# POSSIBLE APPLICATION OF NANOFLUIDS TO IMPROVE PERFORMANCE OF WET COOLING TOWERS

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**Introduction:** Nano meter-sized particles suspended in fluids forming colloidal solutions are called nanofluids [1]. Nanofluids are typically made of metals, oxides, carbides or carbon nanotubes in a base fluid like water, oil and ethylene glycol and have an advantage, in terms of heat exchange (heat transfer) over pure cooling fluids. Their great potential in heat removal improvement was first discovered in 2001, [2]. It was discovered that less than 1% volume fraction of copper nanoparticles or carbon nanotubes dispersed in ethylene glycol or oil can increase their thermal conductivity by 40% and 150% respectively. The ongoing research after that extended to a utilization of nanofluids in many processes and industries, especially where intensive heat transfer/exchange occurs.

Thermal power plants are large consumers of water. This especially refers to the so called cold end of the power plant. It is comprised of condenser, cooling tower, circulating pumps, connecting pipelines and air removal system.

Lignite fired thermal power plants have the highest share in electricity production in the Republic of Macedonia. Thermal power plant Bitola is the biggest producer of electricity in the country. It consists of three units having total installed capacity of 699 MW. Since this power plant does not have access to abundant water, it uses wet cooling towers for cooling of the condenser.

Two circulational pump stations are in operation at TPP "Bitola". One is for units 1 and 2, while the other one is for unit 3 with the possibility of enlargement for another unit. Pumps are of axis type, vertical with variable geometry of the working blades, [3, 4]. Unit is comprised of steam generator, turbine, electric generator, condenser and cooling tower. Two pumps, working in parallel, are used on each unit, while the third one is engaged during extreme weather conditions as an auxilary pump according to needs. Cold water from the cooling tower basin, through open channel that later transforms into two underground pipes (with diameter DN2400 each) is transported into pump station's open basin (chamber). From the open basin water is transported by pumps into main distributive pipeline DN2400. From this pipeline, water flow is divided on two pipes (DN1600) leading to both condenser halves, [5]. Cold end of the Unit-3 is shown on Fig. 1. Nominal flow rate of cooling water through this system is 30000 $m^3$/h per unit. Nominal cooling range (difference between the cooling tower water inlet and outlet temperature) of the tower is 9,2 K. Evaporation losses are calculated to be approximately 1% of the nominal flow of water through the system, [6].

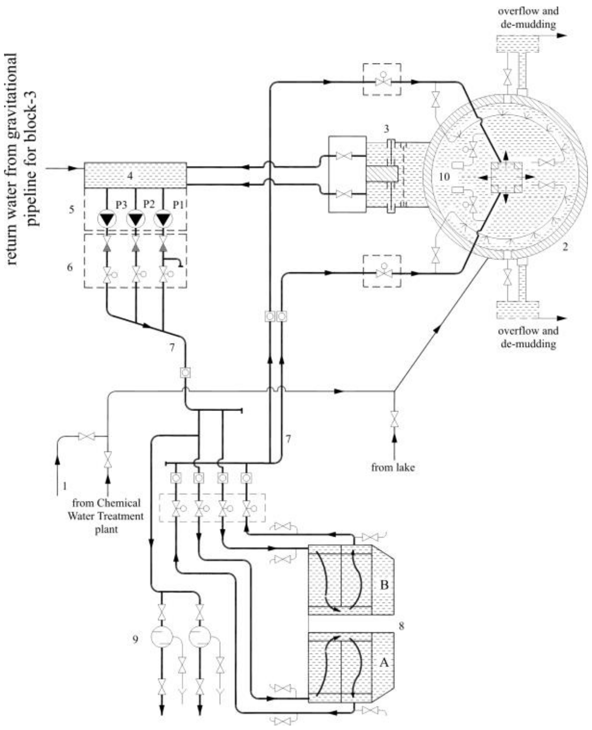


**Fig. 1.** Schematics of the circulation cooling water system for Unit-3; 1 – water treatment station; 2 – natural draught cooling tower; 3 – valves with colander; 4 – entering water chamber; 5 – pump station; 6 – pit with valves; 7 – circulation pipelines; 8 – condenser; 9 – mechanical water filters; 10 – unit for winter operation of the cooling tower.

**Discussion and Results:** A review of scientific and technical literature with reference to research conducted in this field has been made in order to determine feasible utilization of nanofluids for enhancing the heat transfer at the cooling tower in the above described power plant.

Improved efficiency of the whole system due to enhanced thermophysical properties (i.e. thermal conductivity) of nanofluids compared to the base fluid (in this case water) is the main motive of its application. Nanoparticle materials include chemically stable metals (i.e. gold, copper), metal oxides (i.e. alumina, silica, zirconia, titania), oxide ceramics (SiC), metal nitrides (diamond, graphite, carbon nanotubes, fullerene) and functionalised nanoparticles, [7]. Typical nanofluid is characterised with uniform dispersion of nanoparticles.

There are few ways to optimize operating parameters of the cooling tower, such as water flow rate, water temperature, thermal characteristics of tower's fill, geometry of the tower etc. While some of these parameters are not controllable or cost-effective to change, some are not applicable for already operational cooling towers.

The use of nanofluids as coolants in intensive heat transfer processes has been extensively studied, mostly for nuclear reactor applications, [8, 9]. The use of nanofluids in cooling tower is an excellent option to improve its performance. Nanofluids can improve the heat performance of the cooling tower by increasing the sensible and evaporating heat transfer leading to significant reduction in water use of the tower and power plant in general. This is very important because around 60% of the total annual water consumption of the above described thermal power plant is attributed to evaporation from the cooling towers, [6].

Recent researches showed that the use of nanofluid improves the performance of both condenser and cooling tower leading to reduction of sizes of both. Application of nanofluids incorporating nanoparticles with phase-change material cores that melt to absorb heat from steam turbine condensate and solidify as cooling proceeds could reduce overall water consumption by as much as 20%. The improved thermal properties offered by these multifunctional nanoparticles also are expected to decrease coolant flow rates by about 15%, helping lower the associated pumping loads and thus own needs' energy losses, [10], Fig. 2. Internal reports regarding own needs' electricity consumption at the TPP Bitola, [11], show that the electricity consumption of pumps used at power plant's cold end amount to 10% of the total annual own needs' electricity consumption.

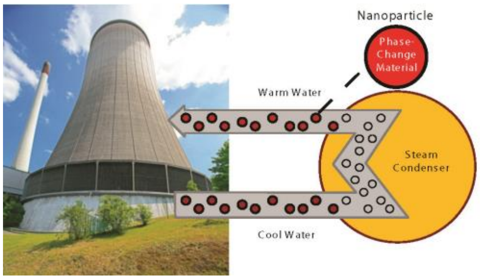


**Fig. 2.** Heat – absorption nanoparticles are expected to significantly improve the thermophysical performance of steam-condensing coolants, reducing freshwater consumption at power plants with wet cooling towers, Source: [10].

Evaporation rate of cooling water at wet cooling tower with natural draught highly depend on external air conditions (mainly air temperature and humidity). According to [12] and by assuming linear correlation between heat transfer coefficient increase by using nanofluids and decrease in evaporation rate of cooling water, dependence between evaporation rate and external air temperature for nominal cooling range of 9,2 K are shown on Fig. 3. Assumption is made for 4 different rates of heat transfer coefficient increase (5%, 10%, 15% and 20% respectively). Other reference parameters for cooling tower of TPP Bitola: relative air humidity 50%, nominal flow of cooling water 30000 $m^3$/h.

**Conclusions:** In this paper, a review on potential applications of nanofluids in heat removal from wet cooling tower is addressed. Current level of research in this potentially promising field of thermal engineering is also briefly described. Lignite fired thermal power plant Bitola in Macedonia, as largest electricity producer in the country has been used as a model for comparison of possible benefits from utilization of nanofluids in steam-condensing process.

There are many advantages of using nanofluids in cooling towers, such as: increase in heat transfer performance of the cold end (cooling tower and condenser) leading to overall increase in efficiency; reduction of water loss through evaporation leading to reduction of water consumption in the cooling tower and in the power plant in general; reduction of sizes of cooling tower and condenser and reduction of electricity consumption of pumps used in this system.

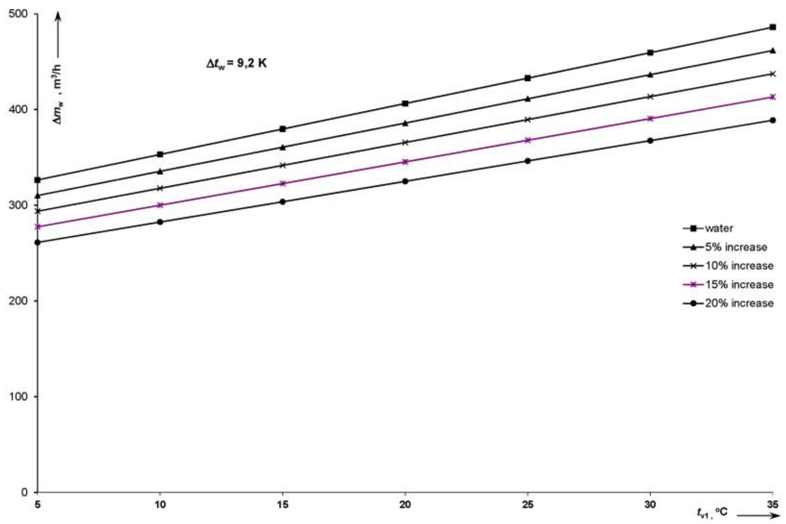


**Fig. 3.** Dependence of evaporation rate of cooling water vs external air temperature relative to increase in heat transfer coefficient by using nanofluids; $\Delta m_w$ – evaporation rate of cooling water, $t_{v1}$ – external air temperature.

Applied on the model power plant these improvements can significantly reduce consumption of fresh water in the plant. At the moment, the plant uses around 12 million $m^3$ of fresh water every year, out of which approximately 7,15 million $m^3$ are consumed by the cold-end itself. Electricity consumption of pumps is estimated at the level of 35 – 40 GWh/year which is more than 1% of the total electricity produced from the power plant in 2014 (3317 GWh), [13]. Thus, possible improvements applied to the referent power plant have great potential.

Still, despite many possible advantages in utilization of nanofluids in the cooling tower application, there are a lot of challenges that need to be addressed and solved prior to wide-scale usage, [7]. These include: high cost of nanofluids and difficulties in production process, stability of nanoparticles in the base fluid, development of practical methods for adding nanoparticles to cooling system to replace losses through drift, evaporation and blowdown. Also, full-scale field demonstrations will be required.

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