Study of Working Efficiency of Cooling Towers of Nuclear Power Plants

Marta Kuznetsova, Victoria Romaniv

Department of Heat Engineering, Thermal and Nuclear Power Plants, Lviv Polytechnic National University, UKRAINE, Lviv, S. Bandery of street 12, E – mail: kuznetsovam83@gmail.com

Abstract – Working efficiency of cooling towers has been analyzed with the aim of detecting the change of their cooling efficiency during operation, as well as effect of organizational and construction decisions on cooling efficiency of the towers. Researches were conducted by comparison of actual temperature of water cooled in cooling towers with calculated value of the temperature. It has been found out that cooling efficiency of cooling tower worsens after continuous service because of disorder of tower flushing uniformity. Cooling efficiency of cooling towers can be increased by increasing the flushing area, as well as by diminishing unorganized leakage of cooling water.

Keywords – power efficiency, cooling tower, flushing area, splashing nozzles.

I. Introduction

The system of nuclear and thermal power plants water supply and cooling of heated circulating water using water from natural reservoirs is the most widespread. But it has significant constraints, because the effect of heated water on the functional state of existing aquatic ecosystems must be taken into consideration. Elevation of the reservoir water temperature over design value (overheating) causes so called “thermal pollution” of water environment.

The effect of temperature on aquatic ecosystems depends on discharged water temperature and sensitivity of different groups of organisms to it. Water temperature elevation up to about 30°C is marginal for most species of aquatic organisms. In addition, use of natural reservoirs as cooling water source has one another disadvantage: its cooling ability strongly depends on the season and considerably decreases in summer. This makes it impossible to ensure optimal conditions of power plants operation all year long. To abandon use of water from natural reservoirs, various systems where water is cooled in cooling towers were developed. Such systems have less negative effect on the environment, including only bearing out of condensed moisture, steam torch and noise. Besides, use of cooling towers in cooling systems of reverse water supply ensures saving of natural water 25-50 times compared to once-through systems and eliminates thermal pollution of natural reservoirs [1]

In most simple case a cooling tower is an apparatus for cooling large amount of water by directed stream of air. The water is cooled due to evaporation of small amount of water flowing down along flushing device, in opposite direction to which stream of air is moved. Evaporation of 1% of water results in decrease of remaining water by 5.48°C.

Working efficiency of cooling towers, wherein liquid and gas phases move in the opposite directions, does not depend on circulating liquid parameters (flow rate and temperature) and environmental conditions only. Rate of upstream air flow and, especially, its distribution in cooling tower volume have considerable effect on the process of cooling by evaporation [2]. In consideration of this, it makes sense to look for the ways of cooling towers working efficiency enhancement that would allow using all the advantages of reverse water supply system from technical, environmental and economical (decrease of specific fuel consumption, consumption of water and electricity, etc.) points of view.

Power plants water cooling systems with cooling towers (fig. 1) are most favourable in regions with limited sources of water [3], because additional fresh water in this case is needed only for recovery of water loss by evaporation and bearing out the tower.

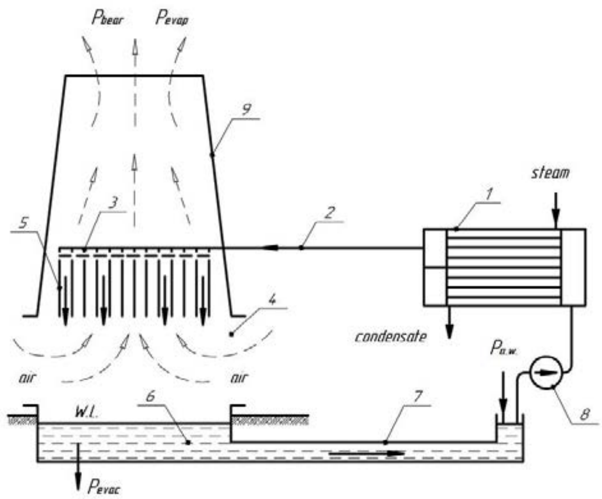

Fig. 1. Scheme of reverse water supply of power plant with cooling tower:
1 – turbine condenser; 2 – unloading pipeline; 3 – distributing chute of cooling tower; 4 – air supply; 5 – flushing device of cooling tower; 6 – water collecting pool; 7 – water supply line; 8 – circulation pump; 9 – draught tower; W.L. – water level; P_{evap} – water loss for evaporation; P_{bear} – loss of water bearing out; P_{evac} – evacuation of return water; $P_{a.w.}$ – additional fresh water

II. Technical water supply system of Rivne nuclear power plant

Technical water supply system of I stage of Rivne nuclear power plants is reverse, two-lifting with circulating water cooled in four film-type cooling towers of design productivity 100 000 m^3/year each. The cooling towers are in-parallel.

Water is supplied to power house by group of pumps installed in two pumping stations, and to the cooling towers by another group of pumps installed in two separate pumping stations.

Highly productive cooling towers of flushing area 10 000 m^2 with 150 m high hyperbolic draught towers of reinforced concrete are used for circulating water cooling. Water losses from the technical water supply system (bearing out, filtration, evaporation etc.) are compensated from the river by pumping station of additional water build on it.

III. Study of cooling efficiency of cooling towers of Rivne nuclear power plant

To determine cooling efficiency of the cooling towers and possibility to enhance it, number of studies has been conducted. According to the research method [1] parameters characterizing the cooling tower work, namely: circulating water flow rate, temperature of inlet and cooled water, environmental conditions, were registered.

Cooling efficiency of the cooling towers was assessed by comparison of actual temperature of water cooled in the towers with calculated value of the temperature, determined from their functional specification.

Works of the cooling towers testing were performed in two stages. On the first stage cooling towers No. 1-4 were tested with existing design systems of water distribution, including typical splashing nozzles, wherein cup deflector is whole and attached to the pipe by two holders (supports).

The aims of research on this stage include determination of cooling efficiency of all four cooling towers, comparison of current working efficiency of cooling tower No.1 with results of its testing in previous period, detection of changes in working efficiency of cooling towers No. 3 and 4 as a result of additional installation of stacks of asbestos-cement sheets.

On the second stage of research cooling towers No. 2 and 4 with their water distribution systems having been fitted with new splashing nozzles, wherein cup deflectors are perforated and attached to the pipe by three holders, were studied. The research aim on this stage was to determine the effect of splashing nozzles replacement on the cooling efficiency.

Analysis of obtained results of cooling towers research and their comparison with results of research of cooling tower No.1 in previous studied period (time interval between studied periods was 6 years) showed worsening of cooling efficiency of cooling towers No.1 and 2. The worsening of cooling efficiency is caused by disorder of uniformity of tower flushing with cooling water because of clogging and failure of typical splashing nozzles. The clogging and failure of splashing nozzles lead to diminution of a splashing torch, making crossing of bases of the torches from adjacent nozzles impossible. Consequently, the flushing of the cooling tower becomes insufficient. Such ineffective utilization of all the flushing area reduces working efficiency of cooling tower on the whole, especially in summer.

Enhancement of cooling efficiency of cooling towers No. 3 and 4 was caused by previous sealing of joints of asbestos-cement pipes of water distribution system, as well as installation of additional stacks of asbestos-cement sheets in existing holes of flushing devices of the cooling towers.

The sealing of joints of asbestos-cement pipes eliminated unorganized leakage of cooling water in amount of about 5 % of all water coming into the cooling tower. This allowed to ensure more uniform supply of cooling water to the flushing devices and reduce the cooling water temperature by about 0.3 ºC.

Installation of additional sheets of flushing device allowed to increase cooling area of each cooling tower by 5.6 % of design cooling area, as well as to reduce unorganized flow of cool air, having not contacted with cooling water, from the cooling tower. Thus, installation of additional flushing blocks in cooling towers No. 3 and 4 allowed achieving cooling water temperature reduction by 0.6 ºC on average.

Conclusion

The research conducted and analysis of obtained results of cooling towers operation allowed to found out that for enhancement of reliability and working efficiency of cooling towers the existing holes in flushing devices should be filled by additional asbestos-cement blocks. This ensures reduction of cooling water temperature by about 0.6 ºC. It is also recommended to replace the flushing devices made of asbestos-cement sheets by modern ones made of polymer materials. Use of polymer materials (high density polyethylene, polyvinyl chloride, polyester resins etc.) for flushing devices to be made of them has the following advantages: such flushing devices are corrosion resistant, have high firmness and low density, tubes, grids and other elements of complex configuration can be easily formed of polymers. Such flushing devices can be made with such configuration, which would combine high cooling efficiency and low aerodynamic drag coefficient. At the same air parameters the flushing devices made of polymer materials are more efficient and allow achieving lower temperatures of cooling water compared to flushing devices made of asbestos-cement sheets [4]. Splashing nozzles of ruggedized construction with perforated cup deflectors should be used in water distribution system of cooling towers. To prevent clogging of splashing nozzles of water distribution pipes of cooling towers, annular efferent washing nozzles should be installed.

References

[1] V. Ponomareyiko *Hradyrny promyslovykh ta enerhetychnykh pidpryyemstv*, Moskva: Énerhoatomyzdat, 1998.

[2] Vlasov A.V. "Yssledovanye vnutrenney aérodynamyky bashennoy ysparytel’noy hradyrny" Inzhenerno-fizychnyy zhurnal, № 5, S. 64-68, 2002.

[3] V.D. Burov and V.V. Dorokhov, Eds., *Teplovi elektrychni stantsiyi*, Moskva: Yzdatel’skyy dom MÉY, 2009.

[4] Kravchenko, V.P. "Zv'yazok z okholodzhuval’noyu zdatnistyu asbestotsementnoho ta setochnoho orosytelya bashennykh hradyriv" Vostochno-Evropeyskyy zhurnal peredovykh tekhnolohiy, № 50, S. 13-16, 2011.