

HYBRID DRY COOLERS IN COOLING SYSTEMS OF HIGH ENERGY PHYSICS ACCELERATORS

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Abstract

Wet water cooling towers in high energy physics facilities are state of the art. The advantages are robustness, effectiveness and cost-effectiveness. The return water temperature is lower than the air temperature due to cooling via evaporation. The disadvantages are the high water consumption, which becomes more costly in the future and the soiling of the heat exchangers. If the water source is taken from wells then the drawdown of the ground water level has to be taken into account.

DESY intends to use hybrid dry coolers for the two future projects: the XFEL linac and the PETRA 3 synchrotron light source. A hybrid dry cooler is a combination of a dry air cooler during cold and moderate seasons and additional wet cooling during the hot summer season. The cooling surface is moistening by adding water to increase the cooling capability by a factor of 250%.

By this the hybrid dry cooler saves a lot of water. The water consumption can be reduced by 80% compared to a wet cooling system. This contribution presents the consumption and the requirement of the make-up water and an estimate of the behaviour of the temperature control.

INTRODUCTION

Up to now DESY re-cools the water cooling circuits by wet cooling towers. The make-up water is taken from the ground by own wells on site. The well water needs treatment like iron removal and softening. To avoid corrosion in the tubes and deposits of calcium carbonate DESY added phosphates into the raw water in order to prevent damages. The concentration of salt and minerals in the circulation cooling tower water increases due to the evaporation of the cooling tower water. The concentration of salt is measured by the conductivity of the water.

DESY has the permission to sweep away the blow down water into the ground. Since some years additives including phosphates are forbidden in the blow down water. The charge for the permission to use ground water for cooling purpose becomes more and more expensive.

WET COOLING TOWERS

In the 60s and 70s re-cooling by wet cooling towers was cheap. The investment cost for the wet cooling system, for the well water and for the waste water have been low. The use of additives for conditioning the well water was less restrictive. Nowadays the situation is completely

different. In principle there should be no additives in the blow down water which is re-injected to the ground.

Another point is to avoid steam plume on top of the cooling towers. Normally a wet cooling tower is working at the vapour saturation line of the ambient air. When the ambient air temperature is high and the relative humidity is low the evaporated water can be absorbed completely by the air. There are no visible plumes. When the ambient air temperature is lower the air cannot absorb the evaporated water entirely. Plumes will build up on top of the cooling towers (figure 1). During frosty weather the water drops create icing on the cooling towers and the surrounding.



Figure 1: The HERA wet cooling towers on a day with more than 95% relative air humidity

During operation the demanded re-cooling power varies. HERA is equipped with 24 single cooling towers. Every fan of the cooling tower has three speeds: full, half and zero speed. Therefore the speed control over all cooling towers is nearly a continuous variation of the fan speed.

The disadvantage of this arrangement is: there are a lot of towers on a small area and an influence between the towers occurs since the cooling towers suck their own steam. This decreases the efficiency only. If the ambient air temperature decreases and is saturated with vapour the intake openings of the cooling tower may get coated by ice (figure 2). The intake openings of the tower will ice up and at the end the cooling of the tower collapses.



Figure 2: Cooling tower with ice up intake openings

Another disadvantage is the pollution and the saturation of the water with oxygen. The rinsing water absorbs the dirt of the incoming air. Since there are no filters in the cooling circuits all dirt and all the spores are going into the heat exchangers and deposit on the cooling plates (figure 3). The organic contamination, the warm water temperature and the sunlight boost the growth of the micro organism.



Figure 3: Dirty heat exchanger plate

In order to control the heat transfer coefficient the temperatures on both sites of the heat exchanger are measured. In combination with the water flow and the transported thermal power the heat transfer coefficient is calculated. Comparing the coefficient to that of a clean heat exchanger one can predict how polluted the plates are.

HYBRID COOLERS

The hybrid cooler as proposed in [1] is a combination of an air cooled heat exchanger and a wet cooling tower. It transfers heat from a process to the atmosphere by means of either dry cooling or evaporative heat transfer. The operating mode depends on the heat load, the air flow rate and the ambient air conditions. The process cooling water flows inside the horizontal tubes. The air heat exchanger

is a finned tube heat exchanger. The bundles are arranged in a V-shape configuration (figure 4 and 5).

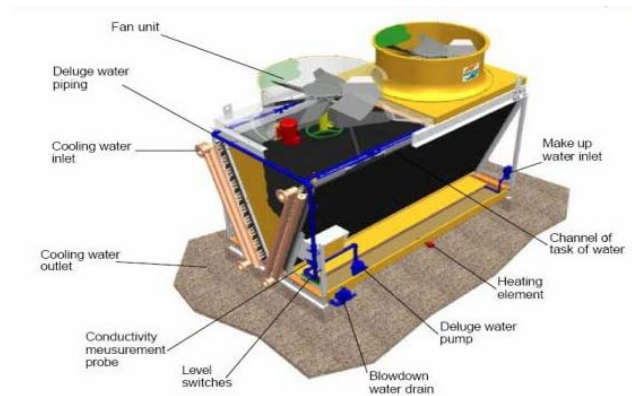


Figure 4: A 3-D plot of a hybrid cooler

1. Primary cooling circuit
2. Cooling water inlet
3. Cooling elements
4. Cooling water outlet
5. Heat source
6. Cooling circuit pump
7. Wetting water circuit
8. Make-up water
9. Wetting water tank
10. Waste water
11. Ambient air
12. Fan
13. Fan motor

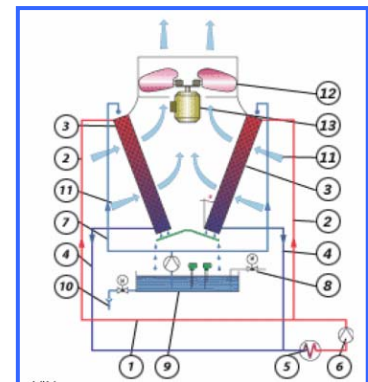


Figure 5: Schemata of a hybrid cooler

Such a hybrid cooler has a design ambient threshold temperature (i.e. 16 °C). Above the threshold temperature the finned tubes are charged with make-up water using the evaporation cooling effect. At the location of Hamburg such a hybrid cooler with a threshold temperature of 16°C will operate approximately 7000 hours per year in the dry mode.

Although the investment cost of a hybrid cooling system is clearly higher, the operating costs of hybrid coolers are well below those of a wet cooling system. With the DESY power requirements the higher investment costs will pay back after approximately two years.

The reasons for this short amortization time are:

- There is no need for an extra water circuit with pumps, heat exchangers, controlling elements, valves etc.
- The maintenance down time is shorter since no muddy heat exchangers have to be cleaned.

The main advantage is the low water consumption. The make-up water is only 20 % of a wet cooler. The quantity of the make-up water decreases with the ambient temperature. Only during hot summer days the hybrid cooler needs approximately as much water as a wet cooling tower. However this is only for a short period time and does not deliver a considerable contribution.

PETRA III COOLING CIRCUIT WITH HYBRID COOLER

PETRA III will be reconstructed to a dedicated synchrotron light source in 2007 and 2008. The cooling system will be rebuilt and adopted to the new demands. For the future cooling system hybrid dry cooler will be used. The make-up water for moistening the coolants of the hybrid coolers should be de-ionised water with a conductivity of $10 \mu\text{S/cm}$.

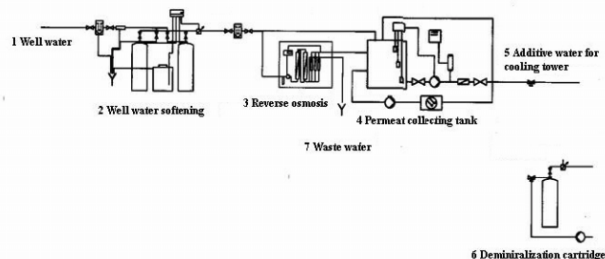


Figure 6: Scheme of the make-up water treatment

The design values for the water treatment (figure 6) are:

- 70 kg consumption of salt per regeneration, once a week
- Reverse osmosis for deionised make-up water
- Permeate output of $8 \text{ m}^3/\text{h}$, conductivity $< 10 \mu\text{S/cm}$
- Permeate collecting tank of 20 m^3
- Additive water for moistening the finned cooling elements
- Conductivity of the make-up water: $< 10 \mu\text{S/cm}$
- Well water softening, max. $14 \text{ m}^3/\text{h}$
- Regeneration of the de-ionized water for the cooling circuits by means of demineralization cartridges, conductivity $< 1 \mu\text{S/cm}$

The design water temperature of the flow water circuit is set to 30°C . The design of the water cooling system is shown in figure 7. For the temperature regulation the controlling elements are the speed control of the fan, the variation of the wetted surfaces and a mixing valve. The hybrid cooler water will be cooled down to 2°C below the reference flow water temperature of 30°C . By mixing the hybrid cooler water with the return water the flow water will be warmed up to the reference temperature of 30°C .

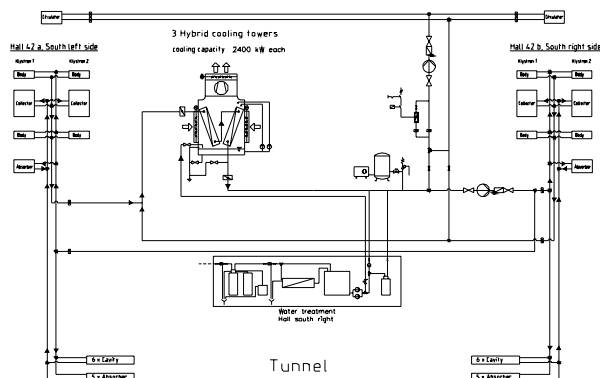


Figure 7: Schemata of the PETRA III water cooling circuit

The control behaviour of that system (figure 7) was investigated by simulations. A self-written simulations program was used which can simulate the dynamical behaviour of hydraulic systems. In this program all elements like pumps, heat exchanger, cooling tower, controlling valves etc. are calculated with its own special technical characteristics by solving differential equations. For the simulation in figure 8 the ambient air temperature was decreased over a wide range from 30°C to 10°C in approximately two hours. The upper line shows the response of the cooling tower and the lower line the flow water temperature.

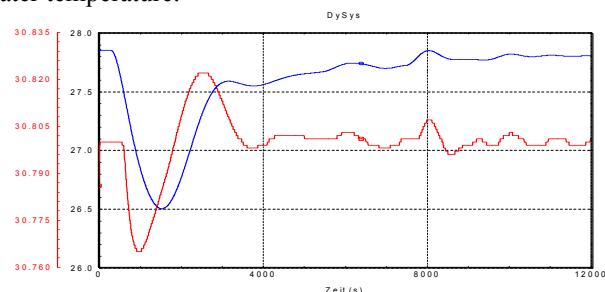


Figure 8: Response of the hybrid cooling tower (upper line) and the flow water temperature (lower line)

The calculated temperature accuracy is very high. Even the dead times due to different tube lengths with their own delay time do not cause problems. The main control element for the precise temperature control is the mixing valve which is installed directly at the entrance of the flow tube into the tunnel.

However in reality there are further restrictions:

- The accuracy of the temperature sensor is limited
- The valve position has some tolerance

The result of the simulation shows:

A precise controlling of the flow water temperature is possible over a wide range of the air temperature.

SUMMARY

Hybrid dry coolers are an interesting alternative to the well known wet cooling towers for re-cooling the tunnel water of high energy physics facilities. During most of the year no make-up water is needed which decreases the water consumption. The evaporation of the make-up water cools down the flow water below the ambient air temperature. This is only necessary during a short period in the summer.

In order to increase the dynamic behaviour of the cooling system a mixing valve is introduced. Simulations of the temperature control behaviour show good results. For the future DESY projects PETRA III and XFEL hybrid cooler are foreseen.

REFERENCES

- [1] Jaeggi Hybridcooler www.jaeggi-guentner.ch
- [2] PETRA III Design Report
- [3] Water Cooling Workshop at DESY, April 19-21, 2004