✓
○	NRVH 28	28	16,5	0,300	0,280	10,96	0,284	1,0	-	65	31	14,38	Partly open	⚠
○	NRVH 35	35	29	0,300	0,280	11,03	0,281	1,0	-	37	54	8,78	Partly open	⚠

c) The minimum required pressure drop to open the valve is 0.3 bar:

Discharge line (Dry expansion system. R513A. Check valve)

Selection: NRVH 22 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRVH 16	16	3,6	0,300	0,280	3,6	5,150	22,0	-	297	7	53,18	Open	✓
○	NRVH 19	20	5,5	0,300	0,280	5,5	1,271	4,6	-	194	10	39,95	Open	✓
◉	NRVH 22	22	8,5	0,300	0,280	8,5	0,484	1,7	-	126	16	24,90	Open	✓
○	NRVH 28	28	16,5	0,300	0,280	10,96	0,284	1,0	-	65	31	14,38	Partly open	⚠
○	NRVH 35	35	29	0,300	0,280	11,03	0,281	1,0	-	37	54	8,78	Partly open	⚠

d) The possible system part load is 26%. Reading in the selection table, the load (in percent) is 126%. With this in mind, you can now calculate the possible system part load:

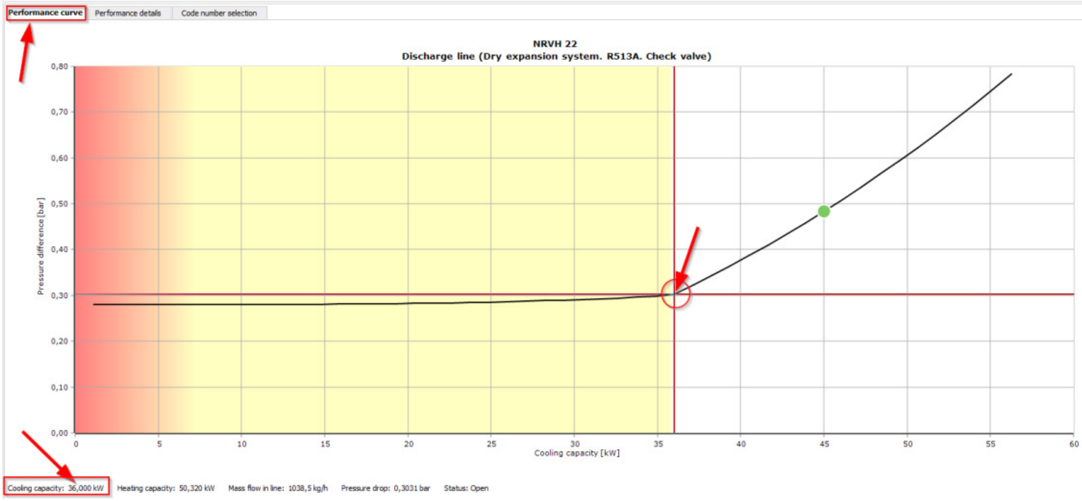
$$126\% - 100\% = 26\%$$

Discharge line (Dry expansion system. R513A. Check valve)

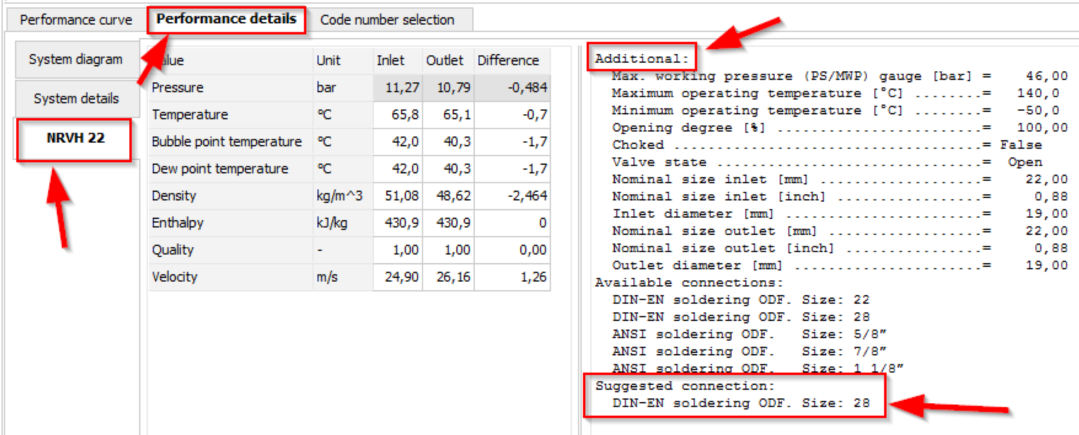
Selection: NRVH 22 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
	NRVH 16	16	3,6	0,300	0,280	3,6	5,150	22,0	-	297	7	53,18	Open	✓
	NRVH 19	20	5,5	0,300	0,280	5,5	1,271	4,6	-	194	10	39,95	Open	✓
◉	NRVH 22	22	8,5	0,300	0,280	8,5	0,484	1,7	-	126	16	24,90	Open	✓
	NRVH 28	28	16,5	0,300	0,280	10,96	0,284	1,0	-	65	31	14,38	Partly open	⚠
	NRVH 35	35	29	0,300	0,280	11,03	0,281	1,0	-	37	54	8,78	Partly open	⚠

e) The minimum capacity required to keep the valve fully open is 36 kW. You reach this figure by looking at the performance curve and finding the area which is not red or yellow (partly open valve). The point on the x-axis where the white area starts marks the capacity limit required to keep the valve fully open:



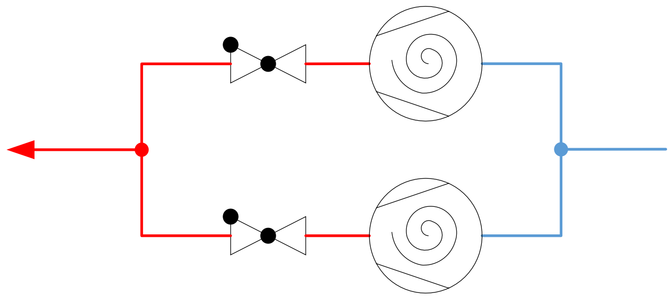
f) You find the suggested connection size by going to "Performance details | NRVH 22" and then looking under "Additional". The correct result here is 28 mm (1 1/8"):



Exercise 4.5 Selecting a check valve with scroll compressors

Using the following operating conditions for the discharge line of two circuits with scroll compressors working in parallel and a small power pack: Please explain, which check valve version should be selected (NRV or NRVH)? The operating conditions are:

- Refrigerant: R513A
- Cooling capacity: 45 kW
- Evaporator temperature: -10 °C
- Superheat: 8 K
- Superheat suction line: 4 K
- Condenser temperature: +42 °C
- Sub cooling: 2 K



a) Which check valve version should be selected?

b) What is the pressure drop across the valve?

c) What is the minimum required pressure drop to fully open the valve?

d) What is the possible system part load?

e) What is the minimum capacity to keep the valve fully open?

f) What is the suggested connection size?

Solution 4.5 Selecting a check valve with scroll compressors

A hermetic scroll compressor works smoother than a reciprocating compressor when compressing the gas, which means fewer mechanical vibrations are created.

In addition, the top shell of the scroll compressor acts as a muffler, due to the relatively large volume, and it will smoothen the remaining gas pulsations.

Keeping the explanation from the previous exercise in mind, it is evident that without the impact of mechanical vibrations and with smoother gas pulsations, check valves with standard springs (NRV) can be used in most cases where the compressor is a hermetic scroll.

Please set the appropriate system, refrigerant and operating conditions for check valve selections based on the given conditions and as explained in the previous exercises.

a) Based on the above input, Coolselector®2 suggests the NRV 28:

Discharge line (Dry expansion system. R513A. Check valve)

Selection: NRV 28 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRV 16	16	3,6	0,050	0,030	3,6	5,150	22,0	-	716	3	53,18	Open	✓
○	NRV 19	18	5,5	0,050	0,030	5,5	1,271	4,6	-	469	4	39,95	Open	✓
○	NRV 22	22	8,5	0,040	0,020	8,5	0,484	1,7	-	339	6	24,90	Open	✓
◉	NRV 28	28	16,5	0,040	0,020	16,5	0,123	0,4	-	175	11	14,38	Open	✓
○	NRV 35	35	29	0,040	0,020	28,97	0,040	0,1	-	99	20	8,78	Partly open	⚠

b) The pressure drop across the valve is 0.123bar:

Discharge line (Dry expansion system. R513A. Check valve)

Selection: NRV 28 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRV 16	16	3,6	0,050	0,030	3,6	5,150	22,0	-	716	3	53,18	Open	✓
○	NRV 19	18	5,5	0,050	0,030	5,5	1,271	4,6	-	469	4	39,95	Open	✓
○	NRV 22	22	8,5	0,040	0,020	8,5	0,484	1,7	-	339	6	24,90	Open	✓
◉	NRV 28	28	16,5	0,040	0,020	16,5	0,123	0,4	-	175	11	14,38	Open	✓
○	NRV 35	35	29	0,040	0,020	28,97	0,040	0,1	-	99	20	8,78	Partly open	⚠

c) The minimum required pressure drop to open the valve is 0.04 bar:

Discharge line (Dry expansion system. R513A. Check valve)

Selection: NRV 28 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRV 16	16	3,6	0,050	0,030	3,6	5,150	22,0	-	716	3	53,18	Open	✓
○	NRV 19	18	5,5	0,050	0,030	5,5	1,271	4,6	-	469	4	39,95	Open	✓
○	NRV 22	22	8,5	0,040	0,020	8,5	0,484	1,7	-	339	6	24,90	Open	✓
◉	NRV 28	28	16,5	0,040	0,020	16,5	0,123	0,4	-	175	11	14,38	Open	✓
○	NRV 35	35	29	0,040	0,020	28,97	0,040	0,1	-	99	20	8,78	Partly open	⚠

d) The possible system part load is 75%. Reading in the selection table, the load (in percent) is 175%. With this in mind, you can now calculate the possible system part load:

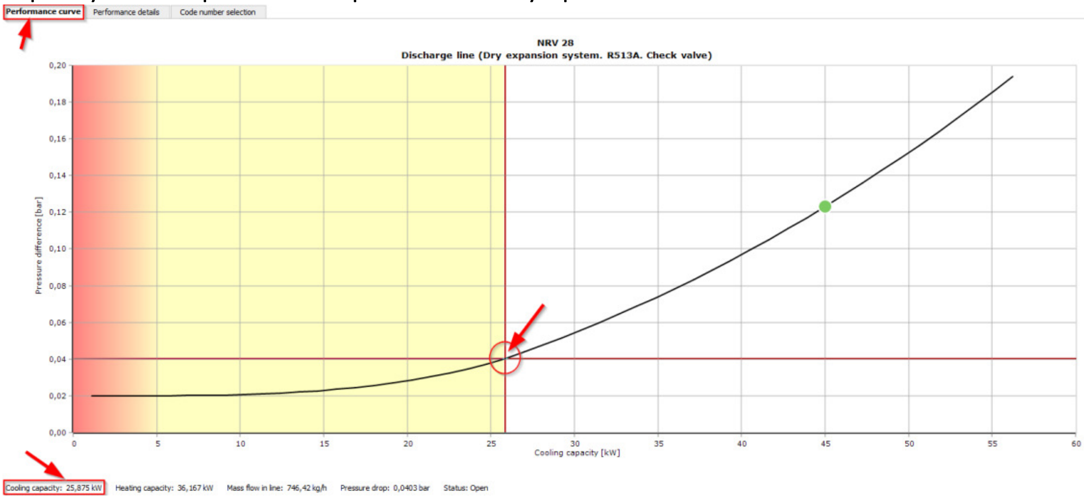
$$175\% - 100\% = 75\%$$

Discharge line (Dry expansion system. R513A. Check valve)

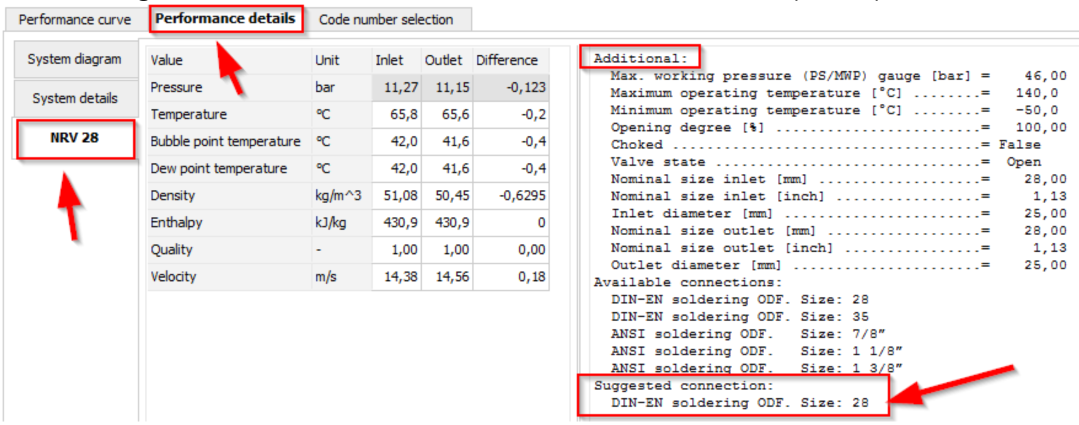
Selection: NRV 28 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRV 16	16	3,6	0,050	0,030	3,6	5,150	22,0	-	716	3	53,18	Open	✓
○	NRV 19	18	5,5	0,050	0,030	5,5	1,271	4,6	-	469	4	39,95	Open	✓
○	NRV 22	22	8,5	0,040	0,020	8,5	0,484	1,7	-	339	6	24,90	Open	✓
◉	NRV 28	28	16,5	0,040	0,020	16,5	0,123	0,4	-	175	11	14,38	Open	✓
○	NRV 35	35	29	0,040	0,020	28,97	0,040	0,1	-	99	20	8,78	Partly open	⚠

e) The minimum capacity required to keep the valve fully open is 25.875 kW. You reach this figure by looking at the performance curve and finding the area which is not red or yellow (partly open valve). The point on the x-axis, where the white area starts, marks the capacity limit required to keep the valve fully open:



f) You find the suggested connection size by going to "Performance details | NRVH 28" and then looking under "Additional". The correct result here is 28 mm (1 1/8"):



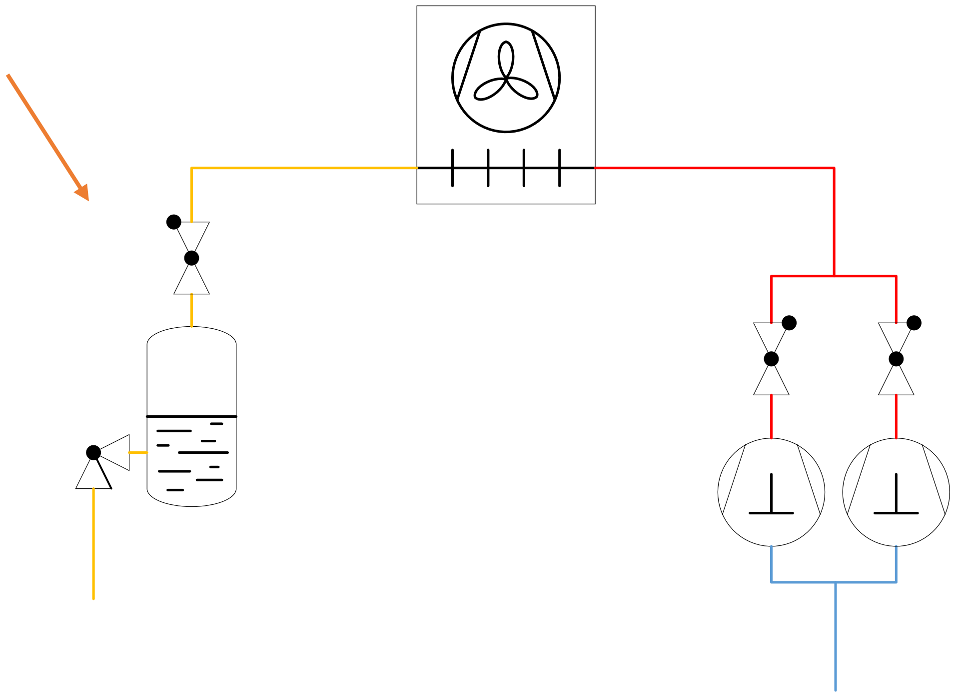
Value	Unit	Inlet	Outlet	Difference
Pressure	bar	11,27	11,15	-0,123
Temperature	°C	65,8	65,6	-0,2
Bubble point temperature	°C	42,0	41,6	-0,4
Dew point temperature	°C	42,0	41,6	-0,4
Density	kg/m^3	51,08	50,45	-0,6295
Enthalpy	kJ/kg	430,9	430,9	0
Quality	-	1,00	1,00	0,00
Velocity	m/s	14,38	14,56	0,18

```
Additional:
  Max. working pressure (PS/MWP) gauge [bar] =    46,00
  Maximum operating temperature [°C] ........=   140,0
  Minimum operating temperature [°C] ........=   -50,0
  Opening degree [%] ........................=   100,00
  Choked ....................................= False
  Valve state ...............................=  Open
  Nominal size inlet [mm] ...................=    28,00
  Nominal size inlet [inch] .................=     1,13
  Inlet diameter [mm] .......................=    25,00
  Nominal size outlet [mm] ..................=    28,00
  Nominal size outlet [inch] ................=     1,13
  Outlet diameter [mm] ......................=    25,00
Available connections:
  DIN-EN soldering ODF.  Size: 28
  DIN-EN soldering ODF.  Size: 35
  ANSI soldering ODF.    Size: 7/8"
  ANSI soldering ODF.    Size: 1 1/8"
  ANSI soldering ODF.    Size: 1 3/8"
Suggested connection:
  DIN-EN soldering ODF.  Size: 28
```

Exercise 4.6 Selecting a check valve for the condenser line

Please explain, which type of Danfoss check valve (NRV/NRVH) should be used for the situation where a check valve is added to the condenser line to avoid charge migration from the receiver to the condenser during longer standstill periods of the compressors e.g. overnight, during the winter period or similar. Please, also include an explanation as to whether the check valve should be fully opened or if it can run as partly open under the following operating conditions:

- Refrigerant: R513a
- Cooling capacity: 45 kW
- Capacity control: Two compressors = 50% / 100%
- Evaporator temperature: -10 °C
- Superheat: 8 K
- Superheat suction line: 4 K
- Condenser temperature: +42 °C
- Sub cooling: 2 K



a) Which check valve version and size should be selected for the system under the given operating conditions?

b) For which capacity should the valve be selected and why?

c) What is the pressure drop across the valve?

d) What is the minimum required pressure drop?

e) What is the saturated temperature drop and what does it mean?

f) What is the suggested connection size and what is the velocity?

g) Would the next larger valve also work?

Solution 4.6 Selecting a check valve for the condenser line

Since no mechanical vibrations or pulsations happen in the condenser line, a check valve with a standard spring (NRV) can be used. Also, due to the fact that there are no vibrations or pulsations, using a partly open condition is possible (down to the minimum pressure drop).

Please set the proper system, refrigerant and operating conditions in the check valve selections based on the given conditions and as explained in the previous exercises.

a) Based on the above input, Coolselector®2 suggests the NRV 22 (standard spring):

Liquid line (Dry expansion system. R513A. Check valve)

Selection: NRV 22 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRV 16	16	3,6	0,050	0,030	3,6	0,114	0,4	-	151	0	2,38	Open	✓
○	NRV 19	18	5,5	0,050	0,030	5,48	0,049	0,2	-	99	0	1,79	Partly open	✓
◉	NRV 22	22	8,5	0,040	0,020	7,512	0,026	0,1	-	71	0	1,11	Partly open	✓
○	NRV 28	28	16,5	0,040	0,020	8,467	0,021	0,1	-	37	0	0,64	Partly open	✓
○	NRV 35	35	29	0,040	0,020	8,576	0,020	0,1	-	21	0	0,39	Partly open	✓

b) The valve should be selected at the most critical load, which in this case is part load. Afterwards, the 100% system load should be verified to check if this is also ok, and to ensure that no pressure/temperature drop, which is too high for the capacity of the valve, will occur.

c) The pressure drop across the valve at part load (22.5 kW) is 0.021 bar.

Operating conditions:

Capacity:
Cooling capacity: 22,50 kW
Mass flow in line: 649,1 kg/h
Heating capacity: 31,45 kW

Evaporation:
Temperature: -10,0 °C
Useful superheat: 8,0 K
Additional superheat: 4,0 K

Condensation:
Temperature: 42,0 °C
Subcooling: 2,0 K
Additional subcooling: 0 K

Additional:
Discharge temperature: 65,8 °C

Selection criteria:
Pressure drop: Default bar
Velocity: 1,00 m/s
Saturation temperature drop: 0,1 K

Liquid line (Dry expansion system. R513A. Check valve)

Selection: NRV 22 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRV 16	16	3,6	0,050	0,030	3,139	0,037	0,1	-	75	0	1,19	Partly open	✓
○	NRV 19	18	5,5	0,050	0,030	3,413	0,032	0,1	-	49	0	0,89	Partly open	✓
◉	NRV 22	22	8,5	0,040	0,020	4,24	0,021	0,1	-	36	0	0,56	Partly open	✓
○	NRV 28	28	16,5	0,040	0,020	4,291	0,020	0,1	-	18	0	0,32	Partly open	✓
○	NRV 35	35	29	0,040	0,020	4,296	0,020	0,1	-	10	0	0,20	Partly open	✓

The pressure drop across the valve at full load (45 kW) is 0.026 bar:

Liquid line (Dry expansion system. R513A. Check valve)

Selection: NRV 22 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRV 16	16	3,6	0,050	0,030	3,6	0,114	,4	-	151	0	2,38	Open	✓
○	NRV 19	18	5,5	0,050	0,030	5,48	0,049	0,2	-	99	0	1,79	Partly open	✓
◉	NRV 22	22	8,5	0,040	0,020	7,512	0,026	0,1	-	71	0	1,11	Partly open	✓
○	NRV 28	28	16,5	0,040	0,020	8,467	0,021	0,1	-	37	0	0,64	Partly open	✓
○	NRV 35	35	29	0,040	0,020	8,576	0,020	0,1	-	21	0	0,39	Partly open	✓

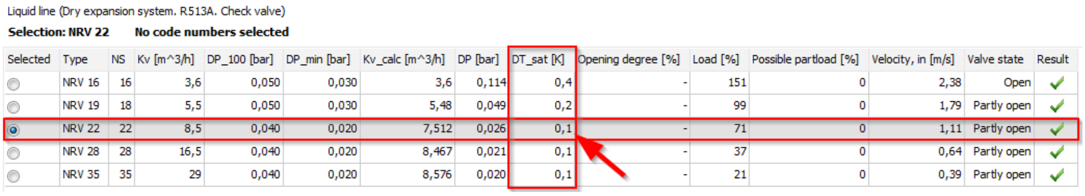
d) The minimum required pressure drop is 0.02 bar. Below this value, the valve becomes unstable.

Liquid line (Dry expansion system. R513A. Check valve)

Selection: NRV 22 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRV 16	16	3,6	0,050	0,030	3,6	0,114	0,4	-	151	0	2,38	Open	✓
○	NRV 19	18	5,5	0,050	0,030	5,48	0,049	0,2	-	99	0	1,79	Partly open	✓
◉	NRV 22	22	8,5	0,040	0,020	7,512	0,026	0,1	-	71	0	1,11	Partly open	✓
○	NRV 28	28	16,5	0,040	0,020	8,467	0,021	0,1	-	37	0	0,64	Partly open	✓
○	NRV 35	35	29	0,040	0,020	8,576	0,020	0,1	-	21	0	0,39	Partly open	✓

e) The saturated temperature drop is 0.1 K.



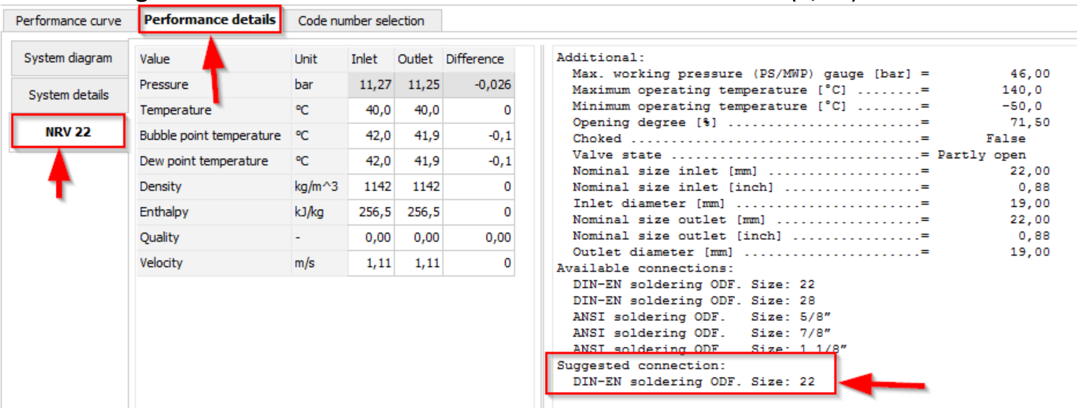
Liquid line (Dry expansion system. R513A. Check valve)

Selection: NRV 22 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
○	NRV 16	16	3,6	0,050	0,030	3,6	0,114	0,4	-	151	0	2,38	Open	✓
○	NRV 19	18	5,5	0,050	0,030	5,48	0,049	0,2	-	99	0	1,79	Partly open	✓
◉	NRV 22	22	8,5	0,040	0,020	7,512	0,026	0,1	-	71	0	1,11	Partly open	✓
○	NRV 28	28	16,5	0,040	0,020	8,467	0,021	0,1	-	37	0	0,64	Partly open	✓
○	NRV 35	35	29	0,040	0,020	8,576	0,020	0,1	-	21	0	0,39	Partly open	✓

It is the pressure drop converted into saturated temperature. Usually at the outlet of condenser, only a little subcooling of the liquid is given. Thus, in the condenser line, it is important to keep the pressure/temperature drop as low as possible to avoid flash gas.

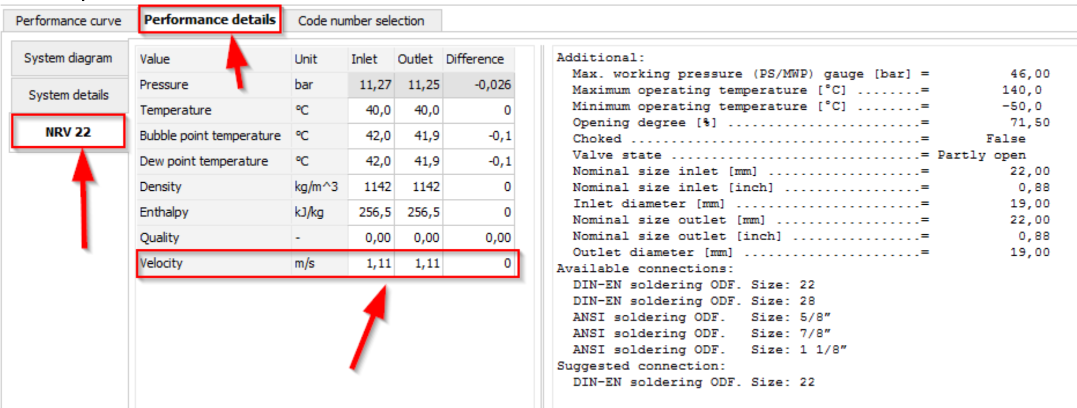
f) You find the suggested connection size by going to "Performance details | NRV 22" and then looking under "Additional". The correct result here is 22 mm (7/8"):



Value	Unit	Inlet	Outlet	Difference
Pressure	bar	11,27	11,25	-0,026
Temperature	°C	40,0	40,0	0
Bubble point temperature	°C	42,0	41,9	-0,1
Dew point temperature	°C	42,0	41,9	-0,1
Density	kg/m^3	1142	1142	0
Enthalpy	kJ/kg	256,5	256,5	0
Quality	-	0,00	0,00	0,00
Velocity	m/s	1,11	1,11	0

```
Additional:
  Max. working pressure (PS/MWP) gauge [bar] =         46,00
  Maximum operating temperature [°C] ........=         140,0
  Minimum operating temperature [°C] ........=         -50,0
  Opening degree [%] ........................=         71,50
  Choked ....................................=         False
  Valve state ...............................= Partly open
  Nominal size inlet [mm] ...................=         22,00
  Nominal size inlet [inch] .................=          0,88
  Inlet diameter [mm] .......................=         19,00
  Nominal size outlet [mm] ..................=         22,00
  Nominal size outlet [inch] ................=          0,88
  Outlet diameter [mm] ......................=         19,00
Available connections:
  DIN-EN soldering ODF. Size: 22
  DIN-EN soldering ODF. Size: 28
  ANSI soldering ODF.   Size: 5/8"
  ANSI soldering ODF.   Size: 7/8"
  ANSI soldering ODF.   Size: 1 1/8"
Suggested connection:
  DIN-EN soldering ODF. Size: 22
```

You find the velocity also under "Performance details | NRV 22". The correct result here is 1.11 m/s:

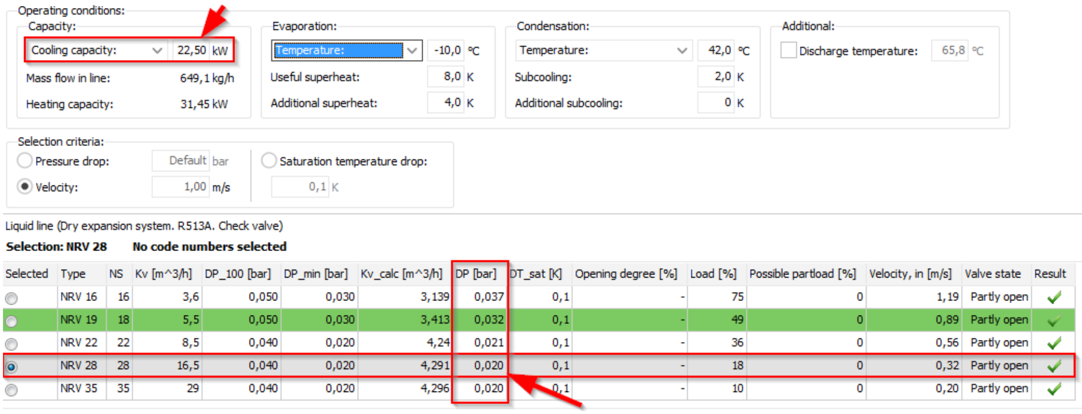


Value	Unit	Inlet	Outlet	Difference
Pressure	bar	11,27	11,25	-0,026
Temperature	°C	40,0	40,0	0
Bubble point temperature	°C	42,0	41,9	-0,1
Dew point temperature	°C	42,0	41,9	-0,1
Density	kg/m^3	1142	1142	0
Enthalpy	kJ/kg	256,5	256,5	0
Quality	-	0,00	0,00	0,00
Velocity	m/s	1,11	1,11	0

```
Additional:
  Max. working pressure (PS/MWP) gauge [bar] =         46,00
  Maximum operating temperature [°C] ........=         140,0
  Minimum operating temperature [°C] ........=         -50,0
  Opening degree [%] ........................=         71,50
  Choked ....................................=         False
  Valve state ...............................= Partly open
  Nominal size inlet [mm] ...................=         22,00
  Nominal size inlet [inch] .................=          0,88
  Inlet diameter [mm] .......................=         19,00
  Nominal size outlet [mm] ..................=         22,00
  Nominal size outlet [inch] ................=          0,88
  Outlet diameter [mm] ......................=         19,00
Available connections:
  DIN-EN soldering ODF. Size: 22
  DIN-EN soldering ODF. Size: 28
  ANSI soldering ODF.   Size: 5/8"
  ANSI soldering ODF.   Size: 7/8"
  ANSI soldering ODF.   Size: 1 1/8"
Suggested connection:
  DIN-EN soldering ODF. Size: 22
```

g) The next size in NRVs is the NRV 28. According to Coolselector®2, this valve is also suitable for the required operating conditions. However, looking closer at this valve, it is evident that the part load pressure drop is almost equal to the minimum pressure drop needed before the valve becomes unstable. Thus, it might not be the best choice for this system due to the lack of safety margins.

Part load pressure drop = 0.20 bar:



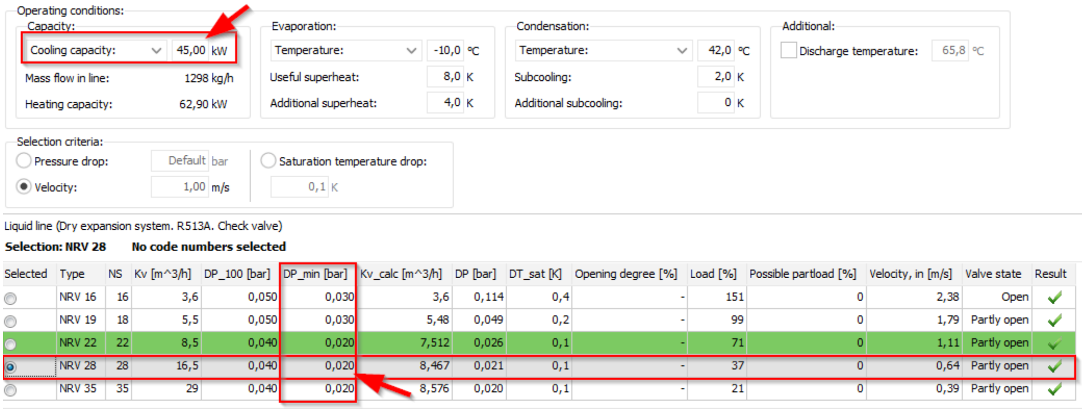
Operating conditions:
Capacity: Cooling capacity: 22,50 kW
Mass flow in line: 649,1 kg/h
Heating capacity: 31,45 kW
Evaporation: Temperature: -10,0 °C
Useful superheat: 8,0 K
Additional superheat: 4,0 K
Condensation: Temperature: 42,0 °C
Subcooling: 2,0 K
Additional subcooling: 0 K
Additional: Discharge temperature: 65,8 °C
Selection criteria:
Pressure drop: Default bar
Velocity: 1,00 m/s
Saturation temperature drop: 0,1 K

Liquid line (Dry expansion system. R513A. Check valve)

Selection: NRV 28 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
	NRV 16	16	3,6	0,050	0,030	3,139	0,037	0,1	-	75	0	1,19	Partly open	✓
	NRV 19	18	5,5	0,050	0,030	3,413	0,032	0,1	-	49	0	0,89	Partly open	✓
	NRV 22	22	8,5	0,040	0,020	4,24	0,021	0,1	-	36	0	0,56	Partly open	✓
◉	NRV 28	28	16,5	0,040	0,020	4,291	0,020	0,1	-	18	0	0,32	Partly open	✓
	NRV 35	35	29	0,040	0,020	4,296	0,020	0,1	-	10	0	0,20	Partly open	✓

Full load minimum pressure drop = 0.20 bar:



Operating conditions:
Capacity: Cooling capacity: 45,00 kW
Mass flow in line: 1298 kg/h
Heating capacity: 62,90 kW
Evaporation: Temperature: -10,0 °C
Useful superheat: 8,0 K
Additional superheat: 4,0 K
Condensation: Temperature: 42,0 °C
Subcooling: 2,0 K
Additional subcooling: 0 K
Additional: Discharge temperature: 65,8 °C
Selection criteria:
Pressure drop: Default bar
Velocity: 1,00 m/s
Saturation temperature drop: 0,1 K

Liquid line (Dry expansion system. R513A. Check valve)

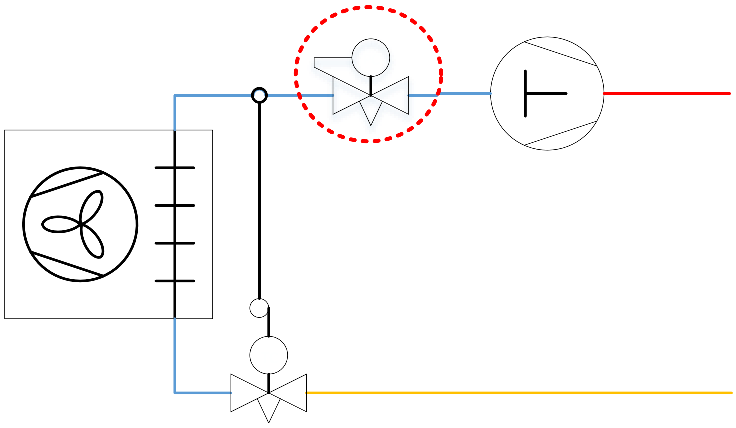
Selection: NRV 28 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	DP_100 [bar]	DP_min [bar]	Kv_calc [m^3/h]	DP [bar]	DT_sat [K]	Opening degree [%]	Load [%]	Possible partload [%]	Velocity, in [m/s]	Valve state	Result
	NRV 16	16	3,6	0,050	0,030	3,6	0,114	0,4	-	151	0	2,38	Open	✓
	NRV 19	18	5,5	0,050	0,030	5,48	0,049	0,2	-	99	0	1,79	Partly open	✓
	NRV 22	22	8,5	0,040	0,020	7,512	0,026	0,1	-	71	0	1,11	Partly open	✓
◉	NRV 28	28	16,5	0,040	0,020	8,467	0,021	0,1	-	37	0	0,64	Partly open	✓
	NRV 35	35	29	0,040	0,020	8,576	0,020	0,1	-	21	0	0,39	Partly open	✓

Exercise 4.7 Selecting an evaporation pressure control valve for a one-to-one system

We would like to guarantee that the temperature in the evaporator of our system will not go below a specific value. This can be done by controlling the different system conditions such as avoiding that the goods freeze. Let us assume that the evaporator is connected to a condensing unit with a fixed speed compressor and the system runs with the following operating conditions:

- Refrigerant: R134a
- Cooling capacity: 1 kW
- Evaporator temperature: 4 °C with a minimum of 0 °C
- Condenser temperature: +40 °C (summer conditions)



a. Avoiding system failure, which effect(s) or condition(s) can make such a system run at a lower evaporation temperature?

b. At the position specified by the red circle in the diagram above, which kind of valve can be used? What is the parameter that the valve controls?

c. What is the appropriate control valve “offset” to keep the evaporation temperature to a limit of 0 °C?

d. Which size control valve should be used? What are the possible impacts to the system based on your choice of a specific control valve?

Solution 4.7 Selecting an evaporation pressure control valve for a one-to-one system

a) The system will run in balance (meaning, without system failure) at the design condition only if the surrounding conditions remain static compared to the design conditions both at the evaporator and the condenser.

1. If the ambient temperature drops, the condensing temperature decreases and hence the cooling capacity increases. This will result in a lower evaporation temperature.
2. If the evaporator inlet temperature drops below the design value (e.g. an air conditioning taking fresh air in from outdoors), the evaporation temperature decreases.
3. Reducing the air flow rate results in the evaporator running at part load and hence the required capacity will also be lower than the capacity provided by the compressor. This also causes a balance point at a lower evaporation temperature.

b) The pressure control has to be towards the evaporator, i.e. the valve should control evaporator outlet pressure. A “KVP” valve is suitable for the capacity range and function.

c) To calculate the offset a step-by-step process should be followed:

1. The evaporation temperature change needs to be converted into saturated pressure change. Like all mechanical pressure control valves, the KVP will change its opening degree if the pressure changes. This change is called ‘a proportional band’ or ‘offset’, if only referring to the move from a closed position to a certain open position.

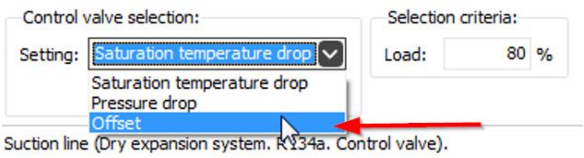
   The value for this offset can be entered in Coolselector®2.

   Step 1: Offset
   Utilizing the evaporation input field in Coolselector®2, we get the following values for evaporation pressure and thus, we can calculate the allowed offset for the valve:

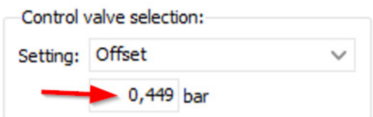
   - 4 °C = 3.378 bar
   - 0 °C = 2.929 bar
   - dT = 4 K; pressure change/Offset: 3.378 bar – 2.929 bar = 0.449 bar

2. Enter the design condition in Coolselector®2 and select the product family “KVP”.

3. Change the selection criteria to “Offset”



4. Enter the calculated Offset (from 1.):



5. Select the valve that is the best fit:.

Suction line (Dry expansion system. R134a. Control valve).

Selection: KVP 15 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	Kv_calc [m^3/h]	Offset [bar]	DP [bar]	DT_sat [K]	Load [%]	Velocity, in [m/s]	Valve state	Result
○	KVP 12	12	2,5	1,512	0,449	0,015	0,1	0	6,41	Open	✓
◉	KVP 15	16	2,5	1,512	0,449	0,015	0,1	0	3,07	Open	✓
○	KVP 22	22	2,5	1,512	0,449	0,015	0,1	0	1,44	Open	✓
○	KVP 28	28	7	2,564	0,449	0,005	0,0	0	0,83	Open	✓
○	KVP 35	35	7	2,564	0,449	0,005	0,0	0	0,51	Open	✓

As is evident from the table above, there are two main sizes of the KVP valve, which share the same Kv-value (2.5), and thus, the same capacity; namely the KVP 12 and the KVP 15. The difference between the two valves is that they are equipped with different connector sizes.

Suction line (Dry expansion system. R134a. Control valve).

Selection: KVP 15 **No code numbers selected**

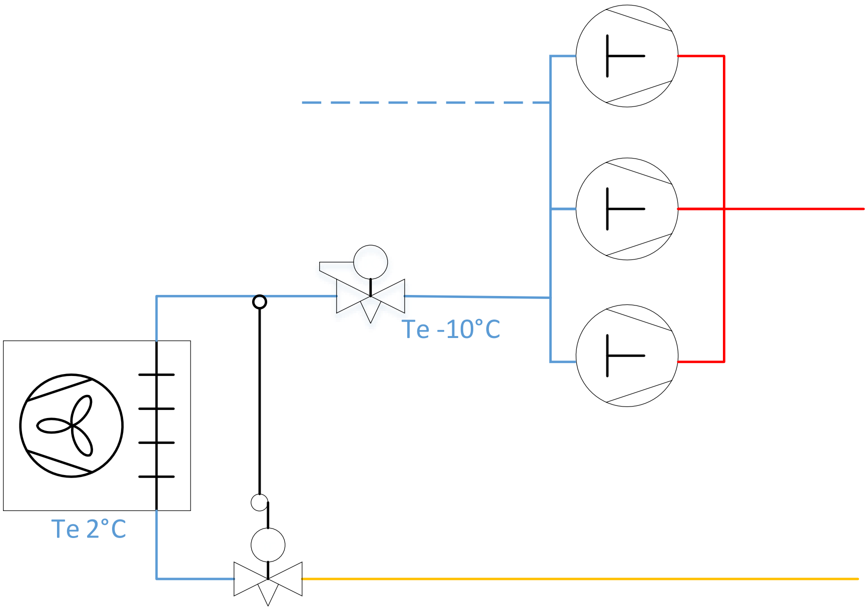
Selected	Type	NS	Kv [m^3/h]	Kv_calc [m^3/h]	Offset [bar]	DP [bar]	DT_sat [K]	Load [%]	Velocity, in [m/s]	Valve state	Result
○	KVP 12	12	2,5	1,512	0,449	0,015	0,1	0	6,41	Open	✓
◉	KVP 15	16	2,5	1,512	0,449	0,015	0,1	0	3,07	Open	✓
○	KVP 22	22	2,5	1,512	0,449	0,015	0,1	0	1,44	Open	✓
○	KVP 28	28	7	2,564	0,449	0,005	0,0	0	0,83	Open	✓
○	KVP 35	35	7	2,564	0,449	0,005	0,0	0	0,51	Open	✓

d) The large types of KVP valves will give less pressure drop, but a saturated pressure drop of only 0.1 K with the small sizes is very low and will result in negligible losses. A system capacity of 1 kW would typically have a suction pipe of 15 mm or 16 mm. So, the correct selection would be the KVP 15.

Exercise 4.8 Selecting an evaporation pressure control valve for a power-pack system

Let us set up this scenario for the exercise; an air-conditioning evaporator shall be connected to a power pack unit. The unit maintains cooling cases and cold rooms in a food store.
The unit works under the following conditions:

- Refrigerant: R449a
- Cooling capacity: 2 kW to 15 kW
- Evaporator temperature: -10 °C
- Condenser temperature: +40 °C (summer conditions)



a) What are the important aspects to consider when selecting the evaporator pressure control valve in this system?

b) What is the suggested KVP valve?

c) Check that the evaporation temperature at part load cannot run below 0 °C.

d) Check if the minimum load capacity can be controlled by the valve?

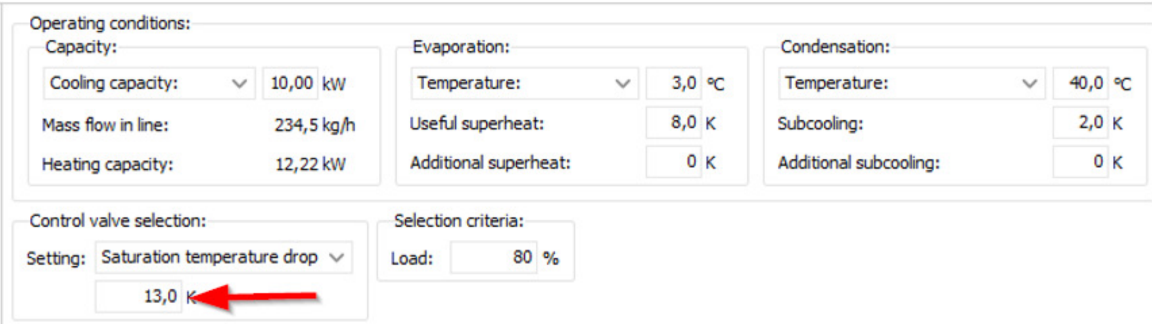
Solution 4.8 Selecting an evaporation pressure control valve for a power-pack system

a) The selection of an evaporation pressure control valve connected to a power pack system is subject to two important aspects:

1. The valve needs to create a pressure drop at the nominal load condition. This is because, typically, the connected evaporator will run at a higher evaporation temperature than the system provides.
2. Possible part load conditions at the evaporator should be considered.

b) Enter the design operating conditions and select the KVP valve product family.

1. The evaporation temperature should be 3 °C, but the system runs at -10 °C. Therefore, the valve must provide a saturated pressure drop of 13 K. Thus, in Coolselector®2, you should enter 13 K as the saturation pressure drop :



2. A KVP of the small port series (meaning, one of the first three in the selection table below) would fit the system requirements:

Suction line (Dry expansion system. R449A. Control valve).

Selection: KVP 22 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	Kv_calc [m^3/h]	Offset [bar]	DP [bar]	DT_sat [K]	Min. capacity [kW]	Max. capacity [kW]	Load [%]	Velocity, in [m/s]	Valve state	Result
○	KVP 12	12	2,5	1,349	0,360	2,056	13,0	1,168	17,72	56	42,30	Open	✓
○	KVP 15	16	2,5	1,349	0,360	2,056	13,0	1,168	17,72	56	20,27	Open	✓
◉	KVP 22	22	2,5	1,349	0,360	2,056	13,0	1,168	17,72	56	9,49	Open	✓
○	KVP 28	28	7	1,349	0,282	2,056	13,0	4,470	50,36	20	5,48	Open	✓
○	KVP 35	35	7	1,349	0,282	2,056	13,0	4,470	50,36	20	3,35	Open	✓

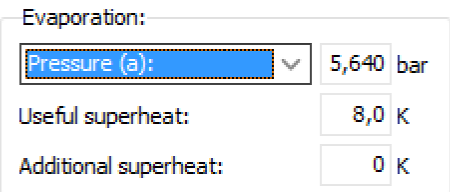
The KVP 22 will give an inlet velocity of about 9.49 m/s and would be the preferred type.

c) An offset (=opening) of 0.36 bar creates a pressure drop of 2.056 bar and through this, the evaporation pressure is increased to the target value of 3 °C.

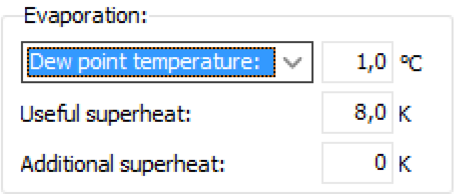
If the evaporator gets less heat load, the mass flow will in turn also be less, which will make the evaporation pressure drop. Due to this, the valve will go to a lower opening degree.

It is important to note, that to avoid ice building up, the lower evaporation should not be less than 0 °C.

When converted to saturated pressure, 3 °C is about 5.64 bar:



Calculate 5.64 bar – 0.36 bar (offset) = 5.28 bar. Change the evaporation pressure to 5.28 bar and switch afterwards to check the resulting temperature:



At 1 °C there is no risk for ice building and thus, we can conclude that one of the smaller KVP valves can be used for this system design.

d) The minimum possible part load, at which the valve is still in stable operation, is about 1.168 kW. Whereas the minimum evaporator capacity is 2 kW. The valve is also suitable for part load.

Suction line (Dry expansion system. R449A. Control valve).

Selection: KVP 22 **No code numbers selected**

Selected	Type	NS	Kv [m^3/h]	Kv_calc [m^3/h]	Offset [bar]	DP [bar]	DT_sat [K]	Min. capacity [kW]	Max. capacity [kW]	Load [%]	Velocity, in [m/s]	Valve state	Result
○	KVP 12	12	2,5	1,349	0,360	2,056	13,0	1,168	17,72	56	42,30	Open	✓
○	KVP 15	16	2,5	1,349	0,360	2,056	13,0	1,168	17,72	56	20,27	Open	✓
◉	KVP 22	22	2,5	1,349	0,360	2,056	13,0	1,168	17,72	56	9,49	Open	✓
○	KVP 28	28	7	1,349	0,282	2,056	13,0	4,470	50,36	20	5,48	Open	✓
○	KVP 35	35	7	1,349	0,282	2,056	13,0	4,470	50,36	20	3,35	Open	✓

Exercise 4.9 Calculating heat load and selecting components for a cold room

Using Coolselector®2, please calculate a cold room for vegetables storage. The cold room is located inside a building, but the back of the room is affected by ambient conditions.

Please use the following information to calculate the cold room:

a) Dimension of the room will be:

- Length: 10 m
- Width: 5 m
- Height: 4 m

b) Insulation:

- Polyurethane, 100 mm

c) Floor:

- Not insulated. Made of concrete to withstand fork-lift trucks.

d) Ambient conditions:

- Ambient condition: 32 °C, 45% RH
- Inside the building: 23 °C, 55% RH
- Below floor: 12 °C

e) Goods stored:

- Type: Fresh vegetables
- Usage: Medium time (several weeks)
- Stored mass: Unclear, but room volume will be used as much as possible. To pick up goods, only a small space to walk through is needed.

f) Refrigeration system:

- Refrigerant: R448A
- A condensing unit can be installed outside behind the room.
- An electronic controller shall be used.

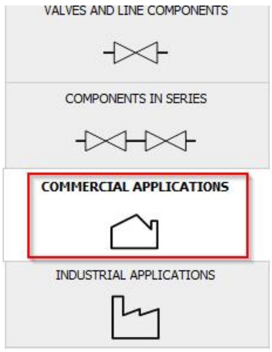
Solution 4.9 Calculating heat load and selecting components for a cold room

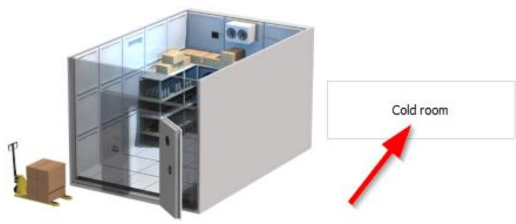
Vegetable storage requires that you pay close attention to the storage conditions.

Therefore, please consider the following before starting the cold room calculation in Coolselector®2:

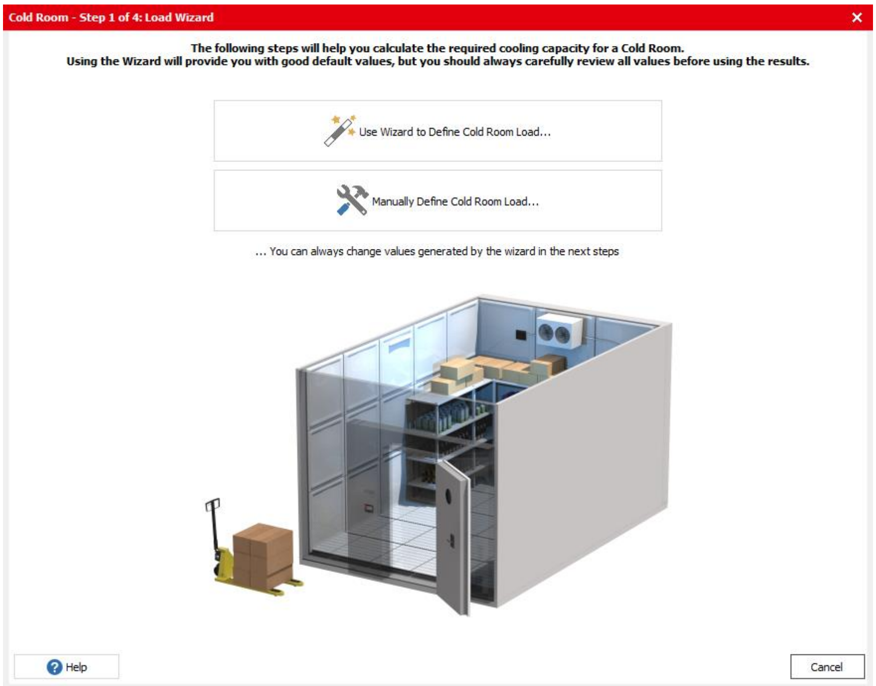
- Room temperature shall be close to the freezing point to keep respiration activity low.
- Humidity shall be as high as possible, preferably 95% or even 98% RH
- No goods will be affected by the direct air flow; this keeps a micro climate around the goods.
- Do not store goods all the way up to the ceiling and keep a good distance to the walls and between the boxes.

Next, in Coolselector®2, go to 'Commercial Applications' and start a cold room calculation:



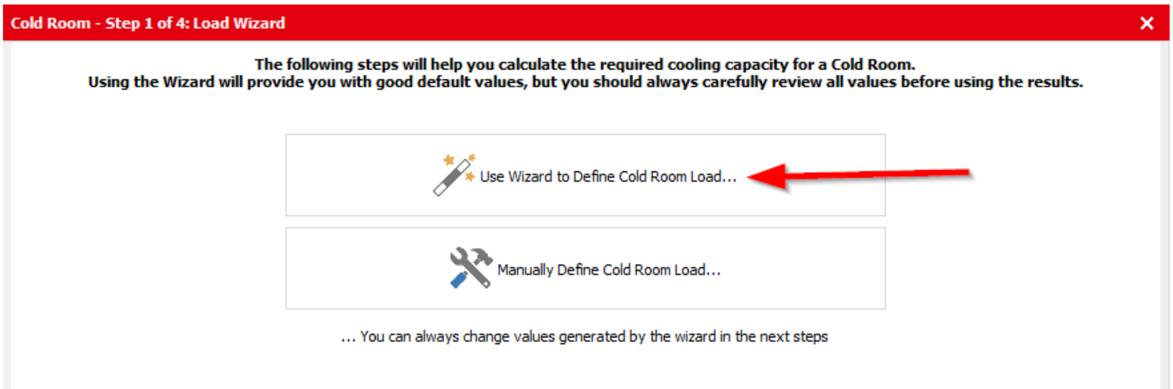


Starting a cold room calculation opens up a dialog box, which allows you to use a wizard, which not only guides you through but also helps with educated estimations of all room parameters. If you are already aware of all relevant values, you can also choose the 'Manually define room loads….' option within Coolselector®2:



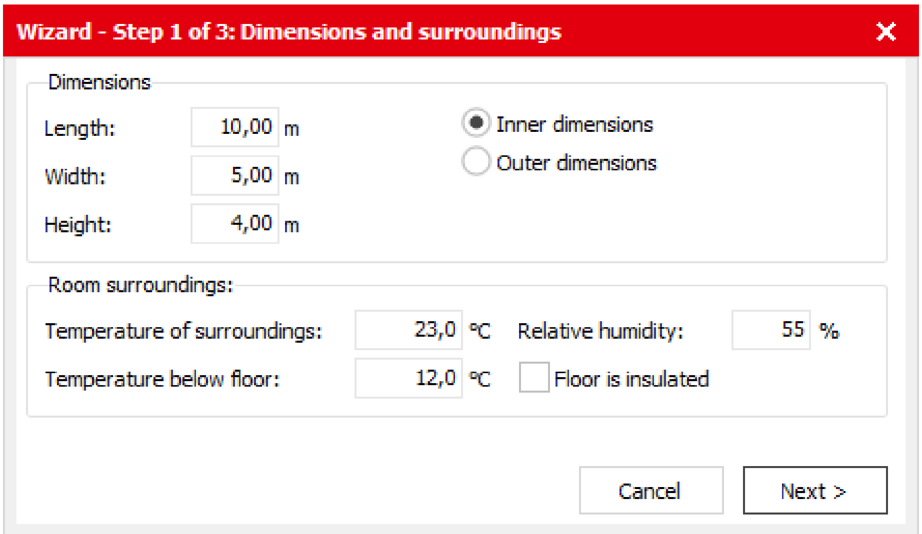
The help function in the bottom left corner provides further information about the methods and processes used in the cold room calculations:

Since in this example some essential parameters like “mass of goods” is not known, it is recommended to use the wizard for this assignment:



Wizard - Step 1 of 3: Dimensions and surroundings

Enter the known dimensions and surrounding conditions. Since the maximum load will be calculated, the maximum surrounding values should be entered:



Tip: Do not use values that may occur rarely and only for a short time

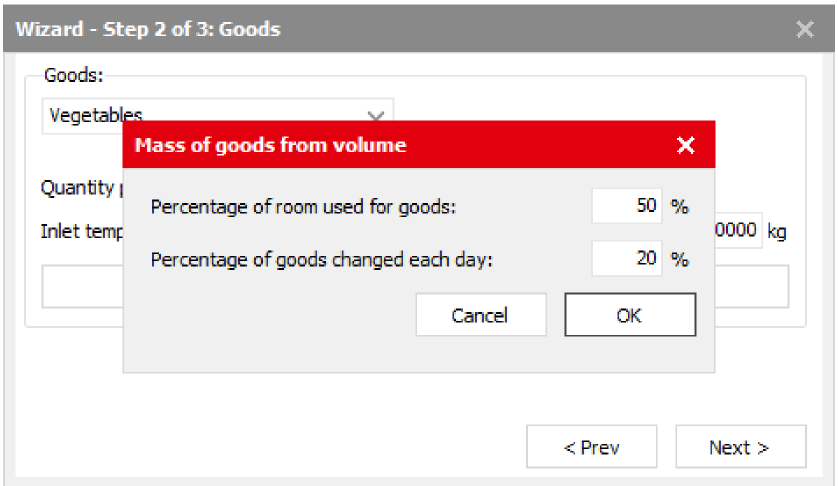
Wizard - Step 2 of 3: Goods

First of all, we know from the assignment that the goods to be stored are “vegetables”, so choose this in the first drop-down list.

In the assignment, only a little information is given about the usage of the storage. A calculation based on storable mass per m³ will help: Click on “Estimate mass from room volume…”.

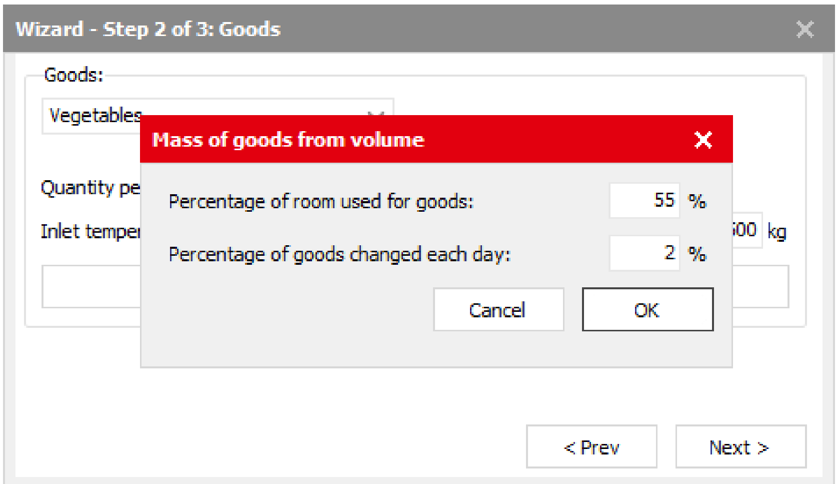
To baseline the estimation, the percentage of room effectively used for placing goods can be entered. Remember, air needs to flow around the goods and a person also needs to be able to walk between the racks to pick up goods.

The longer the time goods are stored for, the less space is needed for walking through the room. The goods can just be stacked up if the storing time is long:



Our case is somewhere in between short-term and long-term storage. The standard value of 50% for vegetables seems to be a little bit too low. Thus, we will increase it to 55%.

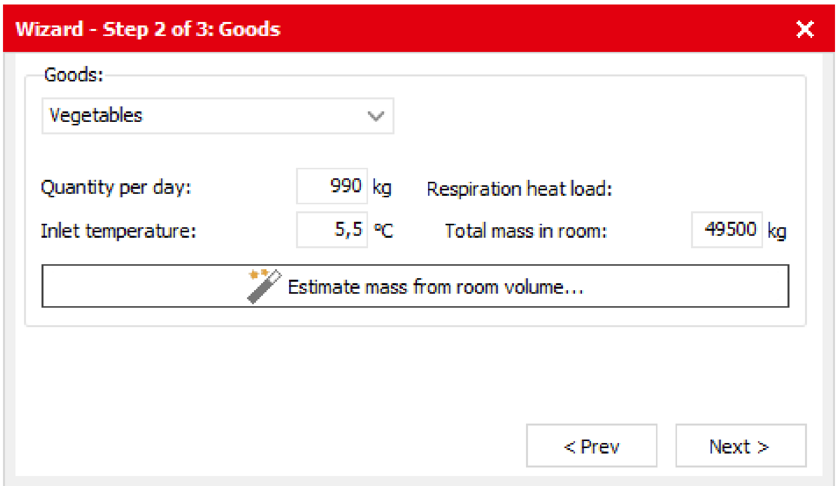
Since the goods will be stored on average for ‘some weeks’, the exchange rate per day will be much lower than 20%. Thus, we will reduce it to 2%:



If you now click “OK”, Coolselector®2 will do the necessary calculations and update the values for “Total mass in room” and the “Quantity per day”.

By default, the inlet temperature is set to 5 K above the recommended storage temperature (see Step 3 of 3). The goods are assumed to have been pre-cooled. In case the vegetables are stored directly after harvesting, the inlet temperature would naturally be higher.

In our case, we assume the goods are pre-cooled, and we keep the standard inlet temperature as it is and click on "Next":



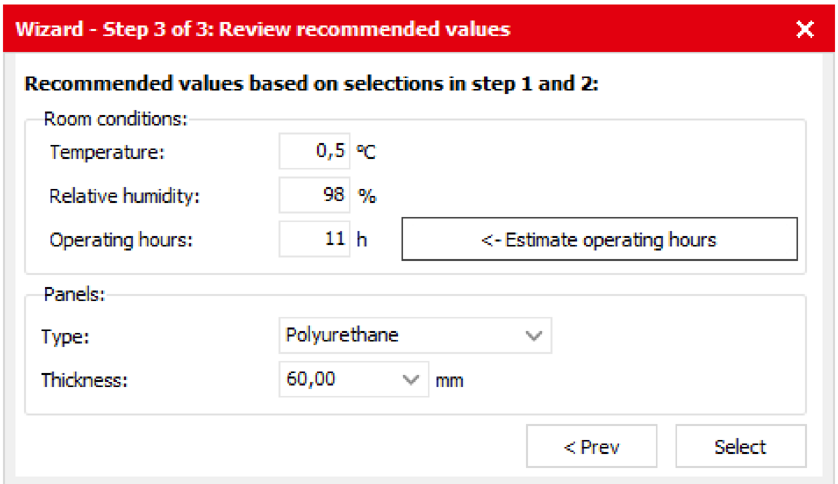
Wizard - Step 3 of 3: Review recommended values

In most cases, vegetables are stored differently in the cold room compared to on, for example, a sales shelf and often the humidity has to remain high.

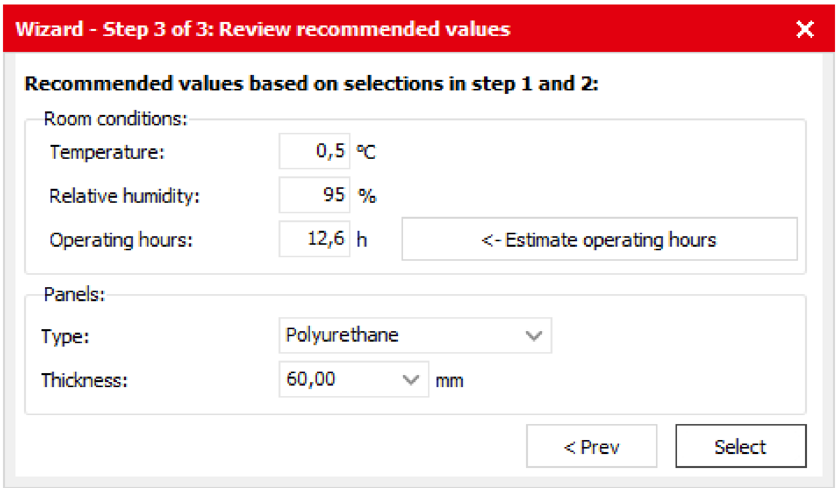
To reach a high humidity level within the cold room, the dehumidification needs to be kept low. Two parameters are available for adjustment to achieve this, namely:

- Temperature difference between evaporator and room temperature.
- Working time (on-time) of the refrigeration system.

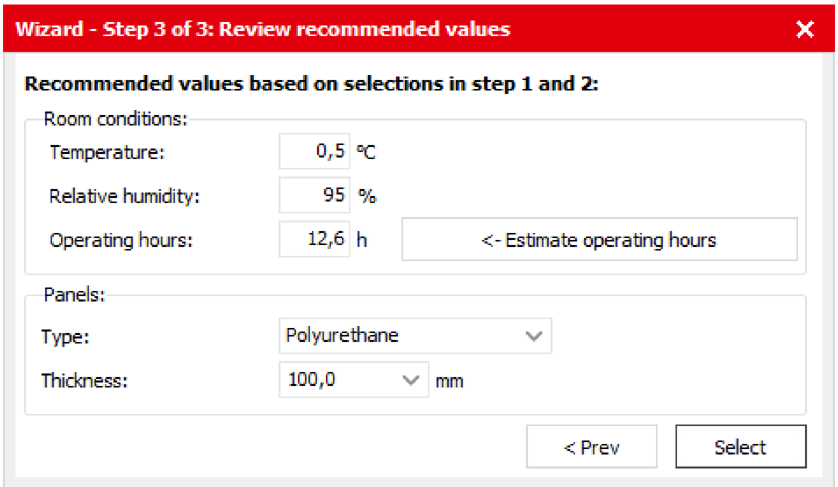
Based on these parameters, the operating hours are estimated/recommended. If you want the humidity to be higher than the default value of 95%, enter a new value like 98% and click "Estimate the operating hours". Coolselector®2 will now change the operating hours and it is evident that the refrigeration system should only run for 11 hrs (estimated) to achieve the higher value:



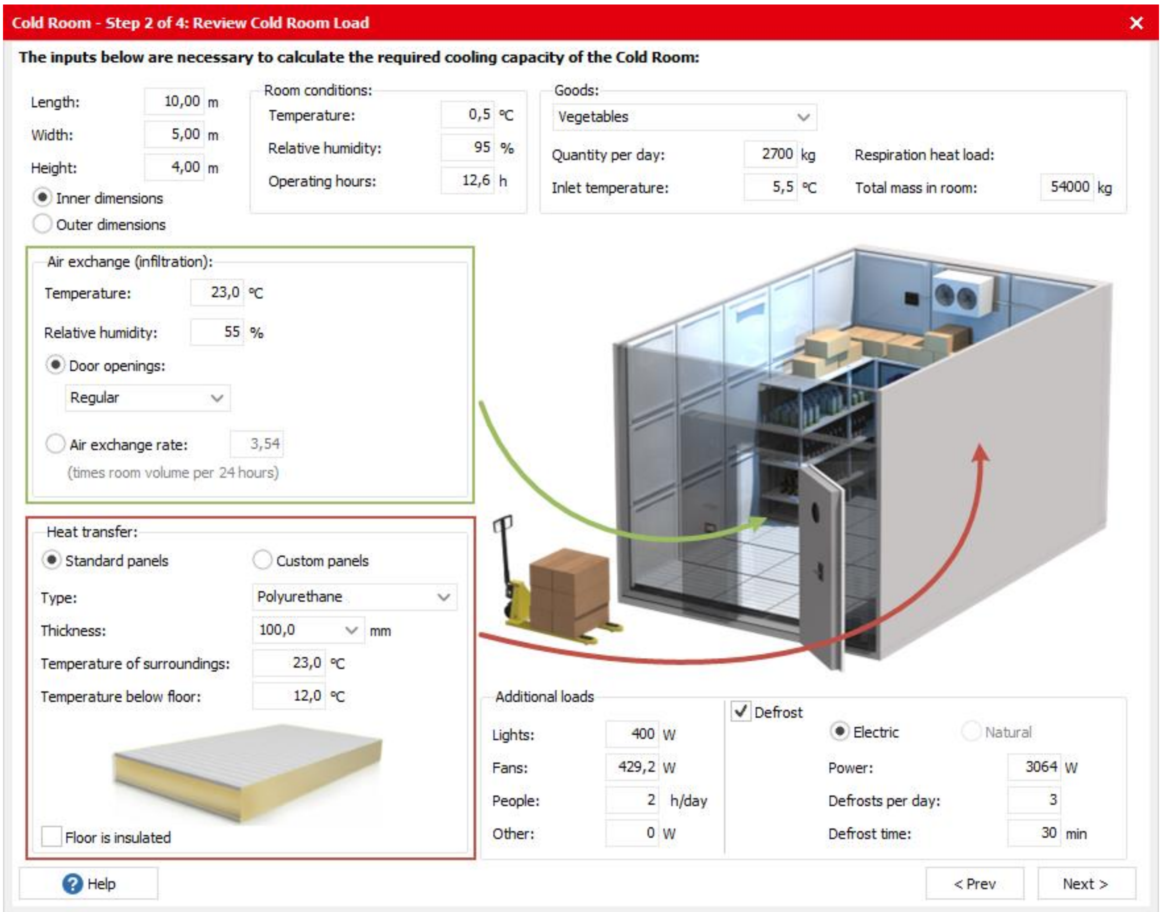
However, in our case, 95% RH will suffice. Thus, change the value back to 95% RH and click on "Estimate operating hours…" again:



Set the insulation panels to Polyurethane and 100 mm thickness and click "select":



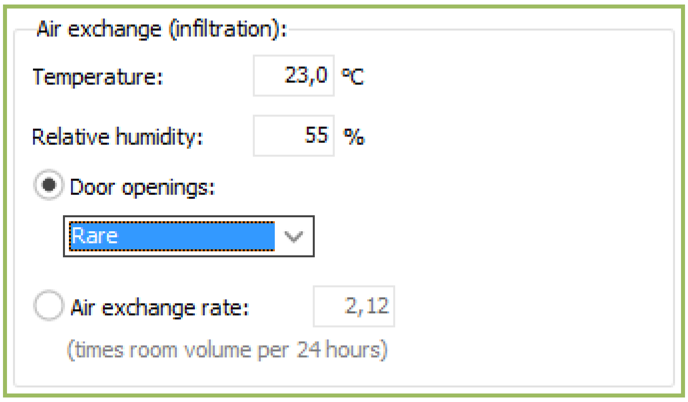
All values are now transferred to the overview “Review Cold Room Load”. All typically relevant values impacting the heat load are listed and available for adjustment if necessary:



Some values on the overview were not specified using the Wizard. These include:

a) **Air exchange:** Each door opening causes air exchange and will thus impact the heat load. In our case, we stated that the door will only rarely be opened (990 kg might be just one or two boxes).

Select “Rare” option for “Door openings” and the resulting air exchange rate per 24h will be re-calculated.



b) **Different ambient temperatures:** The backside panel of the room will be exposed to the ambient temperature of 32 °C. By selecting “Custom panels”, each room side can be defined individually.

Tip: 'Conductivity value' counts for insulation material only. If no floor insulation is used, the conductivity of concrete is automatically taken into account.

Heat transfer:

○ Standard panels ● Custom panels

	Thickness	Conductivity	Temperature
Wall	mm	W/(m·K)	°C
Front:	100,0	0,023	23,0
Left:	100,0	0,023	23,0
Right:	100,0	0,023	23,0
Back:	100,0	0,023	32,0
Ceiling:	100,0	0,023	23,0
Floor:	100,0	0,023	12,0

☐ Floor is insulated

c) **Additional heat loads:** Additional loads by refrigeration system equipment also need to be added.

d) **Light:** Based on the room area. A value is calculated based on 8 W/m². Here energy-optimized light will be used, which requires only 5 W/m². As a result, this reduces the light power from 400 W to 250 W.

e) **Fans and defrost heater:** Since no equipment has been selected at this moment, it can only be estimated. In the background, the required cooling capacity has already been calculated. Based on this and typical evaporators, both fan and defrost heater power is calculated and suggested. Naturally, these values can be changed if necessary.

f) **People:** Due to the rare door openings, people may only stay inside the room for a total of 1 h (assumed).

Other: A fork-lift truck is required to transport the boxes. Assuming a small electrical vehicle with a power of 1.2 kW is used, usage time inside the room is estimated at 20 min/day. Calculate:

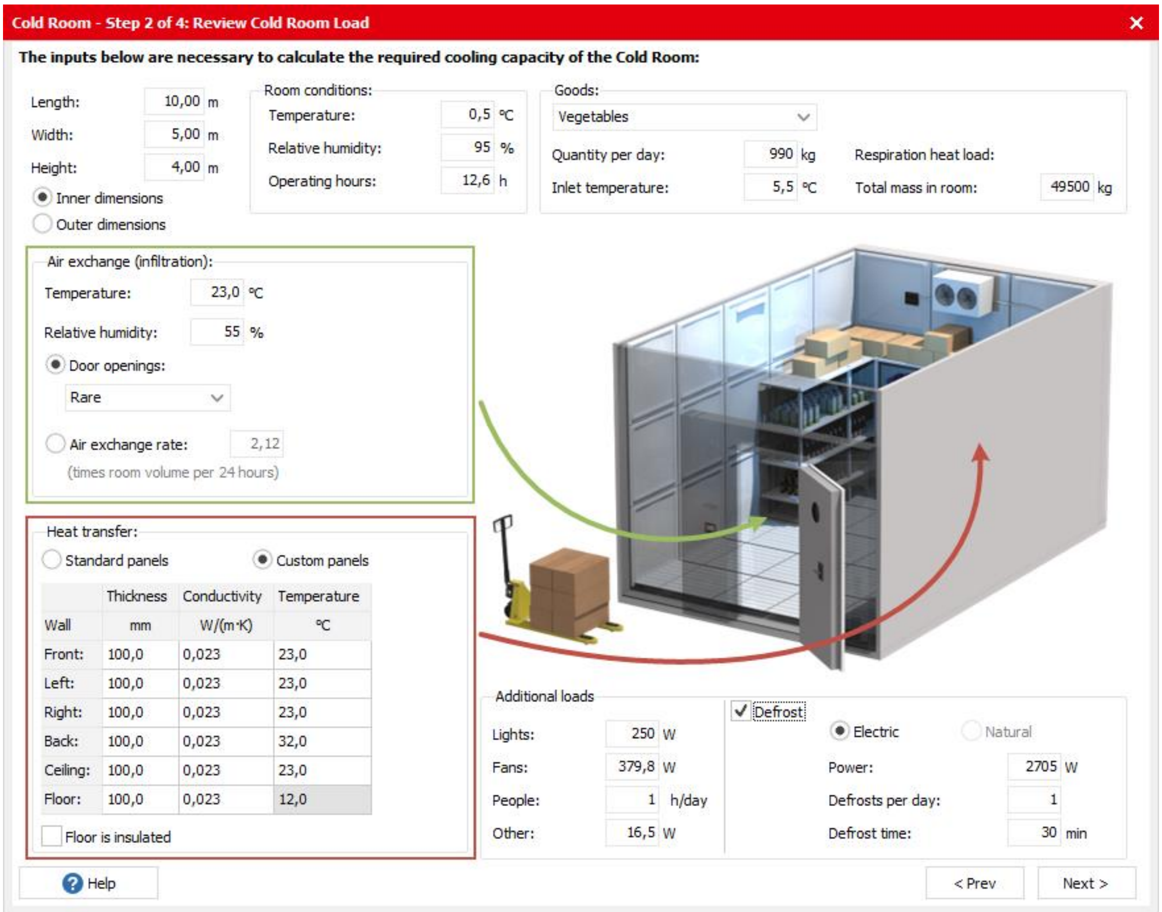
$$1200[W].\frac{0,33[h]}{24[h]} = 16,5[W]$$

Defrost: Defrosting by natural air circulation is not possible at 0.5 °C. Therefore, electrical defrost is selected. Since the room is only rarely opened, the amount of incoming humidity is below average. Thus, the defrosts per day can be set to 1:

Additional loads

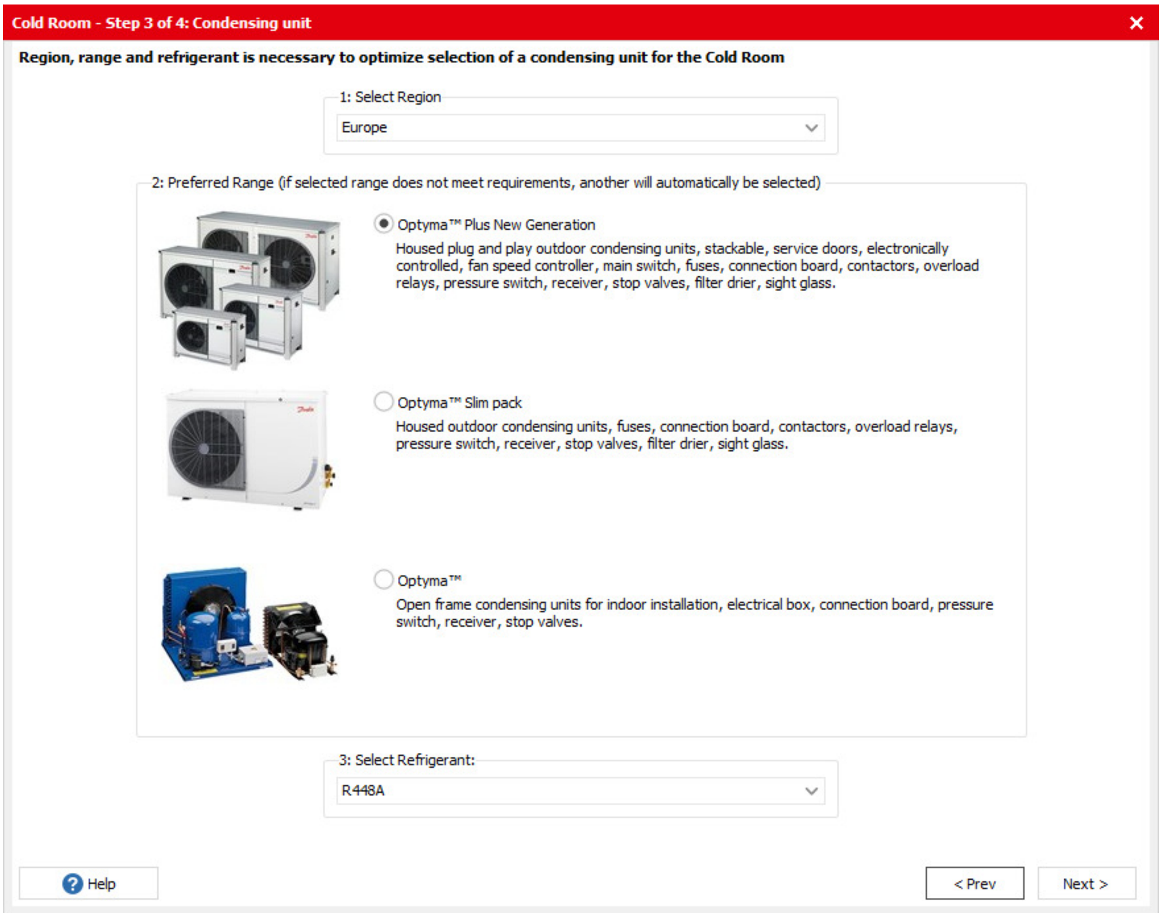
			☑ Defrost	● Electric	○ Natural
Lights:	250	W			
Fans:	379,8	W	Power:	2705	W
People:	1	h/day	Defrosts per day:	1	
Other:	16,5	W	Defrost time:	30	min

Now all inputs are done, and you can click “Next”:



For the next step in the cold room calculation, you are required to select the relevant condensing unit. To do so, follow these steps and then click "Next":

- Select your region to get the available condensing unit series (in our example we use 'Europe').
- Select a housed condensing unit, which can be placed outdoors behind the cold room.
- Select the refrigerant: R448A.

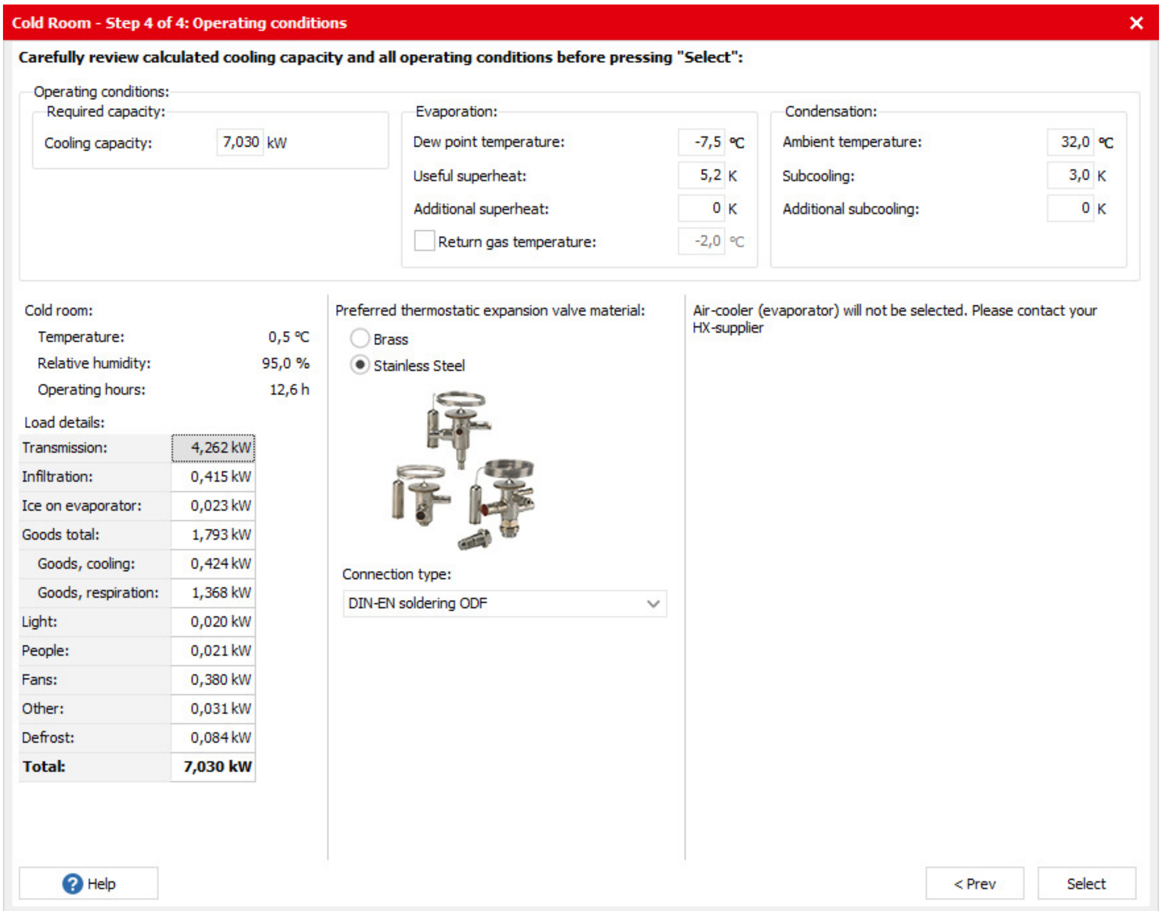


For the 4th and final step of the cold room calculations, you need to tell Coolselector®2 something about the given operating conditions.

This is also where the heat load calculation results can be reviewed, as well as the recommended system conditions. The suggested evaporation temperature and superheat values have been calculated based on the required temperature difference between the evaporator and the room (please also refer to “Wizard - Step 3 of 3”).

As was the case previously, all recommended values can be adjusted if deemed necessary.

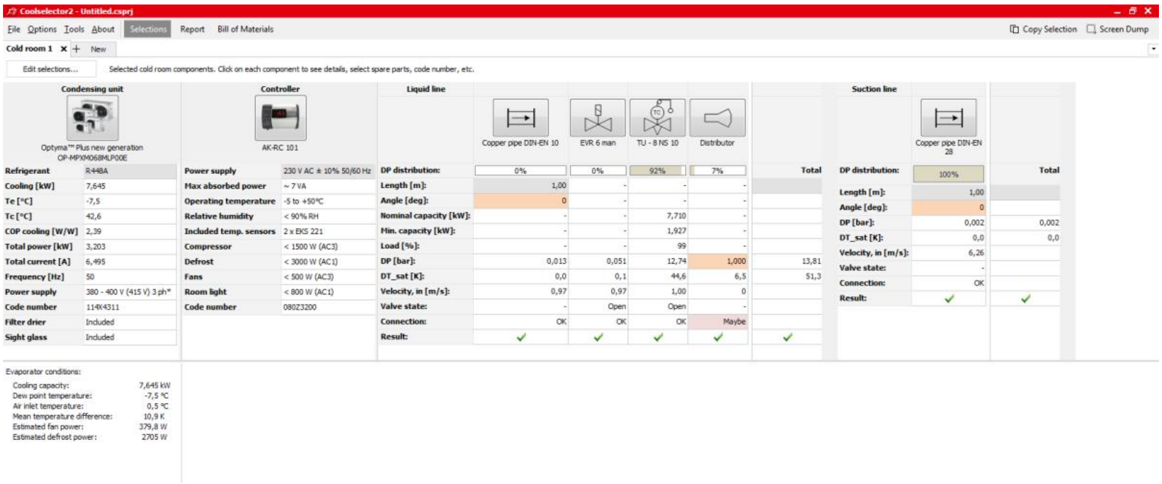
Select your preferred thermostatic expansion valve material. In our case, we will choose stainless steel:



After you have done this, click on “Select”, and Coolselector®2 will now start the component selection and create the cold room application as specified (this may take some seconds).

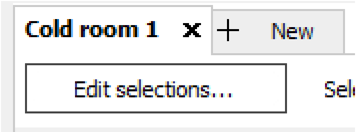
Based on the required cooling capacity, the best fitted condensing unit will be selected.

All other components will be sized and selected based on the condensing unit found:

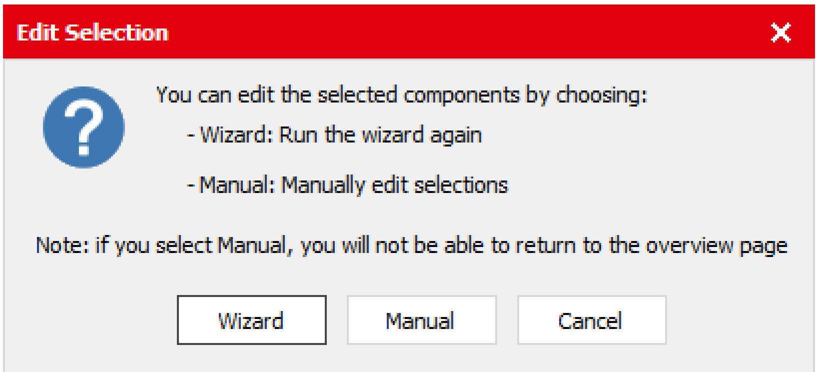


For the evaporator selection, all required values are listed on the screen.

If you want to adjust the calculation, simply click on “Edit selections…” at the top of the screen:

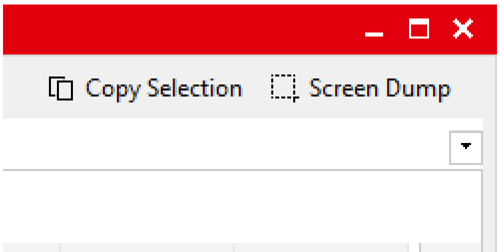


Doing this will bring up the following dialogue box:



“Wizard” will restart the wizard from the beginning, of course keeping all inputs intact.

“Manual” will split all selections and allow you to manually select all individual components. *Note:* From there it is not possible to return to the wizard. It is recommended that if you wish to use this option, you first do a “Copy selection” from the top right-hand corner in order to ensure that you have a back-up copy:



“Manual” may be a relevant option if, for example, the pipe calculation has to be adapted to the real installation with all bits and pieces (Please also refer to the section about ‘components in series’).

Finally, you can now create a report as explained in detail in chapter three:

And/or create a “Bill of Materials” which contains all components and their order numbers:

Coolselector®2

Version 2.3.1 | Database 33.33.1.13.3.14

Project name:	Cold Room for vegetables
Comments:	Test run
Created by:	Cold Room Engineering
Printed:	Mittwoch, 8. August 2018
Preferences used:	My preferences

Quantity	Product Description	Code number	Type Code	Sales Price
	Cold room 1			
1	Condensing unit: OP-MPXM068MLP00E, R448A.	114X4311		
1	Cold room controller: AK-RC 101	080Z3200		
	Liquid line			
1	Solenoid valve: EVR 6 man			
1	TXV: TU - 8 NS 10	068U3859		
1	Distributer: Distributor			
	Cold room 1 - Copy			
1	Condensing unit: OP-MPXM068MLP00E, R448A.	114X4311		
1	Cold room controller: AK-RC 101	080Z3200		
	Liquid line			
1	Solenoid valve: EVR 6 man			
1	TXV: TU - 8 NS 10	068U3859		
1	Distributer: Distributor			

5 Industrial applications

Exercise 5.1 Selecting a valve in liquid feed line

a) Select a single EVRA solenoid valve in a pump system in the liquid feed line using the following operating conditions:

- Refrigerant: Ammonia
- Mass flow in line: 800 kg/h
- Evaporating temperature: -10 °C
- Superheat: 0 K
- Circulation rate: 2.5
- Pump pressure rise: 2.0 bar

b) Which EVRA was selected?

c) Which criteria did Coolselector®2 use to select this valve? What is the cooling capacity corresponding to the 800 kg/h?

d) In part load conditions, the required cooling drops to 90 kW – how will the selected valve perform under these conditions?

e) Return to the full load capacity (800 kg/h). Select each valve in the result list:

1. If a warning is raised for the valve:
    - Explain the warning to yourself – try to understand why it occurs.
    - How many different warnings does the valve have?
2. Why does the performance curve change between the different valves?

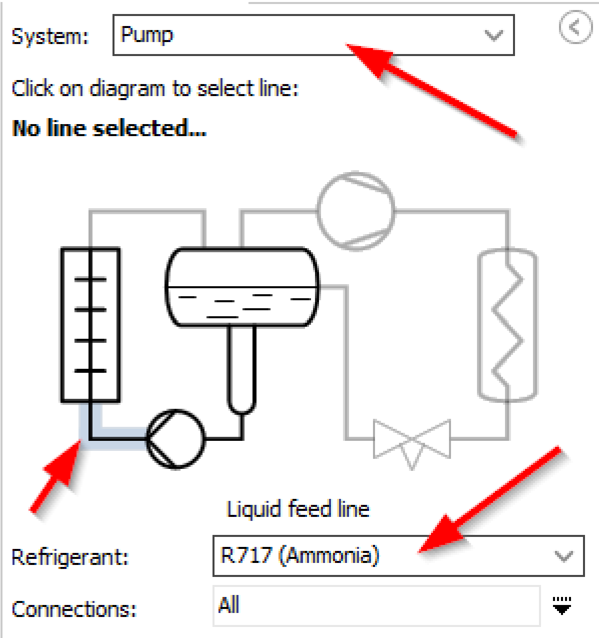
f) Should you always avoid selecting valves where a warning is displayed?

g) Select a manual regulating valve in the liquid feed line using the same operating conditions as above. Use selection criteria of 0.1 bar.

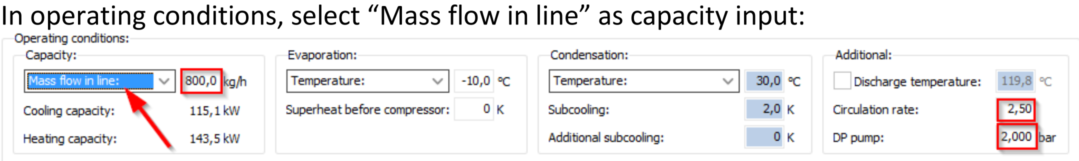
h) How many times should you turn the manual regulation valve to get a 0.10 bar pressure drop?

Solution 5.1 Selecting a valve in liquid feed line

a) Go to “New” tab, select “Valves and Line Components” and click on the “Solenoid valves” button. Select “Pump” system, click on the “Liquid feed line” and select “R717 (Ammonia)” as the refrigerant:



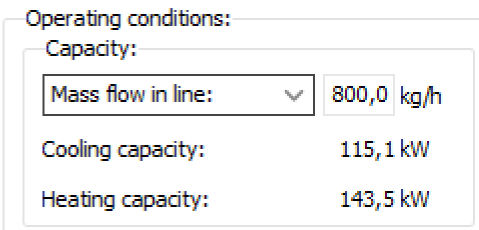
In operating conditions, select “Mass flow in line” as capacity input:

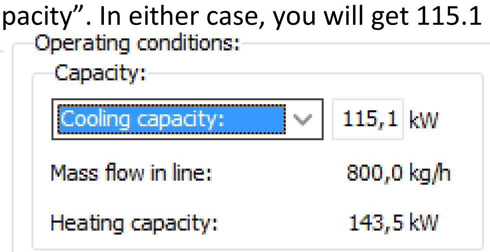


Note that all inputs colored blue are optional – i.e. what you enter does not affect the selection, but some of the results will be affected (even though the condensing temperature is optional, it will affect the heating capacity). Select EVRA in the “Product families” list.

b) EVRA 25 is selected
Coolselector®2 used a selection criterion of 1 m/s to select the valve:

c) You can either read the Cooling capacity right under the entered mass flow value, or change the capacity input to “Cooling capacity”. In either case, you will get 115.1 kW:





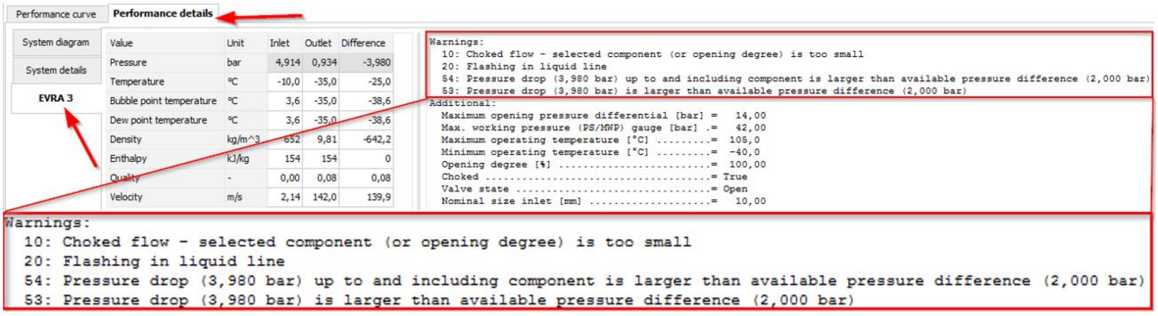
d) Coolselector®2 will now suggest EVRA 15 as the suggestion (it will be colored green), but it will keep EVRA 25 as the selected valve, and you can examine performance under the new operating conditions.
Coolselector®2 does not report any errors or warnings for this operating condition, so EVRA 25 will probably still be OK.

e) A few things to note about the different EVRA valves:
EVRA 3 is a direct-operated solenoid. It is too small for the given capacity and flow will be choked and the pressure difference will be larger than the available pressure difference.

Choked flow means that the mass flow though the valve has reached a maximum under the given conditions. I.e. even though the pressure drop across the valve increases, the mass flow will no longer increase.

The available pressure difference for the liquid feed line is the pump pressure (= 2 bar). Pressure drop through a component cannot be larger than this value.

If you look in “Performance details” and “Component performance details”, you will see that Coolselector®2 reports 4 warnings for the EVRA 3:



EVRA 10, 15 and 20 are diaphragm valves, so they have a minimum pressure drop of 0.05 bar below which they are closed. This is illustrated in the performance curve for the valves.

EVRA 20 is too large as the pressure drop is below the minimum so the valve is closed (and it is not possible to draw the performance curve).

EVRA 25, 32 and 40 are all servo-piston type valves, so below a certain minimum opening they will start to flutter (open/close rapidly) – this is illustrated in the performance curve as increasing red color as the mass flow decreases.

Note that the selected EVRA is not fully open in the given operating conditions. This might at first be an unfamiliar concept – i.e. that a solenoid valve is not fully open in normal operating conditions – but it is quite normal behavior for servo-piston solenoids (especially in liquid lines).

f) Warnings in Coolselector®2 are chosen based on experience, with the main purpose to warn you that the selected product under the actual operation condition may create problems.

Warnings consider typical operation variations a system may experience, like possible pulsations in a discharge line caused by, for example, reciprocating compressors, or a similar impact.

The purpose of warnings is to make you aware that you need to consider the actual selection/operation. A warning does not always mean that the product cannot be used.

Typical in repeatable applications, e.g. OEM solutions, where the customer conducts a specific application test, or has built up experience that shows that the product operates perfectly, it is possible to ignore the standard warnings.

But if in doubt, or if you do not know the exact application where the valve will be used, you should be careful selecting a valve with a warning — depending on the type of warning.

g) Specify selection criterion to be 0.10 bar and select either REG angle or REG straight.

Selected	Type	NS	Kv [m^3/h]	Kv_calc [m^3/h]	Opening degree [%]	Turns	DP [bar]	DT_sat [K]	Min. capacity [kg/h]	Max. capacity [kg/h]	Load [%]	Velocity, in [m/s]	Valve state	Result
○	REG 15-A straight	15	1,5	1,5	100	9	0,100	0,6	14,91	382,7	209	1,56	Open	⚠
○	REG 15-B straight	15	5	3,135	59	5 3/4	0,100	0,6	36,88	1276	63	1,56	Open	✓
○	REG 20-A straight	20	1,5	1,5	100	9	0,100	0,6	14,91	382,7	209	0,87	Open	⚠
◉	REG 20-B straight	20	5	3,135	59	5 3/4	0,100	0,6	36,88	1276	63	0,87	Open	✓

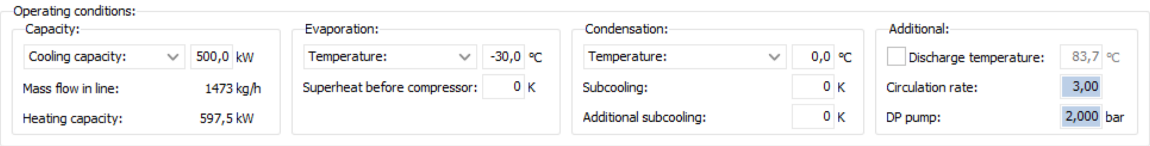
As can be seen, the suggestion is 15-B. If you look at the velocity, you will notice that 20-B has a velocity of 0.87 while the velocity in 15-B is 1.56. While having a velocity of 1.56 is not problematic, in this case 20-B is probably a better choice. This is a good example of where you can see the options and calculation results based on the inputs, and should choose according to the system requirements, despite the Coolselector®2 suggestion.

h) You can see the number of turns required in the table for any of the valves:

Selected	Type	NS	Kv [m^3/h]	Kv_calc [m^3/h]	Opening degree [%]	Turns	DP [bar]	DT_sat [K]	Min. capacity [kg/h]	Max. capacity [kg/h]	Load [%]	Velocity, in [m/s]	Valve state	Result
○	REG 15-A straight	15	1,5	1,5	100	9	0,100	0,6	14,91	382,7	209	1,56	Open	⚠
○	REG 15-B straight	15	5	3,135	59	5 3/4	0,100	0,6	36,88	1276	63	1,56	Open	✓
○	REG 20-A straight	20	1,5	1,5	100	9	0,100	0,6	14,91	382,7	209	0,87	Open	⚠
◉	REG 20-B straight	20	5	3,135	59	5 3/4	0,100	0,6	36,88	1276	63	0,87	Open	✓

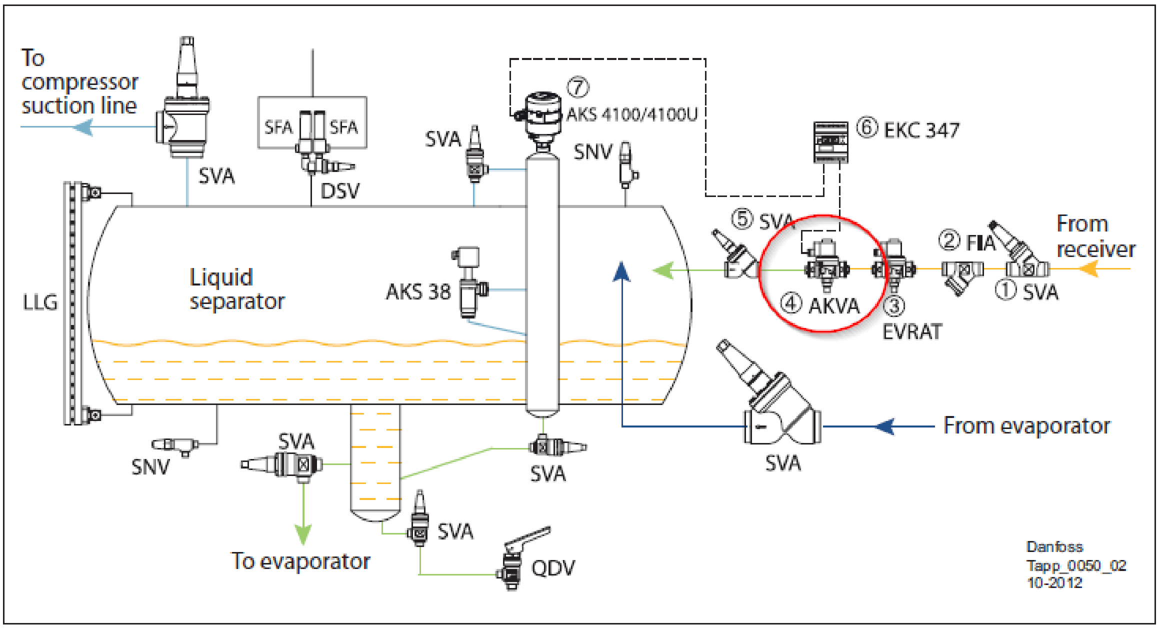
Exercise 5.2 Selecting an expansion valve

Select an AKVA electronic expansion valve for a pump system with ammonia with the following operating conditions:



Operating conditions:

Capacity:		Evaporation:		Condensation:		Additional:	
Cooling capacity:	500,0 kW	Temperature:	-30,0 °C	Temperature:	0,0 °C	Discharge temperature:	83,7 °C
Mass flow in line:	1473 kg/h	Superheat before compressor:	0 K	Subcooling:	0 K	Circulation rate:	3,00
Heating capacity:	597,5 kW			Additional subcooling:	0 K	DP pump:	2,000 bar



a) What type of system can have a condensing temperature of 0 °C and an evaporating temperature of -30 °C?

b) What is the velocity out of the selected AKVA?

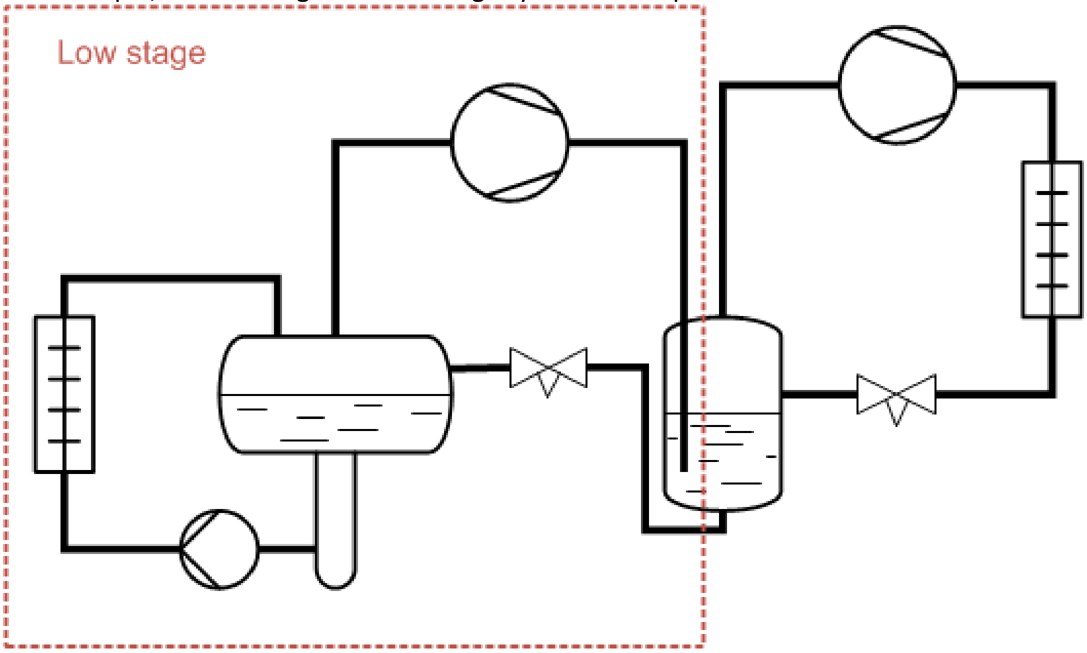
c) Select an ICM expansion valve instead

  1. Why does the performance curve look so different?
  2. What is the difference between “Load [%]” and “Opening degree [%]” for the ICM?

d) Change the evaporating temperature to -50 °C; what will the velocity out of the selected ICM be?

Solution 5.2 Selecting an expansion valve

a) For example, the low stage in a two-stage system with open intercooler:



Note that even though Coolselector®2 only supports a limited number of cycles, you can almost always make the selections you want by selecting the right line type and specifying proper operating condition. For example, if you want to select the expansion valve for the high stage of the two-stage system, you must add the condensing heat from the low stage system to the cooling capacity of the high stage system.

It is worth mentioning that operating conditions which are highlighted with a mate blue are optional ones which would not affect your current selection. You can see that they would differ based on the system and the line that you choose.

b) AKVA 20-3 is the selected valve. The velocity out of the valve is 37 m/s. It can be found in the performance details:

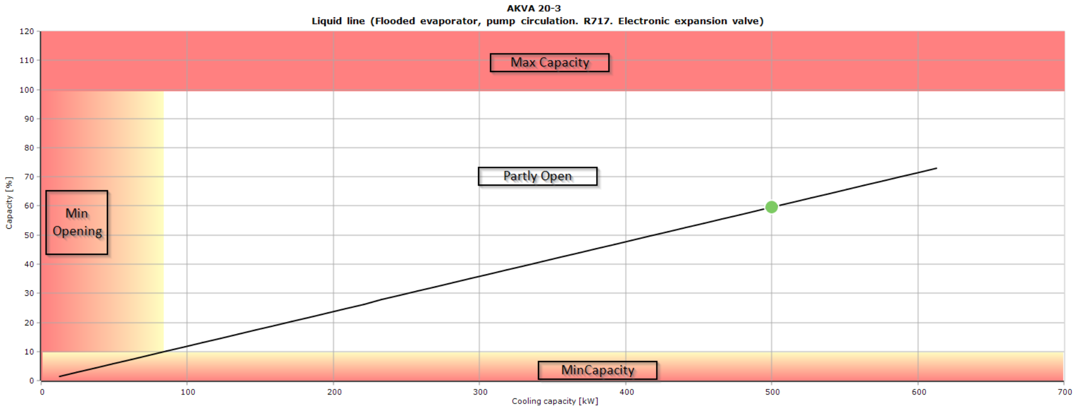
System diagram

System details

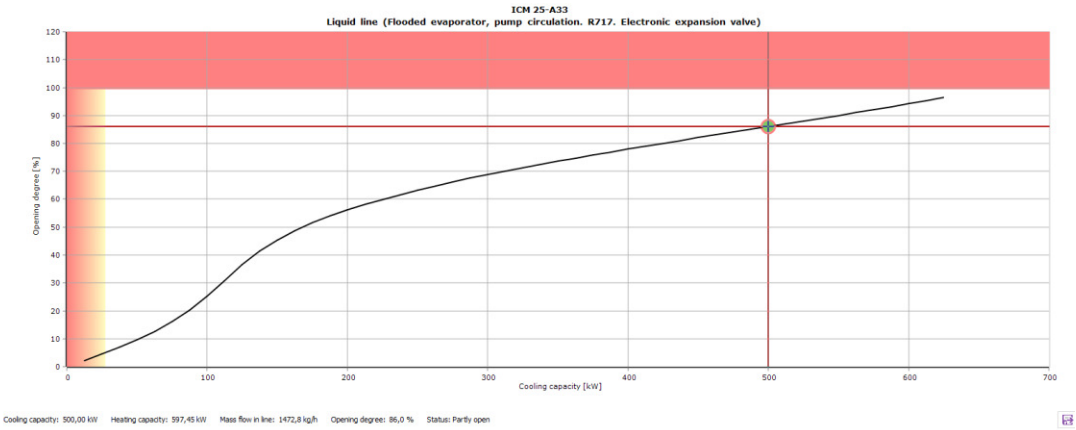
AKVA 20-3

Value	Unit	Inlet	Outlet	Difference
Pressure	bar	4,301	1,198	-3,103
Temperature	°C	0,0	-30,0	-30,0
Bubble point temperature	°C	0,0	-30,0	-30,0
Dew point temperature	°C	0,0	-30,0	-30,0
Density	kg/m^3	638,5	10,17	-628,3
Enthalpy	kJ/kg	199,9	199,9	0
Quality	-	0,00	0,10	0,10
Velocity	m/s	0,59	$\boxed{37,01}$	36,42

c) The AKVA 20 is a servo-piston valve, which can also be used as a solenoid valve. For this reason, the performance curve shows 4 different areas:



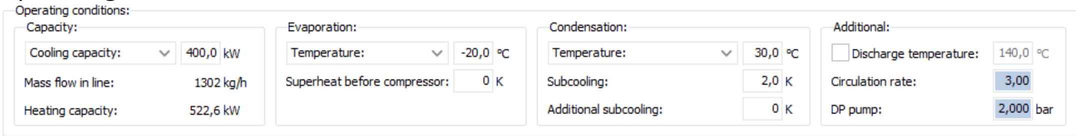
The load % is defined as: $\frac{Mass\ flow\ at\ current\ opening}{Mass\ flow\ at\ fully\ open}$. The ICM is an electronic stepper motor-controlled valve. And because the opening curve for the ICM is not completely linear, there will be a difference between the load percentage and opening degree.



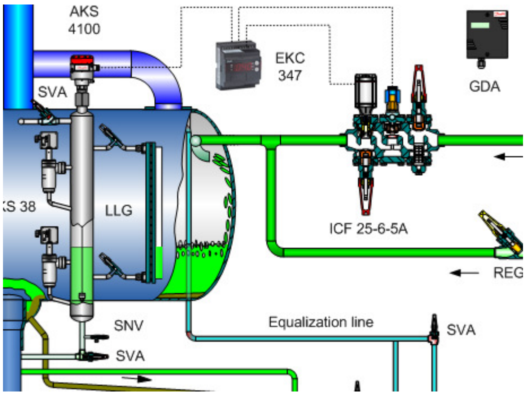
d) At -50 °C the velocity out of the selected ICM (ICM 25-A33) will be 277.5 m/s! This is a very high velocity but given the operating conditions and the size of the selected valve, this will be the velocity out of the expansion valve. In real systems, there will be piping, and additional pressure drops after the expansion valve, so that some of the expansion partly takes place in the piping after the valve. We'll look closer into this when we get to "Components in series". But you should, as far as possible, always select (expansion) valves using "Components in series", as this will give a more realistic picture of the operating conditions surrounding the valve.

Exercise 5.3 Selecting an ICF

a) Select an ICF valve for a liquid line in an ammonia pump system using the following operating conditions:

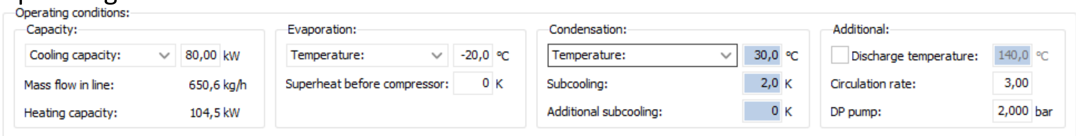


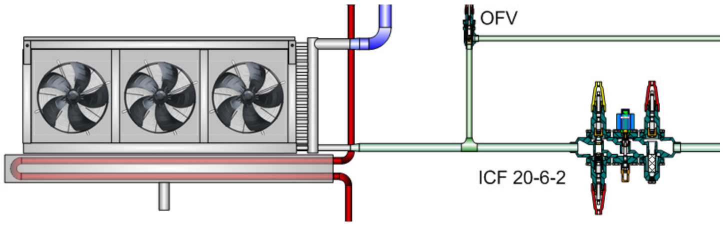
Inspect the ICF Quick selection list and select the ICF 20-6 which you think best matches your system.



1. Explain why you selected the specific ICF
2. Change the cooling capacity to 500 kW. If you get a warning, try to figure out why this warning is raised.
3. If you get a warning, try to remove the warning by changing the solenoid valve module.
4. Add the selected ICF to your favorites.

b) Select a new ICF for a liquid feed line in an ammonia pump system using the following operating conditions:





Select the first ICF from the Quick selection list.

1. Select the high capacity solenoid valve instead of the standard valve. Will this lower the pressure drop?
2. Minimize the pressure drop in the selected ICF by changing the predefined solenoid valve module and/or the predefined control valve module. What is the lowest pressure drop you can get?

For your own practice:

3. Check if the configuration you have made is an existing configuration (has a code number).
4. Add the selected ICF configuration to your Favorites.

Solution 5.3 Selecting an ICF

a) Go to the menu for valves and line components in a new tab and choose the “ICF valve station” from the options. Enter the operating conditions.

1. Given the operating conditions, you are presented with 6 options:

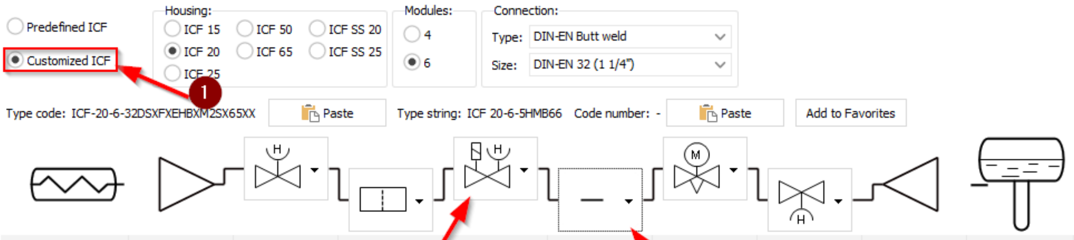
ICF Quick Selection ◉ DIN-EN Butt weld ○ DIN-EN SS Butt weld (stainless) ○ ANSI Socket/Butt weld

House	Connection	M1	M2	M3	M4	M5	M6	Type code	App code	Code number	Kv [m^3/h]	Load [%]	Result
ICF-20-6	25D	ICFS 20_m Stop valve	ICFF 20_m Standard filter	ICFE 20_m Solenoid valve	ICFO 20_m Manual opening	ICM 20-A33_m Motor valve	ICFS 20_m Stop valve	ICF-20-6-25DSXFXEXOXM1SX65XX	5	027L3388	0.1996	407.4	⚠
ICF-20-6	25D	ICFS 20_m Stop valve	ICFF 20_m Standard filter	ICFE 20_m Solenoid valve	ICFO 20_m Manual opening	ICM 20-A_m Motor valve	ICFS 20_m Stop valve	ICF-20-6-25DSXFXEXOXMASX65XX	5	027L3036	0.5887	136.7	⚠
ICF-20-6	32D	ICFS 20_m Stop valve	ICFF 20_m Standard filter	ICFE 20_m Solenoid valve	ICFO 20_m Manual opening	ICM 20-B66_m Motor valve	ICFS 20_m Stop valve	ICF-20-6-32DSXFXEXOXM2SX65XX	5	027L3374	1.417	52.6	✓
ICF-25-6	40D	ICFS 25_m Stop valve	ICFF 25_m Standard filter	ICFE 25_m Solenoid valve w/m open	ICFB 25_m Blank top cover	ICM 25-A33_m Motor valve	ICFS 25_m Stop valve	ICF-25-6-40DSXFXEHBXM1SX65XX	5	027L4170	1.954	39.5	✓
ICF-20-6	32D	ICFS 20_m Stop valve	ICFF 20_m Standard filter	ICFE 20-H_m Solenoid valve. High cap w/m open	ICFB 20_m Blank top cover	ICM 20-B_m Motor valve	ICFS 20_m Stop valve	ICF-20-6-32DSXFXEHBXMBSX65XX	5	027L3390	2.043	35.9	✓
ICF-25-6	40D	ICFS 25_m Stop valve	ICFF 25_m Standard filter	ICFE 25_m Solenoid valve w/m open	ICFB 25_m Blank top cover	ICM 25-A_m Motor valve	ICFS 25_m Stop valve	ICF-25-6-40DSXFXEHBXMASX65XX	5	027L4174	5.028	14.2	✓

We select the shown ICF because of the load % – it is not too low and there is plenty of excess capacity (the default selection criteria for expansion valves is a load percentage of 80%).

2. For the selected ICF you will get a warning stating that the saturation temperature drop in front of the valve is larger than 1K. This warning is used because a very high mass flow (and thereby pressure drop) in front of the expansion valve will lead to high velocities after the expansion valve (check the outlet velocity of the ICF). The maximum allowed saturation temperature drop in front of the expansion valve in an ICF can be changed in preferences.

3. You can remove the warning by changing to a high-capacity solenoid and changing the manual opening module to a blank cover. Double click on the IC and select “Customized ICF” and apply the changes. When you’ve done this, remember to go back and check operation at 400 kW.



	Condenser	House in	ICFS 20_m	ICFF 20_m	ICFE 20-H_m	ICFB 20_m	ICM 20-B66_m	ICFS 20_m	House out	Separator
			Stop	Filter	Solenoid	Blank	EEV	Stop		
DP distribution:		0%	0%	1%	2%	0%	79%	9%	8%	Total
Opening degree [%]:		-	-	-	59	-	81	-	-	
Max. capacity [kW]:		-	-	-	-	-	742,1	-	-	
Min. capacity [kW]:		-	-	-	-	-	4,054	-	-	
Load [%]:		-	-	-	-	-	67	-	-	
DP [bar]:		0,021	0,034	0,081	0,170	0,033	7,762	0,867	0,805	9,772
DT_sat [K]:		0,1	0,1	0,2	0,5	0,1	33,9	6,9	8,2	50,0
Velocity, in [m/s]:		0,70	1,94	1,94	1,94	1,94	1,94	49,15	26,90	
Velocity, out [m/s]:		0,70	1,94	1,94	1,94	1,94	49,15	74,85	43,81	
Valve state:		Open	Open	-	Partly open	Open	Open	Open	Open	
Result:		✓	✓	✓	✓	✓	✓	✓	✓	

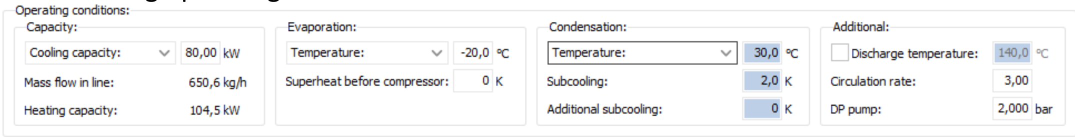
4. Press the <Add to Favorites> button to the left. Note that your favorites are saved per line type (meaning that this favorite will not be visible when you have selected another line type).

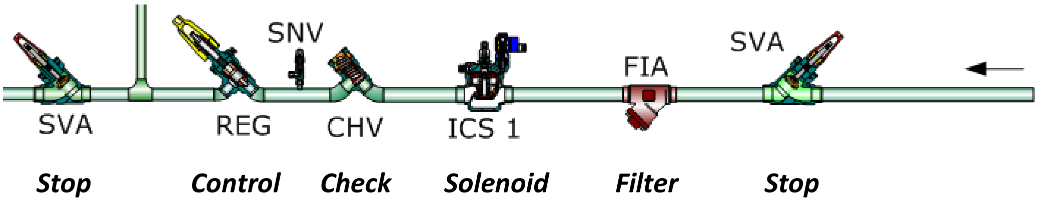
b)

1. In this case, changing to the high-capacity solenoid does lower the pressure drop because the solenoid will be partly open.
2. You can lower the pressure drop by, for example, changing the Solenoid and REG valve to an ICM and selecting an ICF 20-4 instead.

Exercise 5.4 Selecting components in series

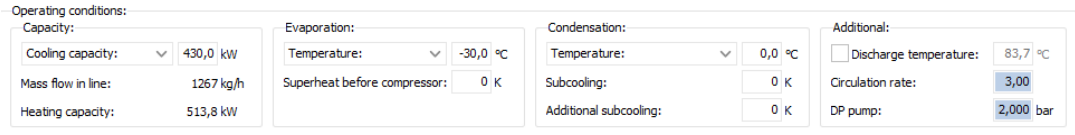
a) Select the following components in a liquid feed line in an ammonia pump system using the following operating conditions:





1. Why does Coolselector®2 start by selecting a size 15 stop valve?
2. Select appropriate valve sizes so that it is possible to remove all expanders and reducers and still have no connection warnings.
3. Select a new line and add the standard ICF you selected in Exercise 5.2-(b) (code number 027L3011). Then change the opening degree of the REG valve to 80%
4. Compare the pressure drop between the line with individual valves and the line with ICF.

b) Create a new liquid line in a pump system with ammonia with the following operating conditions:



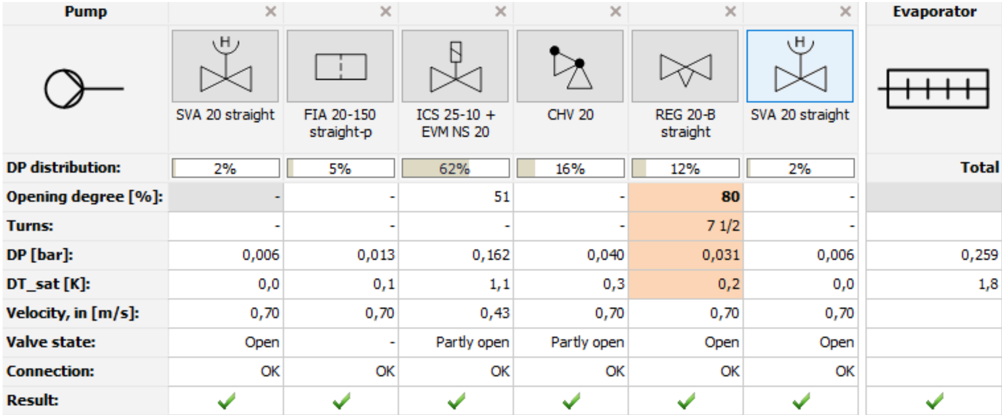
1. Add an AKVA electronic expansion valve to the line. Add a pressure drop of 1 bar to the line after the expansion valve and a pipe of 1 m. Is the AKVA still large enough?
2. Add a 10 m pipe before the AKVA. Is it possible to remove warnings by just changing component sizes? How should they be removed?
3. Change the Cooling capacity to 300 kW and check the velocity in the pipes. Review your results, considering that the AKVA is a pulse-width modulated valve. What will the real velocity through the pipes be?
4. Note that changing the system capacity to the max. capacity for the AKVA again changes the maximum capacity of the AKVA. Why?

Solution 5.4 Selecting components in series

a)

1. Coolselector®2 always uses the default selection criteria specified in your preferences to select the different component types. Try to open your preferences and see what the default selection criteria for a stop valve are in a liquid feed line. (for more information check the last exercise from Chapter 1).

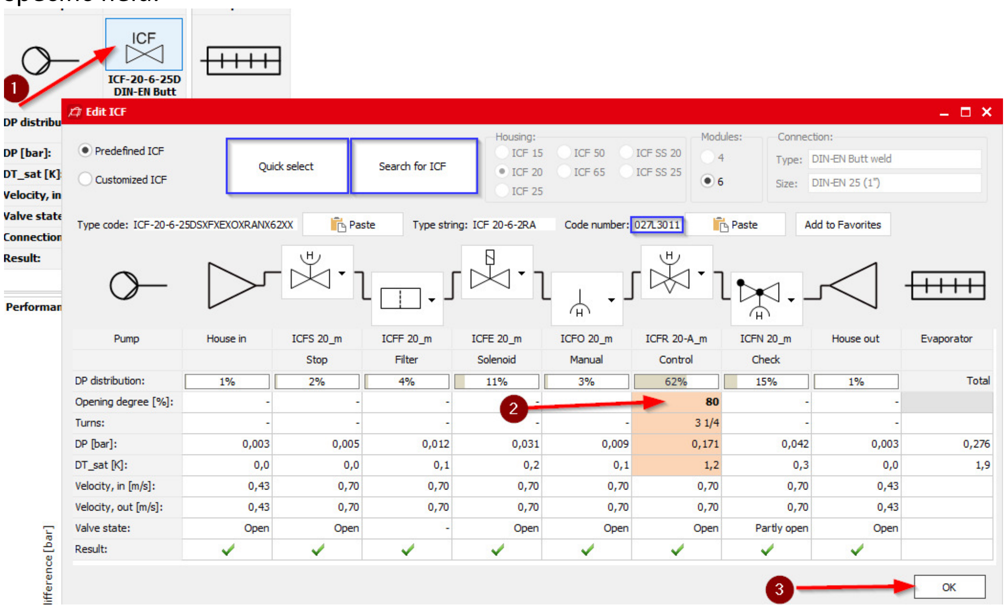
2. The resulting selection should look like this, with a total pressure drop of 0.259 bar:



Pump	SVA 20 straight	FIA 20-150 straight-p	ICS 25-10 + EVM NS 20	CHV 20	REG 20-B straight	SVA 20 straight	Evaporator
DP distribution:	2%	5%	62%	16%	12%	2%	Total
Opening degree [%]:	-	-	51	-	**80**	-	
Turns:	-	-	-	-	7 1/2	-	
DP [bar]:	0,006	0,013	0,162	0,040	0,031	0,006	0,259
DT_sat [K]:	0,0	0,1	1,1	0,3	0,2	0,0	1,8
Velocity, in [m/s]:	0,70	0,70	0,43	0,70	0,70	0,70	
Valve state:	Open	-	Partly open	Partly open	Open	Open	
Connection:	OK	OK	OK	OK	OK	OK	
Result:	✓	✓	✓	✓	✓	✓	✓

Note that flow direction in Coolselector®2 is always left to right. Among opening degree, number of turns, pressure-drop or saturated temperature-drop, you can choose one as input for the mechanical control valves. The input will be shown in bold font and the rest will be calculated based on the specified input.

3. You can add the ICF by going through the list of available choices or by choosing it using the code number or through the search menu. When you select the ICF to be added to the line, Coolselector®2 recognizes that there is a control valve in the selected ICF. Hence, it will ask for the control choice in the valve. You can skip this step by pressing "OK" and then input the opening degree by double clicking on the specific field:



	Pump	House in	ICFS 20_m Stop	ICFF 20_m Filter	ICFE 20_m Solenoid	ICFO 20_m Manual	ICFR 20-A_m Control	ICFN 20_m Check	House out	Evaporator
DP distribution:		1%	2%	4%	11%	3%	62%	15%	1%	Total
Opening degree [%]:		-	-	-	-	-	**80**	-	-	
Turns:		-	-	-	-	-	3 1/4	-	-	
DP [bar]:		0,003	0,005	0,012	0,031	0,009	0,171	0,042	0,003	0,276
DT_sat [K]:		0,0	0,0	0,1	0,2	0,1	1,2	0,3	0,0	1,9
Velocity, in [m/s]:		0,43	0,70	0,70	0,70	0,70	0,70	0,70	0,43	
Velocity, out [m/s]:		0,43	0,70	0,70	0,70	0,70	0,70	0,70	0,43	
Valve state:		Open	Open	-	Open	Open	Open	Partly open	Open	
Result:		✓	✓	✓	✓	✓	✓	✓	✓	

4. The total pressure drop in the ICF solution is 0.276 bar – i.e. practically the same as the individual valves.

b)

1. The AKVA is just large enough (96% load):

Condenser	AKVA 20-2	Constant DP	Steel pipe DIN-EN 40	Separator
DP distribution:	67%	32%	0%	**Total**
Length [m]:	-	-	1,00	
Angle [deg]:	-	-	0	
Max. capacity [kW]:	449,7	-	-	
Min. capacity [kW]:	44,97	-	-	
Load [%]:	96	-	-	
DP [bar]:	2,089	1,000	0,014	3,103
DT_sat [K]:	16,6	13,2	0,2	30,0
Velocity, in [m/s]:	0,51	0	23,27	
Valve state:	Open	-	-	
Connection:	OK	OK	No	
Result:	✓	✓	✓	✓

Also, note that Coolselector®2 gives a warning for connection size after constant pressure-drop element. This is because the tool does not know the connection sizes for the constant pressure drop.

2. Adding any component in front of the expansion valve will issue a warning because the subcooling is 0 K.
Changing the subcooling to 1 K and changing the pipe size to DN 32 will remove all warnings:

Operating conditions:

Capacity:		Evaporation:		Condensation:		Additional:	
Cooling capacity:	430,0 kW	Temperature:	-30,0 °C	Temperature:	0,0 °C	Discharge temperature:	83,7 °C
Mass flow in line:	1262 kg/h	Superheat before compressor:	0 K	Subcooling:	1,0 K	Circulation rate:	3,00
Heating capacity:	513,5 kW			Additional subcooling:	0 K	DP pump:	2,000 bar

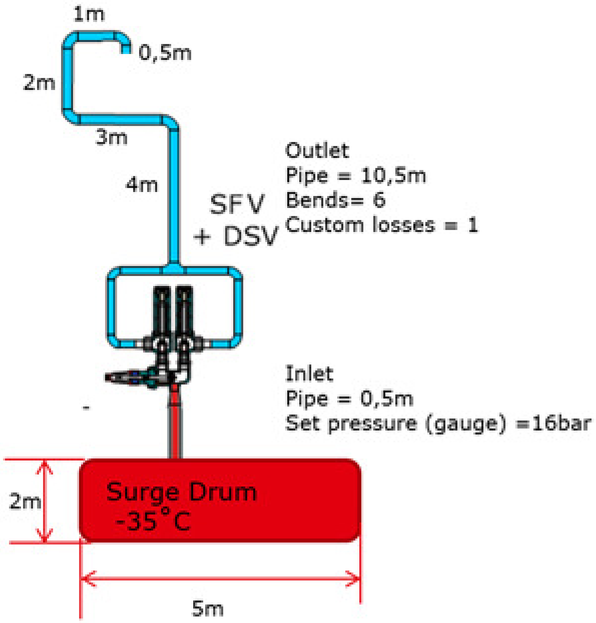
Condenser	Steel pipe DIN-EN 32	AKVA 20-2	Constant DP	Steel pipe DIN-EN 40	Separator
DP distribution:	0%	67%	32%	0%	**Total**
Length [m]:	10,00	-	-	1,00	
Angle [deg]:	0	-	-	0	
Max. capacity [kW]:	-	451,5	-	-	
Min. capacity [kW]:	-	45,15	-	-	
Load [%]:	-	95	-	-	
DP [bar]:	0,005	2,084	1,000	0,014	3,103
DT_sat [K]:	0,0	16,6	13,2	0,2	30,0
Velocity, in [m/s]:	0,50	0,50	0	22,43	
Valve state:	-	Open	-	-	
Connection:	OK	OK	OK	No	
Result:	✓	✓	✓	✓	✓

Note that the pressure drop of 1 bar after the expansion valve significantly decreases the capacity of the expansion valve. So it is always a good idea to check selection of an expansion valve in a line.

3. As the AKVA valve is a pulse-width operated valve, it will be fully open when it is open. So, to find the velocity in the pipes, we need to change the capacity to the max. capacity of the AKVA. You will discover that as you change the cooling capacity of the system, the flow in the pipes will change, which will affect the maximum capacity of the AKVA. This means that you must iterate a few times to find the maximum capacity.

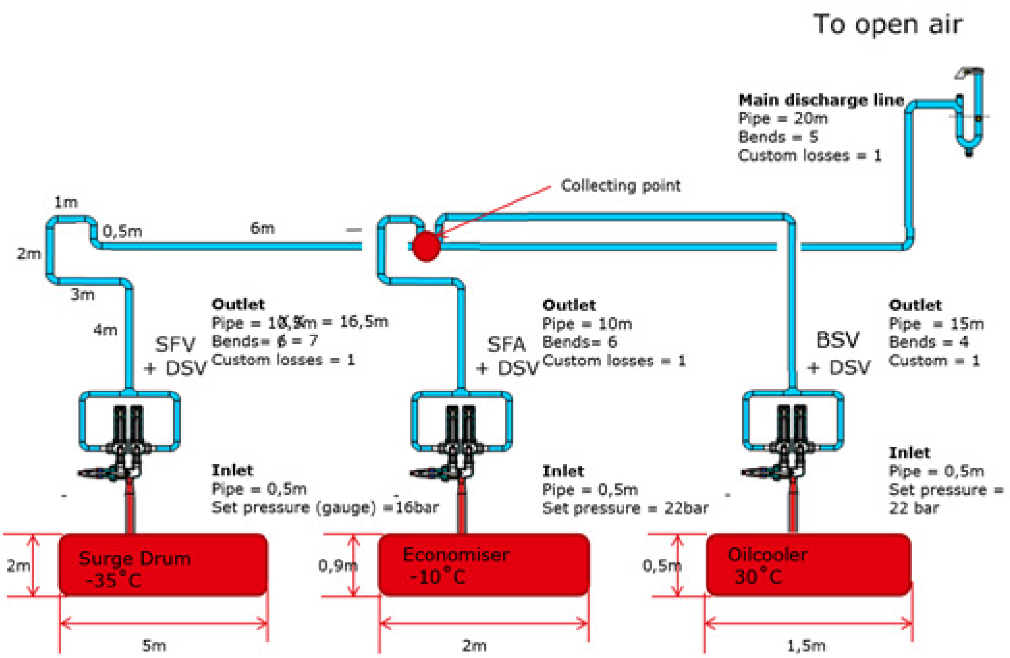
Exercise 5.5 Selecting a safety valve

a) Select a safety valve based on the following information (R717, external relief, 1 bar back pressure):



b) What happens if you select the largest safety valve? Why?

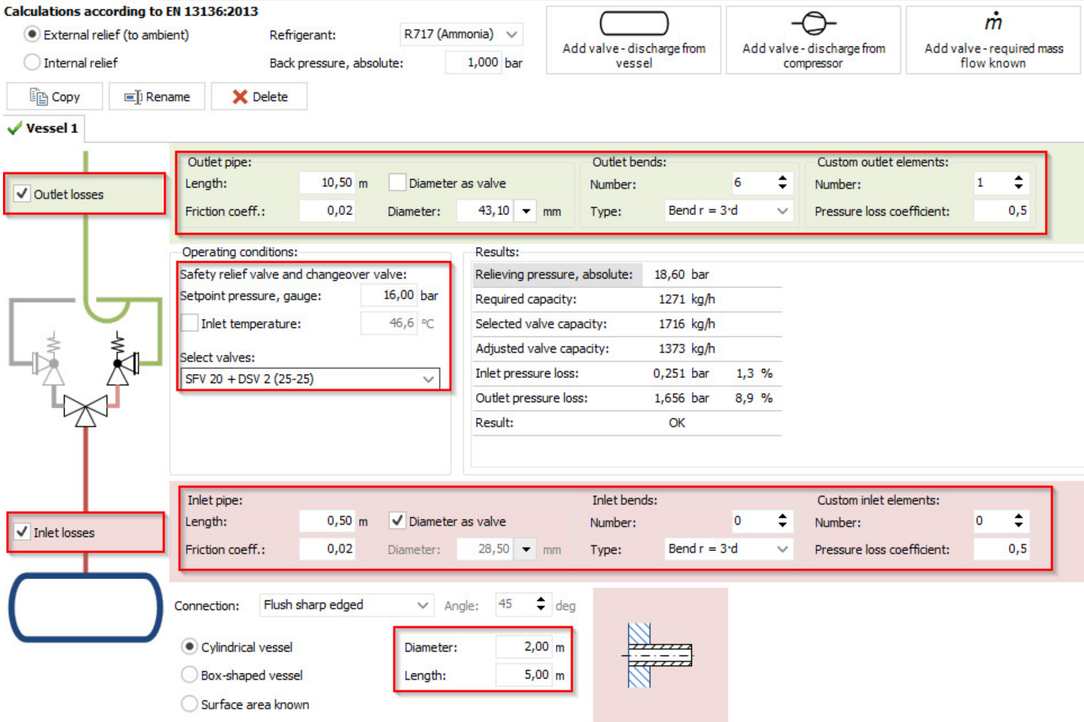
c) Add 2 more vessels, so that you get a system with common outlet:



d) Adjust pipe and valve sizes so that all selections are OK.

Solution 5.5 Selecting a safety valve

a) To keep the outlet pressure below the allowable, you will need to change the outlet pipe diameter to DN 40 and the selected valve should be “SFV 20 + DSV 2 (25-25)”:



b) If you select the largest valve (SFV 25), then the valve capacity also increases. In EN13136 losses in inlet and outlet pipes are based on valve capacity, so even though you can adjust the valve capacity in EN 13136, if it’s much larger than the required capacity then the adjusted capacity gives a too high pressure drop in the outlet line.

c) To remove the warning:

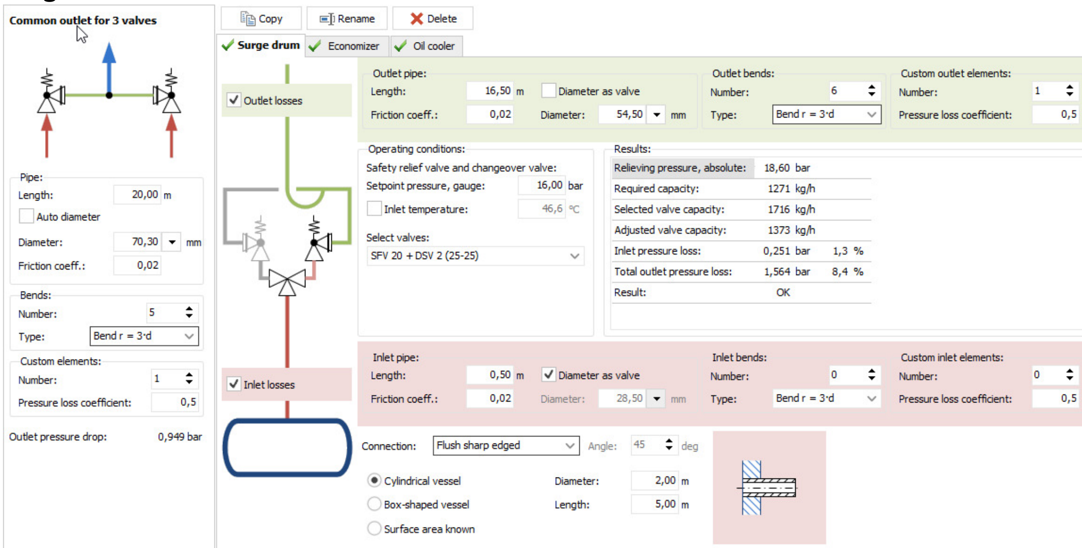
1. For each selection, select the smallest safety relief valve that is large enough to handle the capacity
2. Change the diameter of the common outlet pipe to a very large pipe size
3. One by one change the diameter of the individual outlet pipes until there are no errors for that selection
4. Change the diameter of the common outlet pipe until you reach the smallest diameter without warnings
5. Check whether individual outlet pressure losses are close to 10% for back pressure-dependent valves or 20% for back pressure-independent valves. If they are, evaluate whether it is possible to increase the individual outlet size and decrease the common outlet size without introducing errors. This last point is fine-tuning and you should evaluate whether it is worth increasing individual pipe size so that common pipe size can be decreased.

d) Following the above procedure resulted in these pipe sizes:

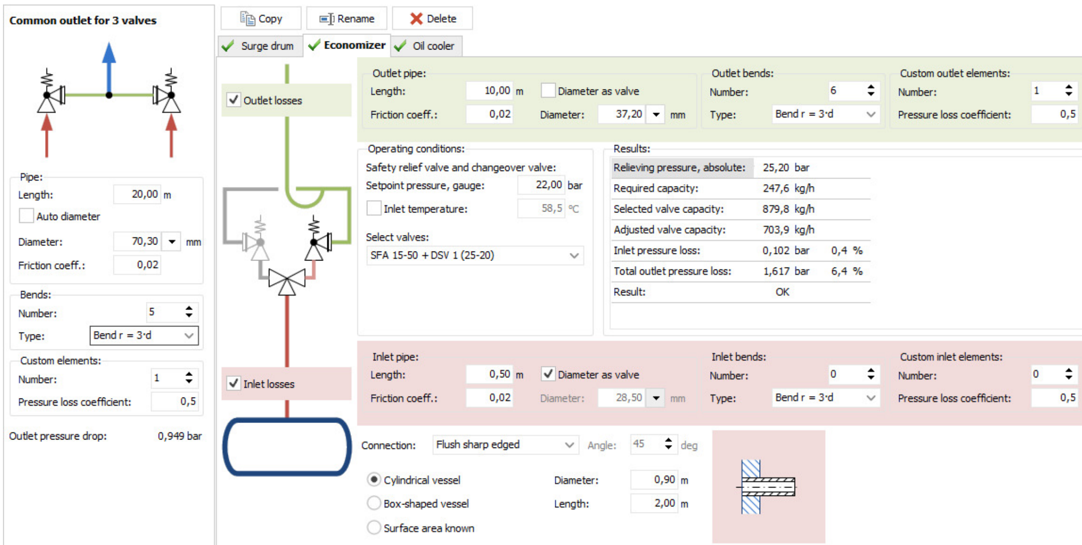
1. Common outlet: DN 65
2. Surge drum: DN 50
3. Economizer: DN 32 (could be DN 25 if common outlet was DN 100)
4. Oil cooler: DN 20 (same as valve).

With the following results:

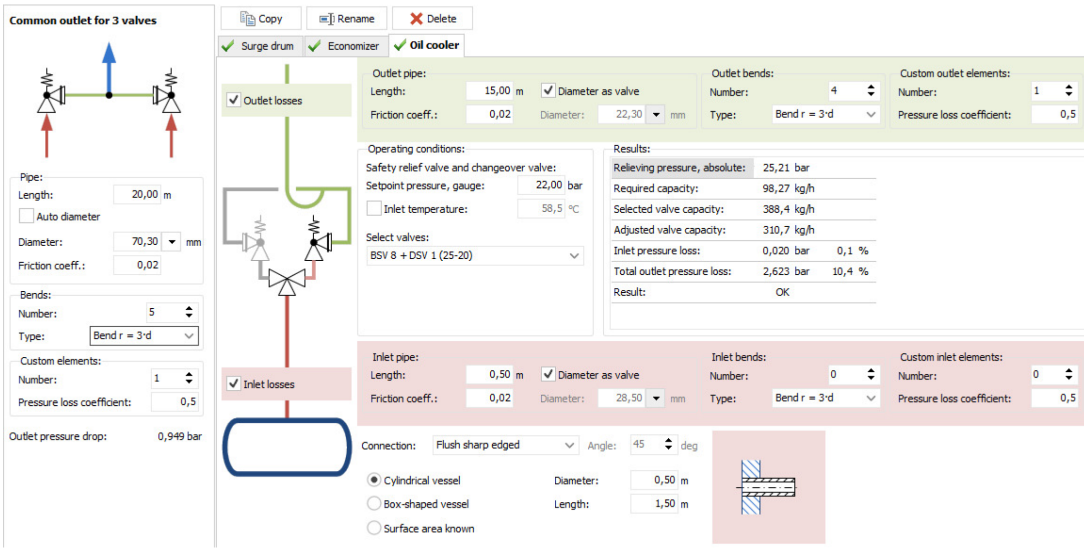
Surge drum:



Economizer:

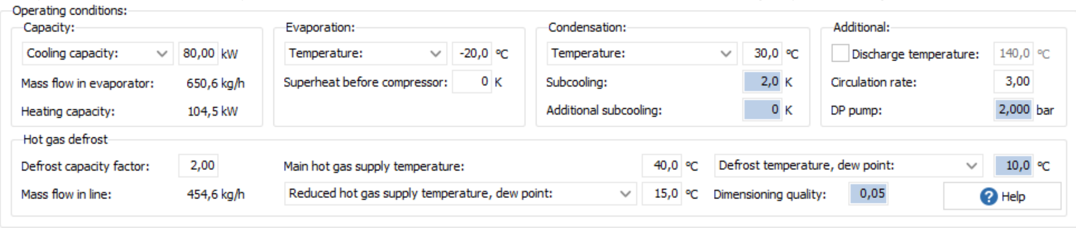


Oil cooler:


Common outlet for 3 valves
Pipe:
Length: 20,00 m
Auto diameter
Diameter: 70,30 mm
Friction coeff.: 0,02
Bends:
Number: 5
Type: Bend r = 3·d
Custom elements:
Number: 1
Pressure loss coefficient: 0,5
Outlet pressure drop: 0,949 bar
Copy
Rename
Delete
Surge drum
Economizer
Oil cooler
Outlet losses
Outlet pipe:
Length: 15,00 m
Diameter as valve
Friction coeff.: 0,02
Diameter: 22,30 mm
Outlet bends:
Number: 4
Type: Bend r = 3·d
Custom outlet elements:
Number: 1
Pressure loss coefficient: 0,5
Operating conditions:
Safety relief valve and changeover valve:
Setpoint pressure, gauge: 22,00 bar
Inlet temperature: 58,5 °C
Select valves:
BSV 8 + DSV 1 (25-20)
Results:
Relieving pressure, absolute: 25,21 bar
Required capacity: 98,27 kg/h
Selected valve capacity: 388,4 kg/h
Adjusted valve capacity: 310,7 kg/h
Inlet pressure loss: 0,020 bar 0,1 %
Total outlet pressure loss: 2,623 bar 10,4 %
Result: OK
Inlet losses
Inlet pipe:
Length: 0,50 m
Diameter as valve
Friction coeff.: 0,02
Diameter: 28,50 mm
Inlet bends:
Number: 0
Type: Bend r = 3·d
Custom inlet elements:
Number: 0
Pressure loss coefficient: 0,5
Connection: Flush sharp edged
Angle: 45 deg
Cylindrical vessel
Box-shaped vessel
Surface area known
Diameter: 0,50 m
Length: 1,50 m

Exercise 5.6 Selecting components in hot gas defrost

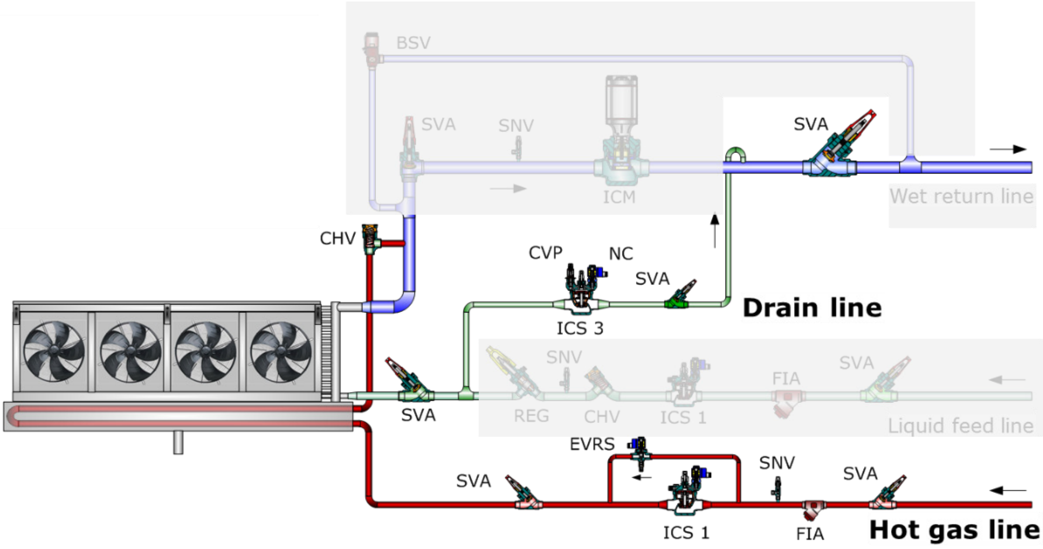
a) A system has 10 evaporators, each on 80 kW. With the following operating conditions:



Select an ICS + CVC in the main defrost line, assuming that 3 evaporators are defrosted simultaneously.

b) The ICS + CVC is placed near the compressors. The distance to the evaporators is 150 m. Evaluate what the reduced supply pressure will be at the evaporators.

c) Select the shown components in a hot gas defrost line and a hot gas defrost drain line:



Using the same operating conditions as above (or modified conditions depending on your evaluation in the previous part of the exercise).

How much gas can the selected ICS + CVP handle? (as a percentage of total mass flow).

Solution 5.6 Selecting components in hot gas defrost

a) When 3 evaporators are defrosted simultaneously, the capacity of the ICS + CVC should be dimensioned for 3*80 = 240 kW. You will find the ICS under “Control and regulating valves”. For 240 kW and the given operating conditions, Coolselector®2 will select an “ICS 25-25 + CVC” which will be loaded 77%.

b) Add 150 m pipe after the ICS + CVC. The result is that the ICS + CVC is now loaded 84%. But more importantly: Coolselector®2 is designed so that a main hot gas defrost line is calculated given the inlet pressure (30 °C) and the reduced pressure (15 °C). You can see this by inspecting the results:

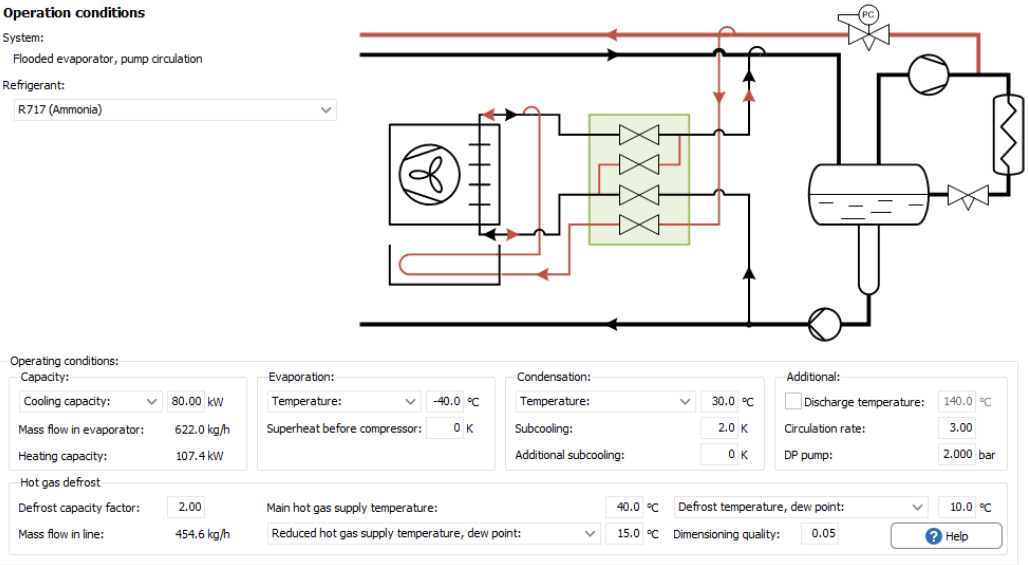
Compressor	ICS 25-25 + CVC NS 32	Steel expander DIN-EN 32 x 50	Steel pipe DIN-EN 50	Hot gas line
DP distribution:	72%	0%	27%	Total
Length [m]:	-	-	150,0	
Angle [deg]:	-	-	0	
Number:	-	1	-	
Max. capacity [kg/h]:	1618	-	-	
Min. capacity [kg/h]:	323,6	-	-	
Load [%]:	84	-	-	
DP [bar]:	3,177	0,006	1,202	4,385
DT_sat [K]:	10,3	0,0	4,7	30-15= 15,0
Velocity, in [m/s]:	69,10	55,85	26,04	
Valve state:	Open	-	-	
Connection:	OK	OK	OK	
Result:	✓	✓	✓	✓

But the ICS+CVC is constructed so that it tries to keep the pressure right after the valve at the given set point, which in this case is 15 °C. So, if the ICS is maintaining a pressure of 15 °C, then the pressure after the 150 m pipe cannot possibly be 15 °C. In fact, by looking at the results, the 150 m pipe lowers the pressure corresponding to 4.7 K, so in order to have 15 °C after the pipe, the set point of the ICS + CVC should be 19.7 °C (corresponding to 8.5 bar absolute).

c) About 14%. This means that at the end of the defrost, the valve might reach its maximum capacity, but as the gas bypass is pure loss this will normally not be a problem. If you have a system without reduced pressure, you should check whether the evaporator is designed for condensing pressure or select a larger drain valve. If the drain valve is too small, the pressure can rise in the evaporator to the condensing pressure at the end of the defrost process. If the valve is too large, on the other hand, it will operate unstably at the beginning of the defrost period as flow will be mostly liquid.

Exercise 5.7 Selecting components for an industrial evaporator valve station

Select an industrial evaporator valve station using only individual components and the following operating conditions:



a) What is the total pressure drop in the four lines? Select an ICF solution using the same operating conditions. What is the total pressure drop in the four lines?

b) Knowing the two solutions, what would you select as the final choice?

c) Add 8 m pipes to the solution you have chosen. Does it change the results significantly?

d) Go to manual mode. What is the available pressure difference for the evaporator, drain pan etc. in hot gas defrost mode?

e) Remove the pipes. Does it change the available pressure difference significantly?

Solution 5.7 Selecting components for an industrial evaporator valve station

a) The table below summarizes the results (drain line not included – pressure drop is the same in both cases):

Line	Liquid feed	Wet return	Hot gas
Solution	ΔP [bar]	ΔP [bar]	ΔP [bar]
Individual	0.249	0.013	0.559
ICF	0.180	0.070	0.457

b) You could select a solution with ICF in liquid feed and hot gas lines and individual in wet return line.

c) Pressure drops do increase (except in the liquid feed line) but it seems the wet return line suffers the most.

d) Use the Defrost pressure graph to measure the available pressure difference to 0.62 bar.

e) Without pipes, the pressure difference is 0.67 bar, which is not significant in this case.

Note that if you use float valves as drain valves, then the pressure drop before the drain valve is significant – simply because the pressure drop increases the gas content before the valve.

6 CO_2 system calculations

Exercise 6.1 Selecting a high-pressure valve

a) Please explain which components characterize a transcritical booster system.

b) Please explain the role that the high-pressure valve plays in a transcritical booster system, and how this is different to a conventional refrigeration system.

c) Please explain why the receiver pressure is kept slightly above freezing and which pressure it should be kept at.

d) Please list some of the pros and cons of a transcritical booster system.

e) In warmer climates, which system concept could be used to enhance the efficiency of a transcritical CO_2 system?

f) In Coolselector®2, select a high-pressure valve (CCMT) with the following operating conditions:

- Cooling capacity, LT: 25.00 kW
- Cooling capacity, MT: 80.00 kW
- Evaporation, LT: -32 °C
- Evaporation, MT: -10 °C
- Gas cooler outlet temperature: +40 °C
- Receiver temperature: +2 °C

g) Which model is the suggested CCMT?

h) What is the differential pressure (in bar) of the selected valve?

i) Now modify the operating conditions to +20 °C for the minimum gas cooler outlet temperature (keep all other values the same as in f)). Which model of the CCMT does Coolselector®2 suggest now?

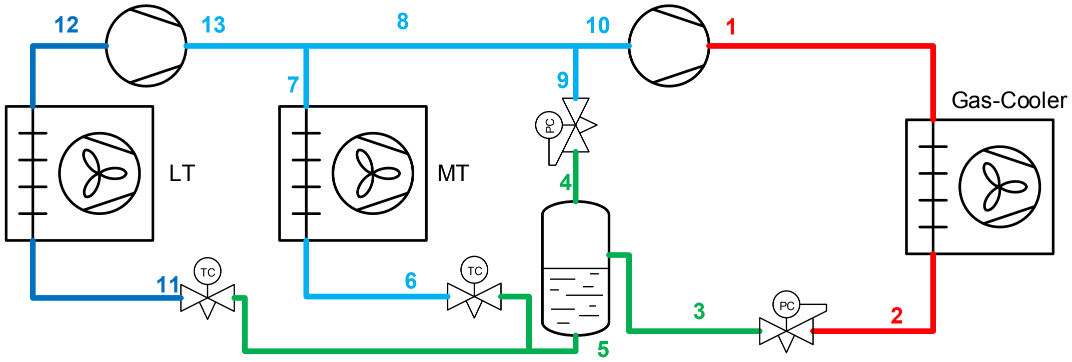
j) What is the differential pressure (in bar) of the selected valve?

k) Please explain the relation between the capacity of the high-pressure valve and the inlet conditions of the valve.

l) Please explain for which conditions the valve should be sized and why.

Solution 6.1 Selecting a high-pressure valve

a) The booster system is the most common system when talking about transcritical CO_2 systems. The system is mainly used in colder climates and on smaller systems in warm climates. The system is the simplest system that can accommodate two suction temperatures and multiple evaporators. The system is characterized by having one compressor group for MT and one for LT and also by having a high-pressure valve and a gas bypass valve.



The cycle is as follows: After the compressor (1) the high-pressure and high-temperature gas is transferred to the gas cooler where it is cooled. The pressure here is typically between 45 and 110 bar. If the pressure is higher than the critical pressure (73 bar), the gas is cooled in a gas cooling process where there is no change of state (no condensation). If the pressure is lower than the critical pressure, the cooling in the gas cooler will happen mainly as condensation. Typically, the gas is cooler using ambient air, but water and other media can also be used. After the gas cooler, the low-temperature, high-pressure gas (2) is transferred to the high-pressure valve.

b) The high-pressure valve is used to control the high pressure in the system in such a way that the optimum efficiency or capacity is obtained. This is different to conventional refrigeration systems because there is not a natural relation between pressure and temperature, as is the case with condensing refrigerants.

After the high-pressure valve (3 in the system diagram) the refrigerant is expanded and is now a mixture of gas and liquid. The ratio between the gas and liquid varies with the temperature out of the gas cooler. Typically, the ratio is between 5% and 50% gas depending on the temperature out of the gas cooler and is highest at high temperatures.

c) In the receiver the flow mixture is separated into gas and liquid. The gas (4) is sent to the gas bypass valve that is controlling the receiver pressure. Typically, the receiver pressure is kept slightly above 37 bar to avoid freezing of the condensed water on the outside of receiver and liquid lines. After the gas bypass valve, the gas (9) is put back in the suction line to the MT compressors.

The liquid from the receiver (5) is transferred into the expansion valves, where it is expanded into the MT and LT evaporators (6/11). Then it evaporates and is returned as superheated gas (7/12). The expansion is controlled by superheat. Typically, the superheat is 6 K -10 K depending on the evaporator. Often higher superheat is seen on CO_2 systems compared to conventional systems. A special control algorithm for CO_2 evaporators is used to control the evaporators to the minimum superheat. Typical evaporation temperature for MT is from -6 °C to -10 °C, and on LT the evaporation temperature often ranges from -35 °C to -30 °C.

The gas out of the LT evaporators (12) is compressed in the LT compressor (13) and is mixed with the gas from the MT evaporators (7) and the gas from the gas bypass (9) and is then compressed in the MT compressors. This closes the cycle.

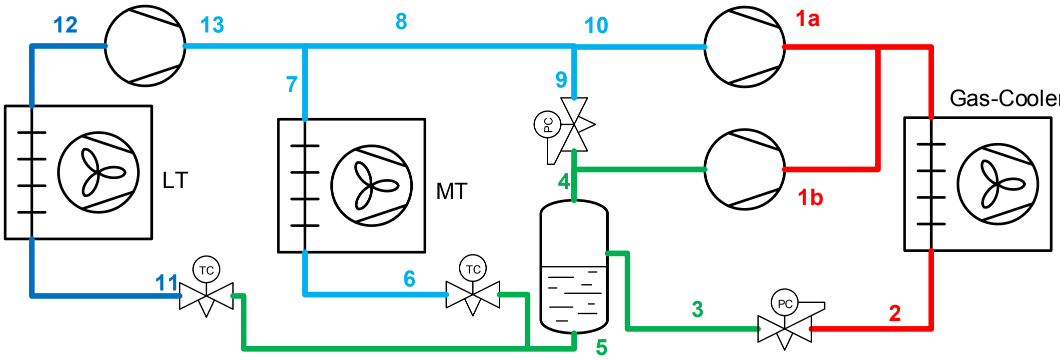
Oil transport in the system is very simple since the oil is mixed in the CO_2 liquid, and after the evaporators the oil is transferred back to the compressors using the gas flow. Oil transfer with CO_2 is easier than with conventional refrigerants due to the high density of the gas and good miscibility of the oil and liquid.

d) The booster system is simple and has been used in supermarkets on a larger scale since 2007 and has the largest install bases of all transcritical systems.

The pros of the booster system are simplicity and good scalability (from small to large systems).

The cons are that in warm ambient temperatures, the energy consumption is too high compared to conventional systems. The high energy consumption can be addressed using some of the other system designs on the market.

e) Parallel compression is one of the system concepts that can be used in warmer climates to enhance the efficiency of a transcritical CO_2 system. The system uses the same layout as the booster system with an extra suction group.



In cold periods the system works as a booster system, but in warm periods the amount of flash gas from the HP expansion (9) gets bigger and the parallel compressors (4) take over, and the gas bypass valve closes (9).

In very warm periods the mass flow ratio between MT and parallel compressors is 55% MT VS. 45% parallel. Because of the higher suction pressure of the parallel compressors the efficiency and total swept volume of the system is smaller than a booster system.

There are some things that need to be considered when designing a system with parallel compression:

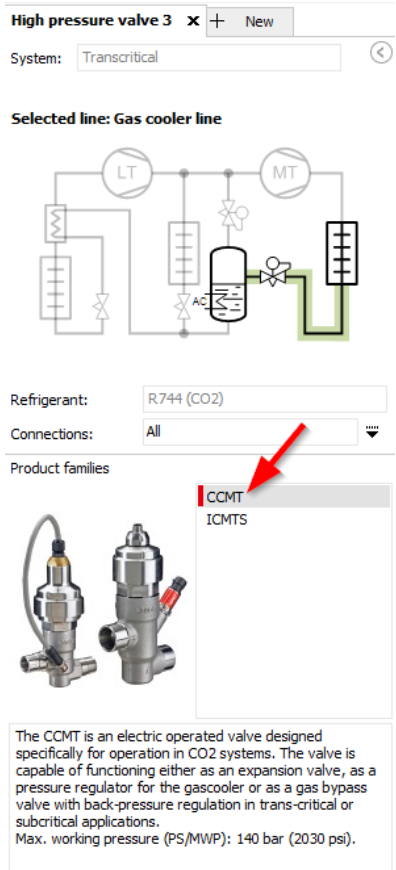
1. One thing is that with higher suction pressure for the parallel compressors, the oil carryover of the compressor increases. That in itself is not necessarily a problem, but it can be a challenge for the oil management system because all the oil consumed by the parallel compressors has to be fed back because there is no oil in the suction gas.
2. If the oil amount in the system is too large, the LT compressors can also be flooded because they receive more oil than can be discharged with the gas.
3. Another thing is selection of the size of the parallel compressor. Very often only one parallel compressor is on the system, and if this is sized for maximum load, then it will often be too big to have a good part load. The consequence of using an

oversized parallel compressor is running periods that are too short, and thus many unnecessary start-stop cycles. On the energy usage side, this configuration offers a very limited saving since it only runs in periods with high ambient temperature and high load. Very often it results in a better system if the parallel compressor is sized to run at low temperatures and in part load. The consequence is that the parallel compressor will then be undersized in warm periods with high load, but the system will compensate partly by increasing the receiver pressure and bleeding the remaining gas through the gas bypass valve. This very often results in better total energy consumption because the parallel compressor has more hours of operation.

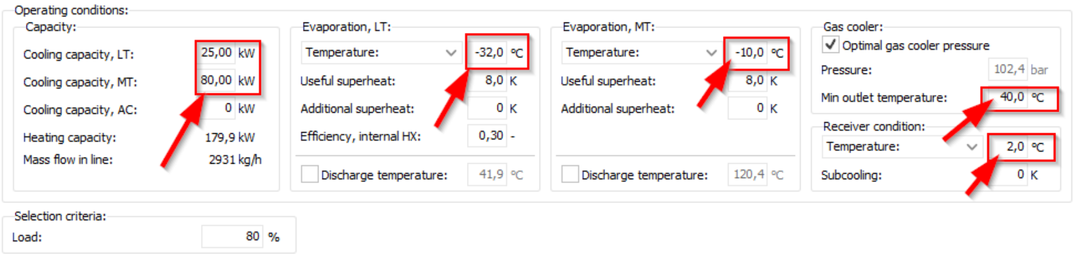
Parallel compression systems have been on the market in larger scale since 2011, mainly in southern Europe where the higher temperatures justify the higher investment. Systems show good improvement of energy efficiency in warm periods and make transcritical CO_2 an alternative to HFC.

f) Go to the “New” tab, select “Valves and Line Components” and click on the “Transcritical high-pressure valves” button.

The gas cooler line is selected as default, as is the refrigerant (R744 (CO_2)); just select the CCMT from ‘Product families’:



Next, type in the given operating conditions:



g) The model suggested by Coolselector®2 for the given operating conditions is the CCMT 8:

Gas cooler line (Transcritical system. R744. High pressure valve)

Selection: CCMT 8 Selected code number: 027H7202

Selected	Type	NS	Max. capacity [kg/h]	Min. capacity [kg/h]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	CCMT 2	15	792,8	12,46	370	65,63	5,81	⚠
○	CCMT 4	15	2100	32,98	140	65,63	5,81	⚠
●	CCMT 8	15	3733	58,64	78	65,63	5,81	✓
○	CCMT 16	25	7469	354,9	39	65,63	1,99	✓
○	CCMT 24	25	11200	532,4	26	65,63	1,99	✓

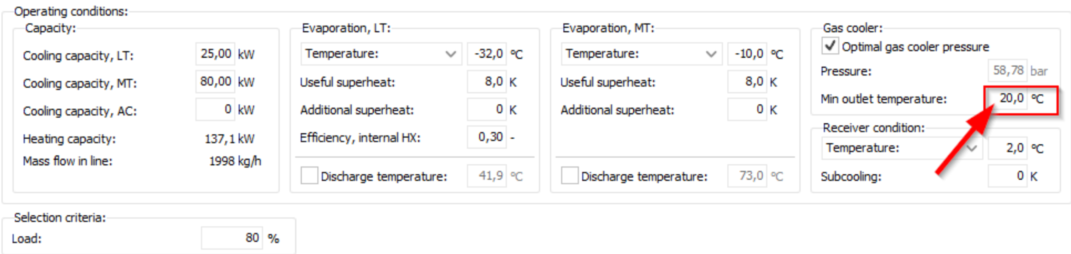
h) The differential pressure of the suggested valve under the given operating conditions is 65.63 bar:

Gas cooler line (Transcritical system. R744. High pressure valve)

Selection: CCMT 8 Selected code number: 027H7202

Selected	Type	NS	Max. capacity [kg/h]	Min. capacity [kg/h]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
○	CCMT 2	15	792,8	12,46	370	65,63	5,81	⚠
○	CCMT 4	15	2100	32,98	140	65,63	5,81	⚠
●	CCMT 8	15	3733	58,64	78	65,63	5,81	✓
○	CCMT 16	25	7469	354,9	39	65,63	1,99	✓
○	CCMT 24	25	11200	532,4	26	65,63	1,99	✓

i) Modify the minimum gas cooler outlet temperature to +20 °C in the operating conditions:



Coolselector®2 now suggests the CCMT 16 as the best suited match for the given operating conditions:

Gas cooler line (Transcritical system. R744. High pressure valve)

Selection: CCMT 16 **Selected code number: 027H7231**

Selected	Type	NS	Max. capacity [kg/h]	Min. capacity [kg/h]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
	CCMT 2	15	506,9	7,968	394	22,05	3,25	⚠
	CCMT 4	15	1343	21,09	149	22,05	3,25	⚠
	CCMT 8	15	2391	37,50	84	22,05	3,25	✓
●	CCMT 16	25	4776	227,0	42	22,05	1,12	✓
	CCMT 24	25	7174	340,4	28	22,05	1,12	✓

j) The differential pressure of the CCMT 16 suggested by Coolselector®2 for the given operating conditions is 22.05 bar:

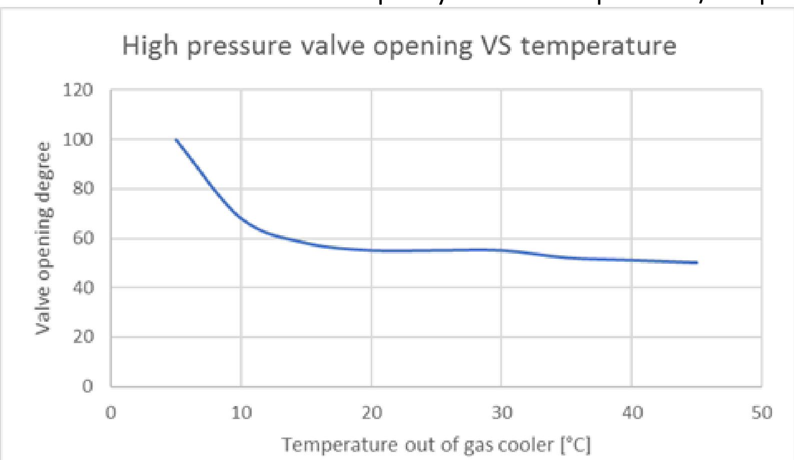
Gas cooler line (Transcritical system. R744. High pressure valve)

Selection: CCMT 16 **Selected code number: 027H7231**

Selected	Type	NS	Max. capacity [kg/h]	Min. capacity [kg/h]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
	CCMT 2	15	506,9	7,968	394	22,05	3,25	⚠
	CCMT 4	15	1343	21,09	149	22,05	3,25	⚠
	CCMT 8	15	2391	37,50	84	22,05	3,25	✓
●	CCMT 16	25	4776	227,0	42	22,05	1,12	✓
	CCMT 24	25	7174	340,4	28	22,05	1,12	✓

k) The capacity of the high-pressure valve is varying with the inlet conditions of the valve. At high pressures the differential pressure is high and the inlet density is high, giving the valve a high capacity.

Below on the chart you can see the opening degree of the valve at different inlet temperatures (Pressure is the setpoint from the controller algorithm). The chart shows that the valve has the lowest capacity at low inlet pressure/temperature.



In principle, the valve should be designed for the lowest temperature out of the gas cooler. However, this would result in a very large valve, and very often the system would not run at full load under this condition. Therefore, a better choice is often to select the valve at 80% load at 20 °C. If the system goes to 100% at lower temperatures and pressure, the valve will open 100%. If this is not enough, the pressure will increase to a level where the valve capacity fits the needed capacity. This will often happen 5-10 bar higher than the set-point, but it will not in any way bring the system to a situation where it is close to pressure switches and safety valves.

Exercise 6.2 Selecting a gas bypass valve

a) What temperature should the gas bypass line be kept above, and why?

b) How would you calculate the total mass flow out of the gas cooler and the MT compressors in a gas bypass system providing the gas fraction is known?

c) Select a high-pressure valve (CCM) with the following operating conditions:

- Cooling capacity, LT: 25.00 kW
- Cooling capacity, MT: 80.00 kW
- Evaporation, LT: -32 °C
- Evaporation, MT: -10 °C
- Gas cooler outlet temperature: +40 °C
- Receiver temperature: +2 °C

d) Which model is the suggested CCM?

e) Now modify the operating conditions to +20 °C for the minimum gas cooler outlet temperature (keep all other values the same as before). Which model of the CCMT does Coolselector®2 suggest now?

f) Which model is the suggested CCM?

g) Why is the gas bypass valve in Coolselector®2 selected at the highest pressure/ temperature out of the gas cooler? Please explain.

h) Please explain how higher suction pressures can be achieved.

i) Please explain how selecting the best valve for a liquid ejector system differs from selecting a valve for a gas bypass system.

j) Please explain which considerations should be taken into account when selecting the best valve for a parallel compression system.

k) Would you recommend downsizing a gas bypass valve in a gas ejector system? Why? Why not?

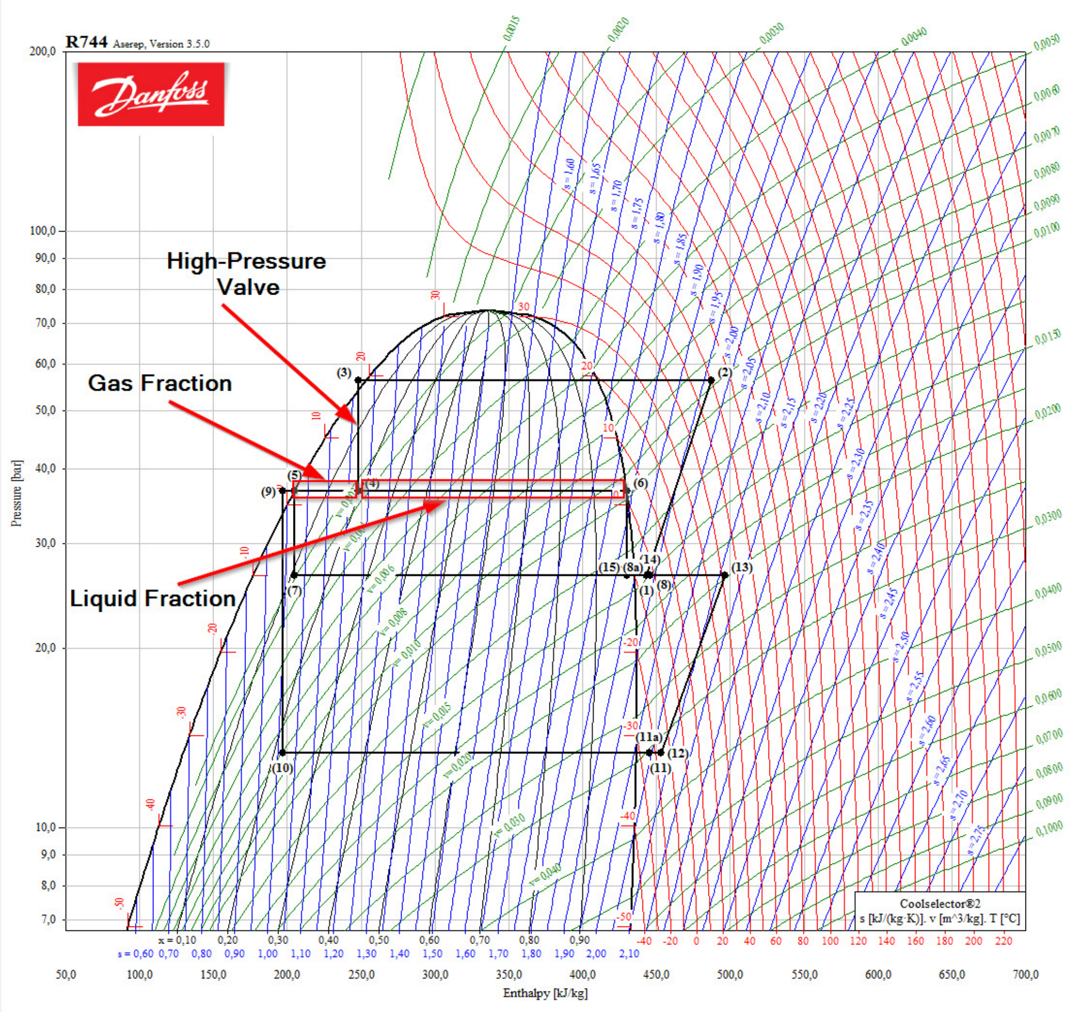
Solution 6.2 Selecting a gas bypass valve

a) It is recommended to keep it above 0 °C to avoid frost on piping, and as low as possible to minimize the liquid fraction in the expansion in the gas bypass valve. A typical receiver pressure would be 35-40 bar.

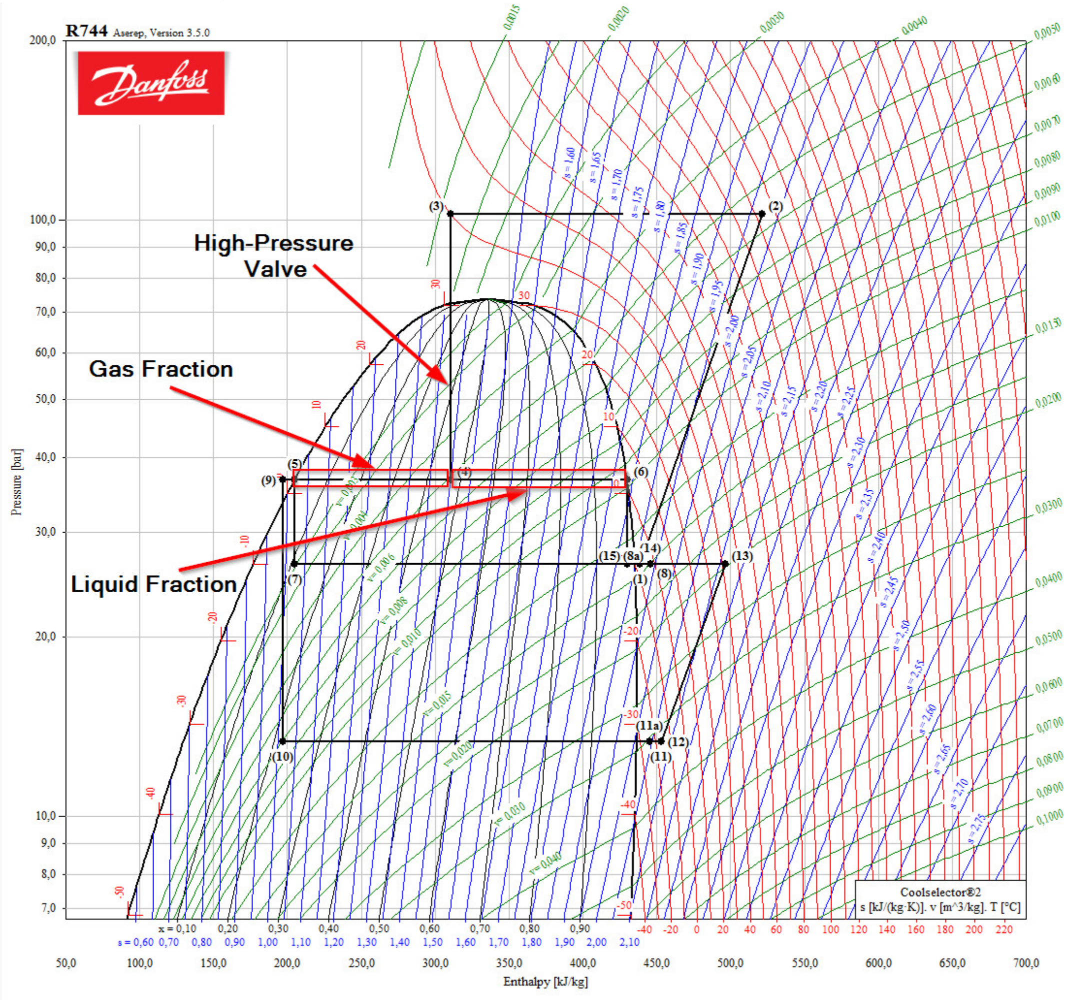
b) When the temperature and pressure out of the gas cooler is known, the gas fraction after the high-pressure valve can be calculated.

Using the MT and LT evaporators' capacity and working conditions, the mass flow-rate through the evaporators can be calculated. If you know the gas fraction, then as a result, the liquid fraction is also known and the mass flow for the MT compressors can then be calculated. This is because the mass flow needed by MT and LT evaporators divided by the liquid fraction yields the total mass flow out of the gas cooler and the MT compressors.

The following diagram shows how at low temperatures the gas fraction after the HP expansion is low:



And as you will see from the next diagram, at high temperatures the gas fraction after the HP expansion is high:



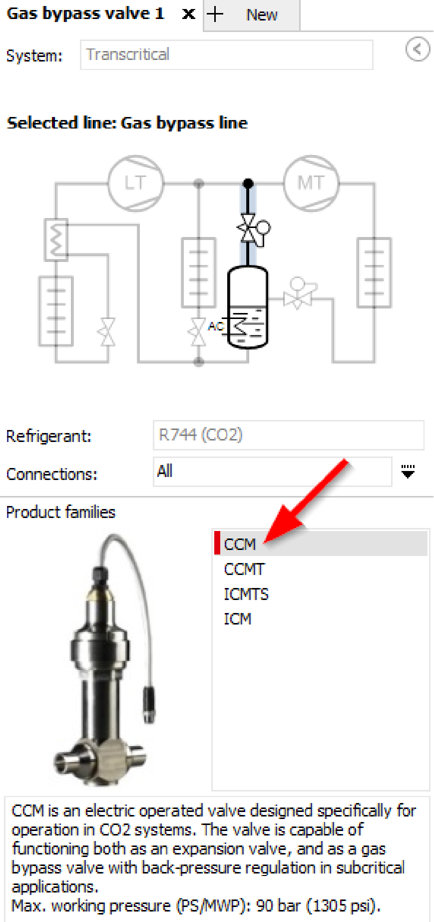
The equations would look like this:

$$\dot{m}_{IT\ comp} = (X) = (45\%) = 45\%$$

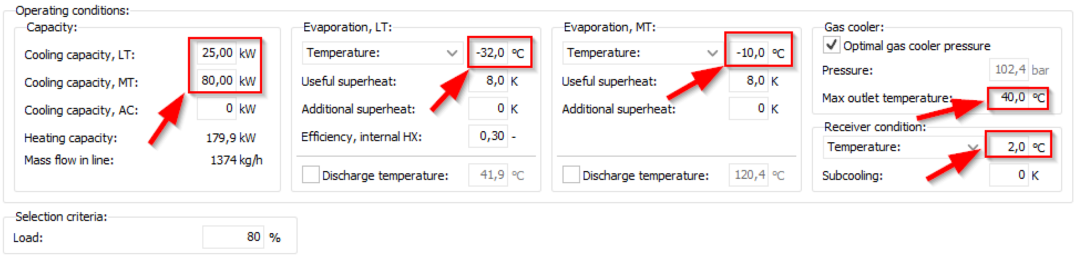
$$\dot{m}_{MT\ comp} = (1 - X) = 100\% - 45\% = 55\%$$

c) Go to a “New” tab, select “Valves and Line Components” and click on the “Transcritical gas bypass valves” button.

The gas bypass line is selected as the default line and R744 (CO_2) as the refrigerant. Just select the CCM from ‘Product families’:



Next, type in the given operating conditions:



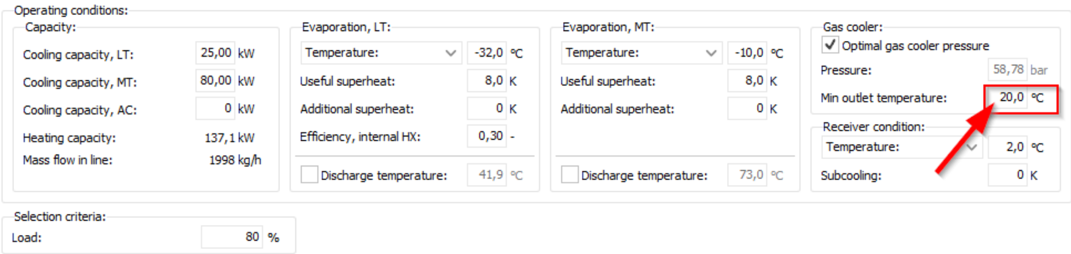
d) The model suggested by Coolselector®2 for the given operating conditions is the CCM 30:

Gas bypass line (Transcritical system. R744. Gas bypass valve)

Selection: CCM 30 **Selected code number: 027H7186**

Selected	Type	NS	Max. capacity [kg/h]	Min. capacity [kg/h]	Load [%]	DP [bar]	Velocity, in [m/s]	DT_sat [K]	Result
○	CCM 10	15	697,0	12,23	197	10,23	16,78	12,0	⚠
○	CCM 20	20	1481	30,19	93	10,23	9,41	12,0	✔
●	CCM 30	25	2178	89,87	63	10,23	5,76	12,0	✔
○	CCM 40	25	3659	152,1	38	10,23	5,76	12,0	✔

e) Modify the minimum gas cooler outlet temperature to +20 °C in the operating conditions:



f) Coolselector®2 now suggests the CCM 10 as the best suited match for the given operating conditions:

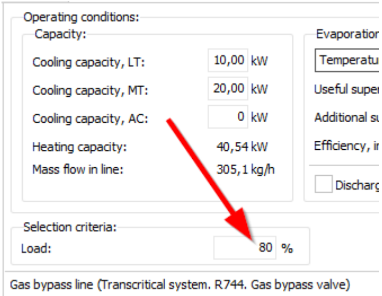
Gas bypass line (Transcritical system. R744. Gas bypass valve)

Selection: CCM 10 **Selected code number: 027H7188**

Selected	Type	NS	Max. capacity [kg/h]	Min. capacity [kg/h]	Load [%]	DP [bar]	Velocity, in [m/s]	DT_sat [K]	Result
◉	CCM 10	15	697,0	12,23	63	10,23	5,39	12,0	✓
○	CCM 20	20	1481	30,19	30	10,23	3,02	12,0	✓
○	CCM 30	25	2178	89,87	20	10,23	1,85	12,0	✓
○	CCM 40	25	3659	152,1	12	10,23	1,85	12,0	✓

The gas bypass valve is calculated using the highest pressure/temperature out of the gas cooler. This is where the gas amount is the largest and will give the largest valve. As a default setting, Coolselector®2 selects the valve at 80% opening, which gives the valve some reserve.

It is possible to override the default setting in Coolselector®2 by changing the load percentage in the selection criteria area:



g) Suction pressure optimization can give higher suction pressures. To compensate for this, it would be necessary to raise the evaporation pressure in Coolselector®2.

h) There is no difference. Selecting a valve for a liquid ejector system is done in exactly the same way as selecting a valve for a gas bypass system.

i) Very often, the gas bypass valve is selected and sized in the same way as in a gas bypass system, but in reality, the valve in a parallel compression system will never open 100% because the parallel compressors will take over. Therefore, the valve could be downsized.

However, in reality the Danfoss CCMT valves perform very well at low opening degrees and therefore there is no real need to downsize when using a CCMT.

j) In gas ejector systems, the flow in the gas bypass valve can be higher than what is normal for other system types, because the ejector is also pumping gas. However, if the parallel compressor is not started, the gas bypass valve needs to be able to handle this. As a result of this, it is not recommended to downsize gas bypass valves for gas ejector systems.

Exercise 6.3 Selecting an expansion valve

a) Select an expansion valve (AKVH) for CO_2 in a liquid line (LT), and with the following operating conditions:

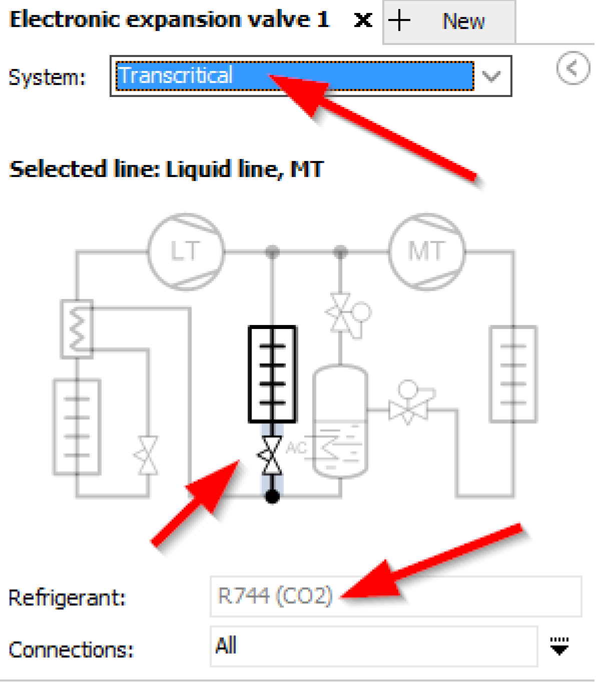
- Max cooling capacity, LT: 5.00 kW
- Highest possible evaporation, LT: -32 °C
- Superheat: 8 K
- Receiver pressure: +2 °C

b) Which model is the suggested expansion valve?

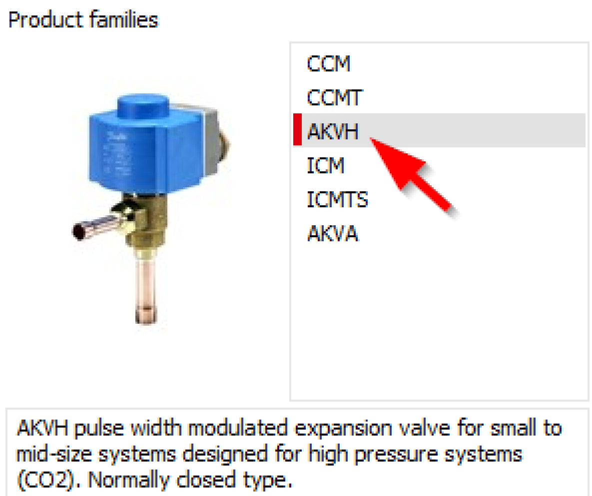
c) Please explain how sizing of expansion valves for CO_2 systems differs from sizing of expansion valves for other refrigerants, and why.

Solution 6.3 Selecting an expansion valve

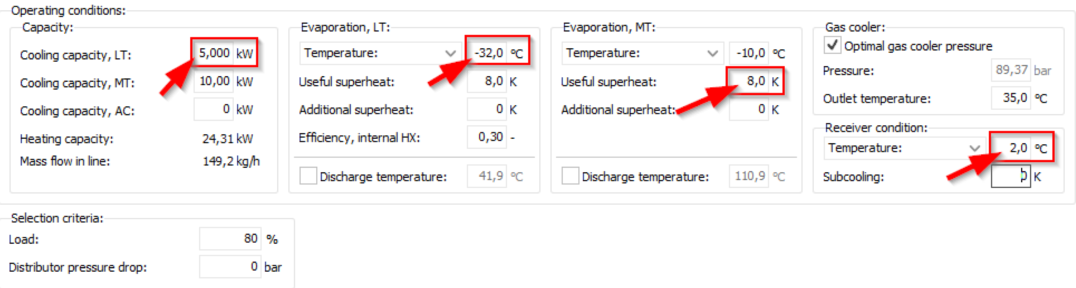
a) Go to "New" tab, select "Valves and Line Components" and click on the "Electronic expansion valves" button. Next set the "System" to 'transcritical' and you will see that 'Liquid line, MT' is chosen by default and the refrigerant is set to R744 (CO_2).



Next select the AKVH product family:



Then type in the operating conditions:



b) The AKVH which Coolselector®2 suggests for the given operating conditions is the AKVH 10-6:

Liquid line, MT (Transcritical system. R744. Electronic expansion valve)

Selection: AKVH 10-6 **No code numbers selected**

Selected	Type	NS	Max. capacity [kg/h]	Min. capacity [kg/h]	Load [%]	DP [bar]	Velocity, in [m/s]	PS/MWP [bar]	Result
○	AKVH 10-2	10	37,46	3,746	398	10,23	0,90	90,00	⚠
○	AKVH 10-3	10	55,09	5,509	271	10,23	0,90	90,00	⚠
○	AKVH 10-4	10	101,4	10,14	147	10,23	0,90	90,00	⚠
○	AKVH 10-5	10	141,1	14,11	106	10,23	0,90	90,00	⚠
◉	AKVH 10-6	10	251,5	25,15	59	10,23	0,90	90,00	✓

c) Sizing of expansion valves for CO_2 systems is not different from other refrigerants in general, but one thing is different, and that is the temperature of the liquid supplied to the valves.

In CO_2 systems, the subcooling is very low and the temperature is lower than the ambient temperature. This results in heat input to the liquid lines and evaporation of the liquid. Therefore, the expansion valve(s) needs to be able to handle some gas and as a result needs to be oversized.

An example of calculation of heat input and gas quality at the expansion valve in the following conditions:

- Ambient temperature: 32 °C
- Liquid temperature: 2 °C (saturated at receiver)
- 7/8" Cu Pipe, 100 meters, 20 mm insulation (λ=0.033 W/mK)
- 1 K pressure drop
- Cooling capacity: 100 kW (1500 kg/hr)

$$Q = \frac{2\,x\,\pi\,x\,L\,x\,\lambda\,x\,\Delta t}{ln\left({r_2}/{r_1}\right)} = \frac{2\,x\,\pi\,x\,100m\,x\,0{,}033\,W/mK\,x\,30\,K}{ln\left({0{,}035m}/{0{,}015m}\right)} = 733W$$

The heat input and pressure drop in total equates to a total gas fraction of approx. 2% in total. Since the density of the gas is 9 times lower, the liquid is approx. 18% of the volume. In part load, this will get even higher. This will reduce the capacity of the valve and therefore, the valve needs to be oversized.

In reality, an oversizing of 70% is commonly used and seems to be a very good value.

Exercise 6.4 Selecting a high-pressure ejector

a) Which types of systems can utilize high-pressure ejectors? What is the benefit of using high-pressure ejectors?

b) Please explain the cycle in a high-pressure ejector system in cold temperature mode.

c) Please explain the cycle in a high-pressure ejector system in warm temperature mode.

d) Using Coolselector®2, size the high-pressure capacity of the ejector using the following operating conditions:

- Cooling capacity, LT: 26.00 kW
- Cooling capacity, MT: 180.00 kW
- Cooling capacity, AC: 0.00 kW
- Evaporation, LT: -30 °C
- Evaporation, MT: -10 °C
- Gas cooler outlet temperature: 40 °C

e) Which ejector model (if any) is suggested by Coolselector®2?

f) Set receiver temperature to 5.7 °C, which model does Coolselector®2 suggest now, and in which quantity?

g) Please explain whether the receiver pressure can be used to enhance performance.

h) What is the capacity load on the ejectors? Is this optimal?

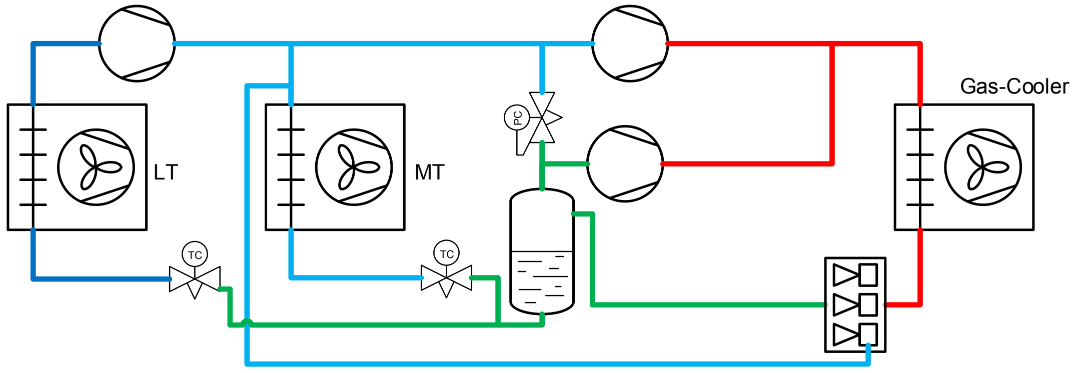
i) Please suggest an alternative way to get the same cooling capacity but without using multiple ejectors.

j) Comparing mass flow for MT and IT combined, which is the more efficient option (multiple ejectors or the alternative design)?

k) Please discuss the pros and cons of selecting the ejectors at 2K higher suction pressure.

Solution 6.4 Selecting a high-pressure ejector

a) High-pressure lift ejectors are always used in systems with parallel compression:



High-pressure ejector systems entered the market in 2015 with the first test installation. The ejector is an add-on to the parallel compression system, enhancing the parallel compressor.

The high-pressure flow from the gas cooler enters the ejector, which in this system works like a high-pressure control valve. The opening of the different ejectors is controlled to give the optimum high pressure and optimize the COP. In the ejector, the energy in the high pressure from the high-pressure side is used to entrain gas from the suction side of the MT compressors and lifts it to the receiver. In the receiver, the gas and liquid are separated, and the gas is sent to the parallel compressor.

The benefit of the ejector is that it enhances the parallel compressor by feeding gas that should have been compressed by the MT compressor to the parallel compressor instead and thereby increases the efficiency of the system by up to 9% (on an annual basis) in warm climates compared to parallel compression and up to 17% compared to a booster system. In very warm periods, the mass flow ratio between MT compressor and parallel compressors is 30% MT vs. 70% parallel. This will produce a significant reduction in swept volume and energy consumption. A saving on swept volume of up to 15-35% is possible (largest in warm climates).

As for parallel compression, the oil management of the parallel compressor needs attention and because the mass flow ratio for the parallel compressors is so high, this requires special attention. However, it is still possible to build a system with safe oil return, if the oil carryover is managed.

Energy studies show that this system type can show better results than HFC systems, not only in peak warm conditions but also annually.

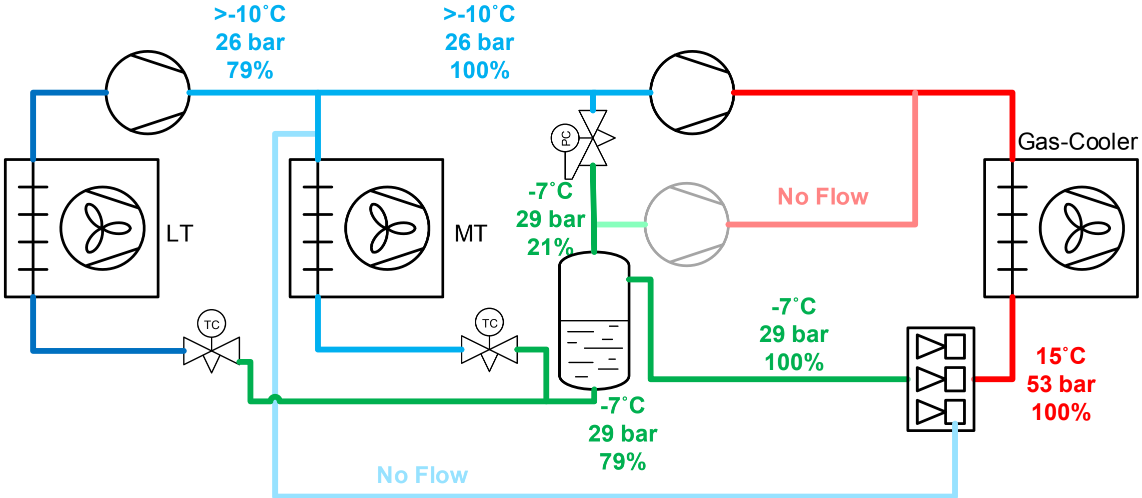
At the same time, the cost of the larger systems (100-150kW and up) can be reduced, whereas for smaller systems the cost is not significantly impacted due to the number of components needed.

b) In cold temperature mode, the high-pressure ejector system operates like a booster system.

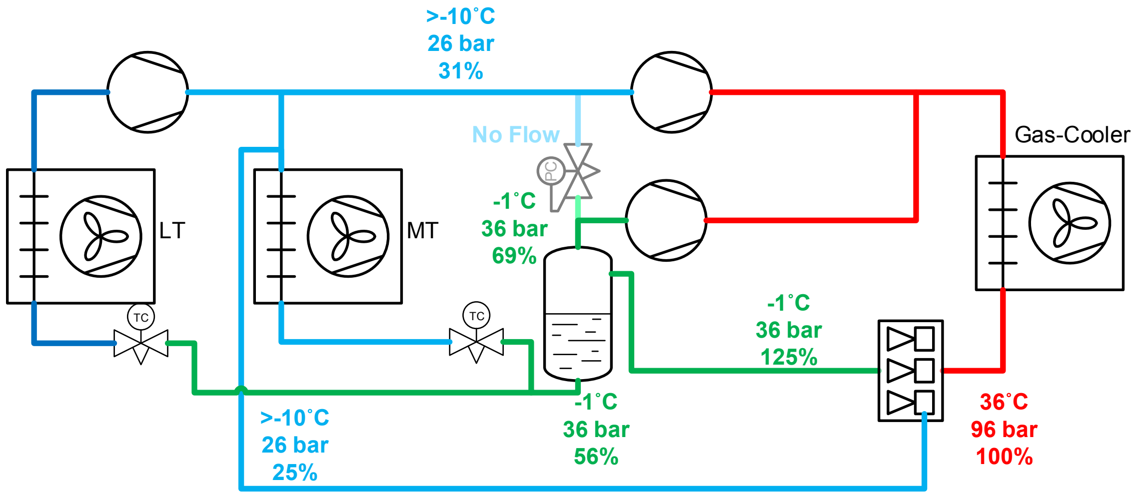
The gas bypass valve takes the flash gas from the receiver and puts the gas into the MT compressors.

The gas from the gas bypass valve mixes with gas from the MT evaporators and from the LT compressors. It is compressed by the MT compressors, which need to be able to compress enough gas to handle the capacity in this situation.

In this mode, the ejector will work as a high-pressure valve and adjust the high pressure according to the normal algorithm.

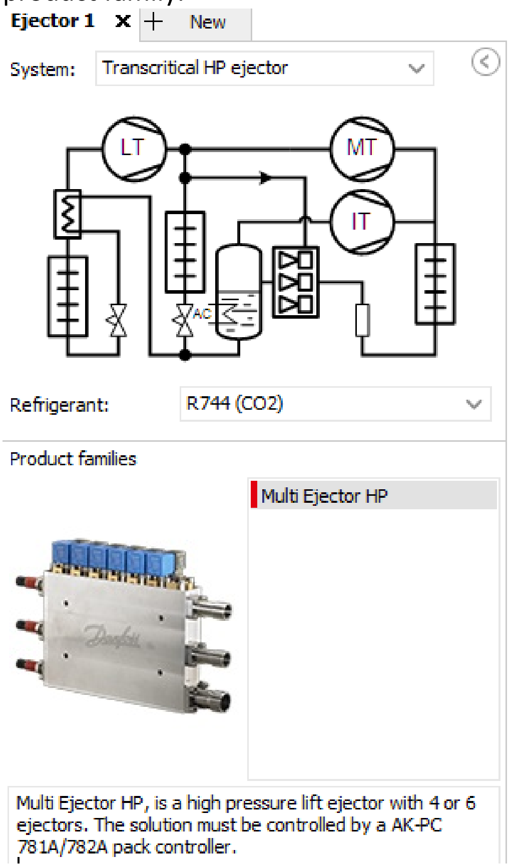


c) When the temperature out of the gas cooler is warmer, the ejector starts to pump. The gas from MT is pumped through the ejector and is lifted to the receiver where it is separated with the gas from the expansion. The liquid flows to the evaporators as well, as the gas is moved to the parallel compressors, where it is compressed. The parallel compressor will do approx. 75% of the total flow and the MT compressors will do the remaining 25%.

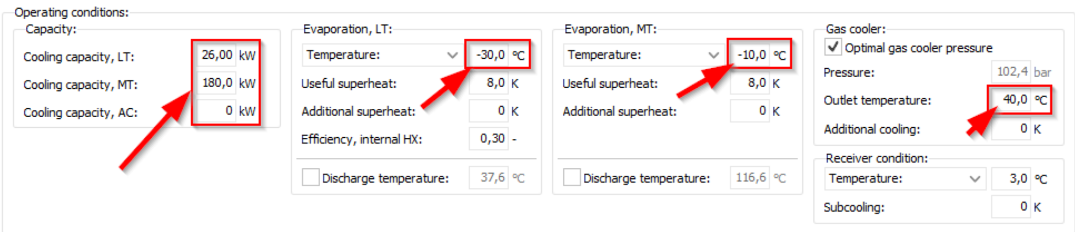


d) Go to “New” tab, select “Valves and Line Components” and click on the “Multi Ejectors” button.

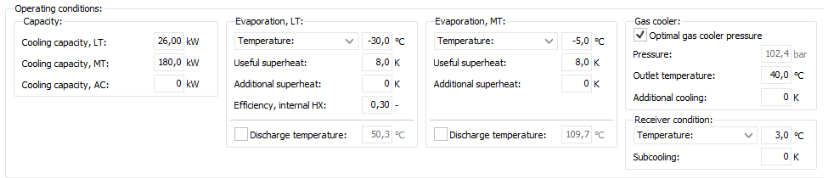
You will find that Coolselector®2 is by default set to Transcritical HP ejector system and the refrigerant is set to R744 (CO_2). Also by default, the Multi Ejector HP is chosen as the product family.



Next, set the given operating conditions:

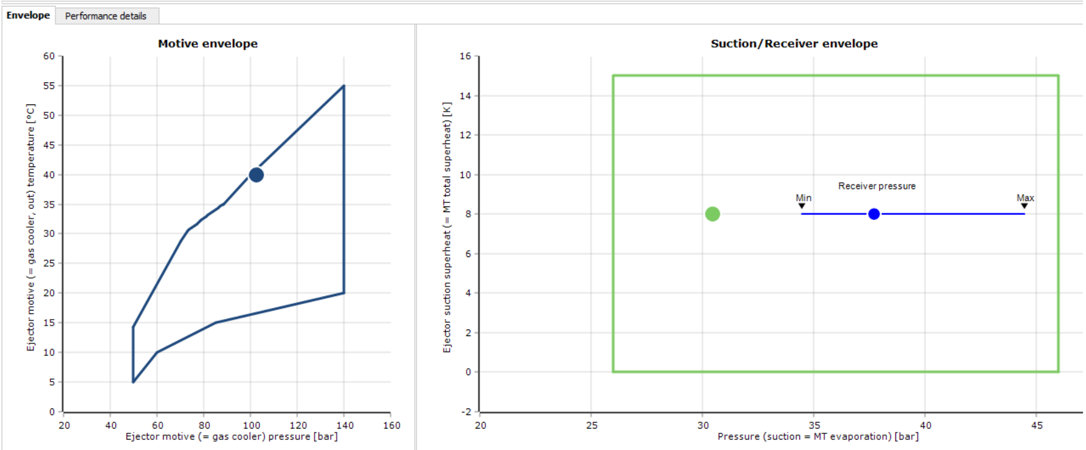


e) Coolselector®2 does not find a suitable model for the given operating conditions. The warning given is that "Ejector suction mass flow limited to MT evaporator mass flow". This can be handled by adding the LT condensing load to the MT capacity and adjusting the superheat at the MT compressors (looking at LT as a large MT evaporator with high superheat).



Selection: Multi Ejector HP 3875. Ejector suction mass flow limited to MT evaporator mass flow

Selected	Type	Number	Capacity [%]	m_evap_LT [kg/h]	m_evap_MT [kg/h]	m_comp_MT [kg/h]	m_comp_IT [kg/h]	m_motive [kg/h]	m_suction [kg/h]	Entrainment ratio	Heating capacity [kW]	Code number	Result
○	Multi Ejector HP 1875	3	87	381,0	2723	381,0	5792	6164	2723	0,44	306,4	032F5673	⚠
◉	Multi Ejector HP 3875	2	64	381,0	2723	381,0	5981	6187	2723	0,47	329,9	032F5674	⚠



f) With the change in receiver condition temperature to 5.7 °C, Coolselector®2 now finds a suggested model.

The suggested ejector model is the Multi Ejector HP 3875 (Code number 032F5674) and the suggested number of multi ejectors is '2':

Selection: Multi Ejector HP 3875

Selected	Type	Number	Capacity [%]	m_evap_LT [kg/h]	m_evap_MT [kg/h]	m_comp_MT [kg/h]	m_comp_IT [kg/h]	m_motive [kg/h]	m_suction [kg/h]	Entrainment ratio	Heating capacity [kW]	Code number	Result
○	Multi Ejector HP 1875	3	85	390,5	2803	1125	5018	6143	2069	0,34	307,6	032F5673	✓
◉	Multi Ejector HP 3875	2	62	390,5	2803	1013	5147	6160	2181	0,35	307,0	032F5674	✓

Understanding the results:

- m_comp_MT [kg/h] is the mass flow in MT compressors
- m_comp_IT [kg/h] is the mass flow in IT compressors. This is used for compressor selection.
- m_suction [kg/h] is the mass flow moved by the ejector from the MT to the IT compressor.
- Entrainment ratio is the ratio of suction mass flow divided by high pressure (motive) mass flow.

Selection: Multi Ejector HP 3875

Selected	Type	Number	Capacity [%]	m_evap_LT [kg/h]	m_evap_MT [kg/h]	m_comp_MT [kg/h]	m_comp_IT [kg/h]	m_motive [kg/h]	m_suction [kg/h]	Entrainment ratio	Heating capacity [kW]	Code number	Result
○	Multi Ejector HP 1875	3	85	390,5	2803	1125	5018	6143	2069	0,34	307,6	032F5673	✓
◉	Multi Ejector HP 3875	2	62	390,5	2803	1013	5147	6160	2181	0,35	307,0	032F5674	✓

g) Yes, the receiver pressure can be used to enhance performance, particularly if, as in this example, there is no AC. In cases where AC is present, the receiver pressure is often fixed to ensure the correct temperature.

h) The capacity load on the ejectors is 62%. This is not optimal, and it might be feasible to consider a 1-ejector solution instead.

i) One way, in which an alternative selection could be implemented would be to consider a design with a parallel installation of an ejector taking care of 80% of the cooling capacity and a high-pressure valve taking care of the remaining 20%.

j) To calculate which is the more efficient option, we must first go back to our example from d) and e) and look at the Mass flow for MT and IT respectively:

$$m\_comp\_MT \; + m\_comp\_IT \; = Total\ Mass\ Flow$$

Selection: Multi Ejector HP 3875

Selected	Type	Number	Capacity [%]	m_evap_LT [kg/h]	m_evap_MT [kg/h]	m_comp_MT [kg/h]	m_comp_IT [kg/h]	m_mot
○	Multi Ejector HP 1875	3	85	390,5	2803	1125	5018	
◉	Multi Ejector HP 3875	2	62	390,5	2803	1013	5147	

$$1013kg/h + 5147kg/h \; = \mathbf{6160kg/h}$$

To calculate the total mass flow for our alternative suggestion is slightly more complicated. First, we must calculate what the 80% load for the ejector will be:

$$Cooling\ Capacity, IT * 80\% = 26kW * 0.8 = 20.8kW$$

$$Cooling\ Capacity, MT * 80\% = 180kW * 0.8 = 144kW$$

And then we can derive that the 20% load on the high-pressure valve will be:

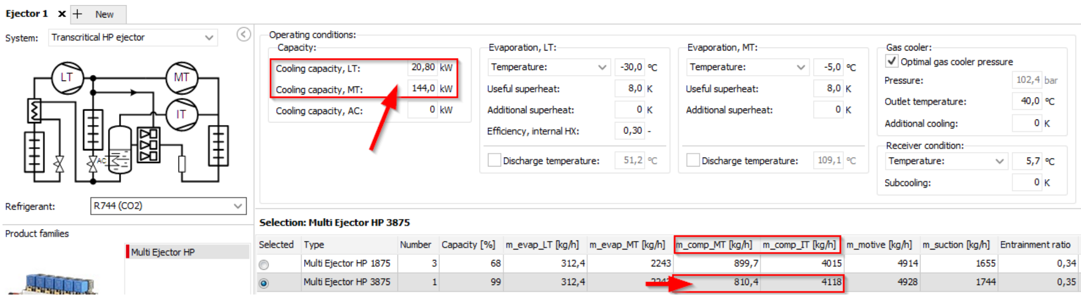
$$Cooling\ Capacity, IT * 20\% = 26kW * 0.2 = 5.2kW$$

$$Cooling\ Capacity, MT * 20\% = 180kW * 0.2 = 36kW$$

Using these figures in Coolselector®2 for the Multi Ejector and the high-pressure valve respectively, we can now find the mass flow in MT and IT compressors respectively for both components:

Multi Ejector HP:

Change the Cooling Capacity, LT to 20.8kW and the Cooling Capacity, MT to 144 kW. It is now possible to read both the m_comp_MT and the m_comp_IT directly in the selection table:

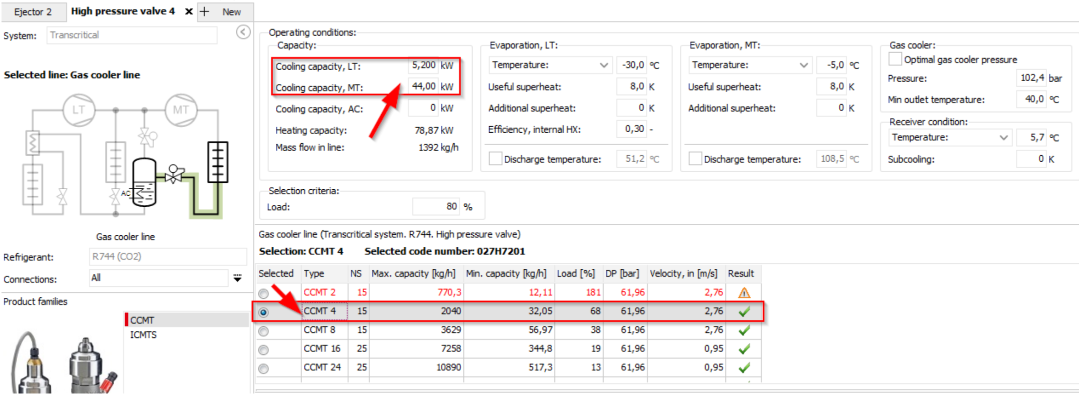


m_comp_MT = 810.4 kg/h

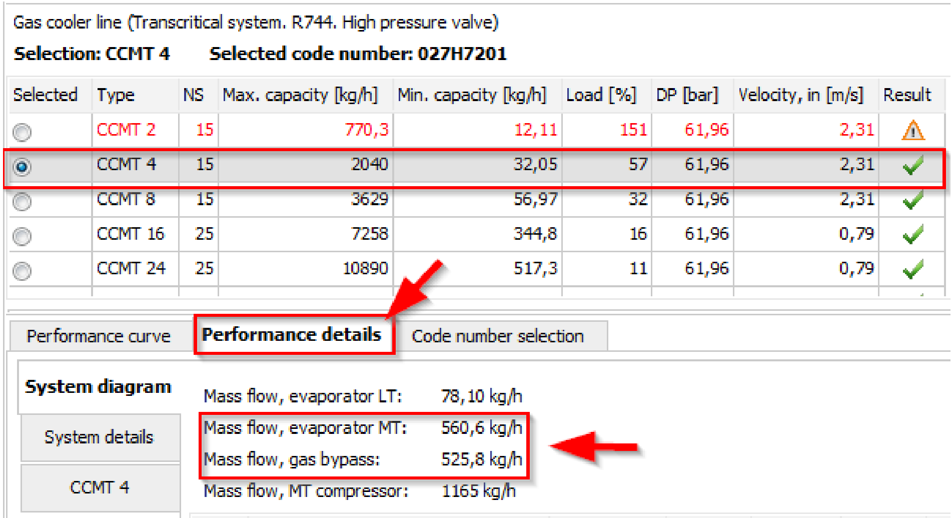
m_comp_IT = 4118 kg/h

For the high-pressure valve, in Coolselector®2 go to ‘high-pressure valves’ and you will see that Coolselector®2 carries over the operating conditions (just remember that Cooling capacity, LT should be set to 5.2kW and Cooling capacity, MT should be set to 36kW).

Select the CCMT to be used as the high-pressure valve, and you will see that Coolselector®2 suggests the CCMT 4:



If you go into the Performance details section of Coolselector you will find the “Mass flow, evaporator MT” and the “Mass flow, gas bypass” values for the CCMT 4 here:



Using simple mathematics, we can now calculate the combined Mass Flow, MT and Mass Flow, LT for the alternative solution:

$$\textbf{Combined Mass Flow, MT}$$
$$= Mass\ Flow, MT, HP\ Ejector + Mass\ Flow, evaporator, HP\ Valve$$
$$= \ 810.4kg/h\ + 560.6kg/h\ = 1371kg/h$$

$$\textbf{Combined Mass Flow, IT}$$
$$= Mass\ Flow, IT, HP\ Ejector + Mass\ Flow, gas\ bypass, HP\ Valve$$
$$= 4118kg/h\ + 525.8kg/h\ = 4643.8\ kg/h$$

$$\textbf{Total Combined Mass Flow, HP Ejector and HP Valve}$$
$$= 1371kg/h + 4643.8kg/h = \mathbf{6014.8kg/h}$$

If we now compare this to the example with the multiple ejectors, we see that running the alternative option gives a better total mass flow, compared to running two multi ejectors at 62% load:

	Primary Selection	Alternative Selection
No of HP devices	2 HP 3875 ejectors	1 HP 3875 + 1 CCMT
Mass Flow, MT	1013 kg/h	1371 kg/h
Mass Flow, IT	5147 kg/h	4643.8 kg/h
Total	6160 kg/h	6014.8 kg/h

k) By selecting the ejectors at 2K higher suction pressure, the parallel compressors are reduced by more than 10%. This will of course damage the performance at the design point, but only for a very limited number of hours per year. On the other hand, the smallest compressor step on the parallel compressors also gets smaller and that will increase the number of running hours with the ejector significantly and benefit the annual energy consumption. *Remember to always use minimum 2 parallel compressors when using ejectors.*

Exercise 6.5 Selecting a low-pressure ejector

a) Which types of systems are low-pressure ejectors always used in? What are the advantages and drawbacks of using low-pressure ejectors?

b) Please explain the cycle in a low-pressure ejector system in cold temperature mode.

c) Please explain the cycle in a low-pressure ejector system in warm temperature mode.

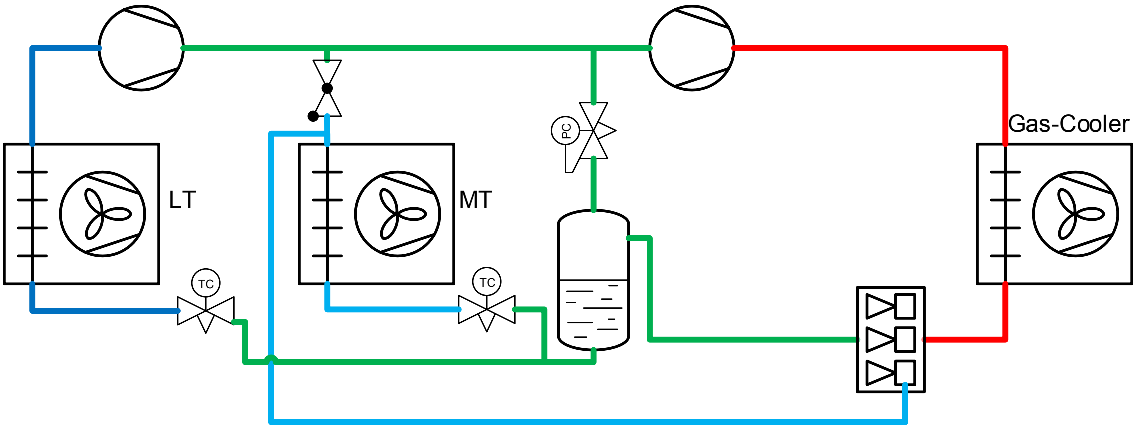
d) Using Coolselector®2, size the low-pressure capacity of the ejector using the following operating conditions:

- Cooling capacity, LT: 12.00 kW
- Cooling capacity, MT: 55.00 kW
- Cooling capacity, AC: 0.00 kW
- Evaporation, LT: -32 °C
- Evaporation, MT: -8 °C

e) Which LP ejector model is suggested by Coolselector®2?

Solution 6.5 Selecting a low-pressure ejector

a) Low-pressure lift application is used in systems without parallel compression



Low-pressure ejector systems are simpler systems than high-pressure ejector systems, since they do not need the parallel compressor to work and provide an energy saving. In winter time, the system works like a normal booster system where the gas bypass valve controls the receiver pressure and the evaporation pressure is controlled by adjusting the compressor capacity according to the required suction/evaporation pressure. At 20-25 °C out of the gas cooler, the ejector starts to pump enough to pump all the gas from the evaporator and lift the gas to the receiver with a pressure lift of approx. 3 bar. As a result hereof, the check valve in the suction line closes and the compressor is then connected directly to the receiver (the gas bypass valve is opened 100%). The consequence of this is that the suction pressure of the compressor is raised 3-7 bar, depending on the temperature out of the gas cooler. This will give a better COP of the system, but the higher suction pressure will also result in higher mass flow in the same compressor and therefore the result is a smaller installed capacity and therefore a first cost saving. The saving in swept volume can be as much as 30% at high ambient temperatures and 15% energy saving compared to a booster system.

In booster/winter mode, the system has a safe oil return, but when the system is in ejector mode, the oil will end in the receiver and will stay there if nothing is done about it. There are many ways to recover the oil and get it back to the compressor. If the oil separator has a low efficiency, the oil problem will be bigger. A part of a safe oil return can be the LT compressors. The LT compressors receive an oil-rich gas mixture from the evaporators. The oil is passed through the LT compressor and can be transferred to the MT compressors if the LT discharge is connected directly to the MT compressor suction. The big question is whether it is enough, and that depends on the load ratio between MT and LT compressor capacity, oil quantity in the system and efficiency of the oil separator. To be on the safe side, an oil recovery system is needed. Here the oil type and type of oil recovery can be useful to think about. An oil with low miscibility, like PAG, can be a better option than oils with high miscibility (like POE). If the receiver is designed for high concentration of the oil, a richer oil rich mixture can be harvested and therefore a smaller amount of energy is needed to boil off the refrigerant.

Another thing which is important when designing the system is that the pressure lift of the LP ejector is relatively low. The system therefore needs to be designed for this. One thing is that AKV valves need to be selected for this, but it is more important to have a look at the evaporators and focus on not having too high a pressure drop. As a rule of thumb, one bar in the suction line, one bar in the evaporator and one bar for the AKV. Pressure drops in the liquid line can normally be neglected. The limitations on max. pressure drop are also setting the limits for where the system can be used. In systems with very big evaporators with distributers, the pressure drop can be too high for the ejector.

The next question is: why a pressure lift of approximately 3 bar? The system can run at higher pressure differences, but then the system needs higher temperatures out of the gas cooler to perform the lift and that limits the operation hours. In turn, this will be a problem for the energy consumption. Differential pressures lower than 3 bar would, on the other hand, be a benefit, but can be difficult to handle in practice. The general consensus is that 3 bar is the best compromise.

Cost of an LP system is assumed to be on the same level as a booster system based on the assumption that savings on the compressors will pay the extra cost of the ejector (system target size 40-150 kW).

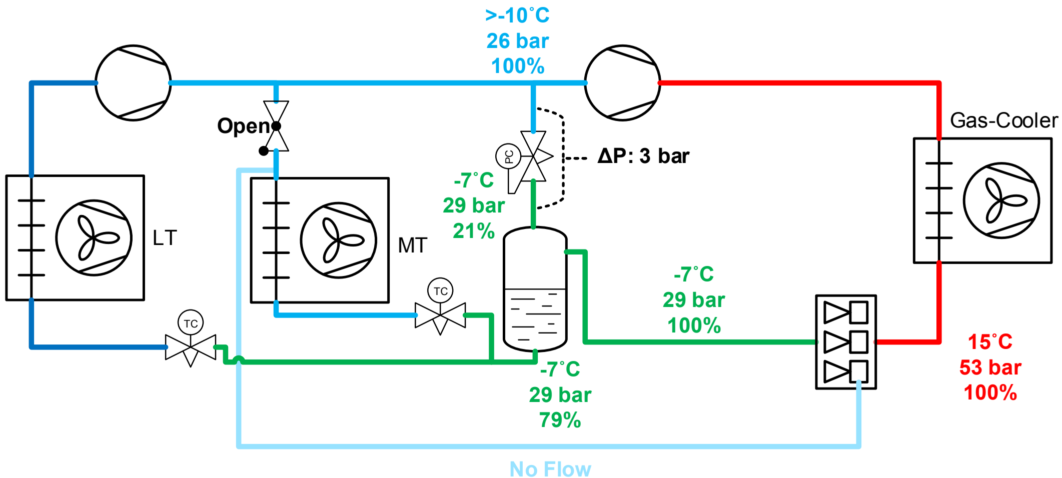
b) In cold temperature mode, the gas coming from the LT compressor and the MT evaporators is sucked through the check valve in the suction line and mixed with gas from the gas bypass valve. The ejector is not capable of lifting the gas from evaporators (maybe a smaller part that will flow back through the gas bypass valve).

The MT compressors are then compressing the gas that flows through the gas cooler to the high-pressure side of the ejector.

In winter mode the ejector is simply controlling the high pressure as a high-pressure valve would have done.

The flow from the ejector will flow to the receiver where liquid and gas from expansion is separated and the gas flows through the gas bypass valve to the MT compressors and the liquid is expanded to the evaporators.

In winter mode the system operates like a normal booster system.

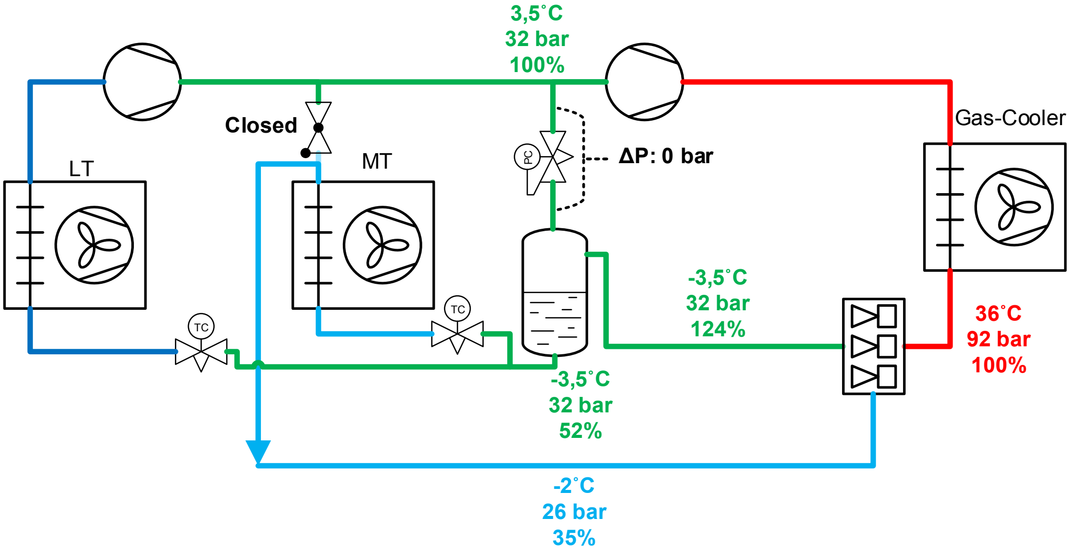


c) In warm temperature mode, the temperature out of the gas cooler is so high that the ejector can lift all the gas from evaporators through the ejector and to the receiver (check valve in suction line between compressors and evaporators is closed due to pressure difference).

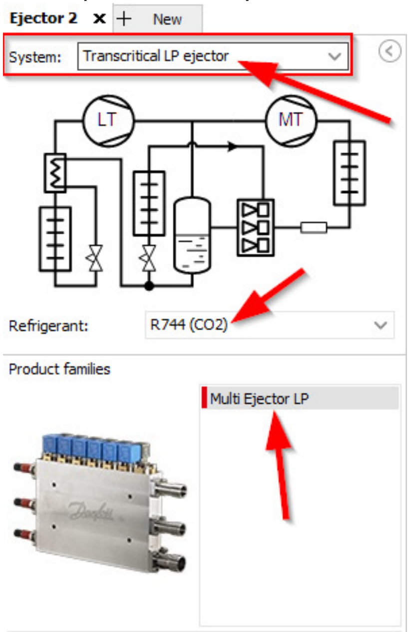
Inside the ejector, the gas from the evaporators is mixed with the gas/liquid flow from the gas cooler and flows to the receiver.

In the receiver, the gas and liquid are separated and the liquid is expanded in the evaporators and the gas flows through the gas bypass valve, which is fully open and has a very low pressure difference.

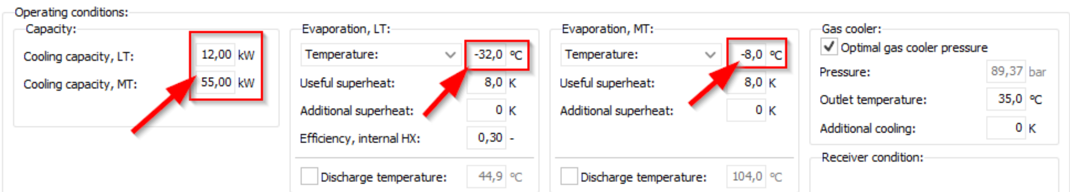
The compressors are sucking the gas directly from the receiver and compressing to the high pressure. The flow is then cooled in the gas cooler and expanded in the ejector.



d) Go to "New" tab, select "Valves and Line Components" and click on the "Multi Ejectors" button. Set the "System" to 'Transcritical LP ejector system' and you will notice that by default the refrigerant is set to R744 (CO_2). Also by default, the Multi Ejector LP is chosen as the product family.



Next, set the given operating conditions:



e) The suggested ejector model is the Multi Ejector LP 1935 (Code number 032F5676)

Selection: Multi Ejector LP 1935

Selected	Type	Number	Capacity [%]	m_evap_LT [kg/h]	m_evap_MT [kg/h]	m_BP [kg/h]	m_comp_MT [kg/h]	Entrainment ratio	P_receiver [bar]	T_receiver [°C]	Heating capacity [kW]	Code number	Result
○	Multi Ejector LP 935	2	82	168,2	788,7	1642	1810	0,44	32,88	-2,2	99,40	032F5675	✓
◉	Multi Ejector LP 1935	1	78	167,5	785,1	1640	1808	0,43	32,45	-2,7	99,77	032F5676	✓

7 Compressors

Exercise 7.1 Selecting a compressor and finding related technical information

a) Select a compressor with the following criteria:

- Application: Refrigeration Medium Temperature
- Refrigerant: R404A
- Power supply: 50 Hz // 400 Volts
- Type: Reciprocating with fixed speed
- Cooling capacity required 10KW at Evaporating T° -10 °C and condensing T° 35 °C with 8K superheat and 2K subcooling

b) Which model is the suggested compressor?

c) Explain which performance details are available for this model.

d) Please explain how you can extract the performance details tables for a given compressor from Coolselector®2 to an Excel sheet.

e) Please locate the envelope and explain what the green “dot” in the envelope signals.

f) How would you check the evolution of the power input or cooling capacity versus the condensation or evaporation?

g) Which tab would you use information from to get details about the thermodynamic calculations of the compressor?

h) What is the estimated discharge temperature (T°) for the suggested compressor?

i) Find the following information about the suggested compressor:

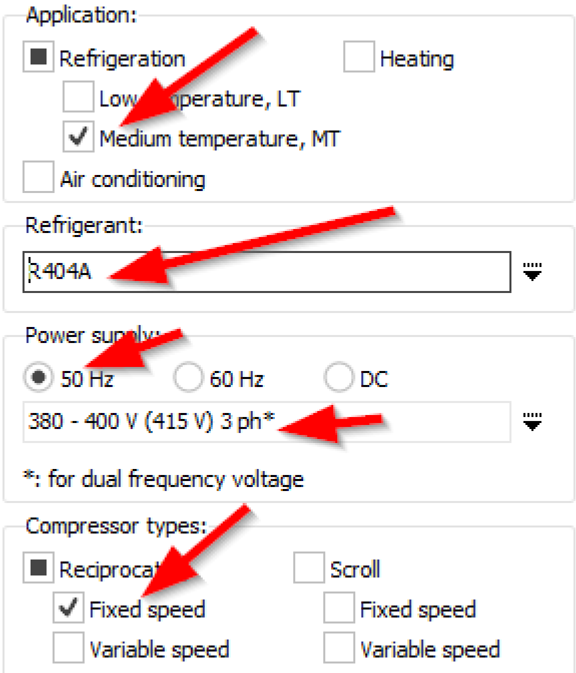
- MCC
- Power connection type
- Connection type
- Oil charge
- Swept volume (Cm3)
- IP protection class
- Refrigerant charge [kg] [Max]

j) Which compressor series does Danfoss have available for R134a?

Solution 7.1 Selecting a compressor and find related technical information

a) Go to “New” tab, select “Compressors and condensing units” and click on the “Compressors” button.

Select application, refrigerant, power supply (Frequency and Voltage), and compressor types on the left-hand side of the screen:

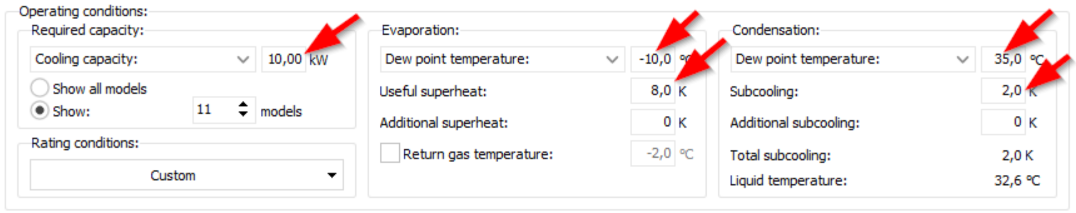


In order to simplify the selection among all compressors, we have classified the compressors in 3 applications types:

1. Refrigeration (low temp/medium temp)
   - Condensing units
   - Racks
   - Low temp is for application with evaporating T° for -30 °C , -20 °C, freezing application
   - Medium temp is for application with evaporating T° ~-15 °C, 5 °C, food preservation
2. Heating
   - Heat pumps
   - Heating only
   - Optimized for heating
3. Air conditioning
   - Chillers
   - Rooftop units
   - Reversible & non-reversible
   - IT cooling
   - Process chiller

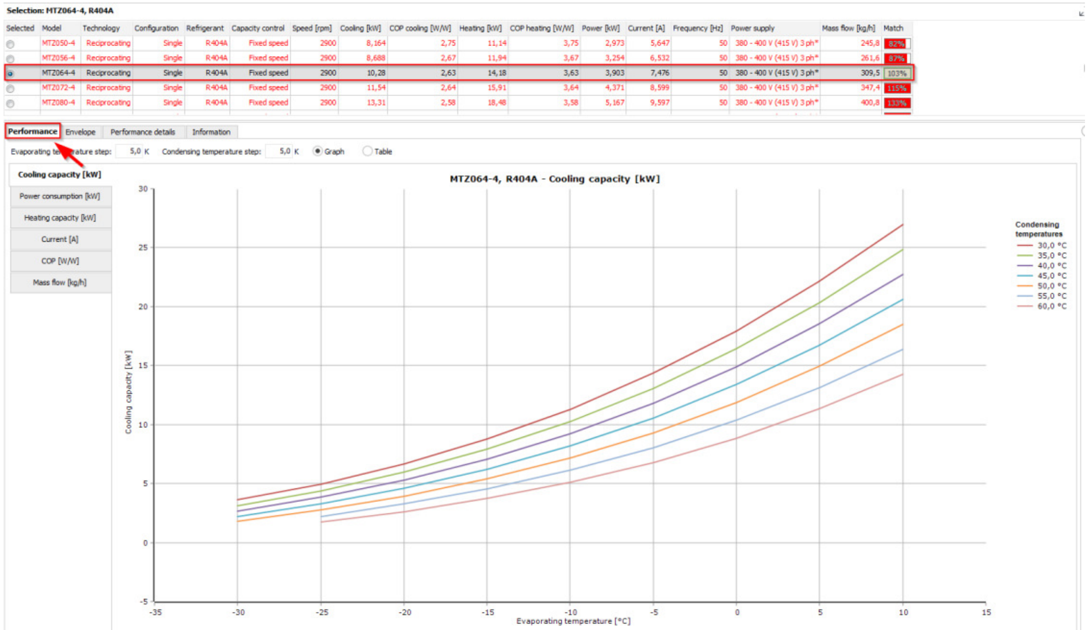
The classification is done based on the most common use of the specific compressor model as well as on the refrigerant, envelope and connection type.

Select the specified cooling capacity, the evaporating condensing superheat and the subcooling conditions in the operating conditions segment:



b) The suggested compressor is model MTZ064-4.

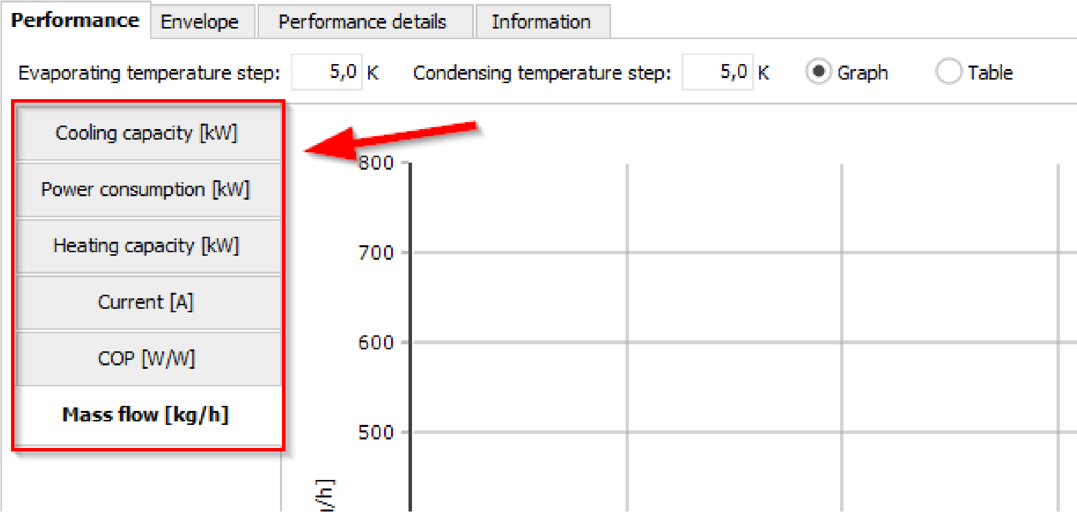
c) The performance details available for this compressor can be found under the "Performance" tab:



The available performance details are:

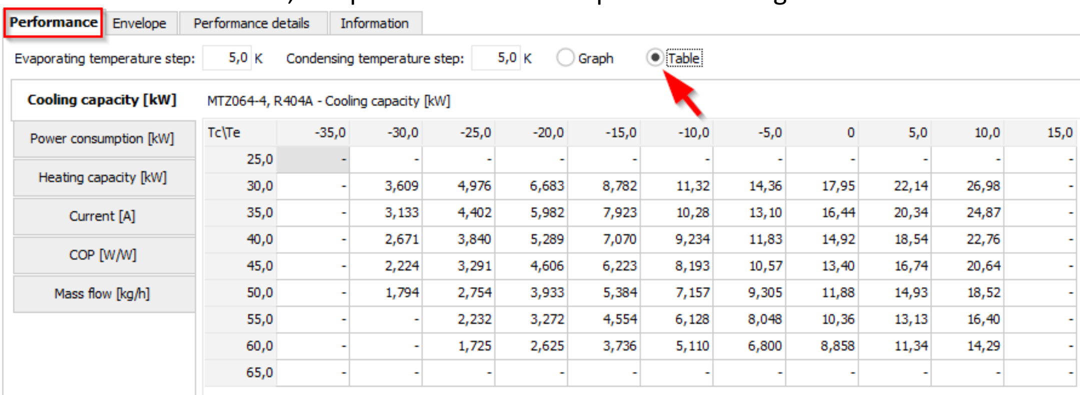
- **Cooling capacity [kW]** - This is the cooling effect at evaporator side including useful superheat.
- **Power consumption [kW]** - This is the electrical power input of compressor.
- **Heating capacity [kW]** - This is the heat rejected at condenser side including subcooling.
- **Current [A]** - This is the current drawn by compressor.
- **COP [W/W]** - This is the ratio between cooling capacity and power consumption.
- **Mass flow [kg/h]** - This is the mass flow of refrigerant.

You can browse through the performance details for the compressor by using the tabs to the left of the graphs:



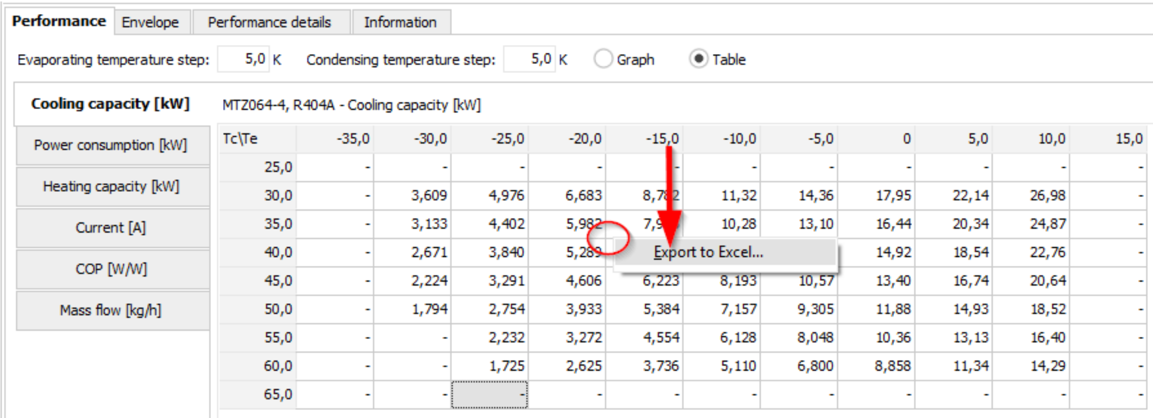
Each tab displays the performance details for the given compressor selected in the table above (in this example the MTZ064-4).

By default, all performance details are shown as graphs. However, by using the radio buttons above the table, it is possible to have the performance figures shown in a table:



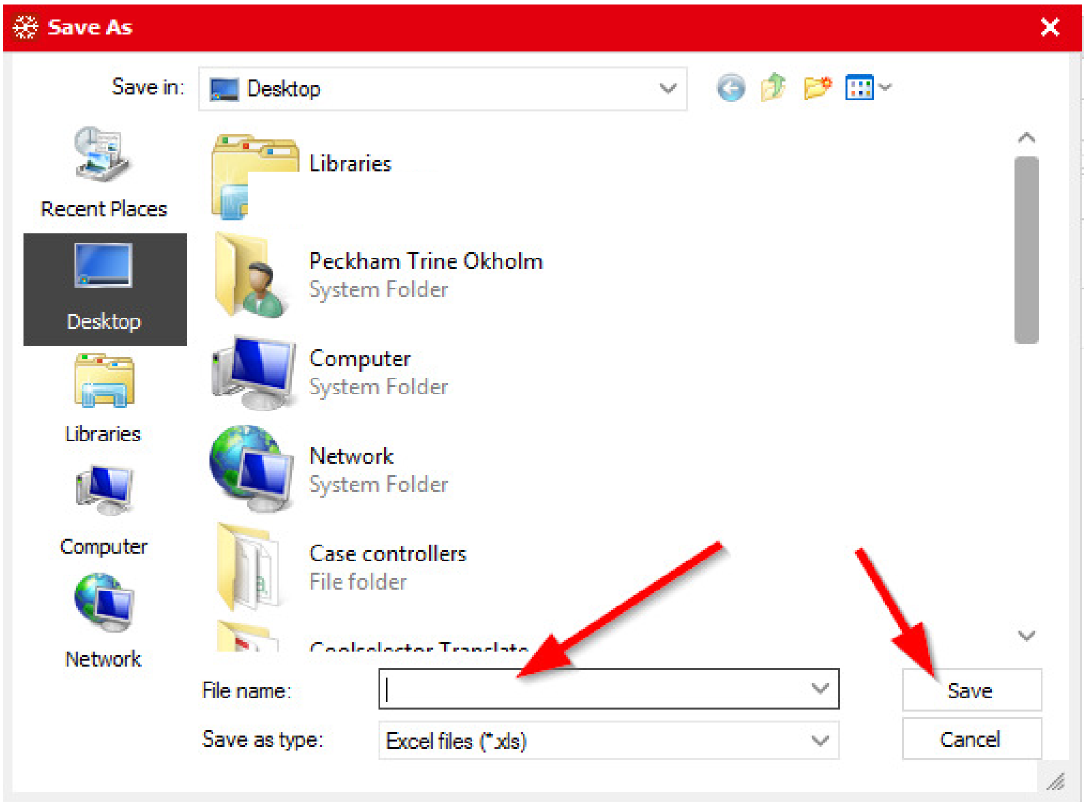
Tc\Te	-35,0	-30,0	-25,0	-20,0	-15,0	-10,0	-5,0	0	5,0	10,0	15,0
25,0	-	-	-	-	-	-	-	-	-	-	-
30,0	-	3,609	4,976	6,683	8,782	11,32	14,36	17,95	22,14	26,98	-
35,0	-	3,133	4,402	5,982	7,923	10,28	13,10	16,44	20,34	24,87	-
40,0	-	2,671	3,840	5,289	7,070	9,234	11,83	14,92	18,54	22,76	-
45,0	-	2,224	3,291	4,606	6,223	8,193	10,57	13,40	16,74	20,64	-
50,0	-	1,794	2,754	3,933	5,384	7,157	9,305	11,88	14,93	18,52	-
55,0	-	-	2,232	3,272	4,554	6,128	8,048	10,36	13,13	16,40	-
60,0	-	-	1,725	2,625	3,736	5,110	6,800	8,858	11,34	14,29	-
65,0	-	-	-	-	-	-	-	-	-	-	-

d) To export the performance details tables to Excel for a given compressor, you need to go to the performance details table, right click and choose "Export to Excel…":

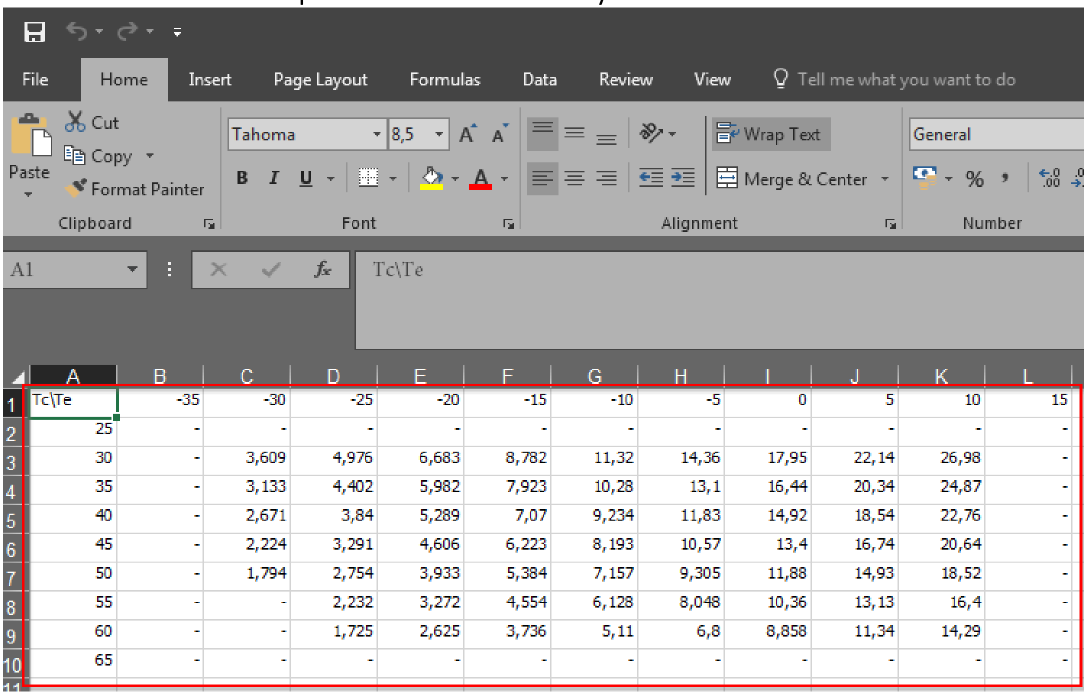


Tc\Te	-35,0	-30,0	-25,0	-20,0	-15,0	-10,0	-5,0	0	5,0	10,0	15,0
25,0	-	-	-	-	-	-	-	-	-	-	-
30,0	-	3,609	4,976	6,683	8,7[illegible]	11,32	14,36	17,95	22,14	26,98	-
35,0	-	3,133	4,402	5,98[illegible]	7,9[illegible]	10,28	13,10	16,44	20,34	24,87	-
40,0	-	2,671	3,840	5,28[illegible]	[illegible]	[illegible]	[illegible]	14,92	18,54	22,76	-
45,0	-	2,224	3,291	4,606	6,223	8,193	10,57	13,40	16,74	20,64	-
50,0	-	1,794	2,754	3,933	5,384	7,157	9,305	11,88	14,93	18,52	-
55,0	-	-	2,232	3,272	4,554	6,128	8,048	10,36	13,13	16,40	-
60,0	-	-	1,725	2,625	3,736	5,110	6,800	8,858	11,34	14,29	-
65,0	-	-	-	-	-	-	-	-	-	-	-

Save the autogenerated Excel file on your computer by giving the file a name and clicking on “Save”:

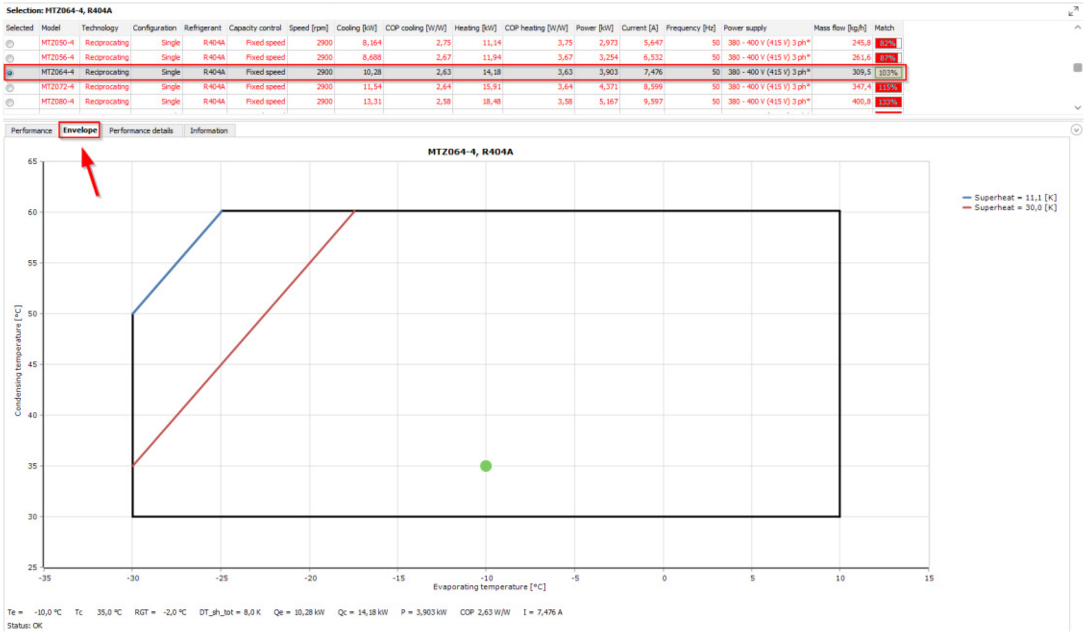


You can now access the performance data directly in Excel:



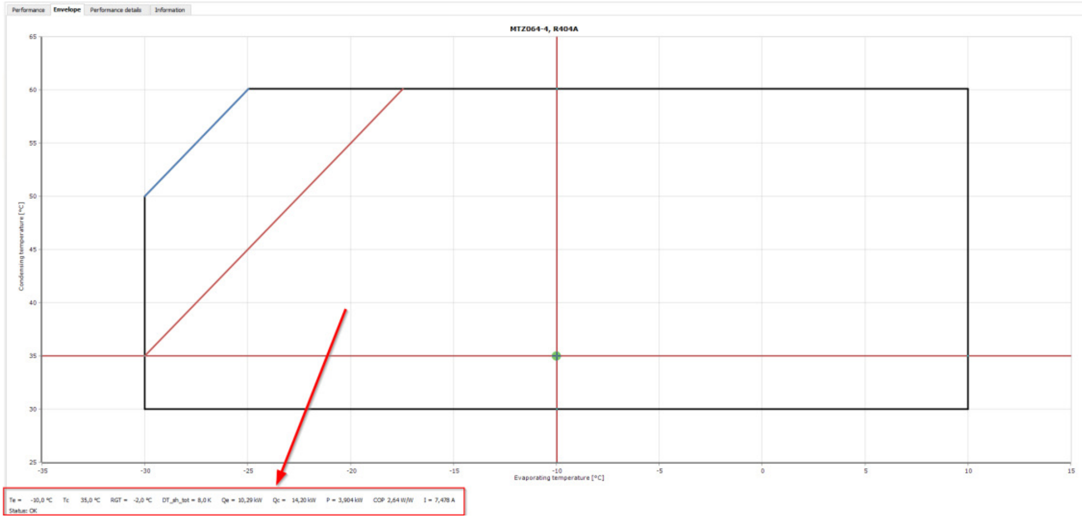
Tc\Te	-35	-30	-25	-20	-15	-10	-5	0	5	10	15
25	-	-	-	-	-	-	-	-	-	-	-
30	-	3,609	4,976	6,683	8,782	11,32	14,36	17,95	22,14	26,98	-
35	-	3,133	4,402	5,982	7,923	10,28	13,1	16,44	20,34	24,87	-
40	-	2,671	3,84	5,289	7,07	9,234	11,83	14,92	18,54	22,76	-
45	-	2,224	3,291	4,606	6,223	8,193	10,57	13,4	16,74	20,64	-
50	-	1,794	2,754	3,933	5,384	7,157	9,305	11,88	14,93	18,52	-
55	-	-	2,232	3,272	4,554	6,128	8,048	10,36	13,13	16,4	-
60	-	-	1,725	2,625	3,736	5,11	6,8	8,858	11,34	14,29	-
65	-	-	-	-	-	-	-	-	-	-	-

e) You will find the envelope by clicking on the tab called “Envelope” underneath the selection table (next to the performance details):



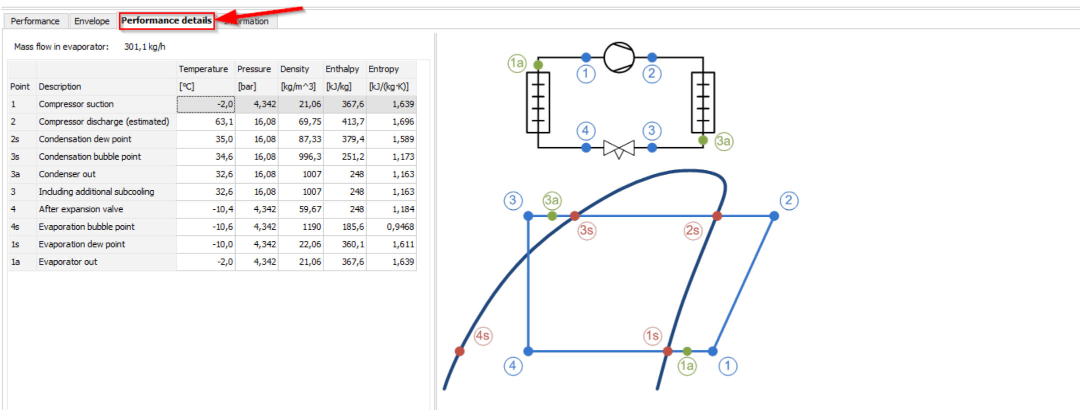
The green “dot” positions the operating conditions selected above within the envelope.

f) To check the power input or cooling capacity versus the condensation or evaporation, move your cursor around inside the envelope and look at the data changing underneath the graph:



- **Te (evaporation temperature) [°C]** - This is the dew T° corresponding to suction pressure.
- **Tc (condensation temperature) [°C]** - This is the dew T° corresponding to discharge pressure.
- **RGT (Return Gas Temperature) [°C]** - This is the suction T°.
- **DT_sh_tot (useful superheat) [K]** - This is the total superheat (useful superheat at evaporator outlet) + (superheat on compressor suction line (Non-useful superheat))
- **Qe (cooling capacity of evaporator) [kW]**
- **Qc (heating capacity of condenser) [kW]**
- **P (compressor power consumption) [kW]**
- **COP (coefficient of performance (see also previous solution)) [W/W]**
- **I (Current) [A]**

g) To get details about the thermodynamic calculations of the compressor, you need to locate the "Performance details" tab within Coolselector®2, underneath the selection table:



		Temperature	Pressure	Density	Enthalpy	Entropy
Point	Description	[°C]	[bar]	[kg/m^3]	[kJ/kg]	[kJ/(kg·K)]
1	Compressor suction	-2,0	4,342	21,06	367,6	1,639
2	Compressor discharge (estimated)	63,1	16,08	69,75	413,7	1,696
2s	Condensation dew point	35,0	16,08	87,33	379,4	1,589
3s	Condensation bubble point	34,6	16,08	996,3	251,2	1,173
3a	Condenser out	32,6	16,08	1007	248	1,163
3	Including additional subcooling	32,6	16,08	1007	248	1,163
4	After expansion valve	-10,4	4,342	59,67	248	1,184
4s	Evaporation bubble point	-10,6	4,342	1190	185,6	0,9468
1s	Evaporation dew point	-10,0	4,342	22,06	360,1	1,611
1a	Evaporator out	-2,0	4,342	21,06	367,6	1,639

In this tab you will find the values of all the thermodynamic parameters used for calculation within Coolselector®2.

h) The estimated discharge temperature (T°) for the suggested compressor (MTZ064-4) is 63.1 °C. You will find this information on row 2 in the table within the “Performance details” tab:

Performance | Envelope | **Performance details** | Information

Mass flow in evaporator: 301,1 kg/h

Point	Description	Temperature [°C]	Pressure [bar]	Density [kg/m^3]	Enthalpy [kJ/kg]	Entropy [kJ/(kg·K)]
1	Compressor suction	-2,0	4,342	21,06	367,6	1,639
2	Compressor discharge (estimated)	63,1	16,08	69,75	413,7	1,696
2s	Condensation dew point	35,0	16,08	87,33	379,4	1,589
3s	Condensation bubble point	34,6	16,08	996,3	251,2	1,173
3a	Condenser out	32,6	16,08	1007	248	1,163
3	Including additional subcooling	32,6	16,08	1007	248	1,163
4	After expansion valve	-10,4	4,342	59,67	248	1,184
4s	Evaporation bubble point	-10,6	4,342	1190	185,6	0,9468
1s	Evaporation dew point	-10,0	4,342	22,06	360,1	1,611
1a	Evaporator out	-2,0	4,342	21,06	367,6	1,639

Estimated discharge T value can be useful to double check the suction superheat:

If the actual discharge T has more than 15K difference compared to the estimated discharge temperature, it may mean that something is wrong:

- Either the suction superheat is measured and/or controlled incorrectly
- Or the compressor is damaged

i) To find the information about the compressor, go to the “Information” tab and select the code number you wish to see the data for. In this case we choose MTZ64-4VM as industrial pack (6 pcs):

Performance | Envelope | Performance details | **Information**

Select code number:

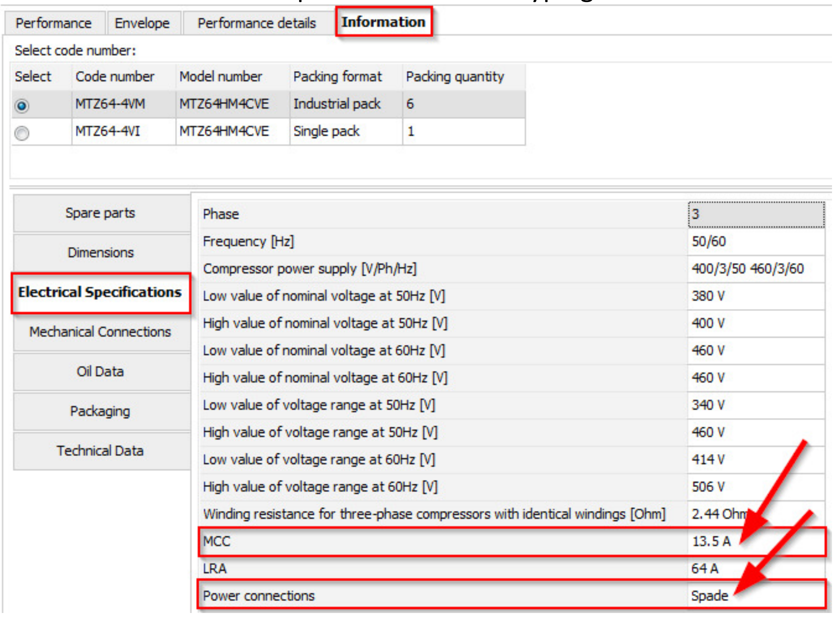
Select	Code number	Model number	Packing format	Packing quantity
◉	MTZ64-4VM	MTZ64HM4CVE	Industrial pack	6
○	MTZ64-4VI	MTZ64HM4CVE	Single pack	1

Spare parts | Dimensions | **Electrical Specifications** | Mechanical Connections | Oil Data | Packaging | Technical Data

Phase	3
Frequency [Hz]	50/60
Compressor power supply [V/Ph/Hz]	400/3/50 460/3/60
Low value of nominal voltage at 50Hz [V]	380 V
High value of nominal voltage at 50Hz [V]	400 V
Low value of nominal voltage at 60Hz [V]	460 V
High value of nominal voltage at 60Hz [V]	460 V
Low value of voltage range at 50Hz [V]	340 V
High value of voltage range at 50Hz [V]	460 V
Low value of voltage range at 60Hz [V]	414 V
High value of voltage range at 60Hz [V]	506 V
Winding resistance for three-phase compressors with identical windings [Ohm]	2.44 Ohm
MCC	13.5 A
LRA	64 A

Underneath you will now see a new list of tabs; it is within these you will find all of the information to answer the question.

To find the MCC and the power connection type go to the “Electrical Specifications” tab:



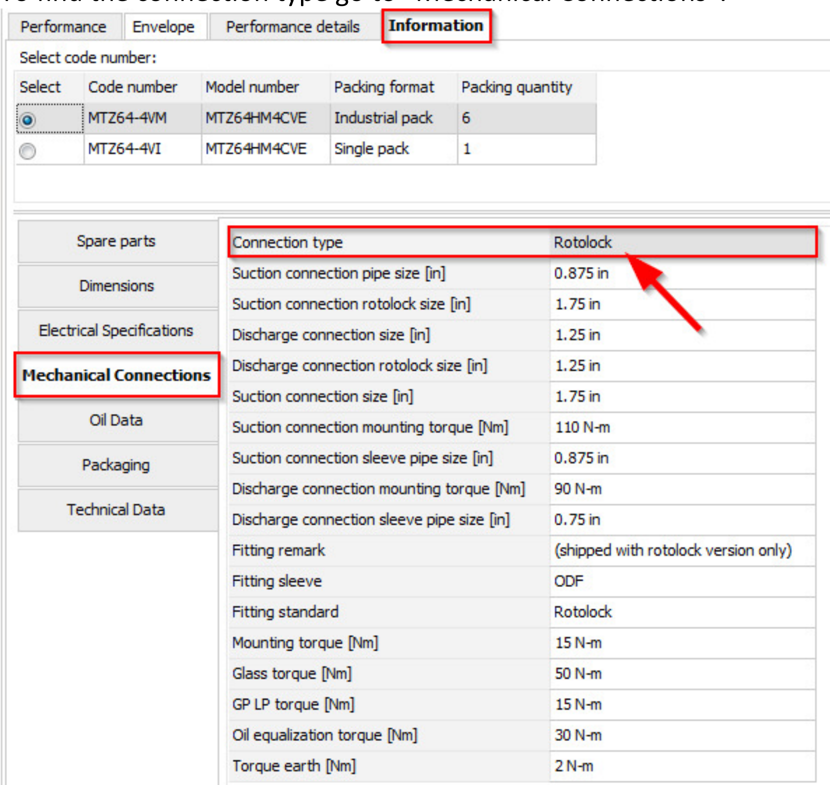
Select	Code number	Model number	Packing format	Packing quantity
◉	MTZ64-4VM	MTZ64HM4CVE	Industrial pack	6
○	MTZ64-4VI	MTZ64HM4CVE	Single pack	1

Phase	3
Frequency [Hz]	50/60
Compressor power supply [V/Ph/Hz]	400/3/50 460/3/60
Low value of nominal voltage at 50Hz [V]	380 V
High value of nominal voltage at 50Hz [V]	400 V
Low value of nominal voltage at 60Hz [V]	460 V
High value of nominal voltage at 60Hz [V]	460 V
Low value of voltage range at 50Hz [V]	340 V
High value of voltage range at 50Hz [V]	460 V
Low value of voltage range at 60Hz [V]	414 V
High value of voltage range at 60Hz [V]	506 V
Winding resistance for three-phase compressors with identical windings [Ohm]	2.44 Ohm
MCC	13.5 A
LRA	64 A
Power connections	Spade

From this you will see that the answer is:

- **MCC: 13.5 A**
- **Power connections: Spade**

To find the connection type go to “Mechanical Connections”:



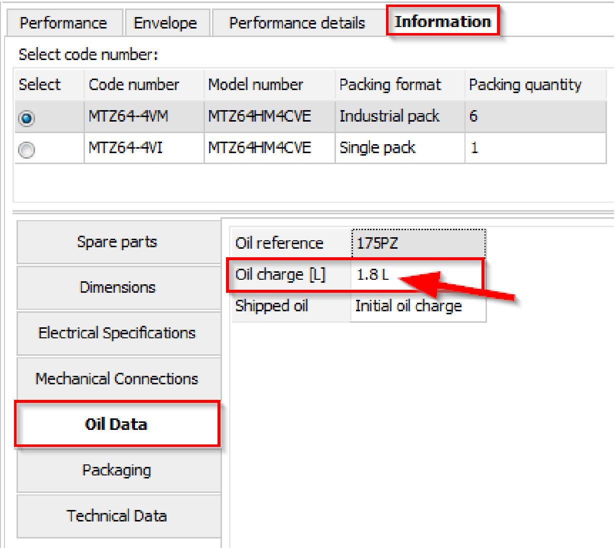
Select	Code number	Model number	Packing format	Packing quantity
◉	MTZ64-4VM	MTZ64HM4CVE	Industrial pack	6
○	MTZ64-4VI	MTZ64HM4CVE	Single pack	1

Connection type	Rotolock
Suction connection pipe size [in]	0.875 in
Suction connection rotolock size [in]	1.75 in
Discharge connection size [in]	1.25 in
Discharge connection rotolock size [in]	1.25 in
Suction connection size [in]	1.75 in
Suction connection mounting torque [Nm]	110 N-m
Suction connection sleeve pipe size [in]	0.875 in
Discharge connection mounting torque [Nm]	90 N-m
Discharge connection sleeve pipe size [in]	0.75 in
Fitting remark	(shipped with rotolock version only)
Fitting sleeve	ODF
Fitting standard	Rotolock
Mounting torque [Nm]	15 N-m
Glass torque [Nm]	50 N-m
GP LP torque [Nm]	15 N-m
Oil equalization torque [Nm]	30 N-m
Torque earth [Nm]	2 N-m

From this you will see that the value is:

- **Connection type: Rotolock**

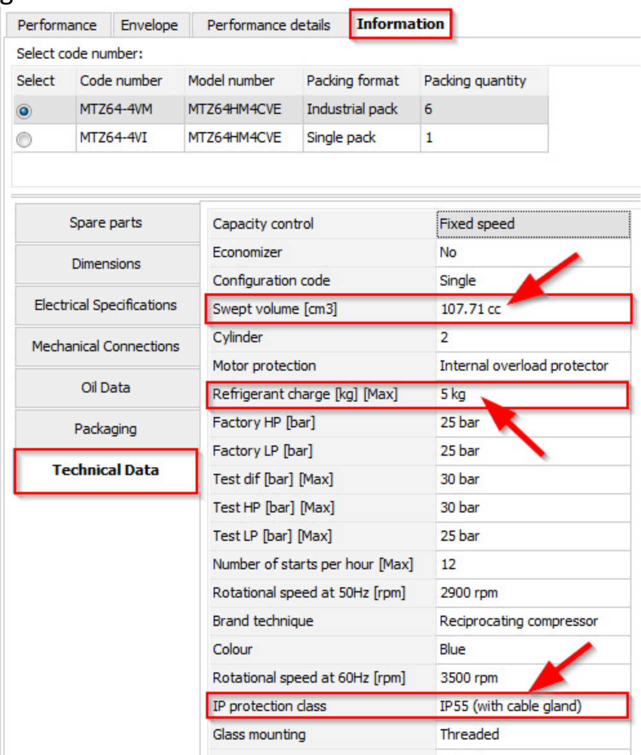
To find the oil charge, go to “Oil Data”:



From this you will see that the value is:

- **Oil charge: 1.8 L**

To find the Swept volume [cm3], refrigerant charge [kg] [Max] and the IP protection class, go to “Technical Data”:

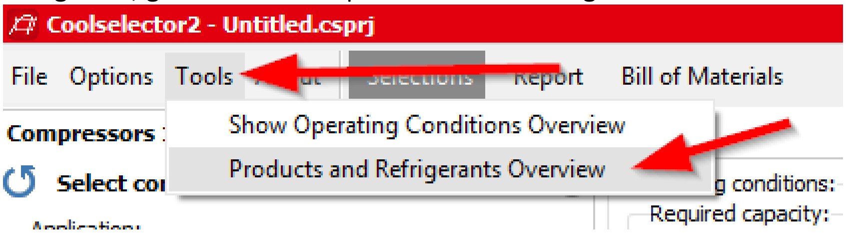


From this you will see that the answer is:

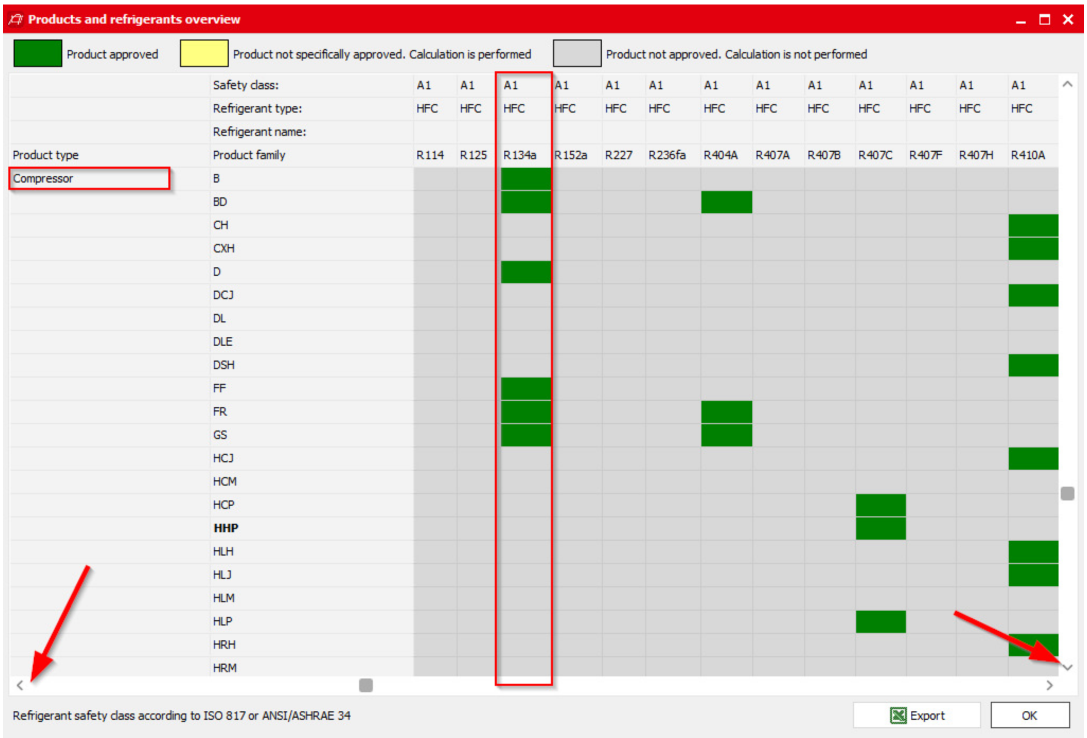
- **Swept volume (Cm3):** 107.71 cc
- **IP protection of electrical Box:** IP55 (with cable gland)
- **Refrigerant charge [kg] [Max]:** 5 kg
- **Refrigerant charge [kg] [Max]:** 5 kg is the charge limit.

This is not the maximum charge allowed in the system. Above that limit you need to take some countermeasure to protect against refrigerant migration dilution. Details of countermeasures are described in the application guidelines for the given compressor.

j) To see which compressors (or other products) Danfoss has available for a specific refrigerant, go to the “Tools | Products and Refrigerant Overview”.



Scroll through the list both vertically and horizontally until you get to compressors and R134a:



The answer to which compressors are available for R134a is:

B, BD, D, FF, FR, GS, L, MLZ, MTZ, NF, NL, NLV, NT, P, PL, S, SC, SY, SZ, TF, TL, TT, U, VTZ, X

Exercise 7.2 Understanding the challenges for compressor selection

a) Please explain how to reset your compressor selection.

b) Then try to select a compressor with the following criteria:

- Model: DSH series
- Cooling capacity: 35 kW
- Dew point temperature for evaporation: +5 °C
- Useful superheat: 10 K
- Dew point temperature for condensation: +35 °C
- Subcooling: 0 K

c) Which compressor model does Coolselector®2 suggest?

d) What is the cooling capacity in kW of the suggested compressor model as well as the other suggested alternative?

e) Now reset your compressor selection and instead select a compressor with the following criteria:

- Model: VZH series
- Rating conditions: EN 12900 | HT | SH 10 K

f) How many Danfoss VZH models have a 100% match to these operating conditions?

g) What is different in the way results are displayed compared to the compressors with “fixed speed”? Please explain.

h) Why can a single variable speed compressor give many different capacities?

i) Now reset your compressor selection and try to select a compressor with the following criteria:

- Application: Refrigeration, Low Temperature (LT)
- Refrigerant: R452A
- Power supply: 50 Hz // 400V
- Compressor type: Reciprocating – fixed speed
- Operating conditions:
  - Cooling capacity: 10 kW
  - Dew point temperature for evaporation: -10 °C
  - Useful superheat: 8 K
  - Dew point temperature for condensation: +30 °C
  - Subcooling: 2 K

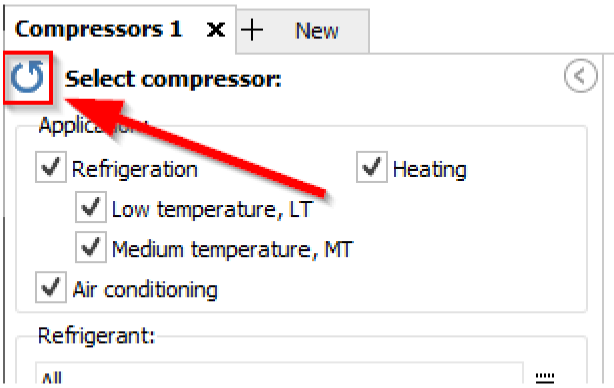
j) Which compressor model does Coolselector®2 suggest?

k) Explain what the challenge in choosing this compressor for these operating conditions is.

l) Please try to explain why this challenge arises and how you could overcome it.

Solution 7.2 Understanding the challenges for compressor selection

a) To reset the selection criteria for a compressor, click on the "reset" icon near the top left corner:

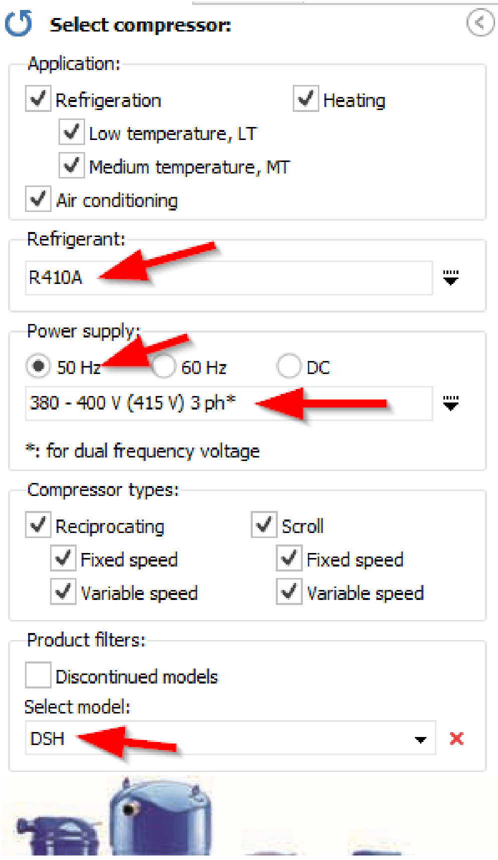


Please note that this will not reset the operating conditions but will reset the selection criteria.

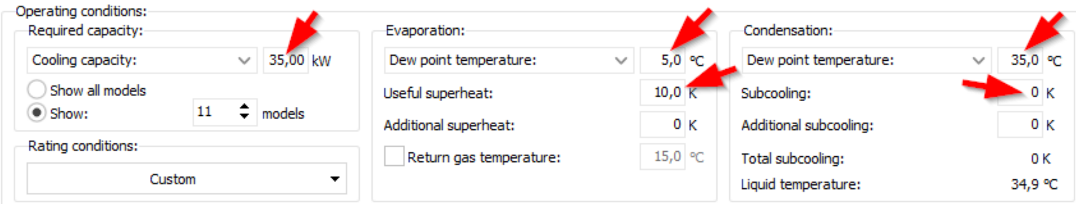
b) To select a compressor with the suggested criteria, use the selection pane on the left-hand side of the screen and input the given selection criteria:

- Refrigerant: R410A
- Power supply: 50Hz and 400V
- Product filters: DSH

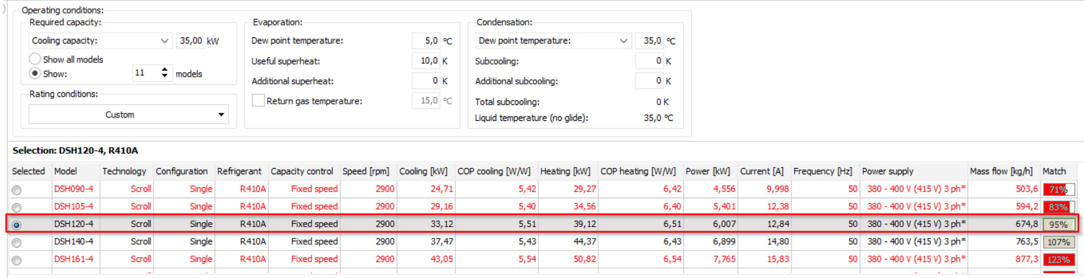
The list of possible models will give you an overview of which exact compressors in the selected model series (DSH) Danfoss has available for the given selection criteria:



Next turn to the operating conditions and type in the given criteria:



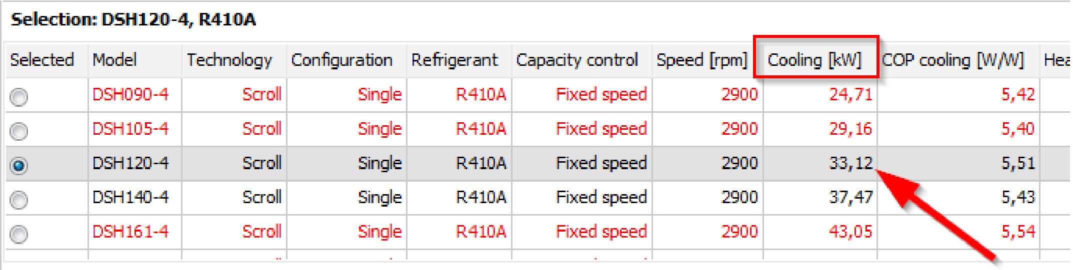
c) Coolselector®2 suggests the DSH120-4.



Selection: DSH120-4, R410A

Selected	Model	Technology	Configuration	Refrigerant	Capacity control	Speed [rpm]	Cooling [kW]	COP cooling [W/W]	Heating [kW]	COP heating [W/W]	Power [kW]	Current [A]	Frequency [Hz]	Power supply	Mass flow [kg/h]	Match
○	DSH090-4	Scroll	Single	R410A	Fixed speed	2900	24,71	5,42	29,27	6,42	4,556	9,998	50	380 - 400 V (415 V) 3 ph*	503,6	71%
○	DSH105-4	Scroll	Single	R410A	Fixed speed	2900	29,16	5,40	34,56	6,40	5,401	12,38	50	380 - 400 V (415 V) 3 ph*	594,2	83%
◉	DSH120-4	Scroll	Single	R410A	Fixed speed	2900	33,12	5,51	39,12	6,51	6,007	12,84	50	380 - 400 V (415 V) 3 ph*	674,8	95%
○	DSH140-4	Scroll	Single	R410A	Fixed speed	2900	37,47	5,43	44,37	6,43	6,899	14,80	50	380 - 400 V (415 V) 3 ph*	763,5	107%
○	DSH161-4	Scroll	Single	R410A	Fixed speed	2900	43,05	5,54	50,82	6,54	7,765	15,83	50	380 - 400 V (415 V) 3 ph*	877,3	123%

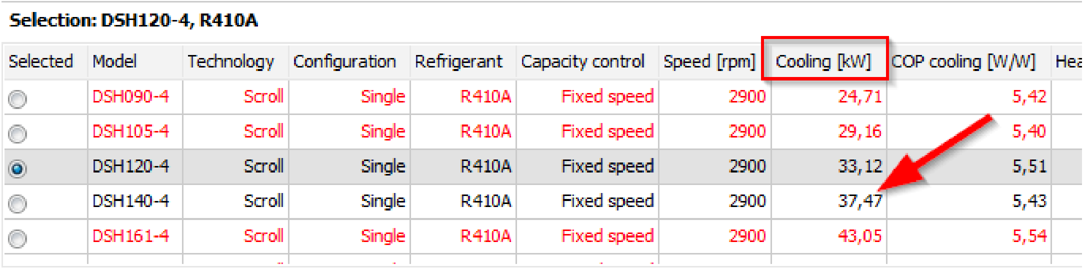
d) The cooling capacity in kW of the suggested compressor (DSH120-4) is 33.12 kW.



Selection: DSH120-4, R410A

Selected	Model	Technology	Configuration	Refrigerant	Capacity control	Speed [rpm]	Cooling [kW]	COP cooling [W/W]	Hea
○	DSH090-4	Scroll	Single	R410A	Fixed speed	2900	24,71	5,42	
○	DSH105-4	Scroll	Single	R410A	Fixed speed	2900	29,16	5,40	
◉	DSH120-4	Scroll	Single	R410A	Fixed speed	2900	33,12	5,51	
○	DSH140-4	Scroll	Single	R410A	Fixed speed	2900	37,47	5,43	
○	DSH161-4	Scroll	Single	R410A	Fixed speed	2900	43,05	5,54	

The cooling capacity of the other possible alternative (DSH140-4) is 37.47 kW.

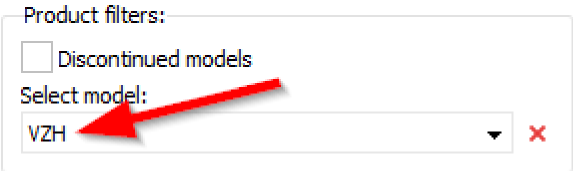


Selection: DSH120-4, R410A

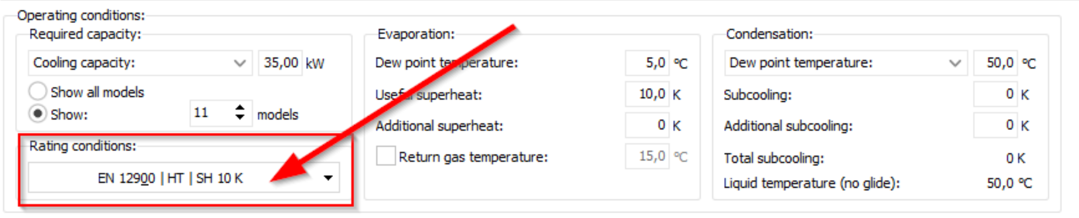
Selected	Model	Technology	Configuration	Refrigerant	Capacity control	Speed [rpm]	Cooling [kW]	COP cooling [W/W]	Hea
○	DSH090-4	Scroll	Single	R410A	Fixed speed	2900	24,71	5,42	
○	DSH105-4	Scroll	Single	R410A	Fixed speed	2900	29,16	5,40	
◉	DSH120-4	Scroll	Single	R410A	Fixed speed	2900	33,12	5,51	
○	DSH140-4	Scroll	Single	R410A	Fixed speed	2900	37,47	5,43	
○	DSH161-4	Scroll	Single	R410A	Fixed speed	2900	43,05	5,54	

Coolselector®2 always gives the suggestion that matches your capacity request in the operating conditions. Only compressors that match the cooling capacity given in the operating conditions (+/-10%) will be valid choices. By choosing a compressor model series to the left under “Select model:” where we in this example chose DSH, you limit the choices suggested in the selection table.

e) In the selection panel on the left-hand side, go to the ‘Select model:’ field and choose VZH:

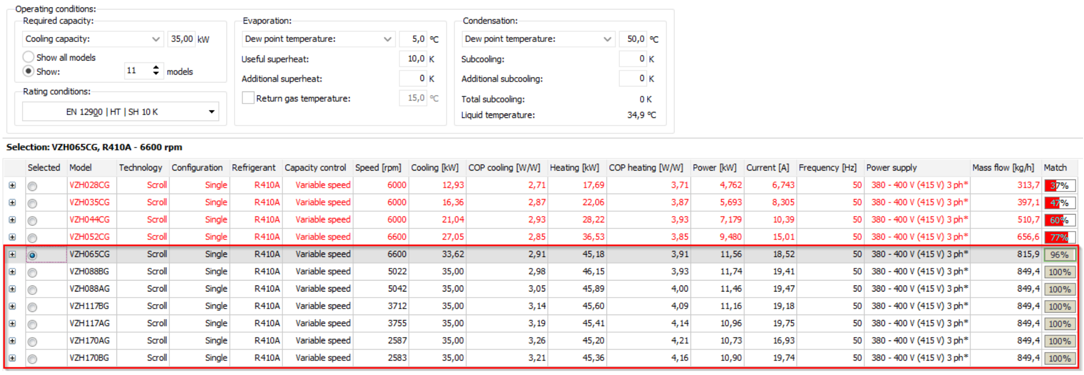


Now turn to the “Operating conditions:” and in “Rating conditions:” choose: “EN 12900 | HT | SH 10 K”. This will reset the operating conditions within Coolselector®2 to match those set forward by this pre-configuration.



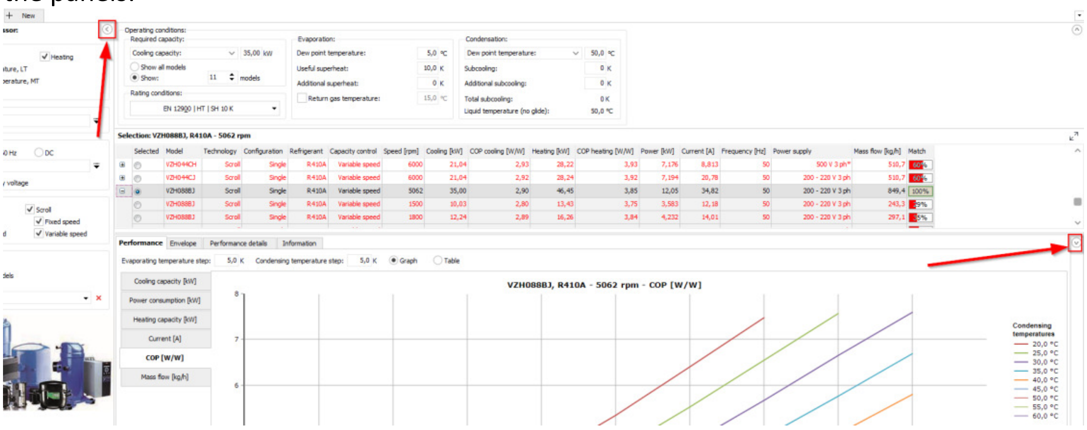
As you will see from the drop-down list under rating conditions there are multiple pre-configurations to choose from. If you wish to set these rating conditions yourself, you can also do this. Coolselector®2 will then inform you that they correspond to a given preconfigured rating condition by changing this field.

f) There are 7 VZH compressors which have a ~100% match to these operating conditions. You find the given compressors by using the +/- buttons next to the compressor models within the selection table:



Selected	Model	Technology	Configuration	Refrigerant	Capacity control	Speed [rpm]	Cooling [kW]	COP cooling [W/W]	Heating [kW]	COP heating [W/W]	Power [kW]	Current [A]	Frequency [Hz]	Power supply	Mass flow [kg/h]	Match
	VZH028CG	Scroll	Single	R410A	Variable speed	6000	12,93	2,71	17,69	3,71	4,762	6,743	50	380 - 400 V (415 V) 3 ph*	313,7	37%
	VZH035CG	Scroll	Single	R410A	Variable speed	6000	16,36	2,87	22,06	3,87	5,693	8,305	50	380 - 400 V (415 V) 3 ph*	397,1	47%
	VZH044CG	Scroll	Single	R410A	Variable speed	6000	21,04	2,93	28,22	3,93	7,179	10,39	50	380 - 400 V (415 V) 3 ph*	510,7	60%
	VZH052CG	Scroll	Single	R410A	Variable speed	6600	27,05	2,85	36,53	3,85	9,480	15,01	50	380 - 400 V (415 V) 3 ph*	656,6	77%
◉	VZH065CG	Scroll	Single	R410A	Variable speed	6600	33,62	2,91	45,18	3,91	11,56	18,52	50	380 - 400 V (415 V) 3 ph*	815,9	96%
	VZH088BG	Scroll	Single	R410A	Variable speed	5022	35,00	2,98	46,15	3,93	11,74	19,41	50	380 - 400 V (415 V) 3 ph*	849,4	100%
	VZH088AG	Scroll	Single	R410A	Variable speed	5042	35,00	3,05	45,89	4,00	11,46	19,47	50	380 - 400 V (415 V) 3 ph*	849,4	100%
	VZH117BG	Scroll	Single	R410A	Variable speed	3712	35,00	3,14	45,60	4,09	11,16	19,18	50	380 - 400 V (415 V) 3 ph*	849,4	100%
	VZH117AG	Scroll	Single	R410A	Variable speed	3755	35,00	3,19	45,41	4,14	10,96	19,75	50	380 - 400 V (415 V) 3 ph*	849,4	100%
	VZH170AG	Scroll	Single	R410A	Variable speed	2587	35,00	3,26	45,20	4,21	10,73	16,93	50	380 - 400 V (415 V) 3 ph*	849,4	100%
	VZH170BG	Scroll	Single	R410A	Variable speed	2583	35,00	3,21	45,36	4,16	10,90	19,74	50	380 - 400 V (415 V) 3 ph*	849,4	100%

You can get a better and larger overview by temporarily removing the selection and performance details from your view. You do this by clicking on the arrows on the edge of the panels:



You can always make the panels reappear by clicking on the same buttons.

You can also configure the number of columns in the table by right clicking with your mouse on any of the table headlines and choosing “Manage columns...”:

Selection: VZH088BJ, R410A - 5062 rpm

Manage columns...

Selected	Model	Technology	Configuration	Refrigerant	Capacity control	Speed [rpm]	Cooling [kW]	COP c
	VZH044CH				Variable speed	6000	21,04	
	VZH044CJ	Scroll	Single	R410A	Variable speed	6000	21,04	
	VZH088BJ	Scroll	Single	R410A	Variable speed	5062	35,00	
	VZH088BJ	Scroll	Single	R410A	Variable speed	1500	10,03	

Check chapter 1 for more information.

g) For variable speed compressors like VZH in this example, the display is quite different. By using the +/- signs you will be able to see all the capacities of the selected model at different speeds:

Selection: VZH065CG, R410A - 6600 rpm

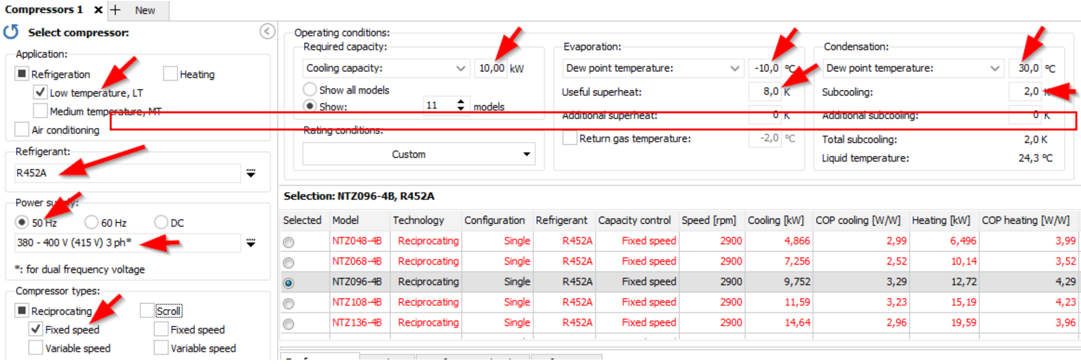
Selected	Model	Technology	Configuration	Refrigerant	Capacity control	Speed [rpm]	Cooling [kW]	COP cooling [W/W]	Heating [kW]	COP heating [W/W]	Power [kW]	Current [A]	Frequency [Hz]	Power supply
	VZH028CG	Scroll	Single	R410A	Variable speed	6000	12,93	2,71	17,69	3,71	4,762	6,743	50	380 - 400 V (415 V) 3 ph*
	VZH035CG	Scroll	Single	R410A	Variable speed	6000	16,36	2,87	22,06	3,87	5,693	8,305	50	380 - 400 V (415 V) 3 ph*
	VZH044CG	Scroll	Single	R410A	Variable speed	6000	21,04	2,93	28,22	3,93	7,179	10,39	50	380 - 400 V (415 V) 3 ph*
	VZH052CG	Scroll	Single	R410A	Variable speed	6600	27,05	2,85	36,53	3,85	9,480	15,01	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	6600	33,62	2,91	45,18	3,91	11,56	18,52	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	-	-	-	-	-	-	-	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	-	-	-	-	-	-	-	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	-	-	-	-	-	-	-	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	1800	8,374	2,68	11,50	3,68	3,124	6,155	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	2100	9,875	2,76	13,45	3,76	3,577	6,770	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	2400	11,39	2,82	15,43	3,82	4,041	7,407	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	2700	12,91	2,86	17,42	3,86	4,514	8,064	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	3000	14,44	2,89	19,44	3,89	4,997	8,743	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	3300	15,98	2,91	21,47	3,91	5,489	9,442	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	3600	17,53	2,93	23,53	3,93	5,992	10,16	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	3900	19,10	2,94	25,60	3,94	6,504	10,90	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	4200	20,67	2,94	27,70	3,94	7,026	11,67	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	4500	22,25	2,94	29,81	3,94	7,558	12,45	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	4800	23,85	2,94	31,95	3,94	8,100	13,25	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	5100	25,45	2,94	34,10	3,94	8,652	14,08	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	5400	27,06	2,94	36,28	3,94	9,213	14,92	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	5700	28,69	2,93	38,47	3,93	9,784	15,79	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	6000	30,32	2,92	40,69	3,92	10,37	16,68	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	6300	31,97	2,92	42,92	3,92	10,96	17,59	50	380 - 400 V (415 V) 3 ph*
	VZH065CG	Scroll	Single	R410A	Variable speed	6600	33,62	2,91	45,18	3,91	11,56	18,52	50	380 - 400 V (415 V) 3 ph*
	VZH088BG	Scroll	Single	R410A	Variable speed	5022	35,00	2,98	46,15	3,93	11,74	19,41	50	380 - 400 V (415 V) 3 ph*
	VZH088AG	Scroll	Single	R410A	Variable speed	5042	35,00	3,05	45,89	4,00	11,46	19,47	50	380 - 400 V (415 V) 3 ph*
	VZH117BG	Scroll	Single	R410A	Variable speed	3712	35,00	3,14	45,60	4,09	11,16	19,18	50	380 - 400 V (415 V) 3 ph*
	VZH117AG	Scroll	Single	R410A	Variable speed	3755	35,00	3,19	45,41	4,14	10,96	19,75	50	380 - 400 V (415 V) 3 ph*
	VZH170AG	Scroll	Single	R410A	Variable speed	2587	35,00	3,26	45,20	4,21	10,73	16,93	50	380 - 400 V (415 V) 3 ph*

Only lines with a combination of speed/cooling capacity that matches your given operating conditions within a reasonable range will be marked in black; the rest are marked in red to indicate that they do not match your operating conditions criteria. The range is set to ±10% by default. You can change this range in the compressor and condensing units preferences. For more information check chapter 1, advanced settings.

h) The capacity of a variable speed compressor depends on the RPM (revolutions per minute). The lines within the selection table in Coolselector®2 show the cooling capacity for any given variable speed compressor with 300 RPM (rounds per minute) or 5 RPS (revolutions per second) steps between them. This is different to a fixed speed compressor table as seen before where there is only one cooling capacity listed per compressor.

The first line gives the exact speed to match the required capacity, in this case 6600 RPM.

i) Choose the compressor by resetting your previous compressor selection and making the new selection as well as entering the new operating conditions:

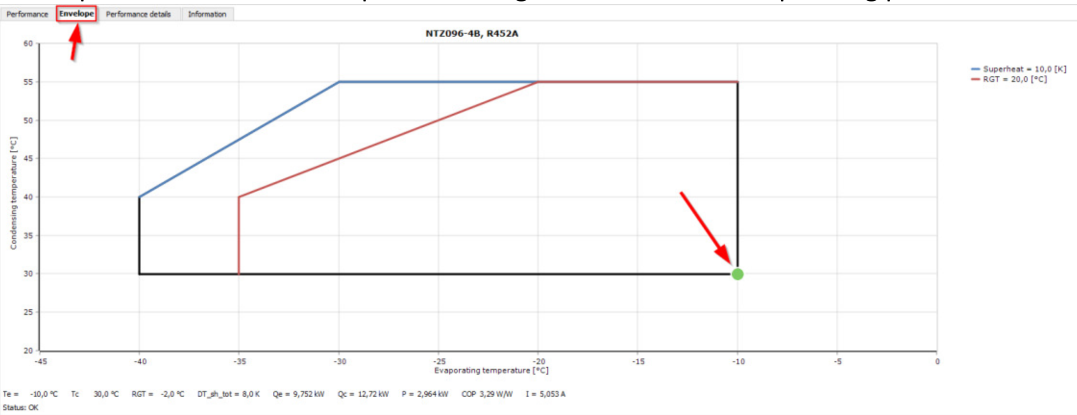


j) The suggested compressor model is NTZ096-4B (reciprocating, fixed speed).

Selection: NTZ096-4B, R452A

Selected	Model	Technology	Configuration	Refrigerant	Capacity control	Speed [rpm]	Cooling [kW]	COP cooling [W/W]	Heating [kW]	COP heating [W/W]	Power [kW]	Current [A]	Frequency [Hz]	Power supply	Mass flow [kg/h]	Match
○	NTZ048-4B	Reciprocating	Single	R452A	Fixed speed	2900	4,866	2,99	6,496	3,99	1,630	2,892	50	380 - 400 V (415 V) 3 ph*	135,6	49%
○	NTZ068-4B	Reciprocating	Single	R452A	Fixed speed	2900	7,256	2,52	10,14	3,52	2,879	4,480	50	380 - 400 V (415 V) 3 ph*	202,2	73%
◉	NTZ096-4B	Reciprocating	Single	R452A	Fixed speed	2900	9,752	3,29	12,72	4,29	2,964	5,053	50	380 - 400 V (415 V) 3 ph*	271,8	98%

The challenge is that the compressor (NTZ096-4B) has an operating point which is at the extreme of the operating envelope. Click on the tab 'Envelope' to see the operating envelope for the selected compressor. The green dot marks the operating point:



This example leads back to an important point when using Coolselector®2 to select a compressor; namely that you need to know at least your application before starting your selection process. This is the best way of ensuring that Coolselector®2 provides you with a suggestion for a compressor with an appropriate envelope. In other words, in our example here, if you select a low-temperature application, an evaporator temperature at -10 °C is at the limit of the envelope and therefore the compressor may not run properly.

When considering which compressor to choose for these conditions, it is suggested that you specify your application with extra care. It would be advisable to make a distinct choice as to whether it is, for example, a low-temp or a medium-temp application, and whether you could consider using a different range (e.g. medium-temp), and check if your operation criteria match your selections. In general, software like Coolselector®2 cannot replace a minimum of knowledge of a technical engineer. At a minimum, it needs to be clear whether the refrigeration system you are building is being built to preserve food (medium temperature), to freeze food (low temp) or if it is a HVAC system.

It is important to note, that the selection criteria are not optional. Intentionally, they are set to show all products when you first start Coolselector®2, but in order to get a relevant suggestion from the software, you need to put in the exact selection criteria that you need for your particular application.

Exercise 7.3 Selecting spare parts for compressors and creating a report

a) Which drive should be used with a VZH170AG compressor for R410A (with cooling condition 20 kW and rating conditions EN 12900 | MT | SH 10 K)?

b) What is the code number of the oil can, which will allow you to do oil top-up on the compressor VZH170AG?

c) Please explain how to add this drive and oil can to the Coolselector®2 report.

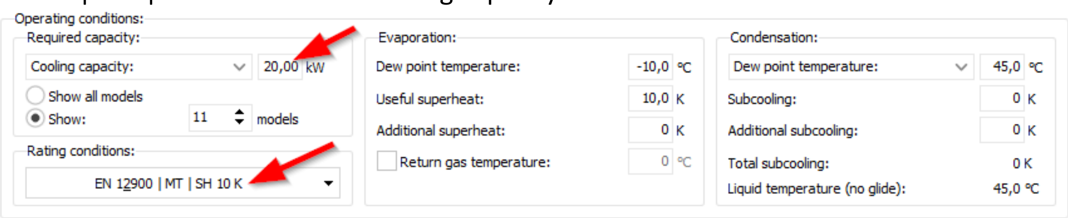
d) Which information is available in the detailed report for this compressor?

e) Which code numbers are available in the bill of materials after selecting this compressor and the two suggested spare parts (drive 01 and oil can)?

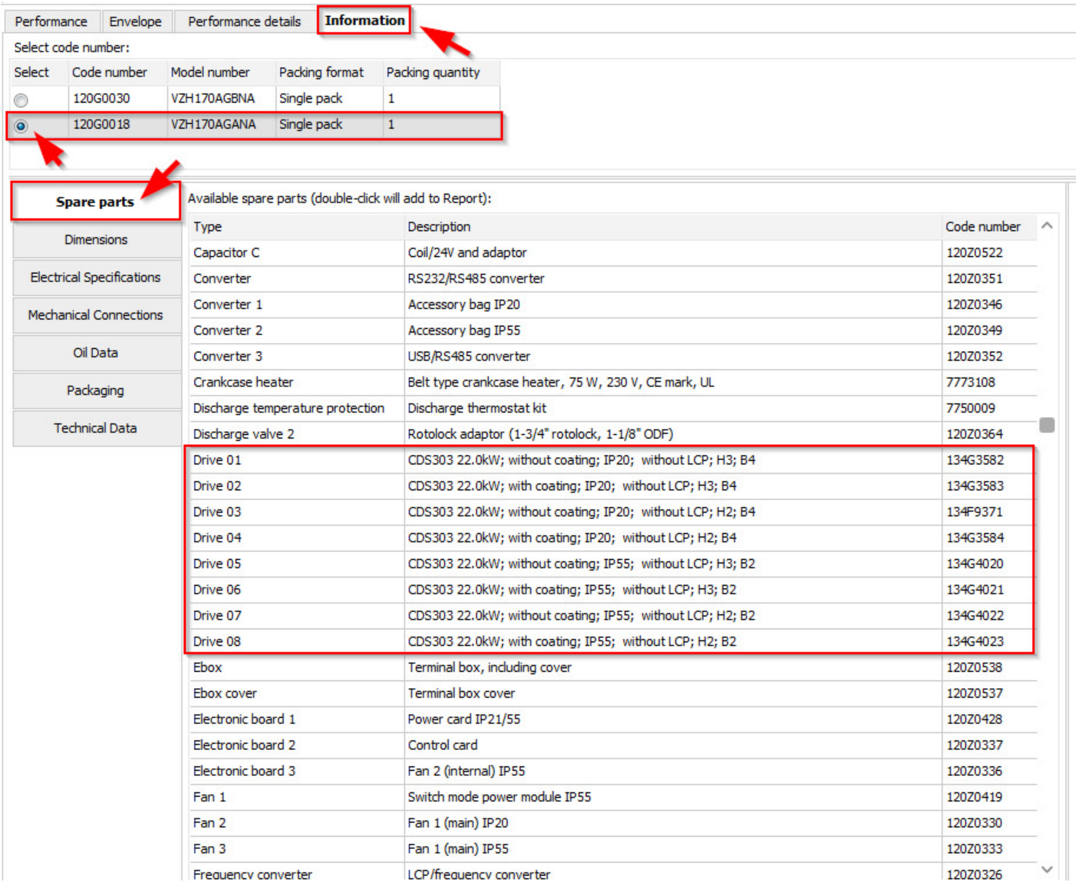
Solution 7.3 Selecting spare parts for compressors and creating a report

a) First locate VZH170AG by resetting any previous compressor selections and going to "Product filters:" and then "Select model:" and locate "VZH170AG, R410A" in the list:

Next, in the "Operating conditions:" pane locate "Rating conditions:" and choose 'EN 12900 | MT | SH 10 K" and set cooling capacity to 20 kW:



After this, go to the “Information” tab and select the correct code number (120G0018). Then select the “Spare parts” subtab and locate the drive choices, and you will find the following results:

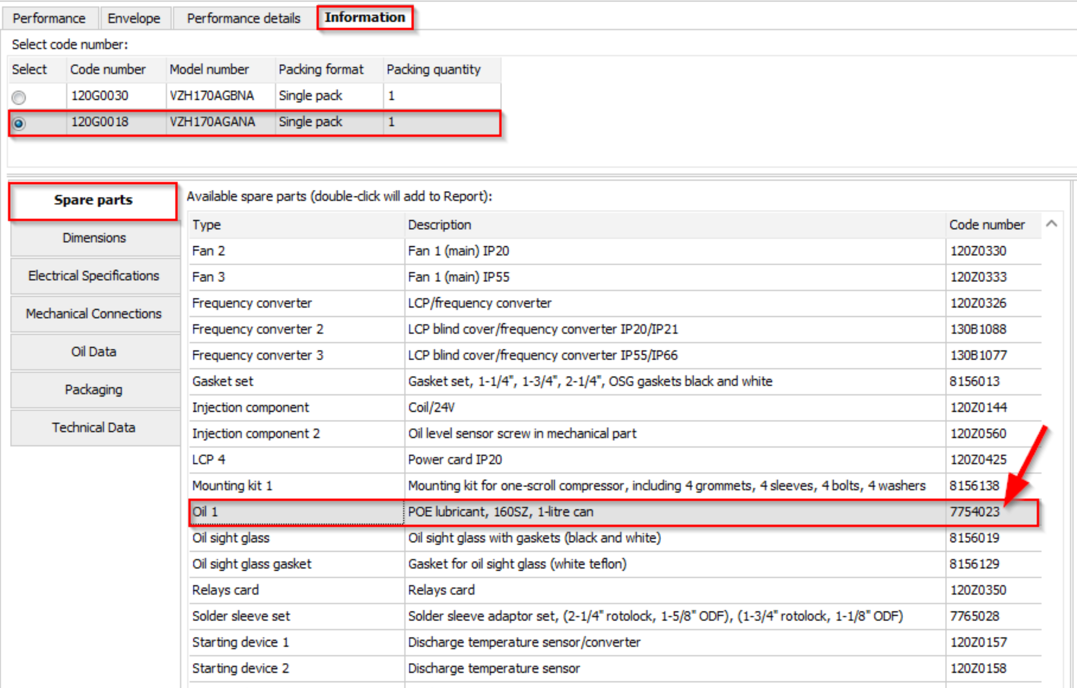


Select	Code number	Model number	Packing format	Packing quantity
	120G0030	VZH170AGBNA	Single pack	1
◉	120G0018	VZH170AGANA	Single pack	1

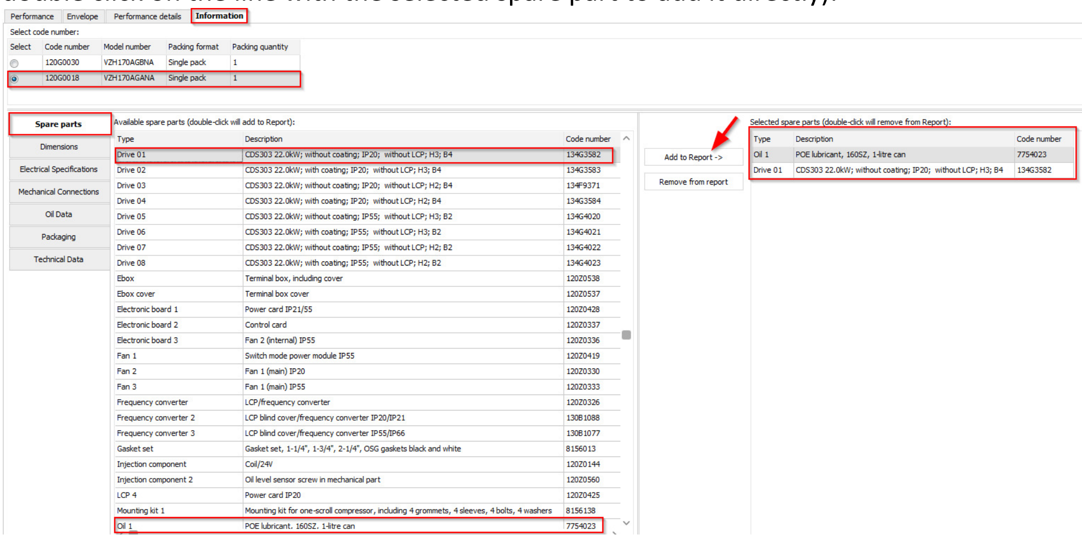
Type	Description	Code number
Capacitor C	Coil/24V and adaptor	120Z0522
Converter	RS232/RS485 converter	120Z0351
Converter 1	Accessory bag IP20	120Z0346
Converter 2	Accessory bag IP55	120Z0349
Converter 3	USB/RS485 converter	120Z0352
Crankcase heater	Belt type crankcase heater, 75 W, 230 V, CE mark, UL	7773108
Discharge temperature protection	Discharge thermostat kit	7750009
Discharge valve 2	Rotolock adaptor (1-3/4" rotolock, 1-1/8" ODF)	120Z0364
Drive 01	CDS303 22.0kW; without coating; IP20; without LCP; H3; B4	134G3582
Drive 02	CDS303 22.0kW; with coating; IP20; without LCP; H3; B4	134G3583
Drive 03	CDS303 22.0kW; without coating; IP20; without LCP; H2; B4	134F9371
Drive 04	CDS303 22.0kW; with coating; IP20; without LCP; H2; B4	134G3584
Drive 05	CDS303 22.0kW; without coating; IP55; without LCP; H3; B2	134G4020
Drive 06	CDS303 22.0kW; with coating; IP55; without LCP; H3; B2	134G4021
Drive 07	CDS303 22.0kW; without coating; IP55; without LCP; H2; B2	134G4022
Drive 08	CDS303 22.0kW; with coating; IP55; without LCP; H2; B2	134G4023
Ebox	Terminal box, including cover	120Z0538
Ebox cover	Terminal box cover	120Z0537
Electronic board 1	Power card IP21/55	120Z0428
Electronic board 2	Control card	120Z0337
Electronic board 3	Fan 2 (internal) IP55	120Z0336
Fan 1	Switch mode power module IP55	120Z0419
Fan 2	Fan 1 (main) IP20	120Z0330
Fan 3	Fan 1 (main) IP55	120Z0333
Frequency converter	LCP/frequency converter	120Z0326

There are several choices of drive for this compressor depending on whether you need board with coating or not, the required IP level, with and without display (LCP), and filter. For more detailed information on this option, please refer to the product guideline.

b) The code number for the oil can be located in the same place as the drives in the previous exercise. Once you locate the oil can, look in the column for “Code number” to get the answer to the question, namely; 7754023.

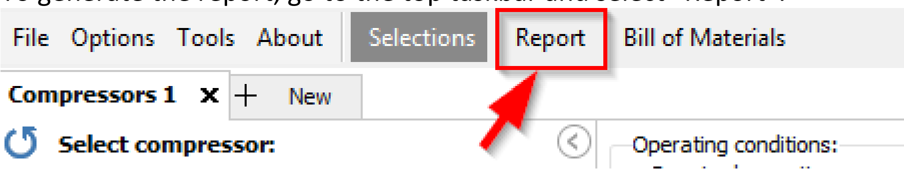


c) To add a spare part to the Coolselector®2 Report, click on the spare part you wish to add (in this case the oil can and e.g. ‘Drive 01’) and click on “Add to Report” (or alternatively, double click on the line with the selected spare part to add it directly):



You will now see the spare parts (and their code numbers) added on the right-hand side of the screen.

d) To generate the report, go to the top taskbar and select “Report”:



The report contains all relevant technical data for the project you are currently working on in Coolselector®2, including the operating conditions for each individual component, technical data such as COP, Power, current etc. (for compressors) as well as the selected code numbers and spare parts. In this example the report should look like this with the code number 120G0018 and drive code numbers 134G3582 and oil can 7754023:

Coolselector2

Project information

Project name:	
Comments:	
Created by:	
Coolselector2 version:	2.3.2. Database: 34.34.1.13.3.15
Printed:	13. august 2018
Preferences used:	All applications

Compressors 1

Operating conditions

Refrigerant:	R410A				
Evaporating dew point temperature:	-10,0	°C	Condensing dew point temperature:	45,0	°C
Evaporating pressure:	5,724	bar	Condensing pressure:	27,18	bar
Useful superheat:	10,0	K	Subcooling:	0	K
Additional superheat:	0	K	Additional subcooling:	0	K
Return gas temperature:	0	°C	Total subcooling:	0	K
			Liquid temperature (no glide):	45,0	°C
Rating conditions:	*EN 1&2900 | MT | SH 10 K*				
Required cooling capacity:	*20,00 kW*				

Selection: VZH170AG, R410A - 2389 rpm

Model	VZH170AG
Technology	Scroll
Configuration	Single
Refrigerant	R410A
Capacity control	Variable speed
Speed [rpm]	2389
Cooling [kW]	20,00
COP cooling [W/W]	2,27
Heating [kW]	28,39
COP heating [W/W]	3,22
Power [kW]	8,826
Current [A]	14,75
Frequency [Hz]	50
Power supply	380 - 400 V (415 V) 3 ph*
Mass flow [kg/h]	472,5

Selected code number and spare parts

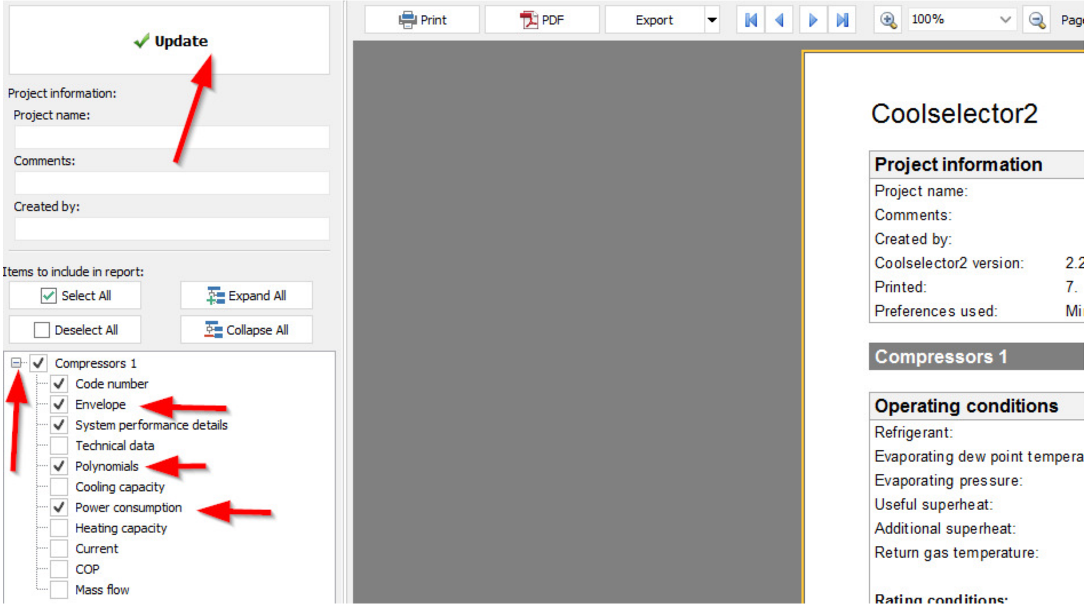
Code number: *120G0018. VZH170AGANA, Single pack pcs, 1*

Spare parts

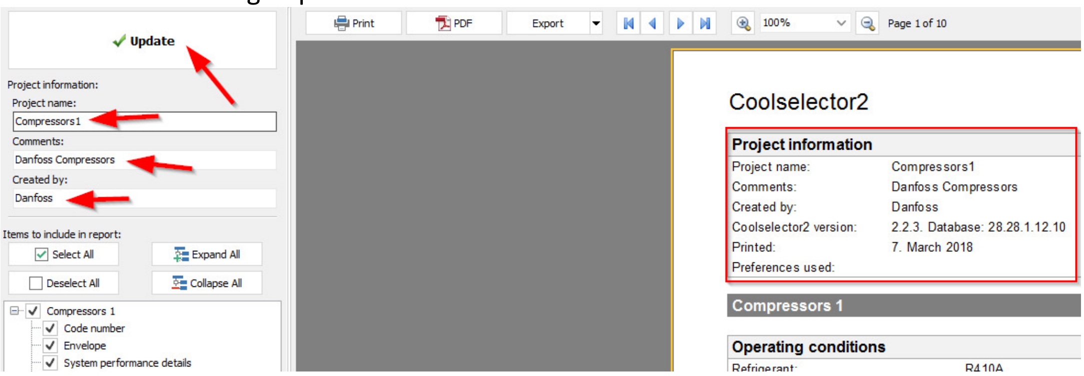
7754023	*Oil 1. POE lubricant, 160SZ, 1-litre can*
134G3582	*Drive 01. CDS303 22.0kW; without coating; IP20; without LCP; H3; B4*

Page 1/1

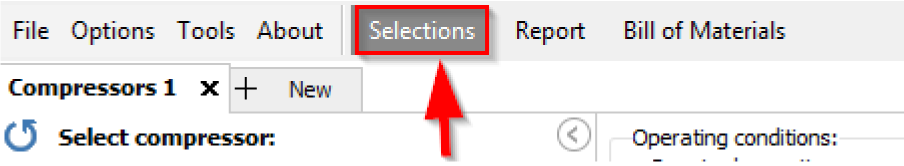
The report will expand as you add more components or calculations to your project in Coolselector®2. To add additional information about the compressor to your report, click on the +/- sign to the left of 'Compressor 1' and add more features to the report. Once done, click "Update" and the report will now be reloaded with further content (e.g. envelope, polynomials and power consumption):



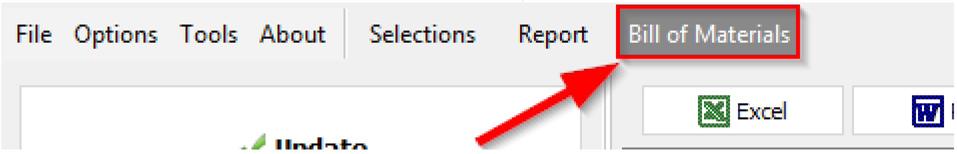
It is also possible to add Project name, Comments and Created by to the report by filling in this fields and clicking "Update":



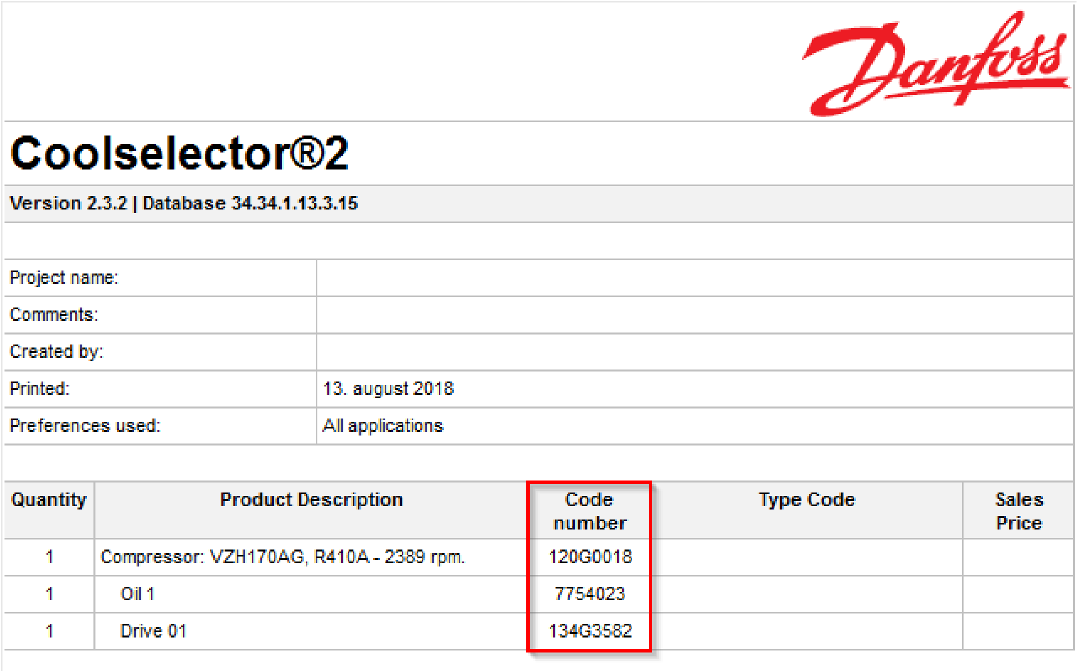
To go back to your selections overview, click on "Selections". You can always return to the report at any point by clicking again on "Report". The report will remember any additional information you added to it and/or your project name, comments and created by data:



e) You will find the "Bill of Materials" in the top task bar next to "Selections" and "Report":



The bill of materials contains information about the selected code numbers in your current Coolselector®2 project as well as any spare parts and accessories you have added (and their code numbers):



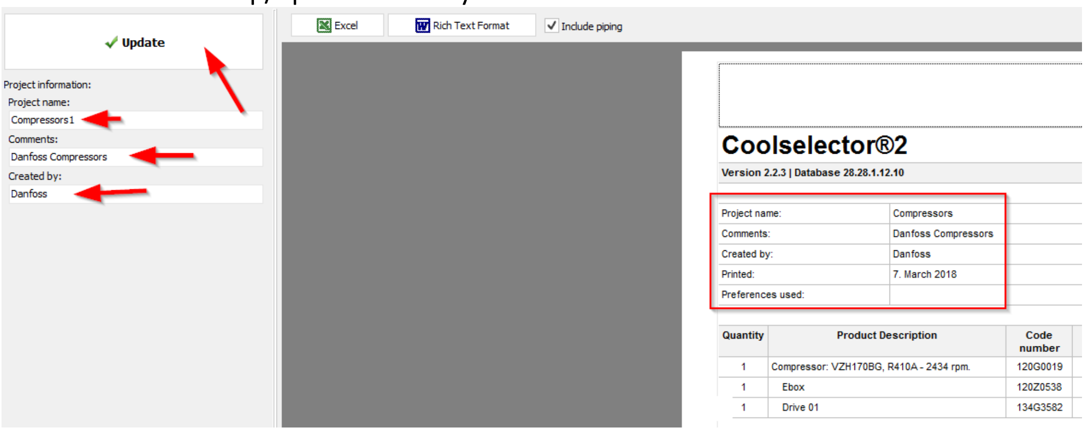
Coolselector®2

Version 2.3.2 | Database 34.34.1.13.3.15

Project name:	
Comments:	
Created by:	
Printed:	13. august 2018
Preferences used:	All applications

Quantity	Product Description	Code number	Type Code	Sales Price
1	Compressor: VZH170AG, R410A - 2389 rpm.	120G0018		
1	Oil 1	7754023		
1	Drive 01	134G3582		

The Bill of Materials will carry over any additional information you added to your project in the Report (and vice versa) such as your project name, comments and created by data – this can also be set up/updated directly from the Bill of Materials itself:



The report and the bill of material synthetize all selections done in Coolselector®2. For example, if you made an expansion device selection in the same session, you will find it here as well.

8 Condensing units

Exercise 8.1 Selecting a condensing unit

a) Select a condensing unit using the Coolselector®2 default conditions and selection criteria.

b) Which condensing unit is suggested by Coolselector®2?

c) Explain why there is a challenge in identifying the correct selection.

d) Now make a selection using the following criteria using the default operating conditions:

- Region: Europe
- Application: All
- Refrigerant: R448A
- Power Supply: 50 Hz // 380 - 400 V (415 V) 3 ph
- Product Range: Optyma™ Slim Pack

e) Which product versions of the Optyma™ Slim Pack can you choose from with the given selection criteria?

f) If the ambient temperature is reduced to +28 °C, what happens to the capacity match for the condensing unit model suggested by Coolselector®2?

g) Why is the capacity match important?

h) In the application part of the selections on the left-hand side, choose “Low back pressure (LBP)”. What result do you get?

i) Now in the same segment, only put a check mark in “universal”. What happens and why?

j) Please explain why keeping the application in mind is important when selecting a condensing unit.

k) Now clear all selections, and instead select the most suitable condensing unit using the following selections:

- Region: Europe
- Refrigerant: R404A
- Power Supply: 50 Hz // 380 - 400 V (415 V) 3ph
- Product range: Optyma™ Plus new generation
- Product version: P00 | Optyma™ Plus – Standard version
- Operating conditions:
    - Cooling capacity: 9.8 kW
    - Dew point temperature: -10 °C
    - Useful superheat: 8K
    - Additional superheat: 4 K
    - Ambient temperature: +32 °C
    - Subcooling; 1 K

l) Which code number does the selected condensing unit have?

m) Check if the chosen condensing unit can run under the following operating conditions:

- Cooling capacity: 9.8 kW
- Dew point temperature: - 9 °C
- Ambient temperature: +32 °C

n) Explain what the challenge is.

o) Reset the selection criteria and determine instead which condensing unit could be a better match if the operating conditions are as follows:

- Cooling capacity: 10 kW
- Dew point temperature: -10 °C
- Ambient temperature: +32 °C

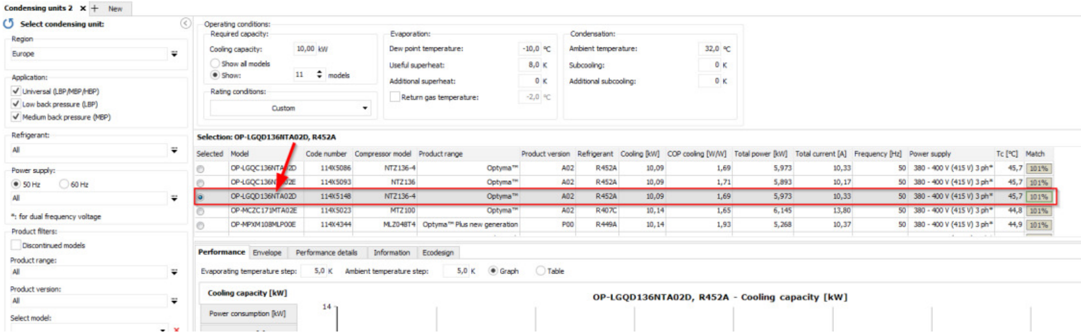
Solution 8.1 Selecting a condensing unit

a) Go to “New” tab, select “Compressors and condensing units” and click on the “Condensing units” button.

Before you start selecting, please remember the basics of component selection:

- The type of application for which the equipment is expected to provide cooling
- Required duty, minimum & maximum
- Refrigerant
- Power supply
- Location & ambient temperature

b) The condensing unit suggested by default by Coolselector®2 is the OP-LGQD 136NTA02D



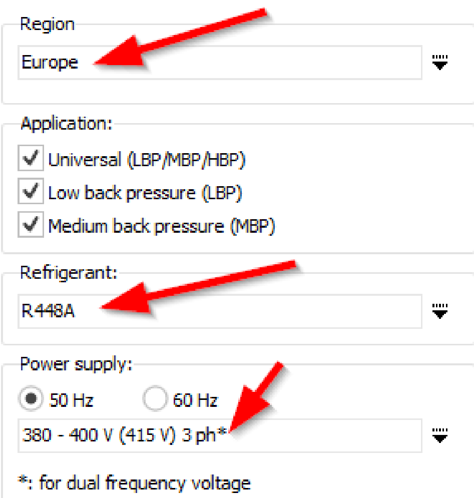
c) It is a challenge to see the correct selection clearly in the results list as there are 11 models to choose from, ranging from 98% capacity to 102%.

Selection: OP-LGQD136NTA02D, R452A

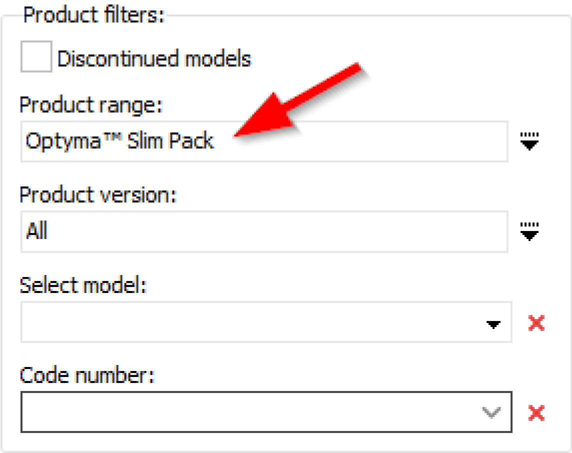
Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [kW]	COP cooling [W/W]	Total power [kW]	Total current [A]	Frequency [Hz]	Power supply	Tc [°C]	Match
	OP-MPXM108MLP00E	114X4344	MLZ048T4	Optyma™ Plus new generation	P00	R407A	9,841	1,90	5,180	10,16	50	380 - 400 V (415 V) 3 ph*	44,5	98%
	OP-MSXM108MLW05E	114X7072	MLZ048T4	Optyma™ Slim Pack	W05	R407A	9,841	1,90	5,180	10,16	50	380 - 400 V (415 V) 3 ph*	44,5	98%
	OP-MSXM108MLW09E	114X7206	MLZ048T4	Optyma™ Slim Pack	W09	R407A	9,841	1,90	5,180	10,16	50	380 - 400 V (415 V) 3 ph*	44,5	98%
	OP-LGQC136NTA02D	114X5086	NTZ136-4	Optyma™	A02	R452A	10,09	1,69	5,973	10,33	50	380 - 400 V (415 V) 3 ph*	45,7	101%
	OP-LGQC136NTA02E	114X5093	NTZ136	Optyma™	A02	R452A	10,09	1,71	5,893	10,17	50	380 - 400 V (415 V) 3 ph*	45,7	101%
	OP-LGQD136NTA02D	114X5148	NTZ136-4	Optyma™	A02	R452A	10,09	1,69	5,973	10,33	50	380 - 400 V (415 V) 3 ph*	45,7	101%
	OP-MCZC171MTA02E	114X5023	MTZ100	Optyma™	A02	R407C	10,14	1,65	6,145	13,80	50	380 - 400 V (415 V) 3 ph*	44,8	101%
	OP-MPXM108MLP00E	114X4344	MLZ048T4	Optyma™ Plus new generation	P00	R449A	10,14	1,93	5,268	10,37	50	380 - 400 V (415 V) 3 ph*	44,9	101%
	OP-MSXM108MLW05E	114X7072	MLZ048T4	Optyma™ Slim Pack	W05	R449A	10,14	1,93	5,268	10,37	50	380 - 400 V (415 V) 3 ph*	44,9	101%
	OP-MSXM108MLW09E	114X7206	MLZ048T4	Optyma™ Slim Pack	W09	R449A	10,14	1,93	5,268	10,37	50	380 - 400 V (415 V) 3 ph*	44,9	101%
	OP-MPXM108MLP00E	114X4344	MLZ048T4	Optyma™ Plus new generation	P00	R448A	10,16	1,93	5,270	10,37	50	380 - 400 V (415 V) 3 ph*	44,9	102%

d) To set the selection criteria, first use the menu on the left-hand side to select the following:

- Region – it is best to select a region to get the correct product range – in this case: ‘Europe’
- Application – it is always a good idea to select the application, but in this case, we will leave it as the default (all selected).
- Refrigerant – it is also a good idea to make this selection – in this case: R448A
- Power supply – to avoid making the wrong selection, this should be selected – in this case: 50 Hz // 380 - 400 V (415 V) 3 ph



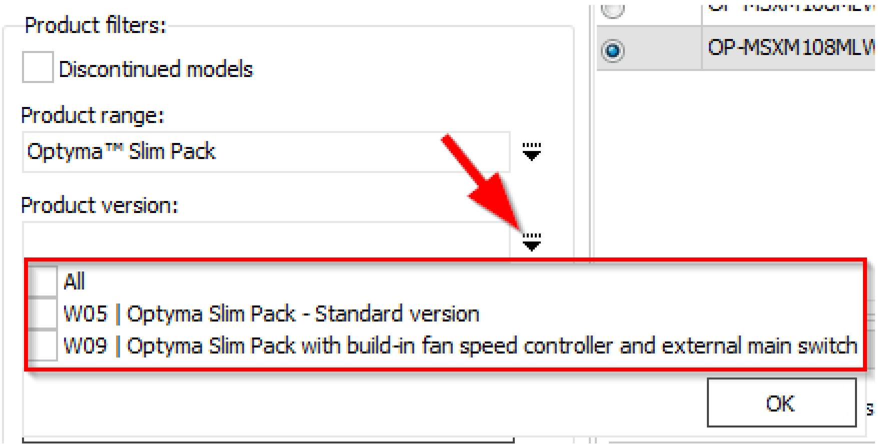
Also from the left-hand side menu, make the following selections in product filters: product range set to Optyma™ Slim Pack.



e) The available models are:

- W05 | Optyma Slim Pack – Standard version
- W09 | Optyma Slim Pack with build-in fan speed controller and external main switch

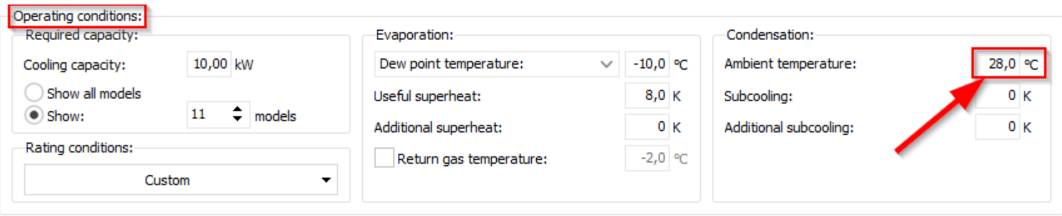
You will find the available product versions in the drop-down box on the left-hand side of the screen called 'Product version'. Please be aware that what is available here will depend on your previous choices, particularly refrigerant selection. Therefore, also be aware that if you change anything in any of the selection boxes above, your selections in product filters are not affected:



Alternatively, you can also see the models by looking in the selection table:

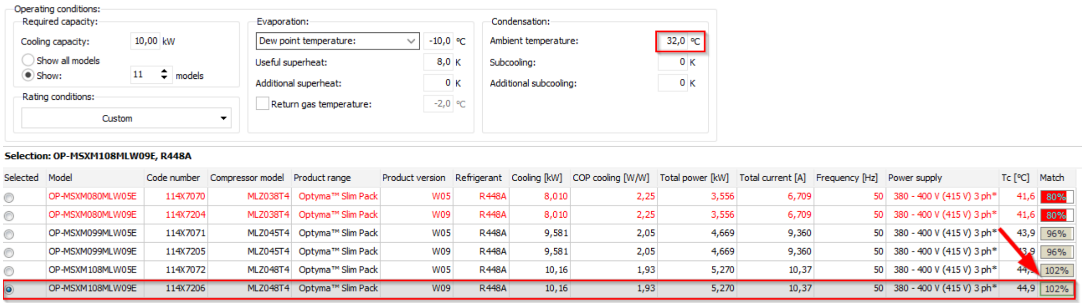
Selected	Model
○	OP-MSXM080MLW05E
○	OP-MSXM080MLW09E
○	OP-MSXM099MLW05E
○	OP-MSXM099MLW09E
○	OP-MSXM108MLW05E
●	OP-MSXM108MLW09E

f) Change the ambient temperature in the 'Operating conditions' at the top of the screen and set it to +28 °C:

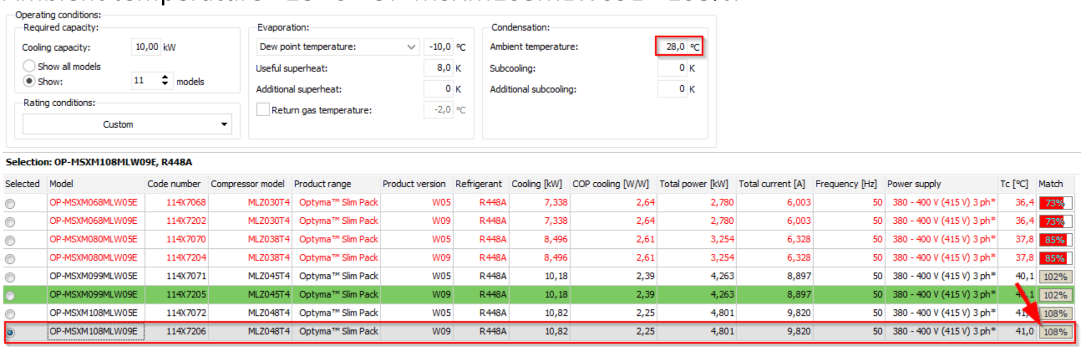


This means that the capacity match for the suggested model (OP-MSXM108MLW09E) goes from 102% to 108% (please note that the suggested model changes):

Ambient temperature +32 °C - OP-MSXM108MLW09E - 102%:



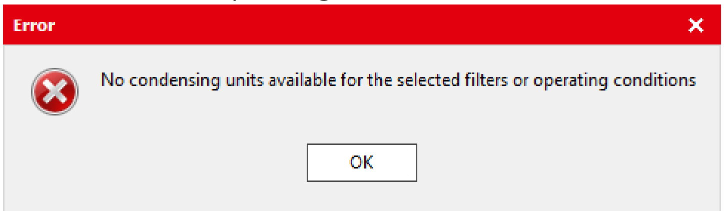
Ambient temperature +28 °C - OP-MSXM108MLW09E - 108%:



g) The capacity match is important because it is preferable to have a condensing unit running more often, rather than having a constant stop/start cycle on the thermostat.

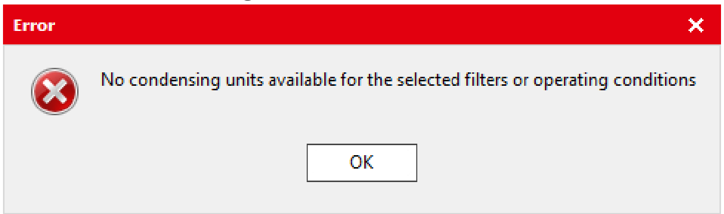
In relation hereto, it is important to remember that all selections in Coolselector®2 are made for a 'worst case scenario' and therefore it is important to keep the application in mind at all times.

h) Go to the 'Applications' part of the selection menu on the left-hand side and uncheck 'universal' and 'MBP'. You will get the message that "No condensing units available for the selected filters or operating conditions":



The reason for this error is that Danfoss have no Optyma™ Slim Packs which are approved for LBP on R448A.

i) If you just tick ‘Universal’ (LBP/MBP/HBP), Coolselector®2 again returns the same error that: “No condensing units available for the selected filters or operating conditions”:



The warning is generated because the selection in Coolselector®2 is based on factory logic. Choosing ‘Universal’ means using a household compressor and based on the selection for electrical supply there is no match for this.

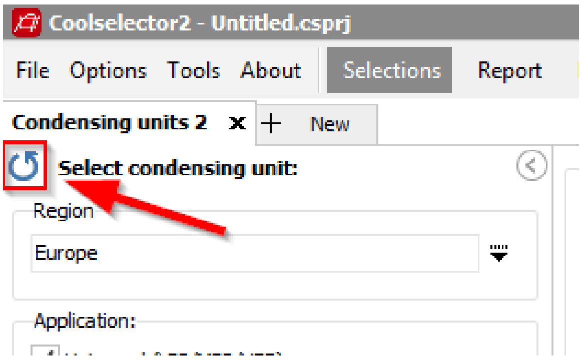
j) We have just seen how both checking ‘LBP’ and ‘Universal’ generates no result. This is due to the selection criteria (and product availability for those). This makes it evident how important it is to consider the application before starting to select a condensing unit in Coolselector®2.

As an example, if it is a simple cold room operating at -20 °C evaporation temperature, then the NTZ compressor is better for this application.

If, however, it is a blast freeze you are looking for, then the MLZ compressor is better since it can cope with a higher suction pressure to begin with during the pull-down cycle.

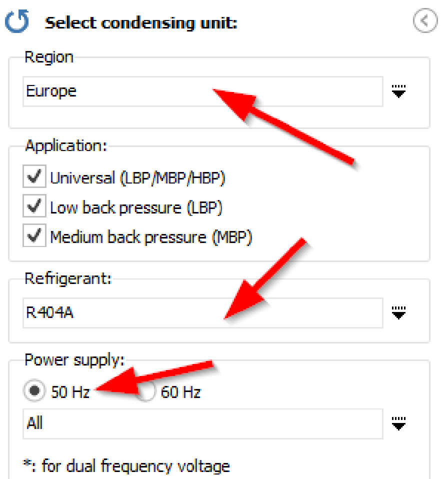
As is evident – always consider your application before using a selection tool!

k) First clear the current selections by clicking on the blue arrow icon near the top left corner of the screen:



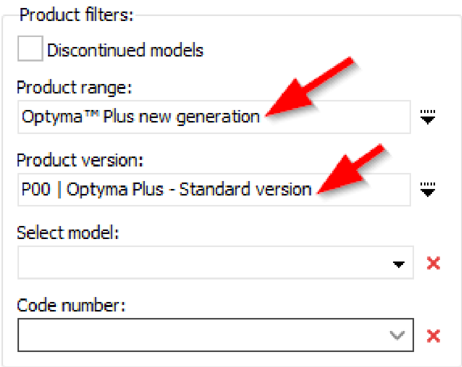
Next, use the menu on the left-hand side to select the following:

- Region: Europe
- Refrigerant: R404A
- Power supply: 50 Hz // 380 - 400 V (415 V) 3 ph

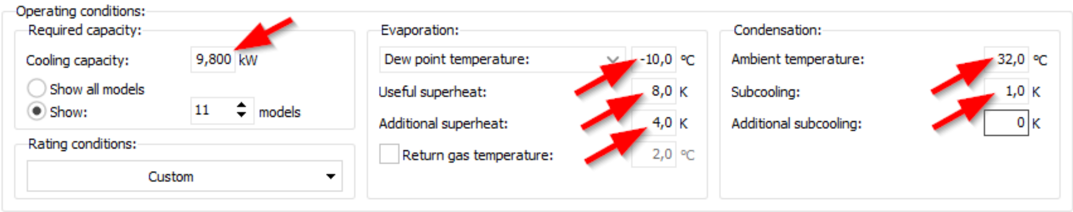


Also, from the left-hand side menu, make the following selections in product filters:

- Product range: Optyma™ Plus new generation
- Product version: P00 | Optyma Plus – Standard version

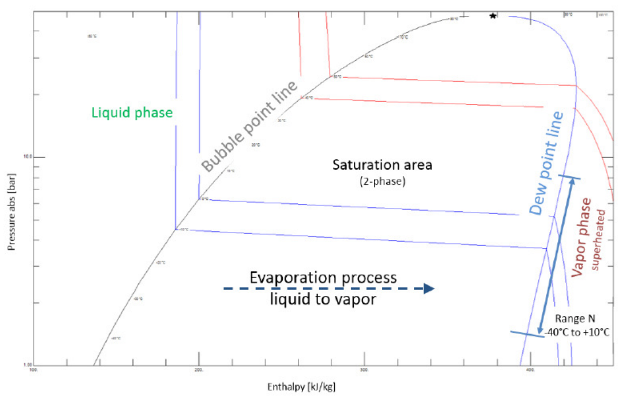


Set the operating conditions as specified in the assignment:



An overview of the “operating conditions” options for condensing units in Coolselector®2:

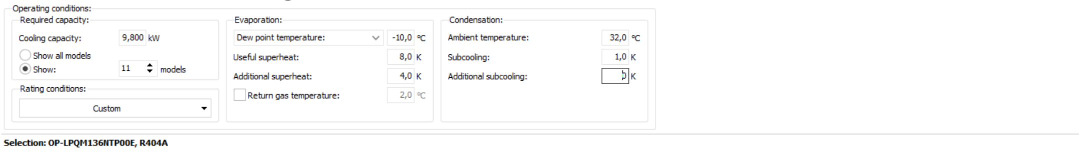
- Required capacity:
  - Cooling capacity: Default set 10 KW
  - Show all models or show a number: Depending on what is selected in the left-hand side menu, this will determine how many models are shown here
  - Rating conditions: Leave as custom unless you want a specific rating condition. The way back is to change a condition, it then reverts to custom
- Evaporation:
  - Dew point temperature: -10 °C is the default
  - Useful Superheat: Meaning SH in the evaporator – 8 K
  - Additional superheat: Meaning suction SH – 4K average value. Depending on the length of suction pipe returning to the compressor & the condition of the insulation on the suction line (heat transfer is from warm to cold)
  - Alternatively, you can specify a return gas temperature



- Condensation
  - Ambient temperature: Default set to 32 °C

- Is the unit inside or outside? We assume it is outside, but it is advised that you always check this condition
- Subcooling: SC at the condenser outlet. Enter 1K subcooling, to avoid errors when continuing with further component selections such as TEV
- Additional subcooling: Leave at 0 K.

l) The selected condensing unit has code number 114X3365.



Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [kW]	COP cooling [W/W]	Total power [kW]	Total current [A]	Frequency [Hz]	Power supply	Tc [°C]	Speed [rpm]	Match
	OP-MPXM080MLP00G	114X4321	MLZ038T5	Optyma™ Plus new generation	P00	R404A	8,183	2,05	3,992	21,13	50	220 - 240 V 1 ph	42,1	2900	84%
	OP-MPXM080MLP00E	114X4324	MLZ038T4	Optyma™ Plus new generation	P00	R404A	8,262	2,17	3,812	7,135	50	380 - 400 V (415 V) 3 ph*	42,0	2900	84%
◉	OP-LPQM136NTP00E	114X3365	NTZ136-4	Optyma™ Plus new generation	P00	R404A	9,803	1,61	6,103	11,06	50	380 - 400 V (415 V) 3 ph*	45,3	2900	100%
	OP-MPXM108MLP00E	114X4344	MLZ048T4	Optyma™ Plus new generation	P00	R404A	10,22	1,89	5,396	11,63	50	380 - 400 V (415 V) 3 ph*	45,0	2900	104%
	OP-MPXM125MLP00E	114X4414	MLZ058T4	Optyma™ Plus new generation	P00	R404A	12,68	2,06	6,148	11,87	50	380 - 400 V (415 V) 3 ph*	42,2	2900	129%

m) It cannot run under those conditions, because the new cooling criteria is outside of the operating envelope.

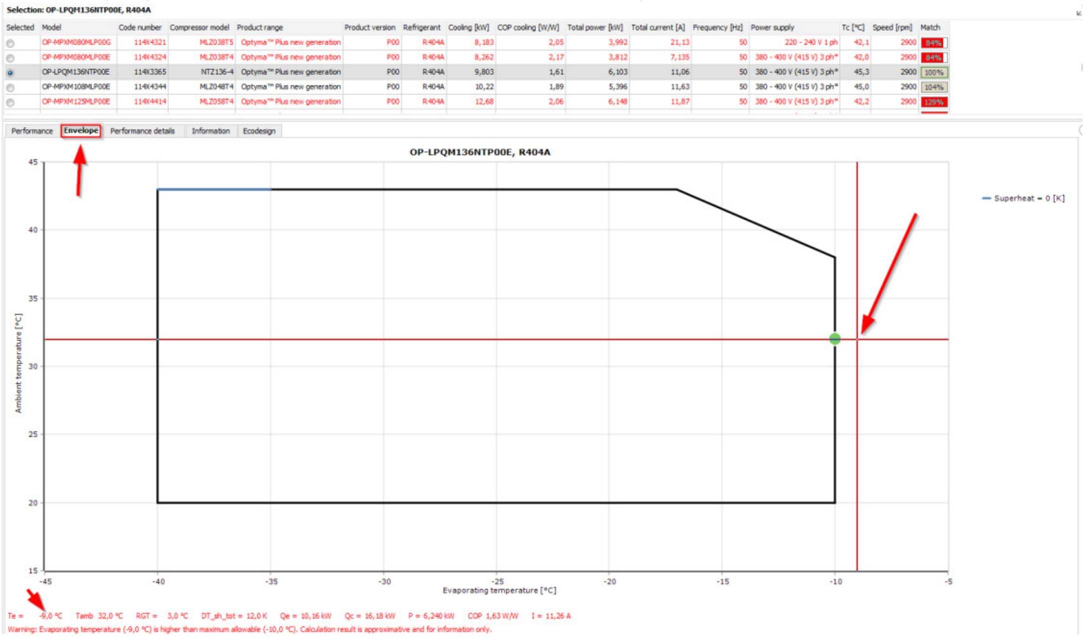
Click on the tab 'Envelope' to see the operating envelope for the selected condensing unit. The green dot marks the operating point, as given by the operating conditions, whilst you can check the performance details, such as COP, on any other combination of ambient and evaporation temperature in the envelope by moving the mouse pointer to the new point.

The COP is a measure of the cooling capacity, compared to the amount of power input to the system. The power input is the sum of the compressor and fan power:

$$COP = \frac{Cooling\ capacity}{Power\ input}$$

Thus, the cursor point on the graph shows where the green point would be for any given combination of evaporation and condensation temperature.

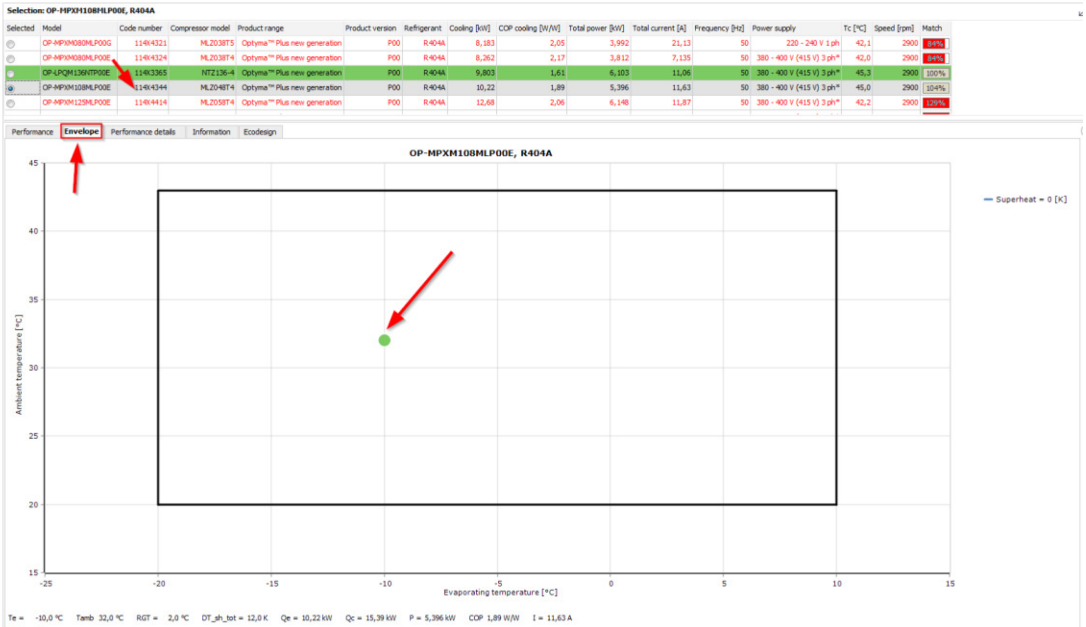
If you move your cursor to fit with -9 °C on the image of the envelope, you will clearly note that the perpendicular vertex is outside of the envelope:



n) The challenge is that the condensing unit (114X3365) has an operating point which is at the extreme of the operating envelope.

o) When considering which condensing unit to choose for these conditions, 114X4344 is a better match, since its operating envelope is more adapted to the application.

In addition to that, 114X4344 is equipped with a scroll compressor, which will have a better COP and will accept more fluids. This means that it will be more flexible for future retrofit.



The important lesson to learn here is to ensure you consider alternative selections given your operation conditions. Coolselector®2 always suggests the best matched selection for the exact given capacity, but your knowledge of the application and specific operating conditions should also be taken into consideration before making the final choice.

Exercise 8.2 Selecting spare parts for a condensing unit

a) Find the code number for the receiver and filter drier spare part for an Optyma™ Slim Pack condensing unit available in Europe with code number 114X7406.

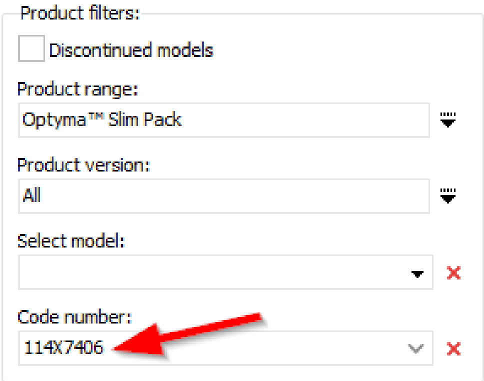
b) What are the code numbers of the suggested filter drier and receiver?

c) Add the spare parts to the Coolselector®2 report.

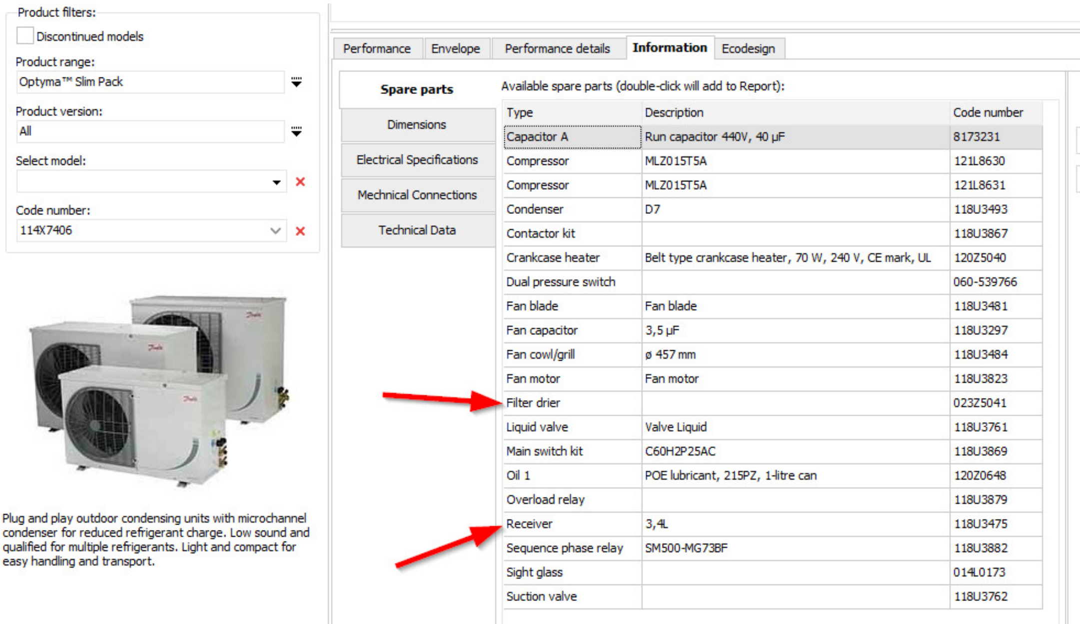
Solution 8.2 Selecting spare parts for a condensing unit

a) Go to “New” tab, select “Compressors and condensing units” and click on the “Condensing units” button.

Go straight down to “Product filters” and type in code number: 114X7406



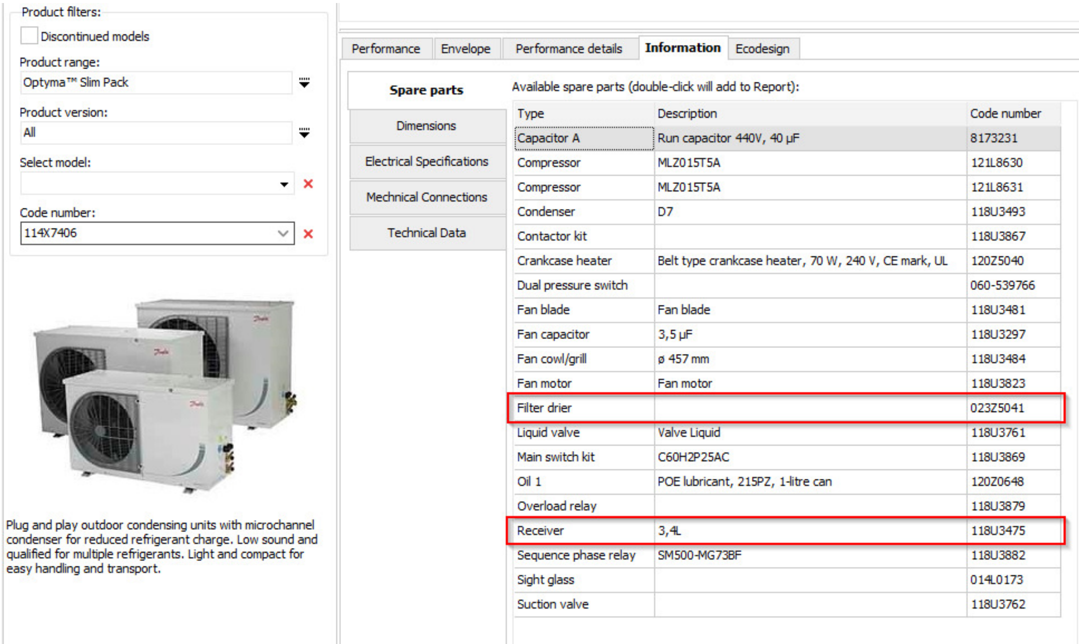
Locate the “Information” tab and find the lines for “filter drier” and “receiver”:



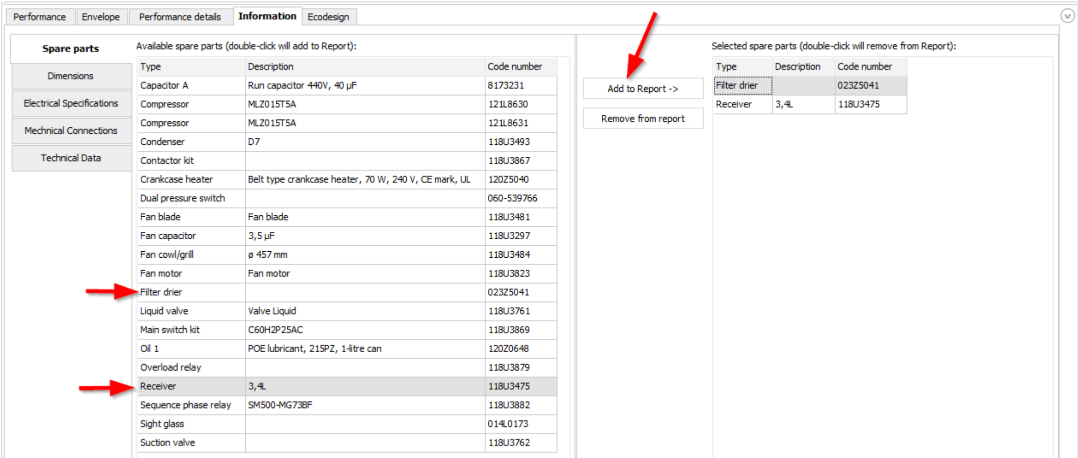
Type	Description	Code number
Capacitor A	Run capacitor 440V, 40 µF	8173231
Compressor	MLZ015T5A	121L8630
Compressor	MLZ015T5A	121L8631
Condenser	D7	118U3493
Contactor kit		118U3867
Crankcase heater	Belt type crankcase heater, 70 W, 240 V, CE mark, UL	120Z5040
Dual pressure switch		060-539766
Fan blade	Fan blade	118U3481
Fan capacitor	3,5 µF	118U3297
Fan cowl/grill	ø 457 mm	118U3484
Fan motor	Fan motor	118U3823
Filter drier		023Z5041
Liquid valve	Valve Liquid	118U3761
Main switch kit	C60H2P25AC	118U3869
Oil 1	POE lubricant, 215PZ, 1-litre can	120Z0648
Overload relay		118U3879
Receiver	3,4L	118U3475
Sequence phase relay	SM500-MG73BF	118U3882
Sight glass		014L0173
Suction valve		118U3762

b) The code numbers are:

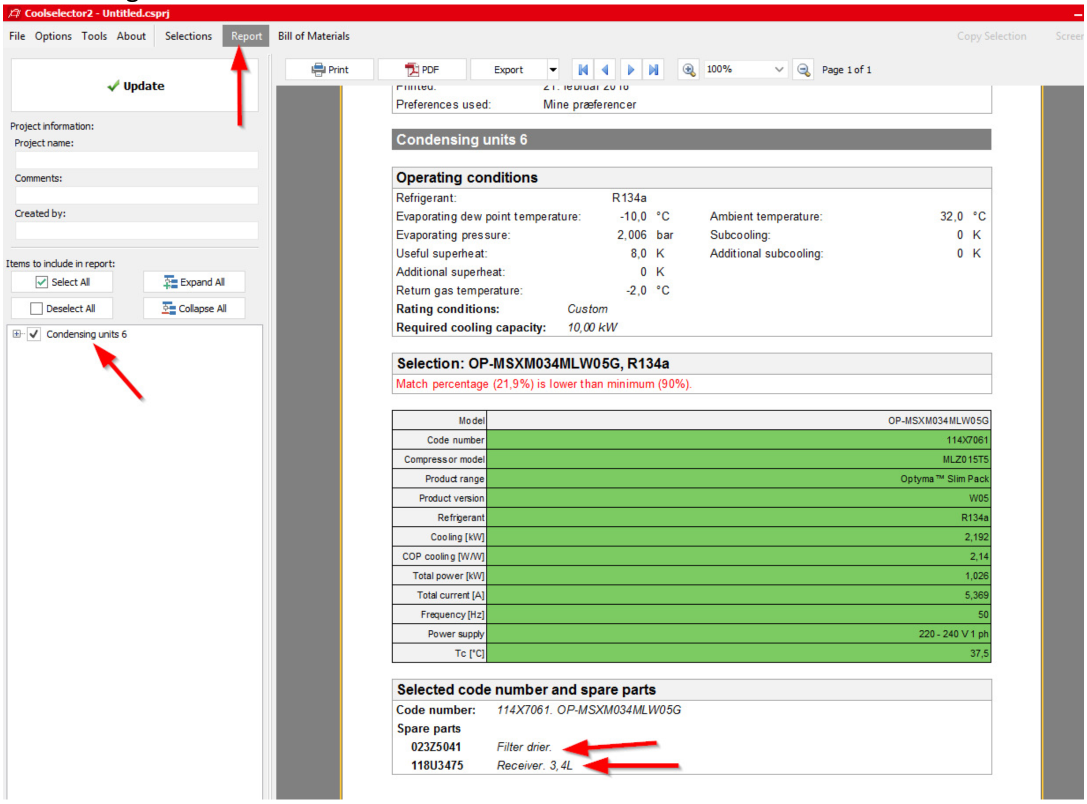
- Filter drier: 023Z5041
- Receiver: 118U3475



c) Click on the line with "filter drier" and then click on "Add to Report ->":



If you now go to the "Report" you will see that these two spare parts are added to the condensing unit:



Exercise 8.3 Selecting a condensing unit in systems with long suction lines

Select a condensing unit with the following selection criteria:

- Region: Europe
- Application: Low Back Pressure (LBP)
- Refrigerant: R452A
- Power supply: 50 Hz, 380-415 V 3 ph
- Product range: Optyma
- Cooling capacity: 10 kW
- Evaporator dew point temperature: -25 °C
- Useful superheat: 8 K
- Additional superheat: 4 K
- Ambient temperature: 32 °C
- Condenser subcooling: 1 K

a) What is the suggested condensing unit? What is the match percentage (duty match)?

b) What is the proper velocity in the suction line of condensing units in general for horizontal and vertical pipes? Can you explain why?

c) In this system there is 20 m of DIN-EN 35 copper pipe in the suction line. How does this suction pipe affect the duty match?

d) What is the effect on duty match if the length of the suction pipe is 70 m? Can you explain why?

Solution 8.3 Selecting a condensing unit in systems with long suction lines

Following the steps similar to exercise Exercise 8.1, Coolselector®2 would suggest the following options for this selection criteria and operating conditions:

Operating conditions:

Required capacity:
- Cooling capacity: 10,00 kW
- Show all models
- Show: 11 models

Rating conditions: Custom

Evaporation:
- Dew point temperature: -25,0 °C
- Useful superheat: 8,0 K
- Additional superheat: 4,0 K
- Return gas temperature: -13,0 °C

Condensation:
- Ambient temperature: 32,0 °C
- Subcooling: 1,0 K
- Additional subcooling: 0 K

Selection: OP-LGQN271NTA02E, R452A

Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [kW]	COP cooling [W/W]	Total power [kW]	Total current [A]	Frequency [Hz]	Power supply	Tc [°C]	Match
○	OP-LGQN108NTA02E	114X5769	NTZ108-4B	Optyma™	A02	R452A	4,583	1,60	2,864	5,670	50	380 - 400 V (415 V) 3 ph*	37,0	46%
○	OP-LCQN136NTA02E	114X5772	NTZ136-4B	Optyma™	A02	R452A	5,493	1,39	3,966	8,136	50	380 - 400 V (415 V) 3 ph*	39,1	55%
○	OP-LGQN136NTA02E	114X5771	NTZ136-4B	Optyma™	A02	R452A	5,594	1,44	3,881	7,491	50	380 - 400 V (415 V) 3 ph*	[illegible],4	56%
○	OP-L[illegible]N215NTA02E	[illegible]X5774	NTZ215-4B	Optyma™	A02	R452A	8,183	1,33	6,136	10,87	50	380 - 400 V (415 V) 3 ph*	38,[illegible]	82%
◉	OP-LGQN271NTA02E	114X5776	NTZ271-4B	Optyma™	A02	R452A	10,39	1,33	7,786	13,28	50	380 - 400 V (415 V) 3 ph*	40,0	104%

a) The suggested condensing unit is OP-LGQN271NTA02E with code number 114X5776. The duty match is 104%.

b) For good oil return, velocity should be between 4 to 8 m/s for horizontal pipe & between 8 to 12 m/s for vertical pipe. Gas velocities greater than 12 m/s will create high noise levels and high suction line pressure drop, which will decrease system capacity.

c) The selected copper pipe size gives a velocity of 10. m/s and a saturation temperature drop of 0.6 K:

Selected	Type	NS	DP [bar]	DT_sat [K]	DP [K/m]	Velocity, in [m/s]	Velocity, out [m/s]	Result
○	DIN-EN 22	22	0,663	8,2	0,411	26,56	37,98	✓
○	DIN-EN 28	28	0,198	2,2	0,112	17,00	18,69	✓
◉	DIN-EN 35	35	0,057	0,6	0,032	10,37	10,65	✓
○	DIN-EN 42	42	0,022	0,2	0,012	6,99	7,05	✓
○	DIN-EN 54	54	0,007	0,1	0,004	4,25	4,26	✓

This means the suction saturated temperature in the condensing unit now would be -25.6 °C (-25 °C original selection - 0.6 K suction saturated temperature drop = -25.6 °C)

If we then run the selection of the condensing unit again with this new lower evaporating temperature, the capacity available only drops by 3% and the condensing unit still has a capacity match of 101% against the required duty.

Selection: OP-LGQN271NTA02E, R452A

Selected	Model	Compressor model	Product range	Code number	Cooling [kW]	Total power [kW]	Frequency [Hz]	Speed [rpm]	Tc [°C]	Match
○	OP-LCQN108NTA02E	NTZ108-4B	Optyma™	114X5768	4.385	2.896	50	2900	37.4	44%
○	OP-LGQN108NTA02E	NTZ108-4B	Optyma™	114X5769	4.446	2.819	50	2900	36.9	44%
○	OP-LCQN136NTA02E	NTZ136-4B	Optyma™	114X5772	5.335	3.903	50	2900	38.9	53%
○	OP-LGQN136NTA02E	NTZ136-4B	Optyma™	114X5771	5.430	3.818	50	2900	38.2	54%
○	OP-LGQN215NTA02E	NTZ215-4B	Optyma™	114X5774	7.939	6.045	50	2900	38.1	79%
◉	OP-LGQN271NTA02E	NTZ271-4B	Optyma™	114X5776	10.09	7.661	50	2900	39.8	101%

d) It can be seen that if we keep the same pipe, it would keep the velocity high enough to ensure good oil return in a mix of vertical & horizontal pipe sections. However, the suction saturation temperature drop would be 2.4 K. This means the condensing unit would now be evaporating at -27.4°C.

If we then run the selection of the condensing unit again with this new lower evaporating temperature, the capacity available drops by 12%, meaning the capacity match is now only 92% against the required capacity.

This highlights the need to understand the consequences of having a long suction pipe and how it effects the capacity of the condensing unit.

Exercise 8.4 Selecting an Optyma Plus™ inverter

a) Select an Optyma Plus™ inverter using the following selection criteria and operating conditions:

- Application: MBP
- Refrigerant: R407F
- Power supply: 50 Hz // 380 - 400 V (415 V) 3 ph
- Product range: Optyma Plus™ Inverter
- Cooling capacity: 9 kW
- Dew point temperature: -5 °C

b) Which Optyma Plus™ inverter is suggested by Coolselector®2?

c) What is the speed at 98% of the load?

d) What is the speed at 90% load?

e) Please explain what is important to remember about speed in relation to the evaporator(s).

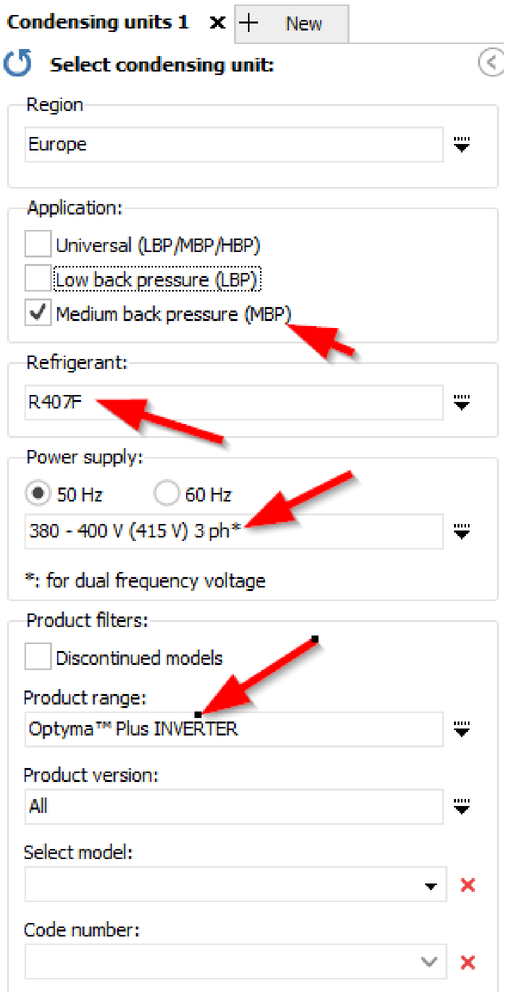
f) Please explain what happens if the ambient temperature drops.

Solution 8.4 Selecting an Optyma™ Plus inverter

a) Go to “New” tab, select “Compressors and condensing units” and click on the “Condensing units” button.

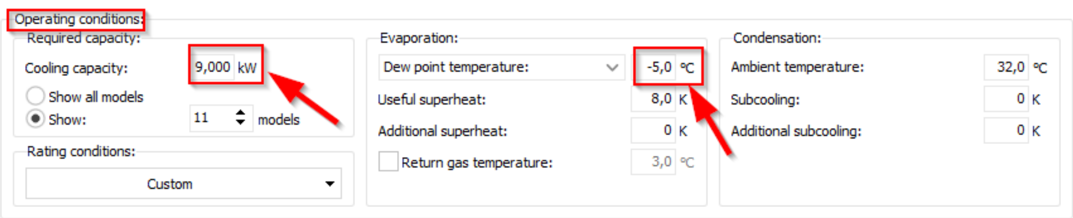
To set the selection criteria, first, use the menu on the left-hand side to select the following:

- Application: MBP
- Refrigerant: R407F
- Power supply: 50 Hz // 380 - 400 V (415 V) 3 ph
- Product range: Optyma Plus™ Inverter



Next, type in the given operating conditions:

- Cooling capacity: 9 kW
- Dew point temperature: -5 °C

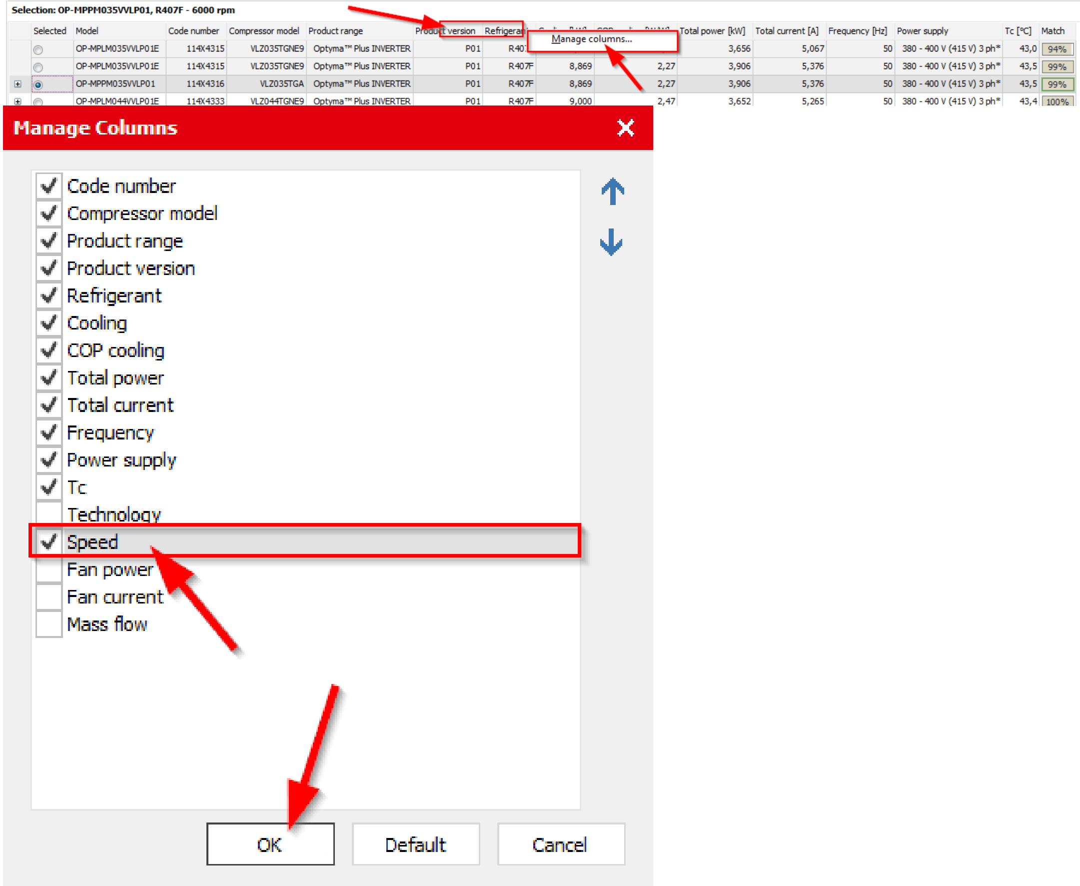


b) Coolselector®2 suggests the Optyma Plus™ inverter model OP-MPPM035VVLP01 (code number 114X4316) as the best match for the given selections and operating conditions:

Selection: OP-MPPM035VVLP01, R407F - 6000 rpm

Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [kW]	COP cooling [W/W]	Total power [kW]	Total current [A]	Frequency [Hz]	Power supply	Tc [°C]	Match
○	OP-MPLM035VVLP01E	114X4315	VLZ035TGNE9	Optyma™ Plus INVERTER	P01	R407F	8,503	2,33	3,656	5,067	50	380 - 400 V (415 V) 3 ph*	43,0	94%
○	OP-MPLM035VVLP01E	114X4315	VLZ035TGNE9	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	99%
◉	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	99%
○	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	2,805	2,49	1,128	1,416	50	380 - 400 V (415 V) 3 ph*	35,4	31%
○	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	3,314	2,60	1,275	1,678	50	380 - 400 V (415 V) 3 ph*	36,0	37%

c) As is evident from the screen dump of the selection table in the previous answer snippet, it is not possible to find the speed directly in the table. However, if you right click with your mouse in the headline area of the selection table, a menu will pop out that allows you to choose additional data columns:

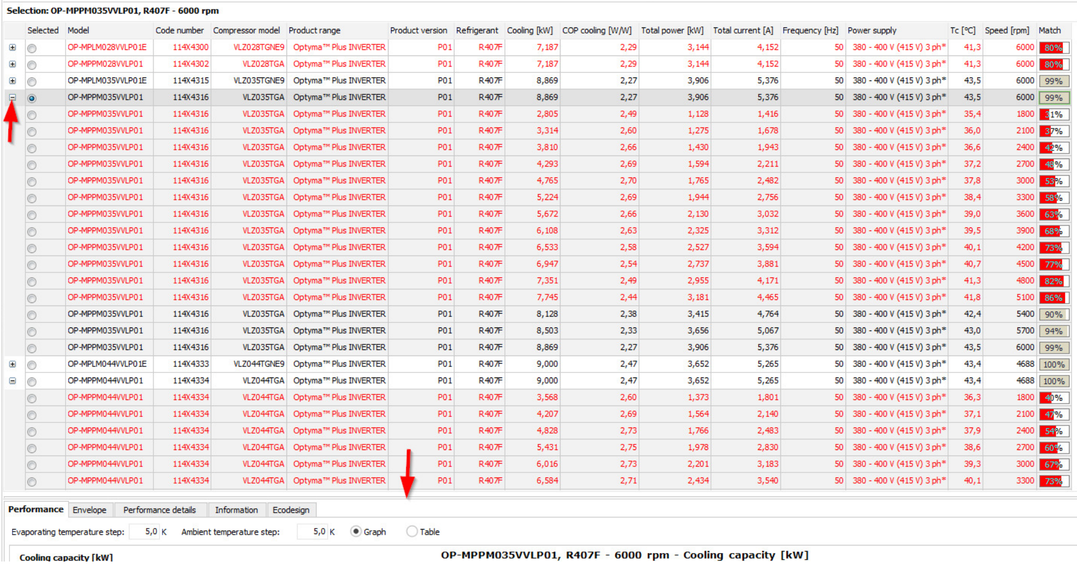


You can now read the result for the speed at 99% of the load (6000 rpm) directly in the selection table:

Selection: OP-MPPM035VVLP01, R407F - 6000 rpm

Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [kW]	COP cooling [W/W]	Total power [kW]	Total current [A]	Frequency [Hz]	Power supply	Tc [°C]	Speed [rpm]	Match
○	OP-MPLM035VVLP01E	114X4315	VLZ035TGNE9	Optyma™ Plus INVERTER	P01	R407F	8,503	2,33	3,656	5,067	50	380 - 400 V (415 V) 3 ph*	43,0	5700	94%
○	OP-MPLM035VVLP01E	114X4315	VLZ035TGNE9	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	6000	99%
◉	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	6000	99%
○	OP-MPLM044VVLP01E	114X4333	VLZ044TGNE9	Optyma™ Plus INVERTER	P01	R407F	9,000	2,47	3,652	5,265	50	380 - 400 V (415 V) 3 ph*	43,4	4688	100%
○	OP-MPPM044VVLP01	114X4334	VLZ044TGA	Optyma™ Plus INVERTER	P01	R407F	9,000	2,47	3,652	5,265	50	380 - 400 V (415 V) 3 ph*	43,4	4688	100%

d) To see the speed at 90% load, you must first click on the + sign on the left-hand side of the selected model. This drills down just that selected unit and shows the duty at the various speed levels. After doing this, you need to make the middle window bigger to get the full drop-down list. You do this by clicking and dragging the line separating the selection window from the operating envelope window with your mouse pointer:



Selection: OP-MPPM035VVLP01, R407F - 6000 rpm

Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [kW]	COP cooling [W/W]	Total power [kW]	Total current [A]	Frequency [Hz]	Power supply	Tc [°C]	Speed [rpm]	Match
	OP-MPLM028VVLP01E	114X4300	VLZ028TGNE9	Optyma™ Plus INVERTER	P01	R407F	7,187	2,29	3,144	4,152	50	380 - 400 V (415 V) 3 ph*	41,3	6000	80%
	OP-MPPM028VVLP01	114X4302	VLZ028TGA	Optyma™ Plus INVERTER	P01	R407F	7,187	2,29	3,144	4,152	50	380 - 400 V (415 V) 3 ph*	41,3	6000	80%
	OP-MPLM035VVLP01E	114X4315	VLZ035TGNE9	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	6000	99%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	6000	99%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	2,805	2,49	1,128	1,416	50	380 - 400 V (415 V) 3 ph*	35,4	1800	31%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	3,314	2,60	1,275	1,678	50	380 - 400 V (415 V) 3 ph*	36,0	2100	37%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	3,810	2,66	1,430	1,943	50	380 - 400 V (415 V) 3 ph*	36,6	2400	42%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	4,293	2,69	1,594	2,211	50	380 - 400 V (415 V) 3 ph*	37,2	2700	48%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	4,765	2,70	1,765	2,482	50	380 - 400 V (415 V) 3 ph*	37,8	3000	53%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	5,224	2,69	1,944	2,756	50	380 - 400 V (415 V) 3 ph*	38,4	3300	58%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	5,672	2,66	2,130	3,032	50	380 - 400 V (415 V) 3 ph*	39,0	3600	63%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	6,108	2,63	2,325	3,312	50	380 - 400 V (415 V) 3 ph*	39,5	3900	68%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	6,533	2,58	2,527	3,594	50	380 - 400 V (415 V) 3 ph*	40,1	4200	73%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	6,947	2,54	2,737	3,881	50	380 - 400 V (415 V) 3 ph*	40,7	4500	77%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	7,351	2,49	2,955	4,171	50	380 - 400 V (415 V) 3 ph*	41,3	4800	82%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	7,745	2,44	3,181	4,465	50	380 - 400 V (415 V) 3 ph*	41,8	5100	86%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,128	2,38	3,415	4,764	50	380 - 400 V (415 V) 3 ph*	42,4	5400	90%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,503	2,33	3,656	5,067	50	380 - 400 V (415 V) 3 ph*	43,0	5700	94%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	6000	99%
	OP-MPLM044VVLP01E	114X4333	VLZ044TGNE9	Optyma™ Plus INVERTER	P01	R407F	9,000	2,47	3,652	5,265	50	380 - 400 V (415 V) 3 ph*	43,4	4688	100%
	OP-MPPM044VVLP01	114X4334	VLZ044TGA	Optyma™ Plus INVERTER	P01	R407F	9,000	2,47	3,652	5,265	50	380 - 400 V (415 V) 3 ph*	43,4	4688	100%
	OP-MPPM044VVLP01	114X4334	VLZ044TGA	Optyma™ Plus INVERTER	P01	R407F	3,568	2,60	1,373	1,801	50	380 - 400 V (415 V) 3 ph*	36,3	1800	40%
	OP-MPPM044VVLP01	114X4334	VLZ044TGA	Optyma™ Plus INVERTER	P01	R407F	4,207	2,69	1,564	2,140	50	380 - 400 V (415 V) 3 ph*	37,1	2100	47%
	OP-MPPM044VVLP01	114X4334	VLZ044TGA	Optyma™ Plus INVERTER	P01	R407F	4,828	2,73	1,766	2,483	50	380 - 400 V (415 V) 3 ph*	37,9	2400	54%
	OP-MPPM044VVLP01	114X4334	VLZ044TGA	Optyma™ Plus INVERTER	P01	R407F	5,431	2,75	1,978	2,830	50	380 - 400 V (415 V) 3 ph*	38,6	2700	60%
	OP-MPPM044VVLP01	114X4334	VLZ044TGA	Optyma™ Plus INVERTER	P01	R407F	6,016	2,73	2,201	3,183	50	380 - 400 V (415 V) 3 ph*	39,3	3000	67%
	OP-MPPM044VVLP01	114X4334	VLZ044TGA	Optyma™ Plus INVERTER	P01	R407F	6,584	2,71	2,434	3,540	50	380 - 400 V (415 V) 3 ph*	40,1	3300	73%

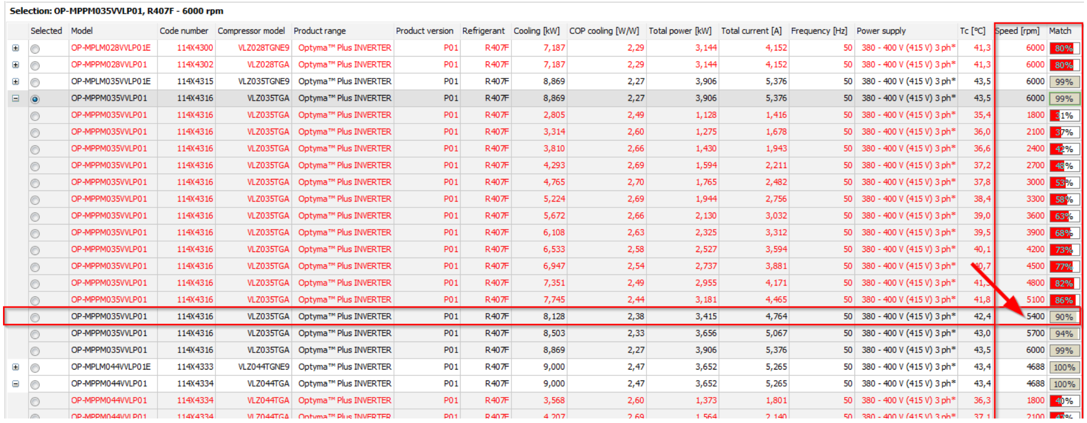
Performance | Envelope | Performance details | Information | Ecodesign

Evaporating temperature step: 5,0 K Ambient temperature step: 5,0 K Graph Table

Cooling capacity [kW]

OP-MPPM035VVLP01, R407F - 6000 rpm - Cooling capacity [kW]

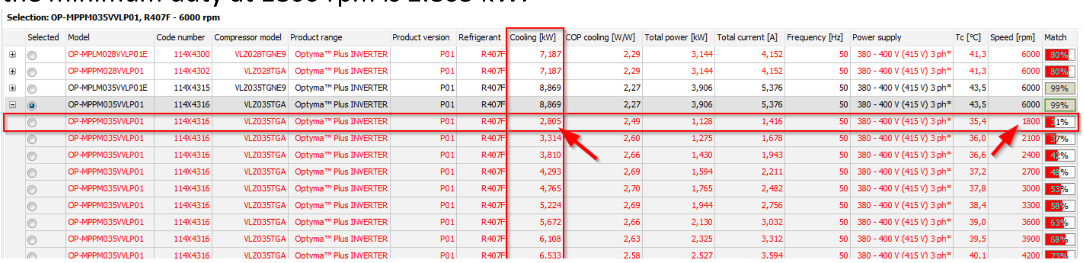
You can now read directly in the table that the speed at 90% of the load is 5400 rpm.



Selection: OP-MPPM035VVLP01, R407F - 6000 rpm

Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [kW]	COP cooling [W/W]	Total power [kW]	Total current [A]	Frequency [Hz]	Power supply	Tc [°C]	Speed [rpm]	Match
	OP-MPLM028VVLP01E	114X4300	VLZ028TGNE9	Optyma™ Plus INVERTER	P01	R407F	7,187	2,29	3,144	4,152	50	380 - 400 V (415 V) 3 ph*	41,3	6000	80%
	OP-MPPM028VVLP01	114X4302	VLZ028TGA	Optyma™ Plus INVERTER	P01	R407F	7,187	2,29	3,144	4,152	50	380 - 400 V (415 V) 3 ph*	41,3	6000	80%
	OP-MPLM035VVLP01E	114X4315	VLZ035TGNE9	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	6000	99%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	6000	99%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	2,805	2,49	1,128	1,416	50	380 - 400 V (415 V) 3 ph*	35,4	1800	31%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	3,314	2,60	1,275	1,678	50	380 - 400 V (415 V) 3 ph*	36,0	2100	37%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	3,810	2,66	1,430	1,943	50	380 - 400 V (415 V) 3 ph*	36,6	2400	42%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	4,293	2,69	1,594	2,211	50	380 - 400 V (415 V) 3 ph*	37,2	2700	48%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	4,765	2,70	1,765	2,482	50	380 - 400 V (415 V) 3 ph*	37,8	3000	53%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	5,224	2,69	1,944	2,756	50	380 - 400 V (415 V) 3 ph*	38,4	3300	58%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	5,672	2,66	2,130	3,032	50	380 - 400 V (415 V) 3 ph*	39,0	3600	63%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	6,108	2,63	2,325	3,312	50	380 - 400 V (415 V) 3 ph*	39,5	3900	68%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	6,533	2,58	2,527	3,594	50	380 - 400 V (415 V) 3 ph*	40,1	4200	73%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	6,947	2,54	2,737	3,881	50	380 - 400 V (415 V) 3 ph*	40,7	4500	77%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	7,351	2,49	2,955	4,171	50	380 - 400 V (415 V) 3 ph*	41,3	4800	82%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	7,745	2,44	3,181	4,465	50	380 - 400 V (415 V) 3 ph*	41,8	5100	86%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,128	2,38	3,415	4,764	50	380 - 400 V (415 V) 3 ph*	42,4	5400	90%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,503	2,33	3,656	5,067	50	380 - 400 V (415 V) 3 ph*	43,0	5700	94%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	6000	99%
	OP-MPLM044VVLP01E	114X4333	VLZ044TGNE9	Optyma™ Plus INVERTER	P01	R407F	9,000	2,47	3,652	5,265	50	380 - 400 V (415 V) 3 ph*	43,4	4688	100%
	OP-MPPM044VVLP01	114X4334	VLZ044TGA	Optyma™ Plus INVERTER	P01	R407F	9,000	2,47	3,652	5,265	50	380 - 400 V (415 V) 3 ph*	43,4	4688	100%
	OP-MPPM044VVLP01	114X4334	VLZ044TGA	Optyma™ Plus INVERTER	P01	R407F	3,568	2,60	1,373	1,801	50	380 - 400 V (415 V) 3 ph*	36,3	1800	40%

e) It is important to consider that the condensing unit capacity at minimum speed is not higher than the cooling capacity of the smallest evaporator. If it is, this can lead the compressor to work outside of its operating envelope and consequently have a reduced lifetime of the compressor. From the selection table in Coolselector®2, you can see that the minimum duty at 1800 rpm is 2.805 kW:



Selection: OP-MPPM035VVLP01, R407F - 6000 rpm

Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [kW]	COP cooling [W/W]	Total power [kW]	Total current [A]	Frequency [Hz]	Power supply	Tc [°C]	Speed [rpm]	Match
	OP-MPLM028VVLP01E	114X4300	VLZ028TGNE9	Optyma™ Plus INVERTER	P01	R407F	7,187	2,29	3,144	4,152	50	380 - 400 V (415 V) 3 ph*	41,3	6000	80%
	OP-MPPM028VVLP01	114X4302	VLZ028TGA	Optyma™ Plus INVERTER	P01	R407F	7,187	2,29	3,144	4,152	50	380 - 400 V (415 V) 3 ph*	41,3	6000	80%
	OP-MPLM035VVLP01E	114X4315	VLZ035TGNE9	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	6000	99%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,869	2,27	3,906	5,376	50	380 - 400 V (415 V) 3 ph*	43,5	6000	99%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	2,805	2,49	1,128	1,416	50	380 - 400 V (415 V) 3 ph*	35,4	1800	31%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	3,314	2,60	1,275	1,678	50	380 - 400 V (415 V) 3 ph*	36,0	2100	37%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	3,810	2,66	1,430	1,943	50	380 - 400 V (415 V) 3 ph*	36,6	2400	42%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	4,293	2,69	1,594	2,211	50	380 - 400 V (415 V) 3 ph*	37,2	2700	48%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	4,765	2,70	1,765	2,482	50	380 - 400 V (415 V) 3 ph*	37,8	3000	53%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	5,224	2,69	1,944	2,756	50	380 - 400 V (415 V) 3 ph*	38,4	3300	58%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	5,672	2,66	2,130	3,032	50	380 - 400 V (415 V) 3 ph*	39,0	3600	63%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	6,108	2,63	2,325	3,312	50	380 - 400 V (415 V) 3 ph*	39,5	3900	68%

f) We just concluded that the minimum duty at 1800 rpm is 2.805kW for the selected condensing unit. However, remember to consider your operating conditions. This figure is relevant only for an ambient temperature of +32 °C. If the ambient temperature is lower, the capacity goes up.

You can test this by setting a lower ambient temperature in Coolselector®2, e.g. +25 °C, you will now see that the minimum duty at 1800 rpm has gone up to 3.036 kW:

Selection: OP-MPPM035VVLP01, R407F - 5583 rpm

Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [kW]	COP cooling [W/W]	Total power [kW]	Total current [A]	Frequency [Hz]	Power supply	Tc [°C]	Speed [rpm]	Match
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	9,000	2,79	3,232	4,447	50	380 - 400 V (415 V) 3 ph*	36,0	5583	100%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	3,036	3,06	0,992	1,261	50	380 - 400 V (415 V) 3 ph*	28,5	1800	34%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	3,579	3,19	1,123	1,488	50	380 - 400 V (415 V) 3 ph*	29,1	2100	40%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	4,110	3,25	1,263	1,722	50	380 - 400 V (415 V) 3 ph*	29,7	2400	46%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	4,628	3,28	1,410	1,961	50	380 - 400 V (415 V) 3 ph*	30,3	2700	51%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	5,134	3,28	1,566	2,204	50	380 - 400 V (415 V) 3 ph*	30,9	3000	57%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	5,628	3,25	1,730	2,452	50	380 - 400 V (415 V) 3 ph*	31,6	3300	63%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	6,110	3,21	1,901	2,704	50	380 - 400 V (415 V) 3 ph*	32,1	3600	68%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	6,580	3,16	2,080	2,959	50	380 - 400 V (415 V) 3 ph*	32,7	3900	73%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	7,038	3,10	2,267	3,218	50	380 - 400 V (415 V) 3 ph*	33,3	4200	78%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	7,484	3,04	2,462	3,479	50	380 - 400 V (415 V) 3 ph*	33,9	4500	83%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	7,919	2,97	2,665	3,743	50	380 - 400 V (415 V) 3 ph*	34,5	4800	88%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,343	2,90	2,875	4,010	50	380 - 400 V (415 V) 3 ph*	35,1	5100	93%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	8,755	2,83	3,094	4,280	50	380 - 400 V (415 V) 3 ph*	35,7	5400	97%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	9,156	2,76	3,320	4,553	50	380 - 400 V (415 V) 3 ph*	36,2	5700	102%
	OP-MPPM035VVLP01	114X4316	VLZ035TGA	Optyma™ Plus INVERTER	P01	R407F	9,547	2,69	3,553	4,830	50	380 - 400 V (415 V) 3 ph*	36,8	6000	106%

Exercise 8.5 Finding AWEF values for condensing units in North America

a) Please explain what AWEF is an abbreviation of.

b) What is AWEF defined as?

c) When is an AWEF value required?

d) Using standard operating conditions and the following settings:

- Region: North America
- Power supply: 60 Hz

What is the AWEF value for the condensing unit with code number 114N3496 for R404A?

e) What could be the cause of the AWEF tab not appearing for a condensing unit in Coolselector®2?

f) Please find the model and code number within Coolselector®2 of a condensing unit that can be used in a walk-in cooler in North America after July 10, 2020 with the following operating conditions:

- Region: North America
- Application: Medium back pressure (MBP)
- Refrigerant: R404A
- Power supply: 60 Hz // 208 – 220 V 1 ph
- Cooling capacity: 1.833 TR (22,000 BTU/h or 6448 W)
- Rating conditions: ARI 520 | MT | RGT 40°F

g) What is the AWEF value for the condensing unit from the previous question?

h) Can the unit also be used with R449A and, if so, what is the AWEF value for this?

Solution 8.5 Finding AWEF values for condensing units in North America

a) AWEF is an abbreviation of '**A**nnual **W**alk-in **E**nergy **F**actor'.

b) AWEF is defined as the ratio of heat removed from the envelope to the total energy input of the refrigeration system over one year.

For the first time, the Department of Energy (DOE) in the United States rule establishes minimum energy efficiency standards expressed in terms of Annual Walk-in Energy Factor (AWEF):

- EERE-2015-BT-STD-0016]   RIN 1904-AD59
- Energy Conservation Program: Energy Conservation Standards for Walk-in Cooler and Freezer Refrigeration Systems

AWEF values are governed by;

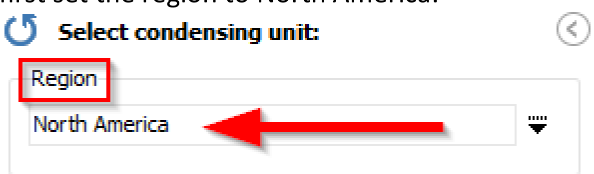
- EERE-2016-BT-TP-0030]   RIN 1904-AD72
- Energy Conservation Program: Test Procedure for Walk-in Coolers and Walk-in Freezers

c) AWEF is required on new walk-in coolers and freezers (cold rooms) or their components installed on or past January 1, 2020 or July 10, 2020 depending on the component.

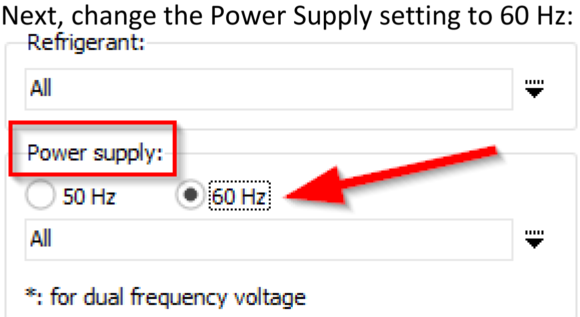
AWEF is valid for (this list is not exhaustive, there may be other examples not included here):

- Complete Walk-In Cooler or Freezer if supplied complete
- Multiplex Refrigeration System – Low or Medium Temperature (Unit cooler/Evap)
- Dedicated Condensing System Indoor and Outdoor (Condensing Unit)
- Doors
- Wall panels

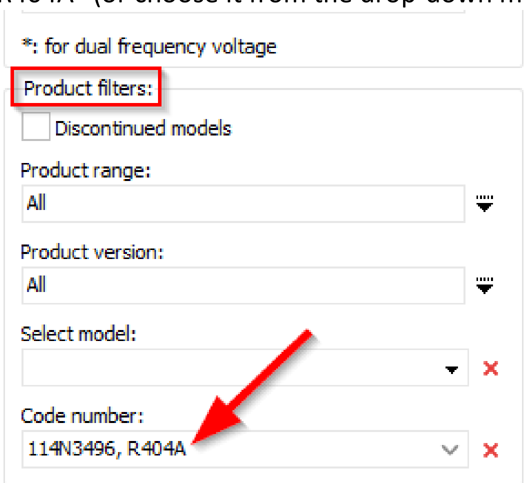
d) To find the AWEF value in Coolselector®2 for code number 114N3496 for R404A, you must first set the region to North America:



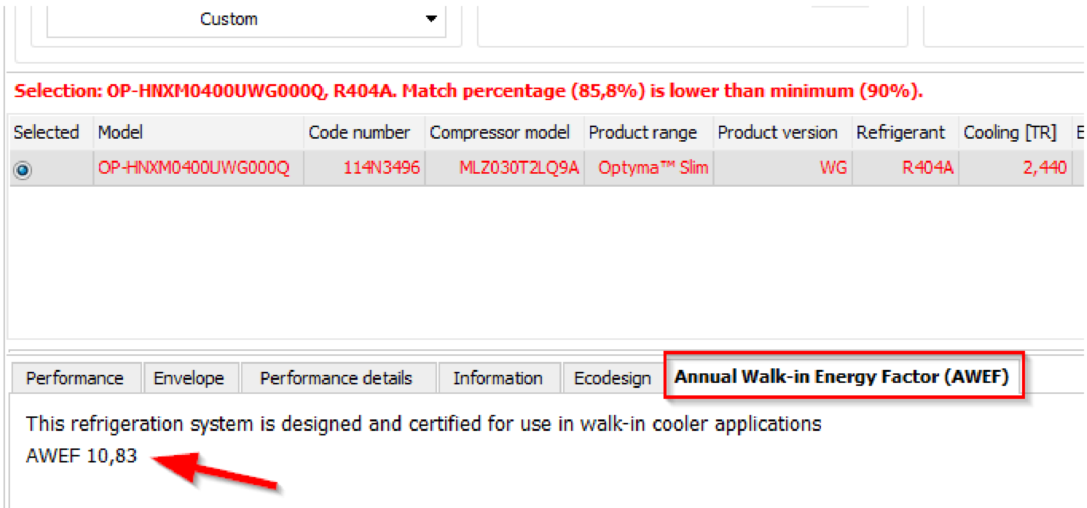
Next, change the Power Supply setting to 60 Hz:



Once this is done, go down to the 'Product filters' and in 'Code number' type "114N3496, R404A" (or choose it from the drop-down menu):



Underneath the selection table, you will now see the tab called "Annual Walk-in Energy Factor (AWEF). Within this tab you can now see that the AWEF value for 114N3496 for R404A is 10.83:

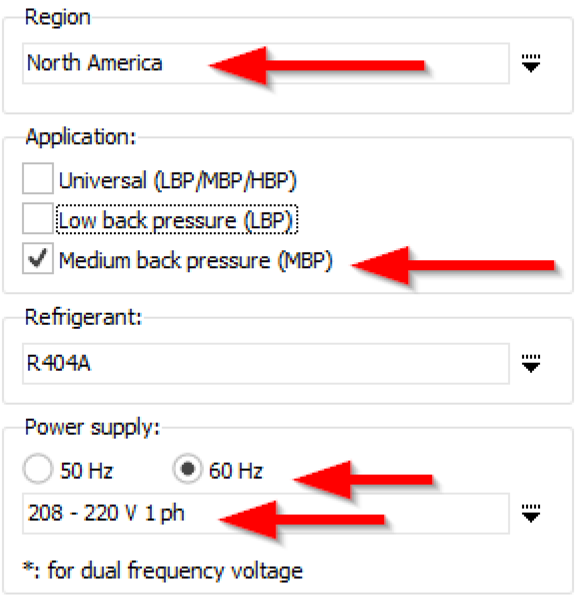


e) The tab for AWEF will only appear if the condensing unit you have selected is rated for walk-in coolers and freezers. If there is no AWEF tab within Coolselector®2, the condensing unit you have selected cannot be used for walk-in coolers and freezers on or past the enforcement date, which is as follows:

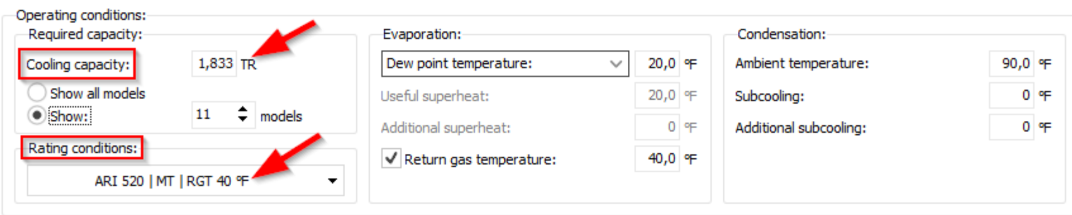
Equipment Class	Capacity	Minimum AWEF (Btu/W-h)	Enforcement Date
Multiplex Refrigeration Systems - Low Temp Unit Cooler / Evap	<15,500Btu/h	$1.575*10^{-5}*Q_{net}$ + 3.91	July 10, 2020
	>15,500Btu/h	4.15	July 10, 2020
Multiplex Refrigeration Systems - Med Temp Unit Cooler / Evap	All	9	July 10, 2020
Dedicated Condensing System - Med Indoor Condensing Unit Outdoor	<9,000 Btu/h	5.61	January 1, 2020
	>9,000Btu/h	5.61	January 1, 2020
Dedicated Condensing System - Med Outdoor	<9,000 Btu/h	7.6	January 1, 2020
	>9,000Btu/h	7.6	January 1, 2020
Dedicated Condensing System – Low, Outdoor with a Net Capacity Condensing Unit Outdoor	<6,500 Btu/h	$6.522*10^{-5}*Q_{net}$ + 2.73	July 10, 2020
	> 6,500 Btu/h	3.15	July 10, 2020
Dedicated Condensing System – Low, Indoor with a Net Capacity Condensing Unit Outdoor	<6,500 Btu/h	$9.091*10^{-5}*Q_{net}$ + 1.81	July 10, 2020
	> 6,500 Btu/h	2.4	July 10, 2020

Note: Q_{net} = Net Capacity

f) To find a condensing unit that can be used in a walk-in cooler in North America after July 10, 2020, first ensure you input the given selections:



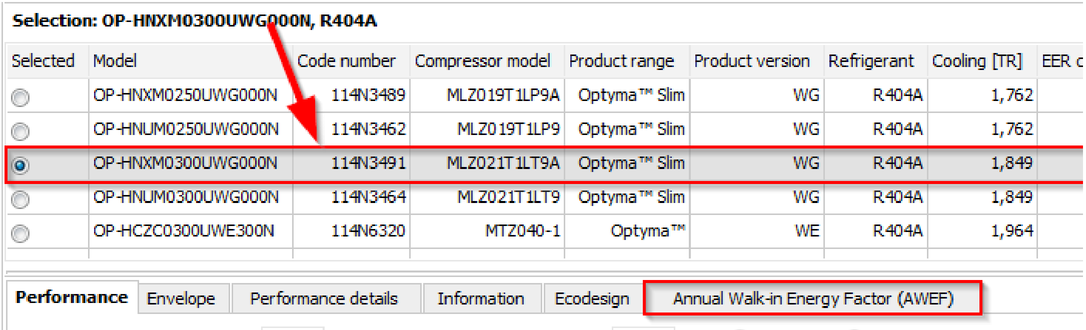
Next, input the given operating conditions:



You will now see that the condensing unit Coolselector®2 suggests

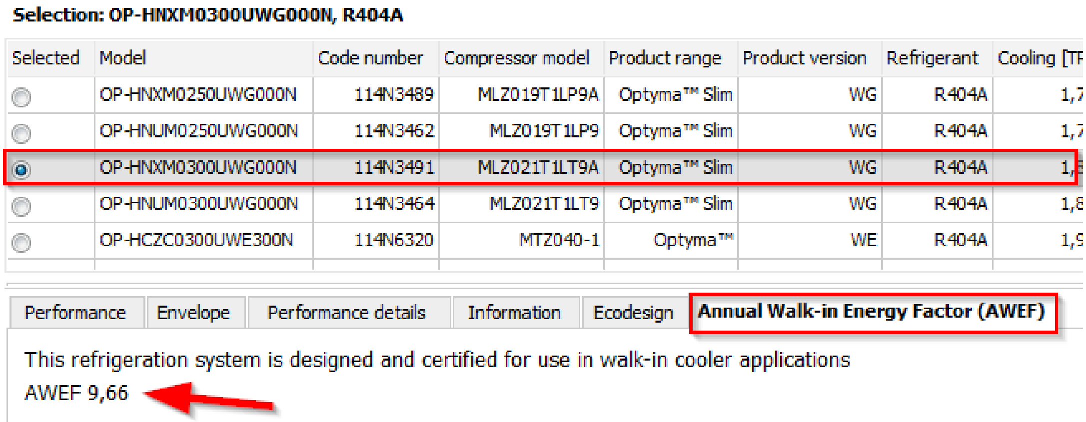
- Model Number: OP-HNXM0300UWG000N
- Code Number: 114N3491

Since the AWEF tab is displayed, you can conclude that this condensing unit can be used in a walk-in cooler in North America after July 10, 2020:



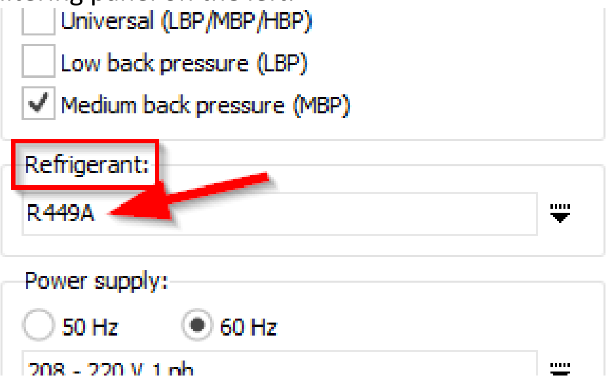
Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [TR]	EER c
	OP-HNXM0250UWG000N	114N3489	MLZ019T1LP9A	Optyma™ Slim	WG	R404A	1,762	
	OP-HNUM0250UWG000N	114N3462	MLZ019T1LP9	Optyma™ Slim	WG	R404A	1,762	
◉	OP-HNXM0300UWG000N	114N3491	MLZ021T1LT9A	Optyma™ Slim	WG	R404A	1,849	
	OP-HNUM0300UWG000N	114N3464	MLZ021T1LT9	Optyma™ Slim	WG	R404A	1,849	
	OP-HCZC0300UWE300N	114N6320	MTZ040-1	Optyma™	WE	R404A	1,964	

g) The AWEF value of the condensing unit (code number 114N3491) is 9.66:

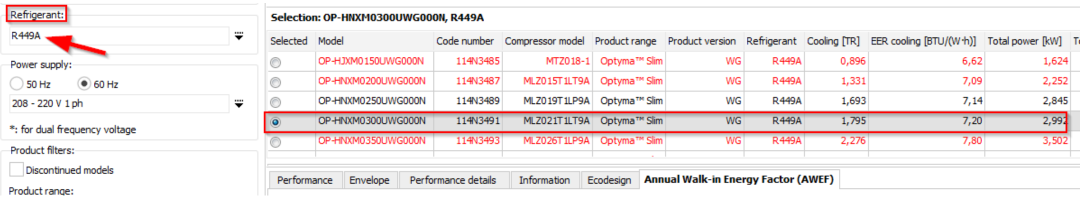

Selection: OP-HNXM0300UWG000N, R404A

Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [TF
○	OP-HNXM0250UWG000N	114N3489	MLZ019T1LP9A	Optyma™ Slim	WG	R404A	1,7
○	OP-HNUM0250UWG000N	114N3462	MLZ019T1LP9	Optyma™ Slim	WG	R404A	1,7
◉	OP-HNXM0300UWG000N	114N3491	MLZ021T1LT9A	Optyma™ Slim	WG	R404A	1,
○	OP-HNUM0300UWG000N	114N3464	MLZ021T1LT9	Optyma™ Slim	WG	R404A	1,8
○	OP-HCZC0300UWE300N	114N6320	MTZ040-1	Optyma™	WE	R404A	1,9

h) To check if this unit is also available with R449A, please change the 'refrigerant' in the filtering panel on the left:



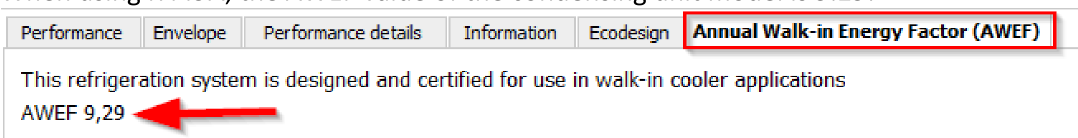
As is evident from the selection table, this model is still the model suggested by Coolselector®2. Thus, we can conclude that; Yes, this unit can also be used with R449A:



Selection: OP-HNXM0300UWG000N, R449A

Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [TR]	EER cooling [BTU/(W·h)]	Total power [kW]	T
○	OP-HJXM0150UWG000N	114N3485	MTZ018-1	Optyma™ Slim	WG	R449A	0,896	6,62	1,624	
○	OP-HNXM0200UWG000N	114N3487	MLZ015T1LT9A	Optyma™ Slim	WG	R449A	1,331	7,09	2,252	
○	OP-HNXM0250UWG000N	114N3489	MLZ019T1LP9A	Optyma™ Slim	WG	R449A	1,693	7,14	2,845	
◉	OP-HNXM0300UWG000N	114N3491	MLZ021T1LT9A	Optyma™ Slim	WG	R449A	1,795	7,20	2,992	
○	OP-HNXM0350UWG000N	114N3493	MLZ026T1LP9A	Optyma™ Slim	WG	R449A	2,276	7,80	3,502	

i) When using R449A, the AWEF value of the condensing unit model is 9.29:



Exercise 8.6 Evaluating a condensing unit based on the Ecodesign Directive

a) What is the annual energy consumption for an Optyma™ Slim Pack W09 model with a cooling capacity above 5 kW?

b) Create an Ecodesign report in pdf for the above-selected model.

Solution 8.6 Evaluating a condensing unit based on the Ecodesign Directive

a) According to the Ecodesign directive, the annual energy consumption and SEPR calculation results are published for models above 5kW for MBP models, and above 2kW for LBP models while for lower capacities only the COP at specific points is used.

EcoDesign/Directive 2009/125/EC (ENTR Lot 1)
(Application and requirements: Condensing units)

Medium Temperature (-10˚C):

	COP		5 kW	SEPR**	
	0,2-1 kW*	1-5 kW*		5-20 kW*	20-50 kW*
07/2016	1,20	1,40		2,25	2,35
07/2018	1,40	1,60		2,55	2,65

Low Temperature (-35˚C):

	COP		2 kW	SEPR**	
	0,1-0,4 kW*	0,4-2 kW*		2-8 kW*	8-20 kW*
07/2016	0,75	0,85		1,50	1,60
07/2018	0,80	0,95		1,60	1,70

*Rated capacity at full load with ambient temperature set at 32 °C (Standards: EN13215 / 13771-2)
**SEPR: is the efficiency ratio for providing cooling at standard rating conditions, representative of the variations in load and ambient temperature throughout the year and calculated as the ratio between annual cooling demand and annual electricity consumption, expressed to two decimal places (Standards: EN13215 / 13771-2).

Mandatory Information

Rated COP (9 Mandatory Values)

Information requirements for a cooling capacity of:

- MBP < 5kW
- LBP < 2kW

Ambient temp.	32 °C	25 °C	43 °C
Cooling capacity (kW)	1	2	3
Power input (kW)	4	5	6
COP_A (rated)	**7**		
COP_2		8	
COP_2			9

Condensing units operating both at MBP and LBP shall comply with the requirements of each category (Medium temperature: -10 °C ; Low temperature: -35 °C).

SEPR (17 Additional Values)

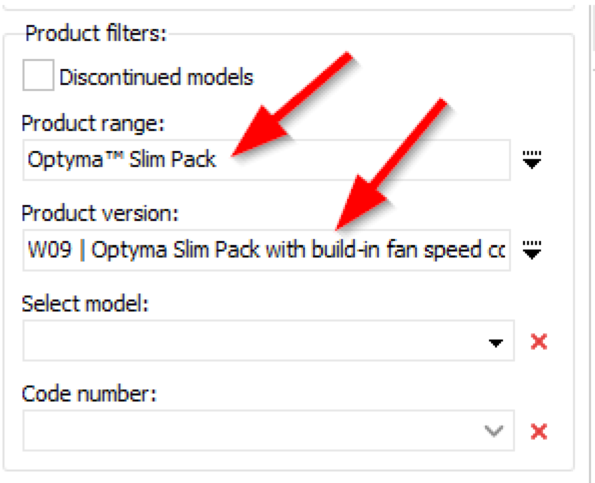
Information requirements for a cooling capacity of:

- MBP ≥ 5kW
- LBP ≥ 2kW

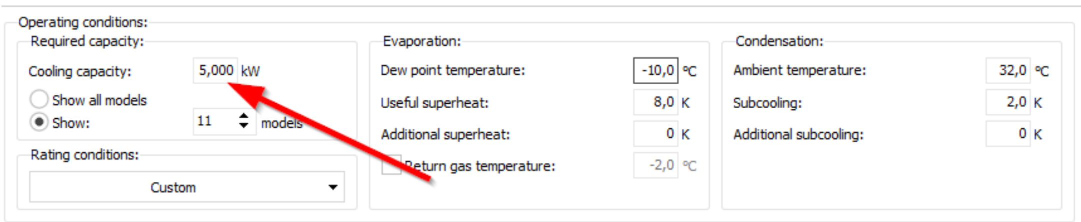
Ambient temp.	32 °C	25 °C	15 °C	5 °C	43 °C
Cooling capacity (kW)	10	11	12	13	14
Power input (kW)	15	16	17	18	19
COP_A (rated)	**20**				
COP_B		21			
COP_C			22		
COPD				23	
COP_2					24
Annual electricity consumption			25		
SEPR			26		

Within Coolselector®2, first go to “New” tab, select “Compressors and condensing units” and click on the “Condensing units” button.

Go straight down to “Product filters”. Select Product Range: Optyma™ Slim Pack and Product version: W09 | Optyma Slim Pack with build-in fan speed controller and external main switch:



Then set the operating conditions to 5 kW:



Select a model with a cooling capacity above 5 kW (for a MBP model):

Selection: OP-MSXM057MLW09E, R407A

Selected	Model	Code number	Compressor model	Product range	Product version	Refrigerant	Cooling [kW]	COP cooling [W/W]
○	OP-LSQM074FHW09E	114X7186	TFH2511Z	Optyma™ Slim Pack	W09	R452A	4,893	1,6
○	OP-LSQM074FHW09E	114X7186	TFH2511Z	Optyma™ Slim Pack	W09	R404A	4,899	1,5
○	OP-LSQM068NTW09E	114X7184	NTZ068-4	Optyma™ Slim Pack	W09	R404A	4,992	1,5
◉	OP-MSXM057MLW09E	114X7200	MLZ026T4	Optyma™ Slim Pack	W09	R407A	5,026	1,7
○	OP-MSXM080MLW09E	114X7204	MLZ038T4	Optyma™ Slim Pack	W09	R134a	5,073	2,2

Next, click on the "Ecodesign" tab and locate the "Annual electricity consumption" in kW/h (the Ecodesign tab is only available for European condensing unit models):

Performance | Envelope | Performance details | Information | **Ecodesign**

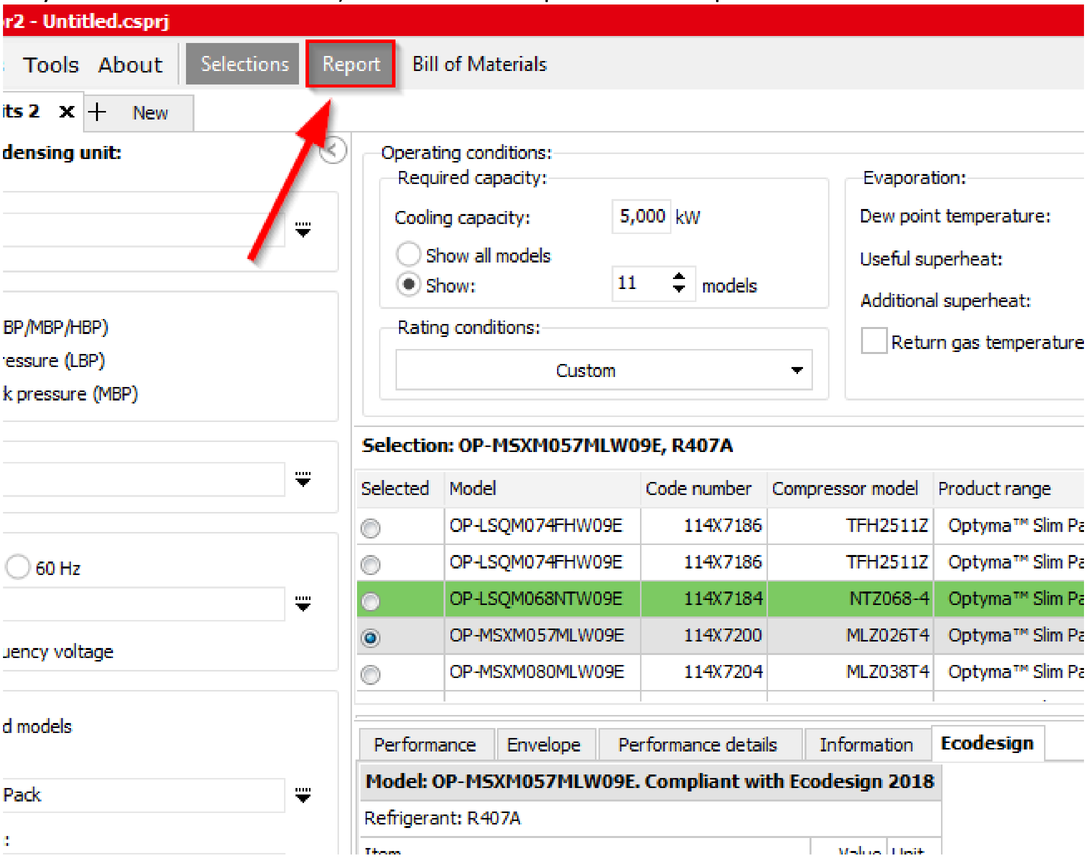
Model: OP-MSXM057MLW09E. Compliant with Ecodesign 2018

Refrigerant: R407A

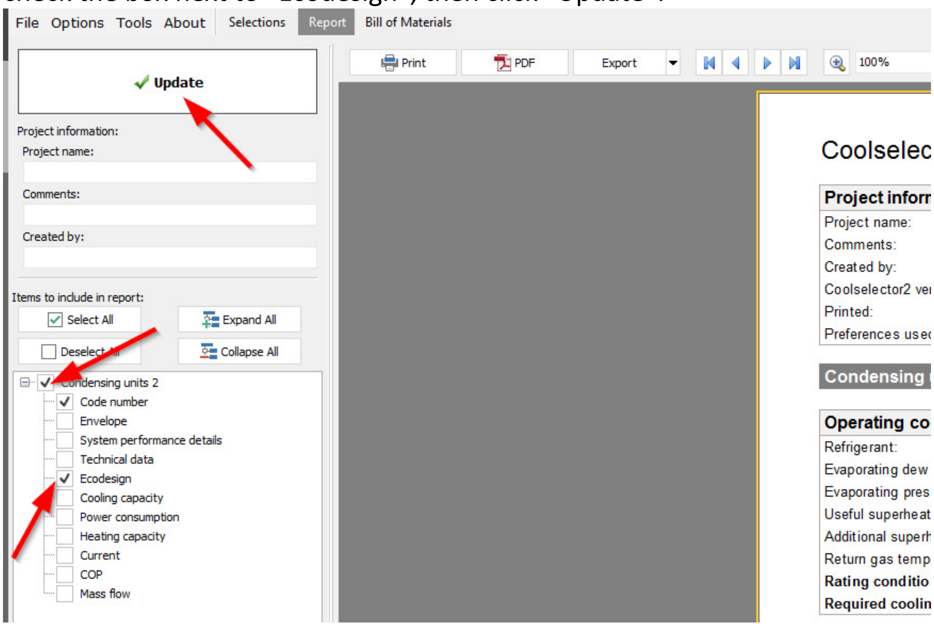
Item	Value	Unit
Evaporating temperature	-10,0	°C
Seasonal Energy Performance Ratio	**2,95**	
Annual electricity consumption	10.758	kWh
Parameters at full load and ambient temperature 32,0 °C		
Rated cooling capacity	5,157	kW
Rated power input	2,834	kW
Rated COP	1,82	
Parameters at full load and ambient temperature 25,0 °C		
Cooling capacity	5,694	kW
Power input	2,434	kW
COP	2,34	
Parameters at full load and ambient temperature 15,0 °C		
Cooling capacity	6,402	kW
Power input	2,010	kW
COP	3,18	
Parameters at full load and ambient temperature 5,0 °C		
Cooling capacity	7,045	kW
Power input	1,713	kW
COP	4,11	
Parameters at full load and ambient temperature 43,0 °C		
Cooling capacity	4,240	kW
Power input	3,695	kW
COP	1,15	

With this information, you can now make a competitor comparison in your country by getting the same data for the competitor product and time it up with the electricity rate per kW/h.

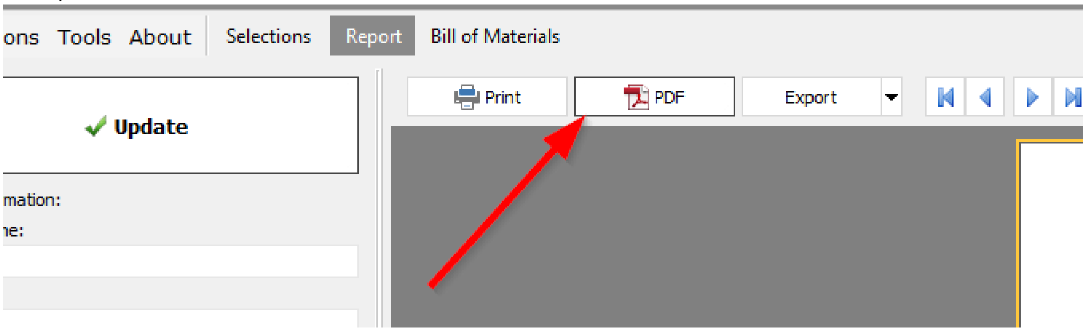
b) Stay on the selection from a) and click on “Report” in the top menu bar:



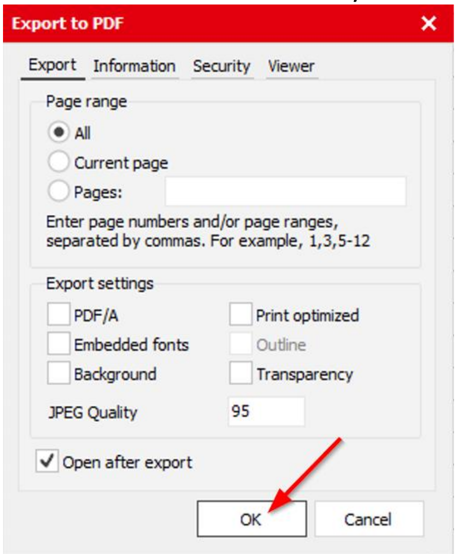
Once you are in the Report, unfold the “Condensing units” menu (by clicking on +) and check the box next to “Ecodesign”, then click “Update”:



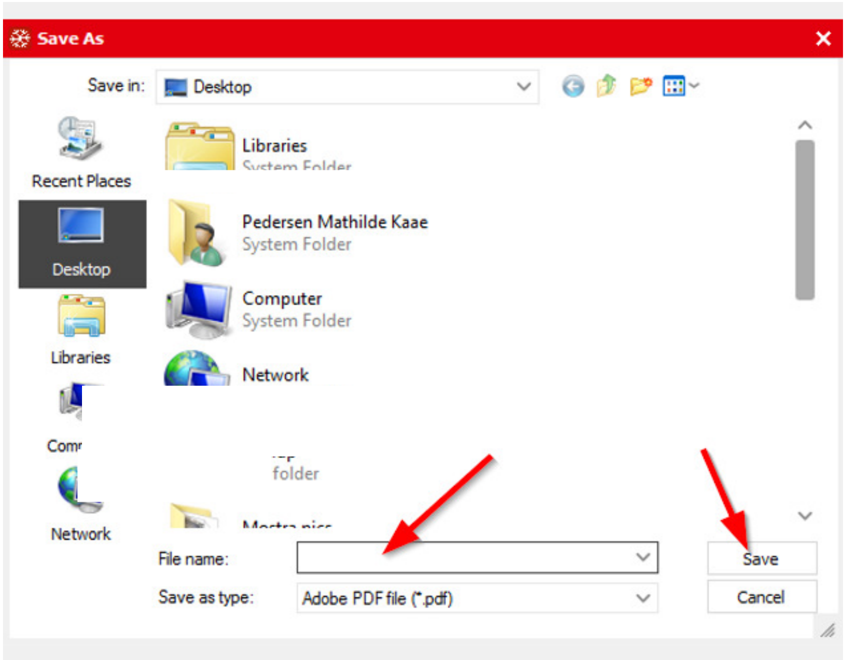
Now, click on “PDF”:



You can now save the file on your computer:



Make sure you give the file a name and click “Save”:



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