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PLUME ABATEMENT – THE NEXT GENERATION

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Abstract

Cooling towers have been modified to reduce the visibility of their effluent water vapor plumes for about 40 years. The evolution, breadth of experience and technologies of plume abatement cooling towers will be described. An evolutionary improvement to existing plume abatement designs using a different heat transfer approach will be described, including some of the development and demonstration achievements to date. Differences from currently used coil-type wet/dry tower designs and benefits of the improved technology for cooling tower applications will be presented.

Introduction

The earliest designs for reduction of visibility due to condensation of water vapor plumes from cooling towers were in the 1960's. The applications were wet/dry or other heat sources in a series path, and were industrial or air-conditioning applications. The applications were considered safety related. In the 1970's, designs evolved which were based on parallel path wet/dry technology. For almost 40 years parallel path wet/dry, or hybrid, technologies have been applied to reduce visible plume from cooling towers. A significant level of operating experience in various configurations and application types, in response to various end user needs, has developed over that period of time. A new technology has emerged which is series path, but does not use dry type exchangers. Instead, the technology uses air to air instead of water to air heat exchange. This technology has been developed, demonstrated and emerges as an attractive option for plume abatement in the new century. The new condensing module technology is based on a natural process with value in terms of energy benefits, piping cost, low maintenance and low complexity.

About Cooling Tower Plumes

The air leaving a cooling tower is essentially saturated, e.g. 100% relative humidity, and when discharging into cold, humid ambient air some of the moisture condenses. This condensate becomes visible if enough is present and looks like clouds or ground fog. The tendency for visibility is well correlated to whether human breath would be visible when exhaled. When it is warm and dry, your breath is not visible. The colder and more humid it is, the more visible your breath becomes.

Why does the visibility of the plume matter? There are four main reasons; aesthetics, community relations, regulatory requirements and safety. Aesthetics is simply the perception that the effluent from a tower obscures visibility of whatever is on the other side of the plume, and may be undesirable. Community relations involves the association of the cloud-like water vapor and condensate effluent from a cooling tower on a cold day with smoke leaving an industrial process stack. A plant with a cooling tower may

be perceived as emitting smoke. Regulatory requirements relate to aesthetics and community relations, but are translated into public policy that requires use of plume-free, or limited plume technology. Safety typically relates to the potential that a visible plume from a cooling tower might obstruct a roadway, or for an airport application, the view from the control tower. Sometimes, concerns about icing from plumes contacting cold roadway or other surfaces also come into play. This is not directly related to visibility of the plume. Any time there is moisture in the air, whether in clouds or ground fog or a plume (visible or not), there is a potential for this moisture to condense and freeze on cold surfaces.

Series Path History

It was recognized in the mid-1960's that if the humidity leaving the tower could be reduced, the plume would be less visible or visible for fewer hours per year. The earliest designs involved adding heat sources to the air leaving the cooling tower or "wet" section, to reduce the relative humidity of the leaving air by heating it up. Two basic approaches were considered. One was to add a finned tube, or more commonly, a bare tube heat exchanger above (or downstream of) the eliminators to heat all of the wet section discharge air. The other was to add heat to the air using burners above the fans (induced draft with propeller-type fans at the tower discharge). The heat exchanger designs either used all or part of the hot water going to the tower, or used an external heat source, such as steam from some other available process, to provide the heating effect. The burner design was applied at an airport in a concrete tower with concrete fan cylinder, and burned a combustible gas, but the plume control was not found to be necessary and the burner system is believed to have been decommissioned in the 1970's.

Series path wet/dry (SPWD) towers, with metallic coils above (or downstream) of the eliminators required premium corrosion resistant materials due to the hot moist environment in the tower plenum. Over a period of time close-spaced fins would tend to clog in this environment. Thus the designs typically had what are called "low fins" that are wide spaced and short fin height, or had no fins at all, "bare tube", particularly with higher temperature steam. The drawbacks to these designs were full time pressure drop for the cooling tower fan, and high pump head for hot water coils. The positive was that the entire volume of wet section air was heated in the coils, so the discharge air was well mixed. External heat source designs with steam, in effect, would be trying to control two processes with one fan, and would have some control complexity as well as a need to insulate the piping to and from the tower in cold climates.

Parallel Path Wet/Dry (PPWD) Towers

Most of the history of wet/dry towers evolved after the development of the basic parallel path tower designs and patents around 1970. This concept involved adding dry sections, using finned tube heat exchangers, above the wet sections, but different from the SPWD's just described, the air was drawn by the induced draft fans in parallel through the dry sections and wet sections, mixed in the plenum, and discharged from the fan at a reduced relative humidity. The air leaving the dry sections is heated without adding moisture, so is hot and has low humidity. The air leaving the wet sections is essentially at 100% humidity (saturated) warm air. The mixed air leaving the tower is at a reduced relative humidity. If the humidity is reduced via a proper balance of dry and wet section performance capability, the air that leaves the tower will not become super-saturated (condensed drops, or visible plume) as it mixes with ambient air, see Figure 1.

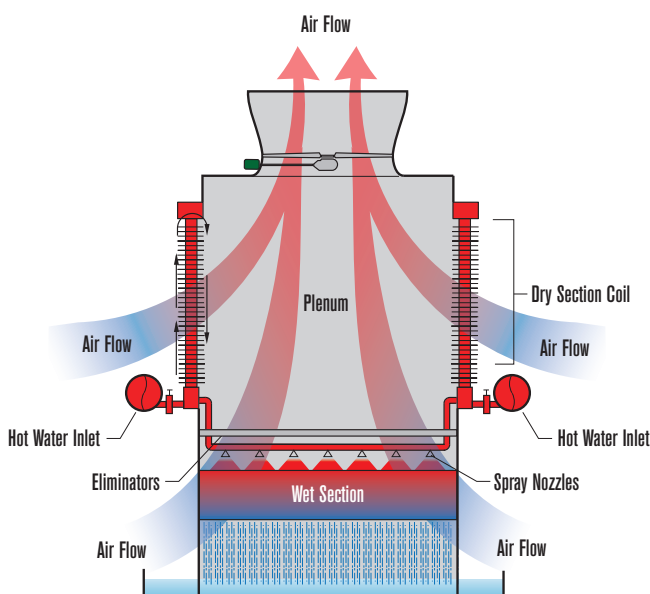


Figure 1. Parallel Path Wet/Dry Tower cross section

Parallel path designs had the advantage of being able to add face dampers on the dry sections that would shut off most of the air flow, enabling nearly full wet cooling tower performance in the summer time at near to wet tower fan power. Dampers typically leak some air, and in addition, some dry section performance may be desired for morning and evening conditions even in the summer, so PPWD towers typically are higher fan power than wet only towers. The selection of PPWD towers for plume abatement is generally against a summer thermal design point and a winter plume design point. Figure 2 shows ambient weather points divided by the saturation curve, to the left of which are super-saturated air, or visible

fogging conditions. To the right of the saturation curve are sub-saturated, or non-visible conditions. If one looks at a visual map of the distribution of ambient points for a given location, the map would look like the gold band across the chart. For a typical wet-only cooling tower, the curve toward the right of the chart is the fogging frequency curve for design flow and cooling range, which divides the weather points into conditions for which the tower would produce visible plume to the left, and those which would not to the right. A substantial percentage of the ambient points are in the visible plume zone for this example case. The fogging frequency for the un-abated tower is about 60%. The fogging frequency curve for a plume abatement tower selected for approximately 10% of the hours per year of visible plume is shown toward the left of the chart. This would allow visible plume at the coldest and most humid hours of the year, typically in early mornings, before dawn. The plume abatement design point would be the point (Wet Bulb & Dry Bulb Temperatures) where the fogging frequency curve crosses the uppermost edge of the weather data band for a location.

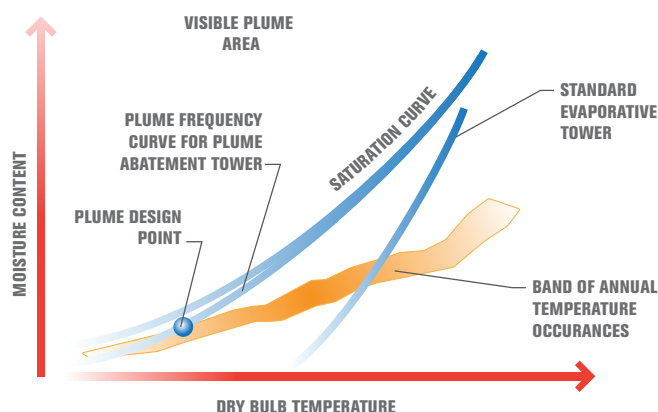


Figure 2. Plume Abatement Design Point Determination

PPWD towers also generally use hot water passing first through the dry section, then through the wet section to get maximum dry performance. This involves additional pumping head to move water both through the coils and above the wet section. Since a risk of freezing the metal coils exists if water is left standing in the coils or if water distribution is not even enough, substantial design effort has gone into hydraulic design and controls to protect the dry sections. Some manufacturers also utilize vacuum pumps to assure that air does not become trapped in portions of the coil system, potentially also trapping water that could freeze. Note also, that PPWD towers involve mixing of low velocity streams of air that do not generate sufficient turbulence for complete mixing across the plan area of the tower plenum. Mixing devices have commonly been used, particularly for counterflow designs, to gain sufficient mixing of the dry and wet streams to prevent unmixed wet air from discharging from the tower visibly.