

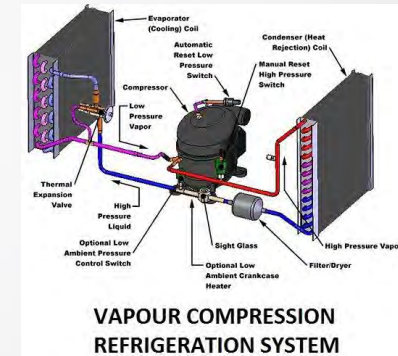


Review of application tools to make accurate line sizing of a refrigeration system

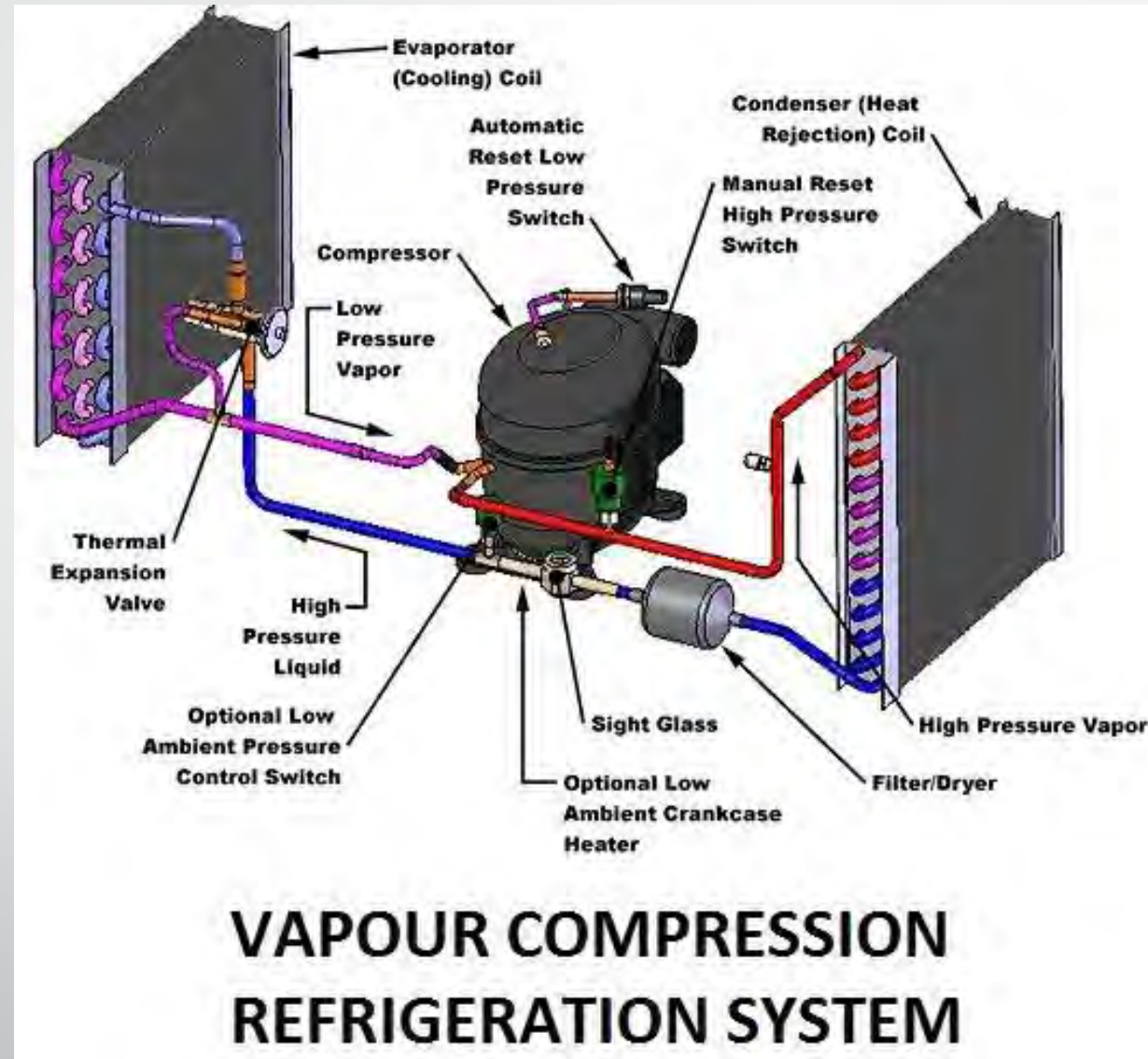
June 2018

Context

- Vapour compression systems
- Refrigerants HFC (R134a, R507A, R410A, ...)
- Custom made equipment
- Custom installations
- Linear velocity m/s through a fixed volume (diameter)



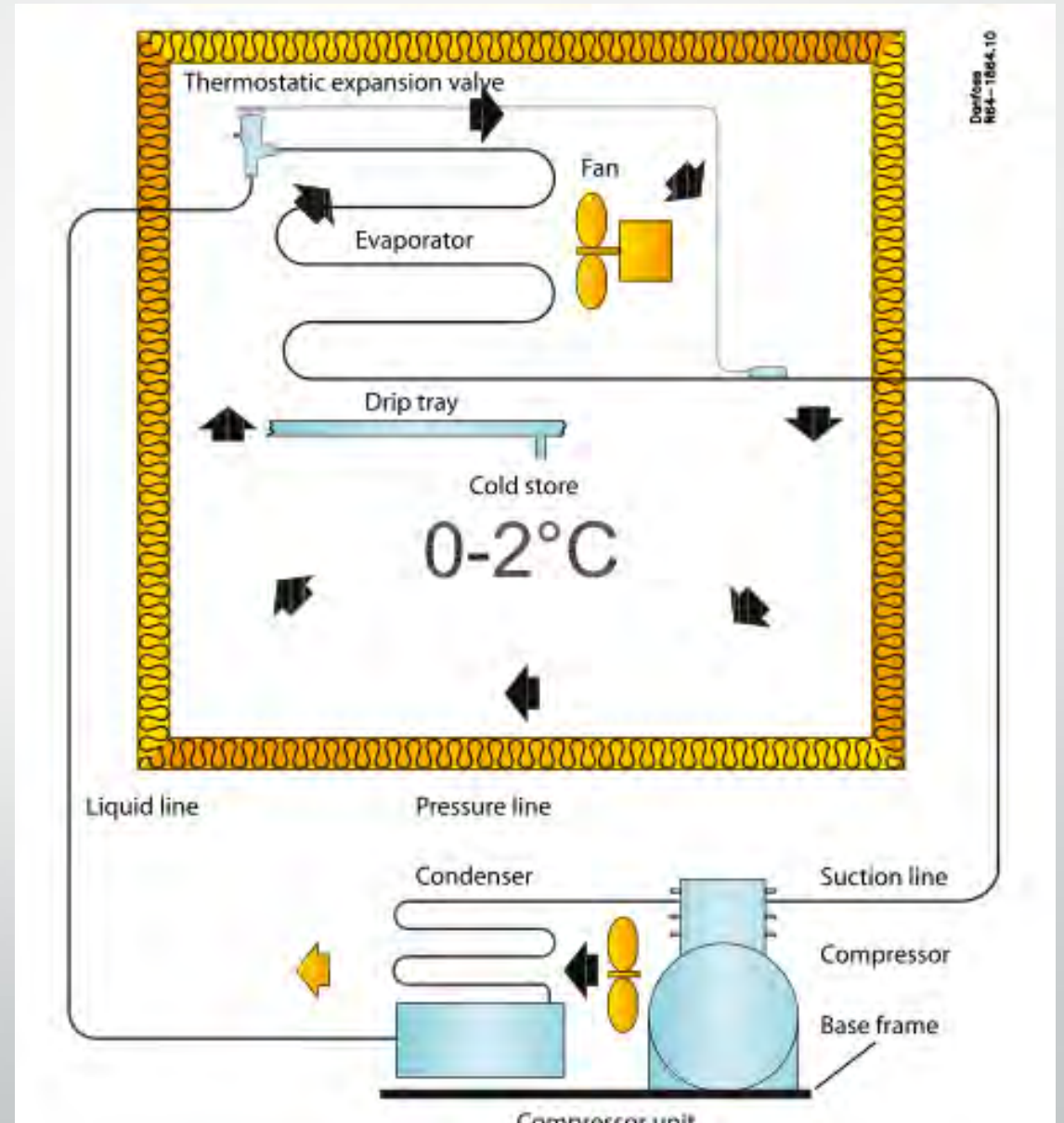
Basic system – Air cooled condenser



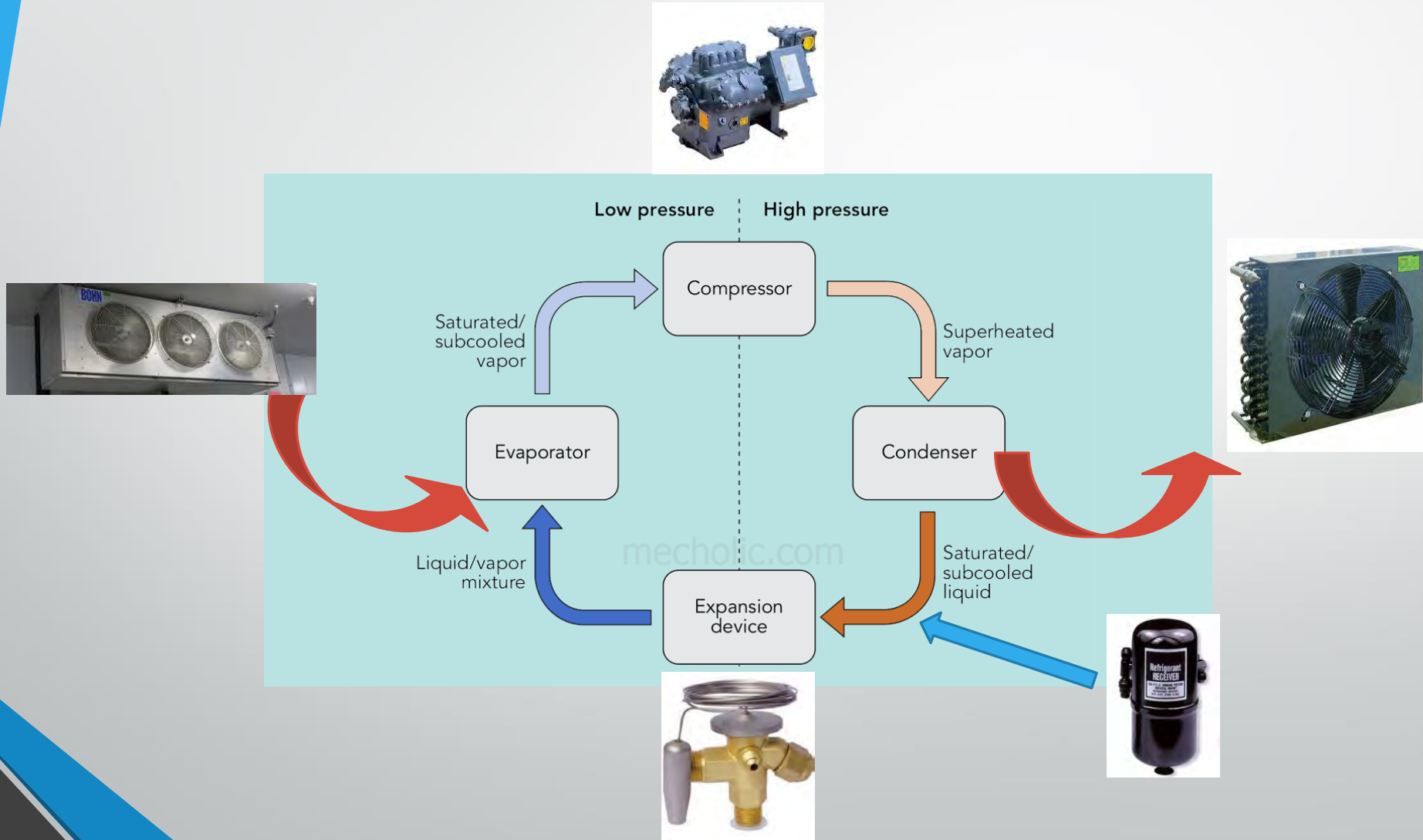
Installation



*Danfoss: An introduction to Basics



Basic system diagram



Design should ideally

(ASHRAE Handbook-Refrigeration -Chapter 1 (section 1.1))

- Ensure the required liquid supply to the evaporators
- Adequate line size without excessive pressure drops
- Prevent excessive oil being trapping in any part of the system
- Ensure the correct oil volume at the compressor
- Prevent liquid or oil or refrigerant from being drawn into the compressor during operation

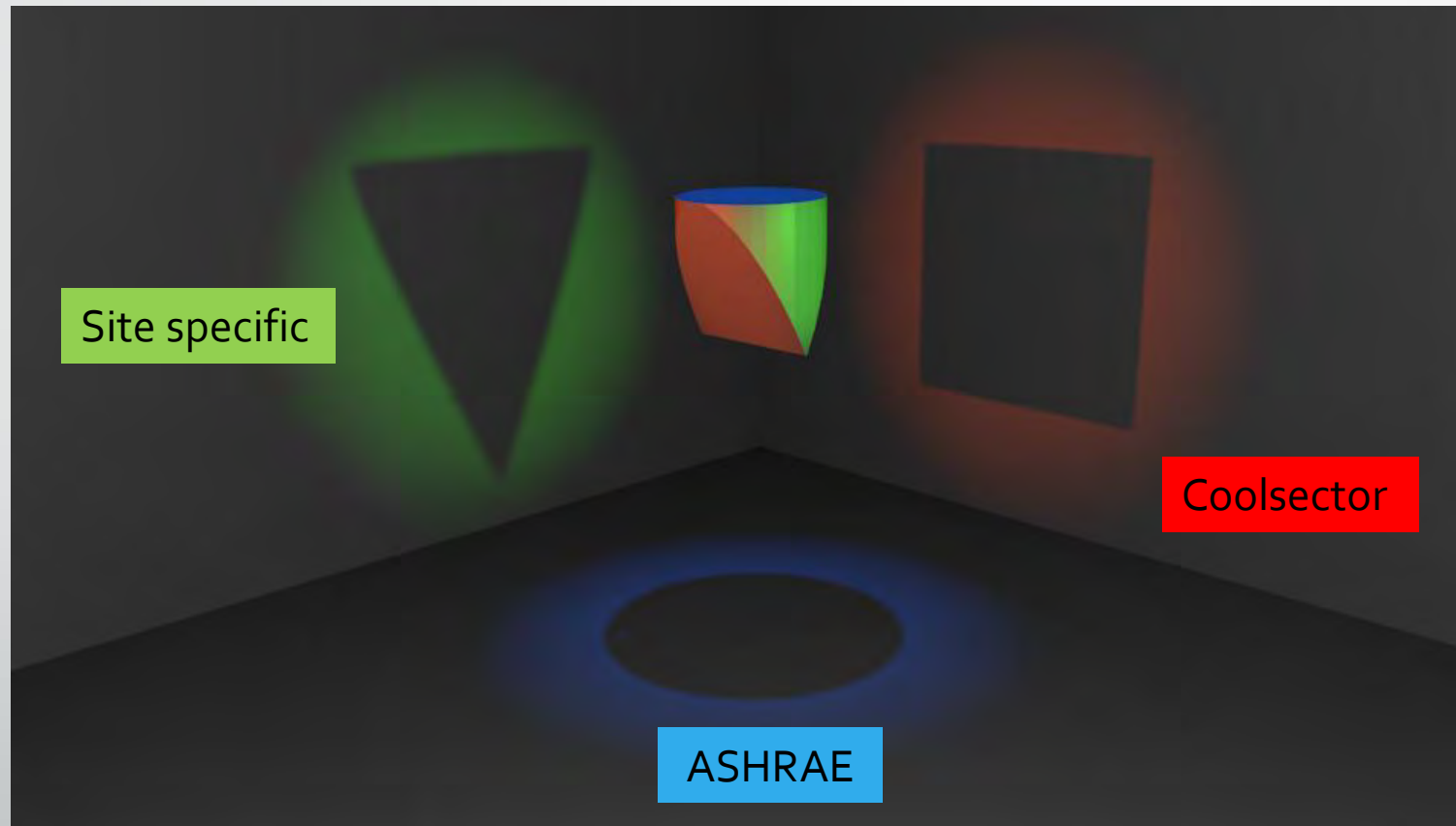
What do you need to start this process?

- Evaporative capacities the system will need to operate at
- Components to be used (Compressors, Condensers, Evaporators,,)
- The conditions that system will need to operate at
 - Suction temperature
 - Condensing temperature
- The Refrigerant (lubricant used)
- Site specific details
 - Length of the pipe runs
 - Ambient conditions

Tools/applications

- ASHRAE Handbook-Refrigeration -Chapter 1 (section 1.1)
- Danfoss "Coolselector2" Application
- Site specific factors – Length, Elevation & Positioning of the pipe runs
- Bitzer software (v6.8.o) – compressor selection

Multiple perspective of the same problem or requirement



Factors to consider ? ASHRAE Chapter 1 (section 1.1)



- Load variation – 33% - 66% -100%?
- Operational time (AC systems doing far less than a freezer room)
- Heat exchanger methods to be used – Air cooled, water cooled
- Oil return methods – refrigerant and oil specific (mineral, POE,,)
- System efficiency, maintainability & simplicity
- Operating pressures (pressure ratio)

Factors to consider ?

ASHRAE Chapter 1 (section 1.1)

*Load variation



Load variation – 33% - 66% -100%?

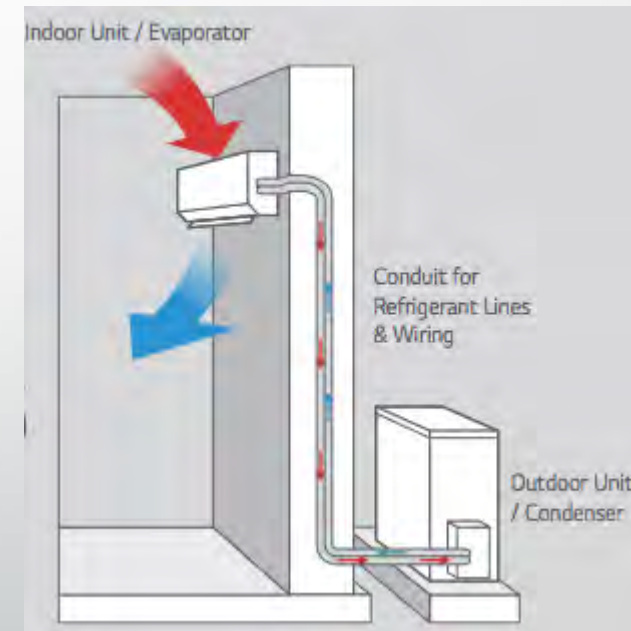
Bitzer 6HE-35Y

- 33.7 kW Evaporative capacity @ -10/45
- 33.3% = 11.23 kW
- $Q = m C \Delta T$
- $Q = m (\Delta h)$

Factors to consider ? ASHRAE Chapter 1 (section 1.1)

*Operational time

- AC systems typically operating at 2000-4000 hr per year
 - 8760 hr year



Factors to consider ? ASHRAE Chapter 1 (section 1.1)

*Oil return

Table 1 Recommended Gas Line Velocities

Suction line	4.5 to 20 m/s
Discharge line	10 to 18 m/s

- HFC using POE oil – NOT mineral
- DX systems have fewer problems than flooded systems
- Design must ensure oil return at lowest load
- Case study (Purdue University 2002 – Spatz & Richard)
 - 10 m/s oil returned within 20 – 30 minutes

Capacity Tables ASHRAE Chapter 1 (section 1.1)

Table 10 Suction Line Capacities in Kilowatts for Refrigerant 22 (Single- or High-Stage Applications) for Pressure Drops of 0.02 and 0.01 K/m Equivalent

Nominal Line OD, mm	Saturated Suction Temperature, °C									
	-40		-30		-20		-5		5	
	$\Delta t = 0.02$ $\Delta p = 97.9$	$\Delta t = 0.01$ $\Delta p = 49.0$	$\Delta t = 0.02$ $\Delta p = 138$	$\Delta t = 0.01$ $\Delta p = 69.2$	$\Delta t = 0.02$ $\Delta p = 189$	$\Delta t = 0.01$ $\Delta p = 94.6$	$\Delta t = 0.02$ $\Delta p = 286$	$\Delta t = 0.01$ $\Delta p = 143$	$\Delta t = 0.02$ $\Delta p = 366$	$\Delta t = 0.01$ $\Delta p = 183$
TYPE L COPPER LINE										
12	0.21	0.14	0.34	0.23	0.51	0.34	0.87	0.59	1.20	0.82
15	0.41	0.28	0.65	0.44	0.97	0.66	1.67	1.14	2.30	1.56
18	0.72	0.49	1.13	0.76	1.70	1.15	2.91	1.98	4.00	2.73
22	1.28	0.86	2.00	1.36	3.00	2.04	5.14	3.50	7.07	4.82
28	2.54	1.72	3.97	2.70	5.95	4.06	10.16	6.95	13.98	9.56
35	4.69	3.19	7.32	4.99	10.96	7.48	18.69	12.80	25.66	17.59
42	7.82	5.32	12.19	8.32	18.20	12.46	31.03	21.27	42.59	29.21
54	15.63	10.66	24.34	16.65	36.26	24.88	61.79	42.43	84.60	58.23
67	27.94	19.11	43.48	29.76	64.79	44.48	110.05	75.68	150.80	103.80
79	43.43	29.74	67.47	46.26	100.51	69.04	170.64	117.39	233.56	161.10
105	93.43	63.99	144.76	99.47	215.39	148.34	365.08	251.92	499.16	344.89

Δp = pressure drop per unit equivalent line length, Pa/m

Δt = corresponding change in saturation temperature, K/m

- Based on Darcy-Weisbach relation & friction factors (Colebrook 1938.1939)
- Volume (Mass flow) = Area (pipe diameter) * length (linear velocity)
 - Liquid state

Example 1 – Bitzer 4NES-14Y (R449A)

[1] BITZER Software v6.8.0 rev1996

Project Mode Options Window

South Africa English SI

Semi-hermetic Reciprocating Compressors

Mode: Refrigeration and Air con

Refrigerant: R449A

Reference temperature: Dew point temp.

Compressor type: Single Compressor

Series: Standard

Motor version: all

Compressor selection

Cooling capacity: 16

Compressor model: 4NES-14Y

Incl. fomer types

Operating point

Evaporating SST: -10 °C

Condensing SDT: 45 °C

Operating conditions

Liq. subc. (in condenser): 10 K

Suct. gas superheat: 20 K

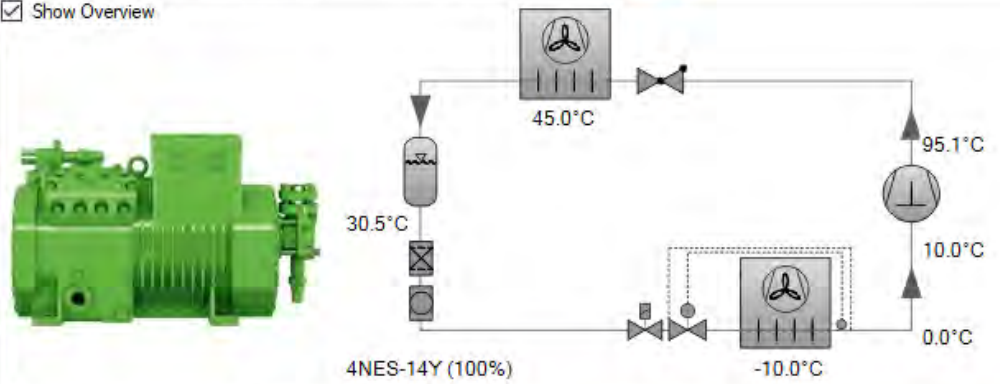
Useful superheat: 10 K

Operating mode: Auto

Capacity control

without

Show Overview



45.0°C

30.5°C

95.1°C

10.0°C

0.0°C

4NES-14Y (100%)

-10.0°C

Result Limits Technical Data Dimensions Information Documentation Trainings

Tentative Data.
*According to EN12900 (20°C suction gas temp., 0K liquid subcooling)

Compressor	4NES-14Y-40P
Capacity steps	100%
Cooling capacity	29.3 kW
Cooling capacity *	27.1 kW
Evaporator capacity	27.7 kW
Power input	11.13 kW
Current (400V)	18.97 A
Voltage range	380-420V
Condenser Capacity	40.4 kW
COP/EER	2.49
COP/EER *	2.44
Mass flow	638 kg/h
Operating mode	Standard
Discharge gas temp. w/o cooling	95.1 °C

Example 1 – Discharge line sizing (1.5m)

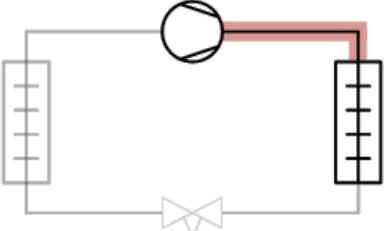
Coolselector2 - Untitled.cspj

File Options Tools About Selections Report Bill of Materials Copy Selection

Piping 1 x + New

System: Dry

Click on diagram to select line:
Selected line: Discharge line



Operating conditions:

Capacity:
 Cooling capacity: 27.70 kW
 Mass flow in line: 637.3 kg/h
 Heating capacity: 39.99 kW

Evaporation:
 Dew point temperature: -10.0 °C
 Useful superheat: 10.0 K
 Additional superheat: 10.0 K

Condensation:
 Dew point temperature: 45.0 °C
 Subcooling: 10.0 K
 Additional subcooling: 0 K

Additional:
 Discharge temperature: 93.0 °C

Selection criteria:
 Pressure drop: Default bar
 Saturation temperature drop: 0.020 K/m
 Velocity: 15.00 m/s

Additional selection criteria:
 Length: 1.50 m
 Angle: 0 deg

Refrigerant: R449A
 Connections: All

Product families

- Copper pipe DIN-EN
- Copper bend 45 DIN-EN
- Copper bend 90 DIN-EN
- Copper reducer DIN-EN
- Copper expander DIN-EN
- Copper pipe ANSI
- Copper bend 45 ANSI
- Copper bend 90 ANSI
- Copper reducer ANSI
- Copper expander ANSI
- Copper pipe ANSI K65
- Copper bend 45 ANSI K65
- Copper bend 90 ANSI K65
- Copper reducer ANSI K65
- Copper expander ANSI K65
- Copper pipe ANSI XHP 90
- Copper pipe ANSI XHP 130

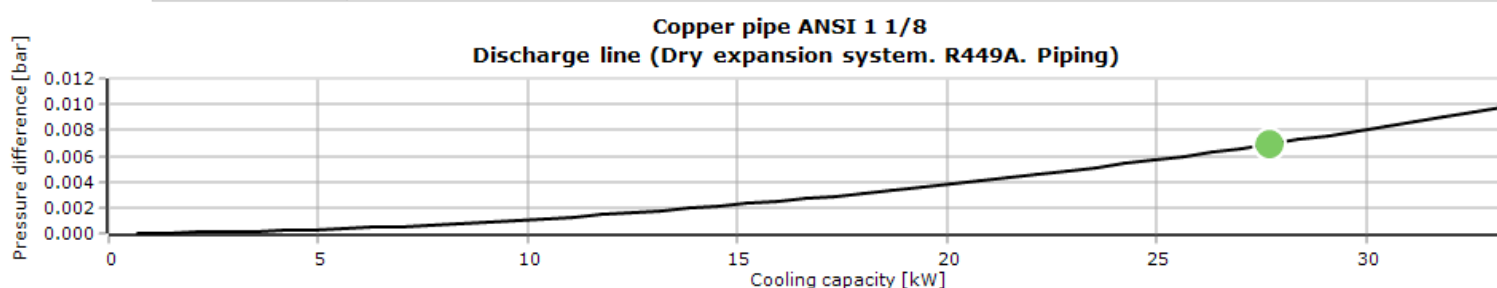
Discharge line (Dry expansion system. R449A. Piping)

Selection: Copper pipe ANSI 1 1/8

Selected	Type	NS	DP [bar]	DT_sat [K]	DP [K/m]	Velocity, in [m/s]	Velocity, out [m/s]	Result
<input type="radio"/>	ANSI 3/4	19.05	0.053	0.1	0.075	11.88	11.92	✓
<input type="radio"/>	ANSI 7/8	22.23	0.026	0.1	0.037	8.91	8.92	✓
<input checked="" type="radio"/>	ANSI 1 1/8	28.58	0.007	0.0	0.010	5.23	5.23	✓
<input type="radio"/>	ANSI 1 3/8	34.93	0.002	0.0	0.004	3.43	3.43	✓
<input type="radio"/>	ANSI 1 5/8	41.28	0.001	0.0	0.002	2.42	2.42	✓

Performance curve Performance details

Copper pipe ANSI 1 1/8
 Discharge line (Dry expansion system. R449A. Piping)



Pressure difference [bar]

Cooling capacity [kW]

Table 1 Recommended Gas Line Velocities

Suction line	4.5 to 20 m/s
Discharge line	10 to 18 m/s

Example 1 – Liquid line sizing (20m)

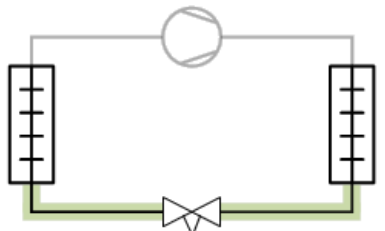
Coolselector2 - Untitled.csprj

File Options Tools About Selections Report Bill of Materials Copy Selection

Piping 1 x + New

System: Dry

Click on diagram to select line:
Selected line: Liquid line



Operating conditions:

Capacity: Cooling capacity: 27.70 kW
Mass flow in line: 637.3 kg/h
Heating capacity: 39.99 kW

Evaporation: Dew point temperature: -10.0 °C
Useful superheat: 10.0 K
Additional superheat: 10.0 K

Condensation: Dew point temperature: 45.0 °C
Subcooling: 10.0 K
Additional subcooling: 0 K

Additional: Discharge temperature: 93.0 °C

Selection criteria: Pressure drop: Default bar Saturation temperature drop: 0.020 K/m
 Velocity: 1.00 m/s

Additional selection criteria: Length: 20.00 m ←
Angle: 0 deg

Liquid line (Dry expansion system. R449A. Piping)

Selection: Copper pipe ANSI 5/8

Selected	Type	NS	DP [bar]	DT_sat [K]	DP [K/m]	Velocity, in [m/s]	Velocity, out [m/s]	Result
<input type="radio"/>	ANSI 3/8	9.53	2.593	6.1	0.305	3.38	3.38	✓
<input type="radio"/>	ANSI 1/2	12.7	0.494	1.1	0.056	1.72	1.72	✓
<input checked="" type="radio"/>	ANSI 5/8	15.88	0.152	0.3	0.017	1.06	1.06	✓
<input type="radio"/>	ANSI 3/4	19.05	0.057	0.1	0.006	0.71	0.71	✓
<input type="radio"/>	ANSI 7/8	22.23	0.028	0.1	0.003	0.53	0.53	✓

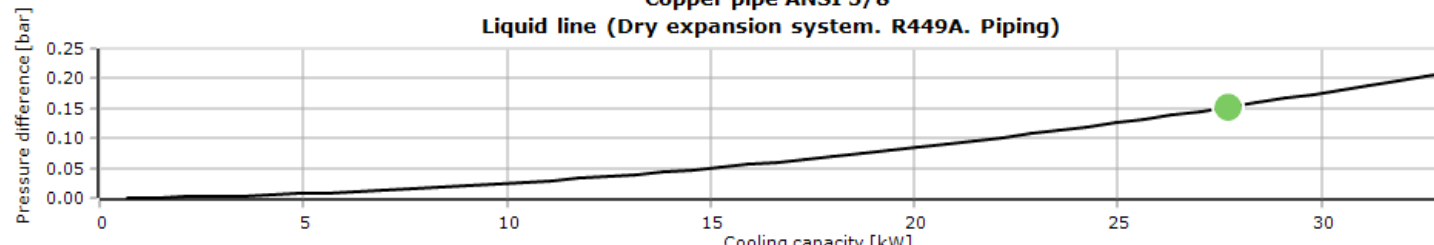
Refrigerant: R449A
Connections: All

Product families

- Copper pipe DIN-EN
- Copper bend 45 DIN-EN
- Copper bend 90 DIN-EN
- Copper reducer DIN-EN
- Copper expander DIN-EN
- Copper pipe ANSI
- Copper bend 45 ANSI
- Copper bend 90 ANSI
- Copper reducer ANSI
- Copper expander ANSI
- Copper pipe ANSI K65
- Copper bend 45 ANSI K65
- Copper bend 90 ANSI K65
- Copper reducer ANSI K65
- Copper expander ANSI K65
- Copper pipe ANSI XHP 90
- Copper pipe ANSI XHP 130

Performance curve Performance details

Copper pipe ANSI 5/8
Liquid line (Dry expansion system. R449A. Piping)



Pressure difference [bar]

Cooling capacity [kW]

What might your sub-cooling reliably be?

Example 1 – Suction line sizing (20m)

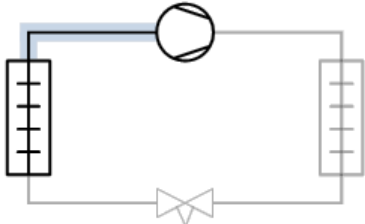
Coolselector2 - Untitled.csprj

File Options Tools About Selections Report Bill of Materials Copy Selection

Piping 1 x + New

System: Dry

Click on diagram to select line:
Selected line: Suction line



Operating conditions:

Capacity: Cooling capacity: 27.70 kW, Mass flow in line: 637.3 kg/h, Heating capacity: 39.99 kW

Evaporation: Dew point temperature: -10.0 °C, Useful superheat: 10.0 K, Additional superheat: 10.0 K

Condensation: Dew point temperature: 45.0 °C, Subcooling: 10.0 K, Additional subcooling: 0 K

Additional: Discharge temperature: 93.0 °C

Selection criteria: Pressure drop: Default bar, Velocity: 12.00 m/s, Saturation temperature drop: 0.020 K/m

Additional selection criteria: Length: 20.00 m, Angle: 0 deg

Suction line (Dry expansion system. R449A. Piping)

Selection: Copper pipe ANSI 1 5/8

Selected	Type	NS	DP [bar]	DT_sat [K]	DP [K/m]	Velocity, in [m/s]	Velocity, out [m/s]	Result
<input type="radio"/>	ANSI 7/8	22.23	2.036	20.8	1.038	39.46	93.57	✓
<input type="radio"/>	ANSI 1 1/8	28.58	0.417	3.3	0.166	23.16	26.34	✓
<input type="radio"/>	ANSI 1 3/8	34.93	0.143	1.1	0.055	15.21	15.87	✓
<input checked="" type="radio"/>	ANSI 1 5/8	41.28	0.060	0.5	0.023	10.74	10.93	✓
<input type="radio"/>	ANSI 2 1/8	53.98	0.016	0.1	0.006	6.18	6.21	✓

Refrigerant: R449A

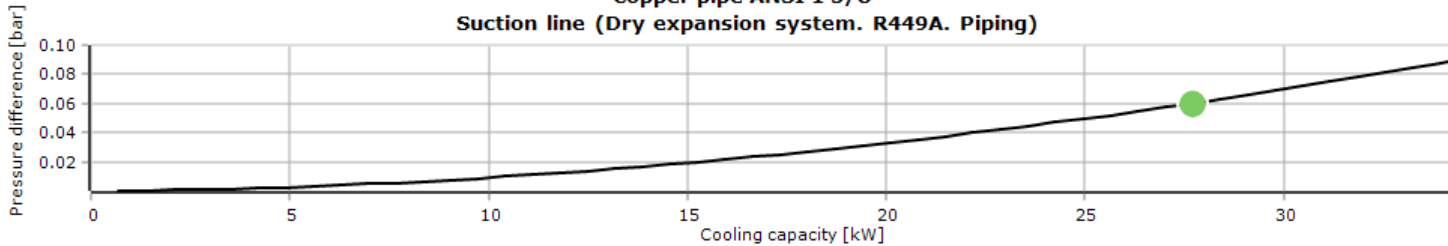
Connections: All

Product families

- Copper reducer DIN-EN
- Copper expander DIN-EN
- Copper pipe ANSI
- Copper bend 45 ANSI
- Copper bend 90 ANSI
- Copper reducer ANSI
- Copper expander ANSI
- Copper pipe ANSI K65
- Copper bend 45 ANSI K65
- Copper bend 90 ANSI K65
- Copper reducer ANSI K65
- Copper expander ANSI K65
- Copper pipe ANSI XHP 90
- Copper pipe ANSI XHP 130
- Copper bend 45 ANSI XHP
- Copper bend 90 ANSI XHP
- Copper reducer ANSI XHP

Performance curve Performance details

Copper pipe ANSI 1 5/8
Suction line (Dry expansion system. R449A. Piping)



Pressure difference [bar]

Cooling capacity [kW]

Line Type	Recommended Velocity Range [m/s]
Suction line	4.5 to 20 m/s
Discharge line	10 to 18 m/s

ASHRAE Chapter 1 section 1.1 – Suction line sizing guidelines

Suction Lines. Suction lines are more critical than liquid and discharge lines from a design and construction standpoint. Refrigerant lines should be sized to (1) provide a minimum pressure drop at full load, (2) return oil from the evaporator to the compressor under minimum load conditions, and (3) prevent oil from draining from an active evaporator into an idle one. A pressure drop in the suction line reduces a system's capacity because it forces the compressor to operate at a lower suction pressure to maintain a desired evaporating temperature in the coil. The suction line is normally sized to have a pressure drop from friction no greater than the equivalent of about a 1 K change in saturation temperature. See Tables 3 to 15 for suction line sizing information.

ASHRAE Chapter 1 section 1.1 – Suction line risers

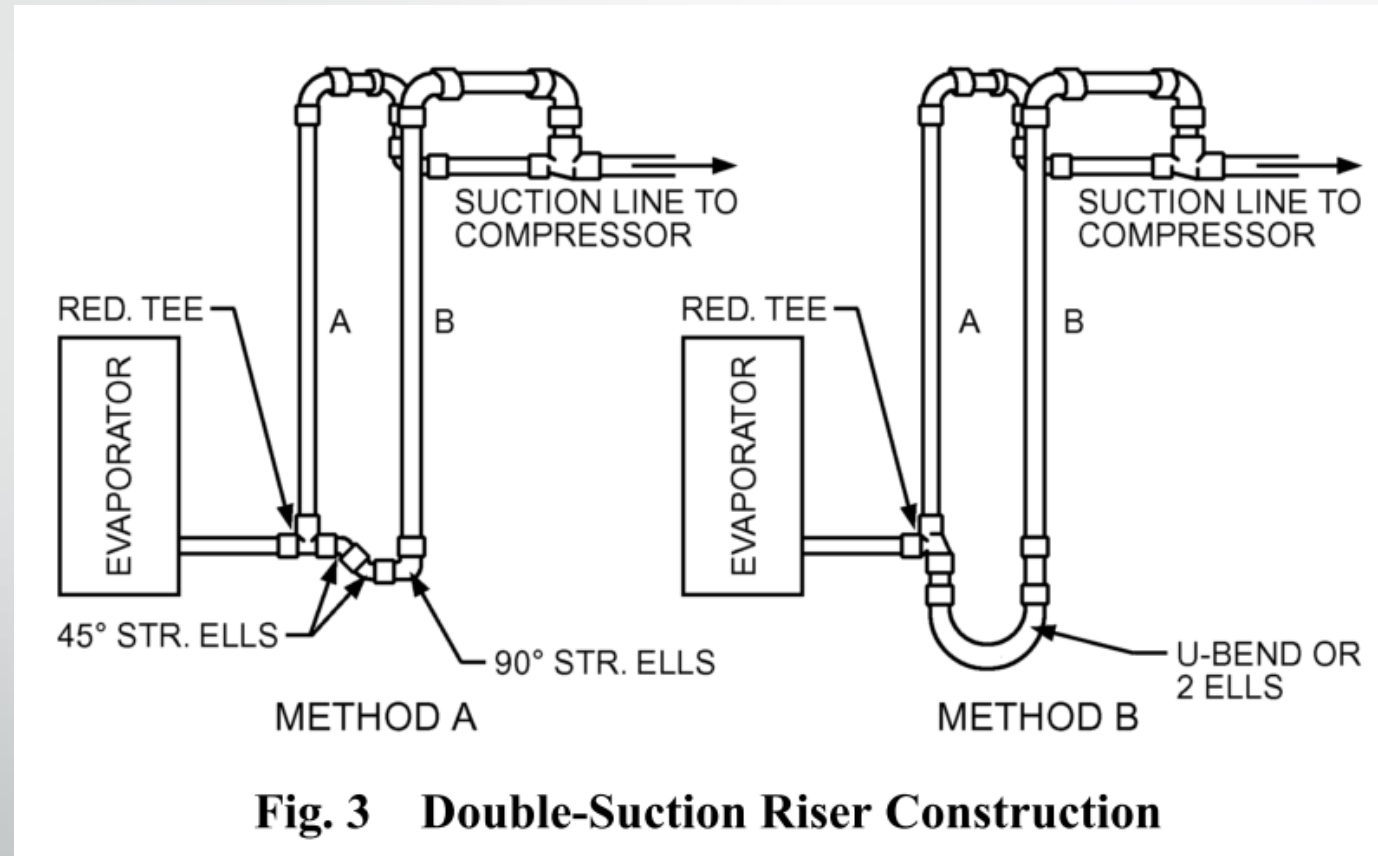


Fig. 3 Double-Suction Riser Construction

ASHRAE Chapter 1 section 1.1 – Evaporator piping

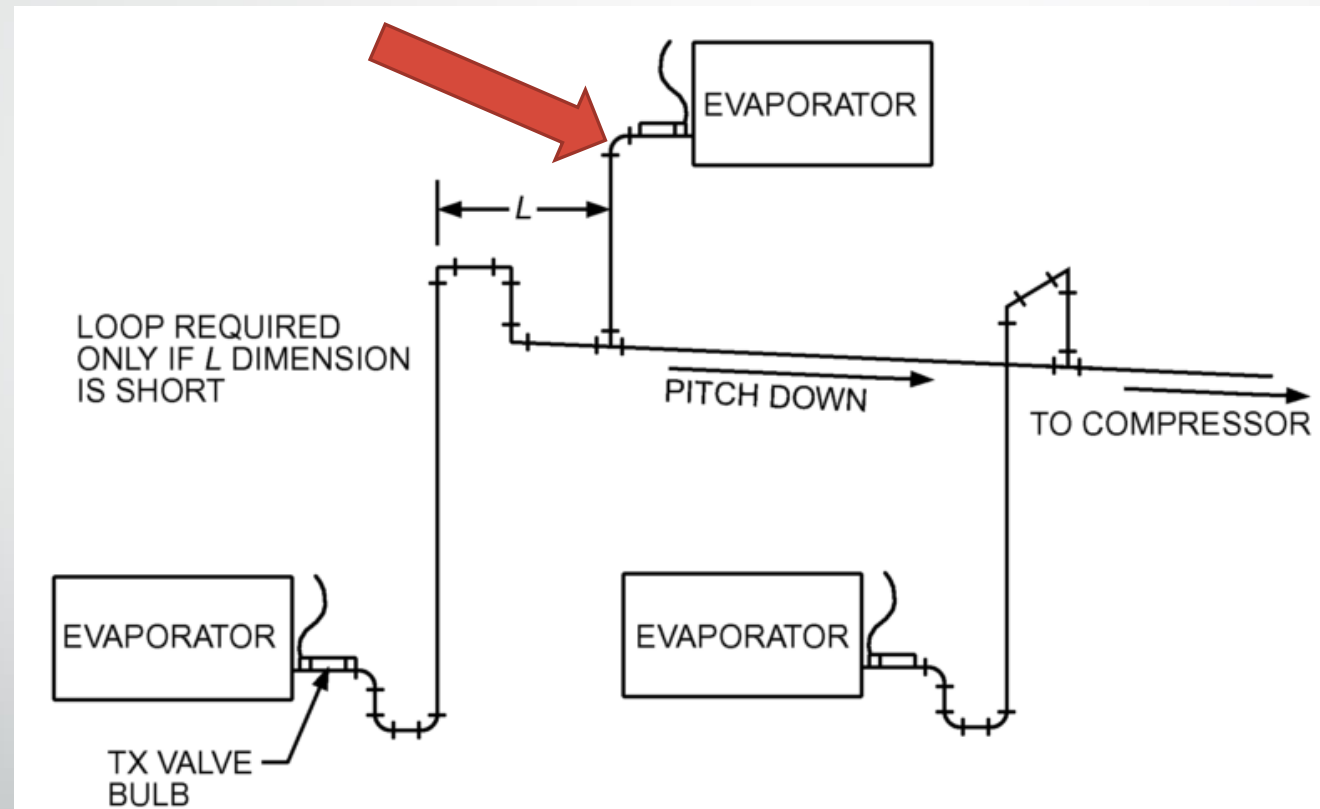
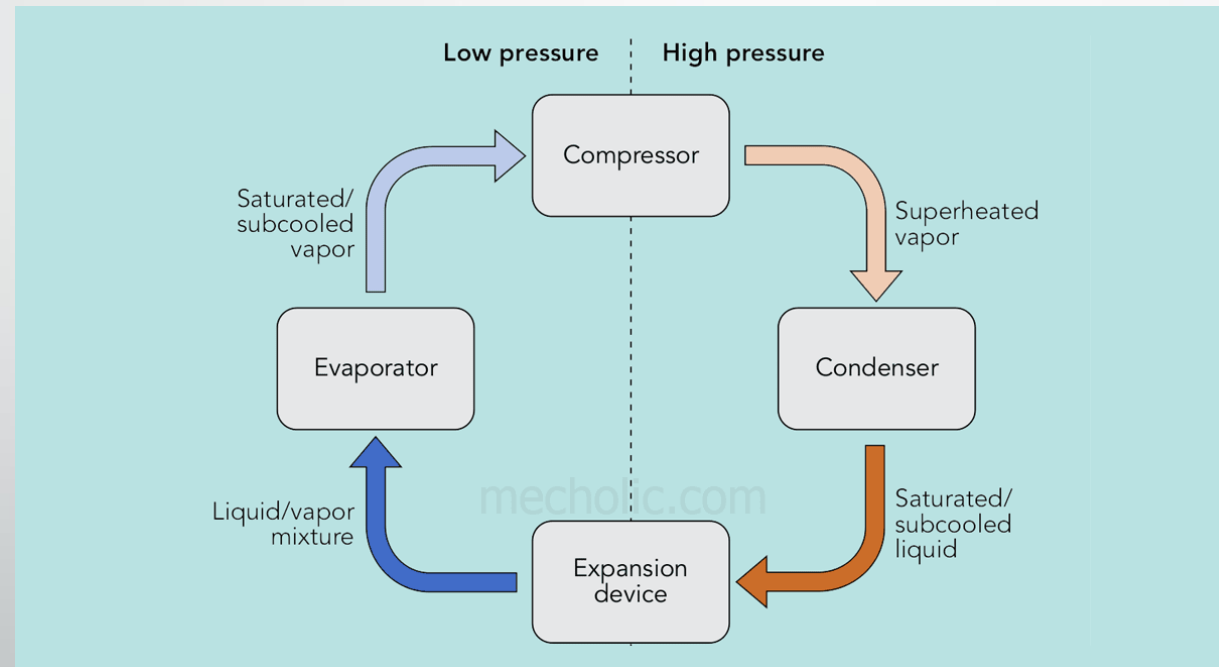


Fig. 5 Typical Piping from Evaporators Located above and below Common Suction Line

Practical considerations

- Connection sizes on system components
 - Compressor Discharge & Suction service valve sizes
 - Condenser inlet and outlet service valve connection sizes



Example 1 – Suction line sizing (200m)

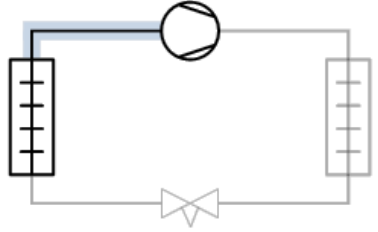
Coolselector2 - Untitled.cspj

File Options Tools About Selections Report Bill of Materials Copy Selection

Piping 1 x + New

System: Dry

Click on diagram to select line:
Selected line: Suction line



Refrigerant: R449A
Connections: All

Product families

- Copper reducer DIN-EN
- Copper expander DIN-EN
- Copper pipe ANSI
- Copper bend 45 ANSI
- Copper bend 90 ANSI
- Copper reducer ANSI
- Copper expander ANSI
- Copper pipe ANSI K65
- Copper bend 45 ANSI K65
- Copper bend 90 ANSI K65
- Copper reducer ANSI K65
- Copper expander ANSI K65
- Copper pipe ANSI XHP 90
- Copper pipe ANSI XHP 130
- Copper bend 45 ANSI XHP
- Copper bend 90 ANSI XHP
- Copper reducer ANSI XHP

Operating conditions:

Capacity: Cooling capacity: 27.70 kW
Mass flow in line: 637.3 kg/h
Heating capacity: 39.99 kW

Evaporation: Dew point temperature: -10.0 °C
Useful superheat: 10.0 K
Additional superheat: 10.0 K

Condensation: Dew point temperature: 45.0 °C
Subcooling: 10.0 K
Additional subcooling: 0 K

Additional: Discharge temperature: 93.0 °C

Selection criteria:

Pressure drop: Default bar
 Velocity: 12.00 m/s

Saturation temperature drop: 0.020 K/m

Additional selection criteria:

Length: 200.0 m
Angle: 0 deg

Suction line (Dry expansion system. R449A. Piping)

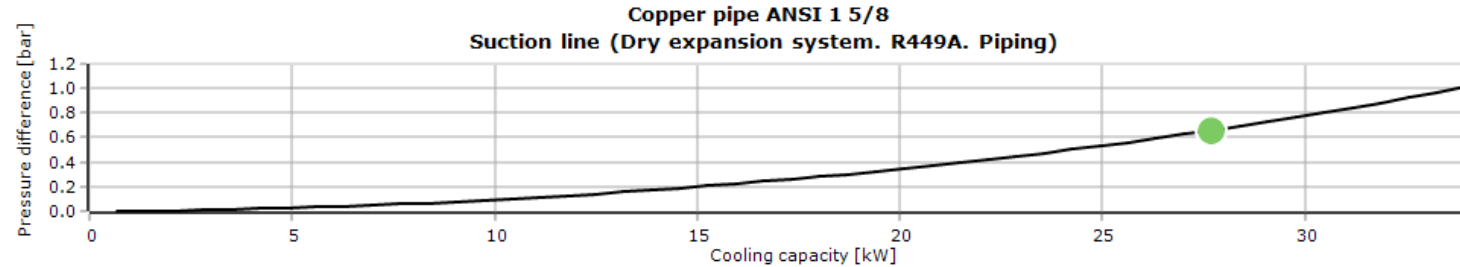
Selection: Copper pipe ANSI 1 5/8

Selected	Type	NS	DP [bar]	DT_sat [K]	DP [K/m]	Velocity, in [m/s]	Velocity, out [m/s]	Result
<input type="radio"/>	ANSI 1 3/8	34.93	1.923	19.2	0.096	15.21	33.58	✓
<input checked="" type="radio"/>	ANSI 1 5/8	41.28	0.658	5.4	0.027	10.74	13.26	✓
<input type="radio"/>	ANSI 2 1/8	53.98	0.159	1.2	0.006	6.18	6.48	✓
<input type="radio"/>	ANSI 2 5/8	66.68	0.055	0.4	0.002	4.00	4.07	✓
<input type="radio"/>	ANSI 3 1/8	79.38	0.023	0.2	0.001	2.81	2.83	✓

Performance curve

Performance details

Copper pipe ANSI 1 5/8
Suction line (Dry expansion system. R449A. Piping)



Cooling capacity [kW]	Pressure difference [bar]
0	0.0
5	0.05
10	0.1
15	0.15
20	0.2
25	0.3
30	0.4
35	0.5
40	0.6

Thanks for your attentions
Questions & Answers ?

