ISSN: 2581-3404 (Online) IF: 5.445 (SJIF)

IJIRTM, Volume-7, Issue-5, September-2023.

CFD Analysis on Thermal Power Plant Cooling Tower

Paras Patel[1], Dr. P K Sharma[2]

[1]M.Tech. Scholar, Department of Mechanical Engineering, NIRT, college, Bhopal, MP, India

[2] Associate Professor, Department of Mechanical Engineering, NIRT, college, Bhopal, MP, India

Abstract: *Cooling towers are used in a variety of applications; from the 400-foot-tall towers at nuclear power plants to small 4 foot cooling boxes used by neighborhood dry cleaners. The most common use is in large building central cooling systems, but also used for refrigeration, cold storage facilities, dry cleaning, medical equipment, manufacturing and industry. Cooling towers are generally the most efficient means to remove large amounts of heat from air and equipment. Unfortunately, cooling towers use large amounts of water when properly maintained, and can waste greater amounts of water when not maintained properly through wasteful practices, inefficient equipment and leaks. Industrial cooling towers are used to remove surplus heat from water. In this study, a review study is carried out to investigate different types of cooling towers, their application, performance, usage and working principles, which can be useful in the field of nuclear plants as well as other energy stations. A number of investigations have been considered to reveal differences between the used cooling towers and finally a Fluent simulation has been carried out to examine major contours and flow field around the cooling tower.*

Keywords: Cooling tower, Heat exchanger, Nuclear Energy, Waste heat.

Introduction

Cooling towers are heat rejection devices used to transfer waste heat to the atmosphere through the cooling of a water stream. Cooling towers are mostly employed for cooling the circulating water used in power plants. A number of numerical and experimental studies have been done on the cooling towers. In this section, a summary of some valuable works is presented.

Power Plant

A thermal power plant is a power station where thermal energy is converted to electric power. In most of the places in the world the turbine is steam-driven. Generally, in the process water is heated, evaporated and spins a steam turbine and finally mechanical energy converted to the electric power by an electrical generator. This process can be well defined by on a Rankine cycle as shown in the Fig. 1.

Natural Draft Cooling Tower: These towers rely on the natural movement of air due to differences in temperature and density to circulate air through the tower. They are often large structures with a distinctive hyperbolic shape. Natural draft cooling towers are known for their efficiency in dissipating large amounts of heat without the need for energy-consuming mechanical fans. However, they are often larger and taller structures compared to mechanical draft cooling towers due to the need to create a sufficient temperature and density differential to drive the airflow.

These cooling towers are commonly used in power plants and large industrial facilities where a significant amount of heat needs to be removed from processes. While natural draft cooling towers offer benefits in terms of energy efficiency, they do require careful design and engineering to ensure proper air circulation and effective cooling.

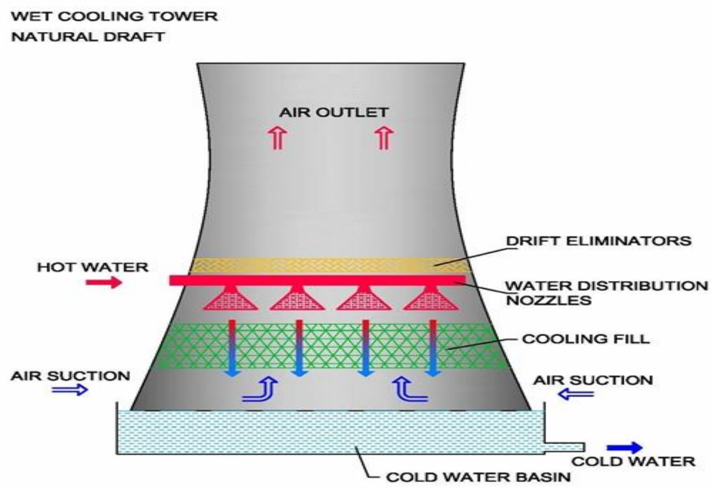

Figure 1: Natural Draft Cooling Tower.

Mechanical Draft Cooling Tower: These towers use mechanical devices such as fans to draw or push air through the tower, enhancing the cooling process. Mechanical draft towers can be further categorized as induced draft (air is pulled through the tower) or forced draft (air is pushed through the tower) based on the fan's location.

Cooling towers play a crucial role in maintaining the efficiency of industrial processes that generate significant amounts of heat. Some common applications of cooling towers include:

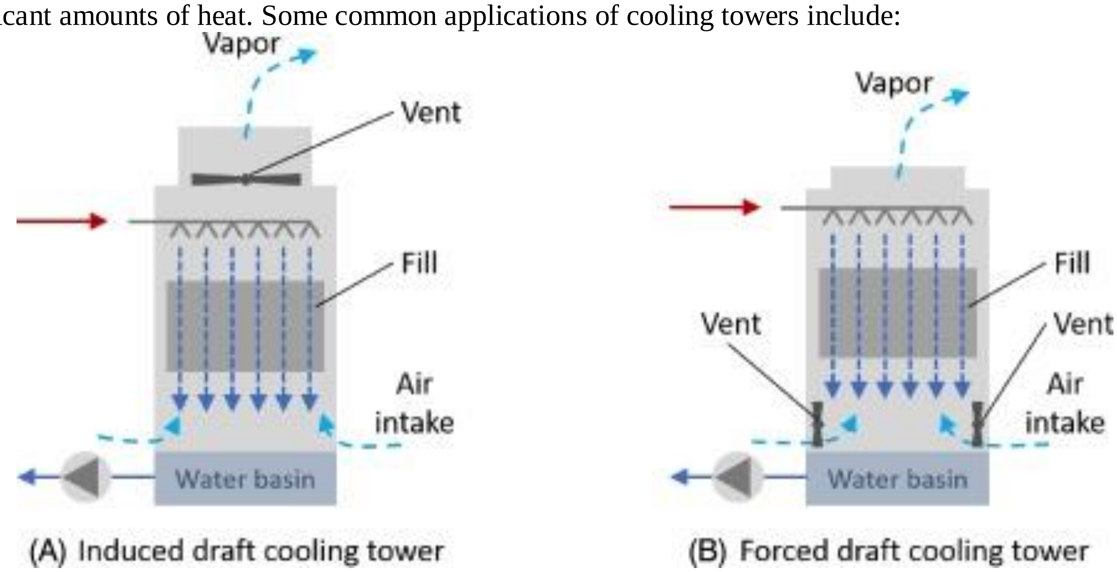

Figure 2: Mechanical draft cooling tower.

Power Plants: Cooling towers are commonly used in power plants to cool the circulating water used in the steam condensation process, which is essential in electricity generation.

Power plants are facilities designed to generate electricity through various methods. Electricity is a vital form of energy that powers homes, businesses, industries, and almost all aspects of modern life. Power plants convert different types of primary energy sources into electricity, which can then be distributed to consumers through power grids. Here are some common types of power plants:

Fossil Fuel Power Plants:

Coal Power Plants: These plants burn coal to produce heat, which is used to generate steam and drive turbines connected to generators.

Natural Gas Power Plants: Natural gas is burned to produce high-temperature gases, which drive turbines to generate electricity. Combined cycle plants use both gas and steam turbines for greater efficiency.

Oil Power Plants: These plants use oil (usually heavy fuel oil) to generate heat, which is then converted into electricity.

Nuclear Power Plants:

Nuclear power plants use nuclear reactions to produce heat, which is used to generate steam and drive turbines. They rely on the controlled fission of radioactive materials such as uranium or plutonium.

Renewable Energy Power Plants:

Hydroelectric Power Plants: These plants harness the energy of flowing water (usually from dams) to turn turbines and generate electricity.

Solar Power Plants: Solar farms use photovoltaic panels or concentrated solar systems to convert sunlight directly into electricity.

Wind Power Plants: Wind turbines capture the kinetic energy of the wind and convert it into electricity through the rotation of blades.

Geothermal Power Plants: These plants utilize heat from within the Earth's crust to produce steam, which drives turbines and generates electricity.

Biomass Power Plants: Biomass, such as wood, agricultural residues, or waste, is burned or converted into biogas to generate heat and electricity.

Hybrid Power Plants:

Some power plants combine multiple energy sources to optimize efficiency and reliability. For example, a solar-wind hybrid power plant could generate electricity using both solar panels and wind turbines.

Cogeneration Power Plants (Combined Heat and Power, CHP):

Cogeneration plants produce both electricity and useful heat from a single energy source. The waste heat produced during electricity generation is used for heating purposes in nearby buildings or industrial processes.

Wave and Tidal Power Plants:

These plants capture the energy of ocean waves and tides to generate electricity. Wave energy converters and tidal stream turbines are used for this purpose.

Fuel Cell Power Plants:

Fuel cells electrochemically convert hydrogen or other fuels into electricity and heat. They are often used for distributed power generation or backup power.

The choice of power plant type depends on factors such as available energy resources, environmental considerations, location, technology, efficiency, cost, and regulatory factors. Over the years, there has been a growing emphasis on transitioning towards cleaner and more sustainable sources of energy to mitigate environmental impacts and reduce reliance on finite fossil fuels.

Manufacturing Facilities: Industries like petrochemicals, steel, and food processing use cooling towers to remove heat generated by various production processes.
HVAC Systems: In large buildings, cooling towers can be part of the HVAC system to regulate indoor temperatures by dissipating excess heat from air conditioning systems.
Data Centers: Cooling towers can be used to cool the equipment in data centers, which generate a significant amount of heat due to the operation of servers and other hardware.
While cooling towers are effective in cooling industrial processes, they also require proper maintenance to prevent issues like scaling, corrosion, and the buildup of algae and bacteria in the water. Improper maintenance can lead to reduced efficiency and potential health hazards.
It's worth noting that in recent years, there has been increasing interest in more energy-efficient and environmentally friendly cooling technologies to address concerns about water consumption and environmental impact.

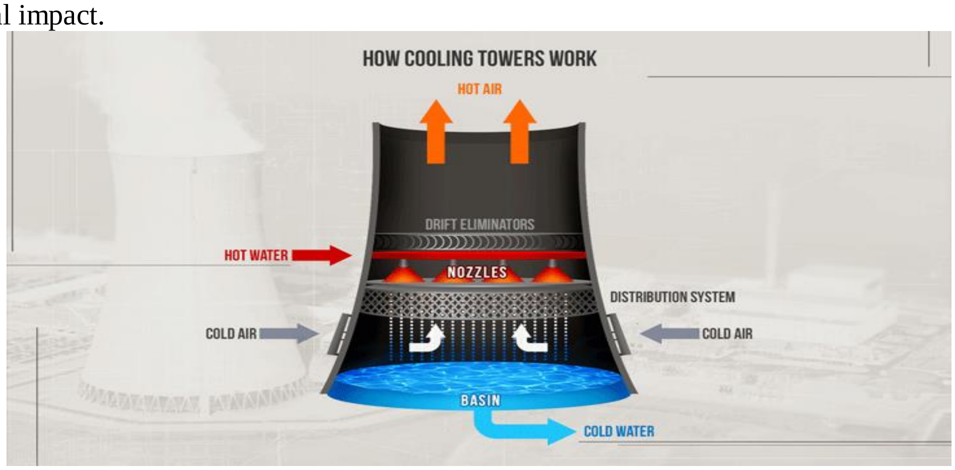

Figure 3: Heat cooling works.

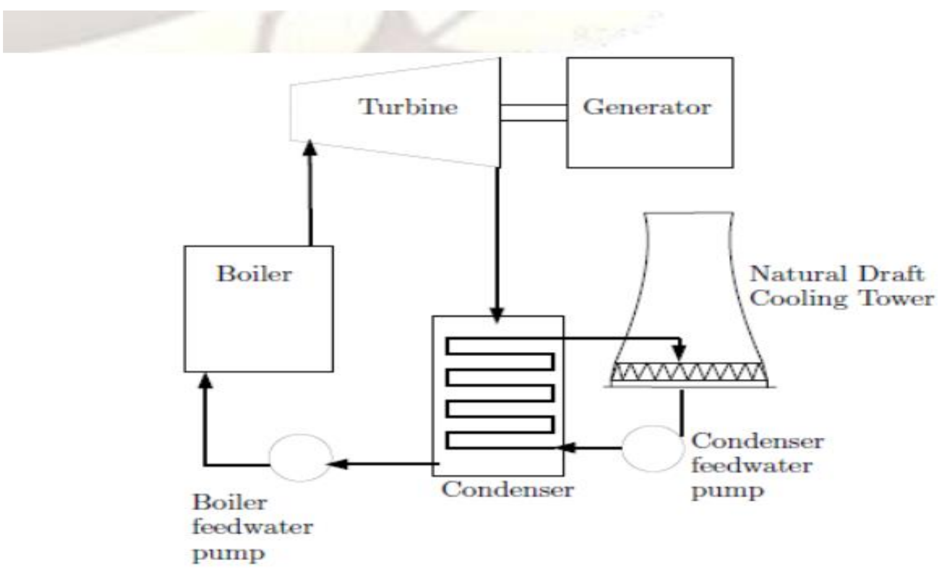

Figure 4: Heat cooling tower works.

Heat Transfer Methods

The main types of the heat transfer methods used in cooling towers can be classified as shown in Fig. 7 and described in following,

Dry cooling towers;

In this method, the working fluid is separated from ambient air and the process is approximately similar to tube type heat exchangers, and convective heat transfer has a major role in this method. Their shapes, are also similar to that of evaporating types except the internal construction. In general, a dry type cooling tower works at the same principles as an automobile radiator.

Wet or evaporating cooling towers;

The principle of evaporative cooling is used in this method. Direct contact of cooling water with air occurs within the cooling tower. Most of the heat is rejected by evaporating a portion of the circulating water, while a lower level of heat is also lost by heat transferring to the air.

Wet/dry type cooling tower;

This new proposed type of cooling tower as a mixed method can reduce water consumption to about 20% of the conventional wet type cooling towers (which is an undesirable issue to power plant cooling- systems). Fig. 8 shows the structure of Wet/dry cooling towers (Shen Chou1973).

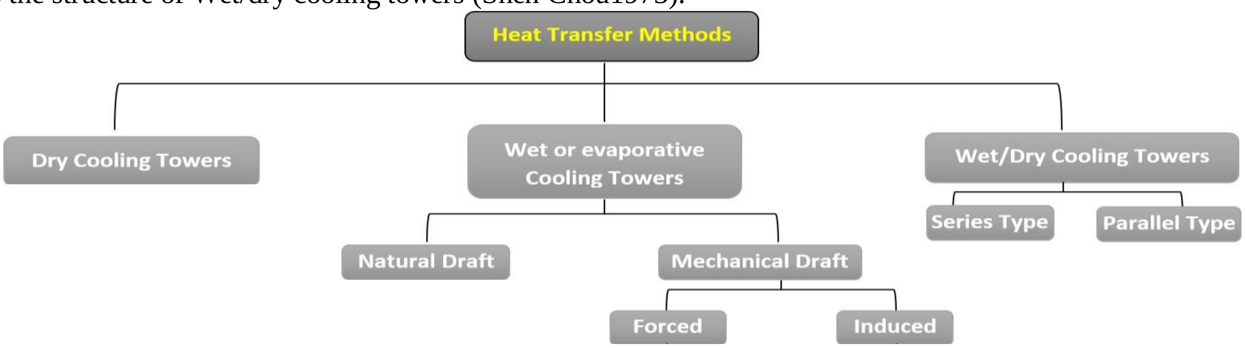

Figure 5: Heat transfer methods.

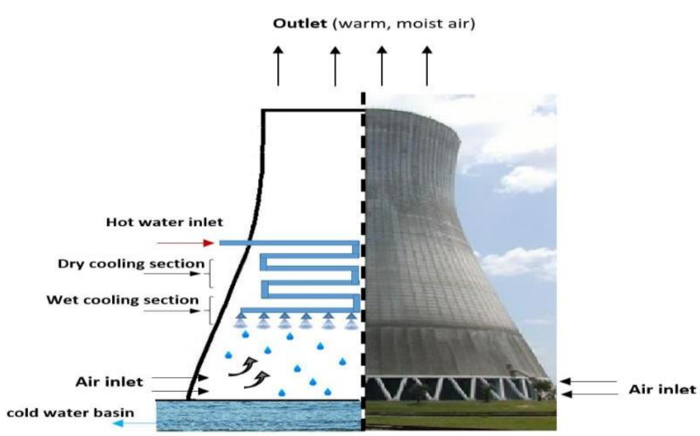

Figure 6: Wet / Dry type cooling tower.

Size of Cooling Towers

The towers size is designed regarding the required cooling performance and are either built in the site (in the case large towers) or in the factory (small towers). Towers size is different from small roof-top type to very large hyperboloid towers that are built even higher than 200 meters and 100 meters in diameter, or rectangular cases higher than 40 meters tall and 80 meters long. For increasing the efficiency of cooling tower one of tallest towers was built in Niederaussem Power Plant in Germany, which is a natural draft cooling tower and is also the largest shell structure in the world (Busch et al 2001).

Effects on Ecosystem

Without cooling tower and using once-through water for the aim of cooling, it would require huge amount of water and warmed water would have to be continuously returned to the river, lake or ocean, from which it was again obtained and resupplied to the power plant. In this regard, discharging warm water consumed in huge power plants may increase the temperature of the receiving lake or river and change the local ecosystem. The raised water temperatures can harm aquatic organisms, kill fish and other living creatures. On the other hand, cooling towers release a large amount of heat into the atmosphere instead, which spreads by wind over a much larger region than that of hot water can distribute local waters. Unfortunately, petroleum refineries also consume very large amount of water in cooling tower as well as coal-fired and nuclear power plants. Locating in coastal areas and using once-through ocean water, cooling towers should be examined for discharge water condition to avoid environmental pollution.

Results

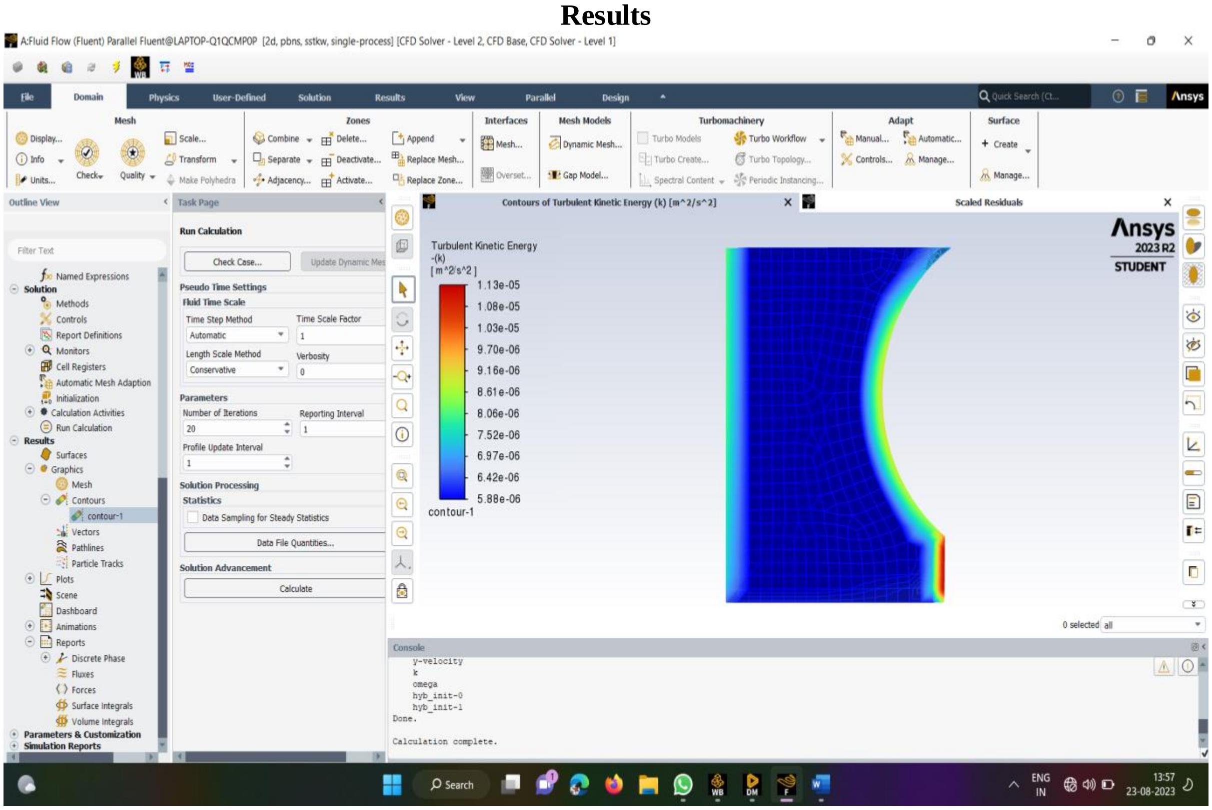

Figure 7: Cooling tower cfd results.

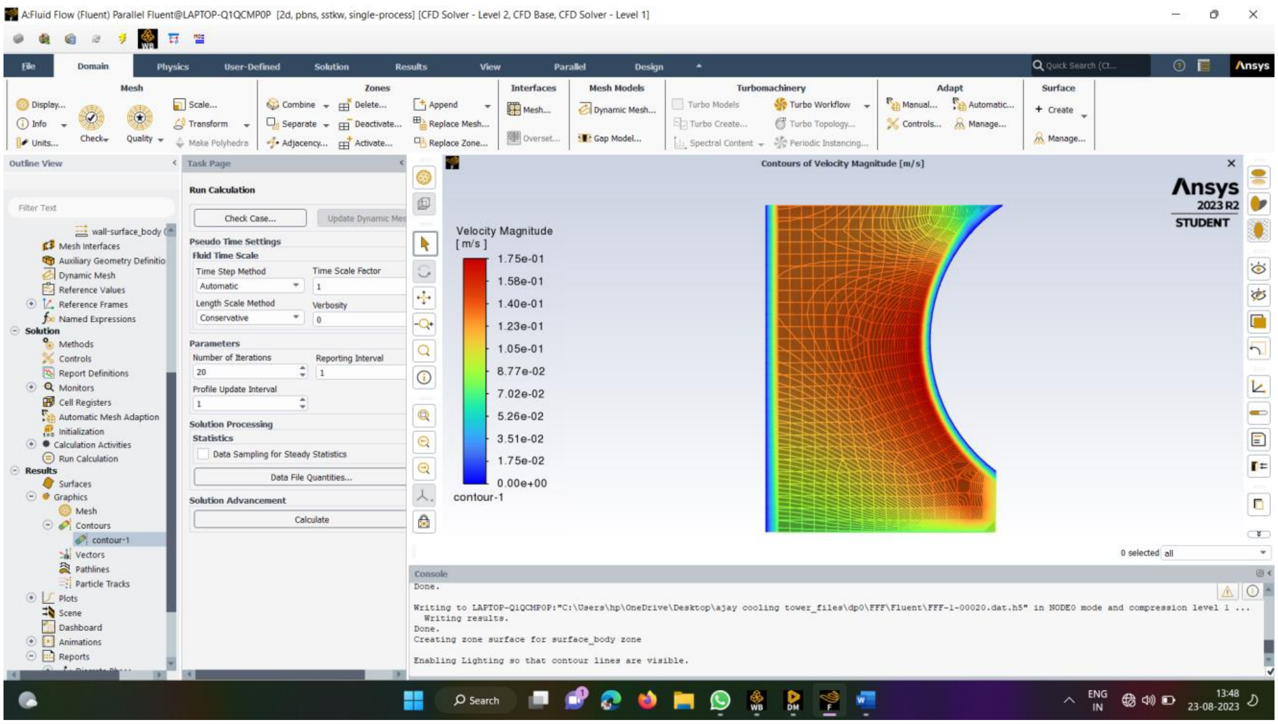

Figure 8: Cooling tower cfd results.

Conclusion

The temperature of natural draft wet cooling tower at inlet of tower the temperature of cold ambient air is 300k., when it comes in contact with hot water in the rain zone suddenly temperature of air increases. Near the axis of tower the temperature of hot air and water particle remain high due to choking of air around axis. The highest heat transfer takes place in fill zone and the temperature of air becomes high. Total pressure suddenly falls to fill area at 20 m than slight increases according to height. The thermal conductivity is very high at and near the axis because of high temperature and low density and very poor near wall. Density is high near wall and low near axis.

References

1. P Chandra Shekhar , Sudhir Singh Rajput "Thermal Analysis of Cooling Tower using Computational Fluid Dynamics" International Journal of Trend in Scientific Research and Development (IJTSRD) Volume 6 Issue 2, January February 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470 .

2. Ahmed Aboulmagd , Ashraf Sayed Ah "Numerical Investigation of Cooling Tower Performance under Constant Heat Load ""International Journal of Trend in Scientific Research and Development (IJTSRD) Volume 6 Issue 2, January February 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470.

3. Guangjun Yang, Li Ding, Tongqing Guo, Xiaoxiao Li, Wenxin Tian, Zhen Xu, Zhigang Wang, Furong Sun, Junjie Min, Jingxin Xu, Sheng Wang, Zhaobing Guo, Study of flue gas emission and improvement

measure in a natural draft dry-cooling towerwith flue gas injection under unfavourable working conditions, Atmospheric Pollution Research, Volume 11, Issue 5, (2020), Pages 963-972.

4. A. Jahangiri, A. Borzooee, E. Armoudli “Thermal performance improvement of the three aligned natural draft dry cooling towers by wind breaking walls and flue gas injection under different crosswind conditions” International Journal of Thermal Sciences 137 (2019), 288–298.

5. Jiang, J. J., Liu, X. H., & Jiang, Y. (2013). Experimental and numerical analysis of a cross-flow closed wet cooling tower. Applied Thermal Engineering, 61(2), 678-689.

6. Asvapoositkul, W.,& Treeutok, S. (2012).Asimplified method on thermal performance capacity evaluation of counter flow cooling tower. Applied Thermal Engineering, 38, 160-167.

7. Lemouari,M.,Boumaza, M., & Kaabi, A. (2009) Experimental analysis of heat and mass transfer phenomena in a direct contact evaporative cooling tower. Energy conversion and management, 50(6), 1610-1617.

8. Muangnoi, T., Asvapoositkul, W., & Wongwises, S. (2008). Effects of inletrelative humidity and inlet temperature on the performance of counter flow wet cooling tower based on exergy analysis. Energy Conversion and Management, 49(10), 2795-2800.

9. Qi, X., & Liu, Z. (2008). Further investigation on the performance of a shower cooling tower. Energy Conversion and Management, 49(4), 570- 577.

10. Kloppers, J. C., & Kröger, D. G. (2005). A critical investigation into the heat and mass transfer analysis of counter flow wet-cooling towers. International Journal of Heat and Mass Transfer, 48(3), 765-777.

11. Fisenko, S. P., Brin, A. A., & Petruchik, A. I. (2004). Evaporative cooling of water in a mechanical draft cooling tower. International Journal of Heat and Mass Transfer, 47(1), 165-177.

12. Facao, J., & Oliveira, A. (2004). Heat and mass transfer correlations for the design of small indirect contact cooling towers. Applied thermal engineering, 24(14), 1969-1978.