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FABRICATION, EXPERIMENTATION, PERFORMANCE EVALUATION OF TWO STAGE AIR COOLER AND COMPARISON WITH CONVENTIONAL AIR COOLER

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ABSTRACT

During summer use of khush curtains and water spraid over the khash (fibre) curtain for air cooling is done. But the determination of the extent of cooling is limited up to the wet bulb temperature in Conventional Cooler air is passes at uniform rate through wetted pad. In this process humidity increases sometimes which is not desirable. In Two Stage Air Cooler the primary air is cooled by a contact surface which is maintained at lower temperature air and water on the other side of the contact surface.

After analysis it is found that in Two Stage Air Cooler Effective temperature decreases COP increases up to 13 which are significantly higher than normal cooler and conventional air conditioner. Refrigeration effect increases. Makeup water recharges time increases for the same configuration has been obtained for it is 24 hours 54 minutes and for conventional cooler it is 15 hours 2 minutes. In two stage air cooler with cover noise has been drastically reduce by the increase damping effect of covers Specific humidity increase is significantly lower than that of in case of Conventional Cooler.

On the basis analysis it is recommended that two stage indirect air cooler is energy effective, eco friendly, cost effective cooling system and with some further modification it may be hope as replacement of air conditioner. In direct cooler expected limit lower temperature was 22.6 where as experimentally the temperature attains are 24. In indirect cooler system the expected temp was 20.5 where as the actual temperature attain is 21.9 less than the wet bulb temperature with lesser relative humidity than 100%).

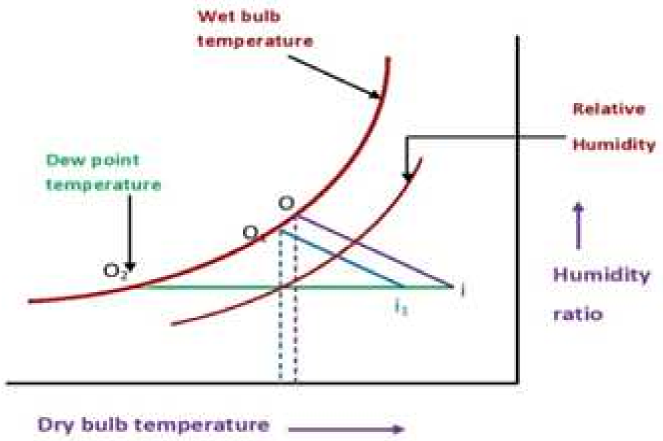
KEYWORDS: Auxiliary Pump, Conventional Air Cooler, DBT, Heat Exchanger, Primary Pump, Two Stage Air Cooler WBT

INTRODUCTION

Principle of evaporative cooling has been used since long back, during summer use of khush (fibre) curtains and water sprayed over it for air cooling. Other example of evaporative cooling are use of shurahi pot for water cooling, cooling tower, spray ponds etc. But the determination of the extent of cooling is limited up to the wet bulb temperature. In Conventional Cooler air is passes at uniform rate through wetted pad. In this process humidity increases sometimes which is not desirable. In Two Stage Air Cooler the primary air is cooled by a contact surface which is maintained at lower than temperature of incoming atmospheric air. In both the process minimum temperature can be achieved theoretically is wet bulb temperature (WBT) of the incoming air.

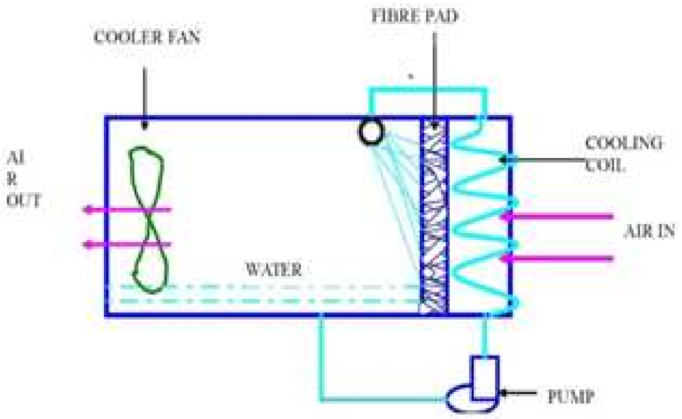
Proposed Modification

The temperature of air decreases from ‘i’ to ‘o’ in Conventional Cooler. in indirect evaporative cooler the temperature of ‘ i_1’ is lower than temperature at‘ i’ and if proceeding is done on the constant WBT Line then it goes up to‘O_1’ which is lower than the previous ‘O’. This indicates that if temperature of air at ‘i’ is cooled to ‘i_1’ prior to entry to main cooler by any means lower temperature can be achieved. This suggests need of cooling of air prior or in other words two stages cooling. The equipment based on this principle is designated as Two Stage Air Cooler and theoretically one may reach up to the dew point temperature.



Experimental Setup

The heat exchanger is fitted on the back panel of the cooler, the inlet is connected with the secondary pump situated inside the cooler tank so that water supply from for the exchanger is from the tank and outlet is connected with a pipe to discharge the water in the same tank connected.



For measurement of temperature of cold water entering the heat exchanger a thermometer probe is inserted in the inlet pipe and for measurement of hot water temperature coming out of the heat exchanger a thermometer probe is inserted in the outlet pipe. For measurement of air temperature at the inlet of heat exchange, outlet of heat exchanger, outlet of cooler and ambient temperature four thermometers installed at respective position. Also for the measurement of energy consumption at different arrangement that is combined direct and indirect and direct only at various speed/velocity energy meter was installed to get energy consumption in kwh.

Arrangement of Instrument to Measure Temperature at Different Points

Heat Exchanger Designed for Two Stage Air Cooler

Nomenclature

DBT = Dry bulb temperature

WBT = Wet bulb temperature

A_1 = area of inlet of cooler

A_3 = area of outlet of cooler

$T_{1\ dbt}$ = dry bulb temperature of air inlet to heat exchanger

$T_{2\ dbt}$ = dry bulb temperature of air after passing through heat exchanger

$T_{3\ dbt}$ = dry bulb temperature at outlet of cooler

T_{1wbt} = wet bulb temperature at inlet of heat exchanger

T_{3wbt} = wet bulb temperature at outlet of cooler

RH_1 = Relative humidity at inlet to heat exchanger

RH_3 = Relative humidity at outlet of cooler

W_1 = specific humidity at inlet of heat exchanger

W_3 = specific humidity at outlet of cooler

h_1 = specific enthalpy at inlet to heat exchanger

h_3 = specific enthalpy at outlet

T_{w1} = Inlet temperature of water

T_{w2}= Outlet temperature of water

S_w= specific heat of water

S_a = specific heat of air

DATA COLLECTION AND CALCULATION

Data was collected on various days on different time. All the parameter required for calculation and performance evaluation of two stage air cooler needed has been arranged in tabular form for convenience in visualisation and graph plotting.

Calculation of Velocity

Velocity was calculated at five different points then average of them is taken for both inlet and outlet for high speed, medium speed and low speed respectively. The velocity of air may vary for different atmospheric conditions.

Table 1: Velocity at Inlet of Cooler at Different Points in Different Speed

Points	Inlet Speed (m/s)	Outlet Speed (m/s)
1	3.70	4.20
2	3.10	3.30
3	2.75	1.10
4	3.20	1.20
5	3.00	1.20
Average	**3.15**	**2.20**

For performance evaluation and analysis experiment is performed in for different cases as following

Case A

Two Stage Air Cooler

In this process both cooler pump and auxiliary pump was switched on air is first cooled sensibly then evaporative cooling is done, side panel of cooler is covered with insulating medium so that there is no mixing of hot air from side panel.

Table 2: DBT and WBT at Different Points at Different Velocity for Two Stage Air Cooler

Average Velocity		DBT			WBT	
1	3	1	2	3	1	3
3.15	2.20	31.5	27.5	21.9	22.6	20.50

Case B

Conventional Cooler

In this process auxiliary pump is switched off so only evaporative cooling of air is done. Side panel of cooler is covered with insulating medium so that there is no mixing of hot air from side panel.

Table 3: DBT and WBT at Different Points at Different Velocity for Conventional Cooler

Average Velocity		DBT		WBT	
1	3	1	3	1	3
3.15	2.20	31.5	24.0	22.5	21.4

Calculation

Calculation is done in and expressed in tabular format so that data for comparison of Two stage air cooler and Conventional air cooler may be viewed clearly and easy to plot graphs.

Table 4: Calculation of Various Parameters for Two Stage Air Cooler

Velocity (m/sec)		Dry Bulb Temperature (°C)			Wet Bulb Temperature (°C)		Relative Humidity (%)	
1	3	1	2	3	1	3	1	3
3.15	2.2	31.5	27.5	21.9	22.6	20.5	46.40	87.37

Dew Point Temperature		Specific Humidity (kg/kg)		Mass Flow Rate of Air (kg/sec)		Specific Volume (m^3/Kg)	
1	3	1	3	1	3	1	3
18.62	19.70	0.01346	0.01443	0.3540	0.3563	0.8809	0.8844

Specific Enthalpy (KJ/Kg)		ΔH (KJ/Kg)	Δw (kg/kg)	Make up Water (kg/hr)	Area (m^2)	
1	3	(1-3)	(3-1)		1	3
66.10	58.67	7.43	9.67*10-4	1.2441	0.099	0.1384

Energy Consumption (Kwh)	Time to Refill Water Tank (hr)	Carnot COP	COP
0.201	24:54	30.71	13.20

Table 5: Calculation of Various Parameters for Conventional Cooler

Velocity (m/sec)		Dry Bulb Temperature (°C)			Wet Bulb Temperature (°C)		Relative Humidity (%)	
1	3	1	2	3	1	3	1	3
3.15	2.2	31.5	31	24.0	22.5	21.4	45.89	79.56

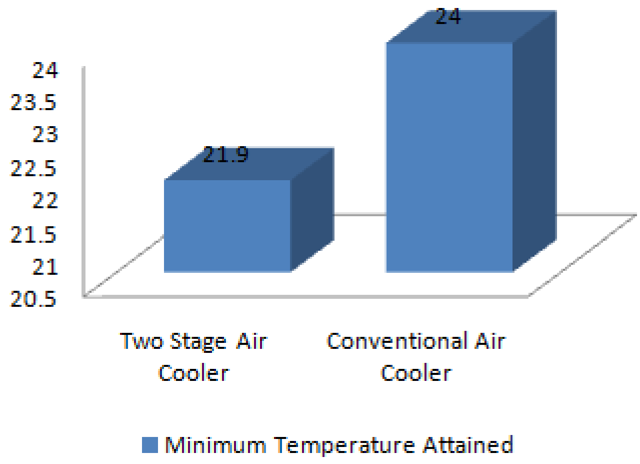
Dew Point Temperature (°C)		Specific Humidity (kg/kg)		Mass Flow Rate of Air (kg/s)		Specific Volume (m^3/kg)	
1	3	1	3	1	3	1	3
18.44	20.25	0.01331	0.01493	0.3527	0.3535	0.8841	0.8612

Specific Enthalpy (kJ/kg)		ΔH (kJ/kg)	Δw (kg/kg)	Make up Water (kg/hr)	Area (m^2)	
1	3	(1-3)	(3-1)		1	3
65.72	62.12	3.60	$1.62*10^{-3}$	2.0616	0.099	0.1384

Energy Consumption (kwh)	Time to Refill Water Tank (hr)	Carnot COP	COP
0.183	15:02	39.6	6.9540

RESULTS AND DISCUSSIONS

Minimum Temperature Attained

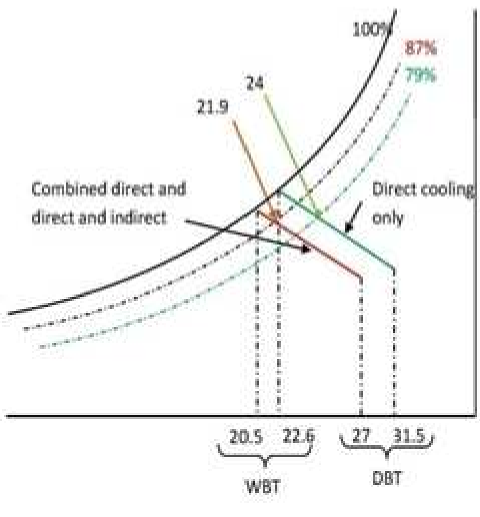


Effects

Temperature attained in Two Stage Air Cooler is lower than Conventional Cooler.

Reason

In Two Stage Air Cooler the air is pre-cooled sensibly in the heat exchanger so the better cooling is performed this departure of temperature may be better explain by psychometric chart.

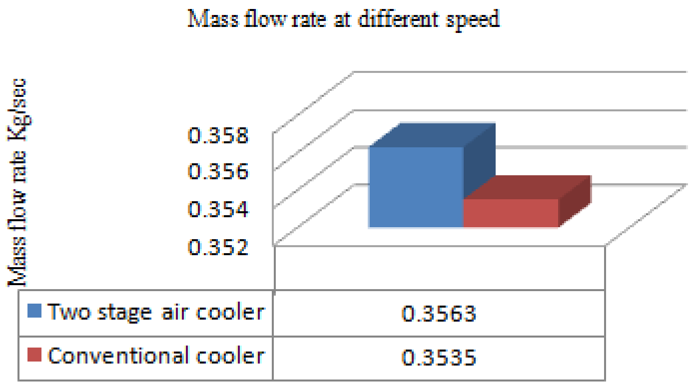


Cooling process in two stage air cooler

This departure may be considered due to water spray at wet bulb temperature provides sensible cooling of air which has already humidified adiabatically.

Mass Flow Rate at Different Speed

Data ref table 4 and 5



Effect

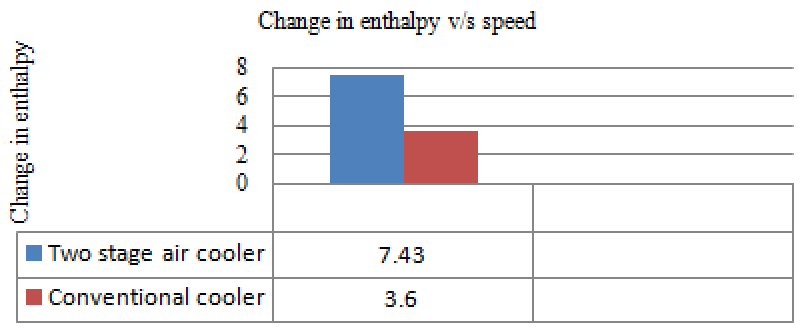
As the velocity decreases mass flow rate also decreases

Reason

Mass flow rate decreases with decreased velocity because area of inlet and outlet is constant so mass flow rate varies according to velocity.

Variation in Change in Enthalpy

Data ref table 4 and 5



Effect

Change in enthalpy for incoming and outgoing air in combined arrangement is more than direct cooling arrangement..

Reason

The incoming air condition is same for both the arrangement but the outgoing air in former case is much lower than Conventional Cooler so in case of Two Stage Air Cooler arrangement change in enthalpy is more.

Refrigeration Effect

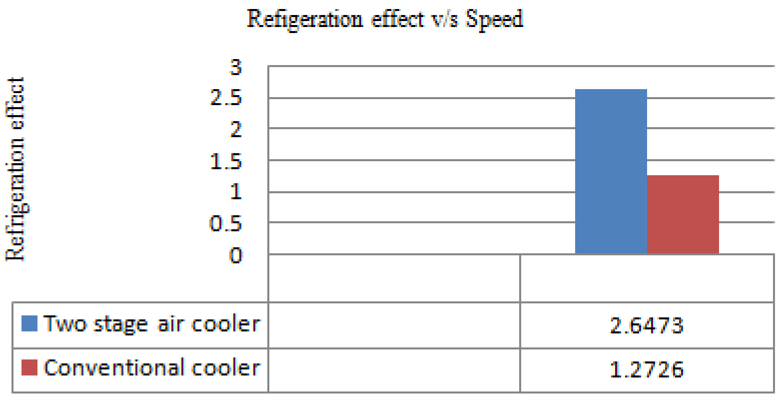
Data ref Table 4 and 5

Effect

Refrigeration effect for Two Stage Air Cooler is more than Conventional Cooler.

Reason

Since the change in enthalpy in case of Two Stage Air Cooler is more than Conventional Cooler only. So refrigeration effect in combined process is also more



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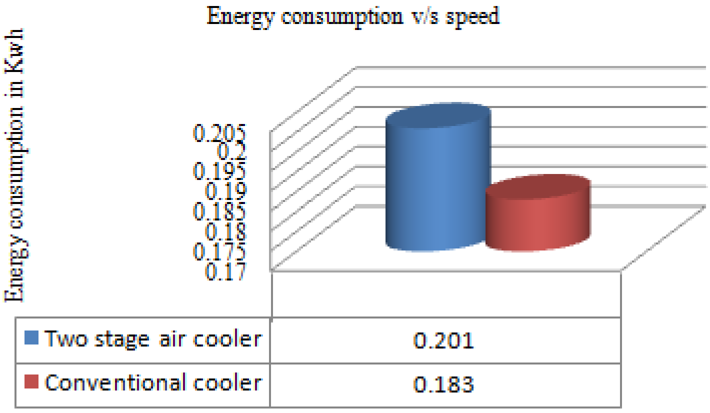
Energy Consumption

Data ref table 4 and 5



Effect

Energy consumption for Two Stage Air Cooler is more than Conventional Cooler only.

Reason

Energy consumption for Two Stage Air Cooler is higher than direct cooling only because in former case along with fan and primary pump secondary pump is also running but in direct cooling secondary pump is not running so energy consumption is less.

Make up Water Requirement

As in cooler the cooling of air is by the process of evaporative cooling so the water evaporated continuously so make up water is need after particular interval of time according to arrangement and use of cooler.

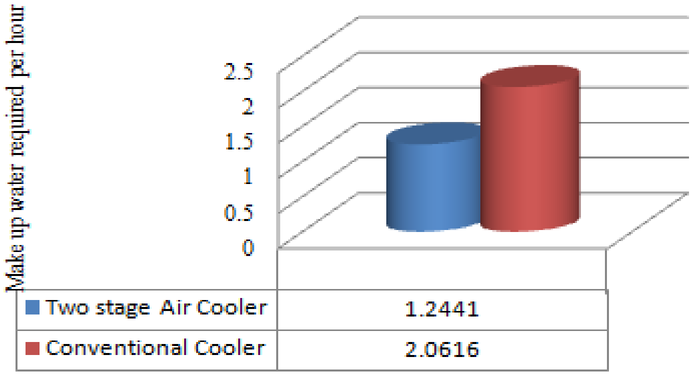
Data ref table 4 and 5

Effect

Make up water requirement is more for Conventional Cooler than Two Stage Air Cooler.

Reason

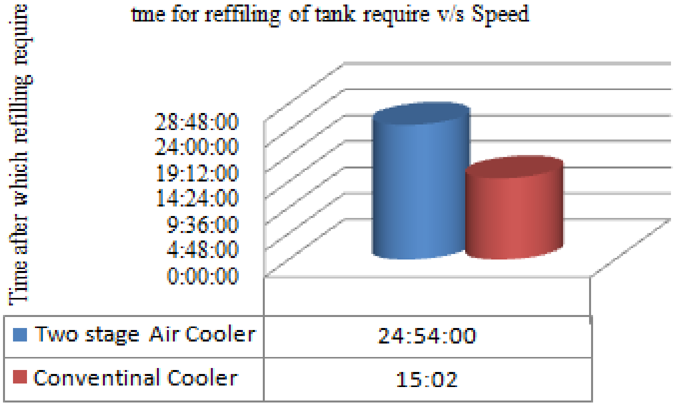
Difference in specific enthalpy at inlet and outlet of cooler is more in case of Conventional Cooler only because at outlet specific enthalpy is more in case of Conventional Cooler.



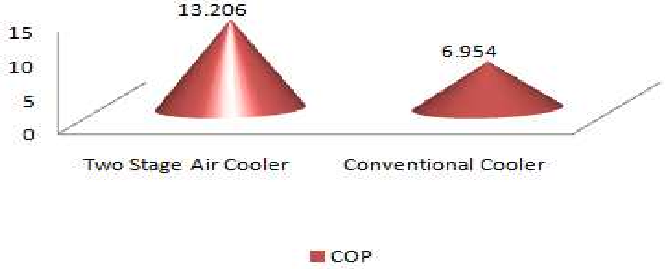
Makeup Water Recharge Time (May vary according to prevailing ambient condition)

As the makeup water needed so the tank has to be refill after particular interval of time depending on the capacity of tank and use of cooler. In this cooler the tank capacity is 31 litres so time to refill the tank for different arrangement and different speed has been given below in tabular form.

Data ref table 4 and 5



Comparison of COP



CONCLUSIONS

Following are the fruitful result outcome of indirect two stage air cooler their details have been provided in result and discussion.

- Effective temperature decreases
- COP increases up to 13 which are significantly higher than normal cooler and conventional air conditioner.
- Refrigeration effect increases.
- Makeup water recharges time increases for the same configuration has been obtained.
- In two stage air cooler with cover noise has been drastically reduce by the increase damping effect of covers
- Specific humidity increase is significantly lower than that of in case of Conventional Cooler.

RECOMMENDATIONS

- Two stage indirect air cooler is energy effective, eco friendly, cost effective cooling system and with some further modification it may be hope as replacement of air conditioner.
- In direct cooler expected limit lower temperature was 22.6 where as experimentally the temperature attains is 24. In indirect cooler system the expected temp was 20.5 where as the actual temperature attain is 21.9 less than the wet bulb temperature with lesser relative humidity than 100%

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