

COMBINED DISTRICT COOLING AND DISTRICT HEATING PRODUCTION WITH LARGE CENTRIFUGAL HEAT PUMPS

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ABSTRACT

This presentation describes a very efficient way to combine district cooling and district heating with centrifugal heat pumps. During heating mode the heat pump is producing hot water temperatures up to 90°C and in cooling mode or in combined mode chilled water of 4°C. It allows therefore selling heating capacity and cooling capacity either individually or simultaneously, allowing a short pay back period of the heat pump installation. Furthermore an efficient way to recover heat from flue gas condensation in a waste incineration plant is described, by using a single stage centrifugal heat pump.

Key words: *district cooling, district heating, heat pump, centrifugal compressor, waste to energy*

1 INTRODUCTION

Due to existing district heating networks, Scandinavia and Finland have traditionally used large heat pump systems. During the 1980's and 1990's, more than 50 large heat pumps with heat capacities per unit of up to 40MW and totally more than 2000GW have been installed. These heat pumps are using mostly waste water and sea water as heat source and are today also used to recover energy for district cooling purposes via plate heat exchangers. Recently, due to increased cooling requirements from the industry, besides district heating, also district cooling is getting very popular in these countries. Furthermore a new heat pump application for centrifugal heat pumps has been developed to be used in waste incineration plants, recovering the heat by condensing the flue gas, generated by the wet cleaning process. Two realized applications at SYSAV Malmö and Dåva Powerstation Umeå are described.

1.1 Solution

Friotherm AG has developed an efficient solution by connecting two single stage compressors in parallel during the cooling season and connecting them in series during times when both cooling and heating is required. In case of heating only, waste- river- or sea water is used as heat source. This feature allows running the heat pumps more than 8000 hours per year. More than 20 heat pump units, with a heat capacity of totally more than 200MW have been recently installed, or are under construction, some of them are described below.

1.2 Projects Realized

1. Fortum Corporation–for Nimrod Stockholm

Fortum corporation, a leading energy company in the Nordic countries, is responsible for heat/cold production and for the district heating/cooling distribution installed in the greater Stockholm area. Alongside good

economics for the customer, Fortum is also focusing on added value such as reliable supplies, simplicity and a strong environmental benefit.

The district heating system is a vital part of the total energy supply of Stockholm. Almost 60 percent of the customers of the city's total heat market have chosen district heating. The distribution network has a length of totally 765 km. The Stockholm City environmental programme has set very ambitious targets until 2006, such as:

- Reduction of fossil fuel use by 20% by further development of district heating
- Increasing the proportion of renewable fuel in district heating from 65% to 80%

In 1995, Stockholm Energy started supplying properties in central Stockholm with cooling from its new district cooling system. Most of the cooling energy is produced by using cold water from the Baltic Sea. Recent developments made it necessary to install additional mechanical cooling equipment to cope with the continuously growing demand.

Friotherm AG delivered four centrifugal heat pump units, when the compressors are connected in parallel with a refrigeration capacity of totally 48 MW, with a chilled water supply temperature of 5°C.

When the compressors are connected in series, they will produce a cooling capacity of totally 24MW and a heating capacity of totally 35.6MW.

Various operation modes:

For the production of the refrigeration capacity required during summer and for heating capacity required during spring, autumn and winter, two modes of operation are available as follows:

Operation in cooling mode

Each heat pump includes one centrifugal compressor 33CX and one centrifugal compressor 28CX.

They can operate either as stand alone, or in parallel, depending on the actual cooling requirement. (see Fig. 2)

Operation in heating mode

In this case, the centrifugal compressors 33CX and 28CX are operating in series; the first and larger compressor 33CX is working as 1st stage unit and the second, smaller 28CX as second stage unit, thus reaching the required 78°C heat water supply temperature. Pressing a push button is sufficient to change the operating mode by actuating the respective valves (see Fig. 3).



Fig. 1. centrifugal heat pump 28CPY after assembly in factory

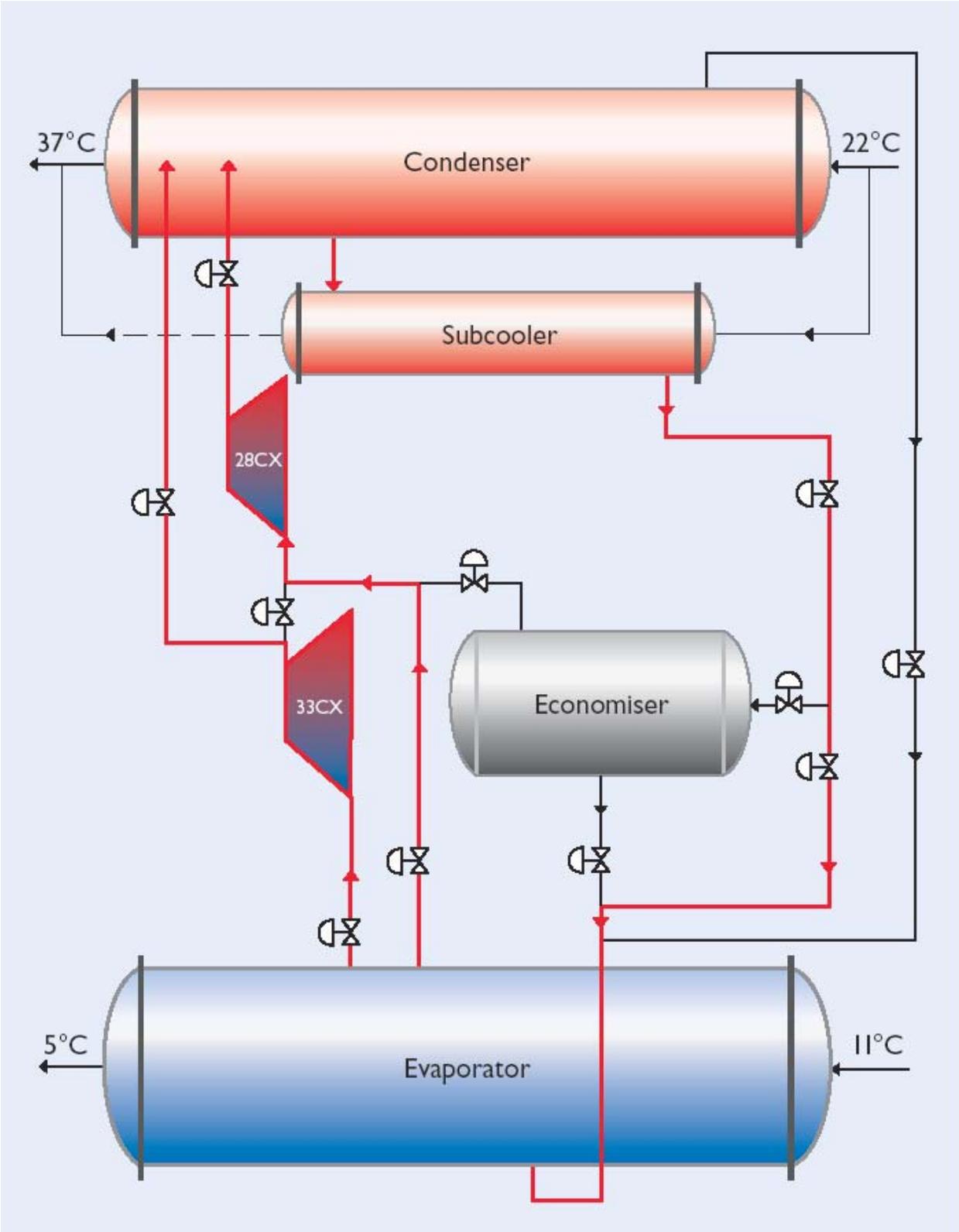


Fig. 2. Compressors are connected in parallel for chilled water production of 12MW of 5°C

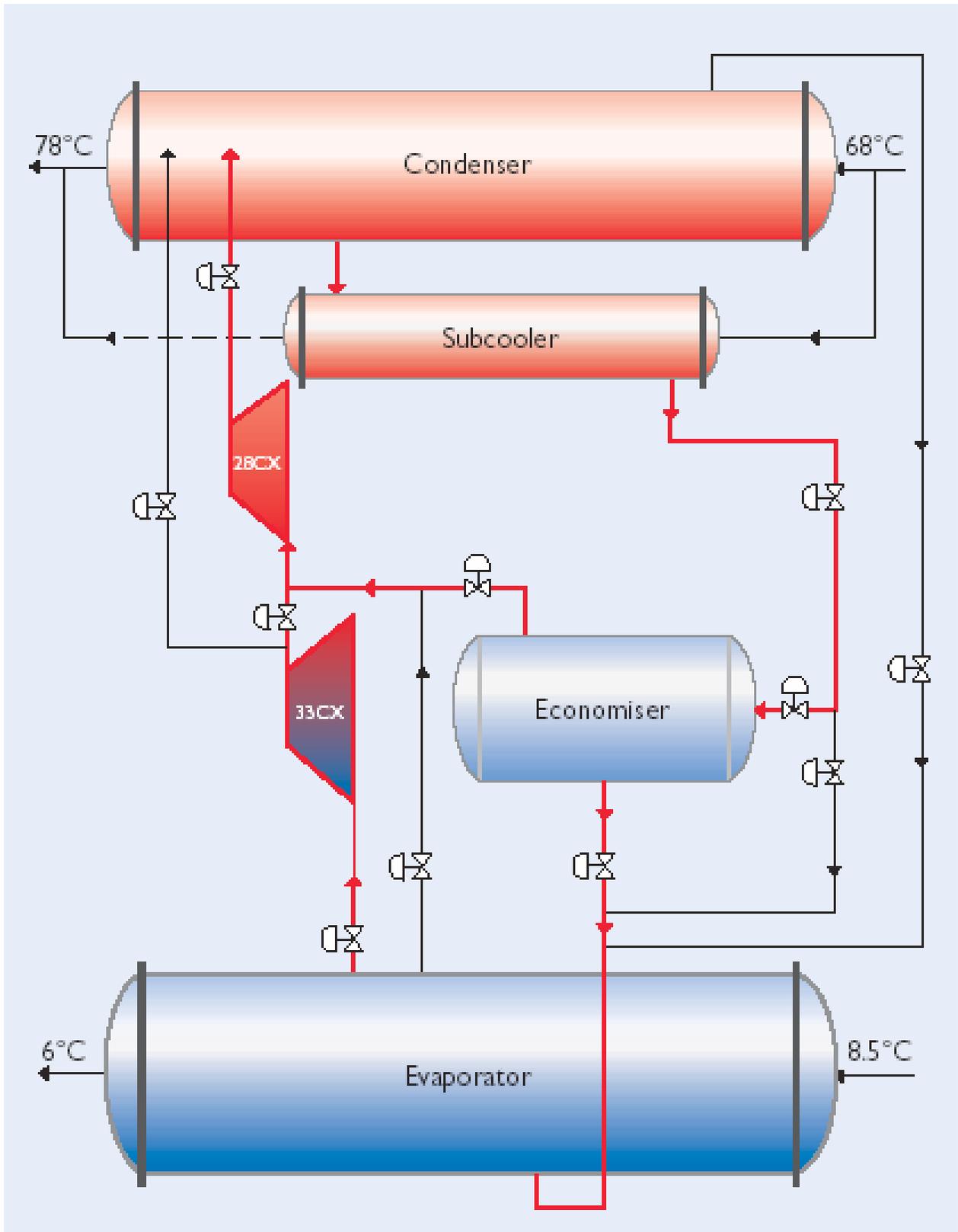


Fig. 3. Compressors are connected in series for hot water production of 9MW at 78°C

2. Fortum Corporation–for Akalla-Kista (the Silicon Valley of Sweden)

Akalla-Kista's heating/cooling system

The district heating/cooling network of Akalla-Kista was always a step ahead of local urban development and therefore was growing in parallel with Science city.

From the beginning, cooling played a vital role as IT companies require cooling of their computers at all times.

Today, the following heat pumps/chiller units are installed:

2 Centrifugal type 33/28CY heat pumps	total heat capacity	17.6MW (two stage)
2 Centrifugal type 33C chiller units	total cooling capacity	12.0MW (single stage)
1 Centrifugal type 33/28CPY heat pump/chiller unit	heat capacity	8.6MW (parallel and series operation)
1 Centrifugal type 33/33CP chiller unit	cooling capacity	13.0MW (parallel operation only)

All heat pump/cooling units are operating with R134a.

Winter operation

The re-cooling cycle of each heat pump is connected to the district cooling system. Any of the heat pumps is only put into operation at times when absorption of the refrigeration capacity is ensured. If the cooling demand is very low, the heat pumps are switched off one after another and heating capacity is provided by combustion or electrical boilers.

The above mentioned centrifugal type 33/28CPY heat pump is operating the same way as described under chapter 1 i.e. in parallel for cooling mode and in series for heating mode.

Summer operation

Because some heating capacity is required at all times, first the heat pumps are put into operation if there is a demand for cooling capacity. If the requirement for cooling capacity increases further, the chiller units are put into operation and heat rejection takes place in the cooling towers.

3. Other projects realized and in operation for combined cooling and heating with 2 stage centrifugal heat pumps.

2 Centrifugal type 28/28CY heat pumps in Sandvika Norway	total heat capacity	13MW
1 Centrifugal type 28/22CY heat pump in Sollentuna Sweden	heat capacity	6MW
3 Centrifugal type 33/28CY heat pumps in Lund Sweden	total heat capacity	28MW
1 Centrifugal type 28/22CY heat pump in Lysaker Norway	heat capacity	6MW
1 Centrifugal type 28/22CY heat pump in Fornebu Norway	heat capacity	6MW
1 Centrifugal type 28/22CY heat pump in Lilleström Norway	heat capacity	6MW

Projects in realization phase:

The largest combined district cooling heating plant with heat pumps in the world:

5 Centrifugal type 50FY heat pumps for Helsinki Energy Finland total heat capacity 90MW at 90°C
during winter time waste water is used as heat source via plate heat exchangers
cooling capacity in summer is 60MW producing chilled water for district cooling of 4°C
the hot water is used for heating tap water, required in the households
delivery will take place end of 2005

see Fig. 4

The largest heat pump in the world using uncleaned waste water as heat source:

1 Centrifugal type 50FY heat pump for Viken Fjernvarme Oslo heat capacity 19MW at 90°C
uncleaned waste water with an average temperature of 10°C is used as heat source
delivery will take place end of 2005

see Fig. 5

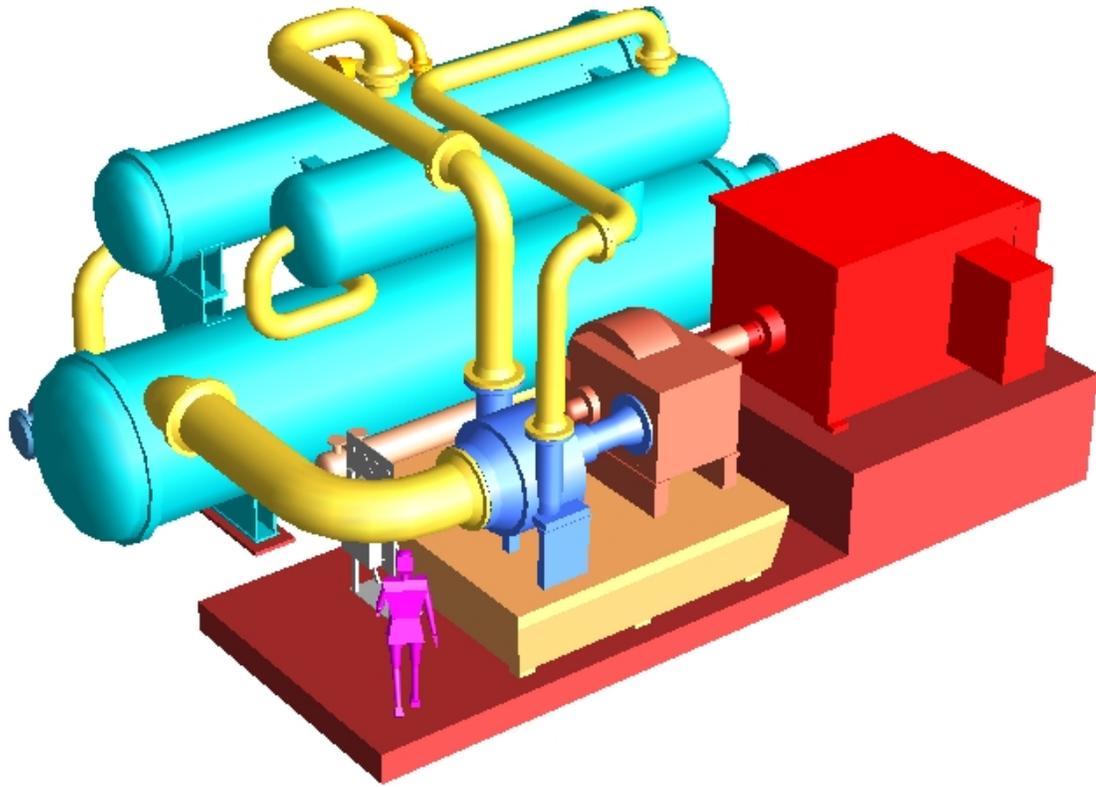


Fig. 4. Two stage centrifugal heat pump for Helsinki Energy Katri Vala

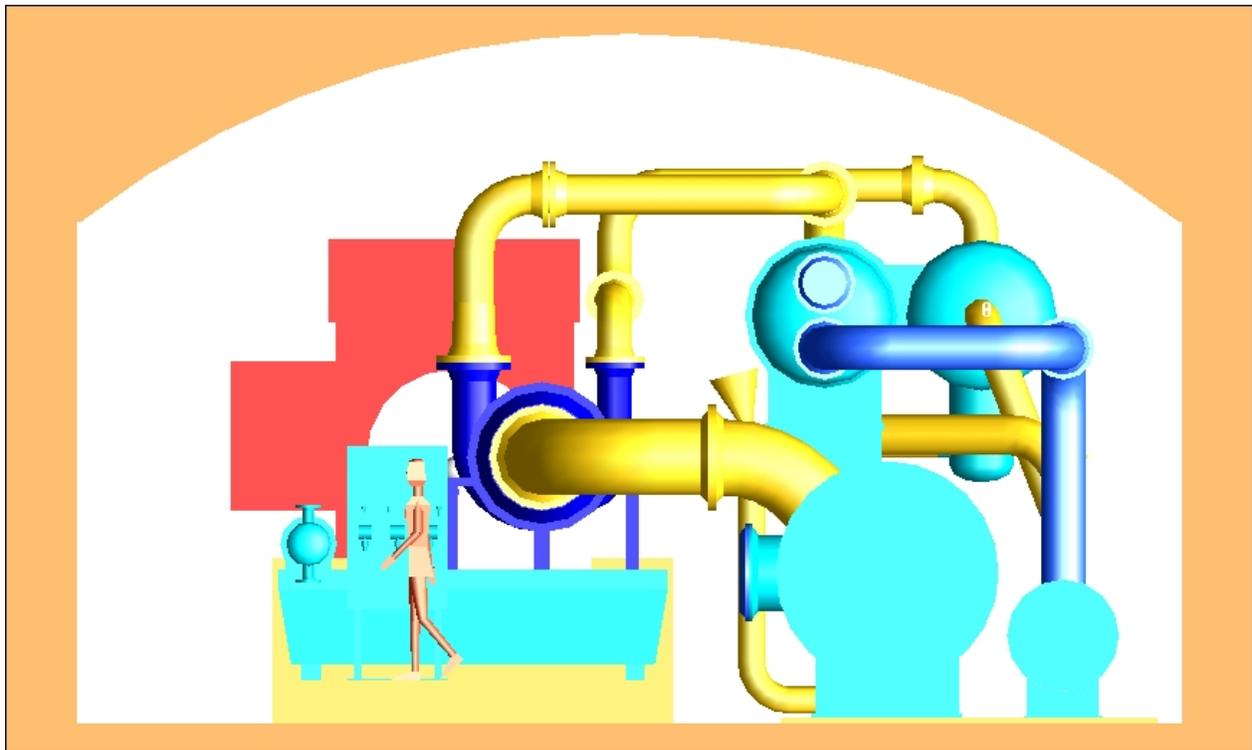


Fig. 5. Two stage centrifugal heat pump for Viken Fjernvarme for Skoyen Vest

4. New application for a mechanical heat pump:

Umeå's Dåva power station, North of Sweden has installed 2 centrifugal type 28C heat pumps with a heat capacity of totally 13700kW, enhancing the overall energy efficiency of the waste burning plant (is also often called waste to energy plant)

see Fig. 6 for the principle of the system

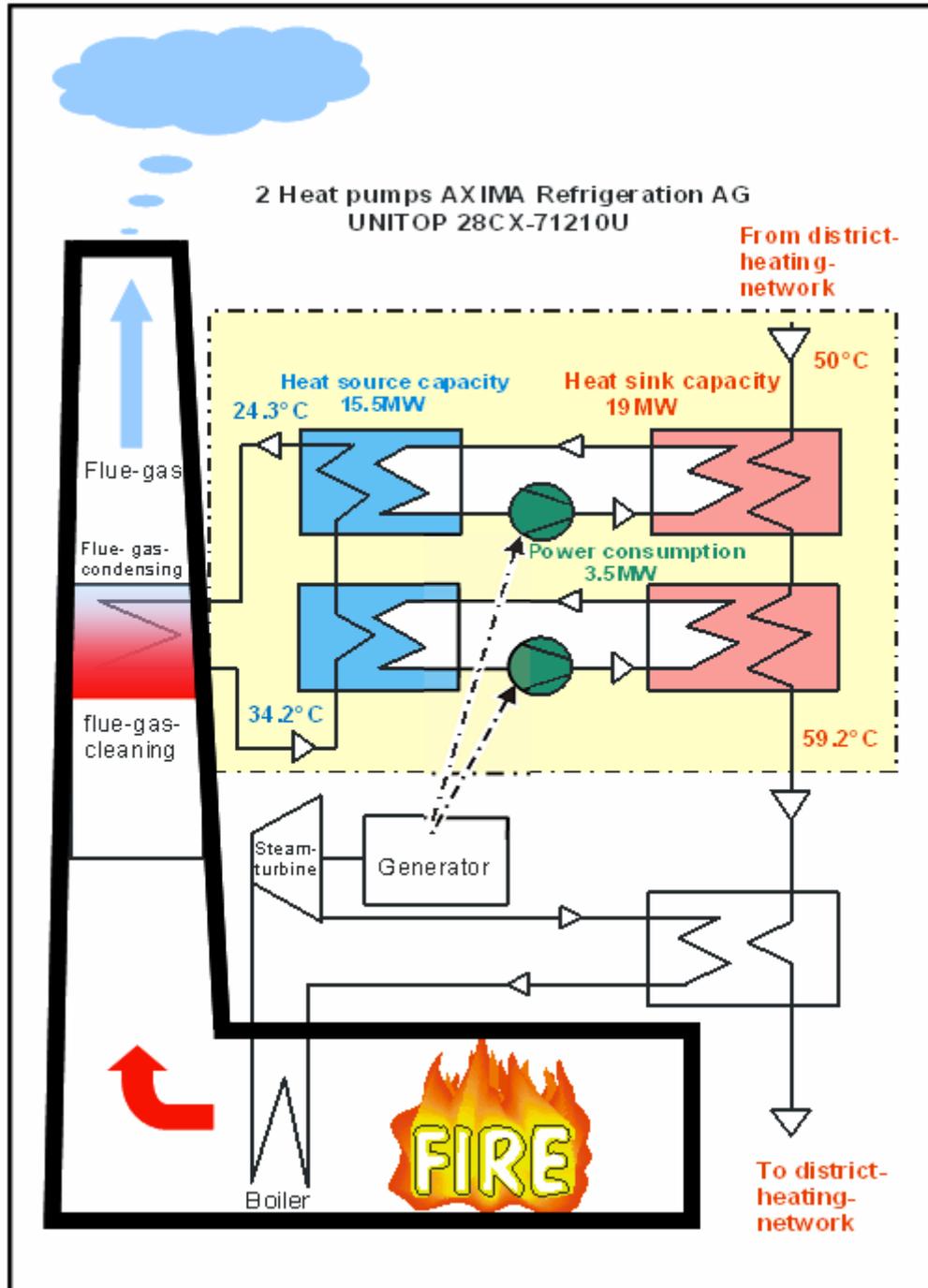


Fig. 6. Schematic view of the centrifugal heat pumps 28C integrated in the waste burning plant for SYSAV Malmö Sweden

5. The same application as before but for SYSAV Malmö:

see Fig. 6 for the principle of the system, and Fig. 7 for the picture of the heat pump

2 Heat pumps centrifugal type 28C

Heating capacity, totally 19'000 kW

Power absorbed 3'500 kW

COP 5.43

Heat source temperature in +34.2 °C

Heat source temperature out +24.3 °C

Heating water temperature in +50 °C

Heating water temperature out +59.2 °C

Capacity control 10–100%

Main features of the single stage open type centrifugal heat pump type 28C

- Open-type single stage compressor
- Refrigerants R134a
- Integrated planetary type gear
- Tough industrial design with vertically split casing for easy maintenance
- High efficiency over the entire range
- Operating temperatures $-40^{\circ}\text{C}/+80^{\circ}\text{C}$
- Multiple compressor units available
- Operation in series or in parallel
- Large capacity, small space floor space



Fig. 7. Picture of the centrifugal type heat pump 28C installed at SYSAV Malmö waste burning plant (with silencing hood over the compressor)