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Renewable energy and district heating

District heating and district cooling with large centrifugal chiller - heat pumps

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District heating and District cooling with large centrifugal Chiller - Heat Pumps

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Introduction:

This presentation describes the use of centrifugal chiller - heat pumps operating either in heat recovery or in combined cooling and heating mode, for the use in large district heating and district cooling systems.
Four applications are described:

1. SYSAV Malmö - heat recovery from flue gas condensing, with a heat capacity of 19MW

2. Fortum for Nimrod Stockholm - combined cooling and heating, with a cooling capacity of 48MW

3. Viken Fjernvarme Oslo for Skoyen Vest - heat recovery from uncleaned, untreated waste water with a heat capacity of 20MW at 90°C hot water

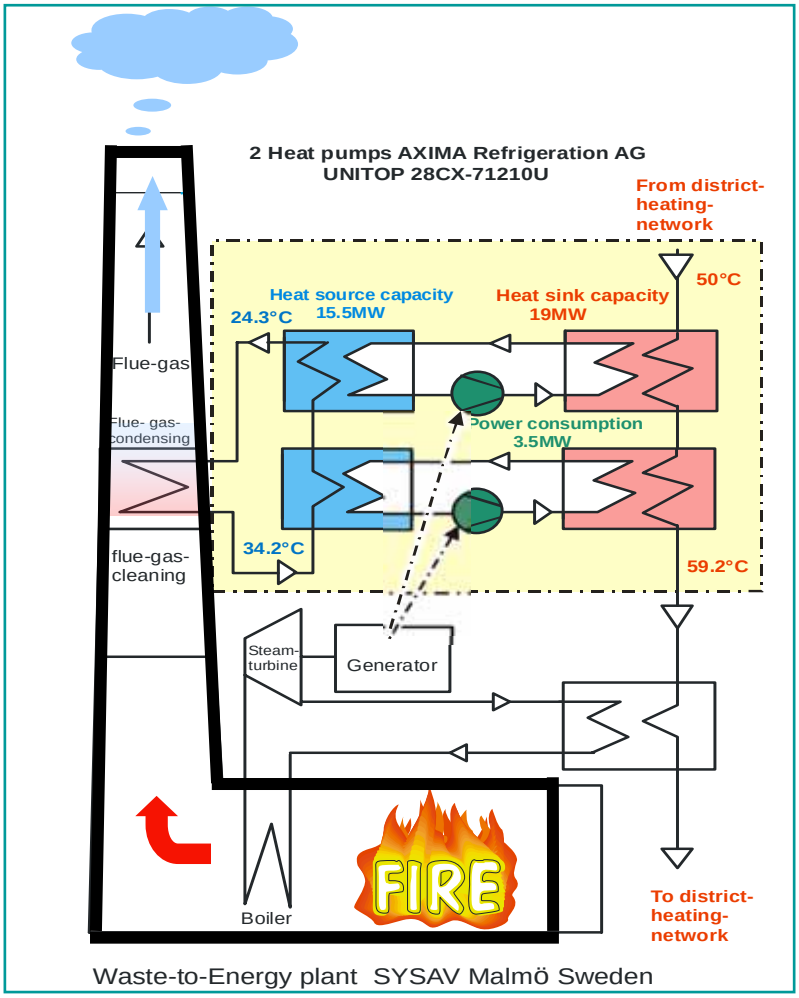
4. Helsinki Energy for Katri Vala - combined cooling and heating with a cooling capacity of 60MW and a heating capacity of 90MW at 88°C hot water.

1. SYSAV Malmö

SYSAV Malmö in Sweden has built a new waste-to-energy plant. An important part in this plant is the installation of a 19MW heat pump using the flue gas condensation as heat source. The heat pump is supplying heat water with a temperature of up to 70°C to the district heating system of the community of Malmö.
The two heat pumps are connected in series on the heat source side and on the heat sink side; this improves considerably the overall coefficient of performance COP. There are operating points with lower district heating temperatures where a COP of up to 6.5 can be achieved.

Technical data:

Number of units	2
Type	UNITOP® 28C
Refrigerant	R134a
Cooling capacity	15'500 kW
Cold water temp. in/out	34.2 / 24.3°C
Cold water flow	1’350 m3/h
Heating temp. in/out	50 / 59.2-70°C
Heating water flow	1’800 m3/h
Power at terminal	3'500 kW
Heating capacity	19'000 kW
Coefficient of performance	5.43



2. Fortum for Nimrod Stockholm

History in district heating:

The city of Stockholm is operating a district heating system since several decades, the heating system includes the whole city including the near suburb.

At the very beginning the heating took place by burning of oil and coal in combination with the production of electricity, CHP (combined heat and power, steam turbine condensing to the district heating network).

Beginning of 1980 due to the steadily increasing oil prices, heat pumps were installed in the Stockholm area with a capacity of more than 600MW. These heat pumps produce today nearly half of the required heat demand of the city. Due to available nuclear power plants the costs of electrical energy is relatively low and has made the operation of heat pumps competitive.

During the Summer period, for the heating of tap water, a further optimisation takes place as the heat pumps are in operation during night time only, filling up the hot water storage tanks with very low electrical energy costs.

Sea water and waste water is mostly used as heat source for the heat pumps.

District cooling as new application.

During the last few years an increasing demand of cooling was required, due to increased use of computer technology.

In the first instance it was obvious to use the freely available chilled water production of the existing heat pumps, however due to the fact that they are usually working directly with waste water or sea water as heat source, an intermediate cycle, with plate heat exchangers was required, with limited capabilities due to the required temperature approach.
This so called free cooling as a by-product of heat pump operation is today not sufficient any more to satisfy the need of cooling demand in the city of Stockholm and its vicinity.

Combined heating and cooling

Due to the fact that with every cooling process there is also waste heat generated, Friotherm AG, which has worked since many years on chillers with heat recovery, has worked out a concept which allows various operating modes in order to operate the chiller / heat pumps more efficient over a longer period and, making therefore the investment more attractive:

There are 4 chiller / heat pumps producing in Summer a total cooling capacity of 48MW however during this period heat recovery is not required as there is sufficient capacity available from the existing heat pumps.
The same units are producing in Spring, Autumn, Winter a cooling capacity 24MW with a full heat recovery of 35.6MW at a temperature level of 78°C.

Each chiller / heat pump consists of two centrifugal compressors Type Uniturbo 33CX and 28CX and is able to operate at the following modes:

a) cooling only:

During Summer with high cooling demand, the waste heat from the condenser is removed with sea water of max. 22°C, the condenser is equipped with Titanium tubes.
The two compressors Uniturbo 33CX and 28CX are then working in parallel, in a single stage mode, with a single stage expansion, producing a cooling capacity of up to 7MW plus 5MW = 12MW i.e. with 4 units a total of 48MW..
Depending on the cooling demand, one or the other, or both compressors can be put in operation.
If needed, the part load of each chiller / heat pump can be controlled down to 10% of its nominal capacity, with a reasonable high efficiency, with the use of inlet guide vanes. The chilled water temperature outlet is kept constant to 5°C

b) combination of cooling and heating:

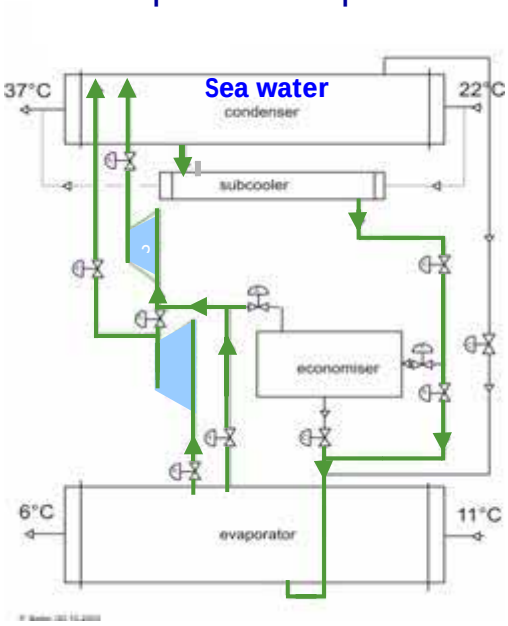
During Spring, Autumn and Winter, with moderate cooling demand of up to 24MW, but simultaneous need of heating, the waste heat from the condenser is supplied to the district heating network at a temperature outlet of 78°C and a max. heat capacity of 35.6MW.
The two compressors Uniturbo 33CX and 28CX are then working in series in two stage compression mode, with two stage expansion using an economiser after the first stage expansion.
The compressor Type Uniturbo 33CX with the larger volume flow is working as 1st stage and the Type Uniturbo 28CX with the smaller volume flow as 2nd stage compressor.
The control system is controlling the required cooling capacity, the surplus heat is supplied fully to the district heating network at a temperature level of up to 78°C. I.e. this operation mode delivers heat which can be sold in addition to the cooling, with a total COP of above 5.

Conclusion:
The possibility to use the units at various modes allows to operate the chiller / heat pumps 8000 hours per year and makes therefore the investment more profitable compared to units

operating only in one mode like cooling only, or heating only.
All operating modes can be changed electronically via the PLC control system; it will close and open the corresponding shut off valves and would change the control parameters.
are producing

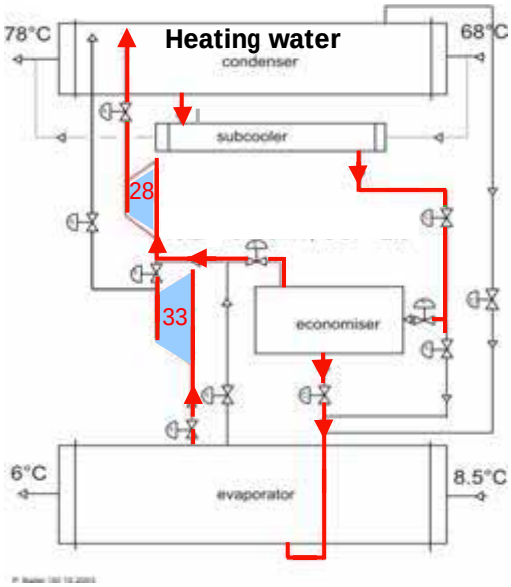
in Summer cooling capacity	48.0 MW
in Winter cooling capacity	23.6 MW
heating capacity	35.6 MW

Single stage operation
2 compressors in parallel



Cooling capacity 12 MW

Two stage operation
2 compressors in series



Heating capacity 9 MW
Cooling capacity 6 MW

3. Viken Fjernvarme Oslo for Skoyen Vest

Oslo is upgrading low temperature energy from waste water "big style" -to +90°C with a heat pump unit type Unitop® 50FY from Friotherm

Commissioning of Norway's largest heat pump took place in December 2005. With a heating capacity of 18'400 kW from a single Unitop® 50FY unit.

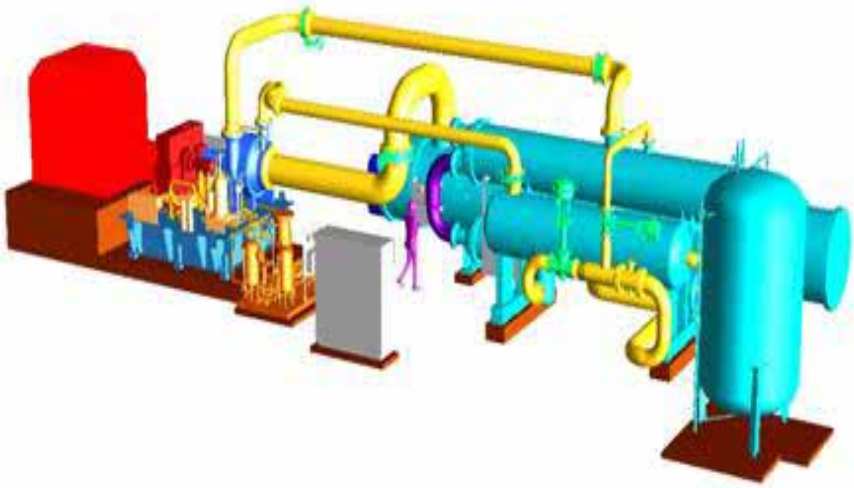
With this heat pump Viken Fjernvarme is enlarging its heating supply by 9% to 1'000 million kWh per year.

This is the worlds largest heat pump using raw waste water as heat source. With a heating capacity of 18'400 kW, the plant generates an annual heating capacity of 90 million kWh by recovering waste heat from one of Oslo's largest waste water channel.
The further development of the district heating system is one of the city of Oslo's most important goals in order to reduce the local impact on the environment. The heating energy produced is preferably recovered from waste burning or produced in by environment friendly techniques like wood burning plants and heat pumps exploiting coastal water as heat source.

The plant is housed in a subterranean cavern which is connected to one of the main waste water channels of Oslo.

Technical data:

Number of units	1
Type	UNITOP® 50 FY
Refrigerant	R134a
Cooling medium	Raw waste water
Cooling capacity	12’134 kW
Cooling water temp. in/out	10.0 / 5.8 °C
Cooling water flow	2400 m3/h
Heating water temp. in/out	67.2 / 90 °C
Heating water flow	541 m3/h
Power at terminal	6’620 kW
Heat capacity	18’754 kW
Coefficient of performance	2.83



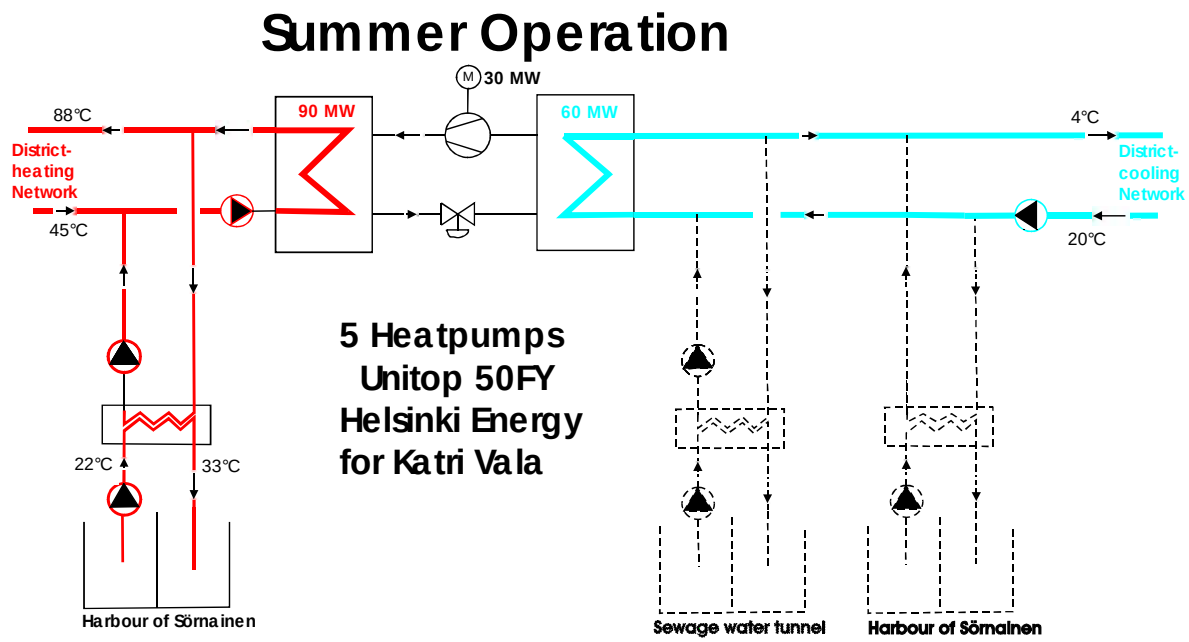
Heat pump UNITOP 50FY Skoyen Vest

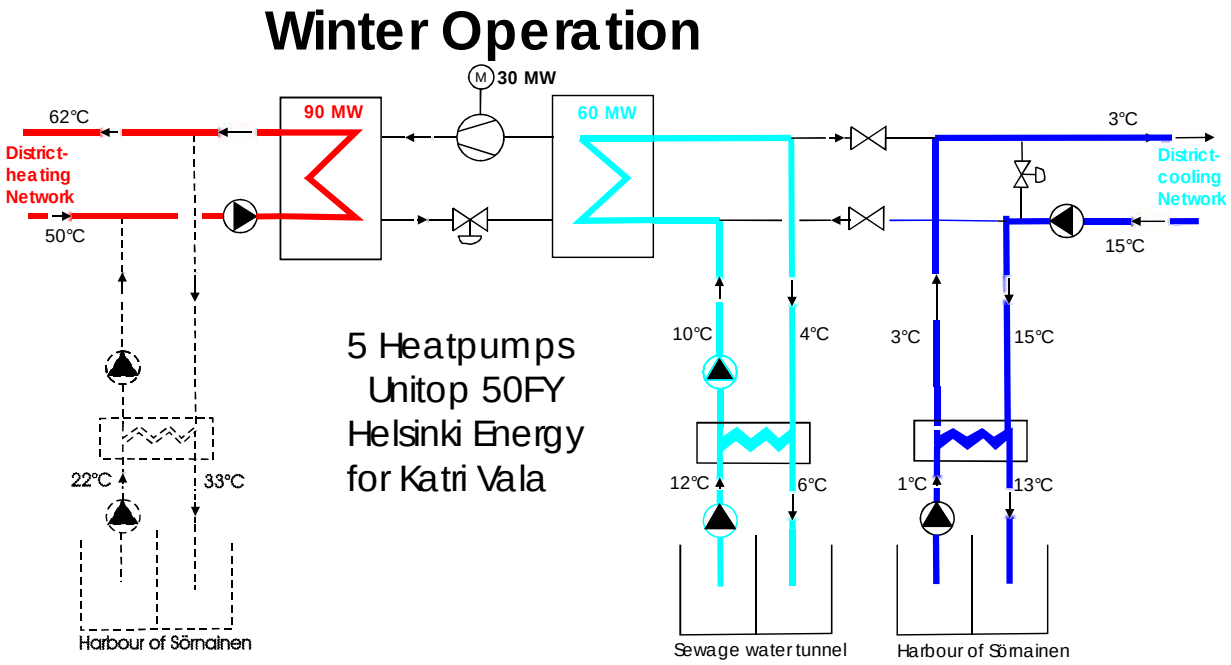
4. Helsinki Energy for Katri Vala

This is the largest chiller heat pump installation in the world producing simultaneously 60MW cooling capacity and 90MW heating capacity= 150MW of cooling + heating capacity
The required electrical input is 30MW i.e a superb COP of 150MW / 30MW=5 can be achieved
During Winter season the required cooling is done by sea water, heat is produced by using cleaned waste water as heat source.
This installation is intended to operate more than 8000hours per year.

Technical data:

	Summer	**Winter**
Number of units	5	
Type	UNITOP® 50 FY	
Refrigerant	R134a	
Cooling medium	District cooling water	Sea water, indirect
Cooling capacity	60'000 kW	60'000 kW
Cold water temp. in/out	20.0 / 4.0 °C	10.0 / 4.0 °C
Cold water flow	3'225 m3/h	8'600 m3/h
Heating water temp. in/out	45.0 / 88.0 °C	50.0 / 62.0 °C
Heating water flow	1'850 m^3/h	6'105 m3/h
Power at terminal	30'565 kW	23'850 kW
Heating capacity	90'565 kW	83'850 kW
Coeff. of performance	2.96	3.51





Heat pump UNITOP 50FY during assembly on site