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Research paper

Improvement of performance unitary refrigerant systems for hot climate in Baghdad city

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Abstract

This research aims to improve work unitary refrigeration systems and decreasing of electric energy consumption in Baghdad city. The work presents study effect of adding the simple evaporative cooling system to the outdoor unit of refrigeration system under various climate conditions, the effect on cooling capacity and the electric current consumption at system. The outdoor air at condenser enter was cooled by the simple system and its effectiveness (43% to 50.4%). The results reveal that dry bulb temperature of air reduces (16% to 25.3%) at enter to the condenser and the rejected heat increases (empirical 43% to 59.8%) under various operating conditions. Indoor air conditions, dry bulb temperature of air at the inlet of evapo-rator reduces (41.3% to 44.4%) and the variation in refrigeration gas temperature in the evaporator is (46.6% to56%). This will increase cooling capacity in evaporator which increased (53.6% to 62%) at work presented conditions. The noticeable that using simple evaporative cooling system reduces the electrical current consumption by (22.5% to 25%) which reduce operating costs.

Nomenclature:
T: Temperature(ºC).
T_{ref}: Refrigeration gas temperature(ºC).
RH: Relative humidity of air (%).
h: Specific enthalpy of air (kJ/kg).
I: Electric current (A).
Q_{rej}: Rejected heat of condenser (kW).
$Q_{c.c.}$: Cooling Capacity (kW).

Keywords: *Refrigerant Systems; Evaporative Cooling; Experimental Analysis; Baghdad Weather Conditions; Condenser; Energy Saving.*

1. Introduction

The hot weather and electric energy is a great problem in countries such as Iraq. In summer, the dry bulb temperature (DBT) of air in shade may reach up to 50˚C.
Electrical energy used for operation of cooling devices is an important part of this problem, which is continually increasing due to the growing demand for better indoor comfort conditions in buildings. There is increasing request for use highly efficient cooling devices having superb performance and lower consumption of power.
Air conditioning of buildings is currently dominated by the conventional unitary refrigeration system. This type of system is highly energy intensive due to heavy use of electricity for operation of the compressor. The rise of refrigeration system efficiency can be done by adding simple evaporative cooling system which increasing the rejected heat of condenser and lowering the compressor power consumption.
There are two ways the most common in the air conditioning systems:

1.1. The evaporative cooling

Is based on a physical phenomenon of converting the sensible heat to the latent heat of air, which leads to dry bulb temperature of air decrease and the relative humidity increase to a certain extent. This process occurs by direct contact between air and water. The difference of temperature between the air and water, will cause heat transfer. The difference of water vapor partial pressure between the air and water, will cause mass transfer [1]. Evaporative cooling can be divided as mentioned in most references of air conditioning into [2]:
Direct Evaporative Cooling:Random-media evaporative cooler system,air washer system and fog cooling system.
Indirect Evaporative Cooling: This method is used in the industrial fields that require control of the moisture from the air.

1.2. Direct expansion systems and heat pumps

A refrigeration system is made of main components:Compressor, condenser, expansion valve and evaporator.

2. Literature review

The following literature review describes important researches:

R. Reinhard et al.[3], investigated in the performance of an evaporative cooled condenser with air-cooled condenser for a split heat pump system.The experimental results showed that the evaporative condenser has a higher capacity than the air-cooled condenser (1.8 to 8.1%), a higher COP (11.1 to 21.6%).F.Yu&K.Chan[4], used evaporative pre-coolers and variable-speed fans where the condenser contains an algorithm to determine the number and speed of the condenser fans staged at any given set point of condensing temperature. It is found that COP can be maximized by adjusting the set point based on any given chiller load and wet-bulb temperature of the outdoor air. Vrachopoulos et al.[5], worked on development the incorporated evaporative condenser for the improvement of the performance of the cooling provision by creating dew point conditions where it has been concluded that the incorporated evaporative condenser improves the coefficient of performance of provisions since it decreases the temperature difference of the compressor operation and brings energy saving reduction.Hajidavallo [6], introduced experimental test by putting two cooling pads and injecting water on them at both sides of the air conditioner. The results indicate that thermal characteristics of the system are considerably improved, and the consumption of powerreduces up to 16% and the performance coefficient increases up to 55%.J. Yang et al.[7] use fog of water to cool air that enter the condenser to improve the chiller performance and reduce compressor power where a simulation analysis on an air-cooled chiller equipped with a water mist pre-cooling system under head pressure control shows that applying water fog precooling enables the coefficient of performance to increase, and condenser effectiveness is enhanced by staging all condenser fans to decrease the condensing temperature.ChainarongChaktranondet al.[8]studied of energy saving in air conditioner (split units) ofby using various evaporative cooling types.The results reveal that power consumption and COP effected by the ambient. At investigated cases, power consumption is decreased (4% to15%) and COP is increased (6%to48%).

K. Aglawe et al [9] Employ an indirect evaporative cooling system in an air conditioner of window type. Theexperimentally investigated was applied with and without evaporative cooling on the condenser and it is found that the condenser pressure reduces to 20%, the evaporator pressure reduces 12% and the coefficient of performance increases.

T. Wang et al. [10] presented an experimental study of using evaporative cooling in the air conditioning system and effect on the Coefficient of Performance. The results show that the Coefficient of Performance increase by using the evaporative cooling condenser from 6.1% to 18% and a power reduction up to 14.3%. The results show that the cost-optimal applicable temperature is around 33.1 °C.S.K. SOYLU et al. [11] presented an experimental study of air-cooled chillers with an evaporative condenser in three cities of Turkey. The results show thatCOP increases in most arid cities as 40.5%, while the lowest increase was in the most humid city as 15.5%. This improvement increased the cooling capacity and the mean electrical consumption is decreased as (6.97% - 15.49%) in the three cities. A.E.Kabeel et al. [12] presented an experimental study of using cold mist water at evaporative air cooled chiller. The results show that the system was able to cool ambient air to a temperature below its inlet wet bulb temperature, enhancement coefficient of performance by up to 91% than that for the conventional air cooled chiller and conventional evaporative air cooled chiller had a higher coefficient of performance by up to 82% than that for the conventional air cooled chiller.

The aim of the present work is enhancement the Performance of the unitary refrigeration system by adding a simple evaporative cooling system. Study effect adding the simple evaporative cooling system to the outdoor unit of refrigeration system under various climate conditions and effect on cooling capacity and electric current consumption of the system. Comparison the directly sprinkle on the condenser and sprinkle on the pad and types it.

3. The experimental work and measuring method

The experimental work was carried out by adding the simple evaporative cooling system to the outdoor unit ofair-conditioner. Fig. (1) Illustrates the main parts of test rig which consists of:

Split unit 24000BTU, water pump, thermocouples, digital thermometer, selector switch, ammeter, digital anemometer, water tank, pads and connection pipes.

The experimental performance analysis of cooling system operated at summer season in Baghdad city. The air is cooling before the inlet of condenser unit by the evaporativecooling system. The cooled air at evaporative cooling system are depended on outdoor conditions(temperature & humidity) and effectiveness of evaporative cooling system,therefor the cooling capacity and electrical energy consumption at refrigeration system will affected. In firstly, the place of media pad should be installed in a way to give a good cooling effect. The pad is installed in front of inlet the condenser. A small water pump was sprinkling water on upper of the media pad by the spraying pipe,will then water return to the tank. The water come of the indoor unit was used to indemnity lost water in tank. Figer (2) Illustrates Schematic of the measurement position for test rig.Many tests conducted which investigate the effect of adding the simple evaporativecooling system on the performance of air conditioning system under various climate conditions. The most important experimental measurements are shown in Tables (1& 2).

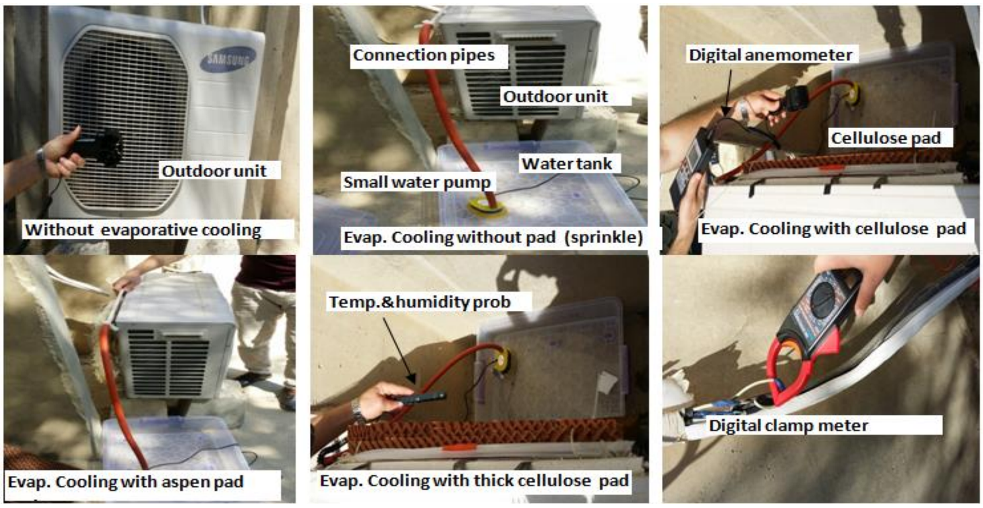

Fig. 1: Illustrates Test Rig, Measurement Apparatuses and Experimental Work.

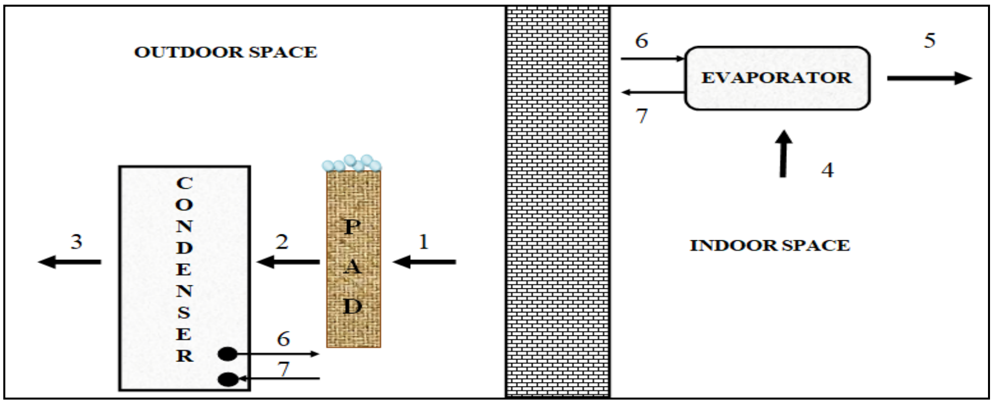

Fig. 2: Schematic of the Measurement Position for Test Rig.

Where:

1) Inlet pad
2) Inlet condenser.
3) Outlet condenser.
4) Inlet evaporator.
5) Outlet evaporator.
6) Refrigeration gas inlet evaporator.
7) Refrigeration gas outlet evaporator.

Table 1: Experimental Results at Air Condition [DBT (35-35.3) ºc &RH(37.1-38) %]

Number of measurement points	Without evaporative cooling I (A) = 12.9 A		With evaporative cooling I (A) = 10 A		Air flow rate (m^3/min)
	T (ºC)	RH (%)	T (ºC)	RH (%)	
1	35.3	38	35	37.1	
2	35.3	38	29.4	56	21.6
3	44.1	23.7	42.2	30	
4	30	37	29	37	16.2
5	22.6	58.5	17	65	
6	8	-	3.5	-	-
7	17.5	-	14.2	-	

Table 2: Experimental Results at Air Condition [DBT (46-47) ºc & RH (13-13.9) %]

Number of measurement points	Without evaporative cooling I (A) = 14.7 A		With evaporative cooling I (A) = 11.2 A		Air flow rate (m^3/min)
	T (ºC)	RH (%)	T (ºC)	RH (%)	
1	46	13	47	13.9	
2	46	13	35.1	38	23.4
3	51.4	10.2	48.9	19	
4	36	27	36	24	16.8
5	27.5	50	20	69	
6	15	-	8	-	-
7	22.4	-	19	-	

4. Results and discussion

Fig (3) & (4) show dry bulb temperature (DBT) before and after adding simple evaporative cooling system at points (1,2and3) for climate air conditions of different. The results show that, (DBT) enter the condenser reduce from (35ºC to 29.4 ºC) and (47ºC to 35.1 ºC). Reducing percentage is (16%) and (25.3%) respectively. This reduction is an indication of heat transfer increasing in the condenser with an evaporative cooling system at climate air-condition of different.

Fig (5) & (6) show relative humidity before and after adding simple evaporative cooling system for climate air condition of different. The results show that, relative humidity in test 2 is low more than test 1, which increasing evaporative cooling operation (DBT is decreasing more after evaporative cooling). As well as, fig. (7) clarifies the change in effectiveness of evaporative cooling at varying the climate air condition. In test 1, the evaporative cooling effectiveness is (43%) and test 2 is (50.4%). As show that evaporative cooling increment at the relative humidity lower. This indicates to raise heat transfer at condenser later.

Fig (8) & (9) illustrate the increase in specific enthalpy of air after adding simple evaporative cooling system. This increase is an indication of heat transfer increasing in the condenser. In test1, the enthalpy of air increases (70.5kJ/kg to 79.9kJ/kg), at add evaporative cooling (66.4kJ/kg to 82.8kJ/kg). Rejected heat of condenser is increased (3.8KW to 6.67KW), view fig.(10),and increased percentage is (43%). In testt2, the enthalpy of air increases (67.3kJ/kg to 73.5kJ/kg) and (70kJ/kg to 85.3kJ/kg) , Rejected heat of condenser is increased (2.61kW to 6.5kW), view fig.(10), and increased percentage is (59.8%).

Indoor air condition space, Fig. (11&12) has shown DBT before and after adding simple evaporative cooling system for air conditions of different. The results show that, DBT decrease more at add evaporative cooling system. This is due to increase heat transfer in the evaporator. In test1, DBT decreases from (30 ºC to 22.6 ºC) and percentage of reducing is (24.6%). While as, DBT decreases from (29 ºC to 17 ºC) at add evaporative cooling system and percentage of reducing is (41.3%). In test 2, DBT decreases from (36 ºC to 27.5 ºC) and percentage of reducing is (23.6%). While, DBT decreases from (36 ºC to 20 ºC) at add evaporative cooling system and percentage of reducing is (44.4%).

Fig (13) &(14) illustrate the decrease in specific enthalpy of air indoor after adding simple evaporative cooling system. This decrease is an indication of cooling capacity increasing in the evapo-

rator. In test 1, enthalpy of air decreases (55.2 kJ/kg to 48.3 kJ/kg), while as, decreases (51.8kJ/kg to 36.9kJ/kg) at add evaporative cooling. Cooling capacity is increased (2.14kW to 4.62kW), view fig.(15), and increased percentage is (53.6%). In test 2, enthalpy of air decreases (61.9kJ/kg to 57kJ/kg) and (59kJ/kg to 46kJ/kg) at add evaporative cooling. Cooling capacity is increased (1.53kW to 4.07kW), view fig. (15) and percentage of increasing is (62%).
Fig (16) illustrates the change in electric current consumption at varying the air- condition in the tests. The results show the consumption of electric current decreased at add evaporative cooling system which causes decrease in condenser pressure and compression ratio. The electric current consumption was decreasing from (2.9 A to 3.8 A) and the percentage of decreasing is (22.5% to 25%).
Fig. (17&18) illustrates the variation in refrigeration gas temperature in the evaporator with add evaporative cooling system. In test1, the decrease of temperature at inlet of evaporator (point 6) is (without 8ºC& with 3.5ºC) and percentage of decreasing is (56%). Whileas, in test 2, the decrease of temperature at inlet of temperature at inlet of evaporator is (without 15ºC & with 8ºC) and percentage of decreasing is (46.6%). This will increase cooling capacity in the evaporator.
Direct water was sprinkle on the condenser and compare with water sprinkle on the evaporative pads. The experimental results revealed that directly sprinkle are best to some extent of the pad, but this method has disadvantages of including more water consumption, harmful saline deposits and corrosion of the condenser coils.
The experimental results revealed that use cellulose corrugated pad which increment the exchange area between air and water is better than other.

5. Conclusions

Improvement of performance in a unitary cooling system with adds simple evaporative cooling system is evaluated. The interesting conclusions can be as follows:

1) The empirical results reveal that dry bulb temperature of air reduce (16% to 25.3%) at enter to the condenser under various operating conditions and the effectiveness of evaporative cooling system was (43% to 50.4%).
2) Rejected heat of condenser increased (43% to 59.8%) under various operating conditions.
3) Indoor space, dry bulb temperature of air at inlet of evaporator reduced (41.3% to 44.4%) under various operating conditions.
4) The variation in refrigeration gas temperature in the evaporator is (46.6% to56%) under various operating conditions. This will increase cooling capacity in the evaporator.
5) Cooling capacity increased (53.6% to 62%) under various operating conditions.
6) The test results show that add an evaporative cooling system decrease the consumption of electric current (22.5% to 25%) which will reduce operating costs.
7) Directly sprinkle are best to some extent of the pad, but this method has disadvantages of including more water consumption, harmful saline deposits and corrosion of the condenser coils, used cellulose corrugated pad is better than another.

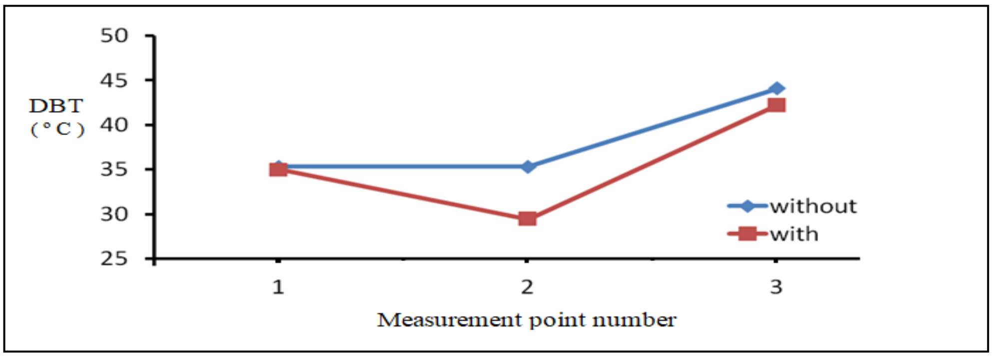

Fig. 3: Illustrates Comparison Dry Bulb Temperature vs. Measurement Points in Test 1.

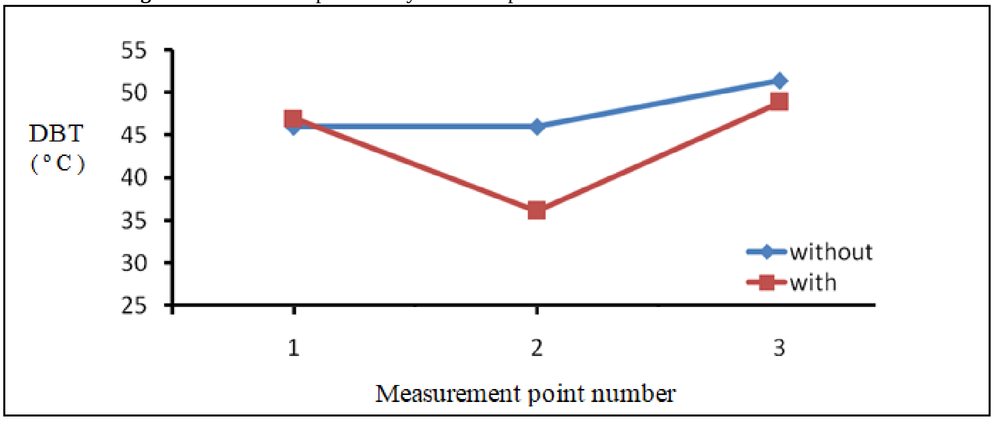

Fig. 4: Shows Comparison Dry Bulb Temperature vs. Measurement Points in Test 2.

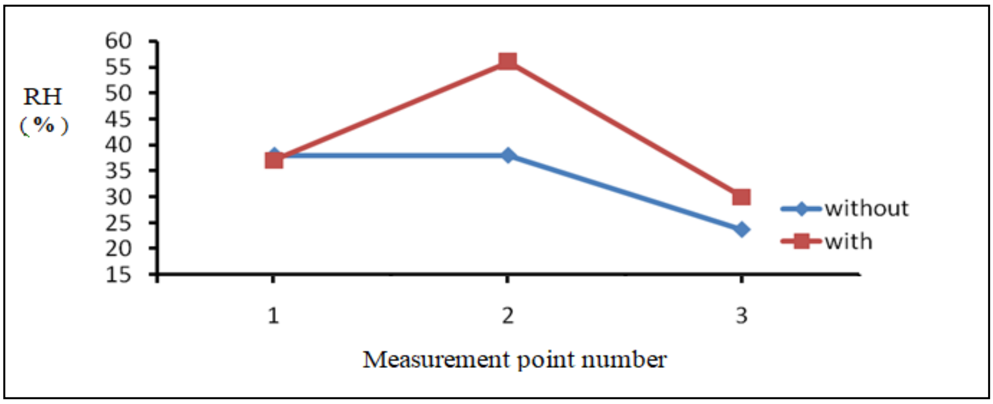

Fig. 5: Shows Comparison Relative Humidity vs. Measurement Points in Test 1.

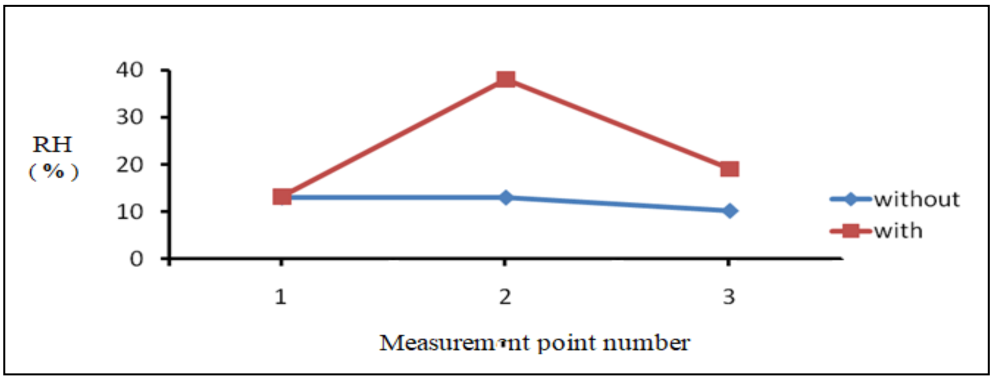

Fig. 6: Shows Comparison Relative Humidity vs. Measurement Points in Test 2.

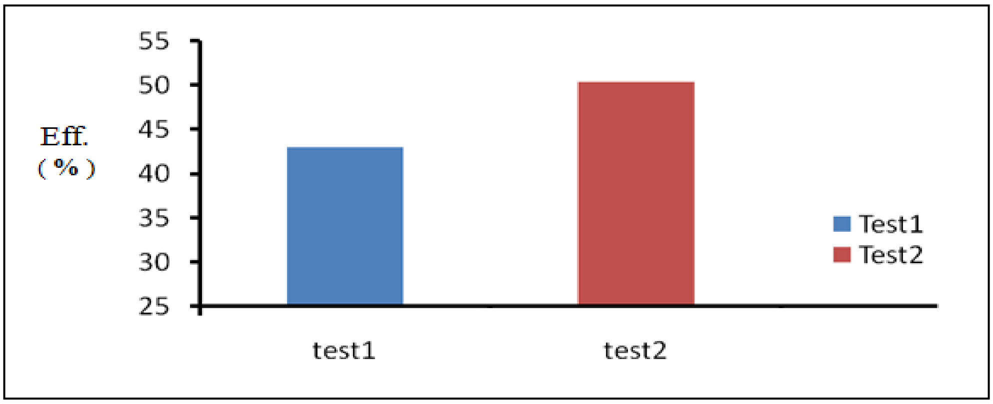

Fig. 7: Illustrates Comparesthe Evaporative Cooling Effectiveness in Tests.

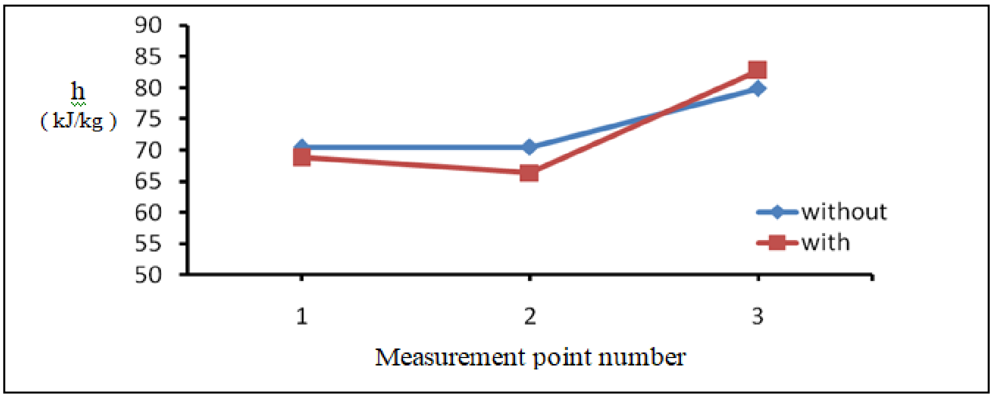

Fig. 8: Illustrates Specific Enthalpy of Air vs. Measurement Points in Test1.

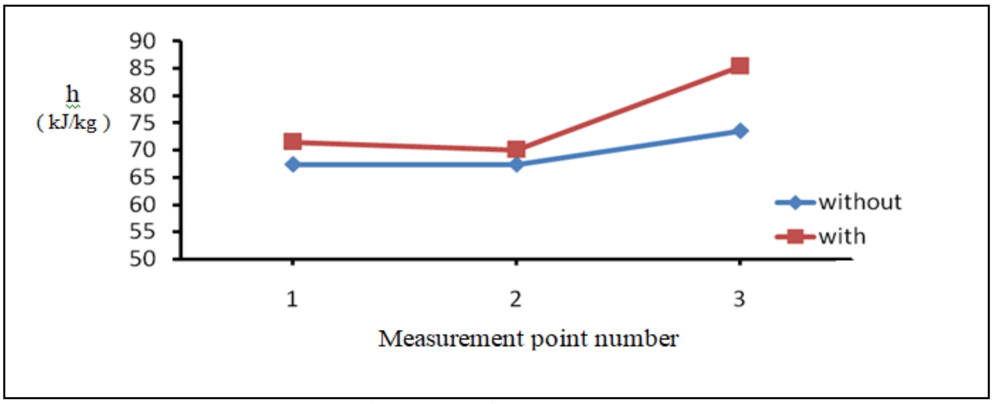

Fig.9: Illustrates Specific Enthalpy of Air vs. Measurement Points in Test 2.

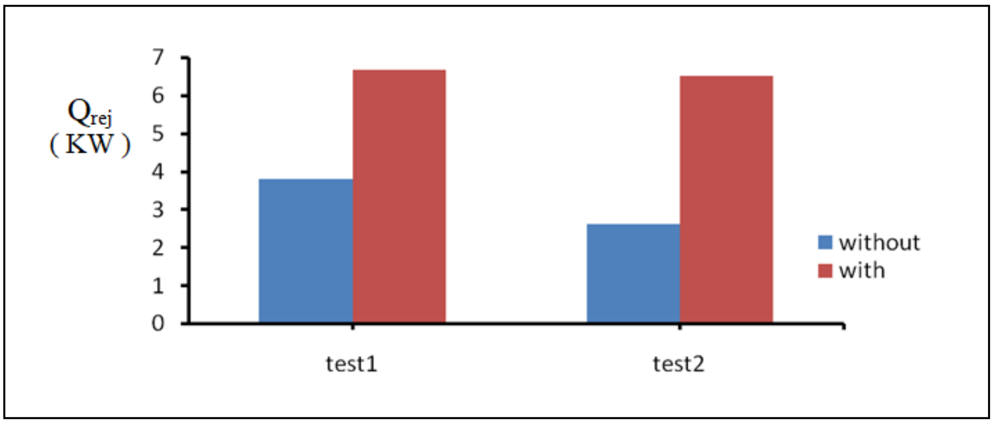

Fig. 10: Illustrates Comparison Rejected Heat of Condenser in Tests.

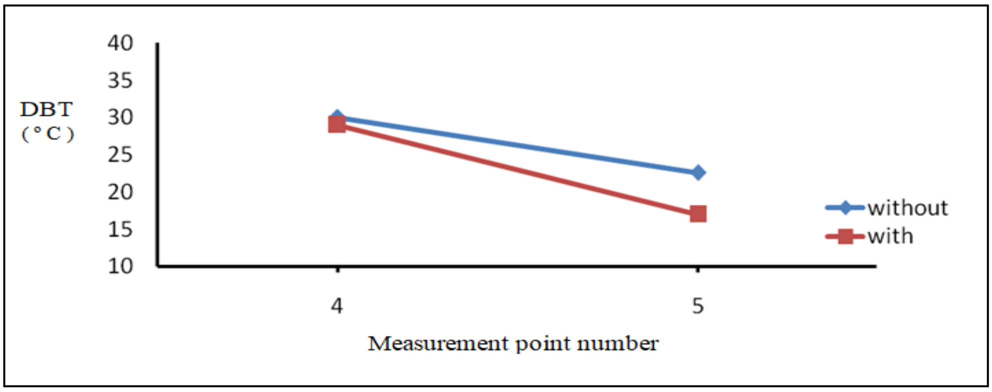

Fig. 11: Shows Comparison Dry Bulb Temperature vs. Measurement Points in Test 1.

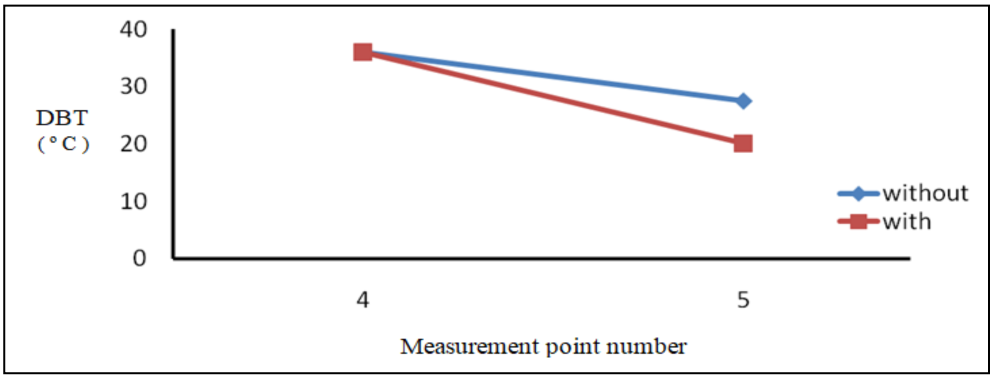

Fig. 12: Shows Comparison Dry Bulb Temperature vs. Measurement Points in Test 2.

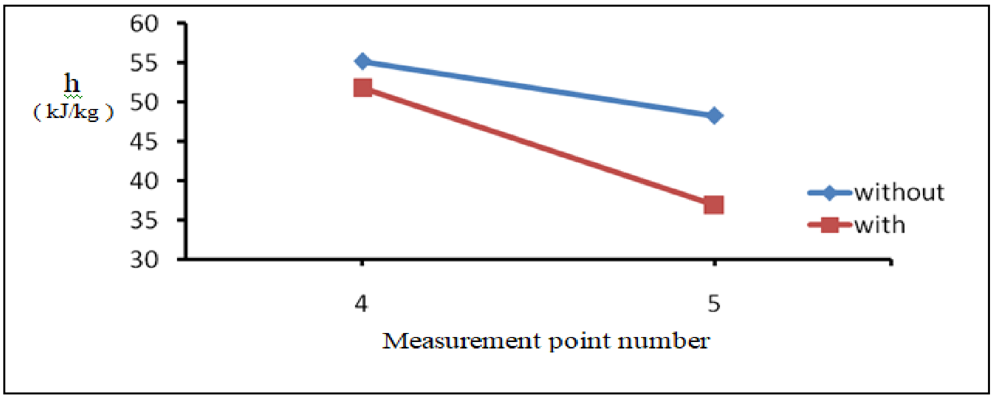

Fig. 13: Illustrates Specific Enthalpy of Air vs. Measurement Points in Test 1.

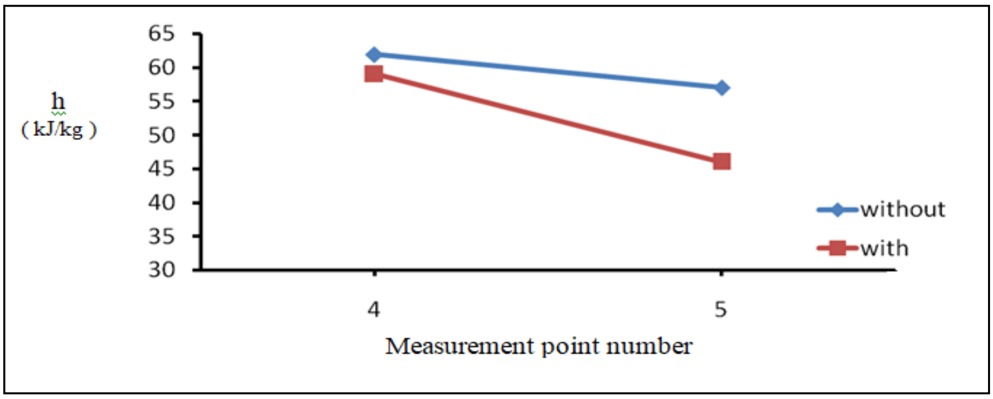

Fig. 14: Illustrates Specific Enthalpy of Air vs. Measurement Points in Test 2.

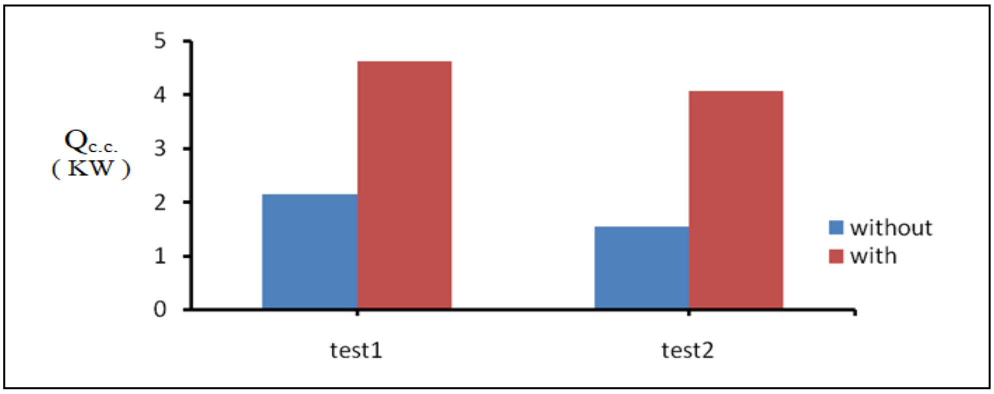

Fig. 15: Illustrates Comparison Cooling Capacity in Tests.

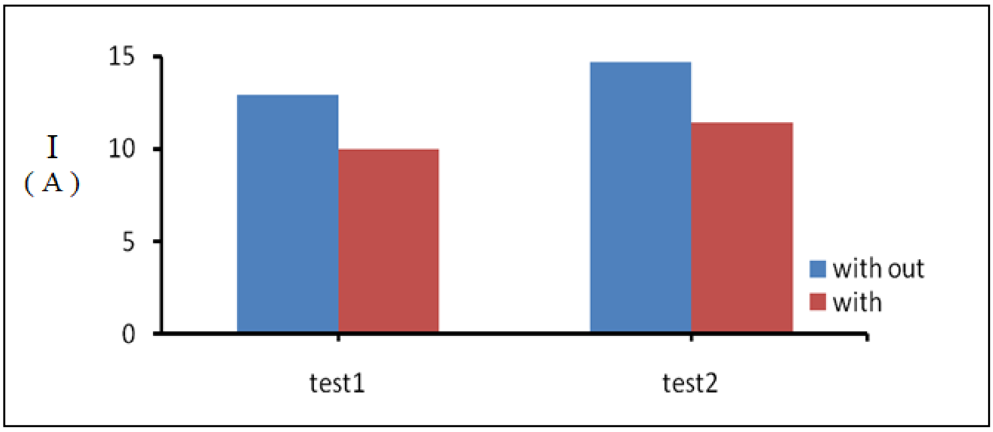

Fig. 16: Illustrates Comparison Electric Current Consumption in Tests.

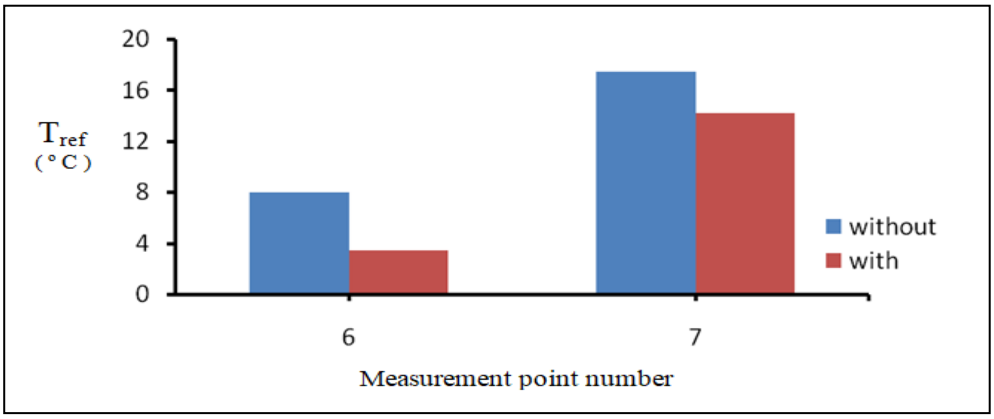

Fig. 17: Show Comparison Refrigeration Gas Temperature vs. Measurement Points in Test1.

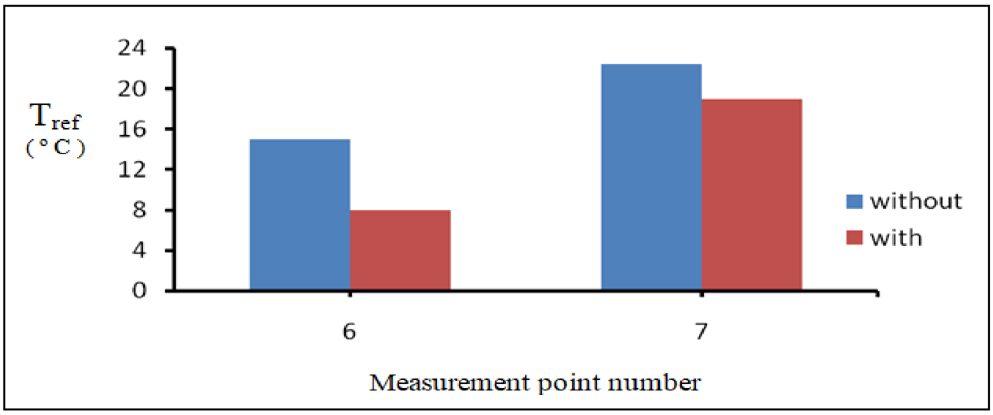

Fig. 18: Show Comparison Refrigeration Gas Temperature vs. Measurement Points in Test 2.

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