TRIGENERATION IN THE FOOD INDUSTRY.

J. Bassols, B.Kuckelkorn, J.Langreck, R.Schneider, H.Veelken

Colibri bv, Tentstraat 5, 6291 BC Vaals, The Netherlands

ABSTRACT

In the food industry cogeneration plants are widely introduced. Many industries use cogeneration plants with either gas engines or turbines to cover their steam, hot water and electrical demands. The combination of an absorption refrigeration with a cogeneration plant allows to use all generated heat for the production of cooling. Absorption refrigeration plants working with ammonia as refrigerant can be driven either by steam, pressurised hot water or directly with the exhaust gases. Examples of typical plants are illustrated on different sectors in the food industry:

KEYWORDS
Absorption refrigeration, ammonia, ice buffers,

1. INTRODUCTION:

In the food industry and chemical industry, cogeneration plants are widely introduced. Many industries use cogeneration plants with either gas engines or turbines to cover their steam, hot water and electrical demands.

To obtain a complete utilisation of the cogeneration plant, a constant demand on heat and power is necessary. The power demand is regulated by the sales of all exceeding power to the grid, but the surplus on heat usually gets lost.

The combination of absorption refrigeration with a cogeneration plant allows using all generated heat for the production of cooling. While the heat or steam demand usually has large fluctuations, the refrigeration demand uses to be more constant, specially at low temperatures, between – 15°C and – 55°C, where the demand is nearly not influenced by the ambient temperature.

2. THE AMMONIA ABSORPTION PROCESS

The technology of absorption refrigeration plants has been used for cooling purposes for over a hundred years now. In plants of today, the most modern technology is being used for the design, the construction of components and the control strategy, which gives these plants a high economic value and an excellent reliability. In a cooling machine, the refrigerant evaporates at low temperature and low pressure. The vapour is extracted from the evaporator, then

J.Bassols, colibri@cobweb.nl

transformed to a higher pressure and liquefied in the condenser. In a compression refrigeration machine, a mechanical compressor is used to take the refrigerant vapour from the lower evaporation pressure to the higher condensation pressure. In an Absorption Refrigeration Plant (ARP), this process is realised by means of a solution circuit, which serves as the (thermal) compressor. In a heat exchanger called the desorber the driving energy, coming for example from the exhaust gases of a cogeneration unit, is contributed to the process. The main difference between a compression and an absorption cycle is that the first needs mechanical energy as the driving energy for the compressor and the latter needs thermal energy for the desorber and only a small amount (1-2% of the cooling capacity) of electricity for the liquid pumps.

In some cases, it is useful to design ARPs with several stages. This is the case when the temperature of the driving energy is not high enough or when cooling is needed at different temperature levels.

An ARP consists mainly of heat exchangers. The only components that have moving parts are the liquid pumps. If these pumps are installed with redundancy a highest reliability with low maintenance costs can be achieved. Traditionally in sectors where reliability is of main importance like Coffee freezing at –55°C, mostly absorption refrigeration plants have been used.

3. TRIGENERATION PLANTS WITH AMMONIA ABSORPTION REFRIGERATION PLANTS

Ammonia absorption refrigeration plants enable the use of cogeneration plants in industries with a main cooling demand. Comparing them with conventional compression refrigeration plants, the main differences are:

Ammonia Absorption:

• Driven by heat, if the heat is residual heat, very low driving costs.
• Good partial load performance (efficiency increases at partial load)
• Low maintenance costs and high availability due to very few moving components.
• Refrigerant is ammonia, safety measures are necessary depending on the application area.
• Relatively high investment costs.

Compression refrigeration:

• Driven by electrical energy, high operation costs.
• Performance decreases with partial load.
• Relatively high maintenance costs
• To achieve a high availability redundancy is needed.
• Alternatively to ammonia there are different safety refrigerants available.
• Low investment costs in comparison with AARP

The economic benefits of the ARP have to be seen in combination with the Cogeneration plant. By itself it is only a component of a larger energy conversion system. The absorption refrigeration plant transforms low value thermal energy in refrigeration at low temperature which has a much higher economic value, therefore increasing the efficiency of the whole plant. The trigeneraton plants, as well as the cogeneration plants are economically profitable in situation of low availability of the electrical energy, high costs of the electrical energy, or political incentives to achieve an efficient use of fossil energy by the introduction of cogeneration plants.

Regarding to the use of ammonia, it is a natural refrigerant with an intensive smell and already poisonous at low concentrations. On the other side, in the food industry it is one of the most currently used refrigerants and the needed safety measures are known. Additionally the largest part of ammonia of an ARP is diluted in an aqueous solution.

4. LINKING THE ARP WITH THE COGENERATION PLANT

In a Trigeneration system the ARP uses the heat coming from the cogeneration plant as the driving energy. In most cases this heat comes out of the exhaust gases from the turbine or engine. The heat transfer from the exhaust gases to the ARP forms the only linkage between the two systems. Depending on the user demands there are different possibilities how to realise this linkage:

4.1 Indirect linkage:

The exhaust gases of the Cogen unit are used to produce steam or hot water in a standard boiler. The ARP is driven with the steam or the hot water coming from this boiler. The advantage of this system is that the steam or the hot water can not only be used to drive the ARP, but also additionally or alternatively for other purposes. In production processes with fluctuations in steam consumption the ARP can form a buffer which consumes the excess steam coming from the Cogen unit. As a consequence the Cogen unit can drive on a constant pattern even at fluctuating steam demands.

4.2 Direct linkage:

The exhaust gases are used directly to drive the ARP. Coming out of the Cogen they enter straight into the desorber of the ARP. To avoid pressure drops and save costs for piping of the exhaust gases, the ARP should be located near the Cogen unit. The desorber will be similar to a conventional steam boiler and can be designed according to the specifications of the engine or turbine.

Advantage: This system saves an extra boiler, which means that it is more compact and cheaper in investment and maintenance costs. These effects are stronger by smaller units than by larger ones.

For all kinds of linkages applies that there is no feedback influence from the ARP to the Cogen. The ARP doesn't need a certain continuity of heat supply. There are no special requirements concerning the start-up, the shut-down or the partial load modes of the ARP. The control strategy of an ARP works independently from the Cogen control system. If there is no refrigeration demand and the Cogen must continue, the exhaust gas flow will be automatically bypassed around the ARP.

4.3 Linking the ARP with the refrigeration consumption

Usually the ARP is operated in combination with an electrical refrigeration plant and is designed for the base load while electrical compressors cover the peak demands. This is the case if the cogeneration plant is not operated continuously, or if there are situations where even being the cogeneration in operation, the steam demand of the factory is such that there is no steam left to power the ARP.
The connection of the ARP to the consumers in combination with a compression refrigeration plant has to be designed very carefully. Following aspects have to be taken into account:

- If the ARP has to be combined with a ammonia compression plant, the ammonia from the ARP, which contains a small quantity of water may not be mixed the ammonia from the compression plant which may contain quantities of oil.
- With an ARP it is possible to achieve in a single stage a temperature of -60°C. The lower the evaporation temperature the bigger the advantages of the absorption system in comparison with the compression system.

The following examples illustrate different possibilities of linking the ARP with the refrigeration consumption.

5. EXAMPLES OF TRIGENERATION PLANTS WITH AMMONIA ARP'S

5.1 Trigeneration with a gas turbine in a margarine factory

A Ruston gas turbine with an electrical power production of 5 MW was installed to cover the electrical and steam demands of a margarine factory in Rotterdam (NL). Later after a restructuration of the production a new situation was created with a large excess of steam and a shortage of refrigeration. Therefore a ARP was installed to produce 1400 kW of refrigeration at –23°C. The plant is operated in parallel to 7 compressors with a refrigeration capacity of 500 kW each. To avoid mixing of the ammonia from the compressors, which always have a content of oil, with the ammonia of the ARP, which has a small quantity of water, a cascade installation was foreseen. In an evaporator / condenser the ammonia from the ARP evaporates on one side of the heat exchanger at –27°C, while on the other side ammonia from the CRP condenses at –23°C.

Figure 2 shows the diagram of the installed ARP. The ARP had to be designed to be situated in an existing machinery room, therefor a tailor made design was needed (Figure 3).

5.2 Trigeneration with two gas engines in a vegetable freezing factory

In a factory for frozen vegetables in Talavera (Spain), a cogeneration plant with two gas engines and a total electrical power production of 4 MW supplies the thermal energy to drive an absorption refrigeration plant. In the cooling rooms, which have to be maintained at –20°C, new evaporators where placed to evaporate directly the ammonia of the ARP at –30°C. Simultaneously about 200 kW process water at 1°C is produced which is used to pre-cool the products and for air conditioning.

Figure 4 shows the diagram of the installed ARP. This ARP consists of two modules which are transported separately and placed on site one above the other (Figure 5).

5.3 Trigeneration with three gas engines in a dairy factory producing

In a dairy factory in Burgos (E), a cogeneration plant with three engines and a total electrical power production of 9 MW supplies the thermal energy to drive an absorption refrigeration plant. The factory needs large quantities of ice water. While the cogeneration plant is only operated 16 h daily, the ice water consumption is distributed irregularly over the 24 hours. There for a large ice storage is provided which is loaded by the ARP. The ARP evaporates at –10°C. It is driven by steam from the cogeneration. The ARP is controlled on one side by an ice thickness measurement sensor which dictates the refrigeration demand and on the other side by the steam availability depending on the actual steam demand of the production. An intelligent system provides a signal anticipating a steam

peak demand. On this signal the ARP reduces its consumption and if necessary shuts down completely the steam consumption. All regulation is full automatic.
Figure 6 shows the diagram of the installed ARP and figure 7 shows the ARP during the pressure tests in the manufactures facilities.

5.4 Trigeneration with three gas engines in meat factory

In a meat factory in Logroño (Spain), a cogeneration plant with two gas engines and a total electrical power production of 9 MW supplies the thermal energy to drive an absorption refrigeration plant.

The plant is connected to the existing ammonia compression refrigeration system. To avoid mixture of the two ammonia circuits, a cascade heat exchanger has been installed.. The plant has a refrigeration capacity of 2500 kW evaporating at –18°C. (Figure 1).

Figure 1 The ARP installed in a meat factory in Logroño (Spain)

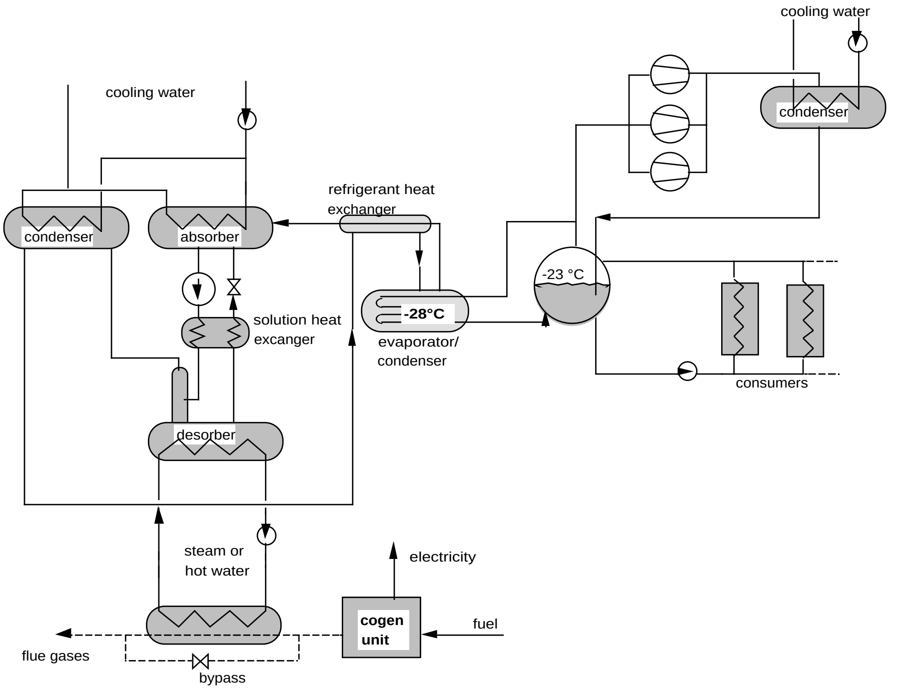

Figure 2 Diagram of the ARP installed in combination with a compression refrigeration plant in a margarine factory in Rotterdam (Netherlands).

Figure 3 The ARP installed in a margarine factory in Rotterdam (Netherlands)

J.Bassols, colibri@cobweb.nl

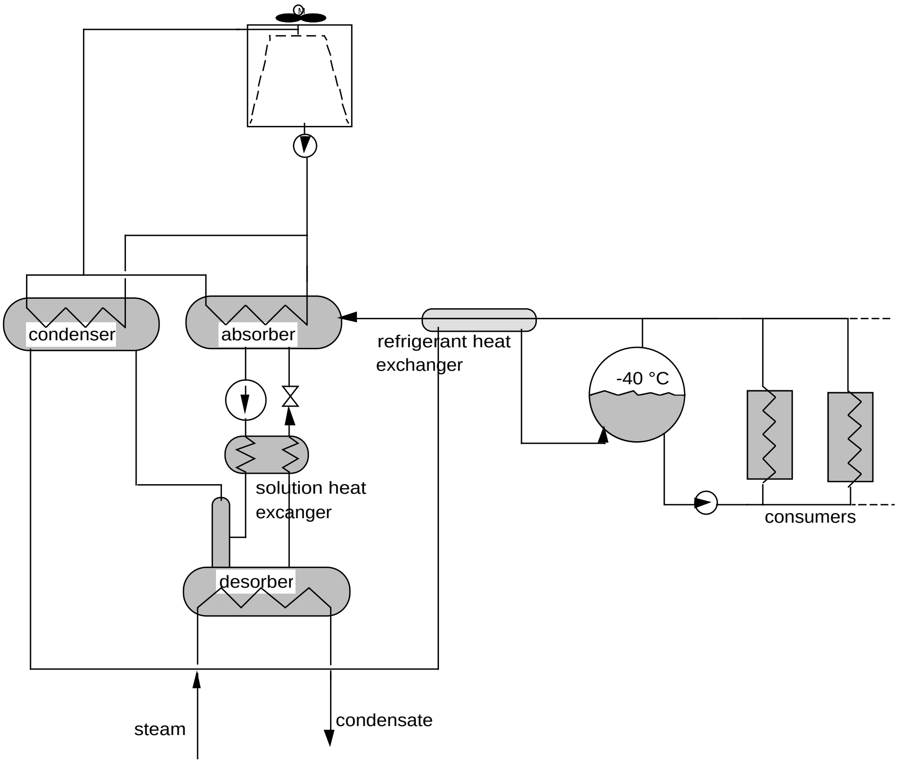

Figure 4 Diagram of the ARP with direct evaporation in the cooling rooms as installed in a vegetable freezing factory in Talavera (Spain)

Figure 5 The ARP installed in a vegetable freezing factory in Talavera (Spain)

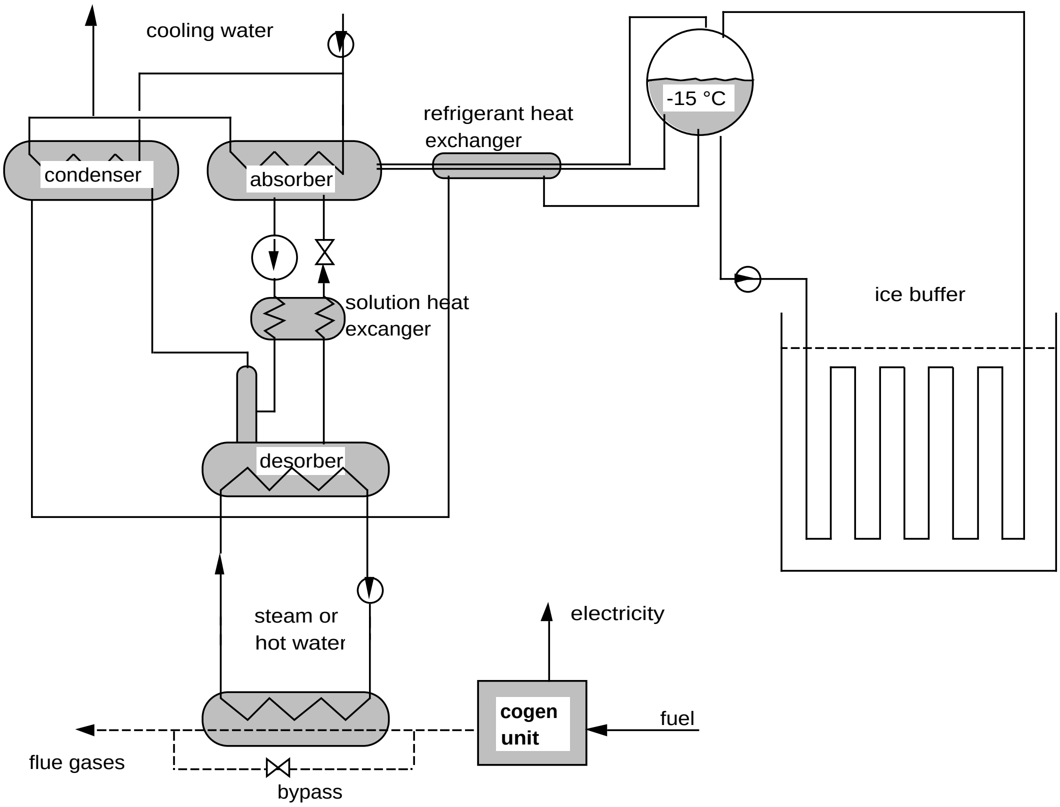

Figure 6 Diagram of the ARP in cobination with an ice buffer as installed in a dairy factory in Burgos (Spain)

Figure 7 Diagram of the ARP on the manufacturers facilities during pressure tests.