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YLAA Remote Evaporator Application Guide

ENGINEERING SUPPLEMENT

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Form 150.72-ES1 (1013)

INTRODUCTION

In cold climates the evaporators in air-cooled chillers can freeze. One way to protect the evaporator is to separate it from the rest of the chiller and install it indoors. While this protects the evaporator from cold ambient air, it creates other risks and costs. This guide explains general remote evaporator application, risks, and other freeze protection methods. It then details YLAA remote evaporator limitations and requirements. Because some of this guide applies to all remote evaporators and some of it is specific to only the YLAA, contact the application engineers for help with specific projects.

APPLICATION

Freeze protection is the primary reason customers want remote evaporators. Regardless of the reason, the decision to split the evaporator from the rest of the chiller is serious. The next section will explain some of the risks of remote evaporators. You must understand those risks to help your customers avoid using remote evaporators where there is little benefit.

Where should customers use remote evaporators? In extremely cold climates like Alaska and much of Canada when other forms of freeze protection are not feasible it is clear that remote evaporators are a valuable solution. But what about places like Washington, D.C. or Portland, Oregon or Kansas City, Missouri? These places can get cold, but are mostly mild. How much freezing risk is there? Are other freeze protection methods sufficient? How critical is the application? The answers to these questions are hard to quantify, but in general only use remote evaporators in places with significant freezing risk; or in applications where damage to the chiller causes other serious problems. Some examples would be Fargo, ND; Quebec City, Canada; Fairbanks, AK; where the ambient temperature can be significantly below freezing for days or weeks at a time, and research laboratories or hospitals where damage to a chiller can cost millions of dollars or put lives at risk.

RISKS

The main risks inherent in remote evaporator applications are poor oil return, saturation temperature change, liquid slugging compressors, and performance loss. Minor risks are poor refrigerant charge, more risk of refrigerant leaks, and high first cost. This guide will focus on the main risks.

Oil return is essential to compressor longevity. Oil must return to the compressor at the same rate it leaves. If it returns too slowly the compressor will run dry and suffer damage from friction. If it returns too quickly it builds up at the compressor and can slug it. These are not concerns for packaged chillers because Johnson Controls carefully designs and tests chillers. But when the evaporator is remote the added piping gives places for oil to settle, especially at low loads. To help oil circulate design pipes as small as possible, slope them correctly, and install traps where necessary.

Friction in piping causes pressure drop in the refrigerant. Pressure drop changes the saturation temperature. Saturation temperature is important because most of the heat transfer at the evaporator and condenser comes from phase change. If refrigerant changes phase in the piping it causes control problems or compressor damage. Design suction lines to have no more than 2°F saturation temperature change and liquid lines to have no more than 1°F saturation temperature change. To limit friction use the largest pipe size possible, limit elbows and other fittings, and put the evaporator close to the chiller. Size pipes large enough to keep friction low but small enough to circulate oil.

Slugging occurs when liquid gets into the compressor. Gasses are compressible, liquids are not. When liquid gets into the compressing chamber it imparts force on the compressor that it is not designed to take. Minor liquid slugging is not likely to destroy a compressor immediately, but still does damage. Slugging is most likely to occur at start-up. Gas refrigerant in the evaporator and suction line can cool and condense when the circuit is off. If the suction line is long, a lot of liquid can form, creating a high risk of slugging. Therefore, keep the evaporator close to the chiller and slope suction lines per the manufacturer's requirements.

Friction in the additional piping causes performance loss. For YLAA chillers there is a 3% capacity loss for every 100 equivalent feet of piping. The equivalent piping length is defined by the longer of the two suction lines. There is also a 1% drop in power consumption for each 100 equivalent feet. Note, while power consumption drops, capacity drops more quickly. That reduces efficiency. For example, a 150 ton YLAA at 15.0 IPLV, with a remote evaporator and 100 equivalent feet of suction piping would produce only 145.5 tons at 14.7 IPLV.

These risks are manageable when designers account for them properly. But many do not understand the risks or how to avoid them. Sometimes designers are completely unaware of the risks, believing remote evaporators are an easy solution. You must educate your customers. Freezing an evaporator is bad. Destroying compressors is terrible, too. Both can be avoided if you help your customer understand the risks and options before the design is finished.

FREEZE PROTECTION METHODS

There are several freeze protection methods to consider before deciding to use remote evaporators. Glycol, heat tracing, pumping, free cooling, and draining systems are options. Customers can use several of these options simultaneously to provide redundant protection. Often these options provide reliable freeze protection with less risk than remote evaporators.

Glycol is popular and effective for freeze protection. A major advantage to glycol is the dual freezing point. Aqueous glycol will freeze into a gel before it freezes solid – the point at which it could burst pipes and vessels. Ice packs to cool your lunch, or for first aid are often water mixed with propylene glycol (PG). In systems that are idle in the winter the liquid can freeze into a gel without damaging pipes or the evaporator. This allows the designer to use a lower glycol percentage. For instance, if the design low ambient temperature is 5°F the system could use 25% PG which begins to freeze around 15°F, but will not burst until 0°F. See the glycol freezing graph. Note, ethylene glycol (EG) will prevent bursting with concentrations between 32% and 80%, and PG will prevent bursting with concentrations 35% or higher. Therefore, it is not necessary to use more than 35% EG or 40% PG to prevent bursting.
The main problem with glycol is performance loss. Glycol adds friction which increases pumping power. Glycol also slows heat transfer in the evaporator and in air coils, reducing system capacity. Glycol cannot be removed without draining the system then refilling it. Therefore, systems with glycol will probably have glycol in the summer as well as winter, increasing operating costs all year. In the previous example of a system with 25% PG and a 44°F set-point, the chiller and coil capacities would reduce by about 3% and the pressure drop increase by about 13%. Several factors affect performance so you must evaluate the performance impact of glycol for each system.

You may have noticed that EG generally provides more freeze protection than PG. But EG is not always a good choice. The reasons are that EG is toxic to humans and many animals, and EG affects heat transfer and pressure drop more dramatically than PG. Therefore, PG is often a better choice for freeze protection.

Heat tracing, sometimes called heat tape, is an electric resistance heater in the form of a wire. It goes between the water pipe and insulation and is usually turned on automatically when the ambient temperature approaches freezing. Heat tracing typically produces only 3 to 8 watts (about 10 to 27 BTU/hour) per foot of wire, but with proper pipe insulation can protect against freezing even when the ambient air is below 0°F. When run parallel to the pipe it provides a minimum level of freeze protection. When wrapped around the pipe in a spiral it provides more heat per length of pipe as the spiral gets tighter. Run multiple circuits to provide backup heat in case one circuit fails.
Heat tracing requires electrical power to work. In critical applications it must be on emergency power, and even then should not be the only freeze protection method. Buildings often lose power during extreme weather, including cold spells. Emergency generators can fail. Therefore, heat tracing is often used with other freeze protection methods.

Pumps add heat to the fluid being pumped. That heat helps to protect against freezing. Further, the outdoor portion of a typical chilled water system with air-cooled chillers is only the tip of the ice berg. Most of the system is indoors. Even though the outdoor portion will lose heat when it is cold outside, the indoor portion of the system gains heat. For instance, if the interior of the building is 70°F, the chilled water temperature is 40°F, and ambient temperature is 10°F, then there is 30°F of temperature difference to drive heat transfer both outside and inside. Assuming a pump is circulating the water, and everything else (insulation, pipe size and lengths, pipe type, air movement over the pipes, etc.) is the same indoors and outdoors, then the water will gain as much heat from air inside the building as it loses to ambient air and will actually get warmer! (Don't forget that the pump is adding heat.) The indoor and outdoor parts of the system are rarely the same, however. Outdoor pipes are usually larger and have more insulation which slows heat loss; but there is significantly more wind which speeds heat transfer. If we assume that larger pipe sizes and thicker insulation balance the wind, and we assume that only a small portion of the system is outside, we see how effective running pumps can be to protect the system against freezing.

Pumping has the same risk as heat tracing; it won't work without electrical power. So carefully consider the application to determine how and when to use pumps as part of a freeze protection plan.

Free cooling is useful when chilled water is needed in the winter. For instance, a data center may not be able to use outside air economizers to cool the facility in the winter because the outside air may reduce relative humid-

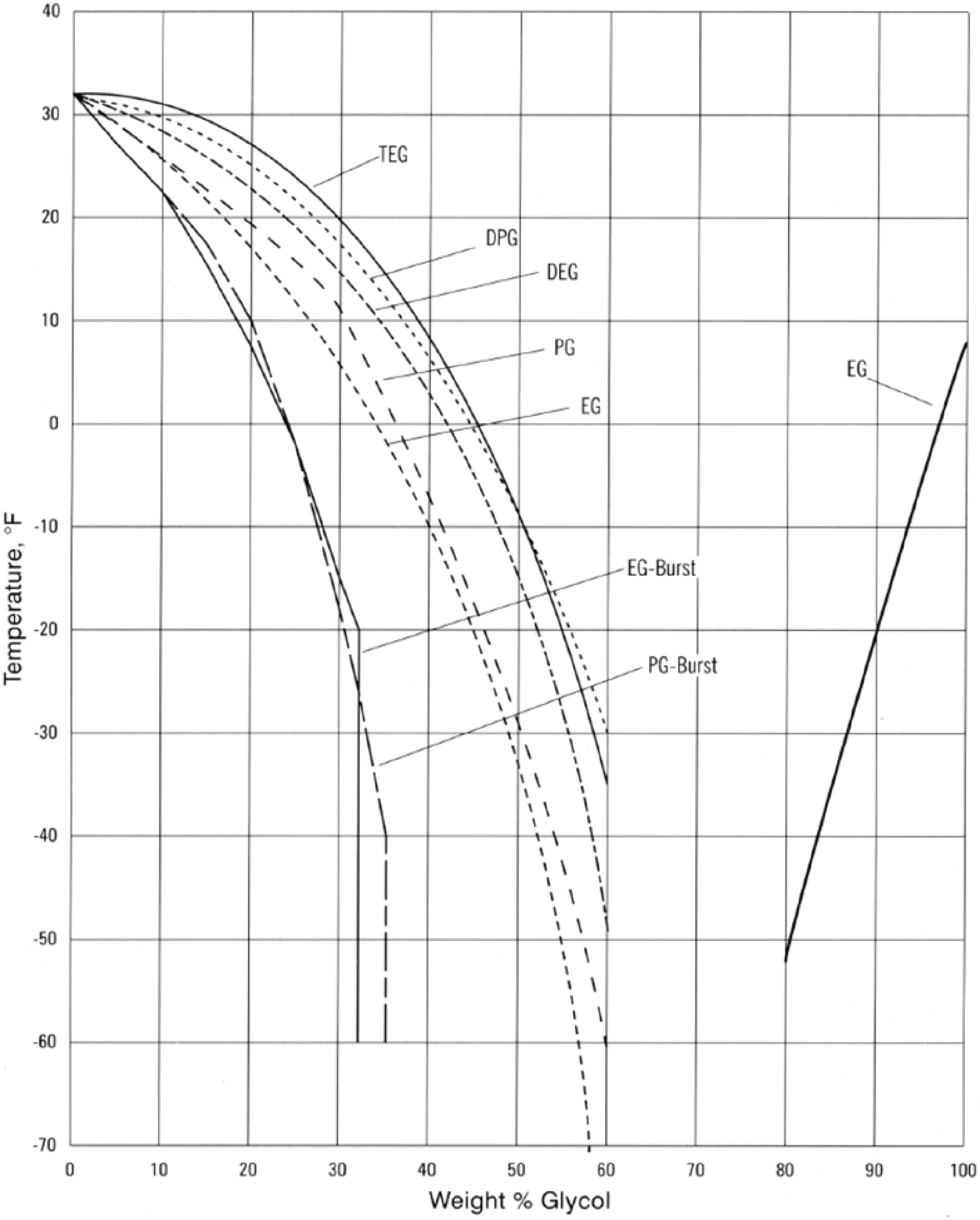


FIGURE 1 - AQUEOUS GLYCOL FREEZE AND BURST POINTS BY % WEIGHT OF GLYCOL

ity in the building too much. But data centers have large heat loads, even in the winter. The heat from servers is perfect for keeping the fluid above freezing, and the cold outside air is perfect for rejecting that heat. Fluid coolers like the VDCF can draw cold air across fluid coils to make chilled water without running compressors. Free cooling is usually effective when the ambient temperature is about 35°F or colder, depending on the desired chilled water temperature. Install fluid coolers in series with air-cooled chillers with a bypass. In the summer, water will flow to chillers and bypass fluid coolers. In the winter, water will flow through idle chillers, then get cooled in fluid coolers. Free cooling coils are designed to reject heat extremely quickly. If water stops flowing but fans keep running these coils could freeze in seconds. Use free cooling with glycol to protect against freezing.

Draining the chilled water system is one of the most reliable ways to protect against freezing. You can't freeze water that isn't there. The difficulty is the work involved. Draining systems takes time. The pipes and evaporators may need to be dried after they are drained to avoid corrosion. Then in the spring the system must be refilled with water and recharged with corrosion inhibitors and chemical stabilizers. The effort can be prohibitive.

You may have noticed that most alternatives involve using glycol. This depends on climate, but in places where remote evaporators are reasonable, glycol is generally part of any freeze protection strategy. Therefore, you need to understand the freeze protection and pumping performance of glycols to weigh the impacts against the risks of using remote evaporators.

LIMITATIONS

The YLAA was designed to be competitive in applications that require remote evaporators. It was not designed to eliminate the risks of remote evaporator applications.

The YLAA can operate with up to 150 equivalent feet of suction piping, depending on the condenser coil type. Equivalent feet account for pressure drop of fittings by equating the fitting pressure drop with a straight run of pipe at the same conditions. For instance, a 2-1/8" copper 90° long radius elbow has the same pressure drop as 3.3 feet of straight 2-1/8" copper refrigerant pipe. So a suction line with 100 feet of pipe and 8 90° long radius elbows would be 127 equivalent feet long. Liquid piping is also limited to 150 equivalent feet, but the suction line usually has longer equivalent length than the liquid line on the same circuit.

Ideally, designers will keep chillers and remote evaporators at the same elevation. Elevation changes are allowed, but it's best to avoid them, if possible. If the chiller is higher than the evaporator, then the piping limit is defined by the equivalent length of the suction line. If the evaporator is higher than the chiller, then there can be no more than 35 feet of elevation difference on the liquid line.

Large traps in suction lines are not allowed. A large trap is generally created when suction piping dips down then back up to avoid an obstruction. For instance, if a suction pipe runs along the ceiling of a mechanical room dips down a foot, runs under an air duct for a few feet, then goes back up; it would have a large trap in it. Large traps collect significant amounts of liquid refrigerant when a circuit is off, which can slug a compressor on start-up.

Underground piping is possibly the worst mistake that is made with split refrigerant systems. It generally creates a large trap, but even if it doesn't, there are several other problems. Almost all problems with split refrigerant systems are caused by the piping. If that piping is buried, it is not accessible and makes it difficult or impossible to trouble shoot. Also, contractors rarely install piping exactly as it was designed. Even if the design avoids large traps, it's likely that the contractor will make one or more traps to avoid underground obstructions. And even if the piping is well designed and installed, it can be damaged during the burying process. If piping must be installed below grade, run it in an accessible trough or tunnel, so that it is accessible for service or repair and is not directly buried.

PIPE DESIGN

In general, the three main goals of refrigerant piping design are to ensure proper oil circulation, to prevent phase change in the piping, and to limit liquid slugging the compressors. Minor goals are to limit first cost and keep system refrigerant charge low. To get good oil circulation pipes must be small. But, large pipes have lower pressure drop to prevent phase change. So sizing pipes is a balance. In general, use the smallest diameter possible to maintain no more than 2°F saturation temperature change in suction lines and 1°F saturation temperature change in liquid lines. The only piping design principles that meet all the goals are short pipe lengths and straight simple routing with the fewest elbows possible. Other requirements and limits depend on the chiller design.

The YLAA is offered with microchannel coils which have little volume for refrigerant. This is usually a benefit, but when remote evaporators are used it creates a problem. The added piping means more refrigerant in the system. When a circuit is off, refrigerant will migrate to the coldest part of the circuit. When it is cold outside the condenser coils are often the coldest part, and microchannel coils may not have enough space. After the condenser coils are full refrigerant will begin to fill up other parts of the system and that can cause problems. It is for this reason that microchannel models have a lower equivalent feet limit compared to round tube condenser models.

Pipes must be large enough to limit pressure drop, but do not have to be sized for oil circulation. However, large pipes have several problems. First, copper pipe is expensive. Second, larger fittings have more pressure drop. For instance, a 2-1/8” copper 90° long radius elbow is equivalent to about 3.3 feet of straight pipe, and a 2-1/2” copper 90° long radius elbow is equivalent to about 4 feet of straight pipe. Because there is a 150 equivalent foot limit on the run, larger pipe sizes can cause a run to exceed that limit. Third, larger pipes require more refrigerant charge. That adds cost and can hurt a building’s ability to qualify for LEED EA credit 4. And larger pipes simply require more space, making it more difficult to route them properly.

For more information on piping and pipe sizing, please refer to the DX Piping Guide (Form 050.40-ES2) that is available on the Johnson Controls portal.

For more information on the YLAA remote evaporator layout including shipped loose parts, please refer to Appendix A at the end of this guide. Shown is a typical layout with the fittings installed and labeled in the piping to help your customer understand what needs to be installed and where it needs to be installed.

CONCLUSION

Remote evaporators are just one of the tools available to protect against freezing. Customers must weigh the risks and costs of various freeze protection strategies to determine the best alternative. You need to understand the risks, costs, limitations, and requirements of the YLAA remote evaporator design, and the benefits and risks of other freeze protection strategies to help your customer choose the best strategy. Please contact the chiller application team for help with specific projects.

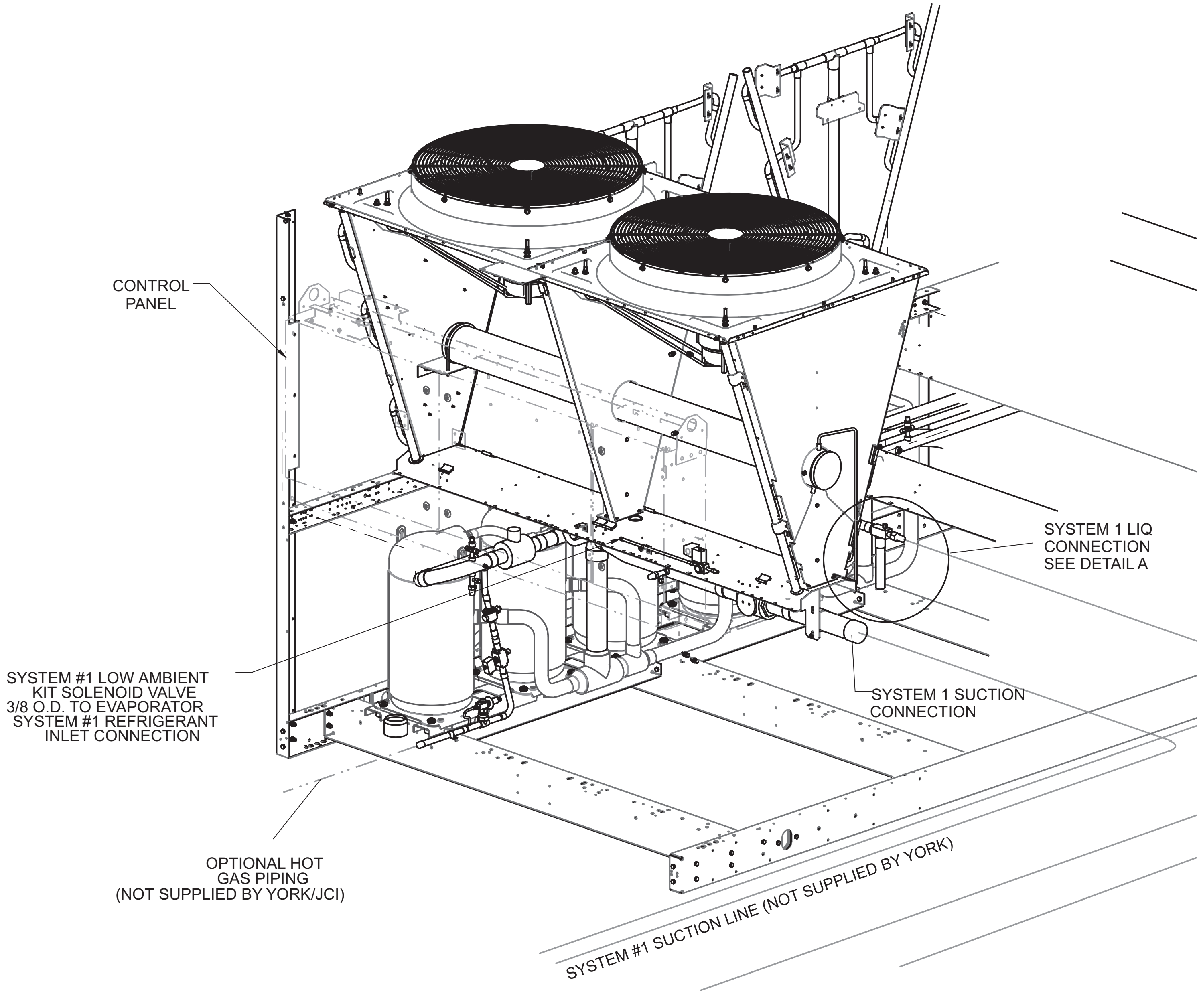
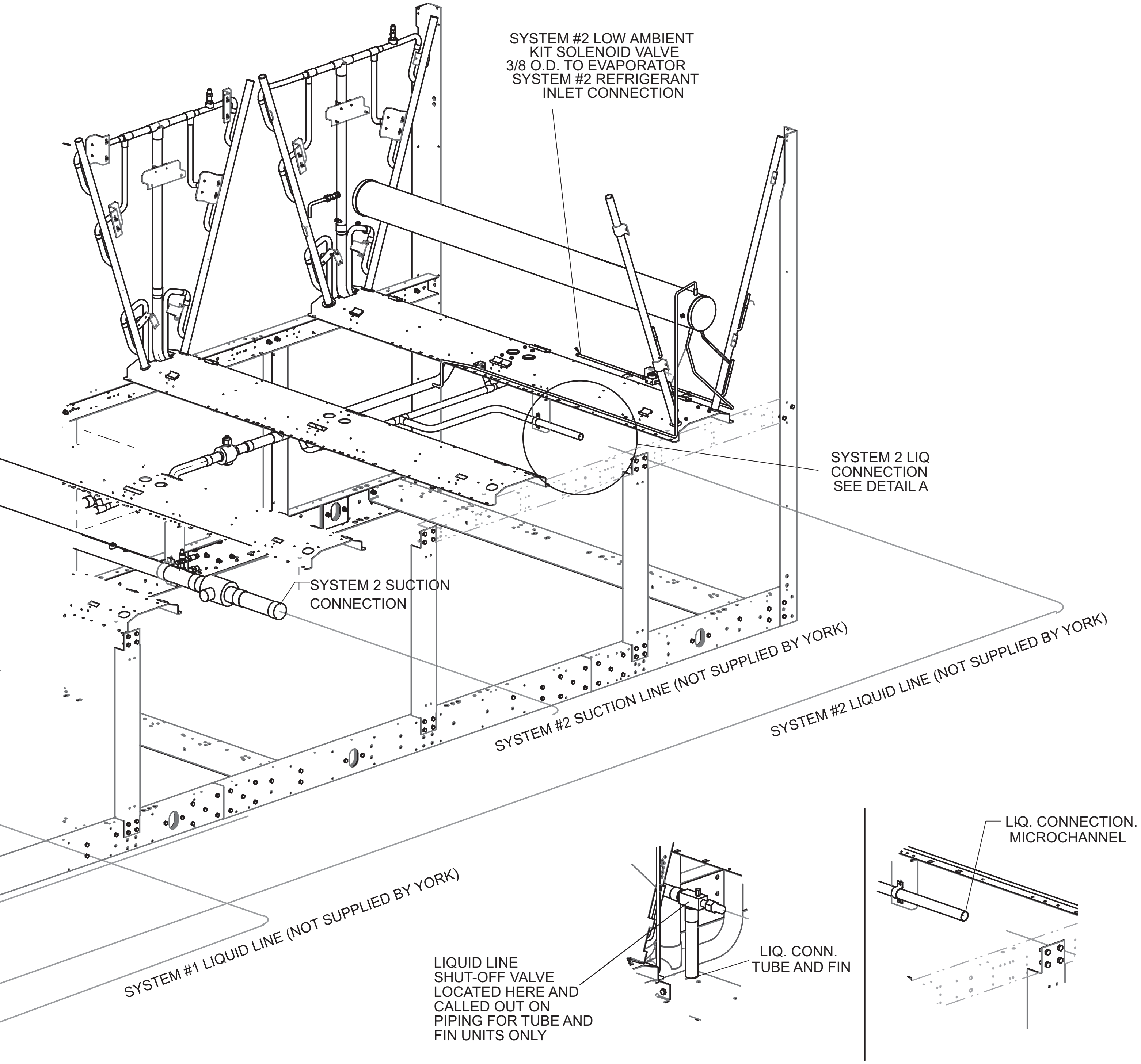


FIGURE 2 - LIQUID CONNECTIONS FOR SYSTEMS 1 & 2



DETAIL A - LIQUID CONNECTIONS SYS 1 & 2

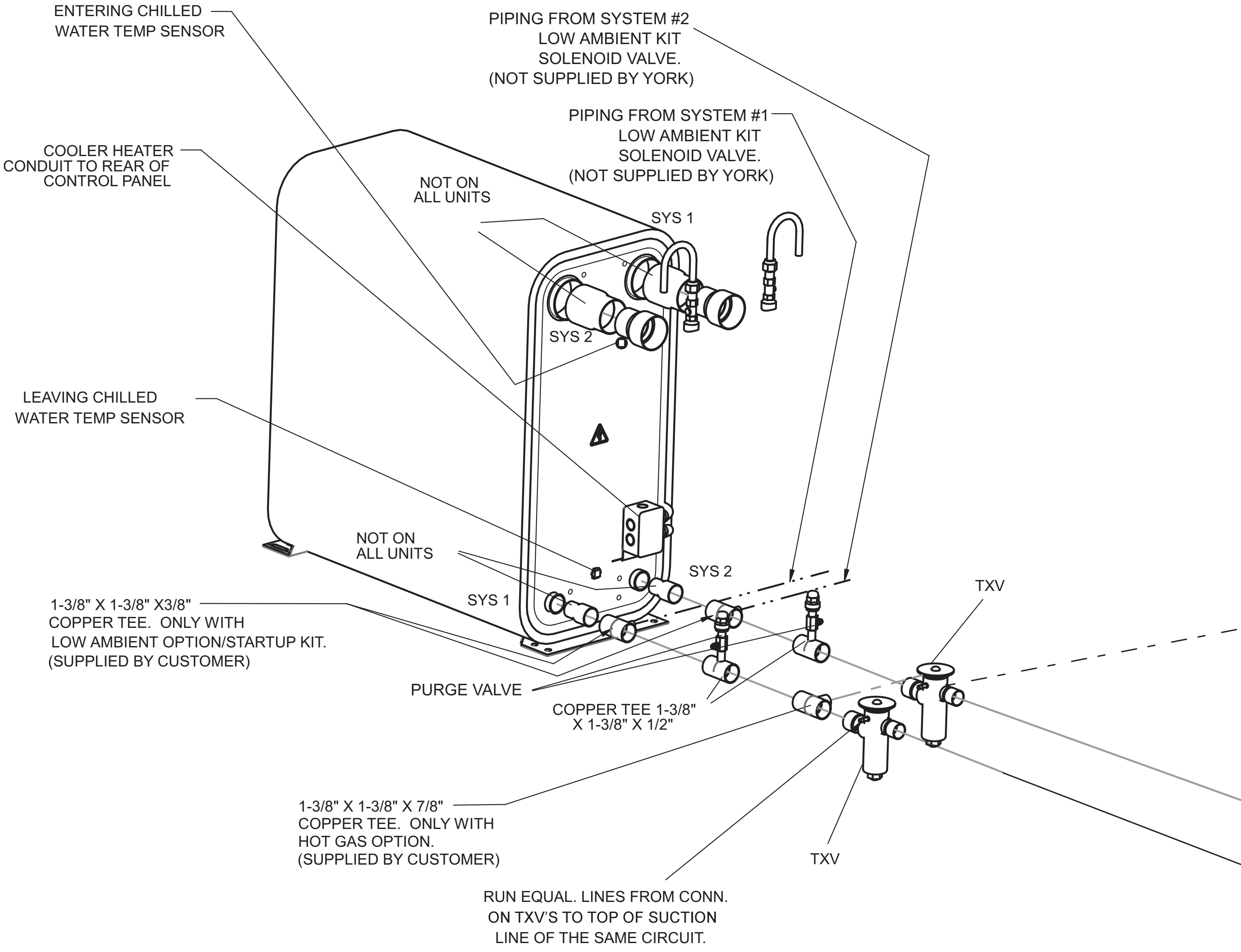
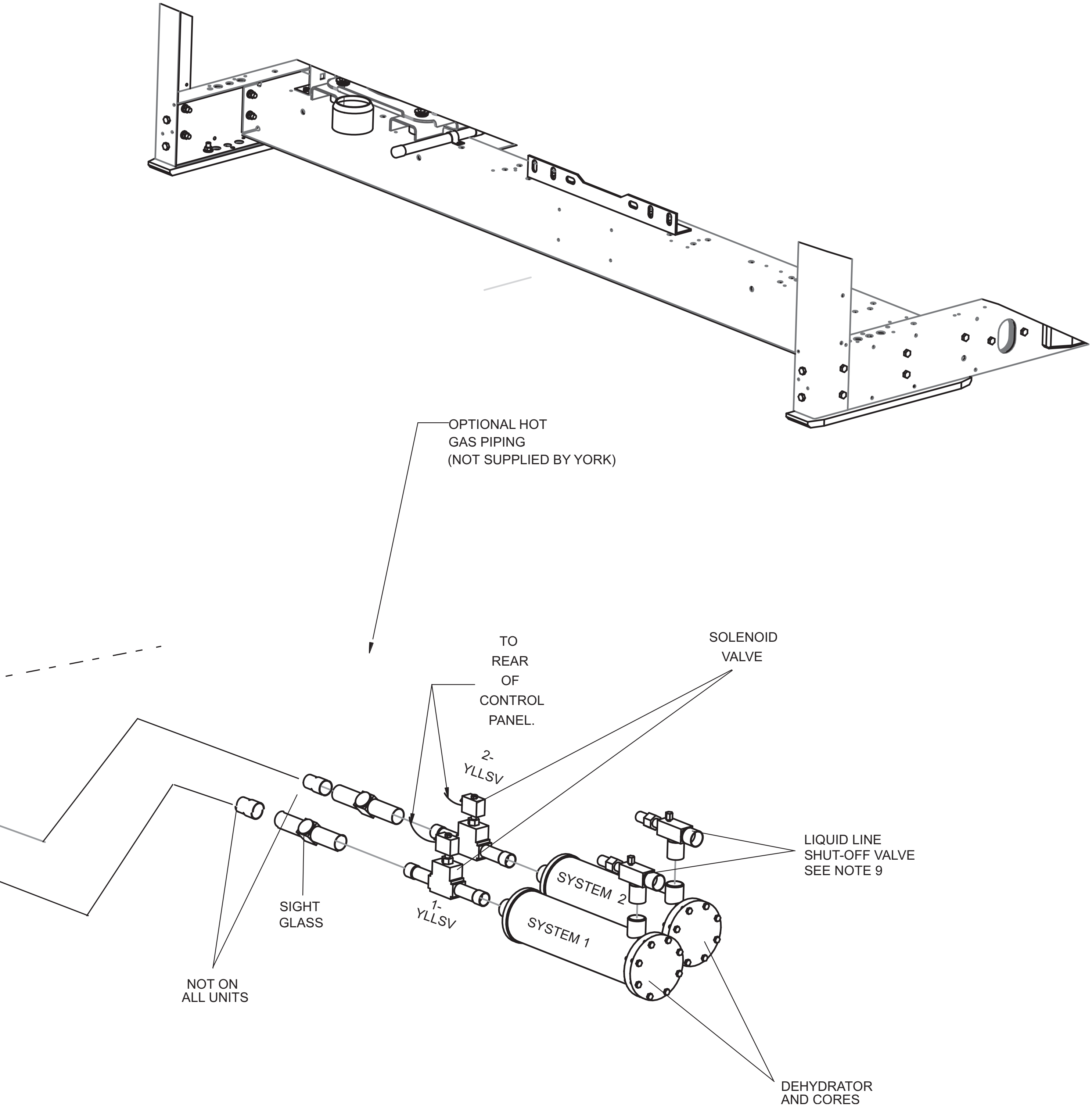


FIGURE 3 - BRAZED PLATE HEAT EXCHANGER CONNECTIONS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SHUT-OFF VALVE
SEE NOTE 9
SYSTEM 2
SYSTEM 1
1-
YLLSV
SIGHT
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