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Research Paper

PERFORMANCE OF AIR CONDITIONING SYSTEM USING AIR COOLED CONDENSER WITH WATER ATOMIZATION

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Nowadays, reduction of energy consumption is a major concern for most hot countries especially In areas with very hot weather conditions (about 50 C), where the air-conditioning systems equipped with air-cooled condenser (direct expansion system DX) are usually used to cool homes. These problems have activated the research programs in order to improve the performance of air-cooled condenser by improving heat transfer rate in the condenser. In this research, a design of evaporative cooling in the air-cooled condenser air-conditioning system is introduced and experimentally investigated. A real air conditioner is used to test the innovation by using a mist system (water atomization) in order to cool down the ambient air before it passing over the condenser. To meet the aim of the study, two room were constructed with same material and same size each equipped with brand new mini split air conditioning units having the same size and same brand name. The experiment was repeated nine times in different weather conditions. All results show that thermodynamic characteristics of the proposed system are considerably improved. The power consumption decreases In average by about 11% and the coefficient of performance increases in average by about 13%.

Keywords: Water Atomization, Mist, Condenser Pre-cooling, Coefficient of performance, Air conditioning, Power saving

INTRODUCTION

In today's fast grow economy and unsecured fuel market, energy conservation is becoming an important issue. Governments and Nations focus attention and work very hard on programs to reduce the demand and/or achieve optimum generation cost. The energy economy can be sufficiently improved by employing techniques to either reduce the energy demand and/or effectively utilize the available resources. Air Conditioning (A/C) systems are major contributors to buildings' According to Austin Energy, AC accounts for 60-70% of the average home's summertime power bill.

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Although the application of evaporative cooling in large industrial refrigeration systems were investigated (Dossat, 1991), but there is little work to investigate the application of evaporative cooling on small size refrigeration system.

The reduction of energy demand is a major concern in areas with very hot weather conditions about 50°C. This can be achieved by using more energy efficient air conditioning equipments. Condenser pre-cooling can be a good solution to improve the energy efficiency of any air conditioning system equipped with air cooled condenser.

The primary objective of this study is to investigate experimentally the effects of condenser pre-cooling using mist cooling system (water atomization) on Coefficient of Performance (COP) and power consumption in air conditioning system equipped with air cooled condenser.

To satisfy the study target a special mist system is designed and equipped to attach it with real AC unit, the experiment is designed to satisfy the following:

- Construct the mist unit for AC unit (split unit).
- Operate the AC unit at different temperatures and humidities and measure the thermal properties inside and outside the cooling zone.
- Understanding the effect of the mist pre cooling system (water atomization) by evaluating compressor power consumption and unit COP (coefficient of performance).
- Comparing the mist effect based in the light the results of two identical units one with mist and the second without mist.

MATERIALS AND METHODS

Experiments were carried out at Kuwait city during the end of summer 2010. Two rooms (3 m x 3 m with height of 2.45 m) were constructed from steel frame with polystyrene sheets. An air conditioning unit is used to cool each room; one unit is attached with mist unit, and the other without mist.

To meet the aim of the study, the two rooms were constructed with the same material , same orientation and same size to insure that they will have same heat load capacity. In addition, two new identical mini split air conditioning unites with cooling capacity 12000 Btu at nominal design capacity. A rectangular steel frame was designed, constricted and attached to the mist system. Four mist nozzles were used to mist the ambient air prior to condenser inlet.

The room construction, location, and dimensions, are presented with the measuring devices specifications (Measuring points in the system, thermocouples locations and pressure gauges), and the air conditioning unit specifications. The mist unit design and manufacturing is given in details.

The air conditioning units are used to cool two similar rooms, each room has 3 m x 3 m section with 2.4 m height, the room was constructed from steel frame, the walls and ceiling was covered by polystyrene sheets 5 cm thickness.

The main construction of the rooms is steel frame; the frame was constructed of steel bars 2.0 cm x 2.0 cm.

The mist unit consists of four nozzles (0.3 orifice), plastic pipes, fittings, and steel frame. The unit produce water spray in the air flow direction, water supply in done using water pump, the mist unit also was covered with cover to make

sure that air enters the condenser is humid air or to control the humidity of air, the distance between mist unit and out door unit is 50 cm. Figures 1 to 3, show the mist unit dimensions and specifications.

Figure 1: Room Details, Frame and Sheets, All Dimensions in Meter

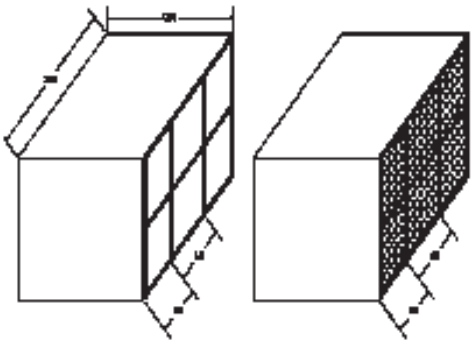


Figure 2: Room Details, Frame and Sheets, All Dimensions in Meter

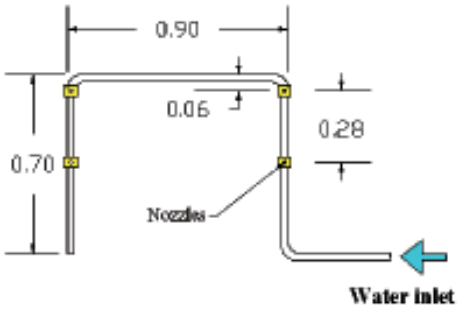
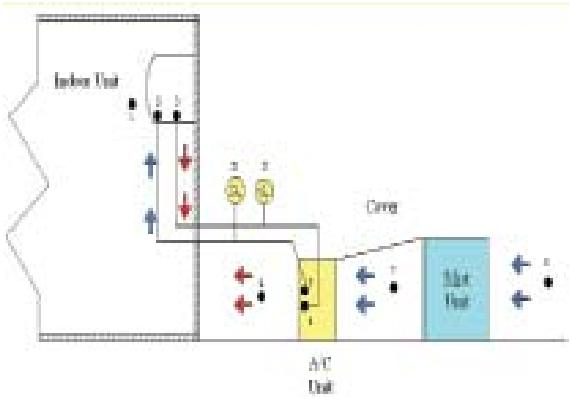


Figure 3: Measuring Points for the Indoor and Outdoor Units



EXPERIMENTAL DATA AND ANALYSIS

In order to estimate the effect of water atomization on the air conditioning system, experimental tests are performed in two identical air conditioning systems in the same time. One of the two units operators with water atomization (mist system), and the other without. The results of the two different units were tabulated. Data are recorded after steady state condition was established in the systems. The properties of refrigerant and air remained constant (after 20 min). All data recorded, Analyses of the data, related tables and graphs were presented and discussed. The measuring points are shown in Figure 1. Many experimental tests were performed at different ambient temperatures. The results of the tests at different ambient temperatures between (35°C to 45.5°C) were recorded. All data collected were tabulated and shown in Table 1. As shown in this table, electric current of the outdoor unite, condenser pressure, compressor exit temperature of air-cooled condenser increase considerably as ambient temperature increases but the pre cooled condenser shows better performance.

RESULTS AND DISCUSSION

Data collected from the experiment were tabulated in Table 1 according to the increased in ambient temperature. Electrical current represent the current withdraw in the outdoor unit which show the total current of the compressor and the condenser fan motor. The relative humidity was vary according to the weather conditions data that were collected from Kuwait airport by Kuwait metrological climate section in the same timing of the experiment which reflect the reliability of the experiment weather data reading.

Table 1: Experimental Results Passed in the Measurement Instruments Units

	ampient T C	RH%	P1(EVP) Psi	P2 (CON) Psi	T1 C	T2 C	T3 C	Current Amps
19/9/10 - 5:15PM								
No mist	37	45	50	260	12	101	40	5.8
Mist	37	45	46	210	13.5	95	32	5.2
2/10/01-2:45PM								
No mist	37.5	46	58	260	14	100	39	6
Mist	37.5	46	50	220	14	93	32	5.5
2/10/01-10:50AM								
No mist	40	31	54	260	13	102	40	6
Mist	40	31	50	220	14.5	97	32	5.4
23/09/10- 4:10 PM								
No mist	41	14	62	260	9	108	44	6.2
Mist	41	14	50	200	7	96	37	5.4
8/10/01-3:45PM								
No mist	42	7.5	54	290	9	100	41	5,75
Mist	42	7.5	50	220	12	92	35	5
8/10/01-2:50PM								
No mist	42.5	6.3	54	290	13	109	44	6.3
Mist	42.5	6.3	44	240	13	103	40	5.8
25/9/2010-3:12 PM								
No mist	44	8.4	52	300	12	114	48	6
Mist	44	8.4	48	240	12	106	36	5
24/09/10- 4:00 PM								
No mist	44.5	3.7	58	310	13	110	49	6
Mist	44.5	3.7	50	250	12	100*	40	5.5
24/09/10- 2:00AM								
No mist	45.5	3.7	62	330	9	100	50	6.2
Mist	45,5	3.7	50	280	9	91	41	5

From the experimental data-using the software EES-the thermodynamic cycle is plotted on p-h R22 chart and the equations mentioned below were written and solved in the same program .

$$Wc = IV \cos \phi \quad ...(1)$$

$$m = Wc/(h_2-h_1) \quad ...(2)$$

$$Qc = m(h1 – h3) \quad ...(3)$$

$$COP = h1 – h4 / h2 – h1 \quad ...(4)$$

$$QEv=h1 – h3 \quad ...(5)$$

$$QCon = h2 – h3 \quad ...(6)$$

Table 2: Equation Symbols Description

Wc	Heat input or mechanical energy input in compressor (KWh or KJ).
m	refrigerant mass flow rate kg/sec.
Qc	Cooling capacity KW
COP	coefficient of performance
QEv	heat rejected in evaporator (KJ/Kg)
QCon	heat rejected in Condenser (KJ/Kg)
V	Voltage V
h1	refrigerant Enthalpy KJ/Kg
h2	refrigerant Enthalpy at compressor outlet KJ/Kg
h3	refrigerant Enthalpy at condenser outlet KJ/Kg
h4	refrigerant Enthalpy at expansion valve outlet KJ/Kg
I	compressor & condenser fan current A

Figures from 4 to 12 shows the experimental results for the nine cases of the Experiment on the p-h diagram, when ambient air temperatures are between 37 to 45.5°C. Thus, a sprayed air cooled condenser will have a lower air inlet temperature that will modify the whole refrigerating cycle. Therefore, one can expect that both the discharge temperature and the mechanical compression power will be decreased. Meanwhile, the refrigeration effect increases as well as the COP of the refrigerating machine. These tendencies will, of course, strongly depend on the external climatic conditions, heat transfer mechanisms will increased when an air cooled condenser is sprayed. In addition, a sensitivity analysis will be performed to estimate the effects of varying the input assumptions.

The results of calculation for power consumption, mass flow rate, cooling capacity, refrigeration effect, cooling capacity and COP for the nine experiments are shown in Table (3a, b, c, d, e). The results show power consumption decrease about 20% and cooling capacity increase about 8.5%. Mass flow rate has decreases slightly and refrigerant effect increase about 10%. The results also show condenser and evaporator pressure of the modified system reduced about 18% and 10% in average, respectively, and the cycle pressure ratio can be reduces up to 12% . Also in the modified system the temperature of the condenser dropped down about 10°C while the evaporator temperature reduced about 7°C. Total electric current consumption of the outdoor unit (compressor and condenser fan motor) reduces between 8% to 19%. The compressor consumes most of the electric current since the current of the condenser fan is very small compare to the compressor current which indicate a good reduction in the compressor power consumption.

The COP which is the most important parameter increase about 24%. This indicates that by employing evaporative cooler not only power consumption decreases but also cooling capacity increases which is tabulated in Table 3.

Table 3: Calculated Air Condition Retrofit Performance

Ampient C	RH%	P1 kPa	P1m kPa	P2 kPa	P2mkPa	COP	COPm	COP%
37	45	446.1	418.5	1894	1549	3.221	3.678	14
37.5	46	501.2	446.1	1894	1618	3.339	3.856	15.5
40	31	473.7	446.1	1894	1618	3.184	3.625	14
41	14	528.8	446.1	1894	1480	2.552	3.015	18.16
42	7.5	473.7	446.1	2101	1618	3.169	3.693	16.56
42.5	6.3	473.7	404.7	2101	1756	2.86	3.148	10.05
44	8.4	459.9	432.3	2170	1756	2.562	3.01	17.5
44.5	3.7	501.2	446.1	2239	1825	2.728	2.23	18.5
45.5	3.7	528.8	446.1	2377	2032	3.025	3.755	24.13

The pH Diagrams for the Nine Experiment Test

Case one performed at 37°C and RH of 45 . The data obtained and the results of calculations show that the mist pre cooled has improved the COP 14% and the power consumptions was decrease about 10%. The refrigerant effects and the cooling has improved 7% and 2.3%, respectively.

Case two performed at 37.5°C and RH of 46 . The data obtained and the results of calculations show that the mist pre cooled has improved the COP 15.5% and the power consumptions was decrease about -8%. The refrigerant effects and the cooling has improved 6.6% and 6%, respectively.

Case three performed at 40°C and RH of 31 . The data obtained and the results of calculations show that the mist pre cooled has improved the COP 14% and the power consumptions was decrease about 10%. The refrigerant effects and the cooling capacity has improved 7% and 2.4%, respectively.

Case four performed at 41°C and RH of 18 . The data obtained and the results of calculations

Figure 4: The ph Diagram for Ambient Temperature 37°C

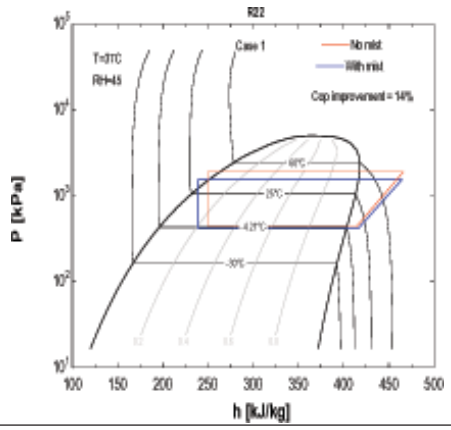


Figure 5: The ph Diagram for Ambient Temperature 37°C

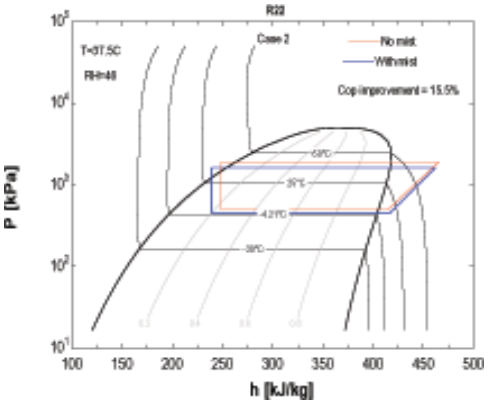


Figure 6: The ph Diagram for Ambient Temperature 40°C

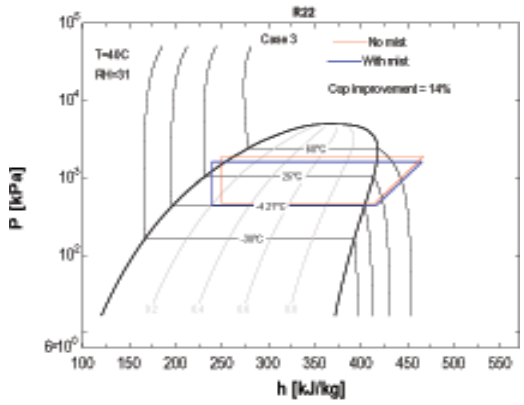


Figure 7: The ph Diagram for Ambient Temperature 41°C

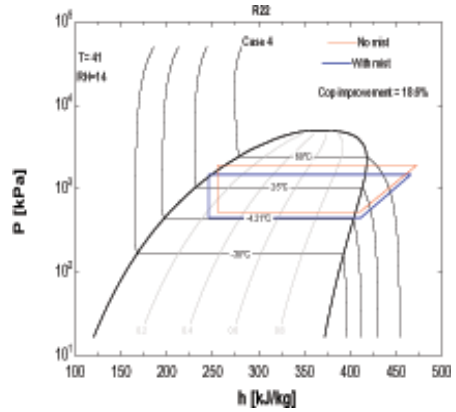


Figure 8: The ph Diagram for Ambient Temperature 42°C

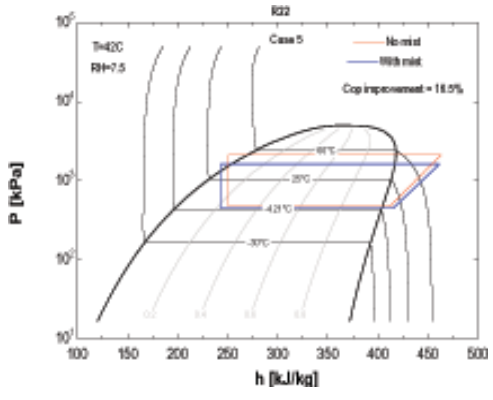


Figure 9: The ph Diagram for Ambient Temperature 42.5°C

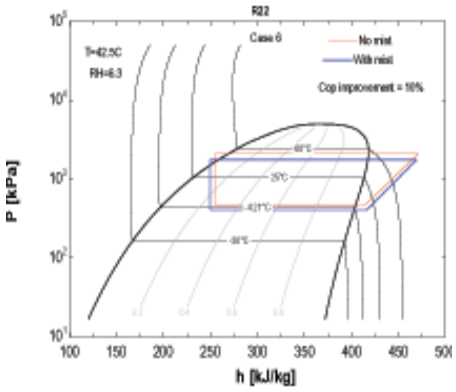


Figure 10: The ph Diagram for Ambient Temperature 44°C

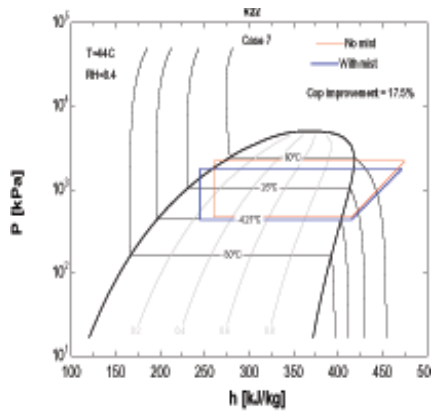


Figure 11: The ph Diagram for Ambient Temperature 44.5°C

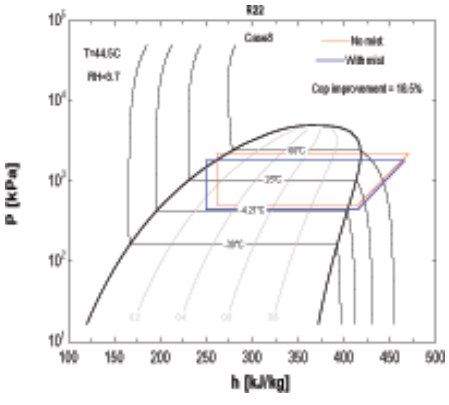
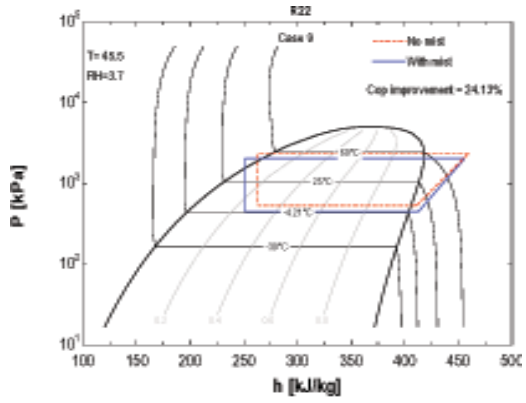


Figure 12: The ph Diagram for Ambient Temperature 45.5ºC



show that the mist pre cooled has improved the COP 18.16% and the power consumptions was decrease about 13%. The refrigerant effects and the cooling capacity has improved 6% and 3%, respectively.

Case five performed at 42°C and RH of 7.5 . The data obtained and the results of calculations show that the mist pre cooled has improved the COP 16.56% and the power consumptions was decrease about 13%. The refrigerant effects and the cooling capacity has improved 6% and 1.5%, respectively.

Case six performed at 42.5°C and RH of 6.3. The data obtained and the results of calculations show that the mist pre cooled has improved the COP 10.5% and the power consumptions was decrease about 8%. The refrigerant effects and the cooling capacity has improved 4% and 1.5%, respectively.

Case seven performed at 44°C and RH of 8.4. The data obtained and the results of calculations show that the mist pre cooled has improved the COP 17.5% and the power consumptions was decrease about 16.5%. The refrigerant effects and the cooling capacity has improved 10% and 2%, respectively.

Case eight performed at 44.5°C and RH of 3.7. The data obtained and the results of calculations show that the mist pre cooled has improved the COP 18.5% and the power consumptions was decrease about 8%. The refrigerant effects and the cooling capacity has improved 8% and 8.5%, respectively.

Case nine performed at 45.5°C and RH of 3.7. The data obtained and the results of calculations show that the mist pre cooled has improved the COP 24% and the power consumptions was decrease about 19%. The refrigerant effects and the cooling capacity has improved 9% and 1%, respectively.

CONCLUSION

Effective use of energy sources needs more efficient use of air conditioners. Evaporative cooler coupled to the air condensers an efficient, reliable and cost-effective method to increase the performance of any air-cooled refrigeration system such as split type air conditioners which have wide spread application in the market. Experimental tests showed that power consumption and performance of evaporative cooled air condenser is improved significantly compared to the air-cooled condenser and the improvements are increased as ambient temperature increases. It is found that increasing ambient air temperature decreases the coefficient of performance of air-cooled condenser considerably but it has much less adverse effect on the performance of evaporative cooled air condenser. Power consumption can be decreased up to 13% and total performance can be improved around 24%.

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