Energy efficiency comparison of screw compressors in liquid chilling units with ammonia and R134a for industrial process applications

The energy efficiency assessment of a technical solution is based on the main energy costs for the operator of the air conditioning system needed to provide the required refrigerating capacity with the desired cold water temperatures under the specific operating conditions.

Operating costs are influenced by refrigerating capacity and the energy efficiency ratio (EER) value for energy conversion, plus financing costs, which depend on the procurement price and interest conditions. However, the running financing costs are relatively small compared to the operating costs.

Operating costs

The efficiency with which electrical energy is converted into "cold" depends not only on the refrigerant but also on the technical parameters of the used components and on the operating conditions. The main components are compressor (quality of compression), heat exchanger (surface area and heat transmission coefficient) and auxiliary equipment (pumps, fans).

Temperature differences in heat exchangers reduce the evaporation temperature and increase the condensation temperature. This causes higher operating costs. Such temperature differences should thus be kept as small as possible.

The refrigerant's influence on the components (e.g. on heat transmission and pressure losses) can be compensated by varying the dimensions, design and/or materials used in the system.

The energetic comparison for different refrigerants therefore presumes the same cold water inlet and outlet temperature at the evaporator and the same cooling water or air inlet and outlet temperature at the condenser and, moreover, the same evaporation and condensation temperatures are used.

Seasonal efficiency assessment (SEPR)

The seasonal efficiency evaluation brings the energetic assessment better in line with the actual conditions of use during a whole year, in comparison to an assessment under full load, as this operating condition is only required for a few hours each year.

The seasonal efficiency assessment uses the key seasonal energy performance indicator SEPR (seasonal energy performance ratio). In this context, a standardised profile of use is defined that takes into account varying cooling load requirements between 80% and 100%, depending on the outside temperature and its duration over a season. Accordingly, the liquid chilling unit is assessed at ambient temperatures between 5°C and 35°C outside temperature. The operating time for a year is set at 8,760 hours.

Calculating the key seasonal energy performance indicator SEPR requires the EER values (Energy Efficiency Ratio) for the four reference conditions A (full load), B, C and D (part loads).

Technical concept

Liquid chilling units with indirect cooling are standard products for process applications. Water is usually chosen as secondary refrigerant and is pumped to the consumers in a pump circuit. Besides synthetic refrigerants, ammonia is increasingly used in Germany and some (Northern) European countries. This document compares liquid chilling units operating with either R134a or with ammonia.

In Germany the installation of ammonia refrigerating systems is allowed in public buildings if there is an indirect cooling system and all the refrigerant-containing components are installed in a machinery room or outdoors.

The refrigerant charge for liquid chillers with ammonia has been drastically reduced by using plate or shell-and-tube heat exchangers with internal evaporation.

For water-cooled systems, the range from 0.040 to 0.100 kg/kW (depending on the type) can serve as a guideline for flooded evaporation. This allows the use of liquid chillers with less than 50 kg of ammonia in a wide range of applications, including publicly accessible rooms without a separate machinery room. The concept of a liquid chilling unit operating with ammonia is not different to liquid chilling units using other refrigerants (see Figure 1).

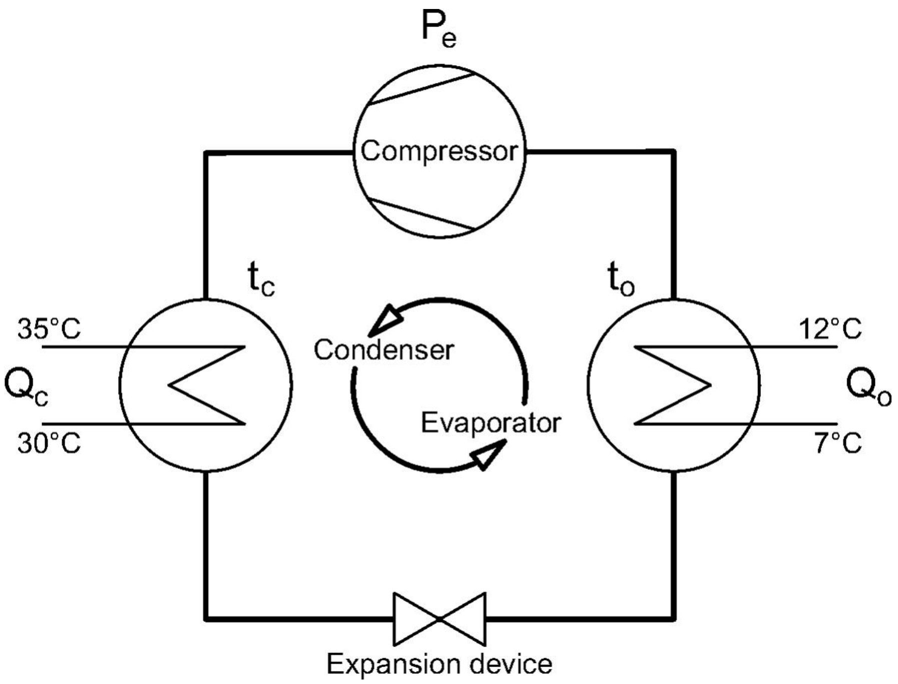

Figure 1: Simplified diagram of a water-cooled liquid chiller with indirect cooling

Evaporator

Flooded evaporators are typically used in ammonia systems. In case of a comparable cold water outlet temperature, the evaporation temperature is lower for evaporators with injection (dry expansion, preferably used for synthetic refrigerants). That is a drawback in energetic terms.

In the following, two liquid chilling units with flooded evaporators are being compared.

Temperatures (full load)

Cold water temperatures, inlet/outlet: 12/7°C

Evaporation temperature: 5°C

Condenser

The refrigerant can be condensed by cooling water, air or evaporation heat. The condensation variant influences the condensing temperature. There is a considerable difference in the condensing temperature between air-cooled and water-cooled condensers. These two condenser types are compared for ammonia and R134a.

Air-cooled liquid chilling unit

Figure 2 shows a simplified piping diagram for an air-cooled liquid chilling unit with flooded evaporator.

Temperatures (full load)

Air temperatures, inlet/outlet: 35/46°C

Condensing temperature: 48°C

Water-cooled liquid chilling unit

Temperatures (full load)

Cooling water temperatures, inlet/outlet: 30/35°C

Condensing temperature: 37°C

Gravity circulation of the refrigerant

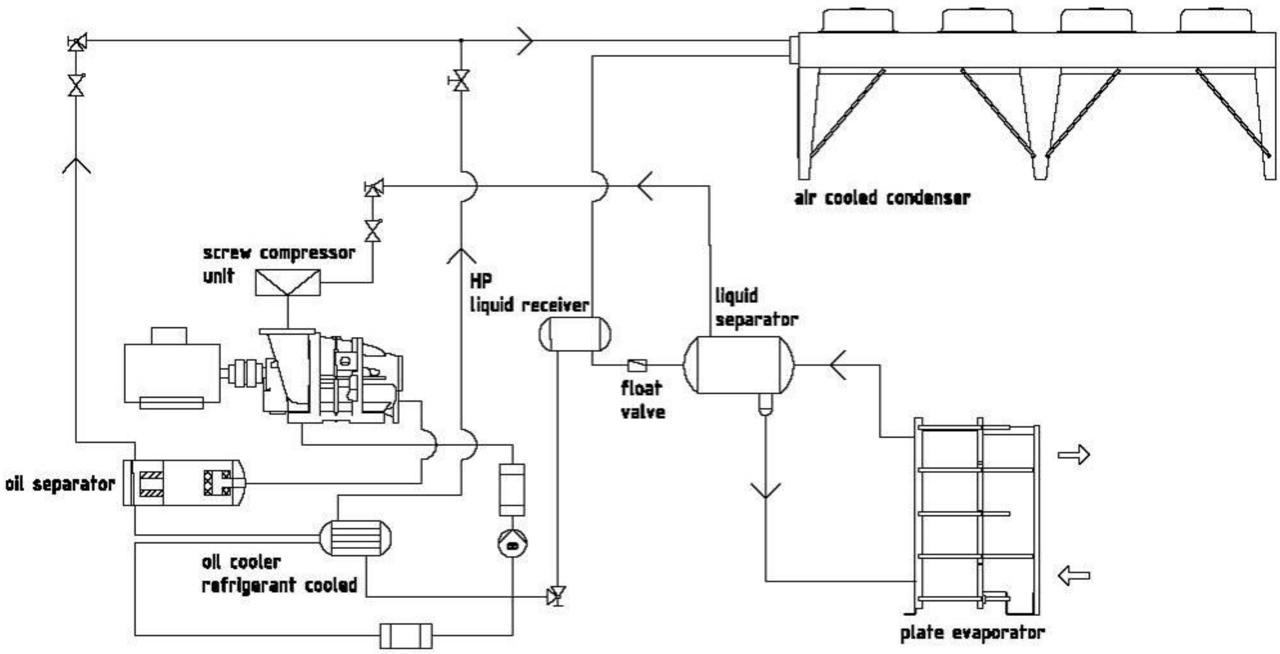

Figure 2: Diagram of an air-cooled ammonia liquid chilling unit with flooded evaporator

EER values and energy costs

The EER values can be improved by increasing the evaporation temperature and/or decreasing the condensing temperature. However, this entails the use of heat exchangers, which usually result in higher manufacturing costs. It is common practice to improve key performance indicators in this way to decrease the differences in efficiency between the refrigerants ammonia and R134a in liquid chilling units.

The EER values can also be improved by reducing the suction gas superheat for dry expansion systems.
Lower superheat is possible for example with electronic expansion valves instead of thermostatic expansion valves.

The decision for one or the other type of liquid chiller will depend on the purchase cost, the actual conditions at the installation site and the expected number of annual operating hours. Computation of the total cost including both capital and energy costs permits a quantitative decision from an economic perspective.

The table shows the differences for a liquid chilling unit with screw compressor, 1,100 kW full load refrigerating capacity and operating all year round, on the basis of the seasonal cooling load and temperature profile quoted above.

Table: Annual energy demand E_a and relation between the SEPR values for R134a and ammonia

Refrigerant	Cooling fluid	$SEPR_{R134a}$ / $SEPR_{Ammonia}$	E_a [MWh]
Ammonia	Water	1.0	870
R134a	Water	0.90	960
Ammonia	Air	1.0	1,200
R134a	Air	0.90	1,320

The specific conditions often rule out the use of a water-cooled chiller in the machinery room on cost grounds. Hence, in such cases the increased energy demand of an air-cooled liquid chiller has to be accepted. However, in view of increasing cooling water costs (water treatment), this solution is not necessarily less cost-efficient.

The decision for one or the other refrigerant can be made on the basis of an evaluation of the total life cycle cost, implying that the purchase cost of the liquid chiller is added to the pure operating costs. In any case this study shows that the energy costs are considerably lower using the refrigerant ammonia rather than the compared refrigerant R134a. The requirement to give priority to environmentally favourable technical solutions can be met by taking the TEWI value into account for the decision process, since the indirect portion of the TEWI value is directly related to the energy consumption.

In case of doubt, the German-language original should be consulted as the authoritative text.

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P. O. Box 71 08 64 ◆ D-60498 Frankfurt

Phone +49 69 6603 1277 ◆ Fax +49 69 6603 2276

e-mail: karin.jahn@eurammon.com

http://www.eurammon.com