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Performance and Experimental Investigation of Air Cooled Condenser in Thermal Power Plant

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Abstract- **This paper gives brief idea of air flow pattern as well as ambient conditions are studied. Fin cleaning plays a vital role in heat rejection. External surface cleaning improves air side heat transfer coefficient. The several factors that affect the performance of condense especially the consequences that result from the fouling of the finned-tubes. Ambient conditions affect the steam temperature and heat rejection rate. It is observed that rise in wind velocity decreases thermal effectiveness of Air-Cooled Condenser- ACC up to considerable level. Ambient temperature not only affects performance of ACC at the same time turbine back pressure also increases with rise in ambient temperature. Skirts are effective solution to reduce the effect of wind on volumetric effectiveness. Hot air recirculation increases with wind velocity. Rectifying the degradations in performance that result from external tube fouling, a number of cleaning procedures are described. In present era wind walls are used to reduce this effect. Second option is to increase fan speed.**

Index terms- **Air Cooled Condenser, Ambient temperature, Dry cooling, Fouling**

I.INTRODUCTION

Since last 35 years there has been a growing and competing demand for water for both domestic and industrial use and this has brought an increased interest in the use of air as a cooling medium in place of water. In the utility industry, the earliest applications for the air-cooled condensing of exhaust steam were modified air-cooled heat exchangers similar to those already in use by the process industries. Eventually, air-cooled condensers designed for the utility industry evolved into a configuration that recognized the special needs of condensing a large volume of low-pressure vapor as well as the removal of non-condensable. With an increase in the ambient temperature, the effectiveness of these cooling systems decreases resulting in a corresponding reduction in turbine efficiency. The reduction in turbine output during hot periods may result in a significant loss in income, especially in areas where the demand and cost for power during these periods is high.

II. CURRENT WORLD WIDE SCENARIO OF ACC

Selection of cooling technology for use in power plants is an economic decision which is frequently influenced by local environmental factors. In the early days, use of dry cooling methods was sometimes the only feasible option due to scarcity of water at otherwise attractive plant sites in arid and semi-arid regions of the world. However, the combined trends of increasing demands for power, more widespread scarcity of available water for cooling and increasing costs of water and tighter environmental restraints related to use of wet cooling systems served to broaden selection of the ACC option, in term of both number and size of units.

III. THE ENVIRONMENTAL PROTECTION AGENCY AND DRY COOLING

In 2000, the U.S. Environmental Protection Agency conducted a comparative study of the environmental impacts of wet vs. dry cooling. Their conclusion was that the energy consumption per lb. condensate was higher for dry cooling than for wet cooling and that the atmospheric emissions associated with that energy consumption was also higher. These disadvantages are offset by the cooling water intake flow being reduced by 99% over that required by a once through system; or 4-7% over a closed cooling water system. They also noted that dry cooling eliminates visual plumes, fog, mineral drift and water treatment and waste disposal issues. However, their conclusion was that, ‘dry cooling does not represent the “Best Technology Available (BTA) for minimizing environmental impact”.

Based on various analyses the actual corrosion appears to be a flow accelerated corrosion (FAC) derivative where local indigenous magnetite is removed from the surface of the ACC tube leaving a very intergranular surface appearance. Adjacent to these areas where the local turbulence of the two phases media is not as great, the magnetite deposits on the surface. There are clear boundaries between the regions where corrosion/ FAC takes place (white bare metal) and regions where deposition (black areas) occurs.

Fig 1.1 DHACI Indices 1-5 for upper ducts and tube entries

IV. AIR-COOLED CONDENSER DETAILS

ACC transfers exhaust steam into condensate, then gives condensate to water circulation. Exhaust steam comes from turbine gets into ACC steam collection header through steam pipe. In the steam collection header, steam falls down in fin tubes in “A” frame of air-cooled condenser due to vacuum.

Air Cooled Condenser		
1	Manufacturer	Wuxi Dongsheng
2	Manufacturer address	Shandong Jinan Power Equipment Factory, Jinan 250100, China
3	No of Condenser	4 Nos
4	Fan Type	Forced type
5	No of fan	6 Nos.
6	Fan Dia. Ø (Mtr)	9. 8
7	Blade material	FRP
8	Hub Material	C40 - hot dip galvanized
9	Size of Exhaust steam duct (mm)	1800
10	Size of branch pipe going from main pipe to each stack of 3 fans	1600
11	Total weight Air condenser cooling (T /Unit)	600
12	Flow finned tubes	XT10x3-2-247-0.3Q-12.8/TC-2
13	Counter flow finned tubes	XT9.4x3-2-232-0.3Q-12.8/TC-2
14	A Frame	GXT22X36-97.25/7
15	Forced draft fan system	G-TF97.25B5 -C91
16	Block wind wall	D9726
17	Motor kW / Voltage	90 / 416

Table 1.1. Specifications of Air -Cooled Condenser

Figure 1.2 Air cooled condenser (UltraTech Cement Ltd.)

V. RESULTS AND DISCUSSION

5.1 Effect of Wind velocity on Effectiveness

As the wind speed increases inlet flow distortion experienced. The thermal effectiveness decreases as the wind velocity increases as shown in the graph. The flow distortion and regarding low pressure region at the upstream region of the fan contributes in the decrease of ACC performance. The wind itself has positive impact on certain fans also.

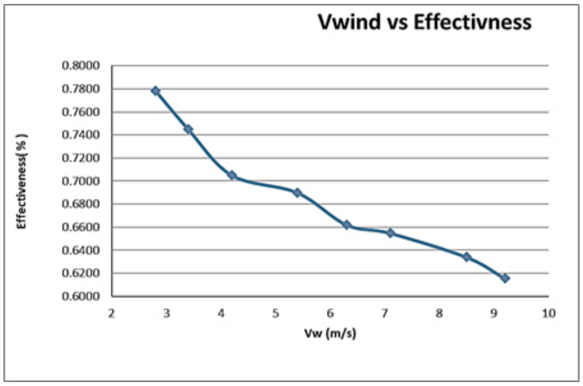

Fig 1.3 Wind Velocity Vs. Effectiveness

The volumetric effectiveness also can be increased. Relatively at low wind speeds effectiveness is higher. As the wind velocity increases due to flow distortion and low-pressure regions thermal effectiveness of ACC is reducing up to level of 61.5%. The favorable thing for ACC is that wind velocity improves volumetric effectiveness.

5.2 Effect of Ambient temperature on Heat rejection

As ambient temperature increases from 22˚C heat rejection rate decreases as its effect on LMTD. Up to large extent heat rejection rate depends on inlet (ambient) temperature and ambient temperature depends on the seasons. Normally in winter heat rejection rate is as per design. In summer as the ambient temperature increases it adversely effect on heat rejection because it decreases LMTD and ultimately heat rejection. Due to this reason in some of the areas of the world they are using water spray techniques to maintain heat rejection rate constant. Ultra tech power plant is situated at sea shore and where ambient temperature never exceeds 36˚C. In countries like India ACC can work better nearer to sea shore.

Fan No.	Air Side Area Aa (m^2)	Steam Side Area As (m^2)	UA (W/˚K)
1	27610	2562	9.434×10^5
2	16565	1537	5.666×10^5
3	22087	2050	7.556×10^5
4	27610	2562	9.434×10^5
5	16565	1537	5.666×10^5
6	22087	2050	7.556×10^5

Table 1.2. Steam and Air side areas of all fans

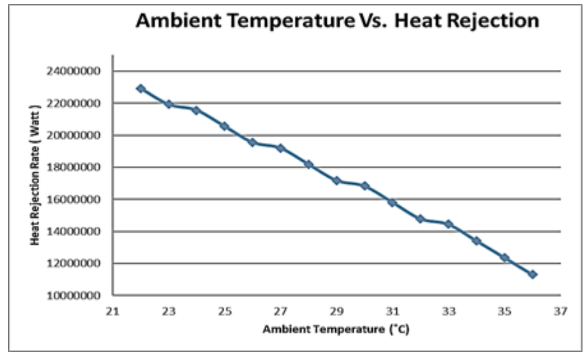

Fig 1.4 Variation in heat rejection rate Vs. Ambient temperature

5.3 Effect of Skirt effect on volumetric performance of ACC.

The addition of skirt does increase the performance of an ACC measurably under windy conditions, by modifying the flow into the ACC and by reducing the hot air recirculation that exists at the downstream edge fans. The low-pressure region at the inlet of the upstream edge fans is displaced away from the fan inlet, resulting in an increase in the volumetric effectiveness of the upstream edge fans and a corresponding increase in the volumetric effectiveness of the ACSC.

Vw (m/sec)	V/Vid	V/Vid (With Skirt)
2.8	0.95	0.99
3.4	0.95	0.98
3.9	0.94	0.98
4.4	0.93	0.97
4.8	0.92	0.97
5.4	0.9	0.96
6.2	0.89	0.95
6.8	0.87	0.94
7.6	0.85	0.94
8.2	0.85	0.93
9	0.84	0.92

Table 1.3 Data for Volumetric effectiveness with and without skirt

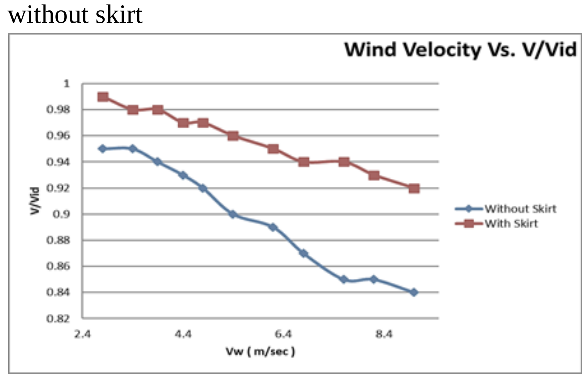

Fig. 1.5 Volumetric effectiveness Vs. Wind Velocity

5.4 Effect on thermal effectiveness by variation of Air flow rate

Heat is rejected in the atmosphere and rejection rate is largely dependent on the surface condition of fins. Due to different weather conditions fouling occurs on the surface of exposed surfaces. Due to the deposition it decreases heat rejection rate and ultimately cleaning becomes inevitable. Thermal effectiveness increases even though mass flow rate of air decreases. By cleaning coefficient of heat transfer (air side) is increasing. For different values of coefficient calculations are made and plotted graph clearly indicates that as cleaning progresses less mass flow rate of air is required. At the same time thermal effectiveness also increases.

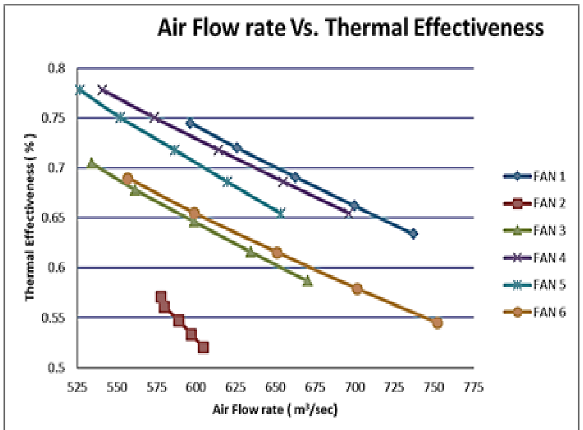

Fig. 1.6 Variation in thermal effectiveness Vs. Air flow rate

Air Side Heat Transfer Co-efficient ($W/m^{2}°k$)	Air flow rate(m^3/Sec)	Effectiveness (%)
35	737	0.6340
36	700	0.6621
37	662.82	0.6908
38	625.65	0.7201
39	596.3	0.7451

Table 1.4 Data of heat transfer coefficient with air flow rate

For different 5 values of heat transfer coefficients calculations have been made. As the cleaning progresses required mass flow rate decreases for the same heat rejection. Cleaning not only reduces mass flow rate of air but gives considerable savings in terms of rupees.

Saving Calculation of ACC Fan Foam Cleaning
Parameter of Stg-3 Before & After Acc Fan Foam Cleaning

Status (Stg-2 Acc Fins Cleaning Work			
	STG-3		STG-1
	Before	After	Current
Load	19.8 MW	23 MW	22.5 MW
Steam Inlet	88 MT	100 MT	97 MT
Vacuum	0.8 atm	0.8 atm	0.8 atm
Sp. Steam cons. (MT/MW)	4.44	4.34	4.31
Steam to coal ratio	5.00	5.00	5.00
Sp. Coal cons. MT/MW	0.89	0.85	0.90
Fuel Cost Rs. / kWh	2.65	2.54	2.68
Fixed Cost Rs. /kWh	0.28	0.28	0.28
Power Cost	2.93	2.82	2.96
Unit generation per day	4,00,000 kWh		
Power Cost per day	1172000	112800	1184000
Diff. in Power Cost	44000	0.00	56000
	Before cleaning	After cleaning	Compared to STG-3 after cleaning
Saving/day in Rs.	44000		56000
Saving/month in Rs.	1320000		1680000
Saving/annum in Rs.	16060000		20440000
Saving/annum in Rs.	1.6 Crore		2.04 Crore
Cost of fins cleaning per STG (Six Nos. ACC fans) = 4.60 lacs			
Payback time achieved in STG-3 = 10.45 days			
Proposed Payback time in STG-1 = 8.21days			

Table 1.5 Savings in Rs. by cleaning of ACC surface.

VI. CONCLUSION

The main focus of this study was to determine characteristic curves of an air-cooled condenser under atmospheric parameters.

1. Hot air recirculation is generally observed in so many plants. To minimize fan rotational speed to be increased. This is not the solution because electrical energy consumption by fan will

increase. The optimum solution is wind wall on the sides of the radiator.

2. Ambient temperature plays key role in the performance of ACC. Generally, ACC is advisable where ambient temperature not rising much, especially at sea shore areas. More than that ambient temperature also effects on turbine back pressure which can reduce output power.
3. After ambient temperature wind velocity is the secondary parameter which effects on ACC performance. As the wind velocity increases effectiveness (thermal and volumetric) decreases and hot air recirculation increases.
4. Various techniques for cleaning are adopted to increase heat transfer rate. As the cleaning progresses for various heat transfer coefficients (air side) improves. Ultimately which accelerates heat rejection rate to atmosphere.

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