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Air Flow Characteristics of an Air Cooled Condenser used in Thermal Power Plant

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Abstract: *The effect of wind speed on a 5 × 5 fan air cooled steam condenser (ACC) under windy conditions is investigated using computational fluid dynamics. It is found that cross winds significantly reduce the air flow rate that is delivered by the fans in normal conditions. The effect of wind speed is found to be varying for different fan deck heights of the air cooled condenser. It is recommended that at the initial stage of a power plant which is equipped with an air cooled condenser, the wind effects analysis is necessary and helpful in mitigating the adverse effect of winds.*

Keywords: *Air cooled condenser, wind effects on ACC, CFD, air flow characteristics, fan deck height*

I. INTRODUCTION

Air cooled steam condenser is a device used to condense the steam by rejecting the heat into the atmosphere. ACC is mainly used in process industry and thermal power plants. In a thermal power plant ACC is used to condense the turbine exhaust low pressure steam at sub-atmosphere pressure so that it can be pumped back to the feed water system. Sub-atmospheric pressure or vacuum pressure in the ACC enables turbine to generate more output or electrical energy. The condensed steam is then sent back to the boiler thus completing the power cycle. As the air cooled condensers do not require cooling water as in case of water cooled condenser; so power plant with air cooled condenser need not to be near the cooling water source and can be installed in the places where water availability is less. Water cooled condenser (WCC) have once-through or recalculating water as a cooling medium, similarly air cooled condensers are once-through system using atmosphere air as heat sink. The turbine exhaust steam entering the ACC is condensed by the atmospheric air flowing across the fin-tube bundle forced by axial flow fans. Axial flow fans of diameter 28- 36 feet are installed below the ACC fin-tube bundles to force the air across the bundles and are driven by single speed, dual speed or variable speed electrical motor. In the arid regions where water is a scare commodity or in countries where significant environment legislations does not follow the use of water, ACC are a smart choice over WCC.

Now-a-days where water scarcity is the biggest problem in the power industry; use of Air cooled condensers is increasing day by day in thermal power plants. Air cooled condenser are bulky in size as compared to same capacity water cooled condenser and due to its bulky size the air cooled condensers are costlier as compared to the water cooled condenser. The main drivers for the increased use of ACC include the scarcity of water and the elimination of evaporative water loss from both once-through and evaporative cooling systems. Reduction or elimination of thermal pollution, entrainment, and impingement issues typically associated with once-through and evaporative cooling and elimination of visible plume and drift from the operating cooling system (though clearly not the primary driver) are the other reasons to prefer ACC over WCC.

II. Background

A number of quality studies exist relative to ACCs though information regarding current designs and operating issues is lacking. For example, the impact of ambient wind on ACC performance is not well understood by owner/operators or their representatives in the specification and bid evaluation process. A variety of wind screen designs are being employed at sites. In some cases, the screens serve multiple purposes such as reduction of entrained debris and reduction of wind effects. In cases where debris entrainment is an issue, the screens may be deployed in the area upwind of the ACC. When winds alone are of concern, wind screens may be deployed under the ACC in a variety of arrangements. Reasons for reduced heat transfer in ACC are recirculation, distorted air inlet flow condition, hot air plumes from surrounding heat sources, and degradation of fan performance. While fixing the location of air cooled condenser the effect of local building, environmental wind, terrain, environmental and ecological restrictions, and upstream heat sources are taken into the consideration. In the recirculation process part of warm outlet air is mixed with the ambient air which results in increased air inlet temperature, hence degrading the ACC performance or increased turbine backpressure. Due to increase in the static pressure at high wind velocities, the fan capacity is reduced thereby reducing the performance of ACC in terms of turbine back pressure. Recirculation as well as reduced air flow has the same effect i.e. increased turbine back pressure.

III. Wind Effects

Wind effects on ACC performance are unique to each and every ACC due to site location and layout, ACC configuration, ambient design condition, fan selection and other factors. While sizing the air cooled condenser which consists of many fans one of the most important factors affecting the size of ACC, other than the wind speed, is the height of the bottom structure. As the number of fans are kept side by side to force the air through the tube banks it is of much importance that the required flow of air for each fan is easily met failing to which will result in the less air flow and thus decreasing the performance of the ACC. This is ensured by providing the sufficient height of the bottom structure and selecting a fan of required static pressure.

The trend of air flow through the ACC shown in Figure 1 is determined by computational fluid dynamics (CFD) method using FLUENT software. The ACC analyzed is a 25 module A-frame type air cooled condenser. It consists of 5 streets each street consisting of 5 modules. Number of streets is indicated along the X-axis and the number of module in each street is indicated along the Z-axis. Fans are numbered according number of streets and number of module in a street i.e. (x, z). For example a fan in 2nd module of 3rd street is denoted by (3, 2).

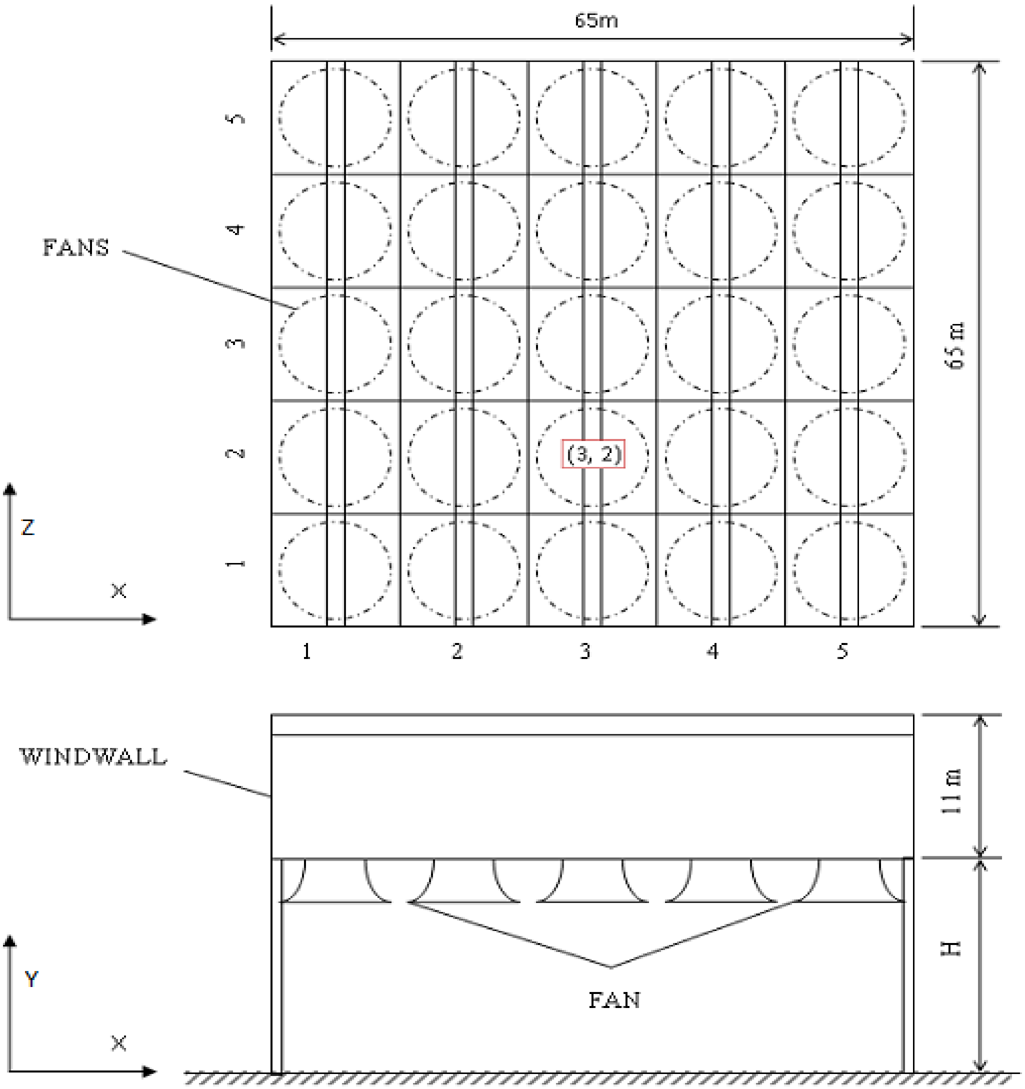

Figure 1: Schematic of ACC consisting 25 modules

IV. Methodology

The ACC is analyzed for various cases and air flow at different wind speed and at different fan deck height is calculated. Below table gives brief details of all the cases for which air flow is calculated. Here it is important to note that all the parameters in the analysis are kept constant except the fan deck height and wind velocity. The analysis is done at standard atmospheric conditions.

Case No.	Fan deck height (H) in meters	Wind velocity (v) in m/s
1	15	1
2	15	2
3	15	3
4	15	4
5	15	5
6	15	6
7	15	7
8	20	1
9	20	2
10	20	3
11	20	4
12	20	5
13	20	6
14	20	7
15	25	1
16	25	2
17	25	3
18	25	4
19	25	5
20	25	6
21	25	7
22	30	1
23	30	2
24	30	3
25	30	4
26	30	5
27	30	6
28	30	7
29	35	1
30	35	2
31	35	3
32	35	4
33	35	5
34	35	6
35	35	7
-	-	-

Table 1: Case definition

Below figures indicate the air flow pattern for different fan deck heights i.e. 15m, 20m 25m, 30m and 35m for wind velocity ranging from 1m/s to 7 m/s.

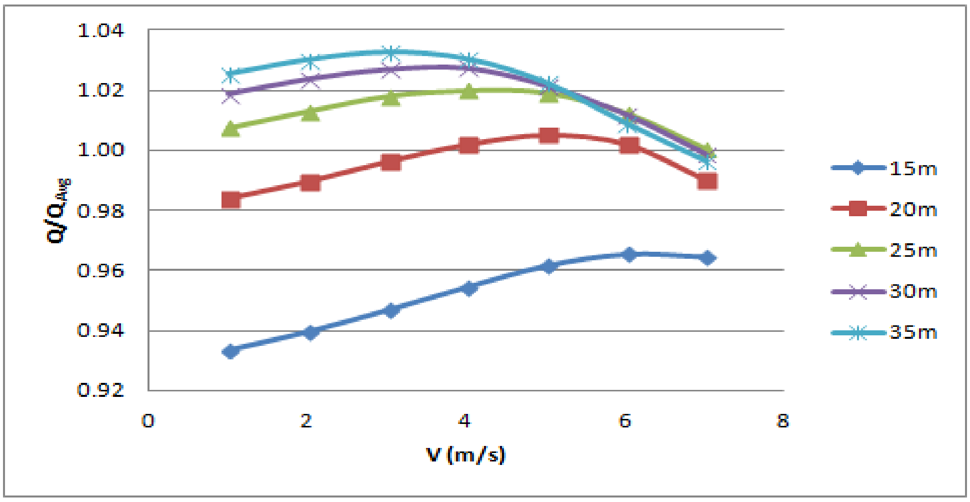

Figure 2: Trend of total air flow at various fan deck heights and wind speeds

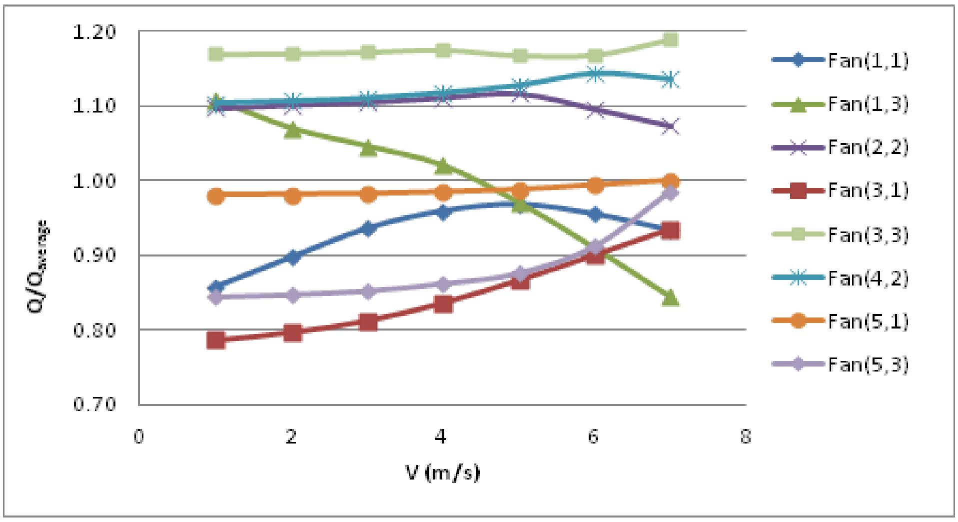

Figure 3: Airflow through fans for 15m fan deck height

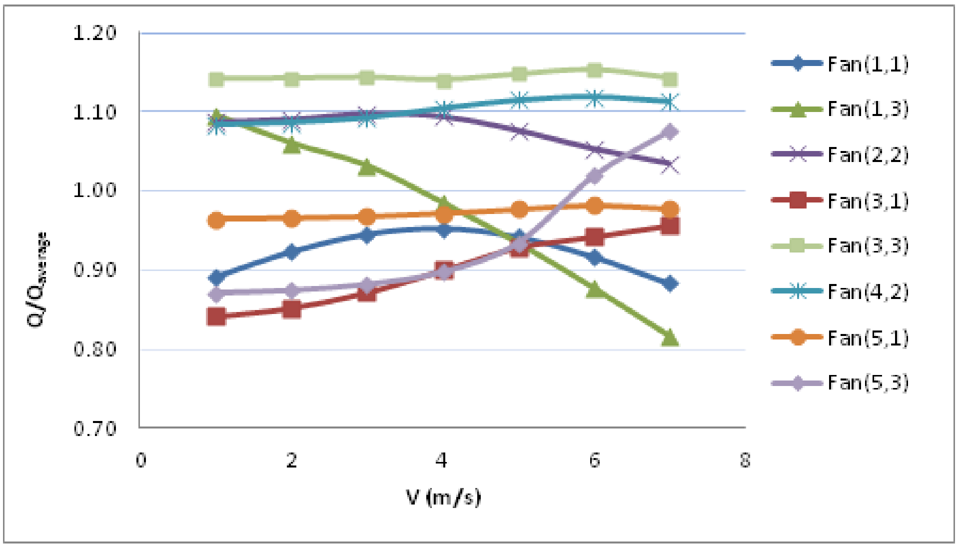

Figure 4: Airflow through fans for 20m fan deck height

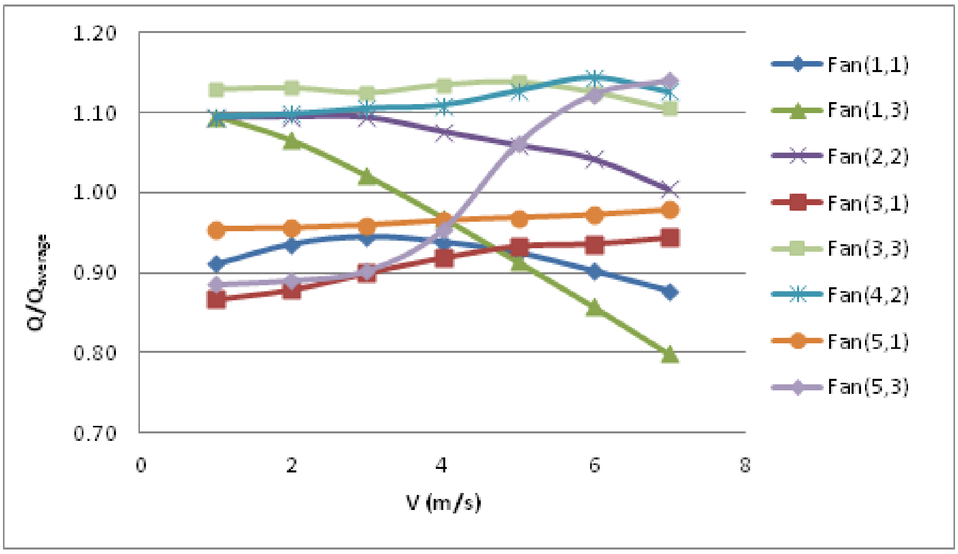

Figure 5: Airflow through fans for 25m fan deck height

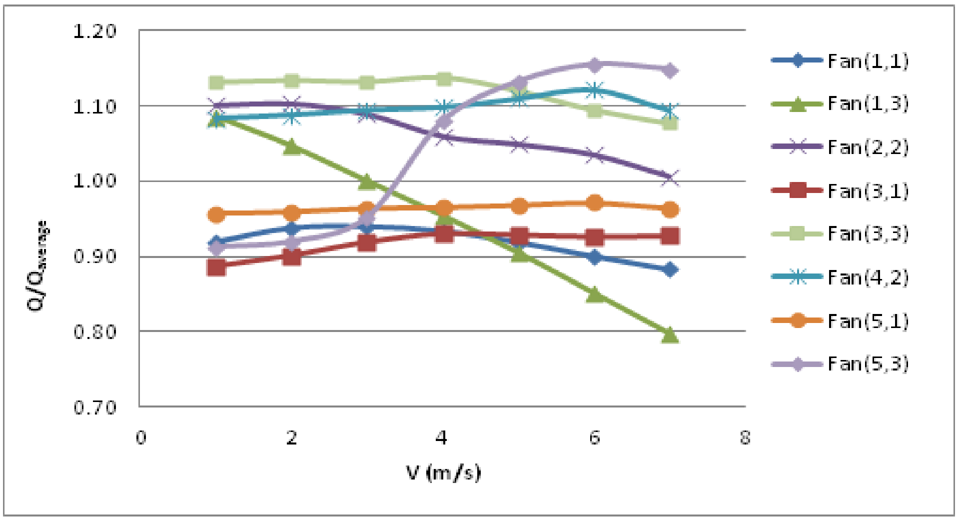

Figure 6: Airflow through fans for 30m fan deck height

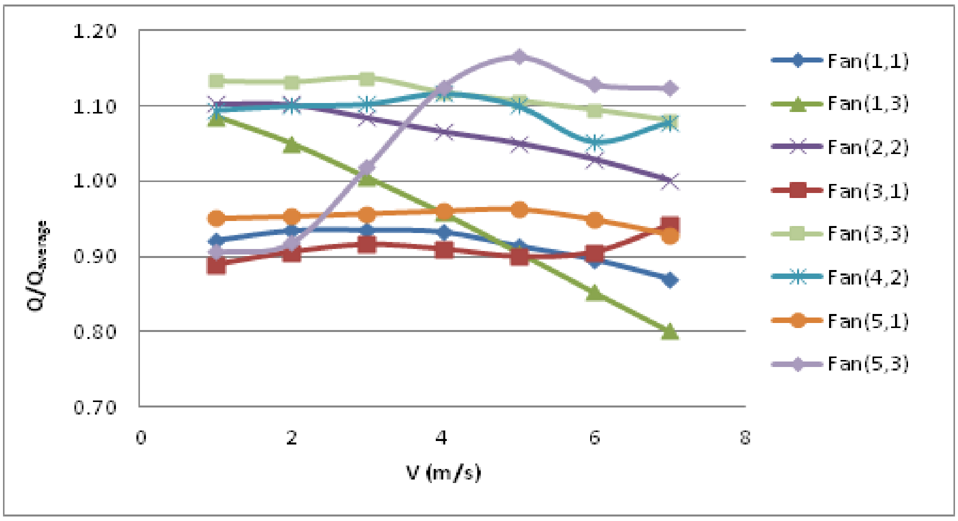

Figure 7: Airflow through fans for 35m fan deck height

V. CONCLUSION

One of the most important factors in sizing of the air cooled condenser is guaranteed power consumption for the fans particularly for one consisting of many fans. The power consumption is directly proportional to the static pressure of fan which is the total system resistance fan has to overcome to be able to force the air through the tube bundles. It consists of tube bundle pressure losses, fan losses, fan inlet losses, ACC perimeter inlet losses etc. ACC perimeter inlet losses can be reduced by increasing the face area of the air inlet to ACC perimeter. This is done by increasing the fan deck height. So the height of fan deck is one of the most important factors to be optimized in order to have lesser power consumption for fans.

As the number of axial flow fans are kept side by side to force the air through the tube banks it is of much importance that the required flow of air for each fan is met failing to which it will result in less air flow and thus decreasing the performance of the ACC. This is ensured by providing the sufficient height of the bottom structure so that the requirement of all the fans is fulfilled. Contrary to this the effect of wind speed is more severe when the height of structure is more as the total air flow is reduced in case of higher winds. So while designing an air cooled condenser it is required to either mitigate the adverse effect of higher wind velocities by providing the wind screens or to select the lower deck heights or a design factor of more than one is to be considered and it is not always advantageous to increase the fan deck height.

Here the most important is to note that the behavior of air flow is very specific to the selected model of ACC and it can vary considerably for any other configuration of the ACC. As the flow characteristic of any Air cooled condensers are very specific to its geometry and the internal construction so the air flow characteristics of the ACC analyzed are not generalized for any other configuration of ACC. This paper gives the basic idea of the flow pattern through the fans at various height of ACC and various wind speeds.

Normally all the fans are identical in an ACC with a constant static pressure which results in unequal air flow even at normal wind velocities. This can be avoided by having different static pressure of fans based on its location within the ACC model. From the current work it is evident that the fans which are at the periphery of ACC are facing the problem of the air starvation at higher winds. Hence the fans located on the periphery of ACC can have the slight higher blade angle thus having more static pressure required to have equal volumetric flow through all fans.

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