Natural Cooling in your paper mill – Closer than you think

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INTRODUCTION:

Cooling is a crucial part of the paper making process. However, control room cooling is an often overlooked part of the cooling system, as it doesn't take a great share of the total energy consumption. The energy saving potential in this part of the mill is however, significant.

Natural cooling is simply cooling with natural sources, such as river water. By utilizing natural cooling, over 70% of the energy used can be saved compared to mechanical cooling solutions. The extracted heat can also be easily recovered to be used elsewhere.

Previously natural cooling has not been thought of as a viable option in cooling control rooms. However, with modern technology and special equipment, the natural cooling possibilities in all parts of your mill are closer than ever. Natural cooling is also a great solution for energy-efficient production hall cooling to increase the comfort of the personnel.

What is natural cooling?

Natural cooling is simply cooling with natural sources. In effect it is transferring heat energy directly into a different medium that is available from the environment itself, compared to mechanically removing heat energy with a compressor and transferring the heat energy into the environment later. If we can remove the mechanical cooling process from the middle, energy is saved and the system runs more efficiently and with less moving parts.

Three ways to use natural cooling include natural water cooling, free-cooling and direct free-cooling.

In natural water cooling the heat energy is transferred into naturally available water, this can be for example water from a river or a lake. Heat energy from air is transferred into the water using air-water heat exchangers.

Free-cooling is transferring the heat energy into free air. In this application the most common way to achieve this is with a dry-cooler, where hot liquid is cooled down in a cooling coil with air, by using a large heat transfer area and fans to move the air through the coil.

In direct free-cooling the cool air is taken from outside and used to directly cool the area down and remove the heated air from the area. This is not usually utilized in the paper mill due to aggressive air on the plant and varying weather conditions (like changing humidity).

What are the benefits of natural cooling?

Energy efficiency is the cornerstone of natural cooling benefits. When removing the mechanical element from the cooling process the energy consumption significantly lowers.

When using natural water cooling the heat recovery is a large part of the benefit. If the harvested heat energy can be used elsewhere, it is possible that it can be transferred there with the heated water. This way the savings can be achieved in two places; in the cooling and also in the heating.

Figure 1: 3MW of free-cooling power with dry-coolers.

Also investment costs can be lower as the technical installation is less complicated. This however, is not always the case, as a mechanical cooling system may have to be installed for times of redundancy or for the times when natural cooling is not available. Examples of this might be during the summer, if the air temperature gets too high for free-cooling, or the level of the water source becomes too low, or its temperature rises significantly.

Challenges of natural cooling

So why does everybody not use natural cooling? Even though natural cooling is a great solution, it also comes with some challenges.

The first big challenge is that the cooling source needs to be readily available. In some locations there is not enough cool water available, and ambient temperatures can be too high in the summer. In Europe these adverse circumstances are mostly found in southern countries, like Turkey.

Also with natural cooling the medium temperatures need to be higher than with traditional cooling solutions. This results in a smaller temperature difference between the cooling medium and the cooled medium, this requires bigger capacity of the cooling units, raising the investment costs. When the temperature difference gets smaller, the heat transfer area needs to be bigger to achieve the same cooling power.

The water quality can be challenging in some locations when it is needed in the cooling process. Particles, acids, and too high pH values can often be found in the water in the paper mill, making the engineering of the cooling system crucial. For longevity of the system, all of this should be taken into a consideration.

Figure 2: Chillers for redundancy and for warmer times of the year.

Overcoming the challenges

How do we overcome the challenges in natural cooling?

Fortunately, most paper mills are located near a water source as water is also used in the paper making process. In most cases the process water can also be used as a source for cooling. In this approach the process water is “loaned” for cooling and given back to circulation after it has absorbed the heat energy from the cooled place. This way the water also gets pre-heated, and we achieve 100% heat recovery.

Small temperature differences between air and water can be solved with specially designed heat transferring units. By designing the units for natural cooling usage, we can achieve the required results when cooling.

For the water quality we can approach the problem in two different ways. We can build an independent circulation, where we insulate the process water from the cooling equipment. Here we can use plate heat exchangers that are specially designed for the process water, and on the other side to have normal Water-Glycol mixture or technical water.

The other way is to build the cooling equipment to endure the aggressive water. This can be achieved with stainless steel pipes inside the coil to prevent corrosion of copper.

Figure 3: Specially engineered climate cabinet, A-shape coil and Siemens S7.

Reference project – 80% of natural cooling for a year with river water

Schoellershammer PM6 control rooms cooled with riverwater

One big project where BM Green Cooling has utilized natural cooling is in the paper mill of Schoellershammer, located in the city of Kreuzau, Germany. Schoellershammer PM6 has its control rooms mainly cooled with natural cooling, but it also has mechanical cooling installed in the event of redundancy, as described earlier.

In the control rooms within the new PM 6 building, the installed power units and electronics create a significant heat load. Without air conditioning, temperatures well above the specified values would arise within a few minutes. This would result in the power electronics failing. To cool the individual control rooms in an energy-efficient manner, special water-cooled cooling cabinets were installed in the control rooms. Their registers and pipes have an anti-corrosive coating to minimize the effects of aggressive gases.

One of the main goals of the new paper machine project for Schoellershammer was energy efficiency, and so energy efficiency was carefully considered in every step of the planning. Therefore, also the control room cooling was thought from a green point of view. BM Green Cooling was chosen as a partner after successful previous projects addressing the cooling requirements of Schoellershammer.

To achieve optimum energy efficiency, the automation also needs to be up to the task, so that the most efficient part of the system is always used and the system always provides the right amount of cooling power. The project was closely designed together with technical experts for the customer, and the controlls were designed with Siemens S7 throughout. The cooling system was seamlessly and bi-directionally integrated into the Distributed Control System for the customer.

Planned concept

The system concept is designed so that medium temperatures to the control rooms of 16°C flow and 20°C return can be operated. The system components used were specifically designed and constructed to be generous for these high medium temperatures.

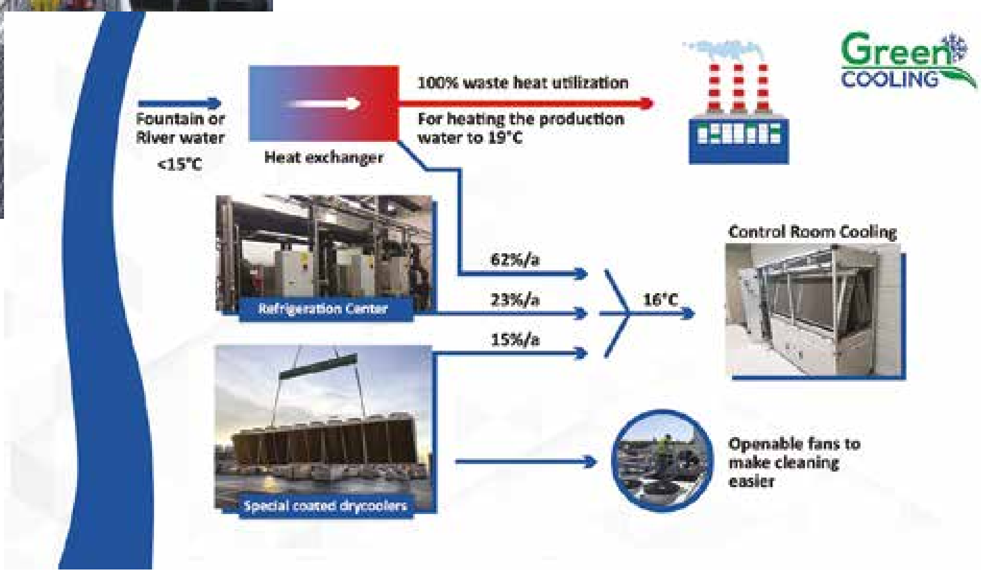
A great advantage at this temperature level is no energy is wasted in dehumidifying the air in the switch rooms and that the system's energy consumption is very low thanks to the river water cooling operating mode, approx. 5425 h/a. The entire installed, mechanical cooling generation has a cooling capacity of 786 kW. As one circuit of a chiller is redundant, so an effective cooling capacity of 655 kW is available. This redundancy ensures operational reliability for 365 days of operation. The entire cooling system is housed in a machine room, containing all 3 chillers, heat exchangers for river water cooling and all associated pumps, as well as control elements that are required for the cold generation.

The heat exchanger for river water cooling heats the riverwater by 4 Kelvin. The heated water is then made available for production. This is the main operating mode of the system. If the river water is too warm, the system switches to the free cooling or mechanical cooling mode, depending on the outside temperature.

The river water cooling mode is operated for approx. 5425 h/a (62%). The free cooling mode is approx. 1304 h/a (15%) and only when the river water and the outside temperature are too high do the chillers still run for approx. 2031 h/a (23%) depending on the load. At the same time, these 3 operating modes guarantee complete redundancy of the technologies to one another. The dry coolers, specially designed according to customer requirements, were installed on a steel frame above the refrigeration center. Every single one of the 30 installed EC fans can be opened individually.

Figure 5: Dry coolers feature openable fans to enable cleaning

Figure 4: Original natural cooling concept diagram for Schoellershammer.



This is the only way to elegantly clean the heat exchanger coils using the counterflow method. The heat exchangers and the manifolds on the dry coolers are specially coated to protect against aggressive gases.

A retention system was installed under each dry cooler, which catches the leakage of water-glycol mixture in the event of a leak in a dry cooler and reports this to the MSR control cabinet. These messages are then automatically reported to the PM control system. The output of the dry cooler is designed for an outside temperature of 38°C (according to DIN 35°C would be sufficient). This ensures smooth summer operations. The dry coolers take on the condensing for the compressors during machine operation and free cooling at low outside temperatures.

The operating status of the system is passed on to the PM control system.

The overall concept is so flexible that some other customers use well water instead of river water. In most cases, machine refrigeration can often be dispensed with entirely, because the well water mostly provides a temperature of =<14°C all year round.

The project in reality

When the cooling system was started, during the first year it was used carefully. We wanted to see how the cooling would work in reality before using it at full capacity, and therefore ran it at cooler river water temperatures than planned. However, after the first year of gathering data and optimizing the automation parameters, we were able to meet our planned percentage shares for cooling during the second year.

Now, some years later, we achieve over 80% river water cooling for the year. This means that the control rooms are cooled mechanically for under 20% of the year. Free-cooling is still used as backup for higher temperatures, and the dry coolers are still used as condensators for the chillers.

Figure 6: Plate heat exchanger for the riverwater

Achieved savings

With natural cooling the energy consumption for the cooling process can be lowered by up to 90% compared to mechanical cooling, as the only power consumption is on the pumps. Then if we calculate that we use natural cooling for 80% of the year, we can expect savings of 72%.

If we were to use mechanical for the whole year with EER (Energy Efficiency Ratio) of 5, we would use 157,2kW of electrical power to cool 786kW of heatload. If we can save this amount of electrical power for 7.008 hours per year, we calculate up to 1.101,7 MWh of electrical power would be saved.

When calculated with 0,485 of CO_2 produced per kWh produced (German average of 2017), the CO_2 savings amount to 534,3 tons of CO_2 saved for a year.

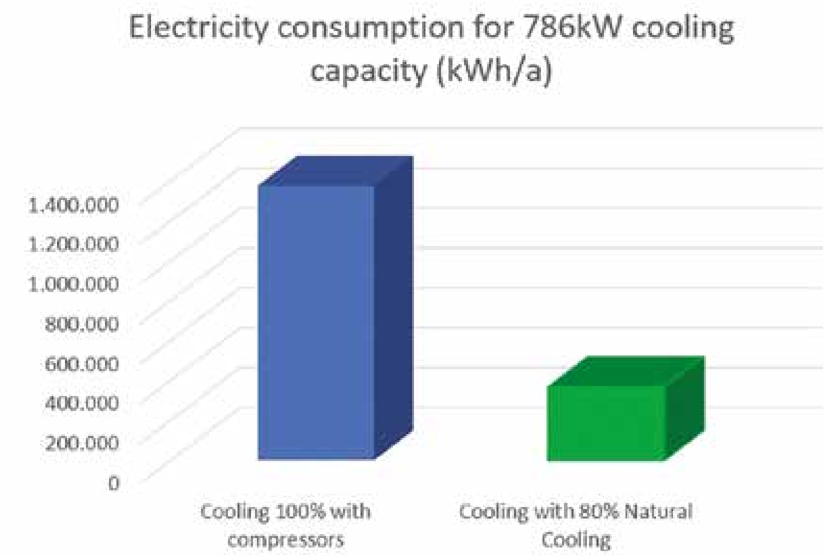


Figure 7: Energy consumption, mechanical cooling versus natural cooling