Local cooling with surplus heat

Ilkka Salo

Besides consuming large amounts of electricity, conventional cooling systems for buildings also use HFC/HCFC refrigerants – more commonly known as 'freons' – which are well-known for being less than environmentally friendly. R&D work carried out by ABB in Finland has shown that both of these drawbacks can be overcome by 'local cooling' – a technique that employs freon-free absorption chillers instead of conventional compressors to produce cooling energy from heat.

Inside the Sibelius Hall – a recently completed congress and concert center in Lahti, Finland. ABB was responsible for the overall technical solution for the building services, which include local cooling.

The problem with today's district heating (DH) systems, which are typically based on combined heat and power generation, is that while the full heat output can be utilized for heating purposes in the winter months, only some of it can be used during the summer. Similarly, many industrial plants produce surplus heat that is left untapped although it could be used for cooling. Often, the heat generated by processes can be only partially utilized while electricity has to be used to produce cooling energy.

By using absorption chillers, this same 'surplus heat' can be utilized to produce cooling energy; ie, heat continues to be delivered via the DH network and cooling energy is produced in-situ for one or more buildings.

From the separate planning of systems...

Although the absorption technique is in itself not new and its environmental benefits – surplus heat used instead of electricity, HFC/HCFC coolants and sound and vibration problems are eliminated – are well known, it has thus far not been widely exploited for cooling buildings.

One of the main reasons for this is that in conventional building design the planning of the cooling energy production and distribution and the planning of the building systems (eg, air-conditioning) are not part of an integrated process,

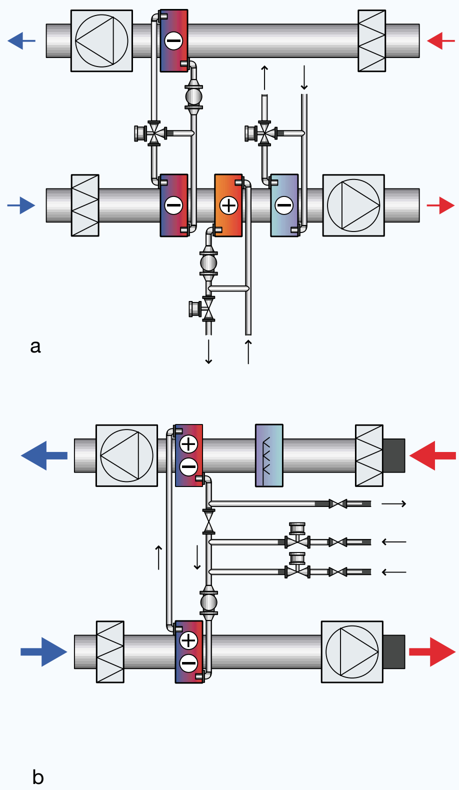
Demonstrating Local Cooling Technology

The DEMLOCS project has demonstrated the potential district heating offers for cooling, heating and air-conditioning buildings, as well as for meaningful energy savings when used in combination with the ThermoNet® building service system (see fig). Participants in the project – part of the EU's *Thermie program* – were ABB Finland, which was also responsible for the coordination, Helsinki Energy, and Danish-based Herning Kommunale Vaerker.

Two cooling plants, one in Helsinki and one in Herning, were designed and built for new and renovated buildings as part of the project, which ran from October 1995 until October 1999. Cooling energy is produced in the Helsinki plant by absorption chillers, and in Herning by ejector coolers.

Both systems are totally HFC/HCFC-free and use district heat at +80°C, which is much lower than that normally needed for this type of cooling. District heating return water is used to heat the buildings.

The Herning plant began producing cooling energy for the designated office building in the summer of 1999, and full-scale monitoring was carried out the following summer (2000). The Helsinki cooling plant was commissioned in time for the 1998 summer, with full-scale cooling energy production timed to coincide with the completion of another building, called Tellus, in Helsinki in summer 1999. The results fulfilled the expectations with a comfortable margin, although the 1999 summer in Finland was unusually warm and long.



Comparison of a conventional air-handling unit (a) with separate circuits for heating, cooling, and heat recovery, etc, and ThermoNet (b), which utilizes Econet building service units and combines all of these functions in a single circuit. Temperature levels are low and energy efficiency is good as a result.

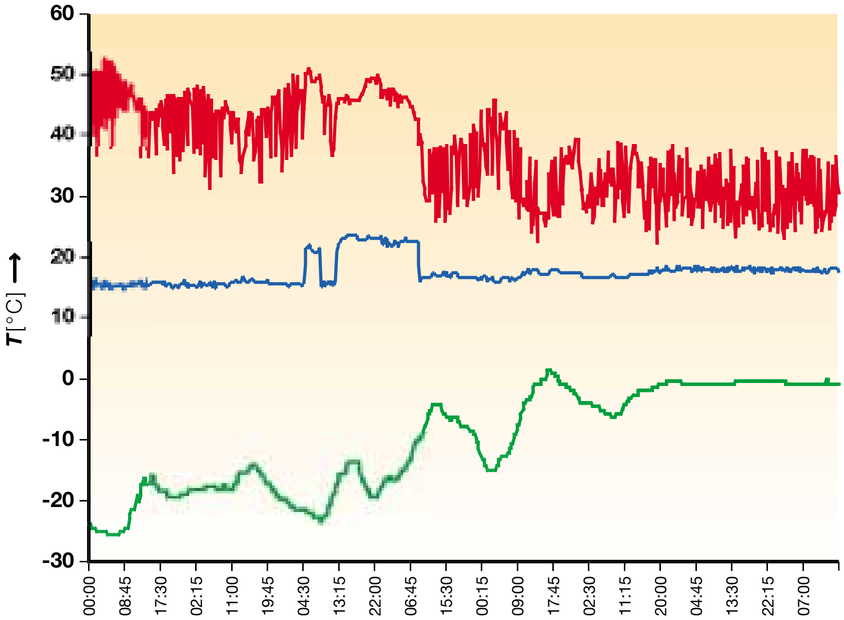
due to which the result is less than optimal. This separate planning has made it both difficult and uneconomical to use low-grade thermal energy, such as district heat, for absorption cooling, especially during the summer months when district heat temperatures are at their lowest.

ABB Finland has considerable experience in utilizing low-grade thermal energy to heat buildings, and in recent years the company has invested a great deal of effort in the study of energy-efficient and environmentally friendly cooling. Combining absorption chillers with state-of-the-art building technology was found to be especially interesting in this respect. R&D work at ABB in Finland has now made it possible, for example, to economically use district energy during the summer months for cooling purposes. One such example is a local cooling plant in Helsinki – part of the DEMLOCS project *(see box)* – which ABB designed and which uses district heat at + 80°C for absorption cooling.

...to a fully integrated design platform

Key to the ABB approach is the parallel design and optimization of the local energy systems and building services, such as air-conditioning, enabling a new,

1 Temperature of heating-water (supply red, return blue) and ambient-air (green) during one week in winter (DEMLOCS project)



processes in ABB's building service system.

Heating season

Utilization of low-grade energy

The DEMLOCS project demonstrates how low-grade energy can be used to heat and cool buildings. **1** shows, as an example, the heating-water and ambient-air temperatures over the course of one week in winter. The air temperature is initially -25°C and rises gradually to 0°C by the end of the week. Over this period, the temperature of the supply water from the district heating network is lowered from 50°C to 30°C, and the temperature of the water returned by the ThermoNet® units **2** to the DH network rises from 15°C to 18°C. Using this method, the entire factory building can be efficiently heated, even with an outside temperature of minus 25°C, by a single energy source – the return water from the DH network.

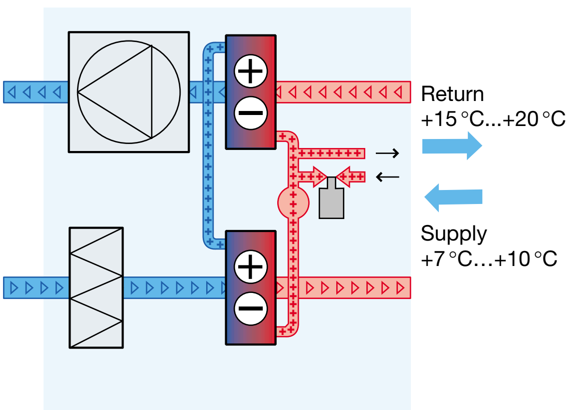
optimal level to be found for the system as a whole.

The cooling needs of the buildings connected to the mentioned Helsinki plant total 1.8 MW, which is easily met by the 0.9 MW capacity of the absorption chiller thanks to the integrated design of the energy production and consumption

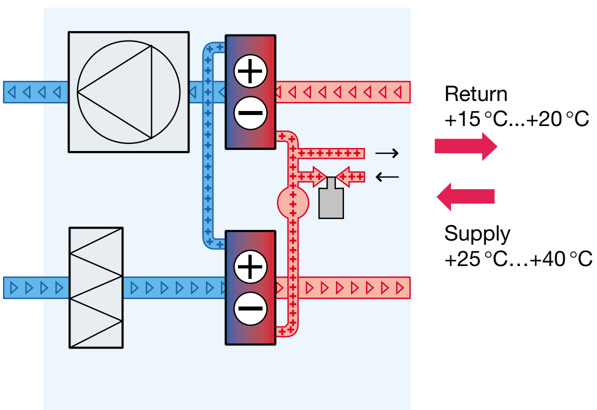
2 How ThermoNet/Econet units work

Cooling (a): The low air/water ΔT allows high cooling-medium temperatures to be used, with high supply/return ΔT.

Heating (b): The low air/water ΔT allows low heating-medium temperatures to be used, with high supply/return ΔT.

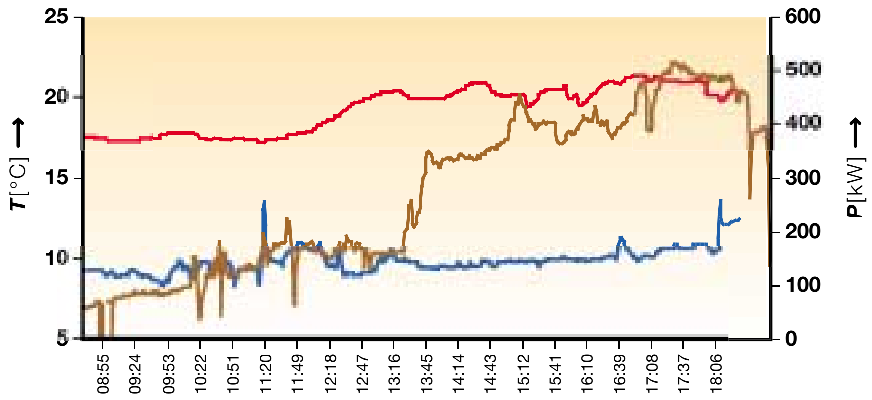


a



b

3 Temperature of the cooling water (supply blue, return red) to and from the ThermoNet units, and the energy consumption curve for a factory building (DEMLOCS project)

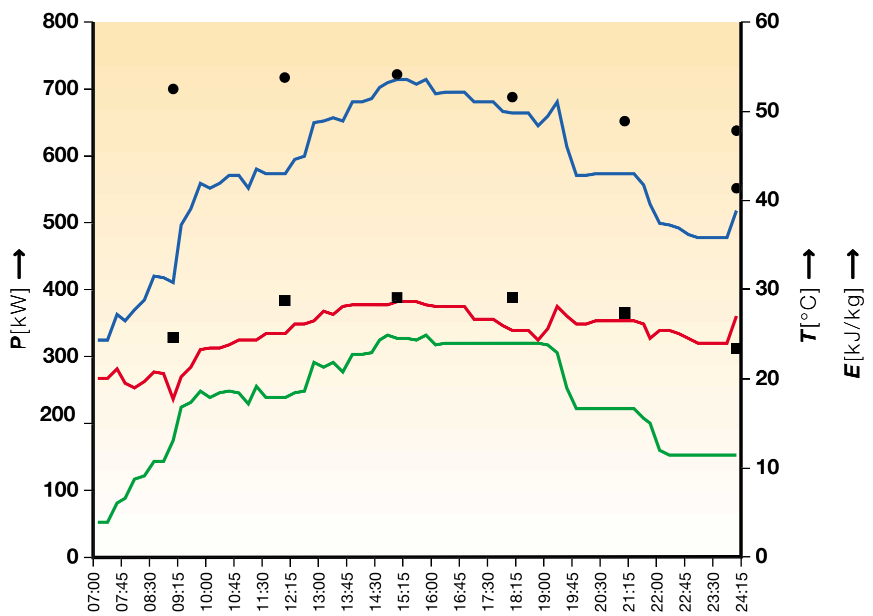


4 How 'cold recovery' works in changing ambient-air conditions

E *Outdoor air enthalpy* ●

T *Outdoor air temperature* ■

P *Demand (blue), consumption (red), cold recovery (green)*



Benefits all round

Local cooling provides significant benefits for both the environment and building owners.

General advantages:

- Electricity replaced by 'surplus heat'
- Reduced emissions, such as CO_2
- HFC/HCFC-free cooling
- Reliable energy system
- Increased energy generation coefficient

Advantages for building owners:

- Lower up-front investment and running costs for own building systems
- No chillers
- Less maintenance
- Lower electricity consumption
- Better space usage
- Increased reliability
- More environmentally compatible
- None of the noise or vibration problems common with conventional compressor cooling

Demonstration of low energy consumption

The *Table* on page 43 shows the specific heat consumption for the factory building in the DEMLOCS project during the heating seasons 1997-98 and 1998-99. The 'Demand' columns show the heat taken from the district heating network plus the heat recovered by the ThermoNet units, while the 'Consumption' columns show just the heat from the DH network. The total consumption figures of 6.2 and 6.3 kWh/m^3 are exceptionally low. For example, the lowest values in the statistics published by MOTIVA, an organization set up by the Finnish Ministry for Trade and Industry to promote the rational use of energy, are more than double these, the average

Table: Specific heat consumption of a factory building during the heating seasons 1997-98 and 1998-99 (does not include hot tap-water). The units in each case are kWh/m³.

Month	Heating index *1997-98* *Demand*	Heating index *1998-99* *Demand*	Heating index *1997-98* *Consumption*	Heating index *1998-99* *Consumption*
September	0	0.1	0	0
October	0.8	1.4	0.3	0.4
November	1.7	2.0	0.9	0.9
December	3.2	2.8	1.9	1.3
January	3.1	3.0	1.7	1.3
February	1.8	2.7	0.8	1.2
March	1.4	2.5	0.4	0.8
April	1.1	2.1	0.2	0.3
May	0.6	0.9	0.1	0.1
Total	13.5	16.4	6.2	6.3

being even 46 kWh/m³. (The MOTIVA statistics cover thousands of buildings in Finland.)

Cooling season

Utilization of low-grade energy

3 shows the supply and return temperatures of the cooling water to and from the ThermoNet units as well as the energy consumption curve for the factory building. The mean supply-water temperature is 10°C (9–12°C), the return-water temperature rising from 17.5°C to 22°C as the consumption of cooling energy increases from 100 kW to 500 kW. The temperature of the cooling water is markedly higher and the temperature difference almost double that commonly found in industry.

Peak-load shaving with 'cold recovery'

The way 'cold recovery' works in changing ambient-air conditions is shown in 4, in which it can be seen that it provides more than 300 kW of the total demand (45% of 700 kW). As is shown, recovery is reduced when the outdoor-air temperature falls and the total cooling demand drops. The result is that the cooling energy consumption remains practically constant, varying between 380 and 270 kW, regardless of variations in the outdoor-air temperature, (and thus the cooling load).

Summary

The Local Cooling concept as demonstrated in Finland and Denmark (see box on page 40) utilized low-temperature heat, in these cases district heat at temperatures above about 75–80°C. However, the same benefits can be achieved anywhere where surplus heat energy is available. Although it is most likely to be used in connection with district heating systems, the concept has the potential to be used with energy sources of all kinds.

Author

Ilkka Salo
ABB Installaatiot Oy
Po box 181
SF-00381 Helsinki
Finland
Fax: +358 1022 28150
ilkka.salo@fi.abb.com