A U turn accumulator installation

U Turn Accumulator - a New Design Concept

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Introduction

Vapour compressor refrigeration systems are broadly divided in two categories:

1. Direct expansion systems (DX)
2. Flooded systems

It is an established and well known fact that flooded systems are more efficient compared to DX systems. Ammonia refrigeration plants predominantly use flooded systems, using evaporators either with gravity cooling or with forced feed pump circulation systems. Refrigeration systems with flooded evaporators are used for both air cooling and liquid chilling applications. Flooded systems require much larger quantity of refrigerant in the system compared to DX systems.

Although ammonia is thermodynamically the most efficient refrigerant, due to its toxicity and flammability characteristics, efforts are being made to design ammonia systems with low refrigerant charge so as to minimize the adverse effects of ammonia leakage. Equipment designers are making every effort to design equipment which would have low refrigerant quantity without sacrificing performance. The use of plate type heat exchangers (PHEs) for condensers and evaporators, therefore, is becoming the preferred choice of system designers as they require very low refrigerant charge in the system compared to conventional shell and tube heat exchangers.

About the Author

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Just to give an example, traditional thumb-rule designs used 2 kg of ammonia per ton as system charge for flooded systems. Factory built ammonia package chillers using PHE condensers and evaporators use less than 1 kg/ton of refrigerant charge.

Accumulator in a Gravity Flooded Chiller

Gravity flooded chillers or coolers require additional equipment, known as accumulator, to separate liquid ammonia and vapour so that only liquid ammonia enters the evaporator and vapours are returned to the compressor. This vessel is also, therefore, known as a liquid separator or gravity separator. Conventional designs use either horizontal or vertical accumulators, depending on various factors.

The design, selection and installation of accumulators has been a nightmare for system designers, as there are no clear cut guidelines since the pressure drop, circuiting arrangement and liquid and suction header sizes vary from manufacturer to manufacturer. The evaporator or air cooler/ chiller manufacturers indicate their inability to suggest the proper size and method for installing the accumulator, treating it as the system designer's responsibility. A survey of gravity flooded ammonia installations would reveal an amazing range of accumulator sizes for identical capacities and a variety of methods for mounting them.

The design of an accumulator or gravity separator is a complex subject, as the forces acting on liquid droplets are gravity pull on one side and compressor drag and buoyancy forces on the other side. The size of the droplet that should be prevented from going into the compressor suction varies for different operating conditions such as saturated evaporating temperature (SET) and saturated condensing temperature (SCT). Also, the velocity to prevent the smallest droplet size from entering the suction piping needs to be determined for each operating condition.

Two important values that are apparently difficult to determine are:

1. What is the distribution of droplet sizes?
2. What is the maximum size of droplet or the quantity of liquid that may be allowed to enter the compressor to prevent accelerated wear or damage to its parts?

Accumulator Design Challenges

The primary goal of a vessel designer is to select the proper velocity, and to size the separator such that the gravity pull force outweighs the drag and buoyancy forces, causing a certain diameter of droplets to separate from vapour flow and to settle down by gravity in the liquid pool, thus preventing liquid drops or mist from entering the compressor. The major issues which continue to challenge system designers/ erection engineers are:

1. What should be the correct size of accumulator to prevent liquid entering the compressor?
2. Whether to use the vertical or the horizontal design – space limitations dictate the choice.
3. Whether there should be a liquid pool upto a certain height in the accumulator, or it should be all vapour, free of liquid.
4. If liquid level is to be maintained in the accumulator, up to what height – many installers avoid liquid and ensure that the liquid level is below the top two rows of the heat exchanger or air coolers, so as to avoid any chance of liquid flow back to the compressor; however, this is achieved at the cost of air cooler or hear exchanger efficiency – since it is not fully flooded, it becomes less effective.
5. The erection engineer is not clear as to the position of accumulator w.r.t. air cooler – whether it should be at the same level as air cooler/ heat exchanger or much above the top row?
6. If it should be above the top row, how much – 100mm or 200mm or even more?
7. What should be the size of the down leg or stand pipe through which the liquid enters bottom feed evaporators?
8. Where should the ammonia liquid entry from the expansion valve be provided in the accumulator? Should it be in the accumulator, and at what level above the liquid operating level or in the stand pipe – again at what level?
9. At what level should the vapour return connection be provided in the accumulator?
10. What should be the distance between the operating liquid level and evaporator gas return pipe?
11. What should be the distance between the operating liquid level and compressor suction pipe?

If liquid is entering the compressor, we have seen peoplein the field struggling to address it by altering one or more of the above parameters on the basis of trial and error, and still remain uncertain whether it would solve the problem. The ASHRAE handbook on refrigeration as well as IIAR piping handbook and the text book by W.F. Stoecker give many valuable suggestions, but many issues remain unanswered and there are no clear cut guidelines if one wishes to design a system for a particular application, since a lot of details need to be worked out based on evaporator characteristics, as mentioned earlier. All these problems would get resolved if the flooded air cooler/ chiller manufacturer would provide accumulator/ liquid separator as an integral part of the equipment.

PHE-Accumulator Combination

A European manufacturer has recently come out successfully with an accumulator design as a part of their PHE liquid chiller. This design is suitable for liquid chilling applications using gravity flooded ammonia systems. The design was showcased in the Chillventa exhibition in Germany in 2010, where the author happened to be present and decided to use it at the first available opportunity.

Gadre Marine, Ratnagiri are well known leaders in the field of fish processing and freezing operations and due to the

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author's long association with them in providing designs for their refrigeration systems, he suggested the use of this PHE-accumulator combination for their chilled water requirement of 3°C. This design has been used in India for the first time, and has been working satisfactorily for over a year.

Advantages

The major advantages of this design to the system designer, installer and end user, as per the information provided by the manufacturer, can be summarized as follows:

1. Fully functional module comprising of a heat exchanger and accumulator from one supplier, eliminating uncertainties.
2. The entire assembly of PHE and U turn accumulator is a factory fitted equipment, duly pressure tested.
3. U turn accumulator is designed for 60% re-entrainment velocity with droplet size of 150 microns, which ensures that liquid droplets do not get carried to the compressor, thus prolonging compressor life with reduced maintenance. PHE can run effectively as per its design. The selection software ensures minimum pressure drop.
4. U turn accumulator is aligned along the length of PHE carrying bar, and does not require extra space.
5. Since there is no extra piping between PHE and accumulator and with short ammonia liquid column and wet return leg, it ensures lower pressure drop and leads to higher efficiency, higher COP and lower power consumption.
6. The U turn accumulator is sized for efficient separation of liquid and vapour by agglomeration, centrifugal force and surface tension along with gravity separation.
7. The design is compact in size with reduced hold up volume; as such, very low ammonia charge is required compared to the conventional accumulator design, which makes the system safer.
8. U turn accumulator, being compact in size, requires small skids and can be accommodated in a lower height, which is a big advantage as many installations have limited or no space available above the chiller.
9. The combined assembly of PHE and accumulator is in one piece and is self supported on three point support (U turn accumulator is entirely supported by PHE), and no external skid or structure is required.
10. PHE can be opened for cleaning/ servicing without disturbing the U turn accumulator.
11. U turn can be designed for extra capacity (capacity expansion).

Conclusion

With these significant benefits, the design is gaining popularity, and within a short span many installations have been commissioned and several more are under execution. Some examples are Sakas Milk Products in Maharashtra, Dairy Fun Ice Creams in Delhi and Hindustan Coca-Cola in U.P. ❖