Field-Erected Ammonia Plant Refrigerant Piping: Part 2

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Part 1 of this article was published in the May-June 2023 issue of Cold Chain

– Consulting Editor

Introduction

We have published an article in the March-April 2022 *Cold Chain* issue on how to construct an energy efficient and moisture-proof cold storage. Although one may consider constructing a cold storage as per the guidelines given and select the most efficient equipment, the erection of plant is generally left to people who are not well conversant with the working of refrigeration system components and what precautions should be taken to ensure proper refrigerant flow and oil management.

Proper field piping of mechanical refrigeration system does not happen by accident. The pipes must be laid out, sized, and then installed correctly. As in other aspects of designed systems, each decision represents a compromise. For example, low-cost piping is the result of using smallest possible sizes, but size must be traded off against the pressure drop caused by resistance to the flow of refrigerant. Because of its small size, the lowest cost piping has such a large pressure drop that it robs the system of capacity and increases operating cost. The pipe size selected must be a reasonable compromise between cost and pressure drop.

Any system erected and commissioned would go on operating in spite of many incorrect piping erection practices, but there is a lot of difference between mere working of a system and a perfectly erected, most efficient working of the system.

In refrigeration systems, it is not at all essential that all pipes should appear horizontally or vertically aligned; rather the piping slopes are essential and it would mean the piping may not look aesthetically good but would be correct as per refrigerant flow requirements.

I have observed more than 200 ammonia field-erected systems and have found that there is a lot of scope for improvement in the piping layout and its erection practices.

In this article, I would try to explain what improvements are possible and what precautions the erection staff should

About the Author

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take while carrying out the piping so that system performs to its best efficiency and energy losses that cannot be measured or commonly known as ghost energy losses can be avoided.

The article does not cover the selection of piping material, its sizing and that is left to a designer. The article is meant only for field personnel who are normally associated with piping erection.

Oil Separator

- Ammonia is immiscible with mineral-based refrigerant oils. Oil has no cooling capacity like refrigerant and anywhere else presence of oil would affect system performance adversely. Hence, it is essential to keep oil only for compressor lubrication and drain it from all other equipment. Systems using this refrigerant rely on other methods to return oil to the compressor.
- These include oil separators, properly sloped lines, and oil drain connections located at various components.
- Instead of moving the oil up, a discharge riser away from the compressor, it is better to capture it as it leaves the compressor. That way oil can be returned directly to the compressor rather than travelling through the entire system before returning to the compressor. This is accomplished by installing a high efficiency oil separator. The oil return line is connected directly to the compressor crankcase. Oil collected in the oil separator returns to the compressor crankcase automatically by gravity since there is a float valve in the oil separator and it opens when a particular oil level is reached. The oil return to crankcase should, however, be connected after ensuring that the oil is clean not burnt and is of proper viscosity.

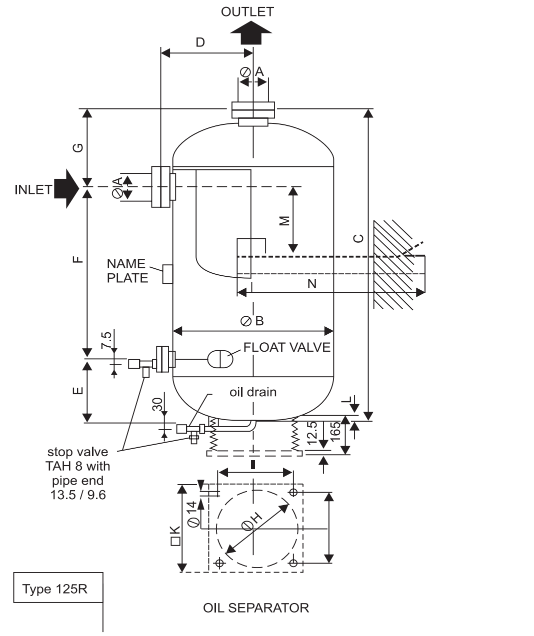

Figure 19: Oil Separator

Oil Separator with Demister Pad of S.S. 85-90% Efficiency

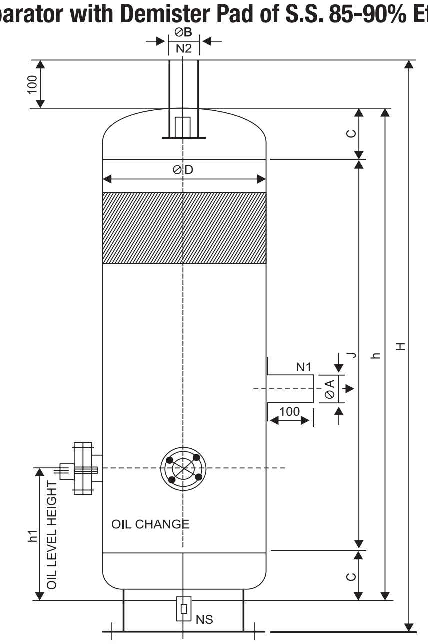

Figure 20: Oil separator working on gravity separation principle

- Gravity rather than refrigerant gas velocity returns the oil. Consequently, the piping can be sized for lower gas velocities with less pressure drop and oil drain connection at a sufficiently higher level than compressor crankcase oil drain inlet connection.

Installation of Interstage Coolers

In a two-stage system using single frame, two-stage compressors or two independent compressors, one for high stage and the second as low stage booster, an interstage cooler is required. This can be a closed interstage cooler where high pressure liquid coming from the receiver is sub-cooled to intermediate temperature and then goes to the LP vessel.

The other design, which is more efficient, is an open interstage cooler, in which the high-pressure liquid from

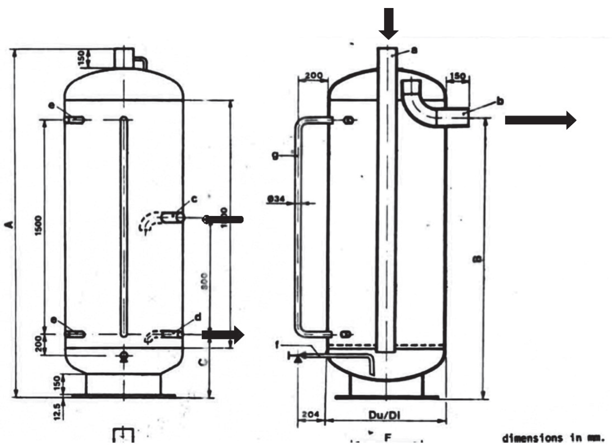

Figure 21: Open interstage cooler

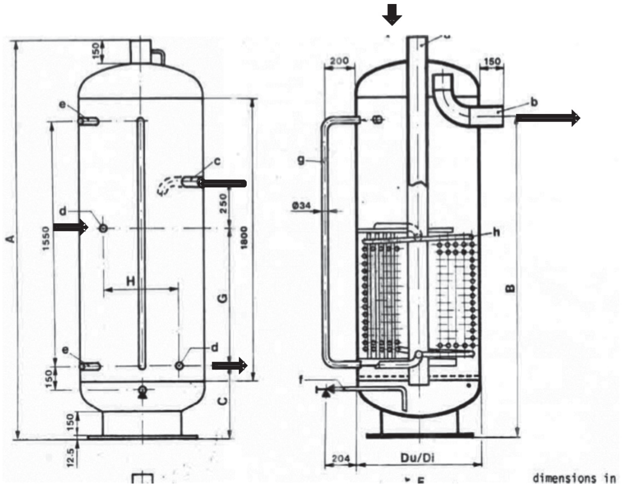

Figure 22: Closed interstage cooler with sub-cooling coil

the receiver is mixed with low-stage discharge gas and both reach equilibrium at interstage pressure or temperature.

The pressure in the interstage cooler in this case is low and the pressure difference available between the interstage cooler and the LP vessel is small. It, therefore, becomes difficult to fill up the LP vessel with liquid due to this low-pressure differential, which is further reduced due to pressure drop in liquid pipeline, solenoid valve, globe valve strainer, etc. It is, therefore, essential to mount the interstage cooler liquid outlet above the level of the LP vessel liquid inlet so that liquid can flow easily from interstage cooler to LP vessel by gravity. The open interstage cooling is the most efficient system. However, it needs skills in erection as well as skilled and experienced manpower to operate such systems. The compressor step control solenoids should be gradually loaded to ensure interstage pressure never exceeds 3.5 to 4 kg/cm^2 and automatic control is preferred over manual control.

Evaporative Condensers

In dual evaporative condenser piping arrangement alternative 1, a common liquid header is used and liquid

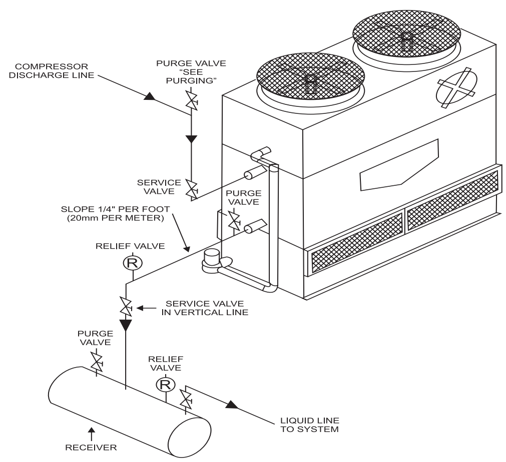

Figure 23: Single Evaporative condenser piping arrangement

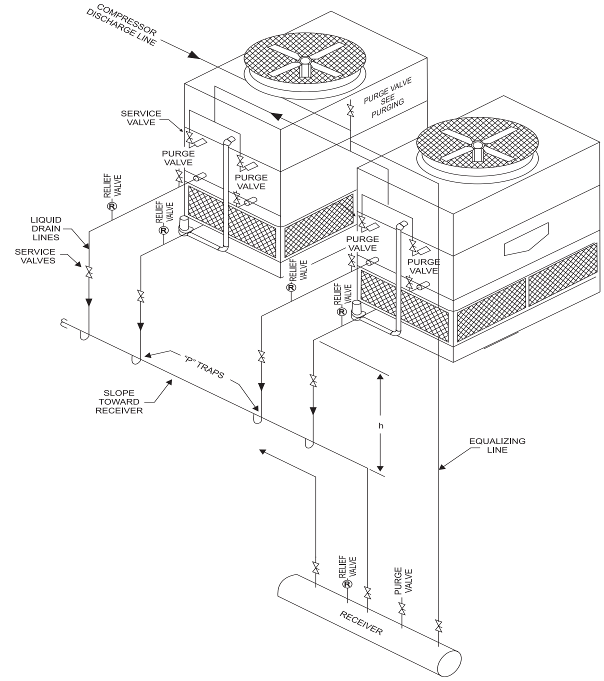

Figure 24: Dual Evaporative condenser piping arrangement alternative 1

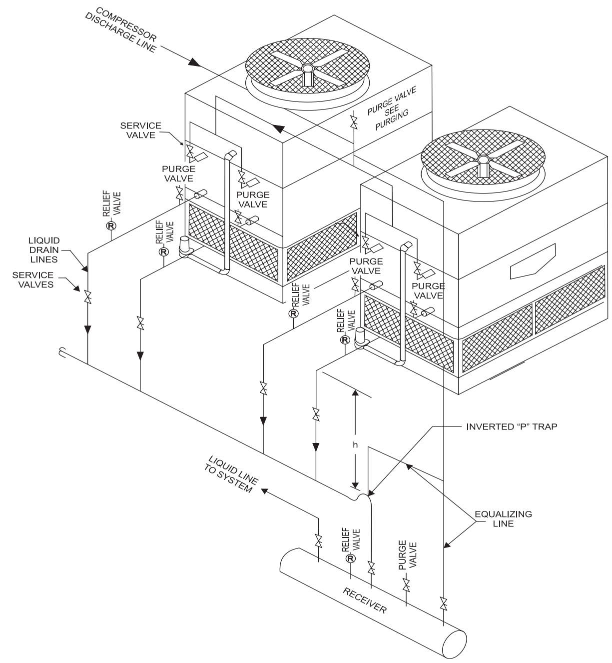

Figure 25: Dual evaporative condenser piping arrangement alternative 2

outlet pipes from evaporative condensers are connected to this header from the bottom 'J' connection. This ensures no liquid is getting trapped and all liquid is freely drained in the receiver.

In this arrangement, all the outlet liquid pipes are connected from top to the liquid header and then a reverse

'U' trap is installed at the end before liquid is drained in the receiver.

Trap and Equalize Condensers

Equalizing connections to ensure pressure in both the condensers remains same are essential. Piping multiple evaporative condensers into a refrigeration system can be tricky, particularly, if the units are not identical. It is easy for condenser banks to lose capacity through refrigerant backflow during off-peak conditions. The same backflow can create safety hazards during maintenance isolation. In some cases, partially isolated condensers can fill with liquid refrigerant in seconds, leading technicians to isolate the unit while full. Refrigerant liquid expands on heating, producing very high pressures as temperature increases. The resulting coil or pipe ruptures can kill. The correct piping arrangement for parallel running of two evaporative condensers or single evaporative condenser with two circuits is shown Figure 30.

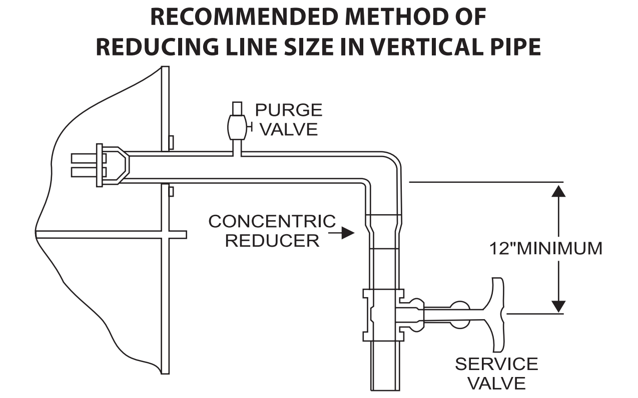

Figure 26: Recommended method of reducing line size in horizontal pipe

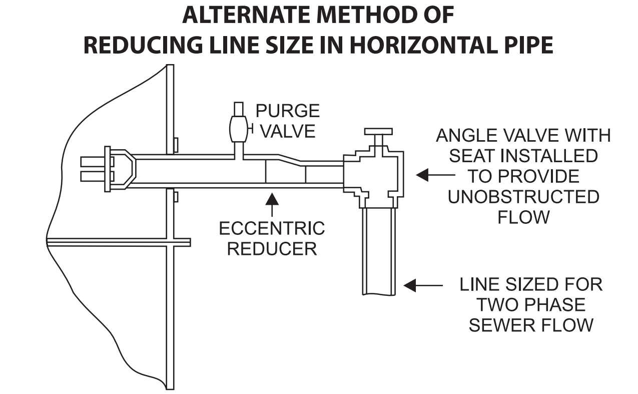

Figure 27: Alternate method of reducing line size in vertical pipe

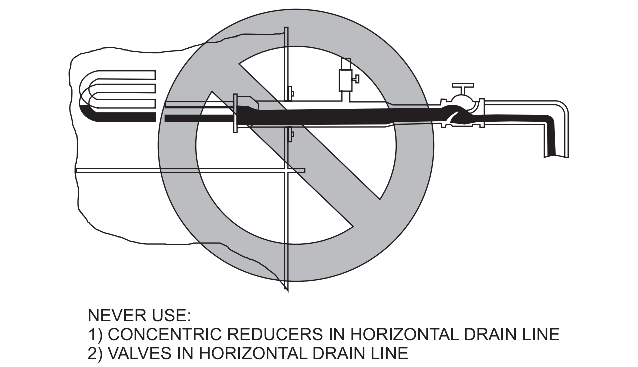

Figure 28: Two evaporative condensers with trapped piping to receiver

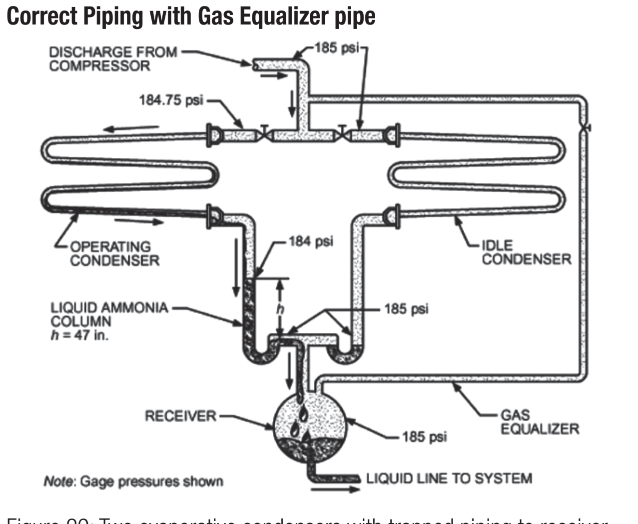

Figure 29: Two evaporative condensers with trapped piping to receiver

In Figure 29, two condensers have been piped to include a liquid drop leg that has been trapped at the bottom of a horizontal liquid header draining to the receiver. An equalizer line has also been added from the receiver to the hot gas discharge line. This is necessary to maintain a stable pressure in the receiver, which will ensure free drainage from the condensers. Under the identical operating conditions as before a liquid head must again be developed in order to produce flow. There is still a one-pound pressure drop 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). The trap creates a liquid seal so that now the one-pound liquid head (h) of 47 inches (1.2m) builds up in the vertical drop leg not in the condenser coil. There must be enough height above the trap in the vertical liquid leg to accommodate a liquid head equal to the maximum pressure drop that will be encountered in the condenser. The example illustrated the extreme case of one unit 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 operation. There also can be substantial differences in pressure drop between two different brands of the same size condenser or even different models of the same manufacturer.

Receiver Piping

Ammonia receiver is a storage vessel, which accommodates entire charge of the system when 80 to 85% is full. Liquid ammonia stored is at high pressure and is then used for various utilities.

It is possible and a good engineering practice to have common evaporative condensers and receivers for the entire system. The system may have several utilities working at different evaporating temperatures. For example, the scheme may be for a fisheries plant where you require chilled water, ice plant for precooling of fish, cold storage and freezer for freezing fish.

Normally, it is a practice to take a common liquid header from the receiver with single outlet and then take different tapings from this common header to various utilities for expansion at required temperatures.

The author has observed in many plants that when you take certain utility on line, for example, if you start the freezing operation when other systems like ice plant, cold storage are operating due to sudden increase in demand of the blast freezer, the major part of liquid gets diverted temporarily to this freezer and the other working utilities are starved of liquid.

To avoid these possibilities, there are two options either size the liquid header big enough so that it serves as good as receiver with plenty of liquid. This alternative leads to large ammonia quantity in the system since machine room and the utilities are generally far away from each other.

The second alternative, which the author has found more useful is to take as many outlets as required by various utilities and size these liquid lines to meet the refrigeration load of each utility so that the lines are smaller, ammonia quantity is reduced and fear of one utility starving temporarily is avoided as shown in *Figure 30*.

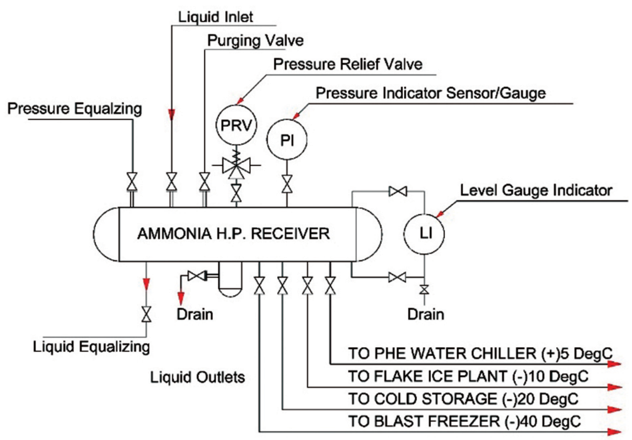

Figure 30: Many outlets as required are taken by the various utilities and size these liquid lines to meet the refrigeration load of each utility

Installation of Air Coolers: Freezing or Cooling Equipment

Low Temperature (-20°C) Cold Room Coolers: (Gravity Flooded system)

Mounting of air cooler and accumulator also needs careful consideration. Most erection engineers install coolers and maintain liquid level in the cooler around 80%. This is incorrect practice as one loses 20% top tubes from liquid flooding and the performance suffers. It is the liquid, which gives cooling when it gets converted into vapors, which have very little cooling ability. It is, therefore, essential to fill up the air cooler with liquid completely and the liquid level in the accumulator should be maintained 300 to 400 mm above the top tube of the air cooler. This ensures that the liquid column available is enough to overcome refrigerant side pressure drop of the air cooler and maintains circulation rate of around 1.8 to 2 times. This, however, depends on individual cooler design and the manufacturer of air cooler as to how the circuiting has been provided and what is the pressure drop on the refrigerant side.

While starting cold rooms from ambient conditions, the cooling load is very high and many times the cooler outlet connections are not designed for this load. If the air cooler outlet connection is not large enough to release evaporated gas, the pressure developed in the cooler forces the liquid back into the accumulator and it can then enter the compressor.

Most erection engineers in such situation worry why liquid is not entering the air cooler and then try to raise accumulator level or increase the diameter of the accumulator to prevent liquid from entering the compressor. Both these practices are incorrect.

It is, therefore, essential to design the air coolers properly by providing a large enough outlet connection. Many times, in such instances where suction connection is not of adequate size, the air cooler fans need to be cycled frequently to bring down the temperature gradually step by step, till such time that the evaporation rate matches with the pipe sizes and vapors do not get trapped in the air coolers.

The most important point to remember in case of such a problem is to investigate why ammonia vapors formed in the air cooler are not escaping from the cooler at the desired rate. Once this is taken care by sizing the outlet of the air cooler sufficiently large to meet initial vigorous boiling, then liquid will automatically enter the cooler by gravity as vapors formed in the air cooler would escape easily and are sucked by the compressor.

Since air coolers are generally mounted near the ceiling and if it is a gravity cooling system, there is no space or enough height to mount accumulators.

It is, therefore, good practice and it is strongly recommended that the accumulator or surge drum along with a valve station consisting of strainer, solenoid valve, hand expansion valve, float switch etc. should be mounted on the cold room outside wall. This needs a walkway to enable service technicians to attend these parts. Inside the cold room, there should be no controls and only liquid inlet and vapor outlet pipe with weld joint should be provided. The flange joint if any also should be outside. This eliminates chances of leakages in the cold room. If the controls are inside the cold room, it becomes very difficult for technicians to reach those heights when the cold storage is loaded with material and also to operate or weld at such low temperatures is very uncomfortable and difficult. The fault generally, therefore, remains unattended.

Figure 31: Air cooler piping on the terrace outside the cold room

As mentioned, for the gravity coolers, it is also recommended that the valve station and the hot gas defrost circuit also in case of pump circulation systems should be mounted outside the room for blast freezers or for air coolers operating in -20°C cold rooms.

Installation instructions

Figure 32: It is necessary to prevent stress in the unit while mounting a unit

- While mounting a unit, prevent stress in the unit.
- Ensure that fixing points have the same spacing and load and they are all at same level even when under load after charging the unit.
- Ensure air flow is not obstructed and enough space is behind the unit (at least 1.5 times the fan diameter) to ensure no air pressure build up.
- Ensure that the drip water drains correctly by providing sufficient vertical height and end of pipe with 'U' and 'P' trap.
- Set up the unit horizontally with one degree angle slope or 1/8" in 12-inch distance for the drain water run-off.
- Take the drip water pipe outside the cold space to ensure water does not freeze.
- If the coil is of S.S, please ask the manufacturer to provide a M.S. pipe of sufficient length so that welding of M.S. to M.S. piping is easier at site, instead of welding M.S. to S.S. at site, which may damage coil inlet outlet pipes.
- Check fan rotation and ensure it is not touching any part of the unit casing.

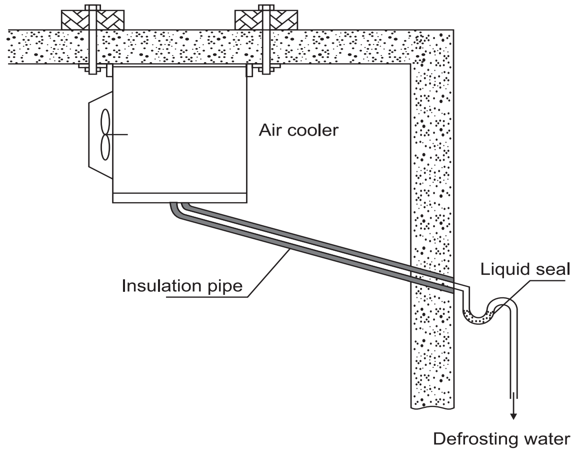

Figure 33: Fan rotation is not touching any part of the unit casing

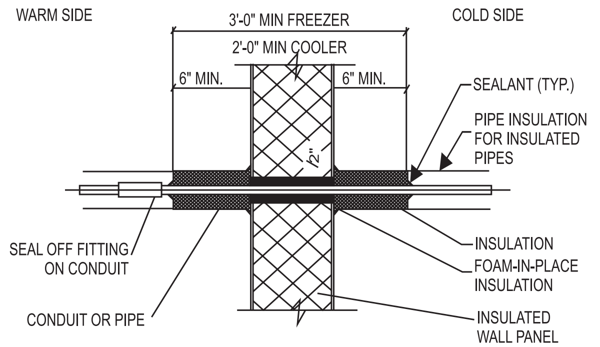

Figure 34: Wall penetration detail

Wall Penetration Sleeve for Air cooler Piping

Air cooler pipes requires to be welded from inside and ammonia gas lines needs to be welded from outside the wall where the valves and control station is located.

The air cooler outlet pipe should be large enough to meet initial load demand as suggested earlier and should slope in the direction of low-pressure vessel as indicated in Figure 36. The recommended magnitude of slope is often specified 1" in 15 ft.

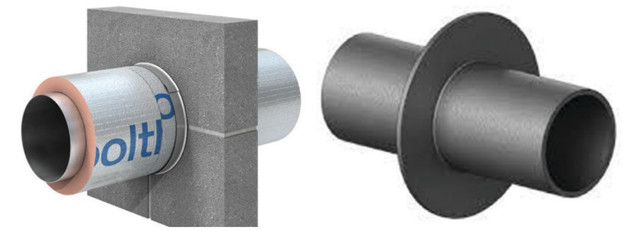

Figure 35: Wall penetration sleeve

An upward loop in the suction line connecting multiple evaporators prevents oil and liquid refrigerant from flowing back into an idle evaporator at part load or shut down.

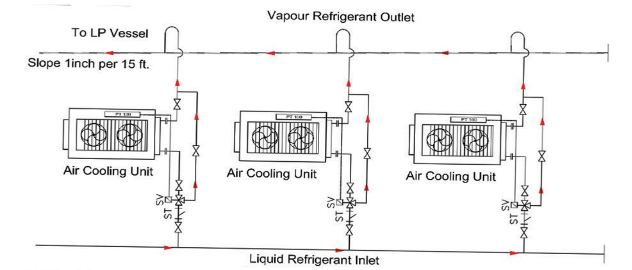

Figure 36: Air cooler outlet pipe should slope in the direction of low-pressure vessel

The outlet line from evaporators to the L.P. vessel should slope in the direction of LP vessel.

Ammonia Pump Circulation LP Package

There is a separate article published earlier on low-pressure system designing and in this article only stress is given on piping slopes and pump reducer selection and installation.

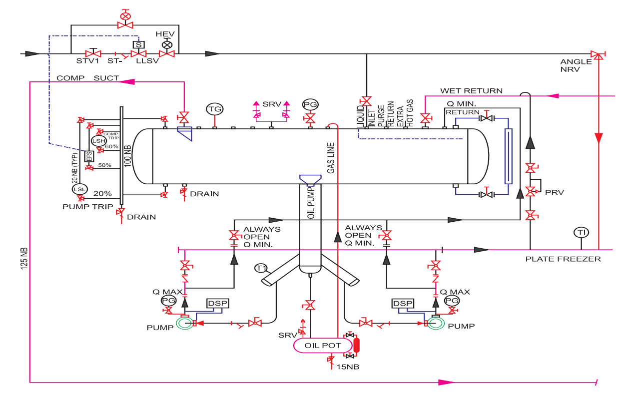

Figure 37: Details of pressure vessel

As shown in Figure 38, the pipes from evaporator as well as from compressor should slope towards L.P. vessel.

Ammonia Pump Inlet Reducer

Figure 39 shows the right method of using the reducers, the top figure shows how the reducer is normally installed, which is an incorrect practice, the correct method is shown in the second figure.

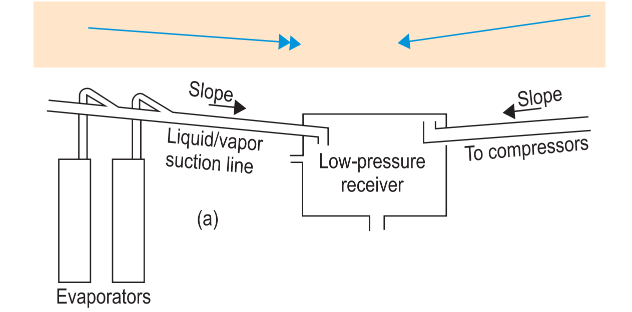

Figure 38: Pipes from evaporator as well as compressor should slope towards L.P. vessel

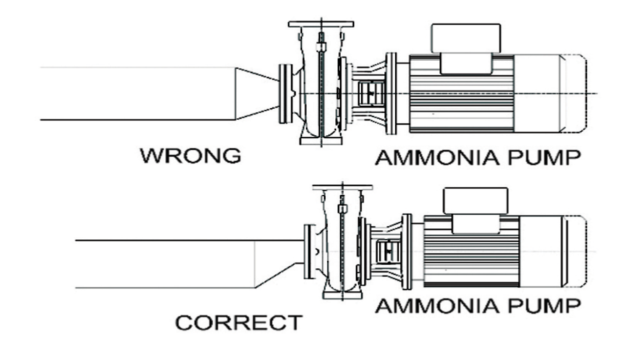

Figure 39: Right method of using the reducers

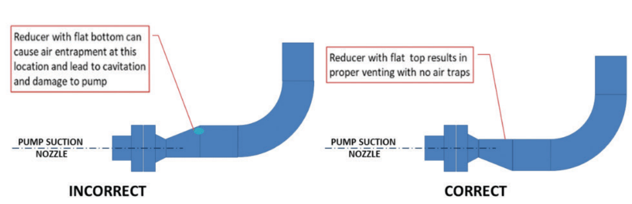

Figure 39: Right method of using the reducers

Conclusion

As mentioned earlier, ammonia refrigeration plants are normally field erected. One may select the best and most efficient equipment, but if the installation and particularly, the piping is not done properly, the plant would face problems. There are many books that give piping diagrams, but the reasons for installing the pipe in a particular manner are absent. In this article, we have made an attempt to explain why the pipe should be installed in a way as shown in drawings or diagrams. It is, therefore, essential to do the installation and proper pipe routing as detailed above by experienced qualified fitters or welders under the supervision of qualified erection staff.

References

1. EVAPCO manual
2. ASHRAE volumes
3. Internet images * Published articles