APPLICATION OF CUSTOMIZED ABSORPTION HEAT PUMPS WITH HEATING CAPACITIES ABOVE 500 kW PROJECT: VIVO, WARNGAU (NEAR MUNICH)

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Abstract: In 2005 a gas fired single effect absorption heat pump was installed at the area of VIVO GmbH, who runs a local civic waste collection point. Besides other recyclable materials, biodegradable waste is collected here and composted. During the composting process heat is generated due to aerobic biological processes. As the exhaust air from the rotting heaps has to be cooled down due to process reasons, the heat has to be transferred to an auxiliary medium. Until 2005 the heat was set free to the environment by free air cooling. The thermally driven heat pump instead utilises this heat and supplies heat on a useful temperature level to a local district heating grid. The local district heating grid supplies heat to office buildings of VIVO GmbH as well as to a nearby industrial area. Hence, the heat pump has two beneficial effects on this application, it cools down a process were cooling is needed and uses this energy for fuel saving in a heating grid, which runs basically on oil burners instead.

Key Words: gas-fired single effect, high temperature heat source, district heating

1 INTRODUCTION

The presented application is a communal composting plant in Warngau, about 50 km south of Munich, where bio waste decomposes to humus (see Figure 1). This composting takes place in a big industry hall. The decomposing is an aerobic process. To keep the process running, air is sucked through the bio waste to support the bacteria with oxygen. The exhaust air has a temperature between 30-65°C, depending on the rotting status of the bio waste. As this air has an offensive smell, it can't be blown directly to the atmosphere but has to pass a biological filter first. This filter can't take temperatures above 50°C for a longer time; therefore the air has to be cooled down. Since 2005, instead of cooling down the air and rejecting the heat to the atmosphere, the energy has been used as heat source for a thermally driven heat pump. Therefore the warm rotting air is passing a heat exchanger, where the energy of the air is transferred to a water circuit. A direct fired gas driven heat pump then utilises the energy of the composting air to supply a district heating system. The district heating system supplies nearby commercial buildings with heat. Due to the high temperatures of the heat source, the heat can be efficiently transferred to a temperature level useful for heating. A simplified scheme of the system is shown in Figure 2.

The low temperature heat is lifted from approximately 40°C to 80°C. The district heating system, connected to the heat pump, is the heat sink for the heat pump. How the consumers of the district heating system utilise the heat is unknown. As a backup for the district heating system two oil burners are available. Those burners are also used for medium and peak heat load in the district heating system during winter. Furthermore there is a combined heating and power (CHP) unit which also supplies heat to the district heating system. As the CHP unit is power led, the heat input from the CHP unit is not stable.

In the heat source water loop, a 3 m³ water storage tank is installed to flatten the temperature of the heat source. This is necessary, as the air is sucked intermittently through different parts of the rotting. While in the front part of the rotting the biological waste is very active, in the rear part it is already mainly decomposed and less active. As the air temperature increases with the activity of the rotting, the outlet temperature from the rotting alternates between 30-65°C. The storage is installed parallel in the system air/water heat exchanger and heat pump evaporator as shown in Figure 2.

Figure 1 left: Composting hall, which is used as heat source, the machine hall where the low temperature heat is exchanged from the air to the water of the evaporator circuit and the bio filter in the front of the photo, right: the absorption heat pump

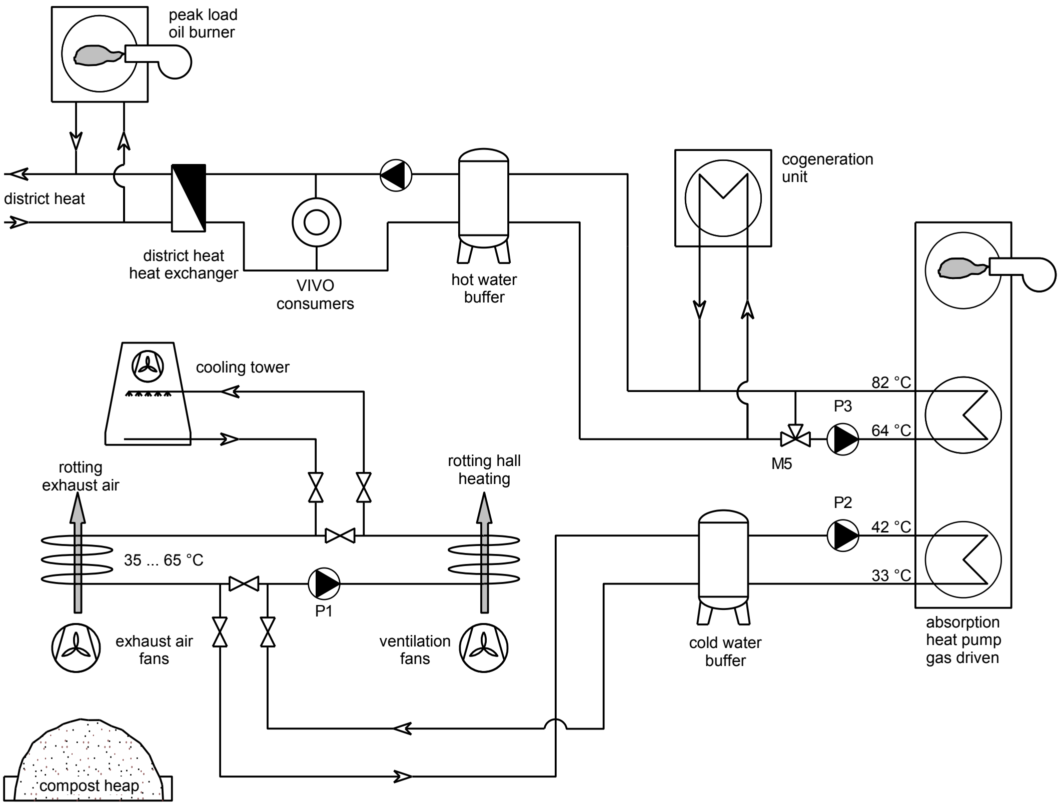

Figure 2: Hydraulic scheme of the system

2 THERMALLY DRIVEN HEAT PUMP

The thermally driven heat pump is manufactured by Thermax Ltd, India (model GHP A417). It is a standard model without special adaption to this plant. The TDHP is a direct gas fired single effect absorption heat pump with 607 kW nominal heating capacity and 240 kW nominal cooling capacity. The TDHP runs on natural gas and is controlled with a modulating burner. The working pair of the TDHP is water and aqueous lithium bromide solution. The refrigerant coming from condenser is cooled by the cooling water in a heat exchanger before entering the evaporator to reduce the flash losses.

The power of the TDHP is adjusted to the water temperature in the cold water storage, to keep this temperature in a defined range. While in operation the TDHP power is normally limited by the power of heat source, as the grid load is higher than the heat provided by CHP and the heat pump.

The nominal operation conditions of the TDHP are listed in Table 1.

Table 1: Nominal specification of the TDHP

	Heat source	Heat rejection	Driving heat
Temperature [°C]	42 - 33	64 - 82	-
Capacity [kW]	240	607	425

The capacity of the gas burner is higher than necessary to operate the TDHP in full load, but as the gas burner is capable to reduce the power down to 40% it fits and can reduce the power of the absorption heat pump down to about 50% cooling part load.

As the internal temperature lift is about 50 K and the heat rejection temperature is at about 80°C, the generator is working on temperatures of about 140°C. This leads to a high corrosion potential.

3 CONTROL STRATEGIES

The capacity of the low temperature heat source is fluctuating and depends on the filling of the heaps and the age of the biological waste. Due to the varying heat source, the power of the TDHP has to be controlled to avoid cooling down the heat source water to much. The temperature of the cold water storage tank is the control variable to increase or decrease the power of the TDHP. It has to be kept within a specified range. Furthermore, the TDHP controls the cooling water inlet temperature by a mixing valve to keep the cooling circuit in its specified range. As the heating demand decreases with higher ambient temperatures, the TDHP is shut down when the district heating grid load is too low. As free cooling of the waste heat is cheaper than operating a gas fired absorption chiller, the TDHP is not operating during summer period.

The basic decision, when to start the operation of the TDHP is made by the technical operators. Also shutdowns or restarts after unscheduled shutdowns are executed by the operation staff. To avoid problems in the district heating system the TDHP is restricted just to be started if the heat demand in the grid is high enough to absorb the heat produced by the TDHP.

4 MONITORING DATA

The measurement data of the 29th January 2007 are discussed in the following passage. The performance and abnormality are also checked and explained.

Table 2 shows the energy balance for the mentioned day. The COP is smaller than expected due to many start-stop cycles of the TDHP. A typical behaviour of the absorption heat pump is shown in Figure 3.

Table 2: Energy balance and performance on 29th January 2007

Energy input cold water [kWh]	Energy output cooling water [kWh]	COP [-]
2448	7560	1.48

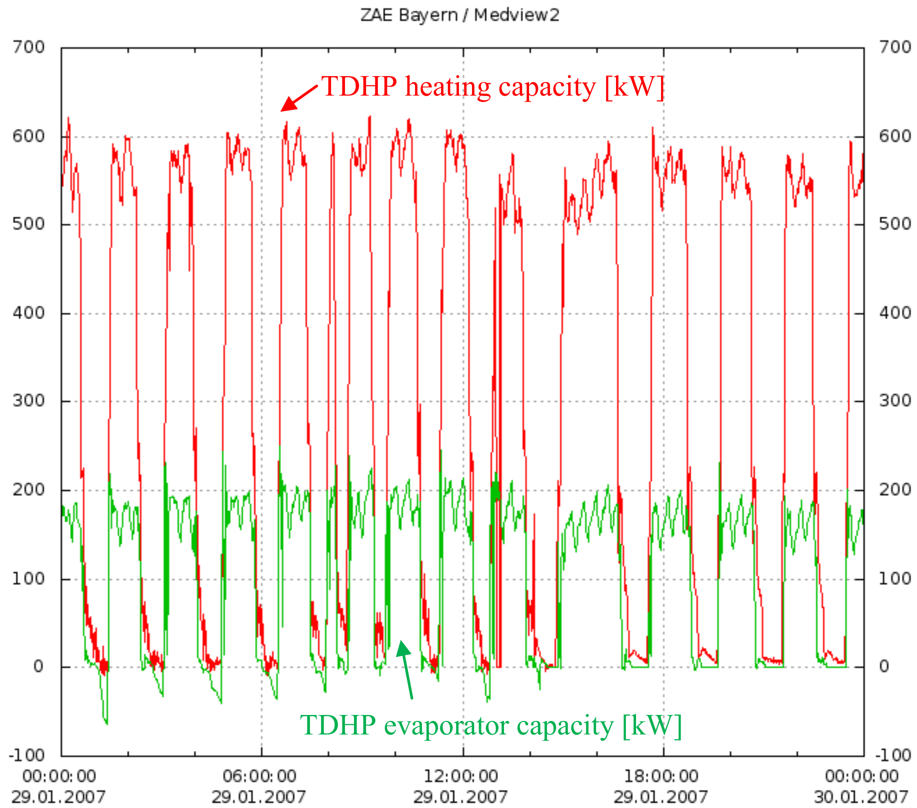

Figure 3 - Heat input and output of the TDHP

The chilled water temperature was always above 42°C (see Figure 4) on this day but the machine shuts down 14 times. The absorption heat pumps external parameters allowed operation in full load most of the time. As the gas burner is running on full load - which is a higher power than the TDHP requires- the concentration of the aqueous lithium bromide solution increased until a safety measure shuts down the TDHP. A shut down could also have been caused if the heat storage in the cool water loop was to warm, what leads to a loss of the external demand for the TDHP. Before this happens the power of the TDHP should be reduced. Although the natural gas burner was able to modulate its power according to the TDHP demands, the modulation was not noticeable because of an error in the communication between THDP and burner. As this was not fixed, neither by the operator nor the manufacturer, the TDHP was operating either in full load or not at all. This led to many dilution cycles with the typical losses. Those losses also decreased the seasonal performance.

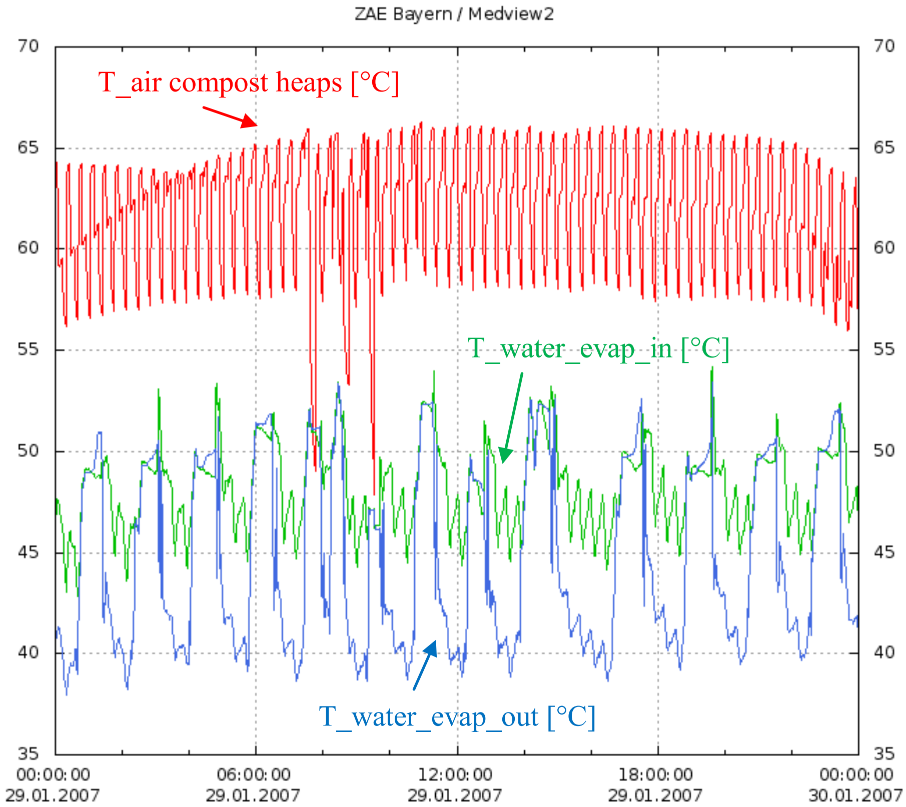

Figure 4 - Temperatures heat source

Figure 4 shows the temperatures of the heat source. In the beginning of the conversion path there is the air temperature from the compost heaps. It is the highest temperature and it alternates between 55-65°C. This is due to the air suction system, because compost heaps from different ages get ventilated one by one and the older the heaps are, the less heat is produced. After the warm air passed the air/water heat exchanger, the pulsation of the temperature signal can be found in the water. The heated water passes the cold storage and flows to the evaporator inlet, where the fluctuation can still be found although in a lower amplitude and frequency due to the cold water storage. The unsteady heat source temperature is one of the reasons why the TDHP is rarely operated in steady state condition. Especially when the compost is producing less heat than absorbed by the TDHP the cold water temperature drops because the modulation of the gas burner does not work. This enforces the machine to switch on and off more often. Low temperatures are the result of less biological activity or empty compost heaps. Those events are seen cumulative on weekends or holidays. If the TDHP didn't restart automatically on holidays and when no operators were around, it could cool down the whole TDHP to temperatures that lead to the risk of crystallization.

5 CONCLUSION

On the local civic waste collection point of VIVO GmbH a direct gas fired TDHP was installed. The TDHP had two beneficial effects. On the one hand, it provided cold for a composting process and on the other hand it supported a district heating system with heat. By delivering heat to a district heating system the fuel consumption of conventional oil burners, which are the main heat producers, is reduced.

The composting process has a high dynamic in heat production which is flattened by storage water tanks. The TDHP is supposed to follow the available heat by adapting its power according to temperatures in the cold water loop. Due to problems in the communication between TDHP and gas burner the power of the absorption heat pump was not reduced automatically. This led to a cycle operation of the TDHP and caused typical dilution losses. Therefore the measured COP of the THDP was lower than dimensioned. Nevertheless it was in the range of 1.3 – 1.5 which is a considerable improvement compared to a normal fuel burner. This is even more true as in this application the heat from the TDHP is replacing heat from an oil burner.

Part of

Thermally driven heat pumps for heating and cooling. – Ed.: Annett Kühn – Berlin: Universitätsverlag der TU Berlin, 2013

ISBN 978-3-7983-2686-6 (print)
ISBN 978-3-7983-2596-8 (online)

urn:nbn:de:kobv:83-opus4-39458
[http://nbn-resolving.de/urn:nbn:de:kobv:83-opus4-39458]