River, Lake and Ocean Water Cooling

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ABSTRACT

Using water directly from rivers, lakes, and oceans is becoming an option for end users to save energy, avoid ozone depleting refrigerants, and save space. The use of water from rivers, lakes, and oceans is not a new concept, but the lower energy use, system simplicity, and lower capital and operational costs have proven to be much more viable than in the past. Already industrial facilities and power plants have been harnessing water cooling from these sources and now many more, smaller projects can also achieve these benefits. In the past many groups would attempt to work together to have aggregated cooling loads large enough for the installation of a cooling system. However, with the advances of pumping, improvements in reliability and experience in the industry many more existing and new facilities have the option to compare river, lake or ocean water cooling.

The first system in the U.S. at Ithica, NY, which serves about 51 megawatts of cooling starting in 2000, will be presented for lake water use. A data center in Hamina, Finland will be reviewed for using seawater. The potential efficiencies, comparisons of savings of equipment and other advantages and disadvantages are also illustrated. For data centers and other critical facilities, the additional requirement to meet higher reliability standards will also be reviewed.

Keywords: river, lake, ocean, efficiency, cooling

1 WATER SOURCES

For most heat transfer applications water is the best medium for moving and rejecting heat. Water can move more heat per unit (gallon or liter) than another other liquid, and it is far more efficient than air systems; because of this chilled water is often used to pull heat from airstreams and water-cooled equipment. Water is most dense at 3.98 degrees C, which is the temperature most often found for deep lakes. Since about 3% of the water on earth is fresh water, systems are being designed to operate with salt water and other non-potable water sources.

Rivers have long been utilized to support power plant operations. The water temperature of rivers tends to vary the most and they are also more closely regulated upstream, downstream, and across borders of nations.

Lakes have a more constant temperature according to the depth available, as the deep water within a lake is less effected by weather and other events.

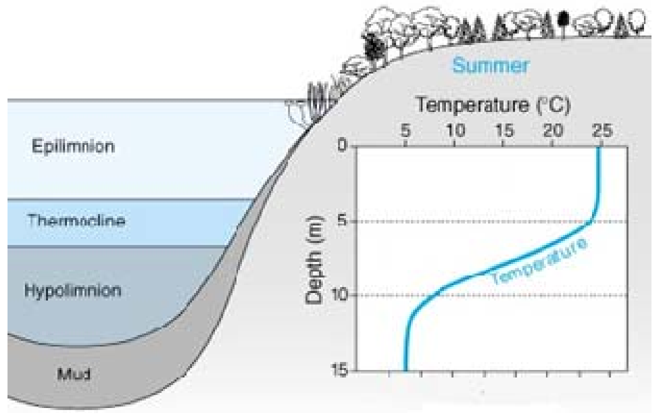

Figure 1: Thermoclines for a typical lake in North America with summer gradients.

Ocean water, like lake water, has wide fluctuations of temperatures at the surface. However, just like a lake, the ocean water temperature approaches a more constant year-round temperature that can be used for cooling. Even in the most tropical locations ocean water can be reliable to achieve 15 degrees C at 500 meters below the surface and about 5 degrees C at about 1,000 meters.

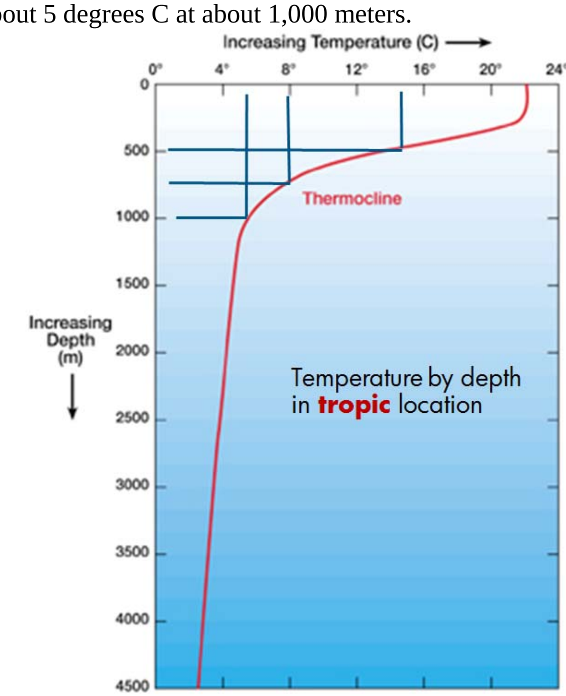

Figure 2: Average ocean water temperature by depth for most tropical locations.

2 COOLING SYSTEMS COMPARISONS

2.1 Typical Cooling Systems

A typical cooling plant is composed of several pieces of expensive and sometimes sensitive equipment. The chilled water removes the heat from the load then uses a chiller to move the heat from chilled water system to the condenser water system. A cooling tower then rejects the heat to the atmosphere. Each water system requires pumps to move the water.

These systems require specialized care and at times complex operational and maintenance procedures. Based on the type of cooling refrigerants, there are hazards related to the personnel and the environment as well as standards and regulations on the minimum equipment performance, the type of accepable refrigerant per country, and other safety considerations for having and operating the equipment. Most of these existing systems also rely on evaporative cooling as the method to reject heat to the atmosphere, and the chemicals and water use has come under more scrutiny in the last few years.

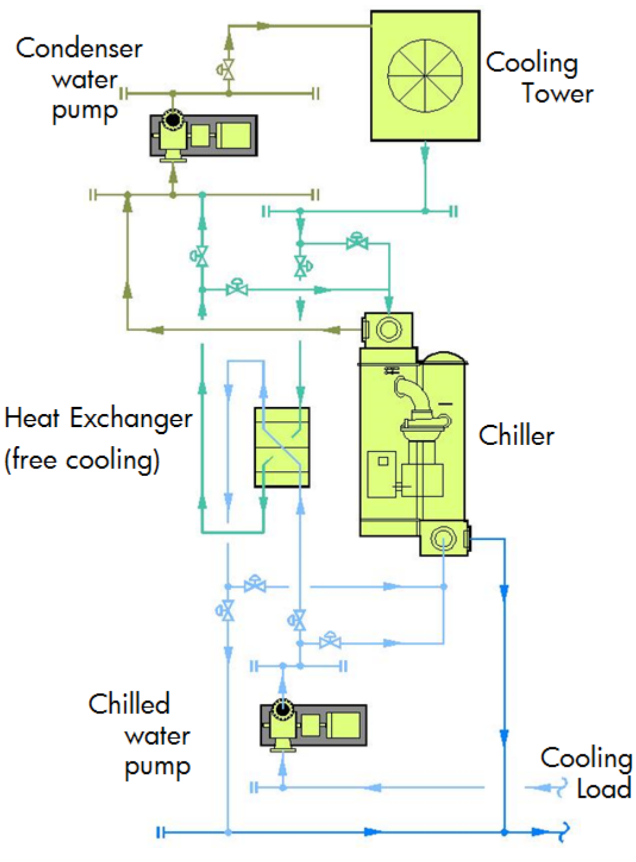

Figure 3: Typical chilled water plant with heat rejection to the atmosphere after several steps of moving heat.

Redundant components are installed to prevent loss of cooling during equipment failures. Since there are many operational components and complex modes of operation, loss of cooling may occur more frequently with inexperienced personnel or poorly maintained equipment.

2.2 River, Lake and Ocean Cooling System

A system utilizing a river, lake or ocean for heat rejection can be simplified by reducing or removing the refrigeration equipment.

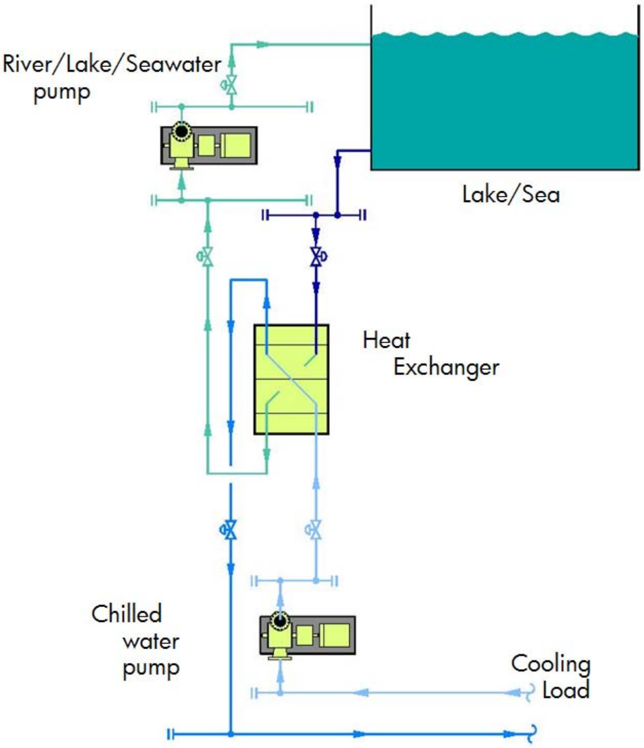

Figure 4: Cooling plant using River/Lake/Seawater for heat rejection.

Combinations can also be used, with the heat sink replacing the cooling tower only or by providing a reduction in size or number of chillers and/or cooling towers.

2.3 Efficiency Comparisons

A high-efficiency, optimized chilled water cooling plant with all-variable speed drives and other energy saving measures will have an operational coeffecient of performance of approximately 6.0, which equates to about 0.6 kW per ton of cooling. This optimized cooling plant might have chillers operating at 0.4 kW per ton and the cooling towers at around 0.1, with the remaining energy of 0.1 kW per ton needed for the pumps. By comparison, the river/lake/seawater cooling system will not need the chillers or cooling towers. However, there may be more pump energy required as factors of location, height, water depth, and more should be considered. Even if the pump energy were doubled, the energy use compared to an excellent chiller plant is about one third. For a megawatt (MW) of cooling required the amount of savings would be about 0.135 MW; over the course of a year this would be over 1 million kWh. Additionally, since the river/lake/seawater system does not require potable water for heat rejection, over a million gallons of fresh water per MW of cooling load would be saved.

Efficiency Comparison Summary		
Equipment	**Traditional Chilled Water kW/ton**	**River, Lake, Ocean Cooling kW/ton**
Chiller	0.40 - 0.54	-
Chilled Water Pumps	0.05 - 0.08	0.05 - 0.08
Cooling Tower	0.08 - 0.12	-
Condenser Water Pumps	0.07 - 0.11	-
River/ Lake/ Ocean Pumps	-	0.08 - 0.13
Total	**0.6 - 0.85**	**0.13 - 0.21**
Minimum Difference	**0.39**	

Table 1: Comparison of traditional chilled water systems and river, lake and ocean water cooling

2.4 Relability Comparisons

The risk for river, lake and ocean water cooling systems from storms, watercraft, and biological sources (fish, shellfish, etc.) should be noted and explored based on the location. Although pumps can be placed in parallel, the piping for a river, lake or ocean water cooling is often not redundant. Due to this, the piping at the shore line can be buried or otherwise hidden since this is the most vulnerable section.

While typical mechanical plants are more flexible for location, they also have vulnerabilities due to having more equipment that can fail without a rigorous maintenance program. For high-availability needs, this can be an issue if personnel are inexperienced or not trained in the details of the system such as refrigerant types, condenser water treatment chemicals,

3 EXISTING SYSTEMS

There are many projects around the globe where river, lake and ocean water is used for purposes beyond industrial, and many of these locations are where electricity, fuel and water are not abundant. Among the best locations are islands, and such projects are either in design or underway, such as Mauritius and Honolulu, HI, USA, or complete, such as the HSBC Building, Hong Kong and the more detailed examples below.

3.1 Cornell Lake Source Cooling Project

Cornell University in Ithica, NY, underwent the first lake source cooling project in the USA. The system began operation in 2000 and supports 50 MW of cooling load for the university as well as other buildings in the city. The cost was about US$59 million and offset the cost of 6 new chiller plants on the campus. By comparison with the old chiller plant systems the average energy savings is about 86%.

The lake source cooling system draws from a depth of 76m to get water at 3.8 to 5.0 degrees C. This water is then cycled through a heat exchanger near the shore of the lake then back out to the lake at a depth where the outlet temperature matches the average stratified lake temperature.

The cooling water system for the university is a closed loop and therefore needs less water treatment. Pumps supporting the water flow on each side of the heat exchanger operate as needed to ensure adequate cooling is available for the university year-round.

Before, during, and after the lake source cooling project Cornell University studied the environmental impact of the project as well as the impact of two other nearby waste water treatment plants. The annual reports for over 14 years show that the weather and tributaries had the most impact on the temperature, phosphorus, fluorescence and other measured items. In addition, the waste water treatment plants had larger attributed impacts to the lake than the lake source cooling project.

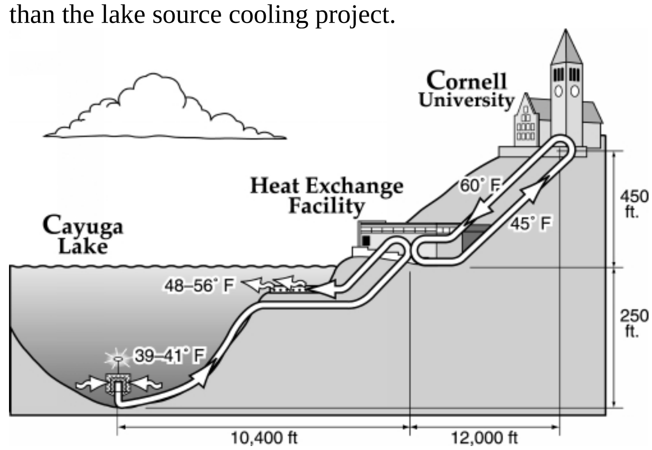

Figure 5: Cornell Lake Source Cooling project diagram

3.2 Ocean Cooled Data Center

In 2009 Google purchased a former paper plant in Hamina, Finland originally built in 1954 and converted it into a data center. The original building used a sea water tunnel 450 meters long for cooling and this was reused for the data center. Since the location is on the Gulf of Finland, the water temperatures are consistently cold at 1 to 3 degrees C; the tunnel is far enough below the surface to avoid any issues of freezing. The building went operational in May, 2010 and has been touted as one of their most energy efficient data centers.

In addition to the data center being able to use a low temperature, the discharge back to the Gulf of Finland is tempered with fresh seawater to discharge water back into the gulf at temperature closer to the the intake to minimize the environmental impact.

Figure 6: Inside the data center cooling plant rows of pumps flank their associated heat exchanger.

4 WATER SOURCE RISKS

Rivers, lakes and oceans all have changes that happen over time. While a traditional chiller plant has equipment failures, the piping for a river, lake or ocean cooling sytem may endure stress in the future as the supports beneath change with the underwater landscape.

In each country government agencies exist to oversee the installation and operation of the projects. In many ways these agencies can be similar to that of a utility such as electricity or potable water supplies. Since there are a large number of industrial sites throughout the world the agencies have a wide range of experience and will work with the design. Since a river, lake or ocean water project is only rejecting heat and not altering the water quality most authorities will allow a project to move forward.

For rivers, risks of sandbars, century-low river flows and other dangers should be examined to determine whether mitigation strategies would be warranted. Although they occur less often than earthquakes, tornadoes or other disasters, the hazards should be examined thoroughly.

Lakes pose less risk than rivers since the water flow, temperature, and shifting from flooding is much less likely.

Ocean water cooling systems have a few other issues to condend with, such as continental shelf and slope shifting on downward or lateral directions. Also underground tunneling may be considered to avoid wave action and disturbance by others.

Lastly, the risk of pipe failure, although similar in possibility to failures of a traditional piping systems, may require additional time and resources to location and fix or replace a failure. However, if the failure occurs underwater, the river, lake or ocean water system may continue to operate as normal and wait for a planned outage for repairs. When operating a data center, other means of redundancy may be required.

5 CONCLUSION

As depicted above, the efficiency gains of river, lake and ocean cooling systems are significantly large enough to examine the possibility replacing traditional cooling systems. There are many details to be examined, but with projected electrical price increases and grid reliability concerns, leveraging the local resources to save energy, water and cost is becoming an easily viable option for most new and upgrade projects.

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