

REFRIGERANT PIPING MANUAL

For Evaporative, Adiabatic Pad, Spray-Assist, Air-Cooled Condensers and Gas Coolers



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Table of Contents

Background.....3

Compressor Discharge (Vapor Refrigerant) Line.....3-4

Liquid Refrigerant (Condensate) Drain Line - Single Condenser.....4-8

Liquid Refrigerant (Condensate) Drain Line - Multiple Condensers.....8-15

Equalizers and Receivers.....15

High-Side Float Regulators.....16

Thermosiphon Oil Cooling.....16-17

Sub-Cooling.....17

Purging.....18

Misc. Piping Considerations.....19

Layout.....19

Carbon Dioxide Refrigerant Piping.....20

Compressor Discharge (Supercritical or Vapor Refrigerant) Line.....20

Gas Cooler Discharge (Supercritical or Liquid CO₂).....21

Evaporative, adiabatic pad, spray-assist and air-cooled condensers are utilized in a variety of refrigeration systems to provide efficient, heat rejection capability. Throughout this document, the term “condenser” will encompass the condenser types mentioned above. A specific condenser type(s) will only be noted when applicable information is provided and does not pertain to other condenser types.

Proper condenser installation as well as connection piping is important to ensure the intended operation is achieved including the overall refrigeration system efficiency. This document provides principles for piping condensers, including single and multiple condensers per installation as well as thermosiphon and sub-cooling piping configurations.

Background

Evaporative condensers have been installed in different refrigeration systems for many years. In addition, and to preserve water, adiabatic, spray-assist and air-cooled condensers are being installed where water availability is scarce, too expensive, or typical annual water usage associated with an evaporative condenser(s) can no longer be supported.

Most evaporative condensers (See Figure 1) utilize some type of serpentine coil design where the vapor refrigerant enters the top of the coil traveling back and forth through several rows as it is cooled and changes phase from superheated vapor to a saturated liquid. This longer travel path by the refrigerant generally produces a small pressure drop. Finned coils, typically utilized on adiabatic, spray-assist and air-cooled condensers, incorporate smaller diameter tubes in comparison to evaporative condensers. As such, and in some applications, the refrigerant pressure drop can be greater. Therefore, proper attention must be given to the condenser piping, primarily the liquid refrigerant (condensate) drain line from the condensing coil outlet to the high pressure receiver or other downstream components.

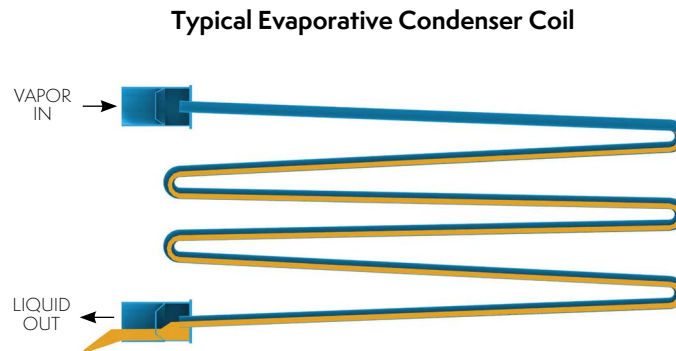


Figure 1

Compressor Discharge (Vapor Refrigerant) Line

A condenser can be piped into a system with either one or multiple compressors. The compressor discharge line should be sized considering the length of pipe run from the compressor to the condenser, and the total allowable pressure drop. Good engineering practice permits a pressure drop corresponding to a 1°F (.56°C) condensing penalty, per 100 equivalent feet (30.5m). The ASHRAE Handbook of Fundamentals uses this criterion as the basis for their compressor discharge line capacity tables. Table 1 is included as a reference to show the line carrying capacity in TR (kW) of refrigeration for several refrigerants in both carbon steel pipe and copper tubing.

The capacities indicated are based on the refrigerant pressure drop for a 1°F (.56°C) change in the saturation temperature per 100 equivalent feet (30.5m) of pipe.

A compressor discharge line sized in accordance with this table typically provides a negligible difference between the actual compressor discharge pressure and that at the entrance to the condenser.



Compressor Discharge Line for Steel Pipe & Copper Tubing

NOMINAL SIZE		R-134a		R-22		R-407C		R-410A		R-507		R-717
STEEL	COPPER in. (mm)	STEEL	COPPER	STEEL	COPPER	STEEL	COPPER	STEEL	COPPER	STEEL	COPPER	STEEL
1 (25)	1-1/8 (29/26)	4 (17)	6 (26)	7 (30)	9 (37)	6 (25)	9 (38)	8 (36)	13 (57)	5 (21)	8 (34)	15 (64)
1-1/4 (32)	1-3/8 (35/32)	10 (44)	10 (45)	14 (62)	15 (64)	12 (52)	15 (66)	18 (76)	23 (99)	11 (46)	14 (59)	39 (168)
1-1/2 (40)	1-5/8 (41/38)	15 (65)	16 (71)	22 (93)	23 (101)	18 (79)	24 (105)	27 (116)	36 (156)	16 (69)	22 (93)	59 (252)
2 (50)	2-1/8 (54/50)	29 (126)	34 (146)	41 (178)	49 (209)	43 (184)	50 (217)	63 (270)	75 (321)	37 (161)	44 (191)	113 (487)
2-1/2 (64)	2-5/8 (67/63)	47 (201)	60 (258)	66 (284)	85 (368)	68 (294)	89 (382)	100 (430)	131 (565)	60 (256)	78 (337)	180 (776)
3 (80)	3-1/8 (79/75)	83 (355)	96 (411)	116 (501)	136 (587)	120 (519)	141 (608)	176 (760)	209 (900)	105 (453)	124 (536)	318 (1370)
4 (100)	4-1/8 (105/99)	168 (723)	200 (862)	237 (1021)	284 (1225)	245 (1056)	295 (1271)	359 (1545)	436 (1878)	214 (921)	260 (1119)	648 (2792)

NOTES:

- CAPACITIES SHOWN ARE TONS OF REFRIGERATION (kW)
- STEEL PIPE 1-1/2 INCH (38mm) AND SMALLER SCH. 80, 2 INCH (50mm) AND LARGER SCH. 40.
- CAPACITIES BASED ON THE FOLLOWING CONDITIONS:
 R-22, R-134a, R-407C, R-410A, AND R-507: 40°F (4.4°C) SUCTION, 105°F (40.6°C) CONDENSING
 R-717: 20°F (-6.7°C) SUCTION, 96.3°F (35.7°C) CONDENSING.
- CAPACITIES BASED ON LINE FRICTION PRESSURE DROP PER 100 FEET (30m) OF EQUIVALENT PIPE LENGTH WHICH CORRESPONDS TO A 1°F (0.56°C) CHANGE IN SATURATION TEMPERATURE. THIS LINE FRICTION PRESSURE DROP PER 100 FEET BY REFRIGERANT IS
 R-22: 3.05 PSI (21.0 KPa) R-407C: 3.50 PSI (24.1 KPa) R-507: 3.65 PSI (25.2 KPa)
 R-134a: 2.20 PSI (15.2 KPa) R-410A: 4.75 PSI (32.8 KPa) R-717: 3.10 PSI (21.4 KPa)

Table 1

Liquid Refrigerant (Condensate) Drain Line—Single Condensers

The liquid refrigerant (condensate) drain line connects the condensing coil outlet to the receiver inlet and is typically configured by utilizing an appropriately downward sloped line coupled to a downstream, vertical section line. The term “drop leg” encompasses the vertical section. Therefore, and throughout the remaining bulletin, “drop leg” as well as the shorter term “liquid drain line” will be utilized.

The suggested piping configuration for a single condenser is illustrated in Figure 2.

This figure shows an air-cooled condenser, with a single, horizontal condensing coil, connected to a vapor refrigerant line upstream and a top inlet, high pressure receiver downstream. The vapor refrigerant line contains a service valve upstream from the connection point to the condenser. The liquid drain line, appropriately sloped (downward from the condenser), contains a purge valve (positioned at the highest point in the pipe). A service valve is installed in the drop leg of the liquid drain line. The receiver is fitted with an appropriately sized purge and relief valve (positioned at the highest point).

The liquid drain line from the condenser to the receiver must receive careful attention. It is fundamental that this line be designed to ensure liquid refrigerant flows freely, by gravity (sewer flow), to the receiver. The line size will depend upon whether it runs directly from the condenser to the top of the receiver or whether it is trapped and connected to the bottom of the receiver.

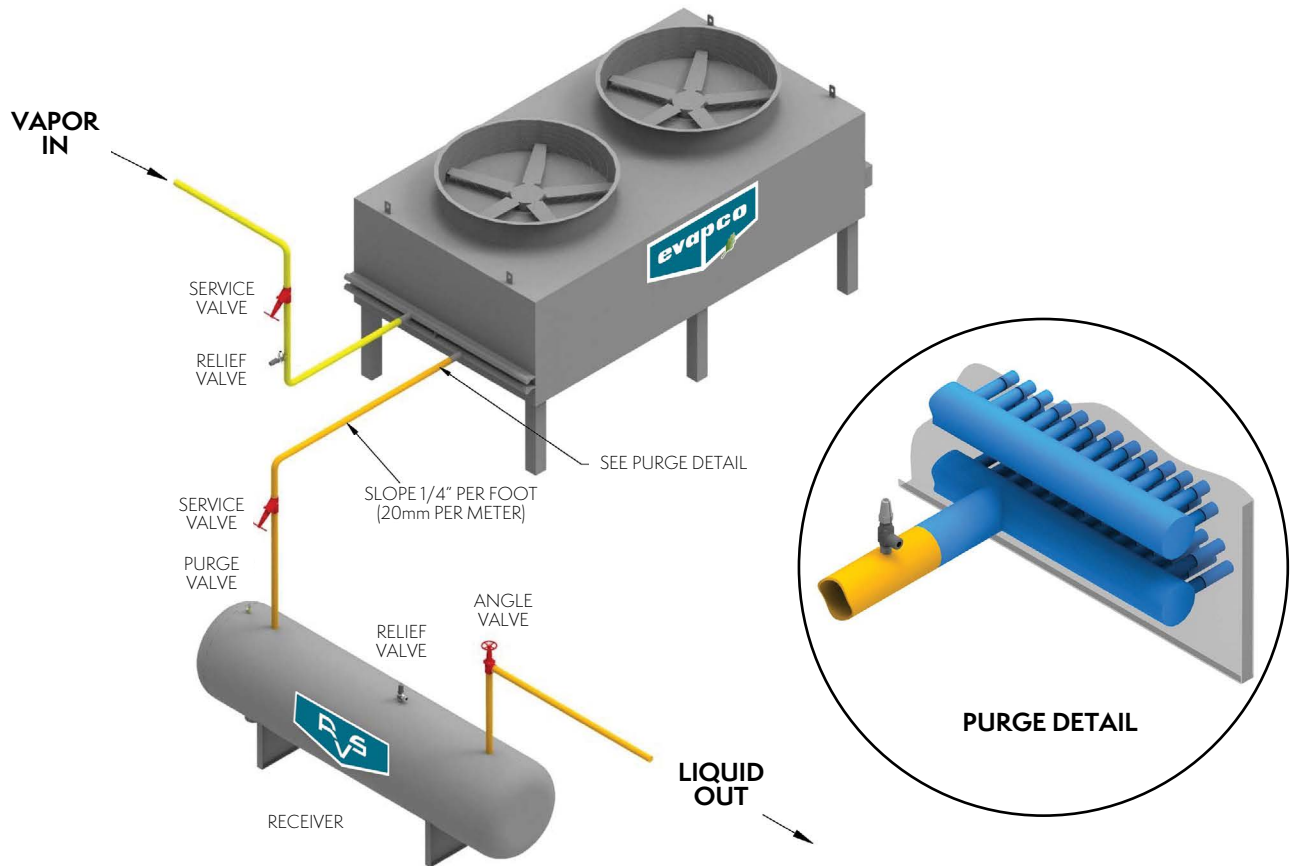


Figure 2

The liquid drain line, shown in Figure 3, must be sized appropriately to enable sewer flow and proper drainage of the low velocity liquid refrigerant into the top of the receiver. This is also referred to as open-channel-type flow where adequate space above the liquid refrigerant flow stream is provided to enable unobstructed vapor refrigerant movement in either direction.

Open-channel-type flow enables the operating pressure in the receiver to be equalized with the pressure at the condensing coil outlet and thus promotes free liquid refrigerant flow between connection points. The liquid drain line should also be sloped downward, to the receiver, at least 1/4 inch per foot (21mm per meter) to facilitate adequate sewer flow.

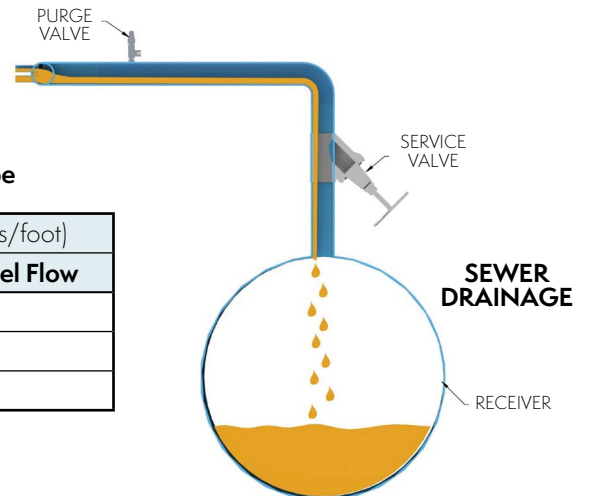


Figure 3

Liquid Refrigerant Drain Line Size – Minimum Downward Slope

Nominal Pipe Size (inches)	Minimum Downward Slope (inches/foot)	
	Full Pipe	Open Channel Flow
1 through 1-1/2	1/4	1/2
2 through 4	3/16	3/8
Greater than 4	1/8	1/4

Table 2



Figure 4 illustrates an air-cooled condenser with a trapped liquid drain line connected to a high pressure receiver. This piping configuration does not allow free vapor refrigerant flow and thus prevents pressure equalization between the receiver and the condensing coil outlet. In this case, a separate line is needed to connect the top of the receiver to the condenser's coil outlet to serve as a pressure equalizer (or equalizer line).

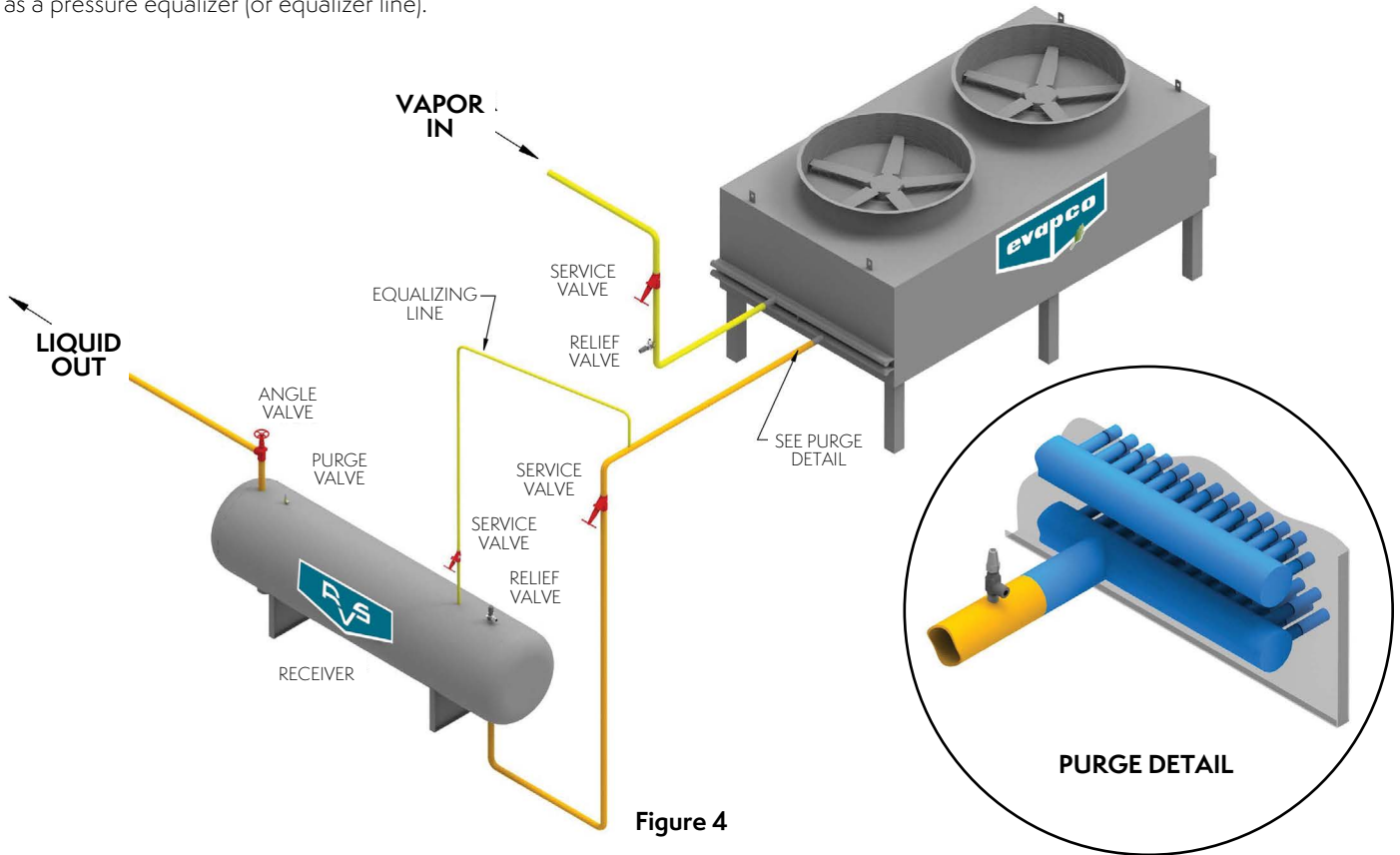


Figure 4

In contrast to open-channel-type flow, there is full-flow where the liquid drain line provides a conduit only for liquid and thus can be reduced in size somewhat. It is also good engineering practice to allow for the frictional pressure drop caused by the liquid refrigerant flow. The suggested maximum capacities (TR (kW)) for the indicated line size regarding open-channel-type and full-flow liquid drain lines are listed in Table 3 for carbon steel pipe and copper tubing with various refrigerants.

Condenser Liquid Drain Line for Steel Pipe & Copper Tubing
Two Phase Sewer Flow

NOMINAL SIZE INCHES (mm)	R-134a		R-22		R-407C		R-410A		R-507		R-717
	STEEL	COPPER	STEEL	COPPER	STEEL	COPPER	STEEL	COPPER	STEEL	COPPER	STEEL
1 (25)	7 (29)	8 (33)	7 (29)	8 (34)	6 (27)	7 (31)	6 (24)	6 (28)	4 (17)	5 (20)	24 (103)
1-1/4 (32)	14 (60)	14 (59)	14 (61)	141 (60)	13 (57)	13 (55)	12 (51)	12 (50)	8 (36)	8 (36)	50 (215)
1-1/2 (40)	22 (93)	22 (93)	22 (94)	22 (95)	20 (87)	20 (88)	18 (78)	18 (79)	13 (56)	13 (56)	77 (332)
2 (50)	39 (168)	36 (155)	40 (172)	37 (158)	37 (159)	34 (146)	33 (142)	30 (131)	24 (102)	22 (94)	140 (603)
2-1/2 (64)	61 (265)	61 (264)	63 (270)	62 (269)	58 (249)	58 (249)	52 (223)	52 (222)	37 (160)	37 (160)	220 (948)
3 (80)	104 (450)	97 (417)	107 (460)	98 (424)	99 (425)	91 (392)	88 (380)	81 (350)	63 (273)	58 (252)	375 (1616)
4 (100)	178 (767)	167 (718)	181 (781)	170 (734)	167 (721)	157 (678)	149 (644)	141 (606)	108 (463)	101 (436)	740 (3188)

Trapped Liquid Line

NOMINAL SIZE INCHES (mm)	R-134a		R-22		R-407C		R-410A		R-507		R-717
	STEEL	COPPER	STEEL	COPPER	STEEL	COPPER	STEEL	COPPER	STEEL	COPPER	STEEL
1 (25)	10 (43)	12 (50)	10 (44)	12 (51)	9 (41)	11 (47)	8 (36)	10 (42)	6 (26)	7 (30)	36 (155)
1-1/4 (32)	21 (90)	21 (89)	21 (92)	21 (90)	20 (85)	19 (83)	18 (76)	17 (75)	13 (55)	12 (54)	75 (323)
1-1/2 (40)	32 (139)	33 (140)	33 (142)	33 (143)	30 (131)	31 (131)	27 (117)	27 (118)	20 (84)	20 (85)	116 (498)
2 (50)	59 (253)	54 (233)	60 (258)	55 (237)	55 (238)	51 (220)	49 (231)	46 (196)	35 (153)	33 (141)	210 (905)
2-1/2 (64)	92 (397)	92 (395)	94 (405)	94 (404)	87 (374)	87 (374)	78 (223)	77 (333)	56 (240)	56 (240)	330 (1422)
3 (80)	157 (975)	145 (625)	160 (690)	148 (636)	148 (637)	136 (587)	132 (570)	122 (525)	95 (409)	88 (378)	563 (2423)
4 (100)	267 (1151)	250 (1077)	272 (1171)	256 (1102)	251 (1082)	236 (1018)	224 (966)	211 (909)	161 (695)	152 (654)	1110 (4782)

NOTES:

- CAPACITIES LISTED IN TONS OF REFRIGERATION (kW).
- STEEL PIPE 1-1/2 INCH (38mm) AND SMALLER SCH. 80, 2 INCH (50mm) AND LARGER SCH. 40.

Table 3

Evaporative condensers are provided with appropriately sized inlet and outlet connections. In some cases, the outlet connection(s) is oversized for the intended application and thus the connecting liquid drain line can be reduced in size and still meet design criteria. Figure 5 illustrates the suggested arrangement with the reduced line size positioned in the drop leg of the liquid drain line (and not reduced and located at the factory connection). In addition, and in accordance with good engineering practice, the installation of a shut off or service valve is preferred in the drop leg of the liquid drain line, at least one foot (0.3 m) below the appropriately downward sloped line. Adiabatic, Spray-Assist and Air-Cooled Condensers are often factory fitted with a smaller outlet connection(s) in comparison to evaporative condensers and thus typically do not need to be reduced in size.

Recommended Method for Reducing Line Size in Vertical Pipe

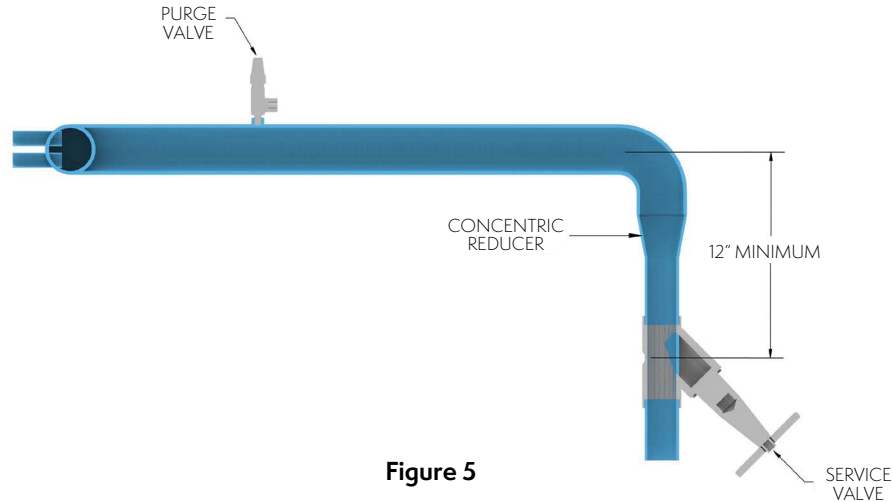


Figure 5

Figure 6 illustrates an often used but not preferred alternate method to reduce the condensing coil's outlet connection size downstream which may provide satisfactory operation. It is acceptable engineering practice to install an eccentric reducer, at a minimum, one pipe diameter upstream from the angle valve inlet, in the appropriately sloped line section. Also, an angle type shutoff valve may be installed provided the seat design allows unobstructed and complete drainage from the upstream, line section.

Alternate Method for Reducing Line Size in Horizontal Pipe

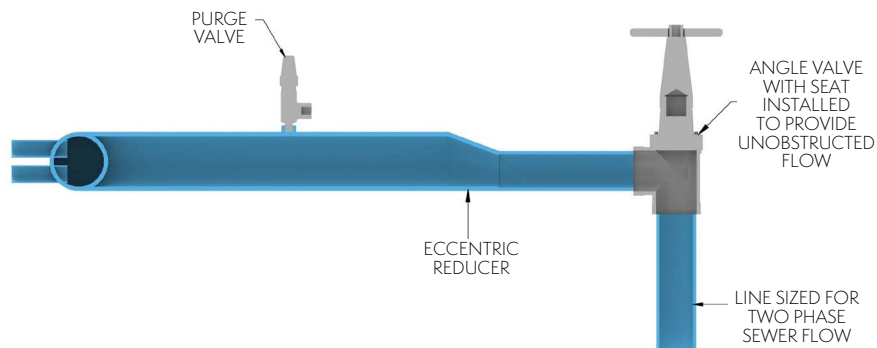


Figure 6

In this arrangement above, the liquid drain line should always be sized for open-channel-type flow (sewer flow) regardless of the connection. It is good engineering practice to keep the liquid refrigerant velocity as low as possible, particularly if an angle valve is installed.

There are condenser installations operating with a liquid drain line(s) reduced in the sloped line section via a concentric reducer coupled with a horizontally positioned globe valve installed. (See Figure 7)

This is an **improper configuration** and should never be considered. A condenser installed with connecting piping as illustrated in Figure 7 can expect to operate with liquid refrigerant backed up into the bottom row (or rows) of the condensing coil which in turn reduces heat rejection capability and may cause other potential problems.

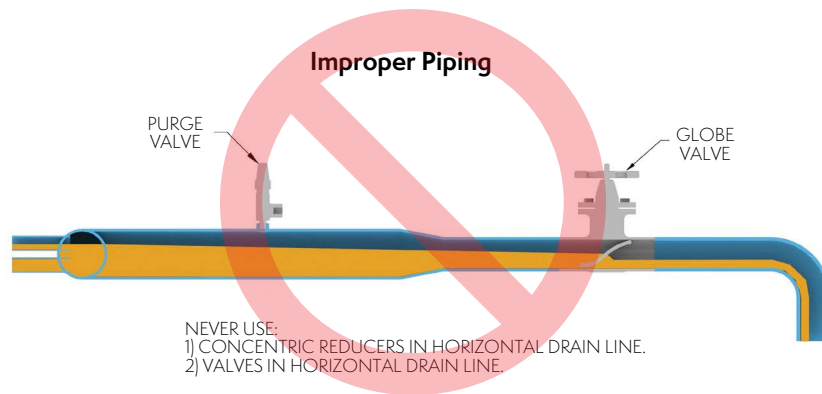


Figure 7

For optimum capacity and low operating head pressure, carefully follow the previous suggestion using the line sizing criteria as absolute maximums at full load conditions. Table 3 is included for reference, listing the capacity in Tons of Refrigeration (kW) for condenser liquid drain lines for several refrigerants for both open-channel-type (two-phase) and full-flow (trapped) liquid refrigerant flow for carbon steel pipe and copper tubing.

Liquid Refrigerant (Condensate) Drain Lines—Multiple Condensers

Multiple condensers operating in parallel must be piped correctly to realize the intended operating capacity and stable operation under all load and ambient conditions. Installations with multiple condensers that are improperly connected can work fine under normal loads when all units are operating simultaneously. However, instability becomes more prevalent during part or full load conditions at lower ambient temperatures when condensers begin cycling off. As such, there may be large fluctuations in the receiver's liquid refrigerant level, or some condensers suddenly seem to become short in capacity. All these symptoms can be attributed to improper piping.

Figure 8 illustrates two large evaporative condensers piped in parallel to a single high pressure receiver. Note that the vapor refrigerant line should be piped as symmetrically as possible. The earlier suggestions regarding good engineering practices for refrigerant line sizing also apply to multiple condenser installations.

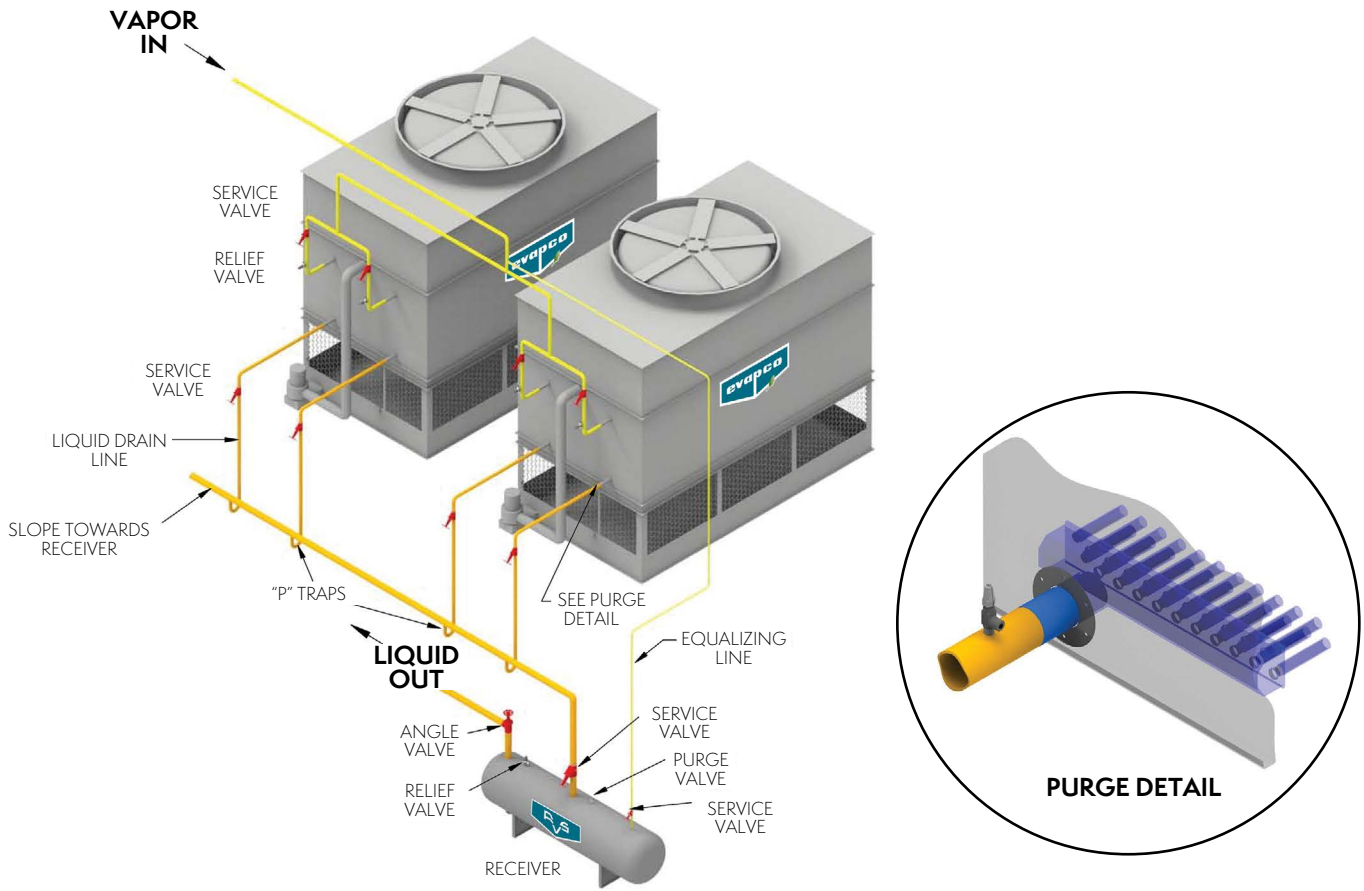


Figure 8



To reiterate, the most important aspect when connecting multiple condensers is the condenser to receiver liquid refrigerant (condensate) drain line piping. The key fundamental aspect is to trap liquid drain lines. The liquid drain line from each condensing coil outlet needs to have a trap positioned in the drop leg. This can be accomplished with a small "P" trap as illustrated in Figure 8 or by using a bottom inlet receiver as illustrated in Figure 9.

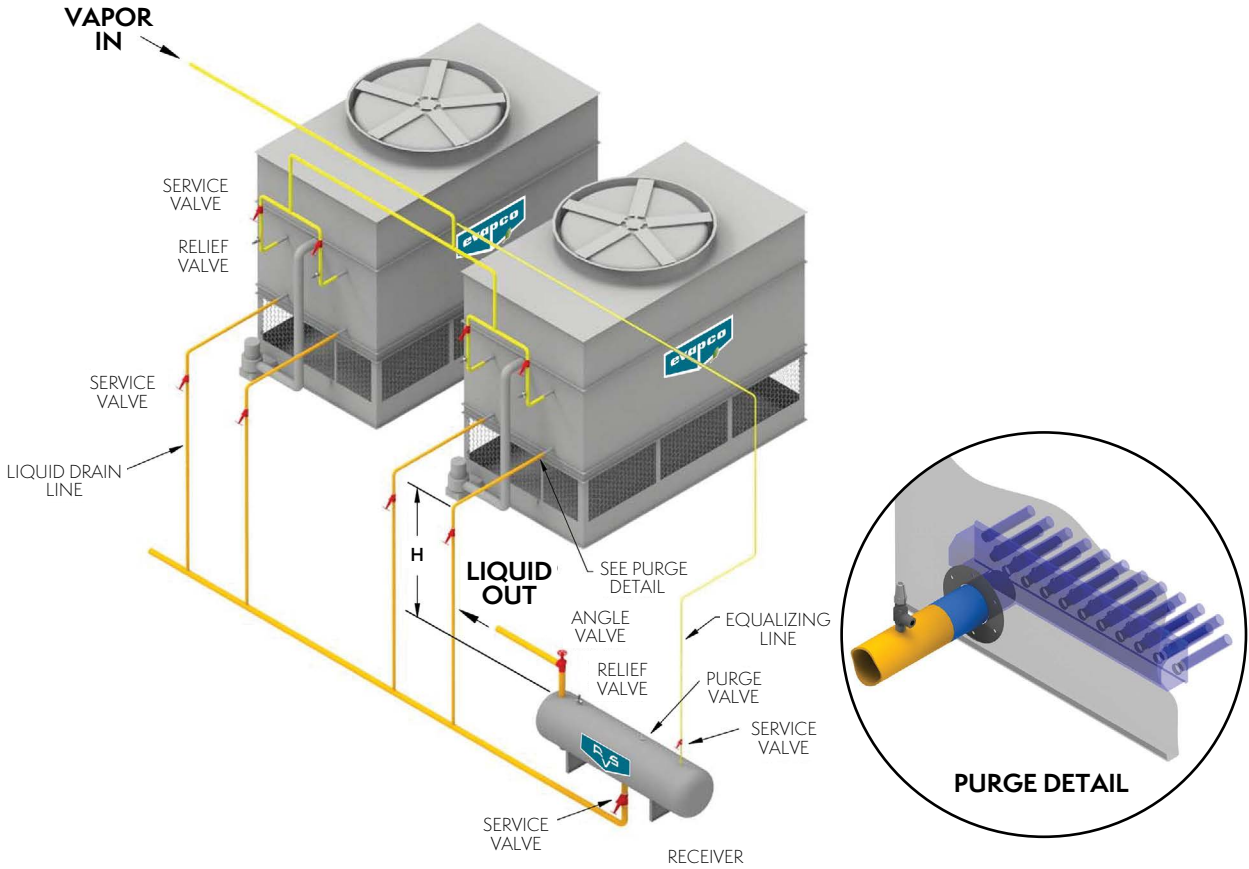


Figure 9

An alternative method for trapping liquid drain lines on multiple condenser installations is illustrated in Figure 10. All condenser liquid drain lines are piped together into one main liquid drain line. A single inverted “P” trap is used to create a liquid seal on the main drain line. In addition, and to prevent siphoning liquid refrigerant from the main drain line, a secondary equalizer line is needed to connect the top of the inverted trap to the primary equalizer line which serves as a vacuum breaker. It is essential to trap liquid drain lines to ensure an appropriate vertical liquid column in each drop leg and thus offset the potential variations in operating pressures between condensing coil outlets. Liquid refrigerant (condensate) will “bottle up” in the condensing coils with the highest pressure drop (or lowest outlet pressure), without incorporating trapped liquid drop legs throughout, subsequently reducing available design capacity and producing unstable operation.

This fundamental and very important concept when piping multiple evaporative condensers into a system is best understood by referring to the following simplified examples.

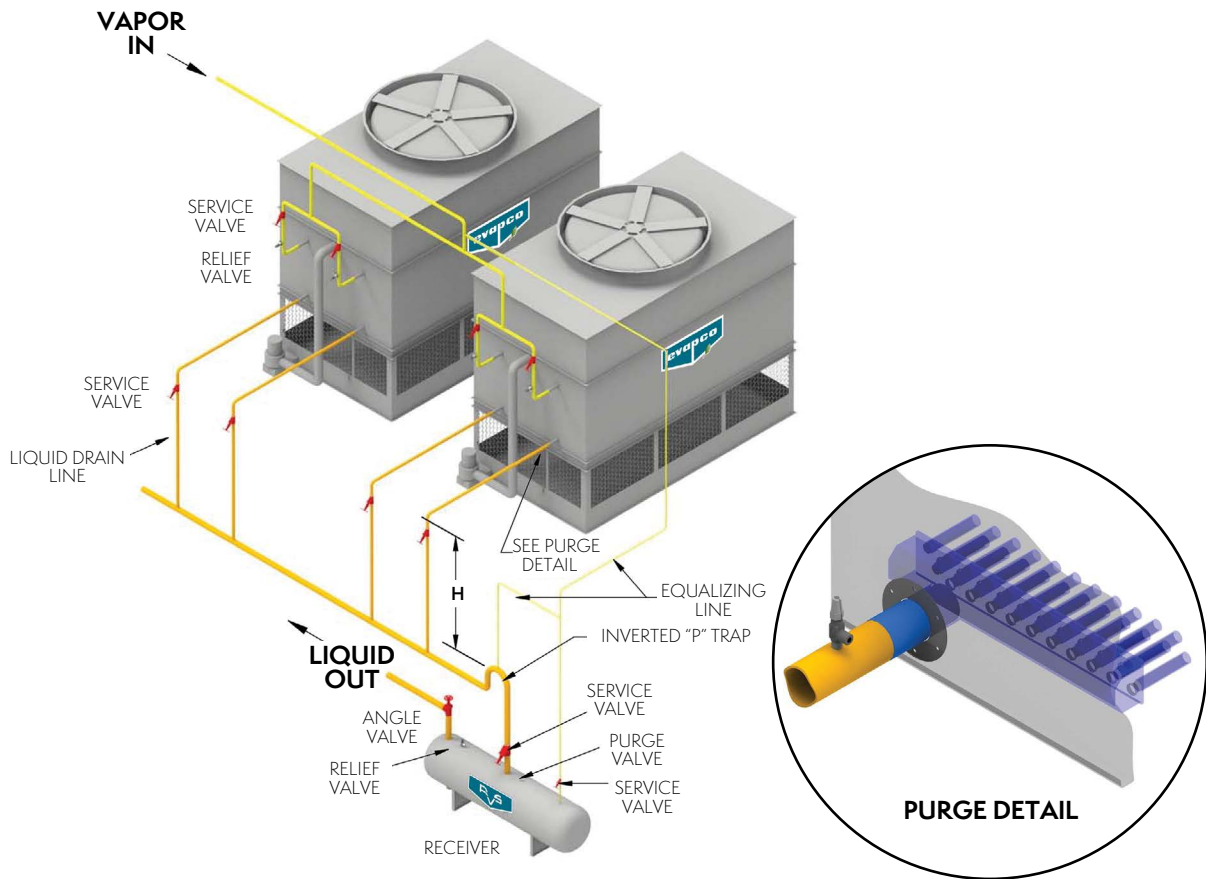


Figure 10

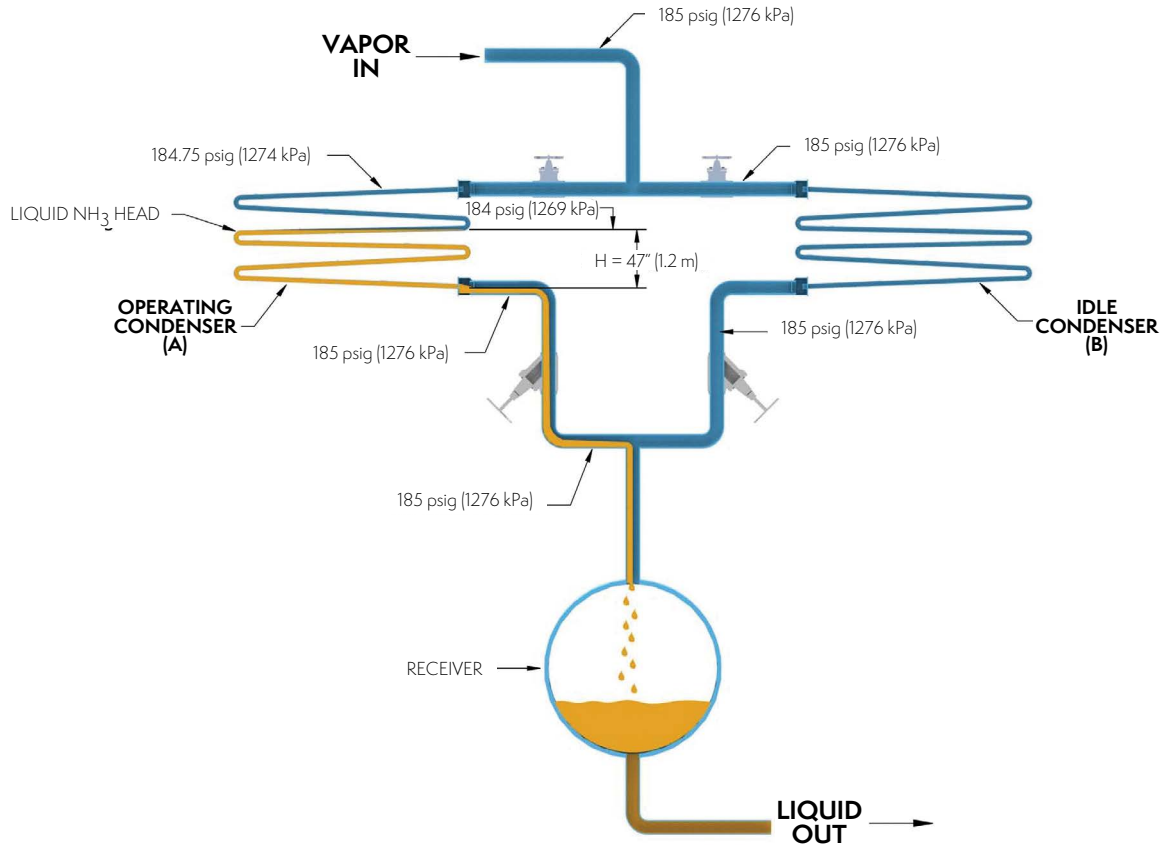


Figure 11

Figure 11 illustrates an incorrect piping arrangement for two NH₃ evaporative condensers A and B piped in parallel. The liquid drain lines, from each condenser, do not incorporate a “P” trap and thus liquid refrigerant flows unrestricted to the receiver. In addition, Condenser (A) is in operation and Condenser (B) is idle. The idle Condenser (B) has no refrigerant flow through the condensing coil and thus there is no pressure drop. Moreover, the indicated vapor refrigerant line pressure of 185 psig. (1276 kPa) equalizes to the connected receiver. The operating Condenser (A), under full load, has a refrigerant pressure drop of 1 psi (6.9 kPa) which consists of 1/4psi (1.7 kPa) across the inlet service valve (vapor refrigerant line) and 3/4 psi (5.2 kPa) through the condensing coil. This situation creates an improper operating condition to facilitate liquid refrigerant flow from Condenser (A) at full load. Moreover, liquid refrigerant cannot flow from the lower operating pressure condensing coil, at 184 psig (1269 kPa) into the higher pressure, main liquid drain line at 185 psig. (1276 kPa). This pressure differential facilitates liquid refrigerant build up or “bottling” in the operating condenser until the pressure difference is offset. In this case, the pressure difference is 185 psig. (1276 kPa) minus 184 psig. (1269 kPa) or 1 psi (6.9 kPa). One pound per square inch (6.9 kPa) is equivalent to 47 inches (1.2m), (ammonia) liquid refrigerant head, which will “bottle up” in the operating condenser to establish refrigerant flow through the condensing coil.

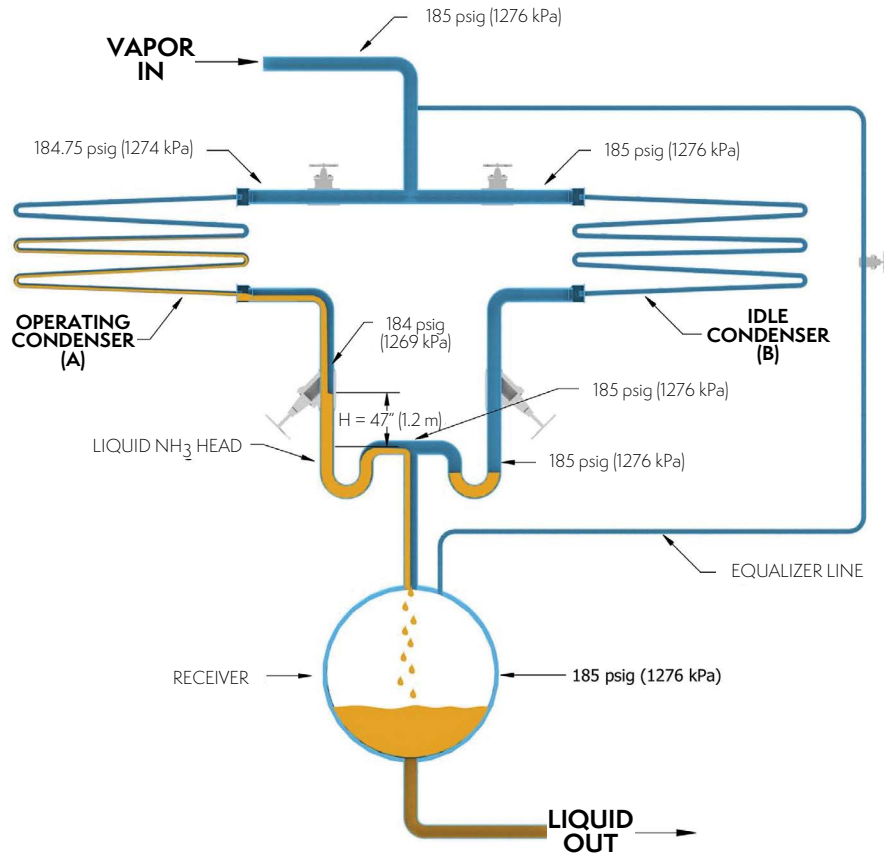


Figure 12

The liquid refrigerant head dimensioned as “H”, in Figure 11, can essentially fill an average operating condensing coil with liquid refrigerant. A condensing coil, filled to this extent with liquid refrigerant, greatly reduces the available condensing surface area, which in turn may starve the system of refrigerant as well as dramatically elevate the system’s head pressure. In addition, and a notable symptom, the liquid drain line would most likely feel cool because the liquid filled condenser would be operating more as a subcooler than condenser.

In Figure 12 the two condensers illustrated in Figure 11 have been re-piped to include a liquid drop leg with a “P” trap at the bottom, upstream to a liquid refrigerant main line draining to the receiver. An equalizer line has also been added connecting the receiver to the vapor refrigerant line. This is necessary to maintain a stable pressure in the receiver which will ensure free liquid refrigerant drainage from the condensers.

The appropriate liquid head must again be developed to produce liquid refrigerant (condensate) flow under the identical operating conditions previously described. A 1 psi pressure drop still exists in the operating condenser producing a lower pressure (184 psig/1269 kPa) at its outlet as compared to the idle condenser (185 psig/1276 kPa) and the receiver (185 psig/1276 kPa). Incorporating a “P” trap in each liquid drain line creates a liquid seal and enables the liquid refrigerant to build in the operating condenser’s drop leg and not in the condensing coil. The pressure associated with a (ammonia) liquid refrigerant column, 47 inches (1.2m) in height, is about 1 psi.

There must be enough height above the trap in the drop leg to accommodate a liquid head equal to the maximum pressure drop that will be encountered in the condensing coil(s). This example illustrates the extreme case of one condenser on and one off, however, the same phenomenon happens to a lesser degree between two different condensers of differing pressure drops when both are in full load operation. There, also, can be substantial differences in refrigerant pressure drop between two different condenser manufacturers with the same design capacity or even different models from the same manufacturer.

EVAPCO's suggestion for evaporative condensers regarding the minimum, drop leg height is 5 feet (1.52m) for ammonia and 10 feet (3.05m) for halocarbon refrigerants. Adiabatic, spray-assist, and air-cooled condensers is 8 feet and 13 feet for ammonia and halocarbon refrigerants, respectively. This is represented as the vertical dimension "H" in Figure 9. Moreover, these are the minimum drop leg heights for satisfactory operation within reasonable excursions beyond "nominal" design conditions and are primarily based upon the maximum condensing coil pressure drop. If service valves are included at each coil's inlet and/or outlet, the pressure drop imposed by these valves must be accounted for by increasing the above recommended minimum drop leg height(s) by an amount equal to the valve pressure drop in feet of liquid refrigerant utilized.

A condenser's heat rejection capability could be considerably higher than design capacity resulting in both higher refrigerant mass flow and pressure drop with fluctuating ambient conditions and condensing pressures. It is suggested, and whenever possible, the drop legs be designed approximately 50% greater in height than the suggested minimum.

(Note other manufacturers may recommend different drop leg heights in comparison to this bulletin's suggested values, depending on their condenser design).

Referring to Figure 9, the liquid drain line drop legs should be sized as a full-flow liquid line. It is good engineering practice to slope the main liquid drain line 1/4" per foot (21mm/meter) towards the receiver and be sized for open-channel-type flow (sewer flow). Note that the main liquid drain line itself is not trapped. The equalizing line runs from the receiver to a centrally located position in the vapor refrigerant line feeding the condensers. This line should not be connected to the condensing coil outlets or multiple condensers as this would facilitate the same effect as eliminating the "P" traps and thus cause bottling in the condensing coils with the lowest outlet pressures.

In a multiple condenser system, using a bottom inlet receiver as shown in Figure 9, the minimum height "H" is calculated from the highest level of liquid in the receiver. Both the liquid drop legs and the now trapped main liquid drain line may be sized as a trapped liquid line. Often an evaporative condenser will be placed in parallel with a water-cooled condenser, whether shell and tube or plate and frame, as illustrated in Figure 13.

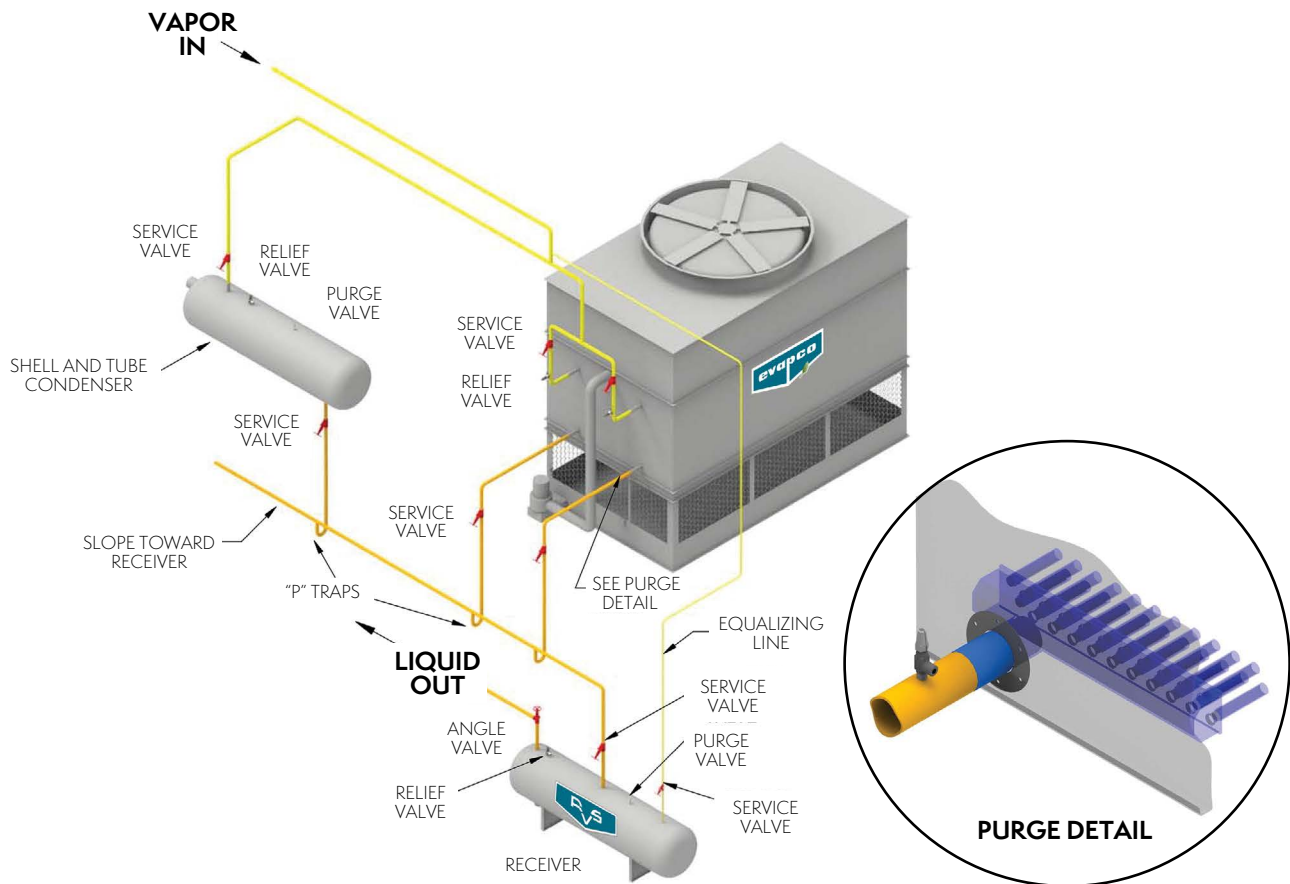


Figure 13



The same piping considerations apply in this case as well. The pressure drop in a water-cooled condenser can be small, however, providing an adequate drop leg height to more than offset the pressure drop in the condenser is suggested. Basically, this type of condenser only needs to be located above the receiver high enough to obtain proper liquid refrigerant flow.

Equalizers & Receivers

This bulletin, so far, describes and illustrates typical condenser piping configurations connected to a high pressure receiver and a means to equalize the pressure between these components. A high pressure receiver provides a liquid refrigerant reservoir and should be sized accordingly to accommodate fluctuations in the liquid refrigerant received during operation from either the high or low side of the system as operating loads and conditions change. It also allows complete drainage of the condensing coil(s) so there is no effective condensing surface loss from liquid refrigerant inadvertently being stored in the coil.

The receiver may either condense vapor or flash liquid refrigerant, depending upon the air temperature in contact with the outside surface. An equalizer line is required to relieve potential internal pressure excursions. For example, if the operating condensing temperature is 90°F (32.2°C) and the connected receiver is in an engine room that is 100°F (37.8°C), there will be liquid flashing and a potentially high operating pressure. Therefore, and to enable the liquid refrigerant to freely drain from the condensing coil(s), the receiver must be equalized and connected to the vapor refrigerant line and associated operating pressure.

In open-channel-type flow, illustrated in Figure 2 via an air-cooled condenser with a single condensing coil (and enlarged in Figure 3), the liquid drain line is not trapped. Equalization between the condensing coil outlet and the receiver can occur in the liquid drain line itself provided it is properly sized for open-channel-type flow (sewer drainage). If the liquid drain line to a single coil unit is trapped, as in Figure 4, then the equalizer line can be connected to the liquid drain line in close proximity to the factory coil outlet/field connection joint. Alternately, and if connected to the vapor refrigerant line, then the liquid drain line drop leg height must be tall enough to offset the coil pressure drop in the condenser as previously presented regarding multiple condensers.

For multiple condenser (as well as condensing coils) installations illustrated in Figures 8 thru 10, 13 and 14, it is good engineering practice for the equalizer line to connect the receiver (highest point) to the vapor refrigerant line positioned as symmetrically to the condensing coil's inlet(s) as possible. However, it is not good engineering practice to equalize to the condensing coil's outlet(s) where multiple condensers are installed, since this negates the liquid drain line trap affect.

The refrigeration system designer, regarding sizing an equalizer line, should take into account the receiver external surface area, line distance between receiver and condenser, liquid drain line drop leg height, temperature difference between the ambient and condensing temperatures and any other equipment in the system that might create flash gas. Table 4 is a guideline for selecting a satisfactory equalizer line size for most ammonia refrigeration systems.

For other applications involving halocarbon refrigerants, the system design engineer must apply the principles described above to identify the proper equalizer line size for their specific installation.

Guide for Sizing Equalizer Lines for R-717

PIPE Size Inches (mm)	MAXIMUM SYSTEM CAPACITY Tons (kW)
3/4" (20)	50 (215)
1" (25)	86 (370)
1-1/4" (32)	160 (689)
1-1/2" (38)	225 (969)
2" (50)	450 (1937)
2-1/2" (65)	650 (2800)
3" (80)	1000 (4300)
4" (100)	1800 (7750)

Table 4



High-Side Float Regulators

High-side float controls and regulators are a separate subject, which will not be considered in this manual. EVAPCO recommends following the specific manufacturer's installation and operating instructions.

Thermosiphon Oil Cooling

Thermosiphon oil cooling is popular in the industrial refrigeration market. Figure 14 illustrates the typical piping configuration when thermosiphon oil cooling is incorporated. Liquid refrigerant flowing from "V" style, air-cooled condenser, drains into a pilot receiver. The pilot receiver then supplies liquid refrigerant to the oil cooler(s) by gravity flow. The heat transfer taking place in the oil cooler(s) will typically impart a phase change to the refrigerant such that some of the liquid refrigerant is converted to vapor, absorbing heat from the oil. The two-phase, liquid/vapor refrigerant mixture is returned to the pilot receiver. The vapor refrigerant is separated in the receiver and returned to the condensers through the gas return/equalizer line. The remaining liquid refrigerant flows from the pilot receiver to the main, high pressure receiver and subsequently to the rest of the system.

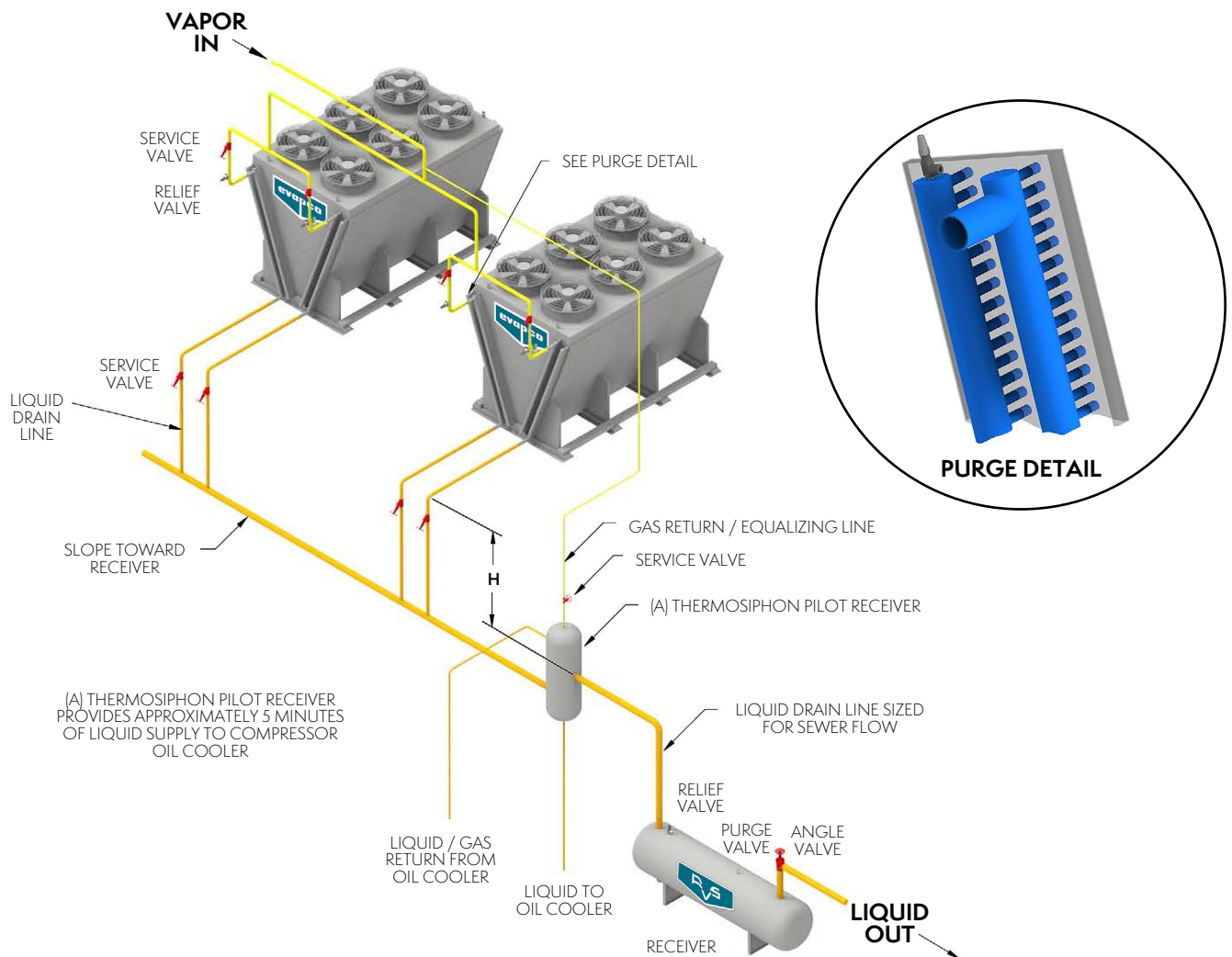


Figure 14

The pilot receiver serves as a refrigerant reservoir whose primary function is to feed the oil cooler(s). Liquid refrigerant utilized for oil cooling is given priority over system liquid supply. Therefore, the liquid outlet connection to the oil cooler(s) is at the bottom of the receiver and is sized using the liquid line criteria described previously in this bulletin. Liquid refrigerant can overflow to the main, high pressure receiver and the connecting line is sized based on open-channel-type (sewer) flow. The 'H' dimension, illustrated Figure 14, represents the drop leg height for this configuration and utilizes the liquid drain line connecting the thermosiphon pilot receiver to the main, high pressure receiver as a reference point (not the main liquid drain line connected to the condensing coil drain lines).

Sub-Cooling

A sub-cooling coil installed in the condenser may be employed to cool the liquid refrigerant for applications involving long runs of liquid lines or direct-expansion (DX) evaporators. Sub-cooling saturated liquid refrigerant will prevent flash gas forming in the liquid line which negatively affects the expansion valve operation.

Figure 15 shows the proper piping configuration with a sub-cooling coil as part of the evaporative condenser. Liquid refrigerant from the condensing coil drains into the receiver and then is returned to the evaporative condenser and into the sub-cooling coil before moving on to the evaporator.

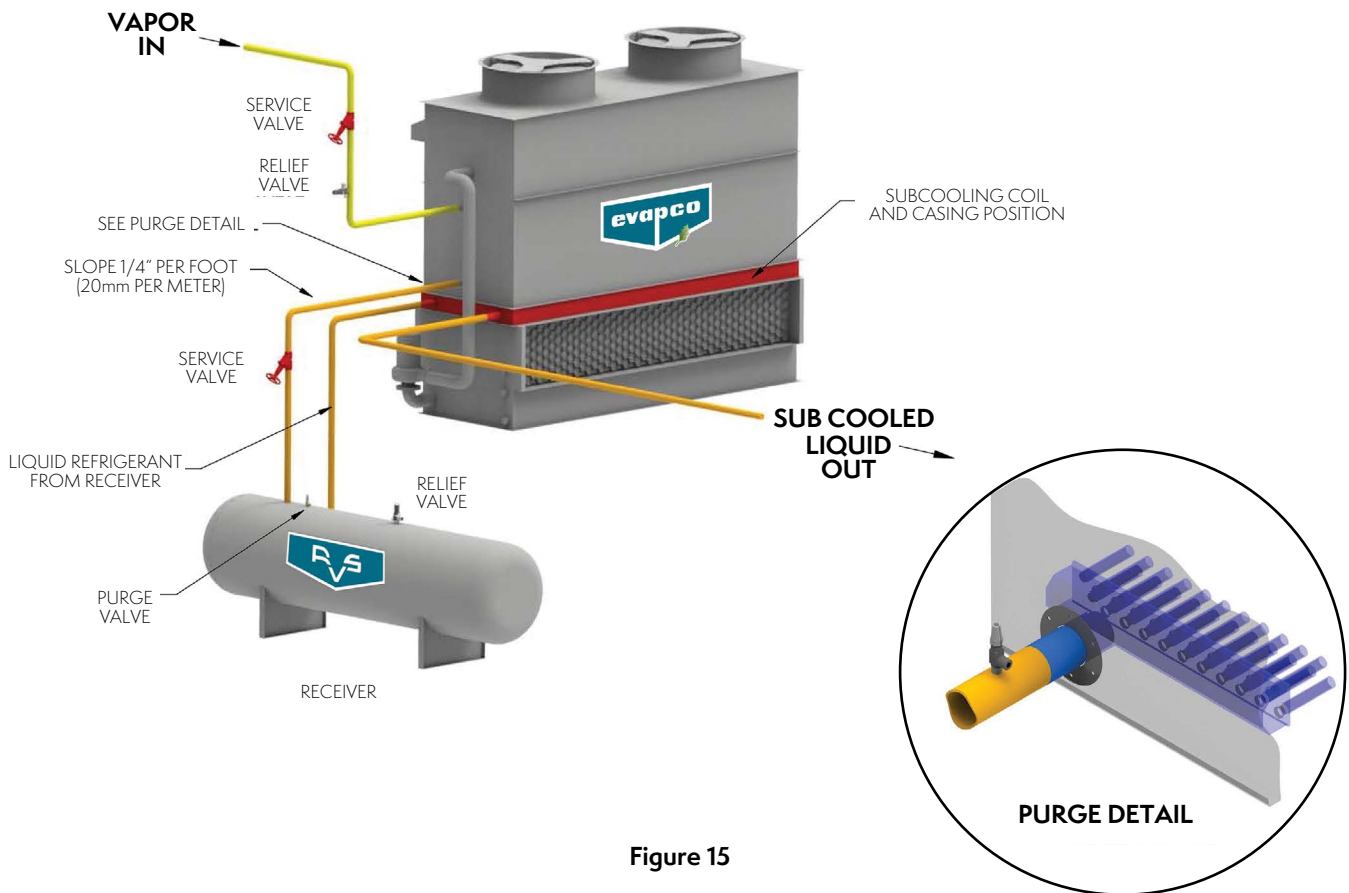


Figure 15

Purging

The sample piping layouts provided in this bulletin have shown one or more purge connections. The design and proper use of these purge outlets to remove non-condensables from the system are important in obtaining the lowest operating cost for the condenser(s) and refrigeration system. Air and other non-condensable gases are present and collect in refrigeration system from several sources:

- 1) Insufficient evacuation prior to initial charging or after the system has been opened for repair.
- 2) Low side system leaks if the operating pressure is below atmosphere.
- 3) Introducing poor quality refrigerant containing non-condensables.
- 4) Chemical breakdown of oil and/or refrigerant.

The presence of non-condensables has the effect of raising the refrigerant's saturation pressure which in turn increases the design condensing pressure as well as the system's operating power requirements. The condensing pressure will continue to rise as non-condensables build-up over time. The percentage of non-condensables in the system's refrigerant versus the amount of increased head pressure is not an exact relationship. Nonetheless, small amounts of non-condensables can produce significant increases to the system's operating cost.

During system operation the non-condensable gases will be swept through the condenser(s) and, therefore, become concentrated at the condensing coil(s) outlet and in the receiver. It is good engineering practice for purge connections, typically 1/2" to 3/4" (15 to 20mm, NPS), to be located at the highest point of the receiver and each condensing coil liquid refrigerant drain line header. It is acceptable for liquid refrigerant drain line horizontal header configurations to have a purge valve installed on each coil outlet connection, as close to the outlet header as possible, if the highest point of the outlet header is not accessible. However, and for header/connection assemblies where the connection is offset lower than the header, as indicated in Figure 16, it is good engineering practice to provide the purge connection at the header and not at the connection. For EVAPCO condensers where the design results in a connection lower than the header, this purge connection will be provided by EVAPCO (valve by others) and will penetrate through the casing panel. This configuration is primarily found in the PHC product line. All individual purge valve outlets can be cross connected into a single purge line which may or may not be connected to an automatic purger.

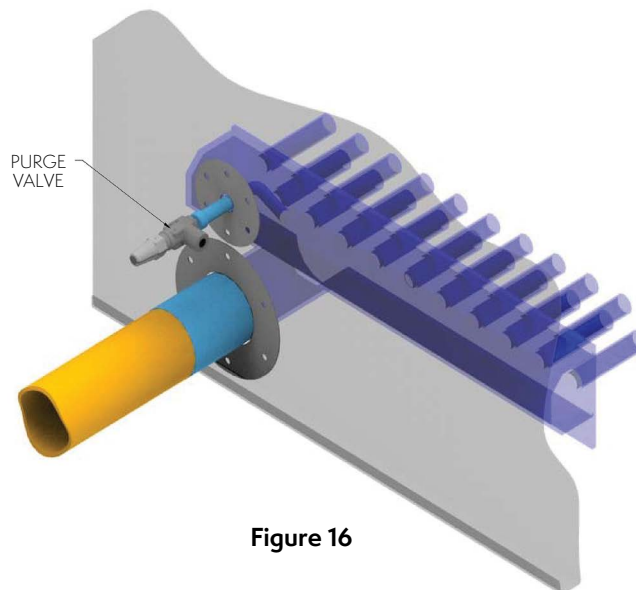


Figure 16

Normally accepted safety procedures and caution must be followed when manual purging is practiced. Purging non-condensables during system operation is the most common practice and is generally considered the most effective. It is suggested that each purge valve, located at each condensing coil outlet header/connection and the receiver, be opened, one at a time, when these locations are cross connected. In doing so, this will avoid interconnecting these outlets and potentially causing liquid refrigerant to back up into the condensing coil(s).

IMPORTANT NOTE: Purging a mixture of non-condensables with certain refrigerants to atmosphere is regulated by federal and local jurisdictions.

Miscellaneous Piping Considerations

- 1) Plan ahead for the possibility of future expansions. This is particularly important in line sizing, determining elevations above the receiver, and providing adequate space to obtain proper airflow.
- 2) Make sure the piping is properly designed to allow some flexibility for thermal expansion and contraction as well as vibration.
- 3) Any refrigeration valves in a horizontal pipe run should be installed with the valve stem also in a horizontal position.
- 4) In NH₃ systems with multiple parallel compressors it is good engineering practice to cross connect the individual vapor refrigerant lines into a common/main vapor refrigerant line to the condensers.
- 5) It is suggested to include a condensing coil safety relief valve(s) when service valves are installed both upstream and downstream from the condensing coil connections. Specific incidents have occurred where the condensing coil(s) has been filled with liquid refrigerant and inadvertently isolated via the service valves. Subsequently, a rise in ambient temperature generated hydraulic forces sufficient to rupture the condensing coil(s).
- 6) Angle valves are commonly used in refrigeration piping and are acceptable. They must be properly oriented with full size orifices and provide the same flow resistance as a normal pipe elbow, same NPS.
- 7) Piping should be installed in accordance with applicable codes and good engineering practice. All piping should be anchored by properly designed hangers and supports with allowance made for possible thermal expansion and contraction. No external loads should be placed upon any condensing coil connection nor should any pipe supports be anchored to the condenser's framework.

Layout

Piping considerations frequently influence the physical placement of condensers. It is important to ensure proper airflow in and out of the condenser and is just as important to the operation of the condenser as proper piping. However, and in some cases, installing an additional, new condenser to an existing system adds little heat rejection capacity due to poor air flowrate provisions.

Condenser layout is a separate subject, which will not be considered in this manual. Refer to EVAPCO Bulletin entitled "Equipment Layout" for additional information on specific condenser types regarding layout or consult the EVAPCO Sales Representative nearest you.



Carbon Dioxide Refrigerant Piping

OVERVIEW

Carbon Dioxide (CO₂/R-744) is a natural refrigerant with significantly different thermophysical properties and higher design operating pressures in comparison to ammonia (NH₃/R-717) and other refrigerants. Due to CO₂'s higher design operating pressure, small reciprocating or scroll compressors are typically utilized in a "rack-style" enclosure. This configuration typically leads to the CO₂ compressor(s) connecting to a singular gas cooler which operates at a much higher pressure drop in comparison to an NH₃ condenser. In addition, and at design entering air dry bulb temperatures approximately 82°F and greater, carbon dioxide as a refrigerant operates above its critical point in a supercritical state (outside the dome, refer to ASHRAE's R-744 P-H diagram). However, lower design entering air dry bulb temperatures will allow carbon dioxide to become sub-critical (under the dome) which places the refrigeration system in sub-critical operation and results in condensing the refrigerant.

Dry and adiabatic type air cooled gas coolers have been the primary, high side heat exchange device to incorporate into a CO₂ refrigeration system. The inherent, high, design operating pressure and allowable refrigerant pressure drop values lead to utilizing smaller diameter tubes with a greater wall thickness in comparison to non-CO₂ evaporative condensers.

Most air cooled gas coolers (see Figure 17) utilize some type of finned coil design where the refrigerant (supercritical or vapor state) enters the top of the coil and travels counterflow to the external air stream through several rows as it is cooled and changes phase to a saturated liquid when operating in condenser mode. The refrigerant travel path coupled with the internal tube diameter typically produces a significantly higher pressure drop in comparison to non-CO₂ refrigerants.

Therefore, good engineering practices for CO₂ refrigeration systems can differ in comparison to non-CO₂ systems. The scope for this section does not encompass all CO₂ refrigeration system configurations and is primarily intended for a rack-style enclosure configuration and associated refrigerant piping.

Compressor Discharge (Supercritical or Vapor Refrigerant) Line

A CO₂ gas cooler can be piped into a refrigeration system with either one or multiple compressors. The compressor discharge line should be sized considering the equivalent, pipe run length from the compressor to the condenser, (internal) pipe diameter, pipe material, and the total allowable pressure drop. Good engineering practice permits a pressure drop corresponding to a 1°F (.56°C) condensing penalty, per 100 equivalent feet (30.5 m). Historically, the ASHRAE Handbook of Fundamentals uses this criterion as the basis for their compressor discharge line capacity tables.

Consideration should also be given to the compressor discharge line, refrigerant velocity, where good engineering practice permits up to 3500 feet per minute (FPM). However, carbon dioxide in a supercritical or vapor state will typically reach a pressure drop corresponding to a 1°F (.56°C) condensing penalty, per 100 equivalent feet (30.5 m) criterion, before approaching the permissible vapor refrigerant velocity of 3500 FPM. It is the design engineer's responsibility to determine the best balance between refrigerant pressure drop and velocity to achieve acceptable operating conditions between the compressor discharge and entrance to the condenser. Please reference the IAR on-line Pipe Sizing Calculator Tool (single phase only) to determine refrigerant pressure drop and velocity for the input refrigerant temperature and pressure as well as nominal pipe diameter, schedule, material, and length.

It is suggested that the compressor discharge line sizing for elevated vapor refrigerant velocities above the permissible value be carefully considered along with the associated pressure drop and other operating parameters. In any system, whether new or old, a measurably higher pressure drop in the compressor discharge line should be considered in sizing the condenser and compressor.

Overall, compressor line sizing for carbon dioxide (CO₂/R-744) in accordance with good engineering practice regarding pressure drop and vapor refrigerant velocity will provide the desired result for most if not all industrial refrigeration applications.

Gas Cooler Discharge (Supercritical or Liquid CO₂)

Historically, the liquid refrigerant (condensate) drain line connects the condensing coil outlet to the receiver inlet and incorporates an appropriately downward sloped line coupled to a downstream, vertical suction line. This is illustrated for a single condenser in Figure 2. Gas coolers using carbon dioxide (CO₂/R-744) as the refrigerant drain into a flash receiver that is lower in pressure by as much as 400-600 psi. With all the above in mind, carbon dioxide will not condense when operating in a supercritical state, which is typically at higher ambient conditions. Moreover, the typical CO₂ refrigeration system and piping design does not rely on gravity or “sewer” flow where operating pressure drop values throughout the system are critical to ensure proper refrigerant flow in non-CO₂ refrigeration systems. There is a significantly greater pressure differential from the compressor outlet to the evaporator inlet which in turn provides the driving force to enable proper refrigerant flow without relying on gravity. As such, classical drop leg requirements, open-channel, and full-flow type considerations as well as frictional pressure drop values after the outlet of the condenser to accommodate a variety of operating conditions are no longer required.

Providing recommended, maximum refrigeration capacities (TR or kW) for various pipe/tube sizes and materials for the supercritical CO₂ or liquid refrigerant (condensate) drain line will be ineffective. The CO₂ refrigeration system’s operating pressure range coupled with the allowable high side heat exchanger pressure drop should be evaluated to determine if any specified line size may cause an unacceptable refrigerant flow scenario.

EVAPCO recommends that the CO₂ gas cooler discharge line velocity not exceed 7.9 ft/sec. This velocity limit is significantly higher than non-CO₂ liquid drain lines by assuming there is a significant pressure differential available at the outlet of the high side heat exchanger to the next downstream component, typically a flash gas receiver and is connected to a CO₂ compression system (e.g., rack-style). In this vein, the typical requirement to incorporate a trap and enough height above the trap to accommodate a liquid head equal to the maximum pressure drop that will be encountered in the condensing coil(s) can be minimized. As such, EVAPCO’s suggestion for air cooled CO₂ gas coolers (dry and adiabatic) operating in supercritical, trans-critical, or sub-critical mode regarding the minimum, drop leg height is 3 feet (1 meter). This is represented as the vertical dimension “H” in Figures 17 and 18. The fluid drain line (shown in figures 17 and 18) needs to be equal to or greater than the elevation of the flash tank inlet on the rack. In addition, EVAPCO recommends symmetrical piping and isolation to individual coils contained in a single unit represented in Figure 18.

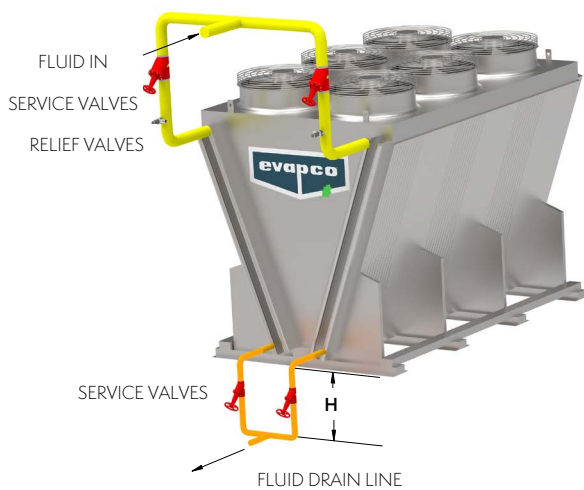


Figure 17

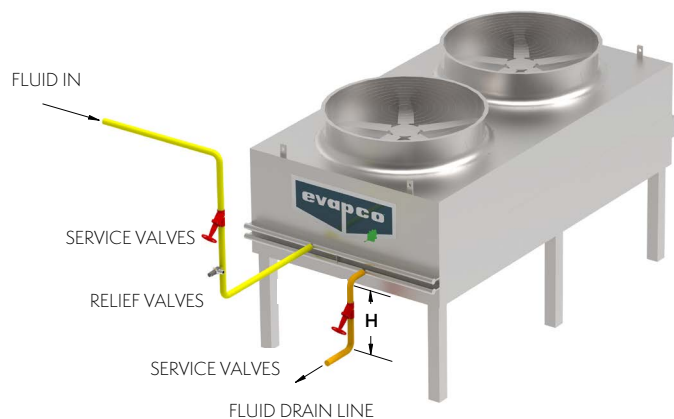


Figure 18

NOTE: Other manufacturers may recommend different drop leg heights or none in comparison to this section’s suggested value, depending upon their overall system design.



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