Seawater cooling

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With an increasing demand for comfort cooling in office buildings, the amount of energy used for cooling is being brought more and more into focus. The increased use of cooling also means that more dry coolers and air-cooled condensers are being installed on the rooftops of buildings. In areas with many dry coolers and air-cooled condensers, this may lead to noise problems, due to the accumulated sound levels.

These problems may be solved by a reduction of the fan velocity. However, this means that more dry coolers must be installed, for which it may be difficult to find room - especially if the architectural aspect has to be taken into consideration.

If the building site is situated near seawater, one option could be to use the seawater to cool the condenser. Especially in connection with the construction of large central cooling plants producing chilled water for district cooling, the use of seawater will be of great benefit to the system in general.

Furthermore, by using seawater for cooling the condenser, a saving of up to 30% of energy used for generation of cooling can be achieved.

Advantages of sea water cooling

In addition to the advantages mentioned above, concerning space and sound, seawater cooling has the important advantage of slow seawater temperature fluctuation; in the summer, the temperature is generally below the air temperature.

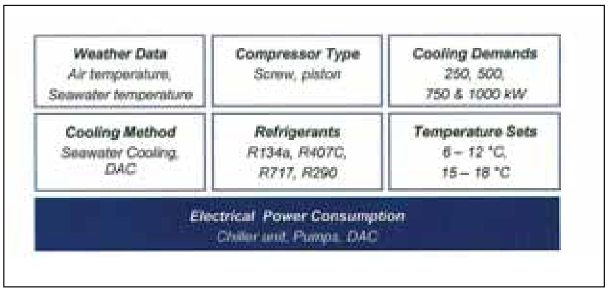


Figure 3. The main problem with the investigated parameters. The white boxes indicate input parameters to the calculation, the blue box the results of the calculations.

At the harbour of Copenhagen, where several office buildings using sea water for cooling are situated, the maximum water temperature rarely exceeds 25°C at the end of summer. This means that the cooling water is added straight into the condenser during peak-load, at a temperature approximately 7°C below the normal outdoor design temperature for a dry cooler.

With an energy saving of approx. 2-4% per degree reduction of the condenser temperature, there is a potential for large energy savings with a temperature reduction of around 7°C.

In order to survey the potential energy saving, a master thesis study titled “Condenser Cooling Strategies” was prepared (master thesis work at the Technical University of Denmark: "Condenser Cooling Strategies" 2003, written by Jimmy H. Toft, DTU). The project was built up around a traditional cooling system using water in both condenser and evaporator. The system is shown in figure 1.

Seawater cooling systems are often designed using an intermediate heat exchanger that separates the sea water and the cooling media in the system, in order to prevent contamination of the condenser (fig. 2a). However, the latest experience shows that by using a better system design, the seawater can be used directly, without creating operational problems. This design offers lower energy consumption and is used in the calculations of the master thesis (fig. 2b).

Product data for different refrigerators, dry coolers and heat exchangers were registered in order to make the calculations as realistic as possible. Weather data for Denmark and sea water temperatures measured in Copenhagen Harbour by the Danish Meteorological Office were registered in the program, so that the right condenser temperatures could be calculated.

All calculations have been carried out for the refrigerant types R134a, R407C and R717, for both screw compressors and reciprocating compressors. The system is designed for the production of 6/12°C cooling water primarily for use in ventilation cooling surfaces. When calculating the hours of operation for free cooling, a base load of 5% related to the total produced cooling output has been assumed. The base load corresponds to the cooling of a server room or a similar load.

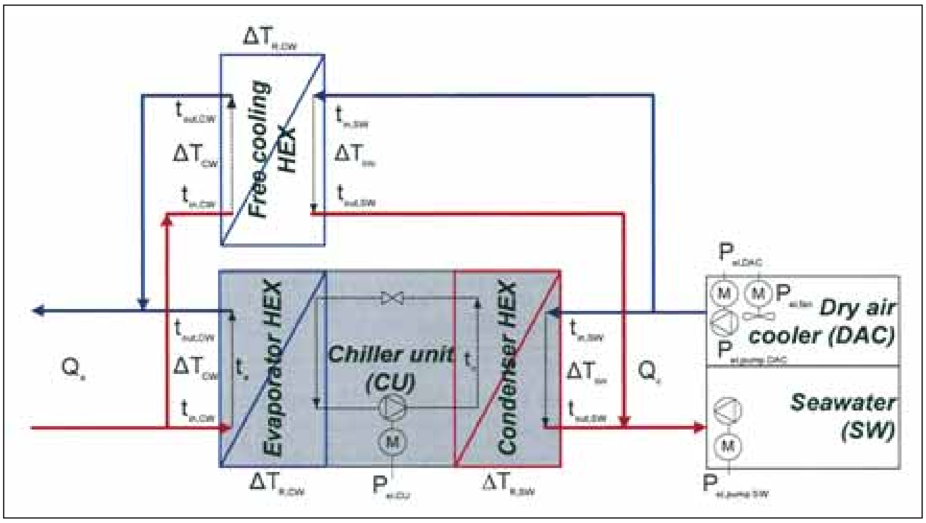
Results

Here, the results stated in the report are briefly summarised.

Depending on the selection of types of refrigerants and compressors, 15-30% energy saving can be obtained using seawater. When seawater and dry coolers are used, a screw compressor with R134a is the most energy efficient.

The table (fig. 4) shows how much energy the different systems use for generation of 1 MW cooling during a one-year period. The installation operates from Monday to Friday in an ordinary office building.

Figure 1. System sketch of the investigated cooling system with free cooling HEX. All parameters concerning the system is sketched on the figure.



The fact that the energy consumption of an ammonia chiller exceeds R134a may be due to the ammonia chiller not being able to handle as low a condenser temperature as the R134a system. As the sea water temperature is only above 15°C for about 1,500 hours a year, a lot of energy can be saved if the ammonia chiller is equipped with a coolant pump, enabling it to handle a condensing temperature as low as 10°C, or even lower.

Furthermore, the calculations show that the reciprocating compressor is the most energy efficient compressor up to a capacity of 750 kW when R717 is used. The screw compressor comes second. For the R134a system the screw compressor is the most energy efficient in the range from 250 to 1,000 kW. No calculations have been made for equipment exceeding 1,000 kW.

Free cooling
When operating in free cooling mode, generation of cooling is maintained without the use of the cooling machine. The energy costs are thereby minimal as they only have to cover costs for the operation of pumps and/or the ventilators in the dry coolers.

To be able to operate in the free cooling mode, the ambient air or the sea water temperature must be lower than cooling water temperature in the system. This means that if the cooling water temperature of the system can be increased, more hours of free cooling operation can be obtained. Another possibility is to lower the temperature difference between seawater and the cooling water in the system.

The report examines the energy saving potential when operating in free coolingmode, using seawater generation of 6&12° cooling water. Calculations show that using a heat exchanger between the seawater and the cooling water, the free cooling operation mode can be extended up to 4 times compared to the use of a dry cooler. Pre-conditions are that 5% of the cooling generation is base load, and that the temperature difference across the heat exchanger is less than 5°C, enabling the heat exchanger to deliver cooling water at 6°C using sea water at a temperature of 2-5°C. If the temperature difference across the heat exchanger is higher or equal to 5°C, the hours of free cooling operation are reduced to almost zero.

Therefore, if the system uses seawater, it can be profitable to buy a larger heat exchanger with a lower temperature difference. Especially when using cooling water at 15/18°C in cooling ceilings and cooling baffles, many hours of free cooling may be achieved by using sea water.

Only the top of the iceberg
The calculations clearly show that large amounts of energy can be saved when seawater is used for cooling the condenser in the refrigerators. The calculated savings of 15-30% are only the top of the iceberg. Energy optimisation, by means of increased control and monitoring of the systems, has not been considered in the project - e.g. measures such ered in the project - e.g. measures such as frequency control of the compressors, or changing the evaporation temperature compared to the actual requirements for cooling of the system.

Furthermore, the calculations are based on the seawater temperature in the Copenhagen Harbour, where the temperature in the summer is assumed to be higher than if the temperature had been measured at a coast near open sea. So during the summer, when the requirements for cooling usually are at their highest, it will be possible to obtain energy savings, if the seawater is taken further out at sea.

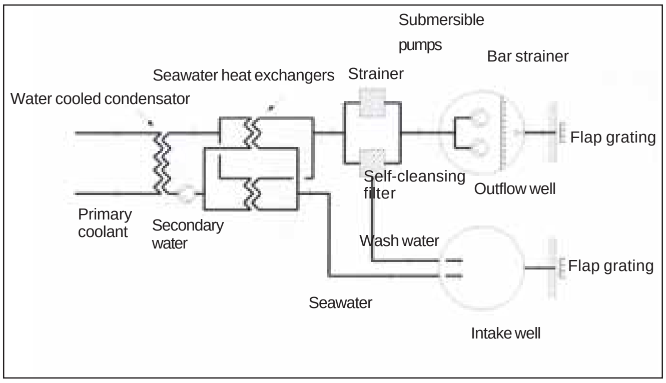


Figure 2a.

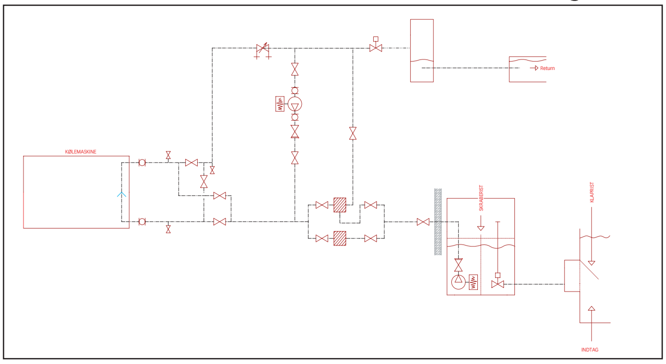


Figure 2b.

The overall picture
When looked upon separately, there is potentially a lot of money to be saved by using seawater. The savings must be seen in relation to increased construction costs for pipe systems leading from the harbour or the sea to a tank near the cooling plant.

However, if the cooling plant is situated near the seawater, the total construction costs will be lower when seawater is used instead of dry coolers. Furthermore, considerable building space does not have to be used for dry coolers, and money does not have to be spent for architectural measures to hide the dry coolers. The noise emission from seawater cooling is close to zero, and therefore costs will be saved for noise reduction, which is often necessary when dry coolers are used.

The conclusion is that seawater cooling is the most favourable option, if seawater is available close to the location of the plant. The energy savings are substantial and a number of other advantages can be obtained when the seawater cooling is used for large cooling plants.

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Figure 4.