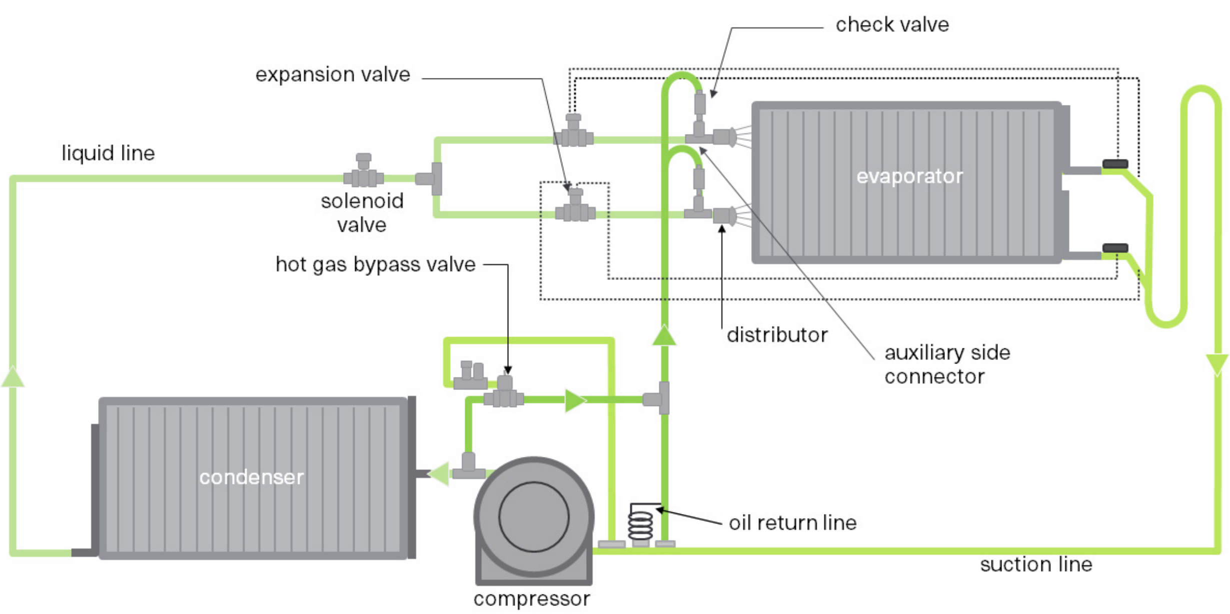
Application Guide

Hot Gas Bypass Installation Guidelines for Direct Expansion (DX) Split Systems



Note: For illustration only, image not to scale. Actual placement of components may be closer or further away.

⚠SAFETY WARNING

Only qualified personnel should install and service the equipment. The installation, starting up, and servicing of heating, ventilating, and air-conditioning equipment can be hazardous and requires specific knowledge and training. Improperly installed, adjusted or altered equipment by an unqualified person could result in death or serious injury. When working on the equipment, observe all precautions in the literature and on the tags, stickers, and labels that are attached to the equipment.

January 2023

APP-APG017D-EN

Preface

As a leading HVAC manufacturer, we deem it our responsibility to serve the building industry by regularly disseminating information that promotes the effective application of building comfort systems. For that reason, we regularly publish educational materials, such as this one, to share information gathered from laboratory research, testing programs, and practical experience.

This publication focuses on hot gas bypass guidelines for direct expansion (DX) split systems. While hot gas bypass might also be used in packaged DX equipment or packaged water chillers, this guide is focused on its use in DX split systems that include field-installed refrigerant piping.

We encourage engineering professionals who design building comfort systems to become familiar with the contents of this guide and to use it as a reference. Architects, building owners, equipment operators, and technicians may also find this publication of interest because it addresses system layout and control.

Trane® has a policy of continuous product and product data improvements and reserves the right to change design and specifications without notice. As such all data in this application guide should be considered for reference only, please consult with a Trane® sales associate for current equipment operating range and performance.

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Overview

HOT GAS BYPASS: WHAT IS IT AND WHAT DOES IT DO

Hot Gas Bypass (HGBP) is a method to artificially influence the compressor/evaporator balance point in order to match the unit capacity to the system load, to prevent coil icing, and to reduce compressor cycling.

When controlling to a specified discharge air temperature, diminishing loads may force a refrigeration system to operate at unstable conditions. The result is compressor and evaporator capacities will balance at ever lower suction pressures driving down the Saturated Suction Temperature (SST). If left unchecked, this will eventually result in evaporator coil frosting, potential compressor flooding, poor system performance, and potential equipment reliability concerns.

During part load operation, HGBP can stabilize the suction temperature of the system balance point by diverting hot, high-pressure refrigerant vapor (hot gas), from the discharge line directly to the low-pressure side of the system. By diverting the hot gas during part load conditions, heat is mixed with two phase refrigerant on the low pressure side of the TXV. This process accelerates the conversion of two phase refrigerant to a superheated gas, and reduces the amount of liquid refrigerant that is available to absorb heat in the evaporator. Reducing the available amount of liquid refrigerant also has the benefit of elevating the SST, which prevents frost from forming.

Traditionally, HGBP has been viewed as a cure all to control capacity at low loads. This has resulted in its indiscriminate use as a “prescriptive” measure. There is also a general lack of understanding of any benefit that creates unrealistic expectations. For example, HGBP will have minimum impact on a system operating with space temperature control.

Additional concerns are that while HGBP may provide frost control and some semblance of capacity control in many applications, many cases exist where HGBP failed to safely stabilize the system or, undermined reliable operation by introducing problems stemming from oil and refrigerant logging in the HGBP line. And in *all* cases, hot gas bypass inflates the life-cycle cost of the system:

- HGBP increases the initial cost. It requires an additional refrigerant line, which also increases the likelihood of refrigerant leaks and oil/refrigerant logging.
- HGBP greatly reduces operating efficiency because the bypassed vapor does no useful cooling.
- HGBP costs more to operate. As the load fluctuates, the compressor consumes more energy because it’s forced to operate at a compression step that is likely one stage higher than the load demands.
- When used for dehumidification, if there is not a form of reheat, the system may subcool the applicable zones.
- HGBP can increase the cost to maintain the system.

Despite these shortcomings, hot gas bypass can be appropriate for cooling applications that demand tighter control. HGBP may also be useful when handling large amounts of outdoor air, widely varying loads, or excessive compressor on/off delays. If designed and installed properly, HGBP can:

- Prevent excessive compressor cycling
- Mitigate coil frosting
- Allow the system to operate at safe balance points during reduced loads

TYPES OF HOT GAS BYPASS

Hot gas bypass is arranged in one of two ways: either to the inlet of the evaporator (See Figure 1) or to the suction line (see Figure 2); both require special care during design and installation.

Figure 1. Hot gas bypassed to evaporator inlet (preferred arrangement for HGBP)

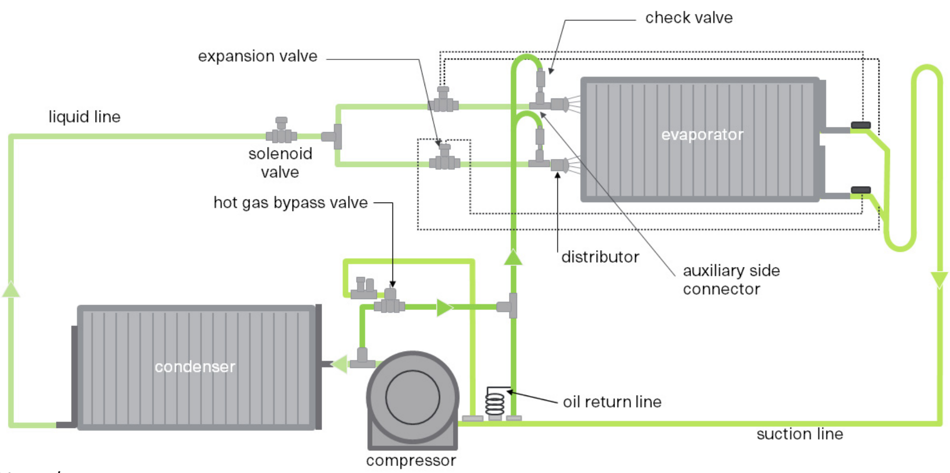

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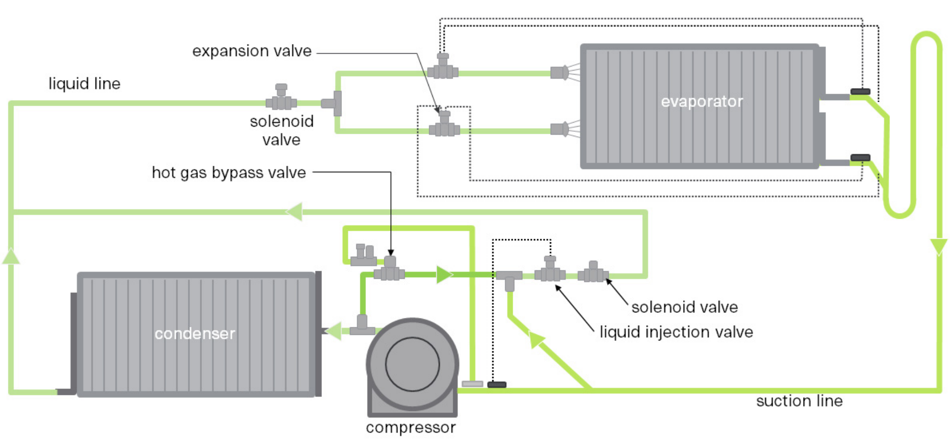
Figure 2. Hot gas bypassed to suction line



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Actual placement of components may be closer or further away.

Hot gas bypass to the evaporator inlet delivers hot refrigerant vapor between the expansion valve and the distributor. During HGBP operation, the expansion valve meters enough liquid refrigerant to both desuperheat the bypassed vapor and satisfy the evaporator load. The resulting refrigerant flow rate is sufficient to carry oil through the coil and suction line.

Hot gas bypass to the suction line bypasses both the condenser and the evaporator, diverting hot vapor from the compressor discharge directly to the suction line. A liquid-injection valve meters liquid refrigerant into the stream of bypassed vapor, cooling it enough to prevent the compressor motor from overheating. This approach may also use a refrigerant receiver to help mix the hot vapor and the liquid refrigerant.

Table 1. Comparison of common HGBP arrangements

Evaporator Inlet (Figure 1)	Suction Line (Figure 2)
Advantages of Evaporator Inlet • Merging the bypassed load with the system load in the evaporator helps the expansion valve maintain the desired superheat control. • Sustaining a higher gas velocity in the evaporator and suction line at low loads, may enable more reliable oil return. • When introducing large amounts of outside air at part load conditions, evaporator inlet HGBP may mitigate coil frosting better than suction line HGBP. • Simple installation using factory provided HGBP connections does not require field modification to the refrigerant circuit.	**Advantages of Suction Line** • Modulating the mass flow of refrigerant through the evaporator coil helps the expansion valve to maintain the desired superheat control. • Less expensive to install because it requires less piping, particularly if the condensing unit and evaporator are far apart. • Third party kits available including an additional liquid line solenoid, expansion valve, and an additional mixing tank for more stable control. • As the evaporator is not warmed by the HGBP, may be better than evaporator inlet HGBP for comfort cooling DX-VAV applications.
Disadvantages of Evaporator Inlet • Installation cost is directly proportional to the distance between the condensing unit and evaporator. • Requires an additional HGBP line and associated refrigerant specialties to be run to the condenser. • To prevent logging oil and refrigerant the HGBP line should be limited to 75 feet.	**Disadvantages of Suction Line** • At low evaporator loads, refrigerant-gas velocity may not be sufficient for adequate oil movement. • Requires field modification to the condensing unit refrigerant circuit. Improper installation may have manufacturers warranty implications. • To prevent logging oil, the suction line should be limited to 75 feet total length.

Application Considerations

ASHRAE® 90.1 AND HOT GAS BYPASS

ASHRAE® 90.1-2019 limits the amount of HGBP that can be used.

Section 6.5.9 “Cooling systems shall not use hot gas bypass or other evaporator pressure control systems unless the system is designed with multiple steps of unloading or continuous capacity modulation. The capacity of the hot gas bypass shall be limited as indicated in Table 6.5.9 for VAV units and single-zone VAV units. Hot gas bypass shall not be used on constant volume units”. Table 6.5.9 states that the maximum HGBP as a percent of total capacity shall not exceed 15 percent for units 20 tons and under and 10 percent of units in excess of 20 tons.

Rated Capacity	Maximum HGBP as Percent of Total
<= 240,000	15%
>240,000	10%

HGBP tonnage can be limited by the HGBP valve selection or the selection of the HGBP line.

HOT GAS BYPASS IN CHILLED WATER SPLIT SYSTEMS

When a DX condensing unit is paired with a chilled-water evaporator, certain process cooling applications may require hot gas bypass to match chiller capacity to an instantaneous load. In such cases, the system is designed to operate continuously and hot gas bypass neutralizes the refrigeration effect when loads are non-existent.

For comfort cooling, however, the addition of hot gas bypass is seldom necessary. That’s because a properly designed chilled water loop can provide an effective buffer between system load and chiller capacity. The key is to establish a loop time that equals the *greater* of two values: either the minimum “compressor off” time for the last stage of cooling, *or* the minimum loop time permitted by the chiller controller. You can accomplish this by changing the design flow rate and/or by adding a buffer tank.

The simplicity of this approach will benefit the owner, as will the operating cost savings. (A chilled water system *without* hot gas bypass requires less power than one that operates the compressors with hot gas bypass.)

HOT GAS BYPASS FOR HUMIDITY CONTROL

As part of an applied DX system using discharge air temperature control, HGBP may be used to help control space humidity when off design conditions occur. However, there may be better approaches if humidity control alone is the driving reason for HGBP. These methods may include unloading or modulating compression, reducing the fan cfm, and adding via hot gas reheat or terminal VAV boxes.

REHEAT WITH HOT GAS BYPASS

Hot gas reheat coils are part of the condenser system because they take heat away from the hot refrigerant. HGBP takes mass away from the condenser system. When reheat (HGRH) and HGBP are used together, they take both heat and mass from the high side refrigerant. The result is a system which is very easily unstable because the condenser ends up so large (cold) that the liquid coming out if it and going to the TXV has no subcooling. Simultaneous use of refrigeration reheat and HGBP should be avoided.

OIL SEPARATOR LIMITATIONS

A challenge with HGBP is during operation some oil will log in inconvenient locations. If sufficient oil logs, the low oil condition at the compressor may cause failure. At first analysis an oil separator would seem to be a solution to this issue.

The challenge with this approach is that even the very best oil separators are not 100 percent efficient. Some oil will always leak past. With extended operation, it may be possible for sufficient oil to leak past and log enough oil to damage the compressor.

In order for an oil separator to be an effective mitigation strategy, additional components may be required. This usually includes a properly sized suction line accumulator, and a control sequence to operate the system as needed to ensure oil recovery.

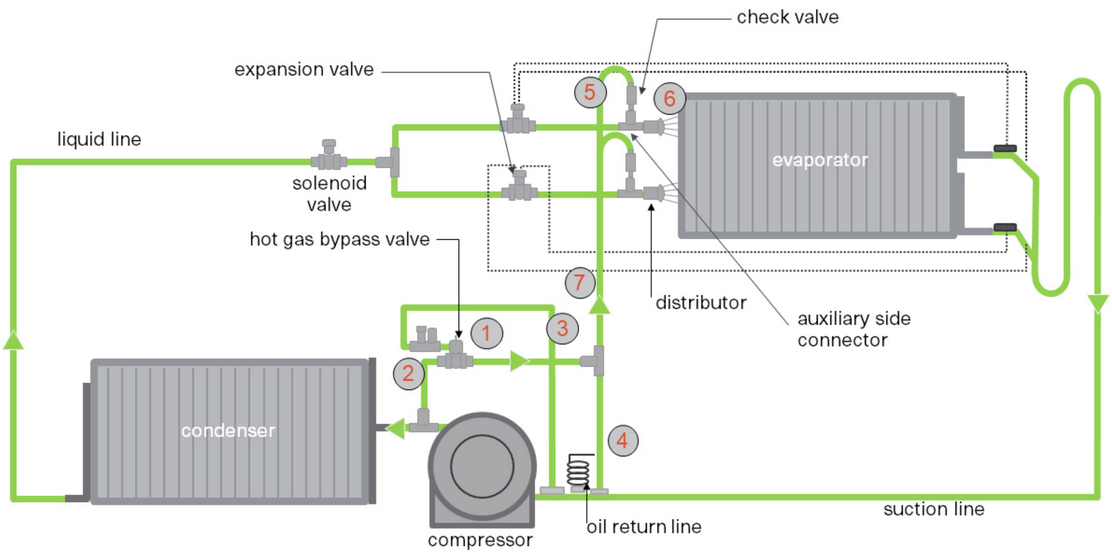
SELECT AN APPROPRIATE HOT GAS BYPASS VALVE

HGBP valves originally controlled suction pressure. These valves were a proportional control system with a very wide operational band that is still used in a number of existing HGBP valves. This wide control band implies that it should not be used for close system control or systems that are designed close to a critical operating condition. There are newer HGBP valves with tighter control bands as well as electronic HGBP valves. The electronic HGBP valves in particular control through algorithms, this makes them much more suitable in applications requiring tighter control tolerance. These electronic valves may control to either suction pressure or discharge air temperature.

If the system controls the compressors to discharge air temperature, it may be best to control the HGBP valve by suction pressure to avoid control conflict. If the system controls the compressors to space temperature, the HGBP valve control can likely be either suction pressure or discharge air temperature. The correct valve should be chosen dependent on job requirements.

Hot Gas Bypass Design

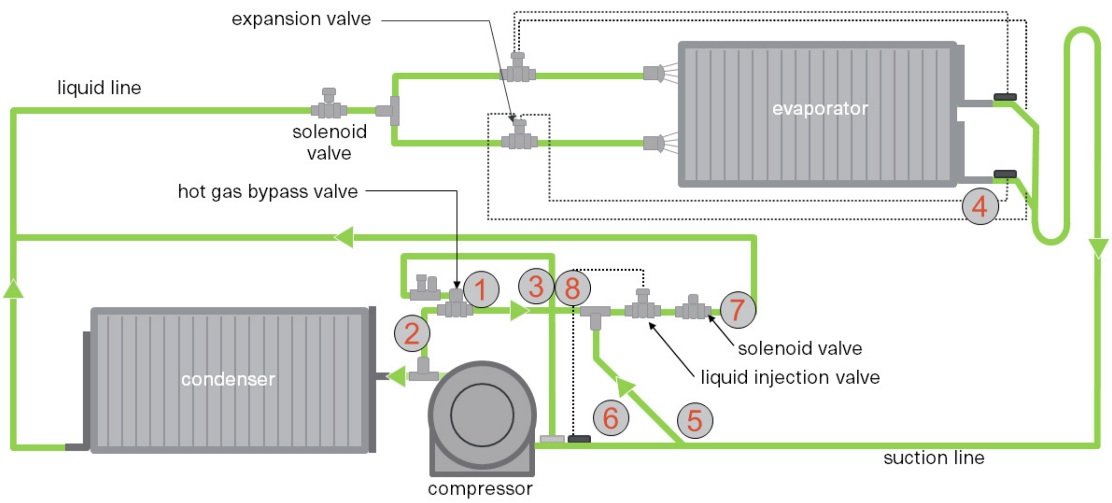
Figure 3. Hot gas bypassed to evaporator inlet (preferred arrangement for HGBP)



Design Keys to successful implementation:

1. Position the HGBP valve *above* the discharge line, near the compressor. If the system includes high side isolation, provide a means to shut off refrigerant flow.
2. Pitch the line *upstream* of the HGBP valve to drain oil back into the discharge line.
3. Pitch the line *downstream* of the HGBP valve toward the evaporator, away from the valve.
4. If the HGBP line includes a riser(s), regardless of height, provide a 12 in. drip leg of the same diameter as the riser(s). Install the drip leg regardless of the height of the riser(s). Add an oil-return line 1 in. (25 mm) from the bottom of the trap; use tubing that is 1/8 in. (6 mm) and at least 5 ft (300 mm) long. Pre-charge the trap with appropriate oil.
5. Divert hot gas to each active distributor at the expected operating points for hot gas bypass.
6. Provide a check valve for each distributor. Install an auxiliary side connector on each distributor to mix hot gas and liquid.
7. Insulate the *entire* length of the HGBP line.

Figure 4. Hot gas bypassed to suction line



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1. Position the HGBP valve *above* the discharge line, near the compressor. If the system includes high side isolation, provide a means to shut off refrigerant flow.
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3. Pitch the line *downstream* of the HGBP valve toward the suction line, away from the valve.
4. Size the HGBP valve and suction line to allow for oil return.
5. Site the suction-line HGBP connection upstream of the pilot-line tap for the HGBP valve and at least 5 ft (1.5 m) upstream from the compressor inlet. Angle the connection into the suction flow.
6. Attach the remote bulb for the liquid-injection valve to the suction line, downstream of the HGBP connection.
7. Provide a solenoid valve upstream of the liquid injection valve. Synchronize the operation of the HGBP and liquid-line solenoid valves.
8. Insulate the *entire* length of the HGBP line.
9. HGBP to a suction line is typically provided as a prepackaged kit from a third party manufacturer, follow all additional instructions from the kit manufacturer.

HOT GAS BYPASS REFRIGERANT LINE DESIGN CONSIDERATIONS

Make gravity work for you—a typical HGBP valve can infinitely vary the rate of hot gas flow. The resulting refrigerant velocity can become so low that it “traps” oil in the HGBP line. Gravity then becomes the sole means for returning oil to the compressor. It is therefore critical to design the refrigerant piping system so that all oil (and condensed refrigerant) drains freely out of the HGBP line. Suction-line lift and the design of the evaporator coil particularly limit the use of HGBP to the suction-line. Because this arrangement bypasses the evaporator and part of the suction line, the refrigerant flow rate upstream of the HGBP point of entry may become too low to move oil. To overcome this limitation, restrict the maximum amount of HGBP to a quantity that maintains sufficient refrigerant velocity for oil entrainment in this particular arrangement.

Independent of which HGBP arrangement is applied, the HGBP line must connect to the *top* of both the discharge line and the evaporator inlet (or suction line). Otherwise, a mixture of oil and refrigerant will pour into the HGBP line, starving the compressor of oil and causing a liquid slug when the HGBP valve opens. The refrigerant that collects in the HGBP line also reduces the refrigerant charge available to the system, which may lower the suction pressure. Ironically, the HGBP valve may respond by opening and allowing bypass flow of hot gas. The repetitive, unstable operation and slugging that result make it critical to prevent this condition.

KEEP THE HOT GAS BYPASS LINE SHORT

Refrigerant vapor will condense in, and fill any portion of, the HGBP line that is colder than the saturated temperature of the suction or discharge gas. The likelihood of this occurring will increase with the length of the line. Oil return also can be a problem in properly designed HGBP lines because the HGBP valve can reduce the flow of bypassed gas to nearly zero—well below the minimum flow rate needed to carry oil back to the compressor. Gravity will be *very* slow to bring the oil that deposits along the length of the HGBP line back to the compressor. The longer the HGBP line, the more oil it will collect. It is imperative to keep the oil charge in the system, not in the HGBP line.

Note: If the refrigeration system includes pump-down, make sure that the HGBP system includes a means to prevent refrigerant flow during the pump-down cycle.

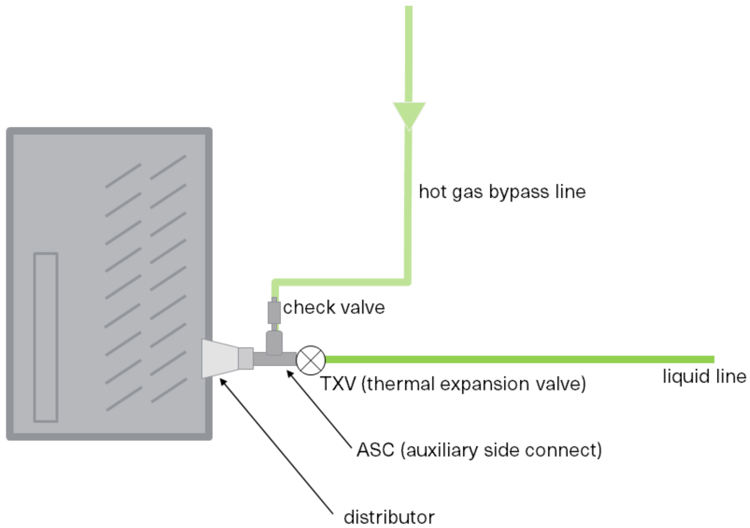
ADD LOW AMBIENT/HEAD-PRESSURE CONTROL

Diverting hot gas from the discharge line and around the condenser reduces the head pressure of the air conditioning system. As head pressure decreases, operation may become unstable — and unreliable. To avoid this risk, include a method for low ambient/head-pressure control in every HGBP application.

USE A SPORLAN AUXILIARY SIDE CONNECTOR*

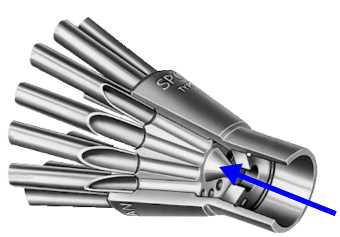
We recommend using a Sporlan Auxiliary Side Connector (ASC) as the tee to introduce hot gas downstream of the TXV (see schematic below) independent of the type of distributor used.

Figure 5. The ASC used as a mixing device

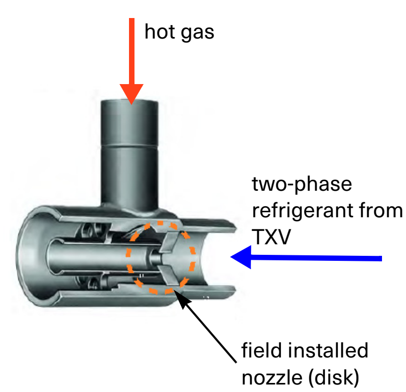


Sporlan makes a nozzle type distributor, meaning that it uses a nozzle (see left-hand picture below) to induce turbulence and to mix the liquid-vapor refrigerant before it enters the distributor tubes. When an ASC is installed ahead of a nozzle type distributor, the nozzle is removed from the distributor and placed in the ASC, upstream of the tee (see right-hand picture below). The ASC is designed for this.

* Images, content, and tables in this section courtesy of Sporlan.



Sporlan (nozzle type) distributor



Sporlan ASC

DX coils in Trane® air handlers (MCC, LPC, UCCA, PCC, and T-Series) use venturi-type distributors to mix liquid and vapor refrigerant. They have no nozzle. When installing the ASC upstream of a venturi-type distributor, a proper nozzle must be selected and purchased to install in the inlet of the ASC.

Note: A Trane® TWE air handler with factory HGBP ships with an ASC style device installed in the AHU. No additional ASC is required. If using another manufacturer's air handler, if it uses a Sporlan distributor, then the nozzle should be removed and installed in the appropriately sized ASC.

We use the ASC as a mixer, not anything else. The ASC is simply sized to fit the copper around it as best possible then reducers are used for fitment.

Figure 6. Venturi distributor with packed elbow

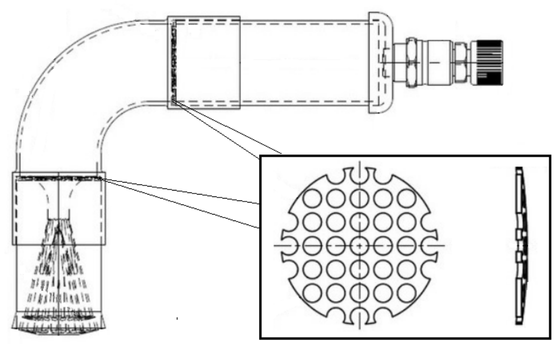
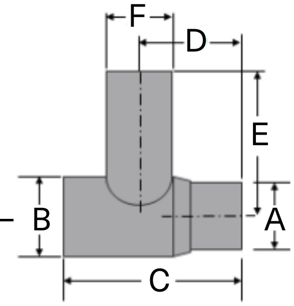


Table 2. ASC and nozzle selection



Note: Piping adapters will likely be needed for connections A and F.

Type	Connection Sizes - Inches			Used with distributor type	Nozzle size	Dimensions - Inches					
	Inlet ODM Solder	Outlet ODF Solder	Auxiliary ODF Solder			A	B	C	D	E	F
ASC-4-3	½	½	3/8	D260, D262	L	½ ODM	½ ODF	1.75	0.85	1.04	3/8 ODF
ASC-5-4	5/8	5/8	½	1620, 1622	J	5/8 ODM	5/8 ODF	1.91	0.95	1.25	½ ODF
ASC-7-4	7/8	7/8	½	1112, 1113	G	7/8 ODM	7/8 ODF	2.25	1.06	1.38	½ ODF
ASC-9-5	1-1/8	1-1/8	5/8	1115, 1116	E	1-1/8 ODM	1-1/8 ODF	2.81	1.47	1.62	5/8 ODF
ASC-11-7	1-3/8	1-3/8	7/8	1117, 1126, 1128	C	1-3/8 ODM	1-3/8 ODF	3.53	1.89	2.19	7/8 ODF
ASC-13-9	1-5/8	1-5/8	1-1/8	1125, 1127, 1143	A	1-5/8 ODM	1-5/8 ODF	3.85	1.95	2.75	1-1/8 ODF

See example for sizing ASC and separate field-installed nozzle.

Table 3. Refrigerant 410A per nozzle orifice size, (Tons)

Nozzle Orifice Size	Refrigerant 410A Tons per distributor
	40°F SST
1/9	0.16
1/6	0.25
1/4	0.40
1/3	0.53
½	0.73
3/4	1.10
1	1.47
1-1/2	2.14
2	2.93
2-1/2	3.66
3	4.39
4	5.88
5	7.25
6	8.69
8	10.5
10	11.7
12	14.5
15	18.0
17	20.1
20	24.2
25	30.5
30	34.8
35	41.9
40	47.0
50	60.9

The ASC and nozzle are sized by matching the size of the evaporator distributor liquid connection to dimension B.

For example, if the distributor's liquid connection is 7/8 inch, then select an ASC-7-4 and nozzle size G.

Note: The AHU evaporator may have more than one size of distributor, each with different connection sizes, so be sure to size each ASC according to the distributor it will be connected to. To simplify the ASC selection process the 40°F SST column may be used for applications from 40°F SST to 55°F SST.

Next, the proper size of the nozzle orifice is determined by the larger of either:

1. The first stage of cooling capacity divided by the number of distributors, or
2. 40 percent of the circuit capacity divided by the number of distributors.

This value is then rounded down to the next available size nozzle orifice.

Example 1: A 30-ton, R-410A evaporator with four distributors. One 30-ton refrigeration circuit, with first stage of capacity of 15 tons, 45°F SST.

The first stage of capacity is 15 tons, which is *larger* than 40 percent of the circuit capacity (30 tons x 40% = 12 tons), so each nozzle orifice is sized for 3.75 tons (15 tons/4 distributors). Looking in the 40°F SST column of Table 3, there is not an option for 3.75 tons, so round down to 3.66 tons and select the number 2-1/2 nozzle orifice. For this example, the installer needs an ASC-7-4 and a separate G 2-1/2 nozzle. Repeat this for each liquid distributor that receives hot gas.

Example 2: A 100-ton, R-410A evaporator with eight total distributors. Two 50-ton refrigeration circuits, with first stage of capacity of 15 tons, each connected to four distributors, 45°F SST.

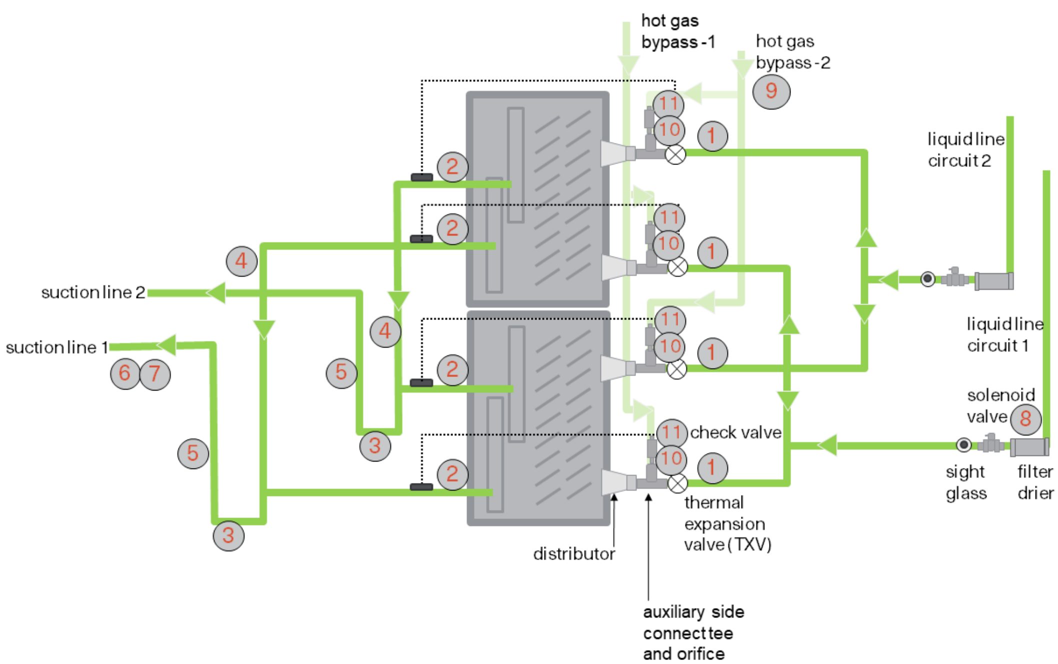
The first stage of capacity is 15 tons, which is *smaller* than 40 percent of the circuit capacity (50 tons x 40% = 20 tons), so each nozzle orifice is sized for 5 tons (20 tons/4 distributors). Looking in the 40°F SST column, there is not an option for 5 tons, so round down to 4.39 tons and select the number 3 nozzle orifice. For this example, the installer needs an ASC-7-4 and a separate G 3 nozzle. Repeat this for each liquid distributor that receives hot gas.

Remember, this nozzle is only used to create refrigerant turbulence, so precision in selection is not required.

HOT GAS BYPASS PIPING AT THE COIL

It is recommended that HGBP be piped to each part of the active evaporator coil when HGBP is used.

Figure 7. Typical piping for multi-circuit system



1. Provide one expansion valve per distributor
2. Slightly pitch the outlet line from the suction header toward the suction riser in direction of flow. Use the tube diameter that matches the suction header outlet.
3. Arrange the suction line so that the refrigerant leaving the coil flows downward past the lowest suction header outlet, before turning upward. Use a DETINT (double elbow that is not a trap) configuration to prevent oil and refrigerant migration when the unit is off.
4. Use the horizontal tube diameter identified in the appropriate application guide.
5. Use the tube diameter recommended in the appropriate application guide for a vertical rise. This riser should be at least 2 feet.
6. Pitch the suction line 1 inch per 10 feet so that the refrigerant flows toward the evaporator.
7. Insulate the suction line.
8. Install a single isolation solenoid valve between the liquid line filter and the sight glass if required by the appropriate application guide.
9. Pipe HGBP to each coil of the active circuit. Pitch the line in direction of flow.
10. Install an ASC at the inlet of each distributor and a nozzle at the inlet of ASC. The HGBP line MUST enter from the top.
11. Install a check valve in each branch of the HGBP line to prevent reverse flow during the off cycle.

SELECT THE APPROPRIATE HOT GAS BYPASS TUBE DIAMETER

Table 4 and Table 5 list the required tube sizes to bypass tonnage at conditions listed in the chart below each table. The max tonnage of hot gas to bypass is less than or equal to the first stage capacity of the refrigerant circuit.

Table 4. Hot gas bypass tube size by tube length and tonnage of minimum step of unloading (Use this table when the unit has low ambient/head pressure control)

Distance not to exceed 75 feet	
tonnage	HGBP pipe size
2.5	1/2
5	5/8
6	5/8
7.5	3/4
10	3/4
12.5	3/4
15	7/8
20	1-1/8
25	1-1/8
30	1-1/8

Saturated condensing temperature	100°F
Actual HGBP temperature	160°F
Required refrigerant velocity	<3500 ft/min
HGBP pressure drop (to be between)	10< PSID <20

Table 5. Hot gas bypass tube size by tube length and tonnage of minimum step of unloading

Distance not to exceed 75 feet	
tonnage	HGBP pipe size
2.5	1/2
5	5/8
6	3/4
7.5	3/4
10	3/4
12.5	7/8
15	1-1/8
20	1-1/8
25	1-1/8
30	1-3/8

Saturated condensing temperature	80°F
Actual HGBP temperature	130°F
Required refrigerant velocity	<3500 ft/min
HGBP pressure drop (to be between)	10< PSID <20

APP-APG017D-EN 26 Jan 2023
Supersedes APP-APG017C-EN 04 May 2020