Field-Erected Ammonia Plant Refrigerant Piping : Part -1

By Ramesh Paranjpey, Distinguished 50-Year Member, ASHRAE

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.

About the Author

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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 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.

Piping Installation Procedure General Guidelines

- The piping should be done in accordance with refrigerant flow requirements and not necessarily from the point of aesthetics.

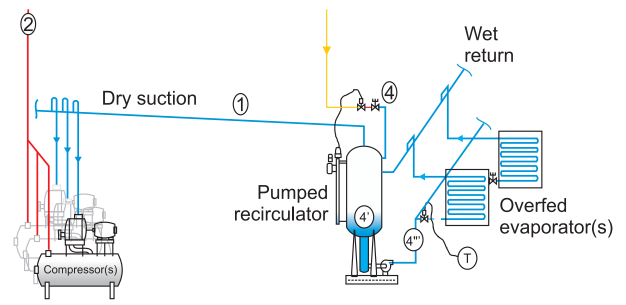

Figure 1: The piping should be done in accordance with refrigerant flow requirements

- Shortest possible routes, least welding and flange joints, avoidance of elbows, reducers, flanges wherever possible should be studied and used.
- Piping material lying at a site should be thoroughly cleaned externally and internally to make them free of rust scale, sand or dirt prior to the installation.

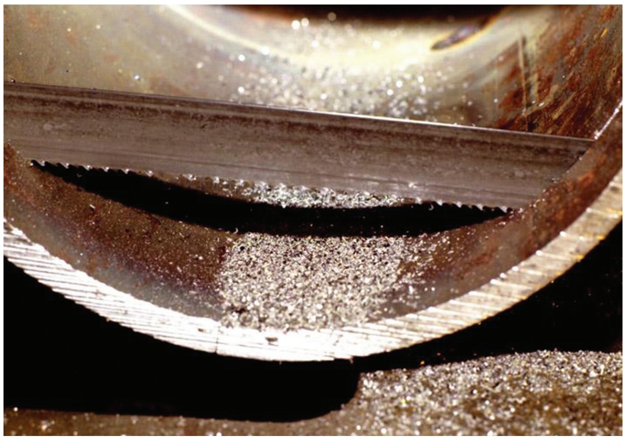

Figure 2: Internal pipe cutting residue and it is necessary to clean it

- All pipes shall be cut and beveled before welding and remove pipe cutting residue.
- An all-welded piping system is superior and preferred as it avoids leaks.

Figure 3: Piping showing all welded joints

- Qualified or certified welders must be used who have experience in ammonia pipe welding.
- Proper piping welding practices such as first root run by Metal Inert Gas (MIG) or Tungsten Inert Gas (TIG) welding should be followed.
- Proper alignment of pipes and provision of proper gap so as to achieve full penetration weld is required.
- Piping should be at least two meter above the floor to ensure free movement of people.
- The distance between the two lines shall be at least three times the thickness over the insulation and four times the flange fittings.
- Hangers or pipe supports shall ensure weight off the compressor, pumps and other installed equipment.
- Pipe hangers or supports should be placed no more than two to three meters apart and within one meter of a change in direction of the piping. For lines less than 140 mm sizes, the supports should not be more than two meters apart.
- All piping must be properly supported by hangers that allow for expansion and contraction caused by the heating and cooling of the piping. Allow about 20 mm of expansion and contraction for every 30 m of piping length.

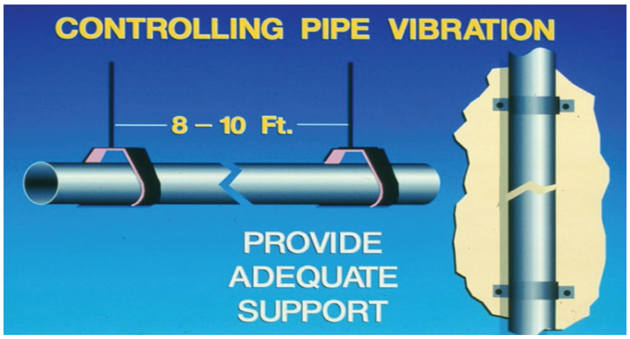

Figure 4: Pipe supports to be provided so that pipe can move freely in supports to take care of expansion and contraction

- The hangers should be designed on the outside of insulated lines.
- All pipe hangers must have a vibration absorbing insulation material between the pipe and the hanger. Otherwise, the vibration of a pipe will be carried through the building, which may amplify noise. Where the pipe passes through a wall, ceiling or floor, a sleeve must be provided that extends about one inch beyond the opening on either side.

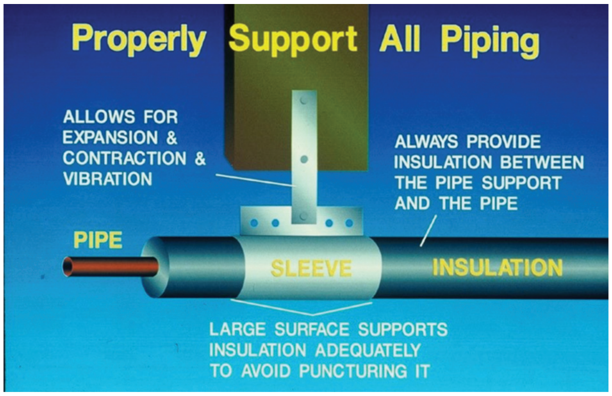

Figure 5: Proper support for all piping

- In *Figure 5*, there is only one upper bolt in the support, and the lower hole is not clamped. The purpose is to ensure free movement of the pipe to the left or right due to temperature changes.
- Sheet metal sleeves on the lower half of the insulation and sleeves where the pipe enters the wall should be used. The support should rest on a concrete paver or wood sleeper with the roof beneath protected by membrane material.
- Care must be taken to avoid rigidly anchoring both ends of a long straight pipe. Such an approach will damage piping or the structure to which it is attached or both.
- Provide bends, loops in long lines to take care of expansion or contraction due to temperature changes.
- To keep the pressure drop minimum, consider angle valves instead of globe valve and a right angle bend wherever possible as it would be having less welding joints, less pressure drop as well as being more compact.

Figure 6: To keep the pressure drop minimum, consider angle valves instead of globe valve and a right angle bend

- Install all globe valves with stem horizontal to avoid dirt or scale to lodge on the valve seat or cause it to leak or for liquid or lubricant to accumulate in the space below the seat. This is a must for all liquid lines.

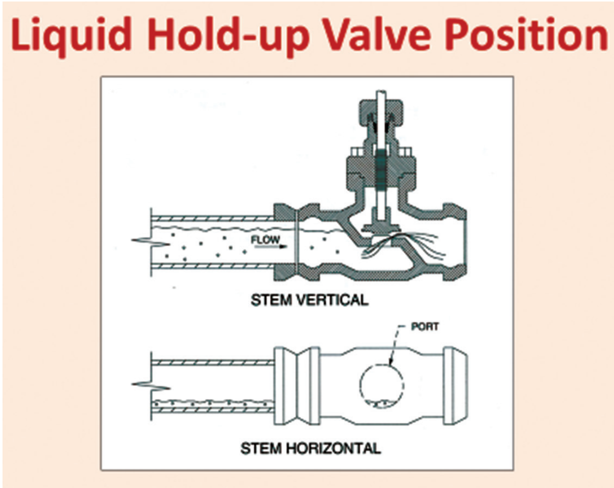

Figure 7: Liquid hold up valve position

- The suction line of the compressor should be sloped away from the compressor towards the evaporator and the discharge line should be sloped away from the compressor towards the condenser. Use proper slopes so that oil accumulates at the desired drain points.
- Provide strainers wherever possible to ensure no damage takes place to the equipment due to contaminants.

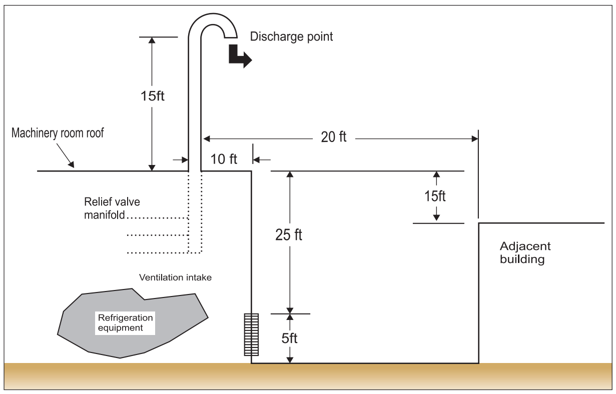

Figure 8: Safety relief valves of proper capacity and outlet piping should be taken above 15 feet and 20 feet away from human occupied areas

- Use dual safety relief valves of proper capacity and outlet piping to be taken above 15 feet and 20 feet away from human occupied areas.

Figure 9: Safety valve piping outlets

- Ensure liquid traps are avoided in the piping. Since liquid is non-compressible, the piping would burst when ambient temperature rises. Combination of solenoid valve or pneumatic valve and check valve in the liquid lines could trap liquid in the line accidentally. In the direction of flow, solenoid valve should be installed first and then check valve. If this order is reversed, some liquid becomes locked in between check valve and solenoid valve when solenoid or pneumatic valve closes. During standstill, this liquid can warm up and lead to cracks in the pipeline or flanges when it expands, especially, in the pipelines carrying cold ammonia. A safety valve in the portion likely to trap liquid is a must if such situation is unavoidable.
- Avoid hydraulic shocks and vibrations in piping and wet rerun lines during defrosting by proper designing.

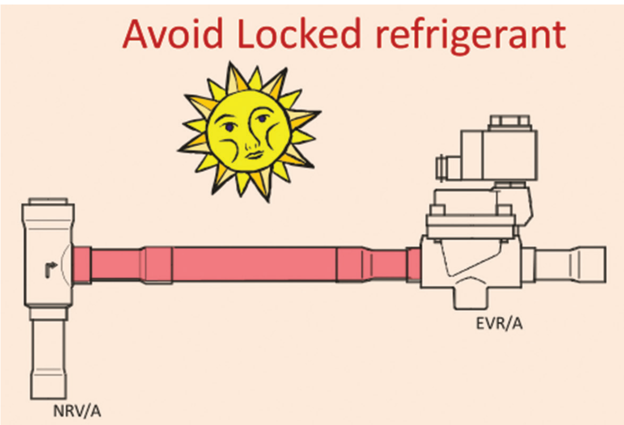

Figure 10: Avoid locked refrigerant

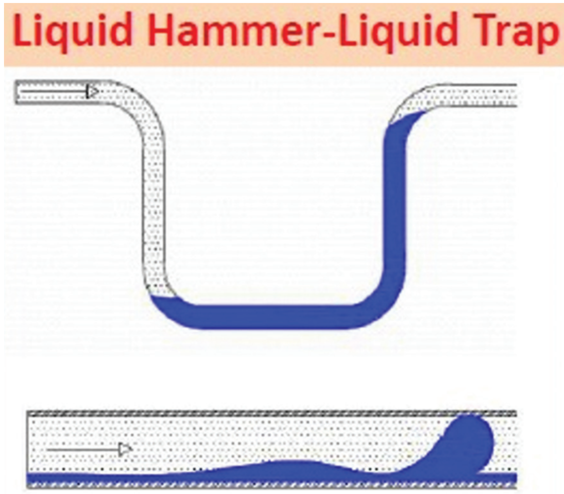

Figure 11: Liquid hammer liquid trap

Hydraulic Shock

Hydraulic shock is a sudden localized spike in pressure that can occur in piping or equipment when there is a rapid change in the velocity of a flowing liquid. Often referred to as water hammer, hydraulic shock is a well-understood phenomenon that has occurred in water and steam systems found in both domestic and industrial settings. In ammonia refrigeration, hydraulic shock events can generate extremely high pressures with the potential to cause the catastrophic failure of piping, valves, and other equipment. The highest pressures often occur when vapor and liquid ammonia are present in a single line and are disturbed by a sudden change in volume. Moderate hydraulic shocks can generate pressures that are evidenced by knocking sounds emanating from piping or valves.

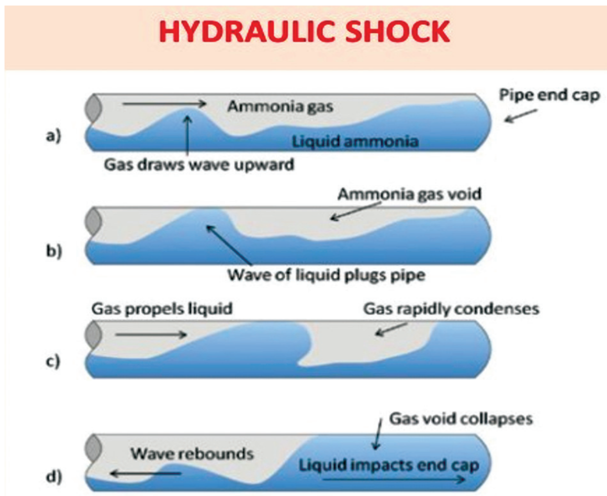

Figure 12: Hydraulic shock

Figure 13: Liquid hammer can destroy even a heavy-duty seamless steel pipe

- Use quick drain shutoff valves for oil draining. Consider using a spring-loaded ball valve (dead-man valve) in conjunction after the shutoff valve on all oil drain points.

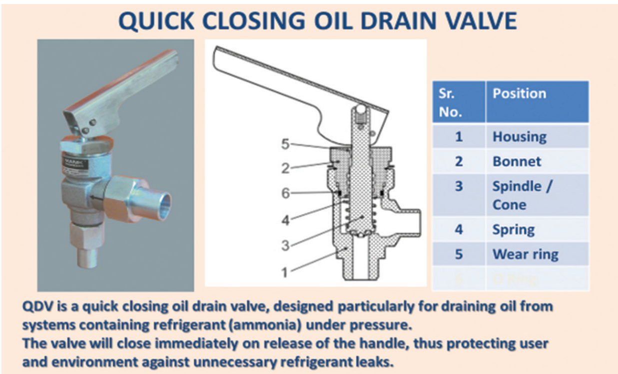

Figure 14: Quick closing oil drain valve

- Paint and prime all pipes and provide proper insulation wherever needed.
- Anti-rust treatment and painting for all piping need to be provided before insulation. Vapor barrier under insulation if damaged, the rusted pipes remain invisible and can cause rupture or accidents.
- Check for corrosion under insulation (CUI) by conducting spot checks, often performed during your mechanical integrity audit. Prevent pipe corrosion by using a corrosion inhibitor or stainless steel pipe.

Figure 15: Corrosion under insulation (CUI) by conducting spot checks

- Provide pipe labeling as per the standard.

Figure 16: Pipe labeling as per the standard

- Use proper piping coloring code to identify piping easily.

Refrigeration Piping Color Coding and Labeling

Using a color coding and a labeling system helps to ensure the facility's engineering staff can identify the piping quickly and easily.

Table 1: Refrigerant Piping Color Code

SR.NO.	DESCRIPTION	SCOPE	COLOUR CODE
1	HP Hot gas	High Stage Discharge	Red
		Booster Discharge	
2	HP liquid refrigerant	Receiver to Economizer	Orange
		Economizer to Intercooler	
3	LP liquid refrigerant	Intercooler to LP Vessel	Light green
4	LP refrigerant vapor	High Stage Suction	Dark green
		Booster Suction	
5	Liquid'vapor mixture of refrigerant	5	Purple
6	Oil Circuit	Both Booster & High Stage	Black

Figure 16: Pipe labeling as per the standard

- Provide proper flow directional arrows and labels.
- Provide safe access to all operating valves and controls in addition to all equipment.
- Provide valve numbering for conveying information by a plant operator to procurement agency as to which valve has gone defective and needs replacement.
- All high points should be provided with vent valves for purging.
- Liquid line valves should be mounted preferably in vertical lines and if mounted in horizontal line, the valve stem should be horizontal.
- Use eccentric reducers wherever possible instead of concentric reducers.
- Back seating type ammonia valves should be used.
- Valves should be installed so as to close against flow or pressure.

- Long stem valves should be used for installation in insulated lines.
- All suction branches should be taken from top of the header. All hot gas connections or branches should be taken from top.
- All liquid branches should be preferably from bottom of the header.
- For long liquid and vapor lines, provide a drain valve in the piping. Also provide safety relief valve in the liquid line to prevent trapped liquid and bursting of pipe when plant is not in operation due to atmospheric temperature variations.
- Provide seal caps for valves not in use such as drain or purge or charging valves.
- Drain or vent caps for valves should have small drilled hole so that pressure relief is available in case minor leaks.
- No shutoff valve should be used before safety valve and if provided it should be in locked open position.
- All operating valves should be approachable either from floor or from fixed platform.

Compressors

The NRV should be after oil separator and not after compressor, because the reciprocating compressor discharge gas pulsations are dampened in the oil separator if the NRV is placed between the compressor and oil separator, the NRV is subjected to these pulsations and it often chatters, or is likely to get damaged earlier than expected. Many people argue that placing it immediately after the compressor prevents liquid condensation during standstill state. This argument is incorrect as there is no liquid in the discharge side and the density of ammonia refrigerant gas is so low that when converted to the liquid, the quantity is insignificant and liquid if at all formed would accumulate in the oil separator and not on the compressor top. The discharge line from compressor to oil separator is also very short and there is not any significant amount of gas present here.

Depending on NRV design, keep NRV in horizontal line, because in a horizontal position, gravity is not acting on NRV parts, if in a vertical location, the parts are acted on by two forces, one is gravity and the other is discharge gas, both directions are opposite to each other and can lead to vibrations, noise and damage to parts.

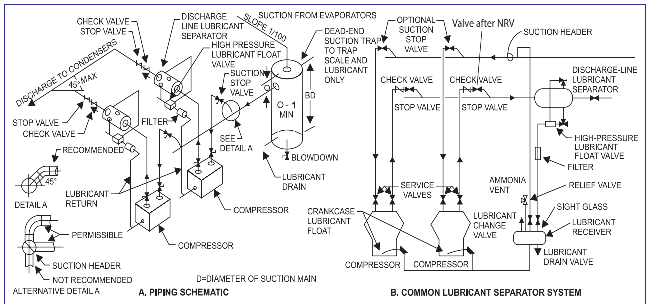

Figure 18: Schematic of reciprocating compressors operating in parallel (Reference: ASHRAE handbook)

Provide independent oil separator for each compressor. The author has observed many installations where there is a single common oil separator and the combined discharge header is connected to this oil separator. This is not a good practice; each compressor has its own characteristic and quantity and quality of oil migration along with discharge gas varies for each machine. It is always a good practice to have independent oil separator for each compressor.

In the oil separator, oil drain should be above oil return level of the compressor. The pressure in oils separator and the compressor is often the same, the oil returns by gravity and hence, there should be sufficient head available between the oil return point of the oil separator and the incoming point of oil return on the compressor crankcase. Also, it is a good practice to drain oil manually when the installation is new and check the oil quality instead of automatically returning to the compressor crankcase. The oil is normally not clean in initial stages and till such time that one is fully convinced that the oil getting accumulated in the separator is clean, the automatic oil return should not be connected and used; otherwise the contaminants would enter the compressor and may create problems.

Connect individual discharge and suction pipe to the header in a sloping manner, the slope being in the direction of flow or easier is to connect from the top in a reverse 'J' pipe like gent's umbrella handle.

- Check alignment of motor with compressor in all three risers.
- Hook up suction and discharge piping without any force needed while inserting bolts in the flanges. The author has observed in many installations that when bolts joining the flanges of compressor and the discharge pipe are loosened, the alignment is not perfect. This happens due to the fact that during welding, there is shrinkage and the alignment gets disturbed. The normal practice is pulling with force and then inserting bolts, this should be avoided as it imposes undue forces on the compressor and may lead to additional vibrations.
- Always use a stop valve after the NRV in the discharge pipe leading to the common header. This is required, because if the NRV gets stuck, one should be able to attend to the same without stopping the entire plant. The stop valve of the particular compressor can be closed and the NRV can then be attended.

In Part 2 of this article, to be published in the September-October 2023 issue of Cold Chain, we shall discuss piping of the remaining components of the refrigeration system

– Consulting Editor.