Reliability of Ammonia Absorption Refrigeration Plants in the Chemical and Food Industry

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ABSTRACT

Reliability, low maintenance costs and simple operating are important arguments for chemical and food industries to install an ammonia absorption refrigeration plant to supply cooling down to -60 °C for their production. A short introduction to the absorption process is given. All components of an AARP are analysed concerning the needs of maintenance and the possibility of failures during operation. A typical maintenance plan for an AARP is explained. It shows that no specialists are required for operating, service and maintenance works. No special spare parts are needed. The plants can be operated completely automatically by a PLC. The possibilities of redundancy are discussed to ensure operation without stopping for several years.

1. INTRODUCTION

Absorption refrigeration plants working with ammonia as a refrigerant (AARP), which are built today, are based on the experiences with such plants for more than a hundred years and equipped with the technology of the state of the art. The main fields of application are food and chemical industries for cold supply down to -60°C. Many production processes in these industries are very dependent on the supply with cold and therefore they need reliable cold supply with low running costs. That is why they often choose for AARPs instead of compression plants even if the initial investment costs are higher.

Benefits of AARPs for industrial cooling:
- high availability of the plants
- plants are not susceptible to repair works
- low maintenance costs
- no specialists required for service and maintenance
- no special spare parts required, use of standard available components
- automatic operation of the plant possible
- flexible to changing operating conditions (temperatures)
- excellent partial load behaviour
- simple back up of all moving components possible
- long life time (more than 30 years possible)
- only small electricity consumption, which can be important for locations with unstable electricity supply

AARPs for refrigeration capacities larger than 100 kW are always tailor made for the customer (Langreck 1999). This guarantees an optimal design of the plant to fulfil all special requirements of the individual customer if it is done by a qualified and experienced supplier.

In many cases AARPs are powered by heat from a cogeneration plant, which is called trigeneration [1,2,3,4,5]. To provide continuous cold supply, also for times when the cogeneration plant is stopped, an alternative heat source (for example a boiler) can be considered.

2. FEATURES OF AN AARP

The main difference between a compression and an absorption refrigeration process is, that the mechanical driven compressor is replaced by a thermal working compressing cycle. This thermal working compressing cycle consists out of two main heat exchangers (absorber and desorber) and one liquid pump. Instead of mechanical (electrical) energy to drive a compressor this thermal working compressing cycle needs mainly heat as a driving energy. Only the liquid pump requires mechanical (electrical) energy. This is the only moving component in an ARP beside some pneumatic driven control valves.

With the exception of the pump and the control valves all other components are heat exchangers, valves, piping and instrumentation which do not need much maintenance or repair works, because there is no mechanical wear. Figure 1 shows the picture of an AARP in the chemical industry.

Figure.1- A typical AARP for 550 kW in a chemical industry

Figure 2 shows a principle flow scheme of an AARP. The ammonia-water solution, circulating in the solution circuit, sucks the low-pressure vapour coming from the evaporator and liquefies it in the absorber. This solution (called "rich solution" because its high concentration of ammonia) is pumped to the desorber in the high-pressure part, where it is heated up to the boiling temperature by means of the driving thermal heat. The ammonia evaporates out of the solution and forms the high-pressure vapour, which can be liquefied in the condenser. The solution (now called "poor solution" because of a lower concentration of ammonia) is going back to the absorber.

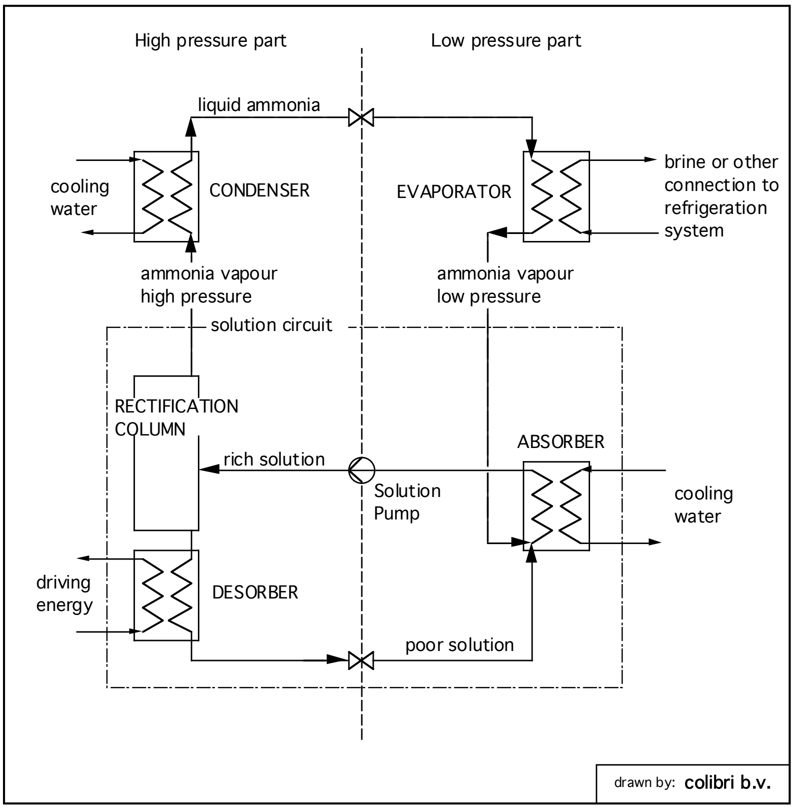

Figure 2: Principle flow scheme of an AARP

3. HOW TO OPERATE AN AARP

3.1 Starting, Stopping and Monitoring of a Plant

Modern plants are equipped with a PLC, which provides fully automatic operation of an AARP including starting and stopping. The program of the PLC can be adjusted to the customers needs, so that he can operate the plant at an optimum for all working conditions. The program checks all functions of the plant and gives an alarm if something goes wrong.

The PLC can be equipped with a remote monitoring system, so that the customer, or also the supplier if desired, can check the functions of the plant from any distance. This allows a quick reaction on any failures. If required the control system of an ARP can also be implemented in the process control system of the customer.

3.2 Filling and Refilling the Plant

An AARP contains water and ammonia. Normally the water content should be enough for the lifetime of the plant. Because of small leakages, which can occur in sealings, sometimes it is necessary to refill ammonia after some years. This can be easily done by anyone experienced in working with ammonia.

3.3 Venting of inert gasses

Plants with evaporation temperatures higher than –32 degC are working with pressures higher than atmospheric pressure, so that no air can get into the plant. These plants are equipped with a simple installation to purge inert gasses manually if necessary.

Plants with evaporation temperatures below –32 degC should be equipped with a purge unit. Such a purge unit can purge automatically inert gasses from the inside of the plant to the atmosphere.

4. ANALYSIS OF THE RELIABILITY OF THE COMPONENTS OF AN AARP

4.1 Heat Exchangers

Depending on the different tasks and the requirements of the customer the choice for the type of each heat exchanger has to be made. Heat exchangers without gaskets (tube and shell, or completely welded plate heat exchangers) are to be preferred in terms of maintenance and secure operation. The internal fluids of the plant (NH3-H2O mixtures of different concentrations) are clean, so that no fouling can occur on this side. The NH3-H2O solution is equipped with an inhibitor so that there are no corrosion problems from the internal side of the heat exchangers when carbon or stainless steel is used. That means no inspection or maintenance is necessary for the internal side of the heat exchangers.

1. Desorber

   For a steam or hot water driven plant the desorber can be realized as a tube and shell or as a completely welded plate heat exchanger. There is not much fouling to be expected for these fluids.
   If it is a directly fired desorber, or if exhaust gasses or other polluted fluids are used as a driving heat, the external side of the heat exchanger has to be cleaned depending on the fouling.

2. Condenser and absorber

   If these heat exchangers are water cooled, the maintenance of the external side depends on the pollution of the cooling water (cooling tower, sea or ground water) and the choice of the heat exchanger material.
   If evaporative coolers are used for these heat exchangers the maintenance instructions of these devices have to be followed (quality of sump water, tightening of belts and greasing of bearings)

3. Evaporator

   All standard evaporators suited for ammonia as a refrigerant can be used. Reliability and maintenance of the refrigeration supply system is the same as for a compression plant. Figure 3 shows three different refrigeration supply systems, which can be connected, to an ARP.

4. Internal heat exchangers

   Because these heat exchangers are only in contact with the internal fluids, they need no maintenance at all.

4.2 Pumps

There are two different types of pumps used in an AARP:

1. Solution pumps

   For these pumps standard industrial pumps with standard shaft seals are used. Depending on the operating conditions sometimes it is necessary to change the shaft seals after some years.

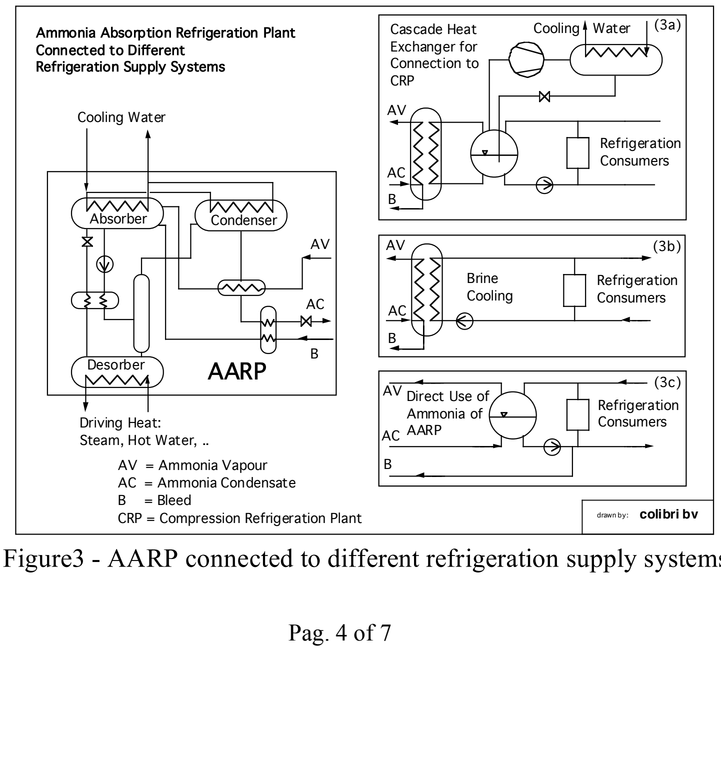

Figure3 - AARP connected to different refrigeration supply systems

2. Ammonia pumps
   These pumps are hermetic pumps, which need no maintenance. They are used for the distribution of ammonia to different evaporators.

4.3 Electrically or Pneumatically Driven Valves

If the quality of the pressurized air is according to the requirements of the supplier these devices do not need any maintenance for years. It may occur that the packings have to be changed after years of operation.

4.4 Manually Operated Valves, Safety Valves, Strainers and Other Devices

1. Manually operated valves
   have a packing, which has to be tightened or replaced from time to time. By using devices with a back seat this can be done during operation.
2. Safety valves
   have to be dismounted and checked from time to time according to the local legislation or other rules. By using a set of redundant safety valves this can be done during operation.
3. Strainers
   have to be cleaned during the first weeks of operation regularly, depending on the quality of clean production and assembly of the plant. After this time the liquids inside the plant should be completely clean.

4.5 Special Equipment (Burners,..)

Special equipment for example burners for directly fired AARPs have to be maintained following the instructions of the supplier and the local legislation (e.g. internal inspection for directly fired desorbers)

4.6 Instrumentation

All instruments are easy to replace in case of failure. Instruments which have important functions for the safety (e.g. high pressure or temperature switches, level controllers in directly fired desorbers, etc.) can be realised redundant.

5. MAINTENANCE SCHEDULE OF AN AARP

Most of the work is checking and can be done by standard instructed staff.

Works recommended every day:
- Checking the process data and parameters on the monitoring screen.
- Checking the plant by looking, hearing and smelling whether something unusually happened

Works recommended once a month:
- Checking the plant for leakages (ammonia, pressurized air, cooling water, heating fluid).
- Checking the packings of the valves for closeness and the caps of the valves for completeness.

Works recommended once a year:
- Checking all safety functions
- Checking all instruments for proper function
- Checking all pneumatic or electrically driven valves for proper function
- Checking the parameters of the control system
- Checking the condition of the insulation and painting
- Checking the ammonia detection system

Work schedule individual by each plant
- checking the cooling water system
- maintaining the evaporative coolers
- checking the safety valves depending on the local legislation

6. REDUNDANCIES AND BACK-UP

6.1 Redundancy of Components with Moving Parts

To get a maximum availability for a long time running an AARP without any stop for maintenance or repair works, it is advisable to have all devices with moving parts redundant. These are the pumps and the control valves. With each pump redundant and a bypass with a manually operated valve for each control valve it is possible to run an AARP for many years without any stop. This very important for industries with continous production lines. Figure 4 shows a picture of a redundant pump and control valve

Figure 4 - Redundancy of pump and control valve

6.2 Redundancy of Heat Exchangers

All heat exchangers which are in contact with external fluids (desorber, condenser, absorber and evaporator) are susceptible to maintenance because of fouling or corrosion on the external side. The right choice of the type and the materials for these heat exchangers and the maintenance of the quality of the external fluids are important measures to extend the uninterrupted operating time of these heat exchangers. If required the plants can be equipped with these heat exchangers in redundancy. This may be because of the following reasons:

- The main heat supply for the desorber is not reliable (for example heat from a cogen plant, which has to be shut down at night for economical reasons). A second desorber with an alternative heat supply (for example a direct fired one, or steam from a boiler) can be installed as a back up.
- The quality of the cooling water for the condenser and absorber causes frequent stops for cleaning these heat exchangers. Having two condensers or absorbers allows operating the plant while one of these heat exchangers is being cleaned.
- Evaporators for air-cooling are provided in many cases in redundancy to continue with cold supply while one evaporator is defrosted.

6.3 Redundancy of the Complete AARP with a Compression Plant

If there is no reliable heat supply, or if an AARP is replacing an existing compression refrigeration plant (CRP), it may be an option to have a compression plant (for example the old one) as a back up for the absorption plant. In fig.3a the flow scheme of such an installation is shown. To separate the refrigerant from the AARP and the CRP a cascade heat exchanger is used

In figure 5 is a picture of such a combination with one of the old compressors in the front. In this margarine factory the old compressors remained to cover the peak loads of refrigeration.

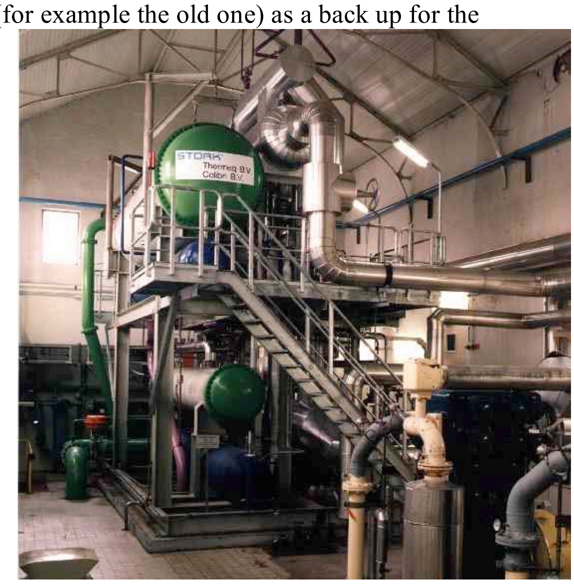

Figure 5 - ARP in combination with CRP for peak load

7. CONCLUSIONS

Absorption refrigeration plants working with ammonia as a refrigerant (AARP) are used mainly in the food and chemical industry to produce cold down to -60 °C. They use heat (steam, hot water, exhaust gasses, ...) as a driving energy, which can be waste heat from production processes or from CHP plants (trigeneration). AARPs are very reliable and need only little maintenance. Most of the components of an AARP are heat exchangers and piping. They are not susceptible to wear and repair works. Those heat exchangers which are coming into contact with external fluids (cooling water, steam, hot water, exhaust gasses,...) may need cleaning from time to time, depending on the quality of these external fluids. The only components with moving parts are liquid pumps, fans for cooling towers and pneumatically or electrically driven control valves. These are standard industrial components, which also do not need much maintenance. They can be equipped in redundancy to assure uninterrupted operation for years.

Most of the maintenance works which have to be done is checking the proper working by monitoring the operating data or checking the plant by sight.

AARPs are controlled by a PLC and can be operated completely automatically including starting and stopping. No specialists are needed neither for operating these plants nor for maintenance works.
The advantages of high reliability for the cold production with very little maintenance costs and easy operating makes these plants interesting for industries which production depend on the continuous delivery of refrigeration.

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