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ENTERING AIR STATE INFLUENCE ON THERMAL PERFORMANCE OF HYPERBOLIC COOLING TOWER

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Abstract: Cooling towers overcome the problem of water supply for thermal power stations in the regions without enough cooling water from natural sources. The thermal capability of cooling tower is conditioned by three parameters: cooling tower range (the temperature difference between the water entering and leaving the cooling tower), entering air state and water flow rate. One of these parameters, the entering air state, can't be exactly estimated, it can only be predicted. The basic available solution is to follow the behavior of atmospheric air with the use of climatic curves. Seeking assurance that a cooling tower correctly performs the specified thermal performance, a three step methodology was used for evaluation of cooling tower performance: evaluation of thermal performance at design conditions, evaluation of tolerance between the design thermal performance and the thermal performance at acceptance test and evaluation of thermal performance at changeable climatic conditions. Its realization is followed through the example of the cooling tower located at the thermal power station in Bitola. Air wet-bulb temperature influence on thermal cooling performance is emphasized. The use of climatic curves is proposed for air state predicting.

Keywords: cooling tower, climatic curves, wet-bulb temperature

INTRODUCTION

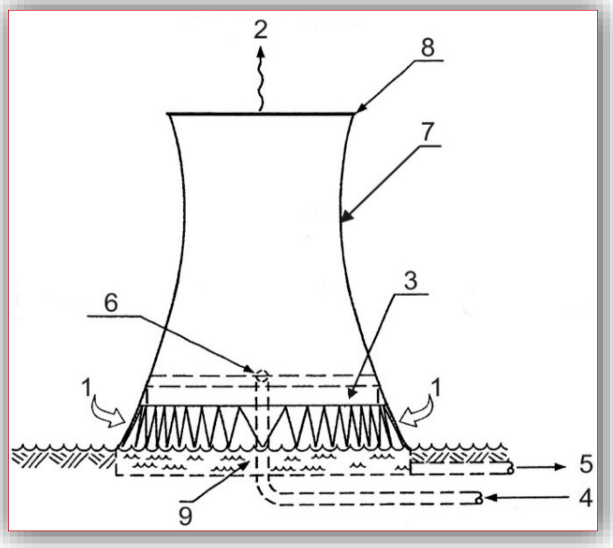
Thermal processes often generate heat that ought to be removed and dissipated in the environment. The main heat transfer medium used for this purpose is water. In cooling tower system, water is conducted in recirculating way.

Cooling towers overcome the problem of water supply for thermal power stations in the regions without enough cooling water from natural sources. Cooling tower system which is once completely filled needs only 2 to 3% of total water quantity, as additional water supply.

Today, cooling towers are exploited even in areas with enough cooling water drown from natural sources, because of the increased temperature of discharge water, unacceptable from ecological standpoint.

Cooling towers for large power installations are chimney type steel-reinforced concrete buildings, Figure 1. They are high first-cost products that haven't energy requirements in exploitation.

Air density differentials that exist between the lighter, heat-humidified chimney air and outdoor atmospheric air cause air movement thought the cooling tower. In this circulation, the air has direct contact with a very large water surface area. Water is cooled in simultaneous heat and mass transfer.



1-entering air, 2-leaving air, 3-heat exchanger, 4-hot water, 5-cold water, 6-distribution system, 7-concrete shell, 8-top platform, 9-cold water basin

Figure 1. Hyperbolic direct-contact cooling tower, [1]

The thermal capability of cooling tower is conditioned by three parameters: 1. cooling tower range (the temperature difference between the water entering and leaving the cooling tower), 2. entering air state and 3. water flow rate.

One of these parameters, the entering air state, can't be exactly estimated, it can be only predicted.

Because the cooling water flows in closed circulation system in which the heat source is some heat exchanger located in the thermal power station, for the steady-state functioning, the temperature difference in that heat exchanger is equal with the range, provided the flow rates through the cooling tower and heat exchanger are the same. Therefore, the range is determined by the heat load and water flow rate, not by size or thermal capability of the cooling tower.

The temperature difference between the water leaving the cooling tower and the entering wet-bulb temperature is the approach of the cooling tower. A larger cooling tower produces a colder leaving water or smaller approach to the entering air wet-bulb temperature.

The heat transferred between the air and water is proportional to the enthalpy difference of the entering and leaving air.

Generally, the specific enthalpy is a most important property in psychrometric calculations of thermal processes. Accurate enthalpy values are important because the total heat content of the air determines the total energy needed to change the conditions of the air from its current condition to the desired condition.

Enthalpy cannot be directly measured. In psychrometric practice, the graphical calculation of the enthalpy value is very common. The chart "specific enthalpy-humidity rate" displays the key thermodynamic characteristics of the air, and lets thermal engineers to quickly estimate the energy required to change the air temperature or air humidity. Because lines of constant enthalpy correspond almost exactly to lines of constant wet-bulb temperature, the change in enthalpy of the air may be determined by the change in wet-bulb temperature of the air.

For designer, purchaser and user of cooling tower, it is clear that the local climatic conditions dominate over the thermal performance of a cooling tower. They all need correct climatic information's. The basic available solution is to follow the behavior of the atmospheric air with the use of climatic curves. A climatic curve graphically represents the behavior of the atmospheric air.

From the observation of the weather conditions in the past, the possible future state of the local atmospheric air can be expected. In general, the period of records used in the calculations is 25 continuous years. Hourly records of air dry-bulb temperature and relative humidity or 438000 input values are included in the statistical data processing. Their examination and interpretation was conducted in order to draw the annual climatic curve. A climatic curve for shorter period also exists, usually as summer climatic curve.

Climatic curve provides the possibility to capture the local climatic trends from the past one or two decades.

In Macedonia, climatic curves are published for Skopje and prepared for Bitola.

EVALUATION OF COOLING TOWER THERMAL PERFORMANCE

The thermal performance of the cooling tower is usually expressed as a range that the cooling tower must accommodate under available air state.

Seeking assurance that a cooling tower correctly performs the specified thermal performance, a three step methodology was used for evaluation of cooling tower performance:

1. evaluation of thermal performance at design conditions,
2. evaluation of tolerance between the design thermal performance and the thermal performance at acceptance test, and
3. evaluation of thermal performance at changeable climatic conditions.

In the first step the designer makes a study of available combinations of heat load and flow rate for selected constructions of cooling towers. The result of this analysis is a series of cooling towers offered on the market by the producer. For each of them the performance curves are presented. Those performance curves are only predicted performance curves supplied by the manufacturer of cooling towers, because the location of a cooling tower is not known yet, that means the local air state is unknown, too, [2]. Computerized selection and rating programs are available from many manufacturers in order to generate performance ratings and curves for their equipment.

In the second step, after the cooling tower is built, an acceptance test is performed. The field acceptance test is conducted in accordance with the available test standard. During the acceptance test, the cooling tower operates under steady heat load and water flow, both near design values. Evaluation of tolerance between the design thermal performance and the thermal performance at acceptance test is realized in accordance with maximum recommended deviations, for range, flow, air state and heat load, in the used standard, [3].

In the third step, two elements were dominant: 1. experience of the cooling tower in operation condensed in updated performance curves and 2. climatic curves. The performance curves and the climatic curves may be used to evaluate a tower for year-round or seasonal use. For the periods with critical range needs, climatic curve was estimated as seasonal climatic curve. Because the critical performance level of an operating cooling tower can be accurately determined only by thermally testing the tower under worst weather conditions, the help of climatic curves is needed, [4]. In psychrometrics long term meteorologically observed air states are statistically treated and then the pairs of air temperature and air relative humidity with maximum frequency of occurrence are inserted into psychrometric chart to obtain climatic curve, [5], [6]. The estimation of weather conditions for the warmest season of the year which is critical for cooling tower performance was realized with the use of summer climatic curve. The entering air wet-bulb temperature cycle through critical months is predicted using climatic curve for the site of cooling tower. Performance analysis have shown that cooling tower systems based upon wet-bulb temperatures which are exceeded in no more than 5% of the total hours during the summer period, have given satisfactory results. The capacity of the total water system is usually sufficient to neutralize the effect of peak wet-bulb temperatures, without detrimental consequences.

How strong the influence of entering air state on thermal performance is, can be observed from the comparison of the results for different climatic conditions (Table 1).

Table 1. Cold water temperature for different air states

Location	Air state from climatic curve		Cold water temperature °C	Difference %
	Temperature °C	Relative humidity %		
Skopje	35	28	32	+10
Bitola	27	45	27	-7
Ljubljana	30	40	22	-24

The three step evaluation was realized on hyperbolic cooling tower, at the thermal power station Bitola, which was selected as representative for the actual investigation. The cooling tower is designed by L. T. Mart Company Ltd, London, a subsidiary of Marley International Inc, and built by Vatrostalna, Zenica, [7], [8]. The dimensions of the cooling tower are: height 108 m, top diameter 55.5 m, neck height 81 m, air entrance height 6.5 m and heat exchanger height 2.5 m.

The values of the parameters involved in the evaluation process from the design, acceptance and operating period are summarized in Table 2.

In the Marley project documentation the designed thermal performance capability of this cooling tower is expressed as water flow rate at two specific operating conditions, range and entering air wet-bulb temperature. Nominal design parameters used in the natural drift hyperbolic cooling tower performance diagram, Marley No D 1005-77, are: hot water temperature 38.2°C, cold water temperature 29°C, wet-bulb temperature 20°C, dry-bulb temperature 25°C, water flow rate 30000 m^3/h and range 9,2°C. From the same performance curves, at extreme weather conditions in the acceptance test period, wet-bulb temperature 19°C, dry-bulb temperature 27°C and 14% lower used water flow, the nominal range is reached. The enthalpy of atmospheric air is 7.5% lower in regard to nominal enthalpy, but the smaller water flow rate contributes to the realization of the nominal range.

Table 2. Relevant parameters from cooling tower performance evaluation

Parameter	Designer offer	Acceptance test	Operating mode
Hot water temperature, °C	38.2	34.3 – 37.6	35 - 47
Cold water temperature, °C	29	23.2 – 27.7	26 - 34
Wet-bulb temperature, °C	20	14.3 – 19.1	14 - 18
Dry-bulb temperature, °C	25	19 - 27	20 - 38
Flow rate, t/s	8.3	7.3 – 7.4	5,8 - 7,7
Approach, °C	9	8.9 – 12.6	12 - 16
Range, °C	9.2	8.9 – 11.1	9 - 13

The period of record, used in the analysis procedure for the operating of the selected cooling tower, spanned 25 years, from 1984 to 2009. The thermal performance of the cooling tower in the operating period was evaluated on the basis of daily reports. Data for the long term operation of the cooling tower shows that the cooling system occasionally is carried through above-average periods for some of the parameters.

To continue performing as designed the cooling tower is continuously inspected and maintained, [9], [10].

CONCLUSION

Three step methodology is proposed for evaluation of cooling tower performance. Its realization is followed through the example of the cooling tower located at the thermal power station Bitola. Air wet-bulb temperature influence on thermal cooling performance is emphasized. The use of climatic curves is proposed for air state predicting.

Note

This paper is based on the paper presented at The 12th International Conference on Accomplishmants in Electrical and Mechanical Engineering and Information Technology – DEMI 2015, organized by the University of Banja Luka, Faculty of Mechanical Engineering and Faculty of Electrical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA (29th – 30th of May, 2015), referred here as[11].

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