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Review on Study of Inlet parameter of cooling Tower

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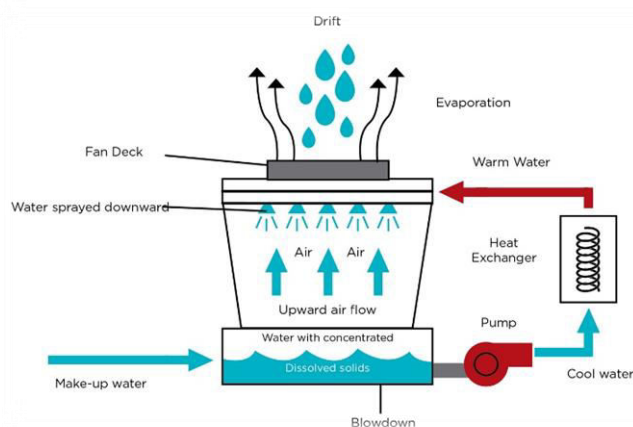
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ABSTRACT: This review paper gives an idea about how we will do study and research on inlet parameters of cooling tower. A cooling tower is a type of heat exchanger used to reduce the temperature of a water stream by extracting heat from water and emitting it to the atmosphere. Cooling towers use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature. Cooling towers are able to lower the water temperatures more than devices that use only air to reject heat, like the radiator in a car, and are therefore more cost-effective and energy efficient. They are generally used in HVAC applications. There are many types of cooling towers available. The forced draft cross flow and counter flow cooling tower are the most common ones used in HVAC applications. Forced draft cooling tower is a type of mechanical draft tower which has a blower type fan at the air intake. With the fan on the air intake, the fan is more susceptible to complications due to freezing conditions. The benefit of the forced draft design is its ability to work with high static pressure. Such setups can be installed in more-confined spaces and even in some indoor situations. This fan geometry is also known as blow-through. The fan forces air into the tower, creating high entering and low exiting air velocities. The low exiting velocity is much more susceptible to recirculation.

KEYWORDS: Air inlet parameters, forced draft cooling tower, HVAC, Blower.

I. INTRODUCTION

Cooling towers are recirculating water systems used to remove heat from building air conditioning equipment and industrial processes. They require specialized maintenance to ensure safe, efficient, and reliable operation, including an effective water treatment program. By understanding how cooling tower systems function, facility owners and operators can operate and maintain their systems more effectively. Cooling tower systems work by using water to extract waste heat from a system and ejecting it into the atmosphere primarily through evaporation. The three key components of a cooling system are the cooling tower, recirculating pump, and heat exchanger. Water first passes through a heat exchanger where it absorbs heat. The water is then distributed over the top of the cooling tower where air travels past the warm water causing a portion of the water to evaporate. The heat is transferred from the water stream to the air stream, raising the air's temperature and its relative humidity to 100%. This warm air is then discharged to the atmosphere, resulting in a cool water stream. The cooled water from the basin is then pumped back through a heat exchanger and the cycle repeats. Evaporative heat rejection devices such as cooling towers provide significantly lower water temperatures than those achievable with air cooled or dry heat rejection devices, thereby achieving a more cost-effective and energy-efficient cooling system. Cooling towers save a lot of water and energy versus air-cooled HVAC or process cooling systems. For example, it can take 50% more electricity to operate a 400-ton air-cooled chiller than it does a 400-ton water-cooled chiller. With the proper cooling system programs in place, building HVAC, cold storage, and industrial cooling systems can be optimized for the most efficient output while minimizing operating costs.



Cooling towers require proper maintenance to ensure the most efficient operation and to reduce downtime. There are several cooling tower challenges: water conservation, corrosion, scale, deposits, and microbiological activity. Evaporated water leaves behind dissolved impurities from the makeup water which can become concentrated leading to scale, deposits, and corrosion. These issues can cause water equipment failure leading to production downtime, added costs, and reduced efficiency. Professional water treatment minimizes these challenges by expert support, focused optimization, and industry Best Practices.

II. LITERATURE SURVEY

Parimala murugaveni, P Mohamed Shameer [1] in their research they carried out cooling tower performance has been analyzed by varying air inlet parameters with different air inlet angles and by attaching a nozzle in air inlet. The cooling tower analyzed here is used specifically for small scale industries, which is a forced draft counterflow cooling tower with single module capacities from 10 to 100 cooling tons. In this paper, they made their body of cooling tower in solidwork and they done analysis of inlet and outlet parameter using ANSYS software Air Inlet Pipe Angles 0° , 30° about horizontal axis, 30° about vertical axis, 30° about both horizontal and vertical axis (that is along z axis). Conclusion: by varying angle of inlet air pipe, we are able to slightly increase effectiveness (from this paper we trying to do extra analysis at 45 degree).

Priyanka G.M.R. Nagraj [2] in their research they carried out with a view to predicting the performance of a shell and finned tube heat exchanger in the light of waste heat recovery application. The performance of the heat exchanger has been evaluated by using the CFD package ANSYS13.0. They made an attempt to predict the performance of the heat exchanger by considering different heat transfer fluid and the result so obtained have been compared. The analysis is carried out and pressure drop and temperature rise along the tube surfaces has been investigated. They found that energy extraction rate is quite significant, that means the effectiveness of exchanger is higher by increasing the contact surface area of hot and cold fluid by using the finned tube heat exchanger.

Mohd Amir, Fithry, Yusoff, MohdZamri [3] in their paper explored the area in the cross-flow cooling tower where the focus on where the porous media or the fill / packing are located and the area in the vicinity for a single-phase flow. The behavior of the air intake flow into the cooling tower from the side part through the fill was observed and how it affects the distribution of the air flow inside the fill will be analyzed. The solution of the related governing equation for the basic flow and for flow involving porous media was presented. It was revealed that the porosity introduced a high pressure drop inside the cooling tower. The pressure inside the cooling tower generally is lower than before the porous media was introduced. The results also revealed that if the heat transfer inside the porous media is to be improved, higher dynamic pressure inside the cooling tower is required which would result in higher fan power output.

Dr. Jalal M. Jalil, Dr. Talib K. Murtadha, Dr. Qasim S. Mehdi [4] conducted numerical and experimental studies for open type forced draft water-cooling tower. The numerical part includes a three-dimensional computational solution of air and water simultaneous equations which represents the fluid flow, heat transfer and mass transfer. They estimated that high air flow rate gives low approach that leads to increase in effectiveness of cooling tower and also the cold-water temperature increases with increment in the air wet bulb temperature. Experimentally, mechanical forced draft counter-flow cooling tower was used to validate the numerical results. The agreement seems acceptable between the numerical and experimental results.



Dr. D. Al. D.H. Alwan Dr. I. W. Maid A. H. [5] in their article, presents an experimental and numerical investigation of the performance of a forced draft counter flow cooling tower with two kinds of wire mesh packing. The packing used in this study is wire mesh with small square holes (WMSSHSP) and expanded wire mesh with diamond holes (EWMDHSP) configurations. In the numerical investigation, the two-dimensional CFD model with finite volume scheme has utilized the standard turbulence model to compute the air properties, while one-dimensional model is used to get the water properties. From the results it is concluded that the (EWMDHSP) enhance the performance of the cooling tower. That is due to the pressure drop in the (WMSSHSP) is higher than that for the (EWMDHSP) because air resistance of the former pack is higher than the latter pack. The agreement seems to be acceptable between the numerical and the experimental results.

Nader Pourmahmoud, Amir Hassan Zadeh, Omid Moutaby, And Abdolreza Bramo [6] performed research on the energy separation and flow field behavior of a vortex tube by utilizing both straight and helical nozzles. They mentioned that higher swirl velocity is obtained at 450 in divergent nozzle and at 300 in convergent nozzle. Higher swirl velocity due to appropriately nozzle shapes can effectively influence the exit gas temperature. Three kinds of nozzles set include of 3 and 6 straight and 3 helical nozzles have been investigated and their principal effects as cold temperature difference was compared by using CFD software.

Santosh Kumar, Chandrasekhar Prasad, Tajo Pawan, Gobinath N, Shyam Kumar, Feroskhan [7] in their research experiments are conducted to examine the performance of a cooling tower used for a stationary IC engine, with different bed materials at three different flow rates. From the experiments, it is evident that at higher flow rates jute carpets with mesh show better cooling, while coming to lower flow rates polystyrene balls perform better. At low flow rates, it is clear that the usage of mesh does not influence the cooling process. At high flow rate, the jute material with mesh provided 50% efficiency while the polystyrene material without mesh corresponds to 25% efficiency. The present research work established the significance of a cooling tower in a small scale for industrial applications through the determination of various performance metrics of the tower.

Sunil Vikas Kesare, Prof. Swami [8] in their research they did Analysis and optimization of Centrifugal Blower impeller by using FEA. To reduce the corrosion problem of the blower SS204L material is used. By corrosion test Stainless steel is more corrosion resistant than M.S.

Pooja Magar, Mahesh Shinde, Prof. Kshirsagar [9] in their research they did Design analysis and optimization of centrifugal Blower. Property of Blower increased without changing material, Stress directly proportional to displacement, FOS is large for 3mm thickness material.

Tushar Ambedkar, Dr. Barve, Nilesh Dhokane Farhan Khammas [10] in their research they did Design analysis of engine cooling fan. Analysis such as static and structural were done on 3D software's.

Farhan Khammas in their research they did improving the Environmental Cooling for Air coolers by Using the in-direct cooling method. Direct evaporative, Indirect evaporation (natural and forced evaporation) is used at different times in day. Indirect cooling has advantages like noise reduction, power consumption saving only occurred in natural case. Indirect method is independent of outdoor condition. [11]

Tawsif Mahmud, Md. Kamrul Islam, Bodius Salam in their research paper they did experimental study of forced draft cross flow wet cooling tower using splash type fill. They deal with an experimental analysis of heat transfer phenomena between water and air by direct contact in a cross-flow forced draft cooling tower model. The tower is filled with splash type packing while sprayer nozzles are used to distribute the warm water. The packing is 10 inch high and consists of four stages having a distance of 2.5 inch between two stages. Each packing provides 11.5 inch \times 1.75-inch cross sectional test area. This study investigates the effect of the air and water flow rates on the cooling capacity and effectiveness of the wet cooling tower as well as the evaporation loss of water into the air stream and the percent loss of water. The observations were made for six different air velocities and three different water flow rates by keeping the inlet water temperature constant. Performance factors like range, approach, effectiveness, cooling capacity, evaporation loss, percent loss is calculated from collected data. The results represent that effectiveness of cooling tower is higher for low water flow rate while the situation is reverse in case of cooling capacity. In contrast, all the parameters except approach increase with the increase of air velocity. As it is observed that cooling tower performance increases with the increase in air velocity, but at the same time evaporation loss and drift loss increases which causes need for extra make up water, so choosing a perfect air velocity which will give better effectiveness and less loss is important. Installing precise temperature control device at inlet to supply continuous hot water at constant temperature and using screen with ventilation in front of stages will be some paths to improve the performance of this cooling tower. [12]



Pavol Vitkovic, Vitkovic Syrovatka, Jiri Nozicka in their research they did design of model of cooling tower build in a laboratory of department of Fluid Dynamics and Thermodynamics and measurement on this cooling tower. The construction, process of measurement, evaluation of measured data together with used measuring instruments and devices are described. For the experiment 8 models with different input parameters for 4 and 5 layers of fill.[13]

J. Jay Prabhakar in their research they did experimental investigation on the effect of fill materials in cooling tower.[14] Shaymaa A. Ahmed, Sheam Abdul Kareem, Hasan F. Makkif in their research they did investigation hydraulic performance of splash fills packing in cooling tower. Their interests with hydraulic characteristics of zig-zag pattern. They used treated waste water and focused fundamentally on the influence of air and water flow rates on hydraulic features of cooling tower for different access water temperatures. The dependency between pressure drops and the air and water flux were spotted. They found that within a certain range the pressure drops increases by 75% due to liquid flux and 70% due to air flux while pressure drop is not affected by changing temperature at all. Two empirical correlations had been founded for dry pressure drop (with $R^2=99.5\%$) and for wet pressure drop (with $R^2=98.13\%$) [15] Pooriya Shahali, Mehdi Rahmati, Seyed Rashid Alavi, Ahmad Sedaghat [19] in their study they did Experimental study on improving operating conditions of wet cooling towers using various rib numbers of packing. In this experimental work, the WCT performance is parametrically investigated in order to understand effects of water flow rate, inlet water temperature, type and arrangement of packing, and mass flow rate of air. Three different types of PVC packings (7, 9 and 18 ribs) are studied in this article separately to investigate influences of rib numbers.[16]

I.M. Kuzmenko [20] in their research they did experimental research they did experimental research of heat transfer in cooling tower. From their research they find that thickness of heat transfer dissipation layer is 3 times bigger than that of boundary layer calculated theoretically. The experimental thickness of water film is much less than thickness of boundary layer in the water film calculated experimentally. Therefore, the process of heat transfer in water film is unsteady. The heat transfer in the water film with a deviation of up to 24 % is describes by a known equation. The difference in water film temperature in the is about 0.52-1.28°C and in the air 34.9-51.3°C. This depends on input of water temperature and slightly depends on the air velocity.[17]

Bilal A. Qureshi, Syed M. Zubair in their research they did a complete model of wet cooling towers with fouling in fills. A complete cooling tower model is investigated by using engineering equation solver (EES) program, which is validated with the experimental data reported in the literature. It is demonstrated through a case study that it is important to include the spray and rain zones in analyses for a greater accuracy in design as well as rating calculations. This is mostly important in medium and large-size cooling towers. The results show a comparative improvement in the prediction of the wet-bulb temperature of the outlet air for the coupled three zone model. A comparison of the calculated volume is carried out against the known volume of the tower as each zone is included in the analysis. The error in volume prediction, with the addition of each zone, is calculated as 6.5%, 3.2% and 2.7%. The results indicate that these zones should be included in reliable analyses of cooling towers. Fouling is a major source of cooling tower performance deterioration and, therefore, a strategy to model fouling in cooling tower fills is also outlined to highlight the importance of fouling in rating calculations of cooling towers.[18]

R. Ramkumar A. Ragupathy has discussed an experimental investigation of the thermal performance of forced draft counter flow wet cooling tower with expanded wire mesh type packing. The packing used in this work is wire mesh with vertical [VOWMP] and horizontal [HOWMP] orientations. The packing is 1.25 m height and having a zigzag form. From the experiments it is concluded that the vertical orientation of the packing enhances the performance of the cooling tower.[19]

XiaoniQi, Yongqi Liu, Zhenyan Liu has described about a descriptive mathematical model of energy and exergy for a shower cooling tower (SCT). The model is used to predict the variation in temperature and exergy along the tower length. The validity of the model for predicting variations in gas and liquid characteristics along the tower length was examined against some operating data measured in a cooling tower company. The results show that the exergy of water decreases as tower height increases. The distribution of the exergy loss is high at the bottom and gradually decreases moving up to the top of the tower. Moreover, 1.50 m/s air velocity results in less exergy destruction. With a decrease in the size of the water droplets, the fluids carrying energy have more opportunities for mass and energy transfers.[20]

B Bhavani Sai, I Swathi, K S L Prasanna, K Srinivasa Rao has described a detailed methodology of a Induced draft cooling tower of counter flow type in which its efficiency, effectiveness, characteristics are calculated. The technical data has been taken from a mechanical draft cooling tower. Cooling towers are heat removal devices used to transfer



process waste heat to the atmosphere. Cooling towers make use of evaporation whereby some of the water is evaporated into a moving air stream and subsequently discharged into the atmosphere. As a result, the remainder of the water is cooled down significantly.[21]

Ding Feng, Xing Ke-jia, Li Shi-Bei, Bai Jun-Hong they have described Sensitiveness of cooling tower based on the atmospheric dispersion model from VDI3784 guidelines in German, the sensitivity analysis of plume rising height from Cooling Tower is calculated by using six factors and five levels of orthogonal test method. The results showed that: the main factors affecting the plume rising height is the atmospheric stability, with the average plume rising height of 469 meters; followed by wind speed, the average range of 447 meters; while the least effect of the flue gas and flue gas flow rate of liquid water content on significant uplift, the average range of 186 meters and 178 meters.[22]

Y.A. Li and M.Z. Yu, F.W. Shang, P. Xie has describes the counter flow closed circuit cooling towers developed by the authors. The new cooling towers have many desirable features, including pure water, low noise, safety, energy effective and so on. The mathematical models of the counter flow closed circuit cooling towers are established in terms of mass and heat balance. An analytical solution of the counter flow closed circuit cooling towers is carried out. Performance curve of the cooling towers is drawn and it is mainly calculated that the outlet temperature of cooling water varies with the spray water flow rate. Results of the theoretical calculation are found to be close to the experimental data.[23]

Lu, W. Cai has described about a universal engineering model, which can be used to formulate both counter flow and cross flow cooling towers. By using fundamental laws of mass and energy balance, the effectiveness of heat exchange is approximated by a second order polynomial equation. Gauss -Newton and Levenberg-Marquardt methods are then used to determine the coefficients from manufactures data. Compared with the existing models, the new model has two main advantages: (1) As the engineering model is derived from engineering perspective, it involves fewer input variables and has better description of the cooling tower operation; (2) There is no iterative computation required, this feature is very important for online optimization of cooling tower performance. Although the model is simple, the results are very accurate. Application examples are given to compare the proposed model with commonly used models.[24]

Falcao and Oliveira compared simplified models with detailed models and noticed that simplified models based on an overall approach provide as good or even better results as those based on finite differences.[25]

Stabat and Marchio presented a simplified model for closed wet cooling towers based on effectiveness models using a simplification of heat and mass balance equation.[26]

A desiccant-wheel behavioural model has been developed. This model fulfils several criteria, such as simplicity of parameterization; accuracy; ability to characterize the equipment behavior under all operation conditions; and short computation time. The method of characteristics has been applied to the heat-and-mass transfer partial-differential equations. This transformation provides equations which are similar to those of a rotary heat-exchanger. Then, the model is described by the effectiveness-NTU method and identified from only one nominal-rating point. The model predictions have been compared with experimental and manufacturers' data for a broad range of operating conditions. Good agreement has been found.[27]

Cooling towers are increasingly used in buildings as a component of environmental cooling systems. When compared with industrial towers, cooling towers with lower capacities and smaller dimensions can be used for this application, with inlet water temperatures ranging from 22 to 25 C. Correlations for heat and mass transfer coefficients were obtained experimentally for a small-size indirect cooling tower, with a nominal cooling capacity of 10 kW. A detailed analysis of the mass transfer coefficient and spray heat transfer coefficient correlations is made, including the effect of the error in their evaluation on tower efficiency. The new correlations are compared with existing ones and results of their application to a simplified cooling tower model.[28]

Research on recirculating cooling water systems has mostly focused on the individual components. However, a particular design method represented by Kim and Smith accounts for the whole system interactions. In this study, the Kim and Smith design method is expanded and a comprehensive simulation model of recirculating cooling system was developed to account for the interaction between the cooling tower performance and the heat-exchanger network configuration. Regarding this model and considering cycle water quality through introducing ozone treatment technology, a modern methodology of recirculating cooling water system design was established and developed. This technique, called the integrated ozone treatment cooling system design, is a superior designed tool based on pinch



analysis and mathematical programming. It also ensures maximum water and energy conservation, minimum cost and environmental impacts. Related coding in MATLAB version 7.3 was used for the illustrative example to get optimal values in cooling water design method computations. The result of the recently introduced design methodology was compared with the Kim and Smith design method.[29]

The research of desiccant materials that can be regenerated under lower temperature, (near-ambient) is the key of augmenting even greater the contribution that the desiccant cooling can bring to the amelioration of comfort, energy and cost savings.[30]

The significance of the developed model is that it can be easily applied to real-time HVAC system optimization where set points of each energy consumption devices in condenser water loop are related to the model. Therefore, the cooling tower model is the constraint condition in the course of energy minimization of the loop. Further work in the area will concentrate on the development of optimization methods and testing them on the real industrial plant based on the proposed model.[31].

A semi-local numerical model of a sprayed air-cooled condenser was developed and coupled to a simple refrigeration system simulation. 1) The key parameters to calculate a sprayed air-cooled condenser were identified: spray flow rate, wet area and collecting ratio. 2) The model highlighted the presence of a spray flow rate threshold, which depends on the refrigerating machine characteristics and initial ambient conditions (before spraying).[32]

The proposed model of dehumidification wheels for desiccant evaporative-cooling applications satisfies the aims of integration into building-simulation tools. The model is: • Easy to parameterize (needing only a knowledge of only one operating point of the wheel). • Rapidly computed (the model including only one loop which implies at maximum 18 iterations. The simulation of one operating point requires less than one thousandth of a second in a MATLAB environment with a Pentium IV 1,9 GHz). • Able to assess all common operating conditions with satisfying accuracy.[33]

The paper describes the proposed solar-driven liquid desiccant evaporative cooling system and the method used for investigating its performance in providing cold water for a radiant air-conditioning system in Khartoum (Central Sudan). The results of the investigation show that the system can operate in humid as well as dry climates and that employing such a system reduces air-conditioning peak electrical demands as compared to vapour compression systems.[34]

Fouling of cooling tower fills is one of the most important factors affecting its thermal performance, which reduces cooling tower effectiveness and capability with time. In this paper, the fouling model presented in an earlier paper using the experimental data on fill fouling, is used to investigate the risk based thermal performance of the cooling tower. It is demonstrated that effectiveness of the cooling tower degrades significantly with time indicating that for a low risk level $\delta p \approx 0.01P$; there is about 6.0% decrease in effectiveness for the given fouling model. The sensitivity analysis of the cooling tower is investigated for both rating and design calculation for different values of mass flow rate ratios. The effect of atmospheric pressure on the thermal performance of the cooling tower is also demonstrated.[35]

A numerical model for studying the evaporative cooling processes that take place in a new type of cooling tower has been developed. In contrast to conventional cooling towers, this new device called Hydro solar Roof presents lower droplet fall and uses renewable energy instead of fans to generate the air mass flow within the tower. The numerical model developed to analyze its performance is based on computational flow dynamics for the two-phase flow of humid air and water droplets. The Eulerian approach is used for the gas flow phase and the Lagrangian approach for the water droplet flow phase, with two-way coupling between both phases. Experimental results from a full-scale prototype in real conditions have been used for validation. The main results of this study show the strong influence of the average water drop size on efficiency of the system and reveal the effect of other variables like wet bulb temperature, water mass flow to air mass flow ratio and temperature gap between water inlet temperature and wet bulb temperature. Nondimensional numerical correlation of efficiency as a function of these significant parameters has been calculated.[36]

A complete cooling tower model is numerically investigated by using a computer code, which is validated with the experimental data. It is demonstrated through a case study that it is important to include the spray and rain zones in analyses for a greater accuracy in design as well as rating calculations. This is mostly important in medium and large-size cooling towers. The results show a comparative improvement in the prediction of the wet bulb temperature of the outlet air for the coupled three zones model. A comparison of the calculated volume is carried out against the known



volume of the tower as each zone is included in the analysis. The error in volume prediction, with the addition of each zone, is calculated as 1.5%, 1.1% and 0.25%. It is seen that there is an improvement in the calculated volume of tower, as compared to the work of Qureshi and Zubair (2006) that used an improved model to predict these parameters with constant Lewis's factor. A combination of the Spray, Fill and Rain zones is included in the model, so the consistency between model and prototype is increased. It results in more accurate solution. The promotion of answers as indicate above has two advantages. First, to reduce computational time, it can be neglected in some case of study such as small size cooling towers. Second, to obtain more accurate results the effects of these two zones (Rain and Spray) can be considered. On the other hand it might be checked that in some case of study the effects of these two zones are higher and it cannot be ignored. It is seen that there is an improvement in the calculated volume of tower, as compared to the work of Qureshi and Zubair (2006) that used an improved model to predict these parameters with constant Lewis factor.[37]

The water distribution characteristic of spray nozzle with plate used in cooling towers is very important for the cooling tower design. We would like to have a uniform water load at the entry to the fill. We are able to set the uniform water load by choosing the distance between nozzles and pipelines. An in this case the water distribution characteristic plays an important role. It provides qualitative evaluation of the uniform water load. Water distribution characteristics can be predicted on the basis of experimental data of the spray nozzle with plate. Water distribution of a spray nozzle often include the maximum operate radius of the nozzle for one distance between a fill and a nozzle usually when we use measuring cylinders. If we would like to obtain the maximum operate radius of a spray nozzle for several distances between a fill and a spray nozzle by one measurement, we choosed the visualization method. It this case we didn't obtain the exact water flow rate. But we obtained important information about how water is distributed below the spray nozzle. The measurement of water distribution characteristics of the nozzle is not sufficient just for the one airstream velocity. And for each airstream velocity it is needed to measure the water distribution characteristics by the visualisation method. The visualisation method shows that the effect of counterflow is very strong if the water film near the spray plate occurs. The water film near the spray plate is very sensitive to air velocity change. In the same case it is able to create the water bell effect.[38]

There was studied the influence of changes in surface tension of water on the ability eliminators capture water droplets. The assumptions confirm on basic experimental measurements, that water with a slightly reduced surface tension is significantly worse captured using conventional eliminators. It was verified from visualizations and observations that more drops of water passing through the channel of eliminator already when the surface tension was reduced by about the 10. 10⁻³ N.m⁻¹, thus to the value 61.7. 10⁻³ N.m⁻¹. These were either captured on the wall, wherein it formed the water film or, if their size was small enough, flew out of the eliminator. Just increased the number of smaller droplets and higher wettability is due to the smaller surface tension. It was observed higher drift of water over eliminators with increasing air velocity and decreasing surface tension. To obtain detailed information, such as droplet size distribution above and below the eliminator and the overall efficiency of the eliminator relative to the water flow, it is necessary to conduct further experiments.[39]

The main findings of the thesis are- Choosing a suitable wetted medium for a specific application requires knowledge of different working parameters. Not only the balance between the cooling potentials and the extra pressure drops but also the consideration of medium cost, service life, type of process to be cooled, environmental conditions, water quality, space availability, locations, economic requirements are absolutely necessary and some trade off have to be made.[40]

In this study, drop sizes in a cylindrical, modified spray tower were measured using a photography technique. The investigation showed that the rippling of the film surface increased with the increase in gas volume rate. When the mass of liquid falling along the wall of the spray tower became larger, a small fraction of liquid was atomized into single droplets. As a result, the interfacial surface decreased. The undulation of the film flow had an influence on the increase in interfacial surface. The liquid droplets formed during the liquid atomization had very different sizes. An increase in the gas flow rate or a decrease in the liquid flow rate caused an increase in both the wave deformation on the liquid film and the number of small droplets. It was shown that the droplets formed in an air-polyacrylamide solution system were larger than those in an air-water system. An increase in the Sauter diameter was also observed. For all modified distributors, a comparable size of interfacial surface with respect to the classical one was obtained. The drop formation conditions in the two types of gas-liquid systems studied were different. The atomization of water was easier than that of the polymer solution.[41]



A novel spraying tower called the spraying tower with upward spraying and downward gas flow (ST-UD) was proposed. Orthogonal simulations were conducted to evaluate the importance of factors and analyzed the relationship between influence factors and evaluation indices in a ST-UD system. Range analysis obtained optimal operating conditions for different indices and indicated that droplet diameter and spraying water flowrate were two main factors affecting the tower effectiveness. It also indicated that droplet diameter, spraying water flow rate and spraying temperature were three major's factors affecting the condensation rate. This may provide a guidance for industries to design spray towers. Trend analysis showed that both the tower effectiveness and the condensation rate increased as droplet diameter decreasing and spraying water flow rate increasing. With spraying velocity increasing, the tower effectiveness decreased slowly at first and subsequently rapidly, and the condensation rate increased firstly, and then decreased fast. Too large or small spraying velocity can have a bad effect on evaluation indices. Finally, as spraying temperature increases, the two indices showed the opposite trend. But there is a critical point (24°C) to make the two indices higher simultaneously. Above all, it's easy to adjust droplet diameter, spraying water flowrate and spraying temperature to get an optimal performance.[42]

Spray nozzle plays an important role in system cost, efficiency, low consumption liquid and droplet size, and operating pressure affects liquid velocity and more contact liquid with pollutants, which subsequently these parameters together have a very important effect on spray tower removal efficiency. A new spray nozzle 8010SS for occupational NH₃ of control and treatment were developed and validated. It has more effect on optimization spray tower, highest removal efficiency and low consumption scrubbing liquid. The presented spray nozzle could increase NH₃ removal efficiency with low Henry's law constant, lower operational costs compared to other spray nozzles and compared to other studies and appropriate for other pollutants that have similar chemical properties to ammonia.[43]

Hyperbolic cooling tower makes use of the difference in temperature between the ambient air and the hotter air inside the tower. As hot air moves upwards through the tower (because hot air rises), fresh cool air is drawn into the tower through an air inlet at the bottom. Hyperbolic shape of cooling tower is usually preferred because of its strength and stability and large available area at the base due to shape. They concluded that when the ring beam is provided at throat, top and upper central locations, it gives the maximum deformation at throat level. When the ring beam is provided at throat, bottom and down central locations, it gives the maximum strain at bottom level. When the ring beam is provided at all locations (Top, throat, bottom, upper central and down central), it gives the maximum stress at bottom level.[44]

The investigation shows the variation as well as nature of hoop, vertical & Von Mises stress along the tower height respectively in windward side, leeward side and critical section. From the close inspection of all the graphs it is observed that the hoop stress values are critical in windward side and same occur at about one-third height of the wall from the base level. Von Mises stresses are critical at the junction in leeward side for the same height of the wall in windward side. Hoop stresses are produced due to ovalisation of wall cross section. Von Mises stresses are critical at the junction in leeward side as well as mid height of the wall in windward side. The hoops stress variation along the entire height is almost same for both types of profile, but at top level it become almost constant for the second profile while it is varying in the first one. The stress and deformation variation in the leeward direction become significant in the hyperbolic-cum-cylindrical profile than hyperbolic one. But the radial deformation become more pronounced in the latter profile which create a significant difference in selecting t type of profile for industrial use. At the end both the profile is almost equally efficient in resisting the stress but the second profile is less effective when it comes to resist the deformation, which is very much significant for tall structure in case of wind loading.[45]

This study used the Poppe model to evaluate selected thermodynamic relations of a rectangular counter-flow industrial cooling tower of a steel rolling mill using the system's inlet and outlet data as initial conditions. The effect of increasing the water temperature on the air moisture content, Merkel number, and specific enthalpy was studied across the fills of the cooling tower. Air moisture content, Merkel number and specific enthalpy of the system increase with increasing water temperature. However, while other variables reach a stationary point at half the nodal segments, the specific enthalpy increases across the fills in the system. It was concluded that the use of nano particles with high heat removal rate could increase the efficiency of the system. Also, an increase in the quantity of the makeup water of a force draft system is recommended towards increasing the system efficiency.[46]

There was studied the influence of changes in surface tension of water on the ability eliminators capture water droplets. The assumptions confirm on basic experimental measurements, that water with a slightly reduced surface tension is significantly worse captured using conventional eliminators. It was verified from visualizations and observations that more drops of water passing through the channel of eliminator already when the surface tension was reduced by about



the 10. 10⁻³ N.m⁻¹, thus to the value 61.7. 10⁻³ N.m⁻¹. These were either captured on the wall, wherein it formed the water film or, if their size was small enough, flew out of the eliminator. Just increased the number of smaller droplets and higher wettability is due to the smaller surface tension. It was observed higher drift of water over eliminators with increasing air velocity and decreasing surface tension. To obtain detailed information, such as droplet size distribution above and below the eliminator and the overall efficiency of the eliminator relative to the water flow, it is necessary to conduct further experiments.[39]

The main findings of the thesis are- Choosing a suitable wetted medium for a specific application requires knowledge of different working parameters. Not only the balance between the cooling potentials and the extra pressure drops but also the consideration of medium cost, service life, type of process to be cooled, environmental conditions, water quality, space availability, locations, economic requirements are absolutely necessary and some trade off have to be made.[40]

In this study, drop sizes in a cylindrical, modified spray tower were measured using a photography technique. The investigation showed that the rippling of the film surface increased with the increase in gas volume rate. When the mass of liquid falling along the wall of the spray tower became larger, a small fraction of liquid was atomized into single droplets. As a result, the interfacial surface decreased. The undulation of the film flow had an influence on the increase in interfacial surface. The liquid droplets formed during the liquid atomization had very different sizes. An increase in the gas flow rate or a decrease in the liquid flow rate caused an increase in both the wave deformation on the liquid film and the number of small droplets. It was shown that the droplets formed in an air–polyacrylamide solution system were larger than those in an air–water system. An increase in the Sauter diameter was also observed. For all modified distributors, a comparable size of interfacial surface with respect to the classical one was obtained. The drop formation conditions in the two types of gas–liquid systems studied were different. The atomization of water was easier than that of the polymer solution.[41]

A novel spraying tower called the spraying tower with upward spraying and downward gas flow (ST-UD) was proposed. Orthogonal simulations were conducted to evaluate the importance of factors and analyzed the relationship between influence factors and evaluation indices in a ST-UD system. Range analysis obtained optimal operating conditions for different indices and indicated that droplet diameter and spraying water flowrate were two main factors affecting the tower effectiveness. It also indicated that droplet diameter, spraying water flow rate and spraying temperature were three major's factors affecting the condensation rate. This may provide a guidance for industries to design spray towers. Trend analysis showed that both the tower effectiveness and the condensation rate increased as droplet diameter decreasing and spraying water flow rate increasing. With spraying velocity increasing, the tower effectiveness decreased slowly at first and subsequently rapidly, and the condensation rate increased firstly, and then decreased fast. Too large or small spraying velocity can have a bad effect on evaluation indices. Finally, as spraying temperature increases, the two indices showed the opposite trend. But there is a critical point (24°C) to make the two indices higher simultaneously. Above all, it's easy to adjust droplet diameter, spraying water flowrate and spraying temperature to get an optimal performance.[42]

Spray nozzle plays an important role in system cost, efficiency, low consumption liquid and droplet size, and operating pressure affects liquid velocity and more contact liquid with pollutants, which subsequently these parameters together have a very important effect on spray tower removal efficiency. A new spray nozzle 8010SS for occupational NH₃ of control and treatment were developed and validated. It has more effect on optimization spray tower, highest removal efficiency and low consumption scrubbing liquid. The presented spray nozzle could increase NH₃ removal efficiency with low Henry's law constant, lower operational costs compared to other spray nozzles and compared to other studies and appropriate for other pollutants that have similar chemical properties to ammonia.[43]

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The major classifications and configurations of cooling towers showed the wet cooling towers consume the highest water while dry cooling towers use the minimum water in a trade-off with performance. The hybrid cooling towers have the advantages of both while they are more costly. optimizing cooling towers water consumption, improving the heat transfer parameters in cooling towers.[47]

There are two primary types of fans: centrifugal and axial. These types are characterized by the path of the airflow through the fan. Centrifugal fans use a rotating impeller to increase the velocity of an airstream. As the air moves from the impeller hub to the blade tips, it gains kinetic energy. This kinetic energy is then converted to a static pressure increase as the air slows before entering the discharge. Centrifugal fans are capable of generating relatively high pressures. They are frequently used in “dirty” airstreams (high moisture and particulate content), in material handling applications, and in system at higher temperatures.[48]

III. MODIFICATION IN COOLING TOWER PARAMETERS

Objectives	Methodology
Increasing contact time of air with hot water	Changing the air inlet angle
Increasing air velocity	Implementing convergent type nozzle
Increasing area of contact of air and hot water	Nozzle implementation enhances swirling motion of air

3.1 Factor affecting Performance:

Variation in inlet angle for air shows a rise in efficiency. By increasing the contact surface between hot and cold fluid Effectiveness can be increased. Porosity (in fins) induces a high pressure drop which can cool down the hot fluid. Bed materials used at different airflow rates can provide better cooling. Corrosion of the blower affects the performance of the tower. Material and Thickness of the blower directly affects the performance. Variation in blade angle can give us required flow rate.



IV. METHODOLOGY

Authors had Concluded following results using ANSYS, the results obtained in these software's showed a very close result. Then the following results were matched with Analytical calculations. Let us consider,

T_1 =inlet temperature.

T_2 =outlet temperature.

T_w =wet bulb temperature.

1) Range=difference between inlet & outlet temperature

$$=T_1-T_2$$

2) Approach= $T_2 - T_w$

3) Effectiveness= (Range)/(Range+ Approach)

4) Evaporation loss = $0.0085 * 1.8 * Q_w * (T_1 - T_2)$

Where, Q_w is water circulation

V. SUMMARY

By varying the inlet angle effectiveness can be slightly increased (Air Inlet Pipe at 30o Inclined Vertically & Horizontally without Nozzle gave effectiveness of 87.66 whereas air inlet at 0 degree gave effectiveness 86.6%). Effectiveness is increased by increasing the contact surface area between hot and cold fluid. Porosity introduced a high pressure drop of hot fluid. 70% of water temp is decreased by evaporation, 30 % by air flow. High air flow rate gives a low approach that increases effectiveness in cooling towers. High flow rate jute carpets provide better cooling, for lower flow rate polystyrene balls perform better. By corrosion test Stainless steel is more corrosion resistant than M.S. Property of Blower increased without changing material, Stress directly proportional to displacement, FOS is large for 3mm thickness material. Blade angles designed analytically are capable of producing required flow rates Indirect cooling has advantages like noise reduction, power consumption saving only occurred in natural cases. Indirect method is independent of outdoor conditions.

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