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Low charge ammonia refrigeration systems

It can be rather costly to install a larger ammonia refrigeration system if the charge is above the local limit. Additional cost to handle the safety issues and regulatory requirements can be sky high. This pushes many investors to go in the direction of CO2, but ammonia can still provide a lower energy consumption unless you need temperatures below -35°C (-31°F).

What can be done to reduce the charge?

There are some tricks to significantly reduce the refrigerant charge and then you can both avoid the administrative burden and reduce the energy consumption. Traditionally the large systems have been designed as pump circulated systems, wherein large quantities of liquid fills simple evaporators which are only suited for overfeed systems.

The alternative is to use DX (direct expansion) which is a more efficient solution. DX is traditionally not used below -20°C (-4°F) but with the right technology it is attractive. The total cost will be at the same level, but evaporators will be more expensive, and piping will be less expensive. Pumps and the associated maintenance work are not needed.

With 1000 kg of ammonia, it is possible to build a 250.000 m3 (9 million cu ft) cold store when DX is used. Such a system is currently under construction in Australia.

Challenges with pump circulated systems.

Besides the challenge with the large charge a lot of energy is wasted transporting the liquid around again and again. The energy loss is mainly caused by a very large pressure loss which results in increased energy consumption in the compressors. Energy used for the circulation pumps and additional air circulation is also a part of the picture but not as large as the pressure loss.

If an evaporator is filled with liquid, it is blocked, and the suction pressure will be low. To increase the pressure, you need to increase the evaporation, and this can be done by making the evaporator larger which is costly or by increasing the heat transfer.

The ideal evaporator for DX has a larger number of thinner pipes and a distributer with a large diameter pipes to avoid pressure loss. For traditional overfeed systems few long evaporator pipes with large diameter are used together with a liquid distributer with narrow pipes. This solution has a lower cost but creates a very high-pressure loss. Especially during part load this type of evaporator tends to be filled up with liquid and the pressure loss will increase even further.

Prefabricated machine room for low charge DX ammonia system

In an overfeed evaporator the heat must conduct through the relatively still liquid which is a slow process. When boiling starts the heat transfer moves to convection which is much more efficient and improves the heat transfer. The efficient evaporation creates a lot of gas and increases the pressure.

With the right components a system DX is more efficient than pump circulated systems.

In a DX system the gas leaving the evaporator must be dry and that can lead to a loss. When most of the liquid is evaporated, a large part of the inner surface will be dry, and the evaporator will suffer from poor heat transfer again. The best evaporators have a construction where the liquid is not just running as a small stream in the bottom of the pipe but utilize a larger part of the surface.

Traditionally the control is based on a calculation of superheat and that leads to a loss depending on how much superheat is needed to secure dry gas. Vapor quality control can reduce the energy consumption between 20 and 50 % depending on how much of the time the system is operating in part load. Especially in part load vapor quality is significantly more efficient.

Water in the ammonia makes the efficiency poor.

Many pump-circulated systems have too much water in the ammonia and that reduces the efficiency. The water affects the evaporation temperature and especially when most of the ammonia has evaporated it gets critical. For high circulation numbers it only reduces the performance and increases the energy consumption, but for small circulation numbers it affects the control as well.

For DX systems water in the ammonia is more critical and requires increased superheat. This leads to a risk of liquid hammering and poor performance and must be avoided. Vapor quality control can detect the water and avoid the liquid hammering risk, but performance will still be poor.

The conclusion is that water must be removed from the ammonia to keep up efficiency and it is even more important for DX systems.

Pros and cons of pump circulated systems.

Pro

- Simple and reliable
- Classic design - high experience
- Low-cost evaporators

Con

- High ammonia charge
- Inefficient especially during part load
- High maintenance

Pros and cons of DX systems.

Pro

- Low ammonia charge.
- High efficiency with vapor quality control
- Simple maintenance

Con

- New technology – lack of experience
- Special evaporators needed.
- Water free ammonia needed.

Defrosting techniques which can reduce the charge.

Defrosting with hot gas increases the charge but is a very efficient way of defrosting. A way of reducing the charge and piping is to use the vapor quality sensor for controlling the defrost and lead the condensate from the hot gas defrosting directly to the liquid line instead of leading it back to the separator – this allows for a smaller separator and less piping.

In warm climates it is possible to install the evaporators in a box outside the cold store and have a door between the evaporator and the cold room. When this door is closed it is possible to open another door to the outside and use the outdoor air for defrosting. It is not as fast as hot gas defrosting, but piping is significantly cheaper. An additional benefit is that no heat from the hot gas is led into the cold store and that the water can be kept outside.

Door for ambient air inlet to evaporator

Reduced damage if leaking

Damage of goods in the cold store is feared by most owners of cold stores. The smaller charge and the use of DX control significantly reduces the amount of ammonia in the evaporator which potentially can leak into the cold room. If an ammonia gas sensor is installed in the cold room it will be possible to close the expansion valve before any harm is done to the goods and people get hurt. This means the risk of damage is almost eliminated.

Track record

Scantec in Australia has built the low charge DX ammonia systems since 2014 but several other companies as well have used vapor quality control for both large and smaller systems. The vapor quality control is used with all common refrigerants and in both DX systems and in overfeed systems. A track record is available here: https://www.hbproducts.dk/en/knowledge/white-papers/save-energy-with-vapor-quality-sensors/351-reference-list-vapor-quality-sensor/file