High temperature district cooling technology

High temperature district cooling (HTDC) refers to district cooling systems operating at higher temperature levels than traditional systems. Using higher temperatures has many potential benefits in terms of reduced energy use, reduced emissions and reduced costs.

Benefits:

- Improves the competitiveness of district cooling by:
  - Lower losses
- Improves the availability of existing and new heat supply technologies:
  - Enables the use of more free cooling sources
  - Enables increased efficiency of heat pumps - more cooling for the same amount of electricity

Supply side HTDC technology

Absorption cooling

COP for an absorption cooling machine is typically 0,6-0,7 and often needs almost 100 °C or more to work properly. The surrounding temperature affecting the recooling temperature of the absorbent is also of importance for the COP of the absorption cooler. The absorption chillers in Gothenburg normally use district heating with a temperature of approximately 90 °C or higher.

In Sweden there is a research program called Fjärrsyn. The program focuses on research that develops the district heating and cooling business. One of the topics for research has been adapting absorption cooling for district heating as a source of heat. In that particular research the focus was to test an absorption cooling machine using lower temperature heat source such as district heating with a temperature of 70 °C and a surrounding temperature of 24 °C. The supply temperature from the absorption cooler should be 6 °C. During the summer the heat temperature from the district heating will be raised to 80 °C when a higher effect is needed. The tests were run for 2 years.

One of the challenges with using district heating as heat source for absorption cooling machines besides the common demand for high temperatures is the water flow variation in the district heating network. Sometimes the flow might be too low, then too high etc. which might cause the absorption cooling machine to start swaying in its process with a low COP as a result. In the figure below the temperatures for the district heating designed absorption cooler is shown. The left hand scale shows the temperature scale and the right hand scale shows the COP for different temperatures.

- The dark red line in the top shows the supply temperature from the district heating network at 70 °C constant temperature.
- The pink line below is the return temperature of 60-65 °C.
- The purple graph with the red line in the middle shows the COP for the cooler with a variation approximately between 0,68 to 0,48 depending of the media temperature.
- The media temperature is the dark green line (forward) and the light green line (return). The forward temperature varies from approximately 26 °C to 33 °C and the return from 32 °C to 21 °C.
- The light blue line is the supply temperature from the absorption cooling machine and the dark blue line the return temperature. The aim is to have a supply temperature of 6 °C and a return of at least 12 °C

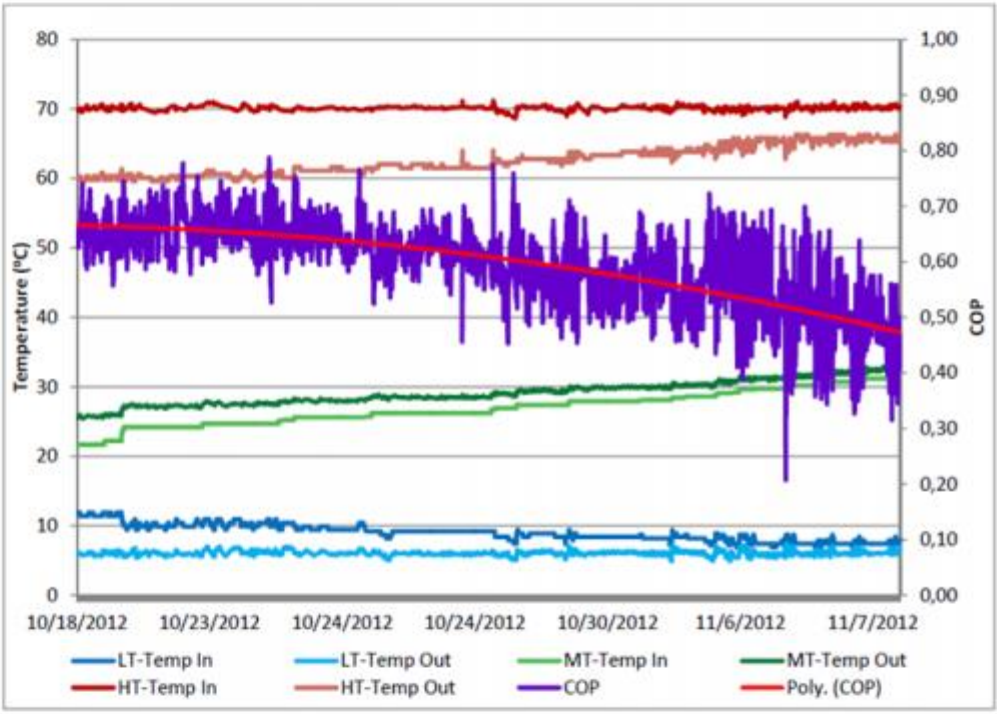

Figure 1 Different supply and return temperature for the district heating run by absorption cooler

The figure below shows the relation between the power from the absorption chiller and the incoming re-cooling temperature. When the re-cooling temperature increases the power decreases.

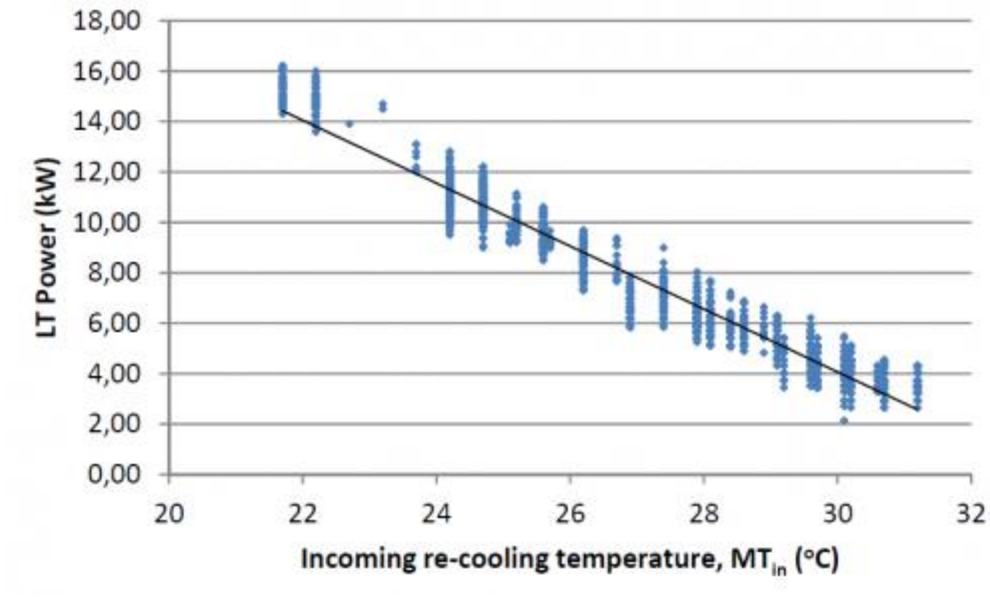

Figure 2 Relationship between power for the absorption cooler and the recooling temperature

The figure below shows the relation between the COP from the absorption chiller and the incoming re-cooling temperature. When the re-cooling temperature increases the COP decreases.

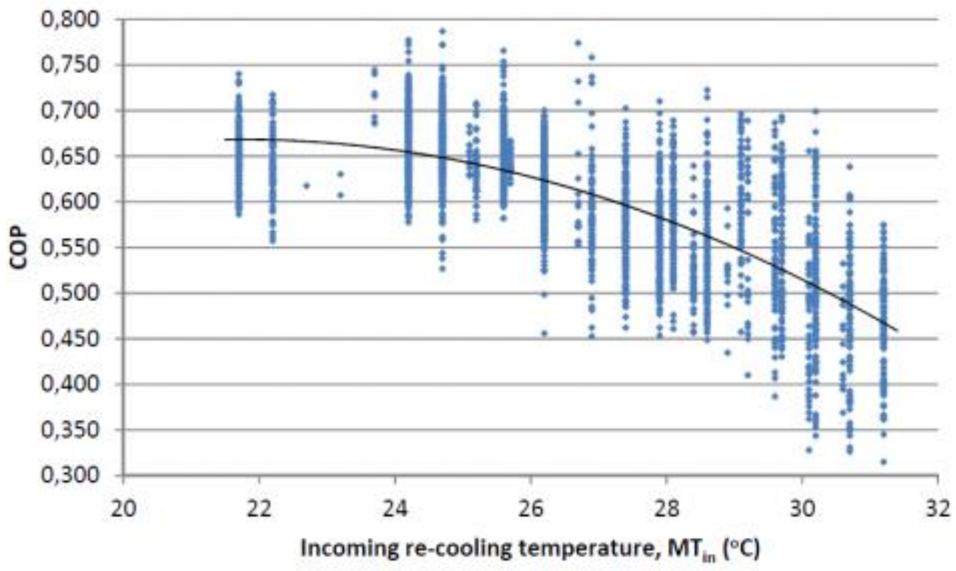

Figure 3 Relationship between COP for the absorption cooler and the recooling temperature

The figure below shows the relation between the difference between incoming and outgoing temperature from the absorption chiller (HT), the variation in media temperature (MT), the variation in cooling supply temperature (LT) and the variation in the incoming re-cooling temperature. When the re-cooling temperature increases the difference in incoming and outgoing temperature decreases for all cases.

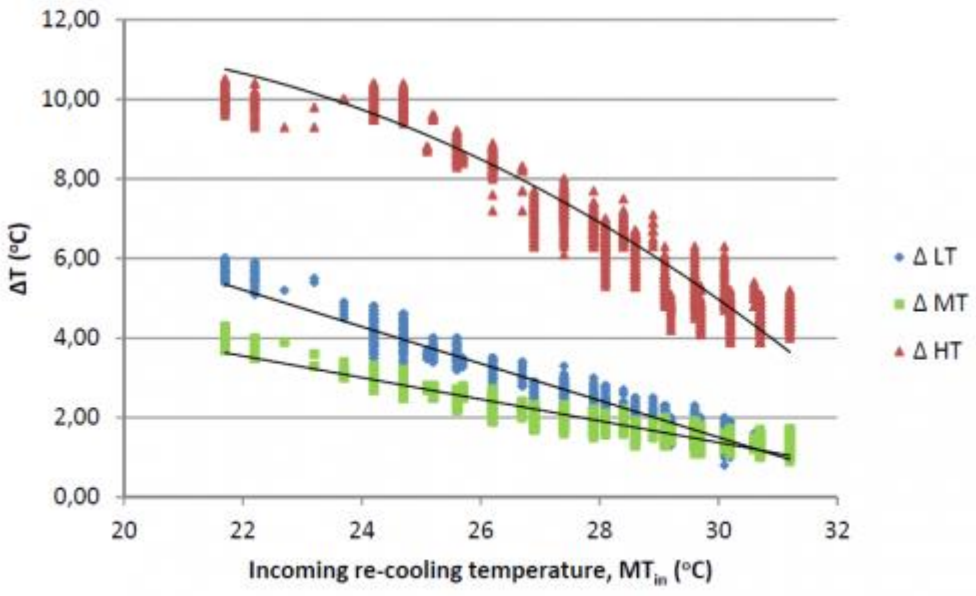

Figure 4 Relationship between delta temperature for the absorption cooler and the re-cooling temperature

The figure below [1] shows the relation between COP and heat temperature for an absorption chiller. The temperature levels differs between different machines but the correlation between COP and change in heat temperature is similar.

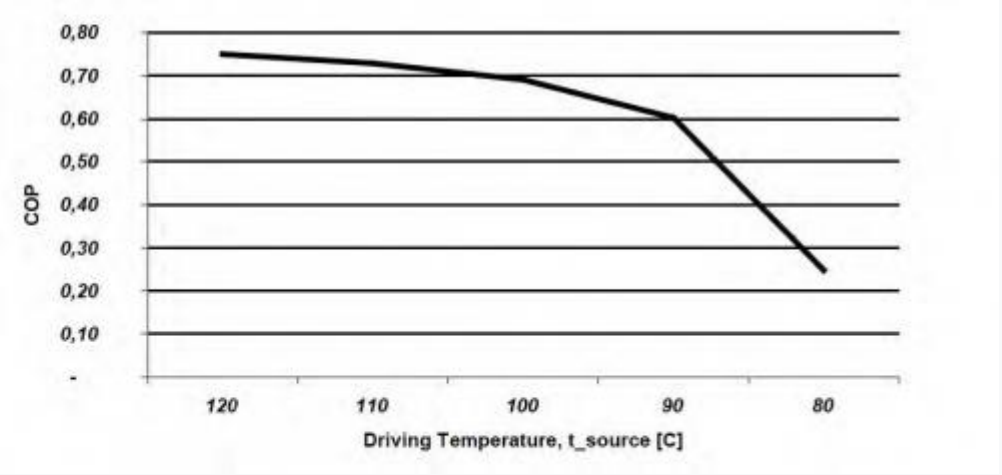

Figure 5 Relationship between COP for an absorption cooler and temperature of the heat source

It is important to have a discussion with the manufacturer of the absorption cooling machine to have it designed for the specific situation where it will be used. Design parameters that might be important are the design of the heat exchangers, controlling systems for pumping internal and external flows.

Sorption cooling

In a case study in Malmö sorption cooling was evaluated under temperatures relevant to HTDC. The supply temperature was 15 °C and the return 22 °C with a COP of 1.5. A Life Cycle Cost analysis was made and the sorption cooling alternative was found to be the least costly way of producing cooling for the building. The investment cost was high but the variable cost was low which made the total cost lower than for the alternatives. The sorption cooling equipment works better with low grade district heating than absorption cooling.

Free cooling

The principle for free cooling is to make use of cooling that is already available. This might be from the bottom of a lake or ocean where the temperature normally is 4 °C, the air during winter or some other source.

The figure below shows the production of cooling in the central district cooling network in Gothenburg using free cooling. During the winter most of the cooling comes from free cooling in the river. When the river water temperature is not low enough or more capacity is needed, absorption chillers and chillers with compressors which are chilled with water from the river is used.

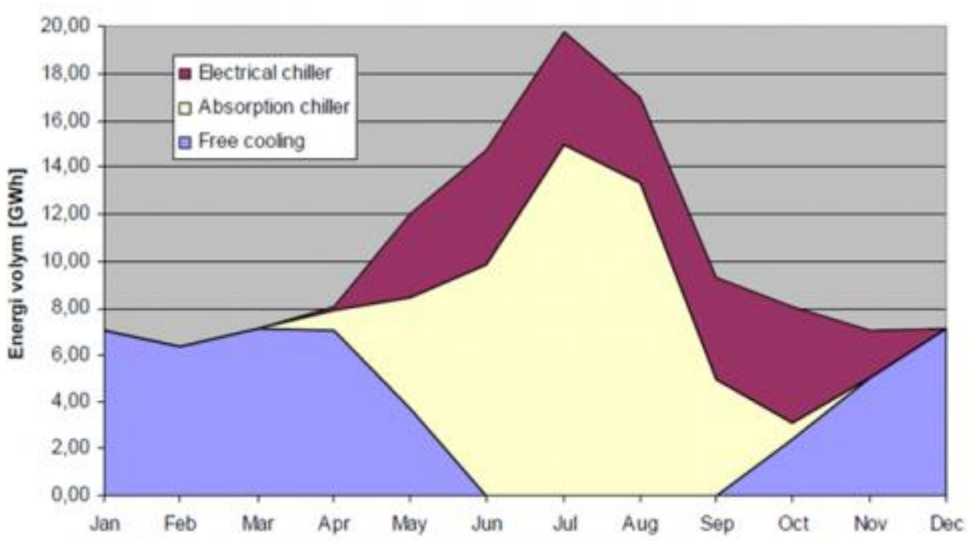

Figure 6 Production mix district cooling in Gothenburg.

High-temperature demand-side DC technologies

District cooling is mostly used in offices, shopping malls, server rooms and other large buildings such as hospitals and concert halls, but could also be of interest in residential houses. The two main ways of having cooling in a building are through thermo active systems and airborne systems. An important aspect for both of these applications is that special care must be taken for the dew point by e.g. using small fans to decrease the dew point. For thermo active systems, the surface temperature must be above the dew point, which is around 19 °C, to e.g. avoid mould.

Thermo Active Building Systems

Thermo active building systems (TABS) [4] [5] are systems that make use of the thermal mass of the components of a building such as floors, ceilings and walls. These components are heated/cooled either by ducts for circulation of air or by embedded pipes for the circulation of water. Nowadays, most installations consist of waterborne systems. A characteristic of waterborne high temperature cooling systems is that the total chilling area must be large, which is very similar to the low temperature heating systems. One possibility for reducing installation costs is to use the same system for heating and cooling. In such cases, special care needs to be taken for comfort issues.
Waterborne systems can be installed in the floor, ceiling or walls where the typical distribution/return temperatures are around 15/17 °C.

A solution called “Concrete Core Conditioning” involves a combination of floor and ceiling cooling. This could be very beneficial for multi-storey buildings by having waterborne systems in the slabs between the storeys. Such systems have the advantage that due to the thermal mass of the slabs, the energy need is spread evenly, thus reducing the peak power and is therefore very appropriate for free cooling. This technique can be used to combine heating and cooling with a single distribution temperature if the building has low cooling and heating demands. Another advantage is the decreased need for advanced control systems. A drawback is that the indoor temperature may vary by up to 5 °C. The surfaces of the ceiling and the floor must be uncovered to ease the heat exchange.

Chilled beams

A chilled beam is a system to cool indoor air where cold water is passed through a beam (a heat exchanger), which cools the air. The chilled beam is placed in or just below the ceiling and the cold air descends passively through convection or actively through impulse from a duct. The typical distribution/return temperatures are around 13/18 °C. The chilled beam is designed to operate above the dew point in order to avoid condensation.

Fan Coils

Fan coils are used for the same purpose as chilled beams. The difference is that larger cooling power can be reduced depending on the use of a fan. There is also a possibility to reduce the moist content in the air if the fan coil has a condensate drain. To reduce the moisture content of the air, the cooling media needs to have a temperature below the dew point. The lower the cooling media temperature is, the more moisture can be removed from the air.

Server room and process cooling

In many buildings in cities with district cooling, there is a need for process cooling. These systems have special cooling demands, depending on the process. It is possible to use higher temperatures in the cooling media, depending on the end temperature for the end user. Larger surfaces for heat exchanging will be needed. If the end user need for cooling is at a lower temperature level, district cooling can be used to reduce the heat from an extra cooling machine for the equipment.

Ventilation systems

Air conditioning in ventilation systems is usually constructed for temperatures of the incoming cooling media such as 7 °C. The temperature can be higher if the surfaces in the heat exchanger are larger and there is no need to reduce the moisture content of the outdoor air. With a lower temperature on the cooling media, moisture can be reduced in the air. This takes more energy to do. When there are chilled beams in the building, it is important to reduce the moisture content beyond the dew point according to the temperature in the cooling media in the chilled beams. Otherwise the outgoing temperature to the chilled beams has to be regulated according to the dew point. Air with high moisture content is perceived to be warmer. This could also be a reason for using a lower temperature for cooling the ventilation air. When using higher temperatures in a district cooling system, the possibility for moisture reduction disappears. The need for moisture reduction is mostly correlated to the outdoor climate, which makes it possible to lower the temperature in the DC system according to the outdoor climate.