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## WHY EVERY AIR COOLED STEAM CONDENSER NEEDS A COOLING TOWER

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## **WHY EVERY AIR COOLED CONDENSER NEEDS A COOLING TOWER**

By Luc De Backer and William M. Wurtz

### ABSTRACT

This technical paper will review the basic types of cooling systems utilized by utility power plants, and explain the reasons why it is advantageous to include a cooling tower in many dry cooling applications.

A system where a cooling tower is used in conjunction with an air cooled steam condenser is called a parallel condensing system. This type of system utilizes three traditional types of heat exchangers: a cooling tower, an air cooled steam condenser and a surface condenser.

An optimized parallel condensing system reduces both investment costs and operational costs while using a minimum amount of water.

## 1. INTRODUCTION

In the steam cycle of a power plant, low-pressure water condensed in the steam condenser is pumped to high pressure before it enters the boiler or Heat Recovery Steam Generator (HRSG) where superheated steam is produced. The superheated steam is sent to the steam turbine where the steam expands to low pressure providing the energy to drive a generator. This low-pressure steam has to be condensed in a condenser in order to complete the steam cycle.

The condensation of steam requires a cooling medium. Traditionally, this has been achieved using water from a river, a stream, a pond or seawater. The cold water is pumped through a heat exchanger and the warm water is discharged back to the water source. This is called ONCE THROUGH cooling system.

A once through system is an open loop system. The need to reduce the vast amount of water requires a closed loop system. Thus the WET COOLING system came into effect, and soon after the DRY COOLING and HYBRID COOLING systems (see Table 1). In a wet cooling system, water is circulated to condense the steam in the same type of heat exchanger that is used in the once through cooling. The warm water, instead of being rejected to the water source, is cooled in a cooling tower using air as the cooling medium. Only the water carried away due to evaporation, drift and blow-down needs to be replenished by make-up water.

| Cooling System | Time period |
|----------------|-------------|
| Once Through   | From 1930s  |
| Wet Cooling    | From 1950s  |
| Dry            | From 1970s  |
| Hybrid         | From 1980s  |
| Parallel       | From 1990s  |

Table 1: Evolution of cooling systems used in power plants [R1]

## 2. WET COOLING SYSTEMS

The wet cooling tower system is based on the principle of evaporation. The heated cooling water coming out of the surface condenser is cooled as it flows through a cooling tower, where air is forced through the tower by either mechanical or natural draft.

In the United States, the natural draft tower, sometimes also called the hyperbolic tower because of its shape, has most often be used at nuclear plants and large coal-fired power plants. Natural draft cooling towers are primarily suited to very large cooling water quantities. The advantage of a natural draft unit is that the power required for fans is eliminated; these are very tall structures (up to 600 feet in height).

In smaller power plants, all wet cooling towers are mechanical draft cooling towers, where the air flow is accomplished by fans (see figure below).

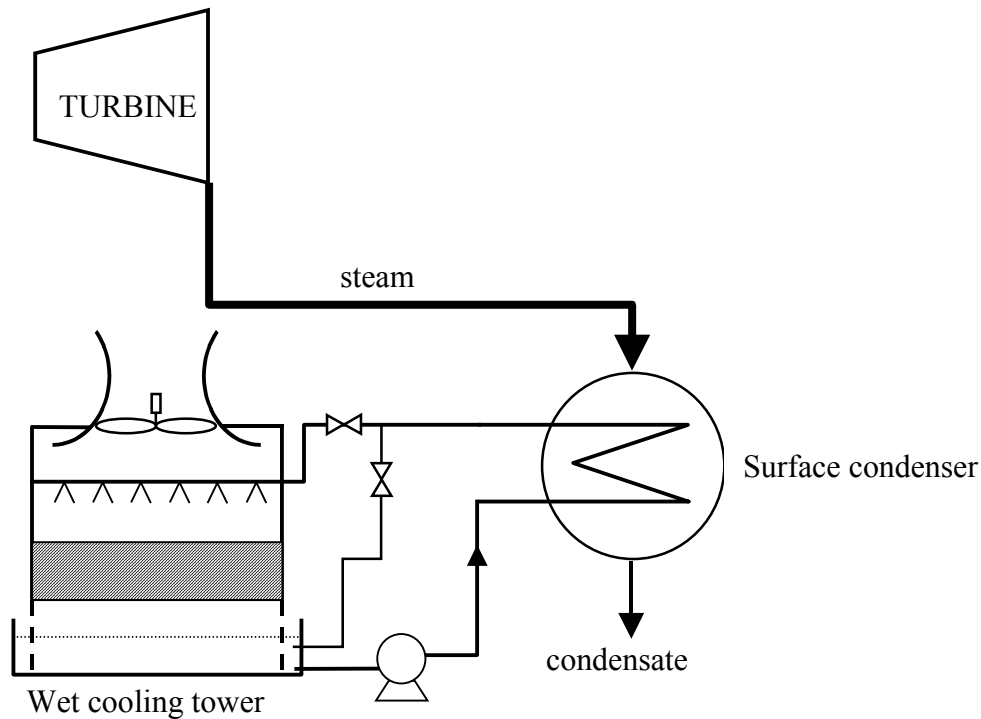


Figure 1: Indirect cooling system with a wet cooling tower and surface condenser.

The steam turbine is not directly connected to the cooling system, so this is in fact an indirect cooling system. The steam from the steam turbine is condensed at the outside of the surface condenser tubes, using cold water coming from the cooling tower. Part of the cooling water is evaporated in the cooling tower, and a continuous source of fresh water (makeup water) is required to operate a wet cooling tower.

Makeup requirements for a cooling tower consists of the summation of evaporation loss, drift loss and blow-down.

## 2.1 Evaporation losses:

Evaporation losses can be estimated using the following equation:

$$m'_{evap} = 0.00095 m'_{cool} (T_{hot} - T_{cold})$$

where  $m'_{cool}$  = cooling water flow rate at the tower inlet  
 $T_{hot}$  = cooling water temperature at tower inlet in °F  
 $T_{cold}$  = cooling water temperature at tower outlet °F

## 2.2 Drift:

Drift is entrained water in the tower discharge vapors. Drift loss is a function of the drift-eliminator design, and a typical value is 0.005 % of the cooling water flow rate. New developments in eliminator design make it possible to reduce drift loss below 0.0005 %. Drift contains chemicals from circulating water.

Below a typical drift drop size spectrum is shown for a counter-flow cooling tower using a modern type of drift eliminator [R2].

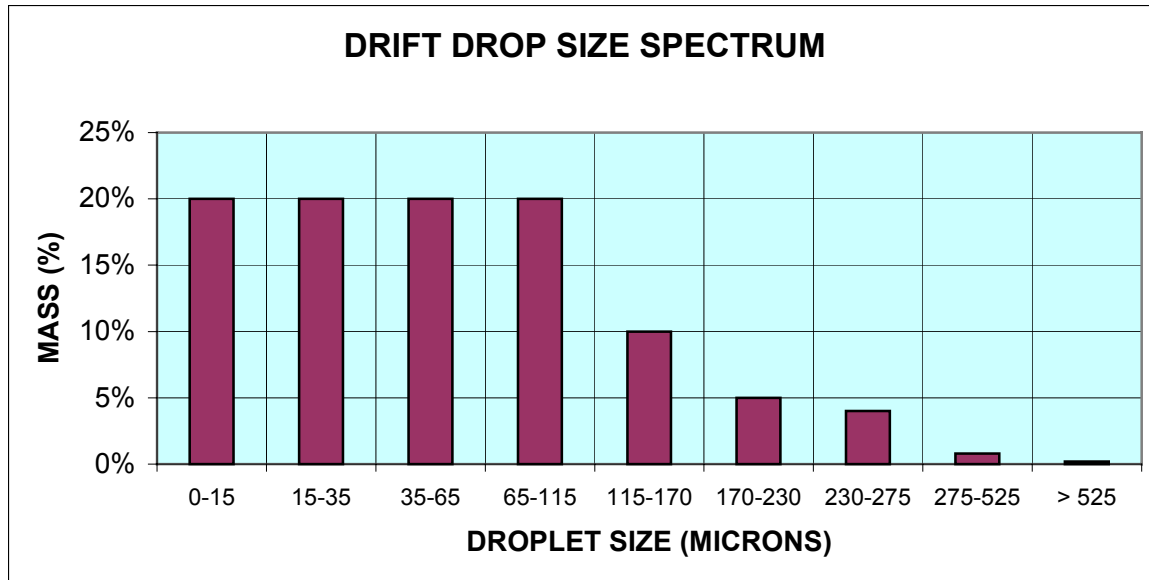


Figure 2. Cooling tower drift drop size spectrum [R2]

## 2.3 Blow-down:

The amount of blow-down can be calculated according to the number of cycles of concentration required to limit scale formation. Cycles of concentration are the ratio of dissolved solids in the recirculation water to dissolved solids in the makeup water. Cycles of concentration involved with cooling tower applications typically range from three to ten cycles. The amount of blow-down can be estimated from the following equation:

$$m'_{\text{blowdown}} = \frac{m'_{\text{evap}}}{(\text{cycles} - 1)}$$

## 2.4 Typical water consumption examples:

As an example, a 600 MW coal fired plant operating at 70 % annual capacity factor typically would require between  $5 \times 10^6 \text{ m}^3$  and  $1 \times 10^7 \text{ m}^3$  of make-up water annually [R3]. The make-up water requirements for nuclear and geothermal plants are even higher.