A Study Of Evaporative Cooled Condensing Units And Its Effect On Energy Consumption Reduction

Jasem Mohammed Abdeen

Abstract: In the Arabian Gulf states, as well as in Middle East and Mediterranean countries, the pressure and temperature of air-conditioning units with air –cooled condensers will increase considerably. As direct result, the high-pressure side of the refrigeration cycle will increase and the power consumption of the air conditioner will be higher than its design. As result, the A/C unit pressure increases and exceeds the pre-set design value of the pressure switch in control circuit. Control shuts down the compressor, as well as reduces the total cooling capacity of air-conditioning unit (A/C) .Therefor the performance of any A/C unit equipped with air- cooled condenser will decreases considerably with high pressure and ambient temperature . One of the best solutions to increase the performance of Air-conditioner is to decrease the condenser coil temperature. To achieve this, it is required to decrease the air ambient temperature on A/C unit before it passes across the condenser coil. The cheapest and easiest way for decreasing the ambient air temperature is using the evaporative cooling system. This could result A significant energy savings would be the result, if thousands of air-conditions in residential and commercial sector. This will save a great amount of megawatts in the network.

1- INTRODUCTION

Most of residential space area is conditioned by DX-packaged or split air-cooled air conditioning (AC) units throughout the Middle East region .These (A/C) consists of a supply air fans, direct expansion (DX) cooling circuit complete with air filters. These A/C systems represent large part of electrical load demand during summer periods of high ambient temperature. Air-cooled, water-cooled and evaporative cooling towers are different types of condensers used in air-conditioning based on vapor compression systems with R-22, R-134A, R-410, or any ozone friendly refrigerant fluids. Because the (air) is, a natural and free source-cooling medium, Air-cooled condenser (tube and fins heat exchangers) i commonly used for many cooling capacities. The energy consumption increased considerably with air-cooled condensers operates in regions with dry and high outside temperature (50 to 60 °C), as it happens in many Middle East & Gulf countries. This study examine field data on different air-conditioner system with water cooled condensers and air-cooled condenser systems at different buildings of the Public Authority for Applied Education and Training in State of Kuwait. It shows the operation data and characteristic in response to varying load conditions; obtainable COP, water consumption rates and the amount of recoverable heat were evaluated .whilst the outdoor air conditions kept within the controlled conditions.

2-EQUIPMENT INSTALLATION LAYOUT:-

Figure (1) shows this work equipment layout. A field data study on different capacity of air-cooled air-condition systems at the public Authority for Applied Education & Training buildings. Work carried out by replacing the fin-tube air-cooled condenser coil with evaporative condenser copper heat exchanger .As shown in figure (1). Water sprayed over the condenser coil through a counter flow heat exchanger path from sump water, pass over the evaporative media, and back to sump water. A fan draws outdoor air through the wetted evaporative media evaporative cooling the water of outdoor wet bulb temperature.

3 - THE CONCEPT

This study involved the modification of standard residential air conditioner condenser by retrofitting a commercially available unit with an evaporative pre –cooler .The main reason was to integrate this method to achieve an efficient residential air conditioner design. Evaporative condensers (ECs) idea is to dissipate condenser heat to a waterbed that cooled by the evaporation of water. The normal aluminum fin & copper tube air-cooled condenser coil replaced with a refrigerant water copper heat exchanger. Refrigerant cooled by spraying water on the evaporative condenser coils during operation. The temperature on condenser coil in this concept will follow the outdoor wet bulb temperature (WB) than the outdoor dry bulb temperature (DB) .This leads for higher operating efficiencies. Evaporative condensing unit makes the compressors to work at lower condensing temperatures and consume 25 – 40% less electricity than the comparable air-cooled units, especially at design conditions, as shown in table (1).

Design Conditions	Ambient Temperature	Condensing Unit Kw/ ton	Condensing Temperature
ARI design Conditions			
Air Cooled	95/75 ºF	1.10 – 1.25	120 - 130º F
Evaporative Cooled	95/75 ºF	0.85 – 0.90	106 -114 ºF
Desert Design Conditions			
Air Cooled	110/72 ºF	1.40	135 - 145º F
Evaporative Cooled	110/72 ºF	0.80 – 0.86	103 - 112º F

Table (1) Evaporative-cooled condensers vs. Air-Cooled

The final construction of the unit will make continuous flow of water spraying on the refrigerant coil, and air passes up through the water covered refrigerant lines as shown in figure (1)

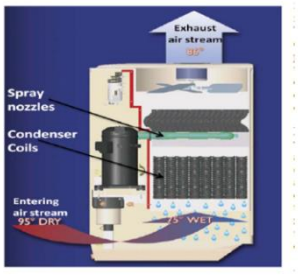

Figure (1) Evaporative Condenser Operation layout

4 - THE DESIGN IDEA :-

This design uses nozzles that spray directly onto the condenser coils. The top mounted spray nozzles has a controller that energizes a solenoid valve with a duty cycle that is determined according to the air ambient temperature. The higher the temperature, the more often the water turns on .A 230 VAC power source is required to power the solenoid valve. The study involved the modification of split & package A/C system on the market with different cooling capacities. Water Cooled Air Conditioner condenser designed to be matched with all air handler / evaporator coils uses R22 refrigerant. The Water Cooled Air Conditioner condenser is fitted with a very quiet high efficiency fan, available with optional variable speed fan controller to conserve water. The evaporative pre-cooler design was comprise of media selection, water delivery & water resource managements. Two pre-cooler design was evaluated throughout the course of the study These were labelled design-1 & design-2 models.

5- DESIGN – 1- RESIDENTIAL AND LIGHT COMMERCIAL UNITS:

A normal practice all water-cooled air conditioner equipped with a condenser fixed outside buildings and the air handler inside within the cooled area. Control panels and compressors
are in a separate box beside the refrigerant cooling tower.as shown in figure (2)

Figure (2) Water-cooled Evaporative condenser

Water-cooled evaporative condenser, along with the Scroll compressors, fans and pumps combined. This done to utilize the natural properties of water to cool the refrigerant up to 40 degrees cooler than is possible with an air-cooled system. Evaporative condenser coils normally fixed in a horizontal level figure (3) to increase contact surface area with water.

Figure (3) Water Cooled Condenser layout

The full build-up of the evaporative condenser shown in figure (4).It comprises of high efficiency fan, fiberglass enclosure, copper pipe heat exchanger ,nozzles,plastic media & base with air inlets .

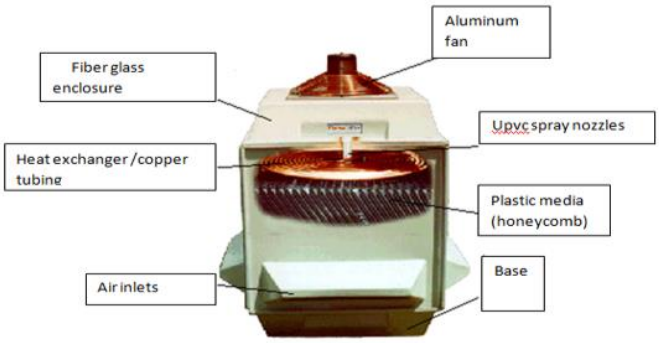

Figure (4) Water Cooled Condenser components

Compressor, water pump and control panel compartment are combined in the compartment as shown in figure (5)

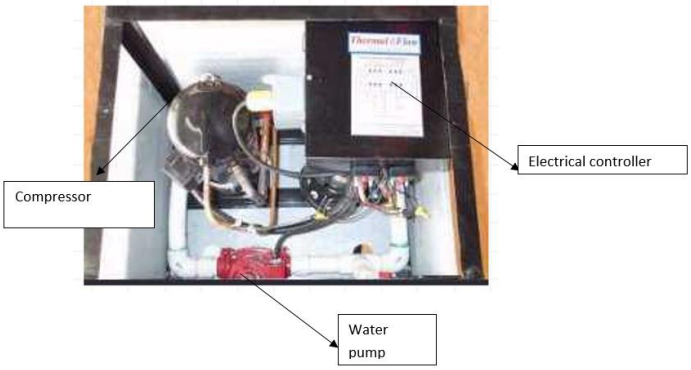

Figure (5) Compressor with Electrical Controller

The air handling unit (AHU)used is a matched in capacity to the evaporative condensing unit .The (AHU) choose is a normal factory production line , charged and tested refrigeration system come full with an aluminum fin , copper tubes DX-coil with expansion valve .

6- FIELD TEST OF 4 TON DX-SPLIT UNIT WITH EVAPORATIVE CONDENSER:-

Studies performed to analyses the temperature drop of air as it passed through the wet media .Air flow rates adjusted to medium speed (fpm). An experimental protocol developed to test the retrofit unit for DX-split unit up to 4 tons. A hundred test conducted showing air-conditioning unit cooling capacity as well as unit power (KW) at different ambient temperatures. Specific results for all tested configuration produced, and data sample shown in table (5) .All performance testing accomplished using (AHRI) standard 210/240-2008 test conditions. Tests were performed at dry condenser coil outdoor temperature of 85 °F , 95 °F , 105°F & 115 °F DB ,then tests were completed by spraying a continuous flow of water on to the refrigerant lines . Table (2) summarize results of the fabricated Design – 1. Unit with water-cooled evaporative condenser.

s	Condenser condition	Air temperature. on condenser coil °F	Saturated condensing temperature . °F	Test results	Saturated Suction temperature. °F			A/C EER	Saving %
					45	50	55		
1	Water Cooled A/C system (evaporative condenser)	60 °F wet bulb (WB)	80°F	Capacity (Btu/h)	60905	66669	72835		
				Flow Rate(lb/h	729	794	863		
				Comp. power (KW)	2.47	2.47	2.48		
				EER (Btu.W.h)	24.7	27	29.3		
				Current (Ampere)	11.8	11.8	11.9		
		70°F wet bulb (WB)	90°F	Capacity (Btu/h)	58405	63990	69965		
				Flow Rate(lb/h	725	790	859		
				Comp. power (KW)	2.74	2.75	2.75	16	
				EER (Btu.W.h)	21.3	23.3	25.4		
				Current (Ampere)	12.9	12.9	12.9		
		80°F wet bulb (WB)	100°F	Capacity (Btu/h)	55820	61230	67015		
				Flow Rate(lb/h	720	785	854		
				Comp. power (KW)	3.05	3.05	3.06		
				EER (Btu.W.h)	18.3	20.1	21.9		
				Current (Ampere)	14.1	14.1	14.1		
2	Normal Air Cooled A/C System	95°F Dry bulb (DB)	120°F	Capacity (Btu/h)	47525	52385	57578		
				Flow Rate(lb/h	698	764	834		
				Comp. power (KW)	4.7	4.7	4.7	9	
				EER (Btu.W.h)	11.3	12.5	13.7		34%
				Current (Ampere)	19	19	19		
		105°F Dry bulb (DB)	130°F	Capacity (Btu/h)	44553	49224	54211		
				Flow Rate(lb/h	687	754	825		
				Comp. power (KW)	4.66	4.66	4.66		
				EER (Btu.W.h)	9.6	10.6	11.6	7.8	51%
				Current (Ampere)	21.3	21.3	21.3		
		115°F Dry bulb (DB)	140°F	Capacity (Btu/h)	39879	44254	49920		
				Flow Rate(lb/h	669	737	808		
				Comp. power (KW)	5.41	5.42	5.43	6	62%
				EER (Btu.W.h)	7.4	8.2	9.0		
				Current (Ampere)	25.8	25.9	25.9		

Table (2) Results of phase- 1 A/C unit with water-cooled evaporative condenser

Indoor fan consumption power is 584 watts and condenser fan & pump consumption power is 305 watts. Specific results for all tested configuration were produced for (4) Ton scroll compressor A/C unit. Simply match the conditions for the region using (WB) wet bulb for water-cooled unit unit's .Use (dB) dry bulb or ambient temperature for air-cooled units.

Example Analysis:-

Air-cooled at standard conditions for EER rating (95°F) dry bulb (DB) and (45°F) suction temperature give the following readings

Capacity : - 47525 BTU/hr.
Compressor : - 4200 Watts
Indoor Fan : - 584 Watts
Outdoor Fan : - 484 Watts
Total Watts : - 5268 Watts

Calculated EER = 47525 / 5268 = 9 EER

Water-cooled at standard conditions for EER rating (70°F) wet bulb (WB) and (45°F) suction temperature give the following readings

Capacity : - 58405 BTU/hr.
Compressor : - 2740 Watts
Indoor Fan : - 584 Watts
Outdoor Fan& pump : - 305 Watts
Total Watts : - 3629 Watts

Calculated EER = 58405 / 3629 = 16 EER

Saving percentage of Water-cooled A/C system at (70°F) wet bulb to Air-cooled A/C system at (95°F) dry bulb (DB) is

(16 – 9) / 16 = 44 %

As shown above test at 95 °F outdoor an increase in efficiency of more than 44% compared to the standard air-cooled A/C system and met the research goal of the study .Performance showing also improvement in cooling efficiency and power consumption .

7 - DESIGN – 2 ROOFTOP UNIT WITH EVAPORATIVE CONDENSER:-

To show the saving generated by evaporative condensing, we considered a theatre hall using a 126-ton rooftop units and full year working time. Specific results for all tested configuration produced for unit with normal air-cooled condenser and then test result produced for same unit with evaporative condenser. Table (3) shows the comparison of evaporative and air-cooled units.

CONDITIONS		AIR-COOLED	Evaporative condenser
Design Ambient Dry Bulb/Wet Bulb (ºF)		110/75	110/72
power Consumption Rate (Per KW Hour)		$ 0.07	$ 0.07
power Demand Rate (Per KW)		$8	$8
Condensing Unit	Efficiency (KW/ton)	1.4	0.85
	Electrical cost	$19,000	$11,350
% Saving			40%

Table (3) Comparison of Evaporative and Air-Cooled Condensing units

With 0.85 KW/ton efficiency condensing unit from the table above, gives 40% reduction of in peak design condensing unit KW and as a result, 40% substantial saving in condensing unit demand costs.

8- CONCLUTIONS:

Heating and cooling systems with water-cooled, spray water and evaporative condenser experimentally evaluated. Replacing the air-cooled- tubed air condenser with evaporative condenser .The test during dry conditions showed 44% improvement in efficiency compared to the standard air-cooled A/C systems and this meet the research goal of the study. The study shown that experimentally evaluated under the same evaporating and condensing temperatures with water –cooled condenser were superior over others in terms of refrigeration capacity and coefficient of performance. In addition, the idea of retrofitting existing units provides great opportunities to lower peak power consumption related to the cooling applications by simply using normal city main supply water.

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