VOL. 5, NO. 2, FEBRUARY 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

IMPROVING THE ENVIRONMENTAL COOLING FOR AIR-COOLERS BY USING THE INDIRECT-COOLING METHOD

Farhan A. Khmamas
Department of Mechanical Engineering, College of Engineering, Al-Nahrain University, Iraq
E-Mail: eng_mah75@yahoo.com

ABSTRACT

Air-coolers are widely used as a cheap and convenient method for cooling; however, noise, humidity, smoking, and difficulty in controlling the interior temperature are its major disadvantages. In this research, we suggest using the indirect evaporative cooling method instead of the direct method. In this method the air-cooler is modified to operate as a cooling tower to produce cooling water by the evaporation process; this represents the outdoor unit. The cooled water is pumped to the indoor unit which consists of a fan coil unit. Many experiments were carried out to calculate the Evaporation Cooling Effectiveness (ECE) in case of the direct and indirect cooling (forced or natural). The results for the two cases were compared. It is concluded that the (ECE) reduces by 15% for forced evaporation case, and by 22% for the natural case, as compared with the direct case and (with in 30/5/2008 and 16/6/2008).

1. INTRODUCTION

In the direct evaporative air cooling air is drawn through porous wetted pods or a spray and its sensible heat energy evaporates some water. The heat and mass transferred between the air and water lowers the air dry-bulb temperature and increases the humidity at a constant wet- bulb temperature, the dry-bulb temperature of the nearly saturated air approaches the ambient air wet-bulb temperature. The process is adiabatic. So no sensible cooling occurs. Figure-1 shows the processes of this cycle Ref [1].

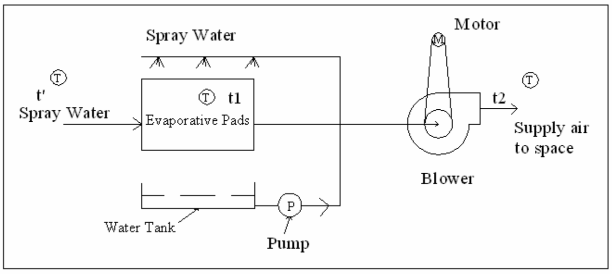


Figure (1) Direct Evaporative Cooling

Principle advantages of the direct and indirect evaporative air conditioning include:

- Substantial energy and cost savings.
- Reduced peak power demand.
- Improved indoor air quality.
- Life cycle cost effectiveness.
- Easily integrated into built - up systems.

In the present work we are making some modification on the direct evaporative cooler to change it to work as indirect type. This modification includes using the normal air cooler as a cooling - tower to be the source of cooled water. The cooling - tower is located at outdoor space. The cooled water represents the fluid media for an indirect cooling process. Then this water is circulated through the indoor unit which is a fan - coil unit. It mainly consists of heat exchanger and air circulating fan. See (Figure-1) Ref [3].

The primary room air then is cooled when it passes through the heat exchanger tubes. This configuration can serve some important advantages such as:

- Low noise.
- Improving the comfort condition.
- Easier for cooling the room space.

In our experiments we make a comparison between using the same air cooler as direct and indirect evaporative systems in order to show how this modification can affect the performance of the cooling cycles, hence the effectiveness factor was calculated for three cases which are:

a) Direct evaporative case.
b) Indirect evaporative case using natural evaporation process.
c) Indirect evaporative case using forced fan.

On 30 days of 12 hours' time duration between (10 am and 10 pm) the data for the three cycles were taken for the comparison purposes.

2. THEORY

In the case of direct evaporative air cooling the saturation effectiveness is a very important factor in determining the performance of an evaporative cooler.

The extent to which the leaving air temperature from a direct evaporative cooler approaches the thermodynamic wet - bulb temperature of the entering air or the extent to which complete saturation is approached is expressed as the direct saturation effectiveness.

Which is defined as: Ref [3]

$$\varepsilon_e = 100\frac{t_1-t_2}{t_1-t'} \quad \text{.......... (1)}$$

Where

VOL. 5, NO. 2, FEBRUARY 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

ε_e = direct evaporative cooling or saturation effectiveness, %

t_1 = dry - bulb temperature of entering air, °C

t_2 = dry - bulb temperature of leaving air, °C

t' = thermodynamic wet - bulb temperature air, °C

While in case of indirect evaporative cooling, the indirect evaporativ effectiveness can be found as follows: Ref [4]

$$\varepsilon_e = 100\frac{T_1 - T_2}{T_1 - T'} \quad \text{……….. (2)}$$

Where

ε_e = indirect evaporative effectiveness.

T_1 = dry - bulb temperature of entering primary air, °C

T = dry - bulb temperature of leaving primary air, °C

T' = wet - bulb temperature of entering secondary air, °C

3. EXPERIMENTAL WORK

A standard commercial type air-cooler with the following specification was used:

Capacity	:	3500 m^3/s
Effectiveness factor:		80 %
Power consumption:		300 W
Dimensions:		(1m x 1m x 1m)

3.1 Direct cooling case

Figure-2 represents the schematic diagram for direct evaporative case and the location for the thermometers used in this test.

3.2 Experiment procedures

The following procedures were used for direct method we make the following:

a) The testing model (air - cooler) is left to operate from 9 am to reach steady operation.
b) Three calibrated thermometers were located at the positions shown in Figure-2 to measure the temperatures t_1, t_2, and t'.
c) At 10 am we reach the first reading for t_1, t_2, and t'.
d) The procedures in (c) are repeated after every hour until 10 pm.

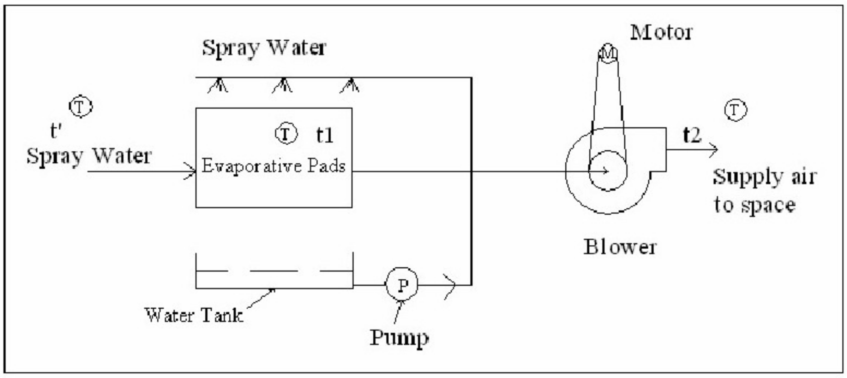


Figure-2. Direct evaporative cooling.

For indirect case we make the following:

a) The testing model consists of two parts one of them is the modified cooling tower at which the dry bulb thermometer is hold to measure T1.
b) To measure T' (the wet bulb) the wet bulb thermometer is used and located near the tower as shown in (Figure-1).
c) To measure T2 the third thermometer is located in front of the supply air.
d) The readings of the three thermometers are observed every 1 hour starting from 10 am to 10 pm.
e) The readings of the three thermometers (T, T2, T') are repeated for the natural case where the fan motor is shut down.

The photographs of testing model is shown in (Figure-3).

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

(a) (b)

Figure-3. Shows the apparatus a) is the side view and b) is the front view of the apparatus.

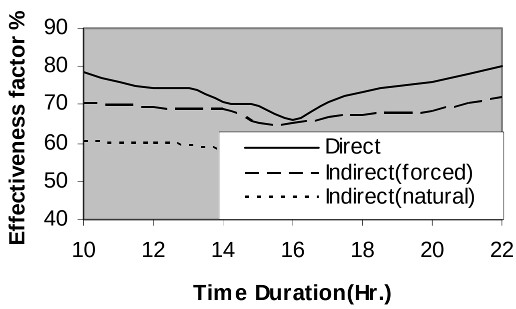
Coil specifications.

Temperature range	0-250°C
Pipe diameter	25 mm
Pipe material	Red brass
Flow rate	0.3 m^3/s
Type	Single (12 row) pipes
Dimensions	1.5m x 0.4m x 0.2m

4. RESULTS

Figure-4 to Figure-7 shows the effectiveness factor of the three cases as follows:

a) Direct cooling.
b) Indirect cooling at force air circulation mode in this case the blower motor is in operation.
c) Indirect cooling at natural air circulation in which the blower motor is off.



Fig(4):Effectiveness factor for direct and indirect evaporative cooling (Baghdad 1/6/2008)

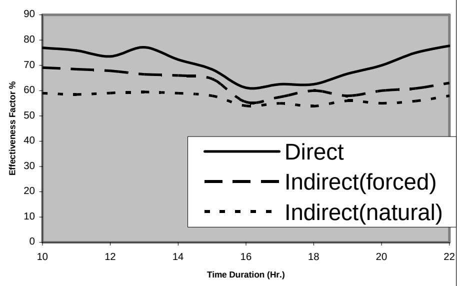


Fig.(5):Effectiveness factor for direct and indirect evaporative coolimg(Baghdad 6/6/2008)

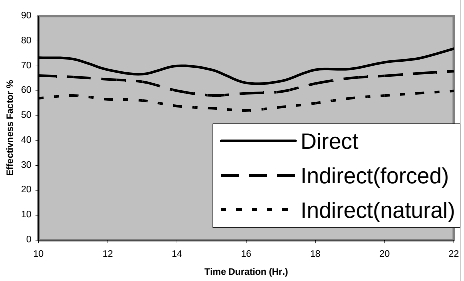


Fig.(6):Effectivness factor for direct and indirect evaporative cooling(Baghdad 11/6/2008)

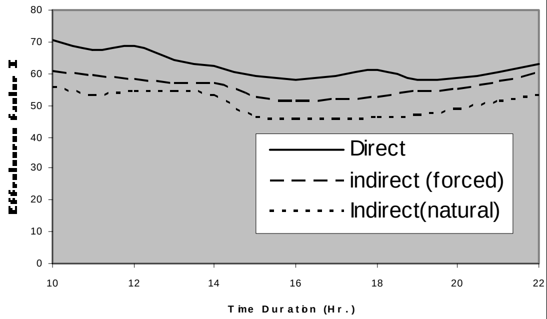


Fig.(7):Effectivness factor for direct and indirect evaporative cooling (Baghdad 16/6/2008)

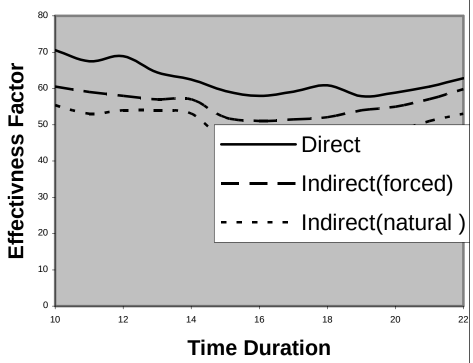


Fig.(8):Effectviness factor for direct and indirect evapurative cooling (Baghdad 30/6/2008)

The data for 30 days were taken and the weekly average was calculated for the observed temperature, so we had five tables for the average data in June for the days (1, 6, 15, 21 and 30) and are given in Tables 1 to 5.

VOL. 5, NO. 2, FEBRUARY 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-1. Experimental data at 1/6/2008.

Hr	t1	t2	t b	E.F. D	E.F. in D1	E.F. in D2	Reduc. 1	Reduc. 2
10	34	23	20	78.57143	70.2	60.5	10.65455	23
11	34	23	19.5	75.86207	69.5	60.003	8.386364	20.90909
12	35	23.5	19.5	74.19355	69.32	59.811	7	19.4
13	35	23.5	19.5	74.19355	68.502	59.512	7.673913	19.80435
14	36	24	19	70.58824	68.810	58.001	2.533333	17.83333
15	37	24.5	19	69.44444	64.897	57.23	6.4	17.92
16	36.5	25	19	66	65.003	56.8	1.515152	13.93939
17	36	24	19	70.58824	66.505	56.5	5.791667	19.95833
18	35.5	23	18.5	73.52941	67.21	56.8	8.88	22.752
19	35	23	19	75	67.542	57.9	10	22.8
20	34	23	19.5	75.86207	68.115	58	10.36364	23.54545
21	33	22.5	19.5	77.77778	70.218	59.9	10	22.98571
22	31	21	18.5	80	72.112	61.2	10	23.5

Table-2. Experimental data at 6/6 /2008.

Hr	t1	t2	t b	E.F. D	E.F. in D1	E.F. in D2
10	33	23	20	76.92308	69.123	58.9953
11	34	23	19.5	75.86207	68.478	58.4987
12	36	23.5	19	73.52941	67.825	59.024
13	37	23.5	19.5	77.14286	66.458	59.512
14	38	25	20	72.22222	66.012	59.0111
15	39	26	20	68.42105	64.6012	57.987
16	38	27	20	61.11111	55.512	54.0112
17	36	26	20	62.5	57.4998	55.0223
18	35	25	19	62.5	59.987	53.897
19	33	25	21	66.66667	58.001	56.0123
20	32	25	22	68	60.02	55.0228
21	31.5	24	21.5	69	60.899	55.8754
22	31	24	22	70	63.0115	58.003

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-3. Experimental data at 15/6/2008.

Hr	t1	t2	t b	E.F. D	E.F. in D1	E.F. in D2
10	35	24	20	73.33333	66.125	57.021
11	36	24	19.5	72.72727	65.548	58.126
12	38	25	19	68.42105	64.548	56.542
13	39	26	19.5	66.66667	63.589	56.1297
14	40	26	20	70	60	53.856
15	39	26	20	68.42105	58.15	53.0321
16	39	27	20	63.15789	59.0159	52.143
17	38	26.5	20	63.88889	59.624	53.504
18	38	25	19	68.42105	62.898	55.025
19	37	26	21	68.75	65.1118	56.995
20	36	26	22	71.42857	66.02	58.111
21	34	24.5	21	73.07692	67.0258	59.087
22	33	23	20	76.92308	67.857	59.987

Table-4. Experimental data at 21/6/2008.

Hr	t1	t2	t b	E.F. D	E.F. in D1	E.F. in D2
10	35	24	20	73.33333	66.03	57.268
11	36	24	19.5	72.72727	65.725	58.188
12	38	25	19	68.42105	64.67	56.625
13	39	26	19.5	66.66667	63.504	56.025
14	43	30	20	56.52174	60.258	54.125
15	39	26	20	68.42105	58.0215	52.998
16	39	27	20	63.15789	59.369	52.158
17	38	26.5	20	63.88889	59.645	53.548
18	38	25	19	68.42105	63.125	55.555
19	37	26	21	68.75	64.897	56.845
20	36	26	22	71.42857	65.897	58.216
21	34	24.5	21	73.07692	67.258	59.248
22	33	23	20	76.92308	68.234	60.127

Table-5. Experimental data at 30/6/2008.

Hr	t1	t2	t b	E.F. D	E.F. in D1	E.F. in D2	Reduc. 1	Reduc. 2
10	37	25	20	70.58824	60.5	55.4	14.29167	21.51667
11	39	25.5	19	67.5	59.12	52.997	12.59259	21.48148
12	41	25.5	18.5	68.88889	58.02	54.002	15.80645	21.6129
13	42.5	28	20	64.44444	57.105	54.0105	11.55172	16.2069
14	44	29	20	62.5	56.987	53.03	8.8	15.2
15	45	29	18	59.25926	52.021	45.827	6.4	17.92
16	44	29.5	19	58	51.001	45.1278	1.515152	13.93939
17	43	30	21	59.09091	51.4857	45.612	5.791667	19.95833
18	42	28	19	60.86957	52.036	46.236	8.88	22.752
19	40	29	21	57.89474	53.987	46.872	10	22.8
20	39	29	22	58.82353	55.056	48.264	6.5	17.9512
21	39	27.5	20	60.52632	57.123	51.115	5.62287	15.73913
22	38	27	20.5	62.85714	59.846	53.089	4.790455	15.68182

Figures 9 and 10 are created to calculate the reduction in the effectiveness for the forced and natural indirect cases as compared with the direct case.

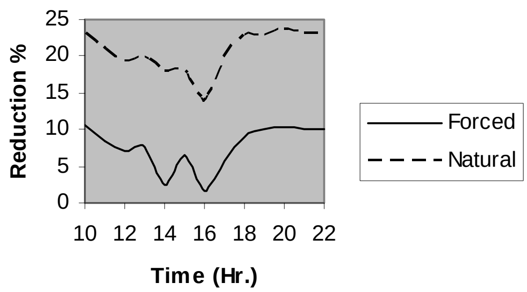


Fig.(9):Reduction in Effectiveness factor for indirect cooling (Baghdad 1/6/2008)

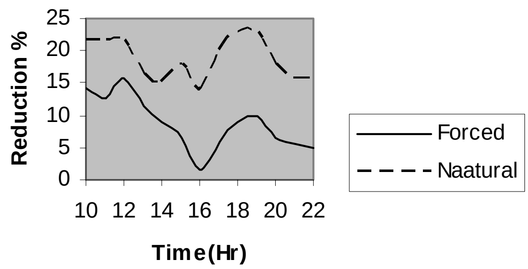


Fig.(10):Reduction in effectivness factor for indirect cooling (Baghdad 30/6/2008)

5. DISCUSSIONS

From Figure-4 we can see the following:

a) The values of the effectiveness tend to become lower at the peak region between (14-17) pm while it becomes higher out of this region.
b) The effectiveness factor occurs at minimum at 16 pm.
c) The curve which represents the indirect forced cooling is lower than that of direct cooling.
d) The worse case for this factor occurs at the natural Indirect cooling case.

In Figure-9 we calculate the reduction values of the two cases of indirect cooling as relative to the direct for the time periods of the reading data as follows:

For forced case:

$$Reduction = \frac{\varepsilon_D - \varepsilon_{IDF}}{\varepsilon_D} * 100 \quad \ldots\ldots (3)$$

Where:

ε_D = is the effectiveness for direct evaporative cooling

ε_{IDF} = is the effectiveness for indirect forced evaporative cooling.

For natural case:

$$Reduction = \frac{\varepsilon_D - \varepsilon_{IDN}}{\varepsilon_D} * 100 \quad \ldots\ldots (4)$$

Where:

ε_{IDN} = is the effectiveness for indirect natural evaporative cooling

As we can see from this Figure the minimum reduction at 16 pm where its equal to 2% for forced case and 14% for the natural case also we can see that the reduction values are fluctuated during the tested time zone. The reason for the reduction of this reduction of the efficiency can be attributed to the fact that in the case of the indirect method the overall efficiency depends on the efficiency of the fan coil unit and the air cooler and due to the losses in the piping circuit.

Although it is seen that the indirect method has less effective than the direct but from this method we gain the following advantages:

a) Noise reduction which represents the noise due to vibration and sound from the air circulating in the duct as shown in Figure-11, while for indirect case this noise is reduced to the minimum Ref [5];
b) The indirect method is independent on the outdoor environment like humidity and dust;
c) Power consumption saving which only happened in natural cooling case Ref [6] because the power for blower motor is reduced to zero, so we gain about 250 watts; and
d) The possibility for controlling the comfort conditions Ref [7], [8] by adjusting the fan speeds of indoor units (fan coil unit). It also is possible to add another control to adjust the supply temperature by using control unit adjustment (valve and non return valve) to vary the flow rate of the cooling water.

Figure-5 to Figure-8 also takes the same behaviors.

REFERENCES

[1] 2000. ASHRAE System and Equipment Chapter. 19 pp. 1-8.

[2] Mathur G.D. 1991. Indirect evaporative cooling with pipe exchangers. ASME Book No. NE. (5): 79-85.

[3] Scofield M. and N.H. DesChamps. 1984. Indirect evaporative cooling using plate type heat exchangers. ASHRAE Transactions. 90(1): 148-153.

[4] Petersin J.L. 1993. An effectiveness model for indirect evaporative coolers. ASHRAE Transactions. 99(2): 392-399.

[5] 2000. ASHRAE Sound and Vibration Control. 2.

[6] Foster R.E. and E. Dijktra. 1996. Evaporative air-conditioning fundamentals: Environmental and Economic benefits worldwide. Refrigeration science and technology proceedings, ISSN 0151 1637. International Institute of Refrigeration, Danish Technological Institute, Danish Refrigeration Association Aarhus, Denmark. pp. 101-110.

[7] Watt J.R. 1986. Evaporative air conditioning handbook. Chapman and Hall, London.

[8] Supple R.G. 1982. Evaporative cooling for comfort. ASHRAE Journal. 24(8): 36.