

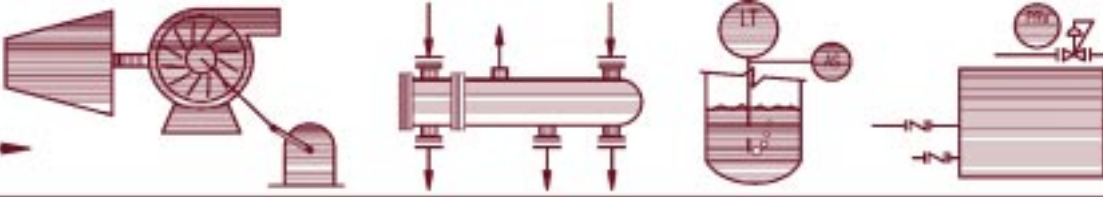
# **ENERGY SOURCE**

A Newsletter published by

**ESI Inc. of Tennessee**

for Industrial Steam and Power Users

Spring 2001



## SELECTING COOLING SYSTEMS FOR STEAM TURBINE GENERATING FACILITIES

By: John A. Weininger, P.E., Vice President of Operations, ESI

The decision as to the type of cooling system to be used in a power generation application is ultimately one of economics. However, this decision is not as straightforward or as simple as many other plant design decisions. Decision factors that must be analyzed include: regulatory constraints, site conditions, capital cost, operating cost, and cycle performance. Regulatory and specific site conditions usually will eliminate, or at least minimize, the number of cooling options that can be considered. Capital cost, operating cost, and cycle performance will then dictate the ultimate choice of a system.

In industrial power generation, there are four broad methods of providing the necessary heat dissipation for cooling systems. Each of these, which are discussed below, utilize variations of the same basic concepts.

### Direct Once-Through Cooling Systems

Direct once-through cooling systems utilize a once-through water cooling media such as a lake, river, or other large body of water. Typically, the water is taken from a lake or river at temperatures of about 70°F and is heated approximately 15-25°F in a condenser and then discharged at a point downstream from the plant. A schematic of this system is presented in Figure 1.

### Mechanical-Draft Wet Cooling Towers

Mechanical-draft wet cooling towers utilize a water media that dissipates heat in a closed loop cycle through direct water-to-air heat exchange primarily through evaporation. Typically, fans are used to move cooling air past the water as it descends through the tower. The cross-flow arrangement shown in Figure 2 is most widely used in the electric utility industry, with air drawn horizontally across the packing, which breaks water into small droplets for increased heat transfer. Air is moved by induced-draft, axial-flow fans. Drift eliminators are placed beyond the packing to separate water droplets from the main air stream.

### Dry Cooling Towers

Dry cooling towers are very similar in concept to “wet” cooling towers except they provide heat transfer (dissipation) entirely by convection, with the cooling media fully enclosed and not in direct contact with the air. This is the same application as an automobile radiator. A schematic of this system is presented in Figure 3.

### Air Condensers

Air condensers utilize air instead of water as the cooling media. A direct air-cooled condenser system, which is shown in Figure 4, circulates turbine exhaust steam directly to a large heat exchange surface (usually a series) where ambient air is blown across this surface via fans. The condensed steam is collected and returned to the feedwater system.

## ENERGY SOURCE

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ESI is an engineering and construction firm that specializes in steam and power projects for industrial and utility clients.

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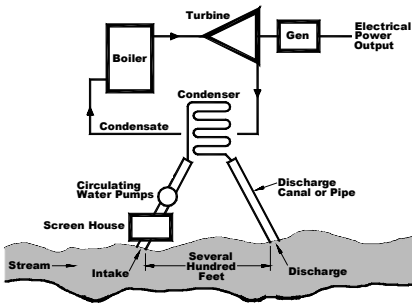
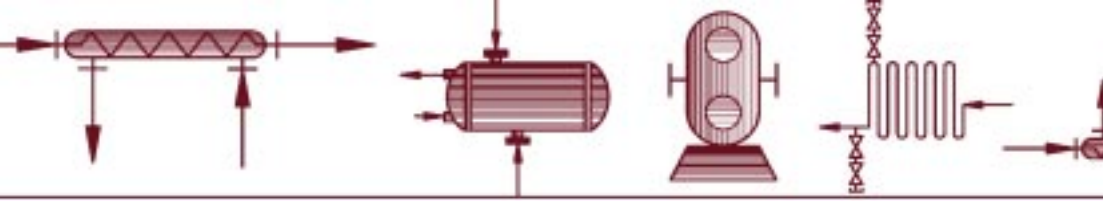


Figure 1. Direct Once-Through Cooling System.

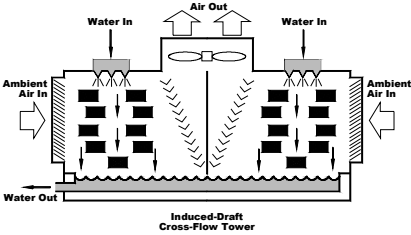


Figure 2. Mechanical-Draft Wet Cooling Tower.

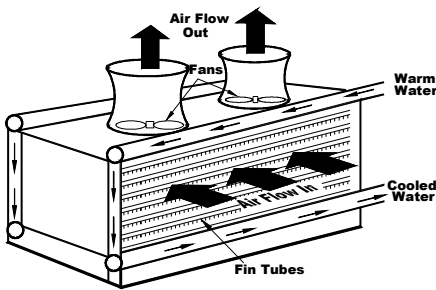


Figure 3. Dry Cooling Tower.

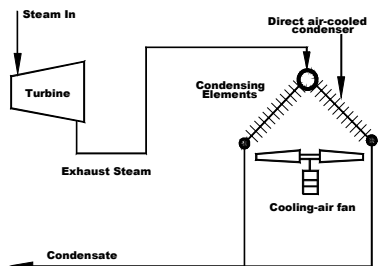


Figure 4. Air Condenser.

### Site and Regulatory Considerations

When deciding which type of cooling system to consider, the specific site conditions and associated regulatory factors must be evaluated. Direct cooling requires the availability of a water source in close proximity to the facility site.

Regulatory requirements will then dictate under what conditions water may be withdrawn and returned. Limitations on water quantity, temperature rise, and discharge quality will usually be placed on any such usage and will require detailed discussions with the governing agency.

Cooling tower and air condenser options will depend on the ambient air conditions at the site. Specifically, air temperature and humidity variations and extremes must be considered as this will directly impact cycle performance. In addition, water availability and water discharge limitations must also be considered. Wet cooling towers require significant clean water for make-up and will also discharge a significant amount of blowdown water containing relatively high dissolved solids content.

Other site conditions unique to the specific location such as space availability and proximity to other objects (cooling tower plume, noise, etc.) must also be considered.

### Capital Cost

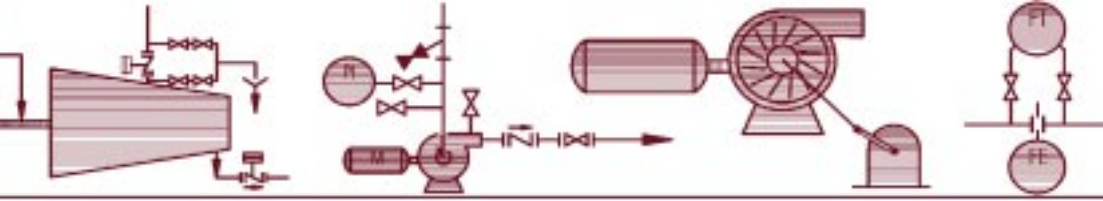
When determining a capital cost for comparison of various cooling methods, it is important that the entire system is considered and not just the major cooling equipment. An important part of the capital cost comparison must be the cost of the turbine and condenser as they will change depending on the cooling system used. Direct cooling system costs also include the circulating water piping system and pumps as major components. The cost of intake and discharge structures must also be considered, including the need for trash

racks, screens, outfall structures, power and control to usually remote locations, condenser tube cleaning systems, etc.

Wet and dry cooling tower systems include components that must be considered beyond the basic cost of the tower, circulating water piping, and pumps. Costs must be allowed for the tower basin, chemical treatment of the water, and potential freeze and fire protection systems.

Capital cost for air condenser systems is much simpler to determine and consists primarily of the condensers themselves (including fans) and the associated steam ductwork between the turbine and condenser.

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### Operating/Maintenance Costs

Operating costs vary significantly from system to system and must be considered over the life of the equipment. Items to investigate include the pumping horsepower, the auxiliary horsepower, make-up water, blowdown water disposal, chemical treatment, tube cleaning, and general maintenance costs. Table I illustrates whether or not these items are required for the four different cooling systems that have been discussed.

**TABLE I.** Summary of Cooling System Operating Requirements.

SYSTEM	Pumping HP	Auxiliary HP	H <sub>2</sub> O Make-Up	Blowdown Disposal	Chemical Treatment	Tube Cleaning
Direct Once-Through Cooling Systems	✓	Minimal Required			Possibly Required	✓
Mechanical-Draft Wet Cooling systems	✓	✓	✓	✓	✓	
Dry Cooling Towers	✓	✓			✓	
Air Condenser		✓				✓

### Cycle Performance

The function of any turbine-generator cooling system is to reject unused heat in the steam condensing stage of the steam cycle. Cycle performance is directly related to turbine back pressure with cycle efficiency increasing as back pressure is decreased; i.e., the lower the back pressure (turbine exhaust), the more useful work the turbine will produce. Turbine back pressure is determined by the condensing temperature achieved in the condenser. The colder the cooling water is, the lower the achievable turbine back pressure.

The factor that expresses the relationship between the steam condensing temperature and the temperature of the “warm” cooling water leaving the condenser is known as the condenser terminal temperature difference (TTD). This value is a measure of the heat transfer efficiency of the condenser.

Direct water cooling systems will generally deliver the lowest overall cooling water temperature since the “warm” cooling water temperature is the actual water source temperature plus the change in temperature across the condenser (range). Typically, this would be approximately 15-25°F; however, environmental limitations may reduce this significantly.

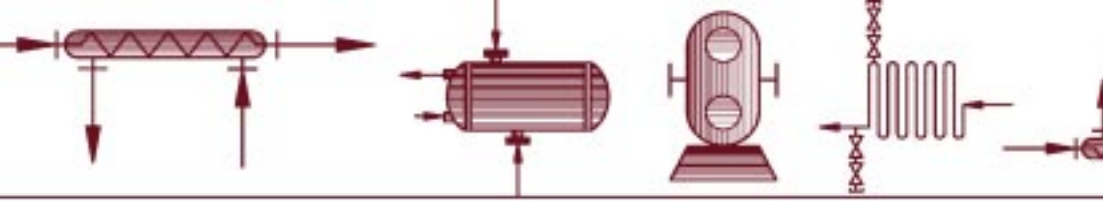
Wet cooling towers normally offer the next best cycle performance. Wet towers are limited by the ambient wet bulb air temperature and can cool water to within 10-15°F of the wet bulb temperature (approach). This usually results in higher cooling water temperatures than in the direct case. In addition, wet towers increase cycle parasitic load by requiring fan loads and larger (increased head) circulating pumps.

The performance of dry towers is less than wet towers since they rely on dry bulb temperatures which are higher than wet bulb, and their approach temperatures are also greater due to heat transfer via convection rather than evaporation. Parasitic losses for pumping and fan loads are comparable or slightly greater than wet towers.

Dry condenser performance is typically very close to dry tower performance, but can be improved somewhat by increasing the size of the system which in turn increases the overall cost of the system. Lack of circulating water pump parasitic load is offset by the need for increased fan loads.

The chart presented in Figure 5 shows typical performance comparisons. However, in order to properly evaluate and compare cycle performance, a heat balance of the

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## ESI's Mission, Core Values, and Operating Code of Ethics

*By: William L. Reeves, P.E., President, ESI*

**E**SI is a design engineering and construction firm that specializes in the design and construction of steam and power facilities. Steam, power, and utility work is the only kind of work that ESI does, so we are very specialized in our project experience and expertise. Our driving purpose is to be the best at what we do, the *SPECIAL FORCES*<sup>TM</sup> of the steam and power business.

Our mission is:

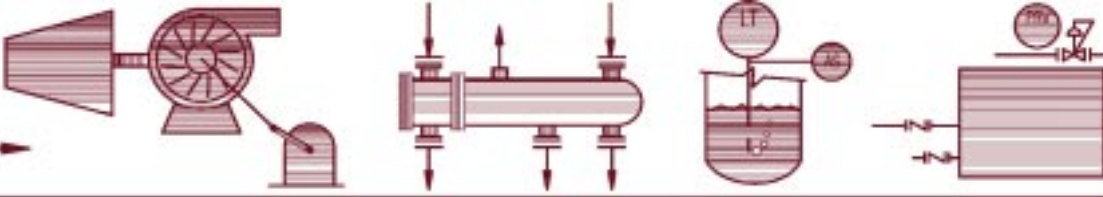
**TO CREATE THE HIGHEST LEVEL OF CLIENT AND EMPLOYEE SATISFACTION WHILE PROVIDING INNOVATIVE, COST-EFFECTIVE, AND ENVIRONMENTALLY-PROVEN SOLUTIONS TO CLIENT NEEDS.**

We feel our success is founded in our CORE VALUES & OPERATING CODE OF ETHICS AND STANDARDS. Every business has a definite culture that defines the character not only of the corporation, but of the individuals that make up the whole. ESI's company culture is defined by the core values that govern our behavior. The core values by which we measure all our efforts are:

**Integrity      Teamwork      Performance      Customer Focus**  
**Innovation      Excellence      Personal Growth**

ESI can only be successful through the empowerment of its managers and associates to execute their job responsibilities to the best of their individual and collective abilities. Following is the operating code of ethics and standards which ESI follows:

- We will build personal relationships with our clients founded upon honesty and mutual respect and trust.
- We will preserve human dignity by conducting ourselves in a manner to afford respect and care for other associates, clients and vendors.
- We will only make commitments to an associate, client, or vendor which we intend to keep and/or fulfill to the best of our ability.
- We will ensure that all our work product and efforts conform with company standards and procedures.
- We will immediately seek confirmation, help, and/or understanding when we are lacking proper experience, are unsure, or confused.
- We will confirm rather than assume.
- We will never attempt to cover up. Instead, we will announce problems or mistakes immediately upon discovery so that we can mitigate damage by collectively attacking the problem with all the necessary resources and experience.
- We will utilize company and client resources in a manner consistent with the utilization of our own personal resources.
- We will never request or expect someone to do anything that we are unwilling to do ourselves. Conversely, we are committed to do those things we request or expect of others.
- We only succeed or fail collectively as a team. Therefore, we will work as a team and pledge to do our part while encouraging and helping our fellow teammates who are struggling to get their part done.
- We will strive to make our work place a fun place to work.



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entire system including turbine-generator, condenser, and cooling system must be developed and considered over the entire year. Comparison at only the maximum temperature or just the design temperature is not sufficient and may lead to an erroneous result since temperatures vary widely throughout the year depending on the specific location.

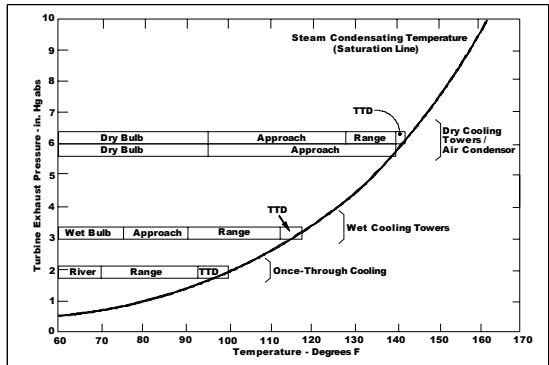
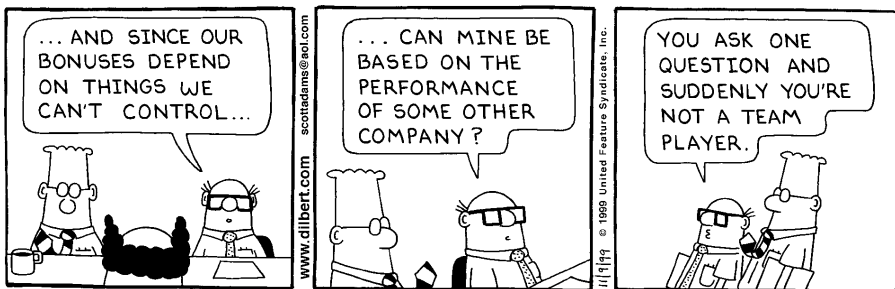


Figure 5. Typical system performance.

In summary, although simplified methods could be used, only a detailed evaluation considering site constraints, capital cost and operating costs can insure real savings over the life of a plant. (See Table II for a summary of the advantages and disadvantages of the four systems considered.) The apparent capital cost savings of otherwise feasible options may be more than offset by other costs when all important factors are considered. If your company is evaluating a cogeneration project, ESI would be happy to perform a low-cost study which would assist greatly in your evaluation. Please contact us at 770-427-6200 or by e-mail at [energysource@esitenn.com](mailto:energysource@esitenn.com).

**TABLE II.** Summary of Cooling System Advantages and Disadvantages.

ADVANTAGES	DISADVANTAGES
<b>Direct Once-Through Cooling Systems</b>	
<ul style="list-style-type: none"> <li>• Normally the simplest method</li> <li>• Normally the most economical method</li> <li>• Minimum water consumption</li> <li>• Generally low pumping head</li> <li>• Low water temperature</li> </ul>	<ul style="list-style-type: none"> <li>• Limited availability of large supplies of cooling water</li> <li>• May violate water quality standards</li> <li>• Possible temperature rise limitations</li> </ul>
<b>Mechanical-Draft Wet Cooling Towers</b>	
<ul style="list-style-type: none"> <li>• Positive control over air supply</li> <li>• Close control of cold-water temperature</li> <li>• Ambient relative humidity has minimal effect on tower performance</li> <li>• The most used system in industrial cooling</li> </ul>	<ul style="list-style-type: none"> <li>• Subject to mechanical failure</li> <li>• Subject to recirculation of the humid exhaust air</li> <li>• High operation and maintenance costs</li> <li>• High evaporative losses</li> <li>• Exhaust air may cause localized icing and fogging</li> <li>• Problem with blowdown disposal</li> </ul>
<b>Dry Cooling Towers</b>	
<ul style="list-style-type: none"> <li>• Avoids problems of fogging, mist, and icing</li> <li>• Eliminates water problems such as availability, evaporative losses, blowdown, and thermal pollution</li> </ul>	<ul style="list-style-type: none"> <li>• High capital and maintenance costs</li> <li>• Large space required</li> <li>• High turbine exhaust pressures</li> </ul>
<b>Air Condenser</b>	
<ul style="list-style-type: none"> <li>• Avoids problems of fogging, mist, and icing</li> <li>• Eliminates water problems such as availability, evaporative losses, blowdown, and thermal pollution</li> </ul>	<ul style="list-style-type: none"> <li>• Poor thermal performance</li> <li>• Large and expensive systems required</li> <li>• Large space required</li> </ul>



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