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STUDY AND MANUFACTURE SIMPLE AIR CONDITIONER

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ABSTRACT
The hot weather and electric energy is a great problem in country such as Iraq. Energy used for cooling is an important part of this energy. The aim of the present work is design and develops a low cost air conditioner and also works by electric charging. The paper presents study of parameters which affect air properties and heat transfer. The results of experimental work show that increasing dry bulb temperature of air (DBT) leads to the increase in (ΔDBT) and other properties. The inlet (DBT) of air varies from (34˚C to 41˚C) leads to the increase in (ΔDBT) from (12.8˚C to 16.7˚C) and specific cooling capacity from (16.12 kJ/kg to 25.84kJ/kg). Effect of air velocity is passive on (ΔDBT), specific cooling capacity and other properties. The increase in air velocity leads to the decrease in (ΔDBT) from (12.5˚C to 3.4˚C) and specific cooling capacity from (22.55kJ/kg to 4.96kJ/kg). The decrease in water temperature leads to increase in (ΔDBT). After a period of operating, water temperature will be high which leads to a decrease in average (ΔDBT). At water temperature is (7.8˚C), (ΔDBT) is (12.54˚C), while at water temperature is (18˚C), (ΔDBT) is (7.9˚C). Has been compare performance evaluation of system with other systems in terms of (ΔDBT) and Energy consumption.

KEYWORDS: Air conditioner, dry bulb temperature, effectiveness, heat transfer, specific cooling capacity.

NOMENCLATURE:
DBT = Dry bulb temperature of air (℃).
DP = Dew point temperature of air (℃).
h = specific enthalpy (kJ/kg).
RH = relative humidity (%).
Tw = Water temperature (℃).
WBT = Wet bulb temperature of air (℃).
Δ = Difference.

INTRODUCTION
The hot weather and electric energy is a great problem in country such as Iraq. In summer, the dry bulb temperature (DBT) of air may reach up to 50 ˚C. Energy used for cooling is an important part of this problem, which is continuously increasing due to the growing demand for better indoor comfort conditions in buildings. There is growing demand for highly efficient heat transfer devices having excellent performance, operational stability and low power consumption. Air conditioning of buildings is currently dominated by conventional compression refrigeration system, which takes over 95% of the market share in this sector. This kind of system is highly energy intensive due to extensive use of electricity for operation of the compressor, and therefore, is neither sustainable nor environmentally friendly [1].

There are two ways the most common in the air conditioning systems:

Evaporative cooling:
The evaporative cooling is based on a physical phenomenon of converting the sensible heat of air to the latent heat which leads to dry bulb temperature of air decrease and the relative humidity increase to a certain extent. This process occurs by contact between air and water [2]. There are two types of evaporative cooling:

Direct evaporative cooling:
This process occurs by direct contact between air and water, the air is drawn through porous wetted pads or a spray and its sensible heat energy evaporates some water; the heat and mass transfer between the air and water lowers the air dry bulb

temperature and increases the humidity. The dry bulb temperature of moist air approaches the ambient air's wet bulb temperature.

Indirect evaporative cooling:
This method is used in the fields that require control of the moisture from the air, such as silk-weaving industry and the garment industry. In indirect evaporative cooling, secondary air removes heat from primary air via a heat exchanger. Supply air to the space passes over the other side of the heat exchanger [3].

Vapor-compression refrigeration systems:
Vapor-compression refrigeration system [4] is one of the many refrigeration cycles and is the most widely used method for air-conditioning of buildings. It is also used in domestic and commercial refrigerators, and a host of other commercial and industrial services. The vapor-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejected that heat elsewhere. All such systems have four components: a compressor, a condenser, a thermal expansion valve and evaporator.

Refrigeration systems used for air-conditioning can be classified mainly in the following categories:

Direct expansion (DX) systems and heat pumps.
Centrifugal chillers.
Absorption systems.

Disadvantages cooling systems:
Evaporative cooling:
It is not used in regions of high humidity.
When the highest degree of efficiency of the cooling does not exceed the degree of the wet bulb.
It is not used in indoor areas and dusty days.
It is not used in hospitals and medical laboratories.

Vapor-compression refrigeration systems:
The cost of buying high.
Most air conditioners use a substantial amount of energy, costing money and contributing to pollution from power plants.
Effects the environment by releasing the CFC.

The present work merges between indirect evaporative cooling and chilled water systems. This work is to study and design a low cost air cooler which can be used in houses, office and treat flaws mentioned above.

LITERATURE REVIEW:

There are several researches about indirect evaporative cooling (IEC) and study the performance of cooling devices that operate by this principle. It has used heat exchangers with surfaces secondary wet (Air - Air) as evaporative coolers indirect and appeared for the first time in the southwestern United States during the year (1930) and characterized as having less power consumption of electrical devices with closed cycles and with lower consumption of water from the refrigerant evaporative Statistics. Stoichkov and Dimitrov [5] introduced a correction factor of IEC for cross flow plate heat exchanger. Guo and Zhao [6] analyzed the thermal performance of an indirect evaporative air cooler numerically. The results showed that the coefficient of performance tends to be very high because the system consumes only fan and water pumping power. Joudi and Mehdi [7] investigated the application of the IEC to provide the variable cooling load of a typical dwelling at Iraq. The results showed that IEC can provide indoor good condition for most periods of the system operation and the performance coefficient is high because it consumes a small amount of electricity for fan and water pump. Hettiarachchi *et al.* [8] investigated the effect of the longitudinal heat conduction in the exchanger wall of a compact-plate cross flow IEC with the NTU method numerically. The results of this research showed that the thermal performance deterioration of evaporative coolers may become significant for some typical operating conditions and could be as high as 10%, while it lies at less than 5% for most conservative conditions. Martin [9] studied heat recovery with a semi-indirect evaporative cooler by the experimental design method. The results showed that for low relative humidity contents and high temperatures of air supply, the main effect is evaporative from the surface of the ceramic pipes. For high temperatures and relative humidity of the air supply, dehumidification takes place and thus condensation appears in the exterior surface of the pipes and the latent and sensible heat recovered are added. A possible use of this recovery system can be in climates with high temperatures and humidity, such as tropical environments where the system could reduce the humidity of the primary air supply by using the cooling power of the secondary air. Riangvilaikul and Kumar [10] carried out experiments to analyze a dew point evaporative cooler performance at various operating conditions. The results indicated that wet bulb effectiveness of the investigated sensible evaporative cooling system ranged between 0.92 and 1.14 and dew point effectiveness between 0.58 and 0.84 depending on inlet air conditions covering dry, temperate and humid climates.

Most researchers have investigated the effects of physical and geometrical parameters on system performance and some introduced better models. Most of this research study focused on the performance of heat exchangers with wet surfaces and how to use them to benefit from them in indirect evaporative cooling. The present work merges between indirect evaporative cooling and chilled water systems. This work is to study and design a low cost air cooler which can be used in houses and office. The work presents study of parameters [Dry bulb temperature of air, the air velocity, and temperature of water] which affect air properties [Dry bulb temperature, relative humidity, moisture content], as well calculate specific cooling capacity , wet bulb effectiveness and dew point effectiveness to evaluation performance of system and compare with other conventional air conditioning systems.

EXPERIMENTAL WORK

Strategies used to improve the efficiency of cooling systems and further reduce costs associated with the operation of system and we can use recycled water in system. The idea of simple air conditioner with cool water is very simple. Get a ice with cold water, empty them in a insulated tank, and use it to cool the room by circulating it through a simple coil/fan mechanism.

The experimental work was carried out by using a simple air conditioner. Fig. (3-1) illustrates the main parts for test rig which consists of:

Fan, pipe coil of copper, water pump, control valve, insulated tank, temperature - humidity meter and anemometer.

The tank is first filled with freezing cold water; you can simply get it from in your home refrigerator itself. The thick insulation lining around the tank helps keep the near-freezing temperature of the water intact and allow its exhaustion very slowly so that the low temperature of the dripping water through the copper coils is sustained for a longer period time. Copper being extremely good conductor of heat instantly starts radiating the coolness through its outer walls into the atmosphere around it. The end of this copper spiral ultimately terminates into tank itself for retrieving the exhausted ice water. A control valve fitted at the end of the copper piping is used to control the flow of the seeping water into the collector tank.

Three sets of experiments were conducted to analyze the performance of the system:

1. Investigation of effect of specific inlet air conditions (temperature & humidity) on the system performance.
2. Examination of the system performance under influence of inlet air flow rates(effect of air velocity).
3. Investigation of effect of water temperature on the system performance.

To evaluate the performance of the investigated cooling system the following relevant parameters were measured:

DBT and RH of the air flow entering and leaving the system.
DBT and RH of the out air flow at several measurement points.
Air velocity.

Measurement equipment was installed in the key points of the experimental setup. The studies were performed under steady-state conditions. Each experiment was repeated to ensure consistency (and repeatability) of the measured data.

Six main parameters (indices) have been selected to study the operational performance of the cooling system:
Temperature level, relative humidity and specific moisture content of outlet air flow.

Specific cooling capacity, which is defined as the difference between inlet and outlet specific enthalpy ($q = h_{out} - h_{in}$).

The wet bulb thermal effectiveness, which is defined as the ratio of the difference between inlet and outlet air temperature to the difference between inlet air temperature and its wet bulb temperature.

The dew point thermal effectiveness, which is defined as the ratio of the difference between inlet and outlet air temperature to the difference between inlet process air temperature and its dew point temperature.

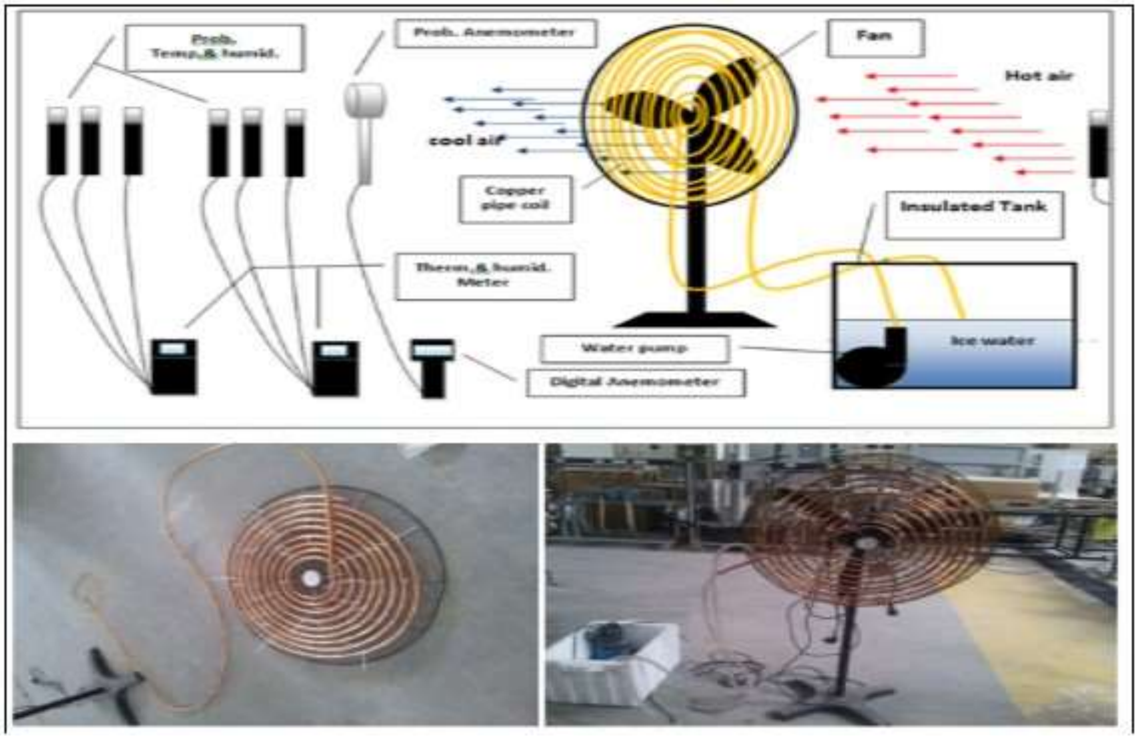

Fig. (3-1) illustrates the main parts for test rig.

RESULTS AND DISCUSSION OF STUDY:

Air conditioner performance at the different inlet conditions:

The performance of the investigated system has been experimentally tested. The recommended operating conditions (see Table 1) were used to set the initial conditions of the test. Experimental results from tests concerning of operating parameters were conducted. The results are including outlet temperatures, relative humidity, specific moisture content, specific cooling capacity, wet bulb effectiveness and dew point effectiveness.

Fig.(4-1) illustrates the effect of dry bulb temperature (DBT) on supply temperature, varying the inlet air temperature between (34˚C and 41˚C). It can be seen that the temperature of supply air in space decreases with increasing inlet dry bulb temperature (DBT). This is due to higher inlet air temperature resulting large difference in temperature between inlet air and the cooling coil (increase in heat transfer). At (DBT= 34˚C), the maximum (ΔDBT) is (12.8˚C), while its value is (16.7˚C) at (DBT=41˚C). This decrease retreats in space due to heat exchange with surrounding air. The maximum wet-bulb effectiveness increases from (93.4% to 98.8%) (see fig. 4-2), and maximum dew point effectiveness increased from (66.6% to 69%) (see fig.4-3). The maximum specific cooling capacity increased from (16.12kJ/kg to 25.84kJ/kg) (see fig.4-4). The maximum relative humidity increases from (28% to 51.6%) at inlet (DBT=34˚C) and from (24.5% to 45.3%) at inlet (DBT=41˚C) which it is within the limits of human comfort (see fig.4-5). moisture content decreases due to increasing condensing water vapor on cooling coil. This drop increases with higher inlet air temperature. The maximum specific moisture content decreases from (9.29g/kg$_a$ to 8.08g/kg$_a$) at inlet (DBT=34˚C) and from (11.93g/kg$_a$ to 8.57g/kg$_a$) at inlet (DBT=41˚C),(see fig.4-6).

Table 1: Operational conditions at the different inlet conditions.

case	DBT ˚C	RH %	WBT ˚C	DP ˚C	h kJ/kg	W g/kg$_a$
1	34	28	20.3	12.9	58.1	9.29

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2	41	24.5	24.1	16.8	72.09	11.93

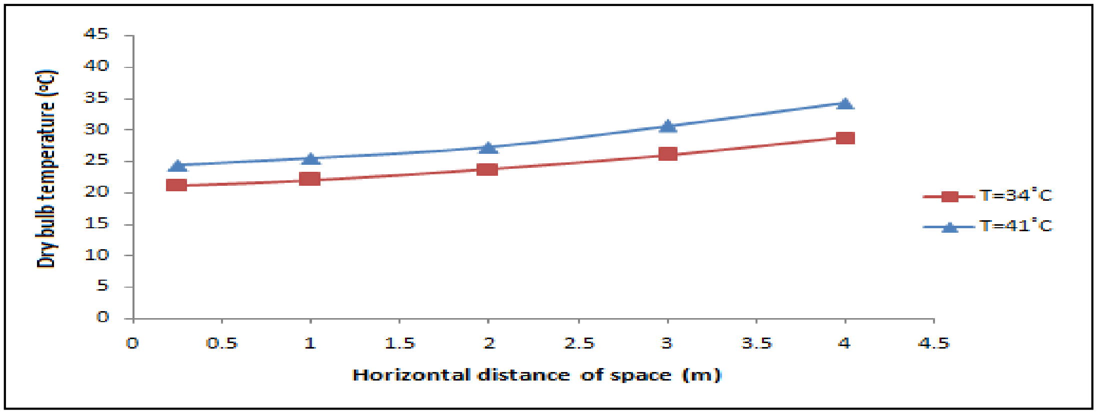

Fig.(4-1) Effect of inlet (DBT) on supply temperature in space

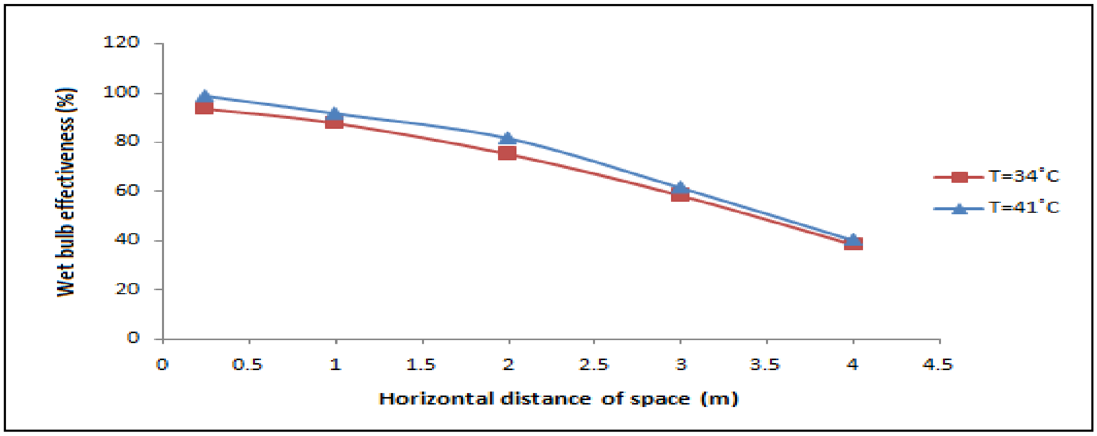

Fig.(4-2) Effect of inlet (DBT) on wet-bulb effectiveness in space

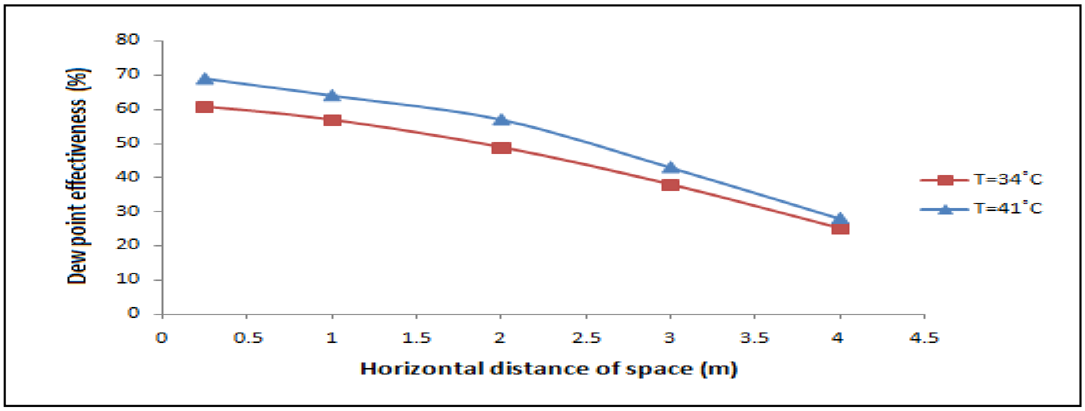

Fig.(4-3) Effect of inlet (DBT) on Dew-point effectiveness in space

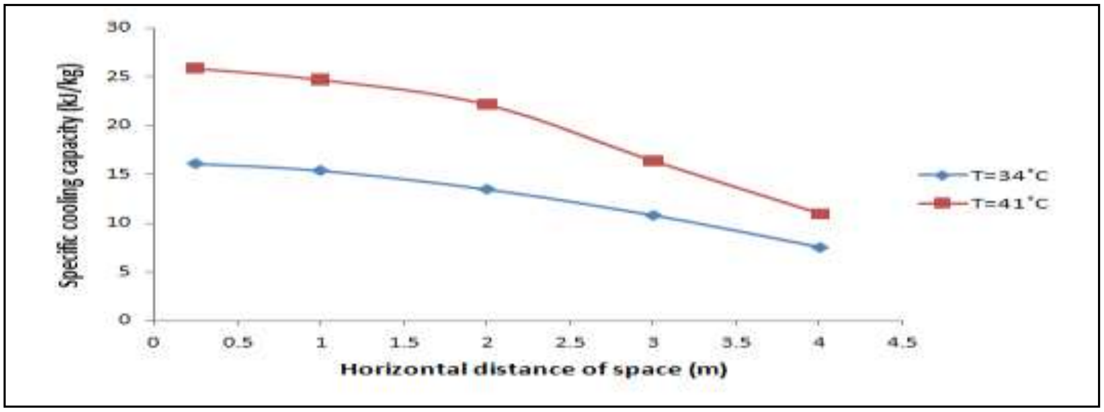

Fig.(4-4) Effect of inlet (DBT) on specific cooling capacity in space

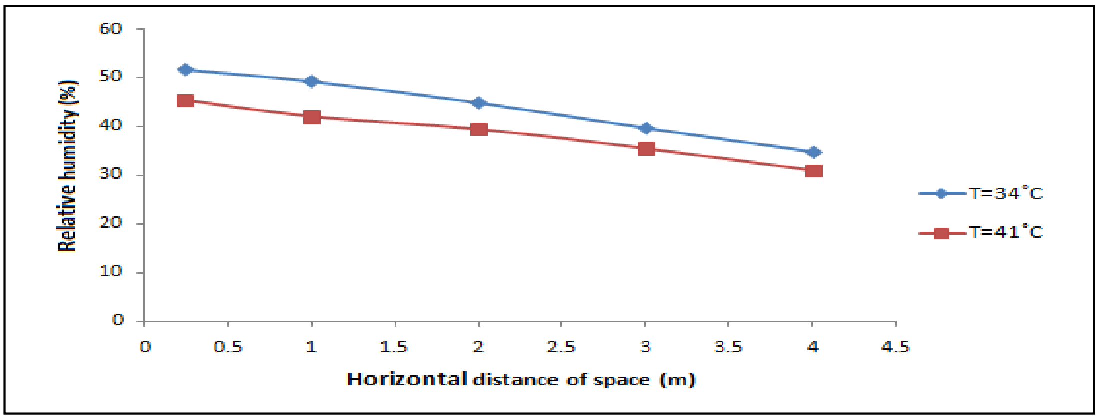

Fig.(4-5) Effect of inlet (DBT) on relative humidity in space

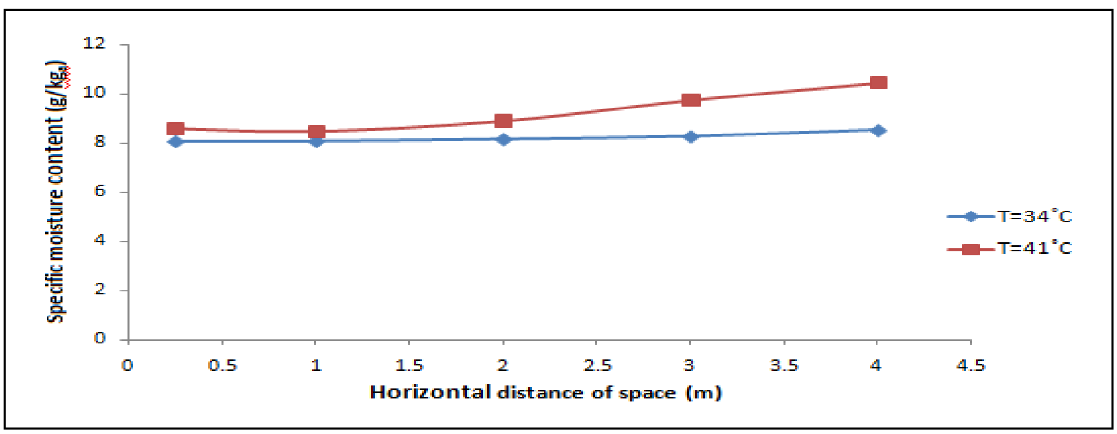

Fig.(4-6) Effect of inlet (DBT) on specific moisture content in space

The study was carried out to investigate effect of air flow rate on the performance of air conditioner (inlet air velocity increases, see Table 2). Inlet air velocity is varying from (0.5 m/s to 3 m/s). Fig. (4-7) presents results and measured data of the outlet air temperature for different air velocity. The experimental results show, that lower supply air temperature can be achieved by reducing the air velocity. At inlet air velocity is (0.5 m/s), the maximum (ΔDBT) is (12.5˚C), while its value is (3.4˚C) at inlet air velocity is (3m/s). The maximum wet-bulb effectiveness decreased from 98.11% to 26.68% (see fig. 4-8), and maximum dew point effectiveness decreased from 66.95% to 18.21% (see fig. 4-9). The maximum relative humidity decreased from 46% to 38% which it is within the limits of human comfort (see fig.4-10). The maximum specific cooling capacity decreased from (22.55 kJ/kg to 4.96 kJ/kg see fig.4-11). The maximum specific moisture content decreases from (11.61g/kg$_a$ to 7.8g/kg$_a$) at inlet air velocity is (0.5 m/s) and from (11.61g/kg$_a$ to 11.04g/kg$_a$) at inlet air velocity is (3 m/s),(see fig.4-12).

Table 2: Operational conditions at the different air velocity.

Inlet air condition	DBT ˚C	RH %	WBT ˚C	DP ˚C	h kJ/kg	W g/kg$_a$
	35	33	22.2	16.4	64.99	11.61
Air velocity (m/s)	Case1	Case2	Case3	Case4		
	0.5	1	2	3		

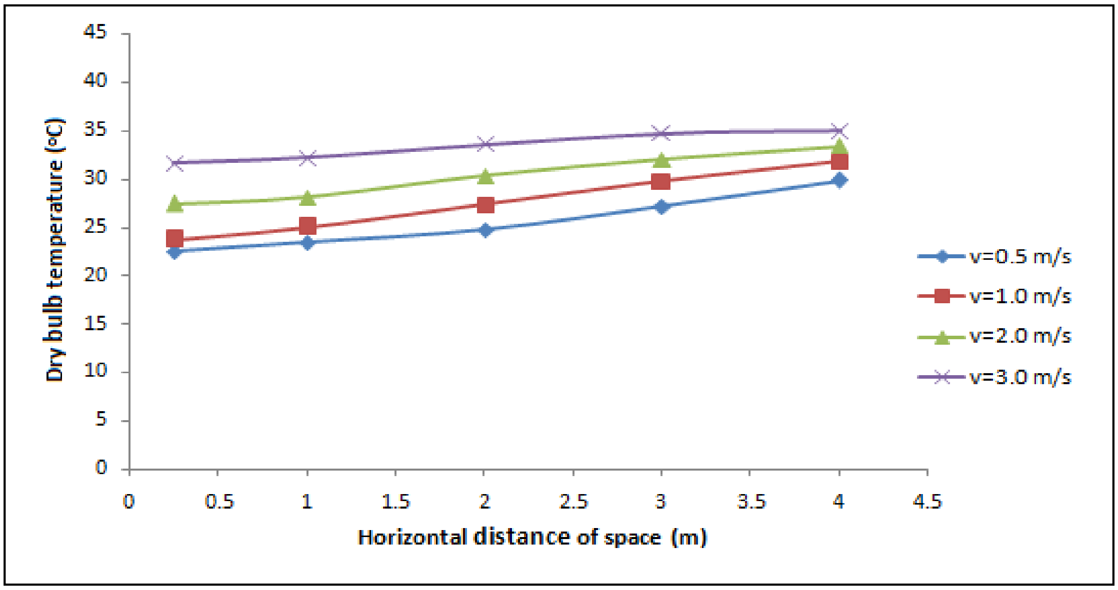

Fig.(4-7) Effect of inlet air velocity on supply temperature in space

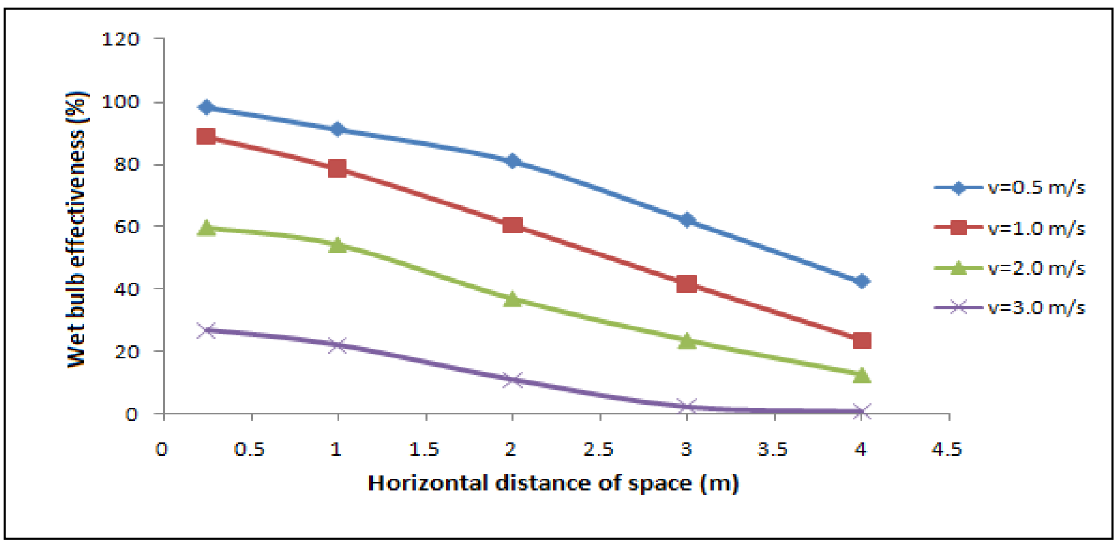

Fig.(4-8) Effect of inlet air velocity on Wet bulb effectiveness in space

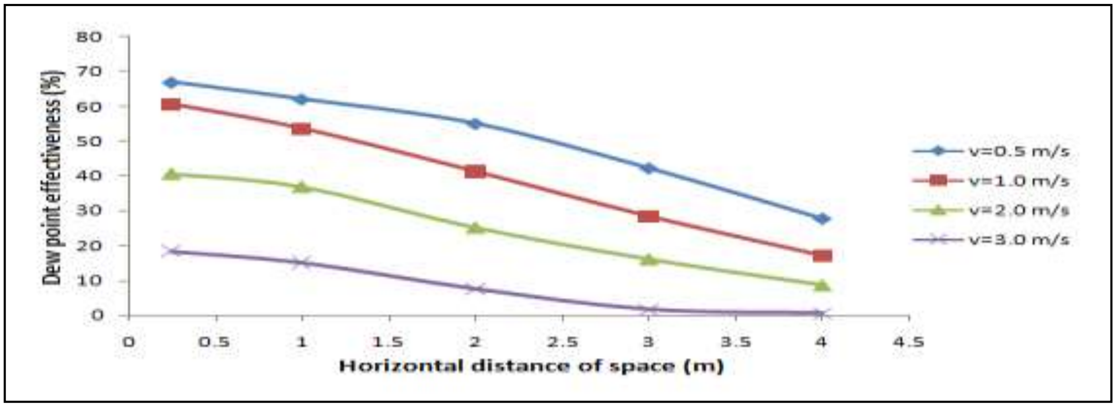

Fig.(4-9) Effect of inlet air velocity on dew point effectiveness in space

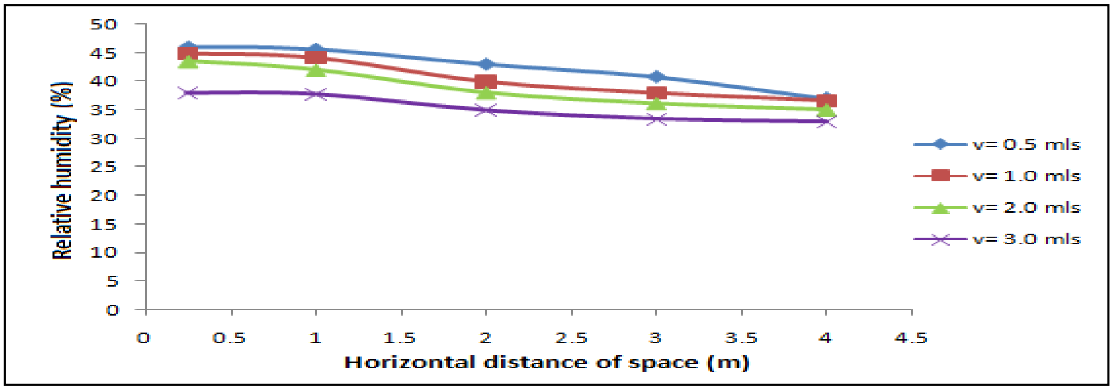

Fig.(4-10) Effect of inlet air velocity on Relative humidity in space

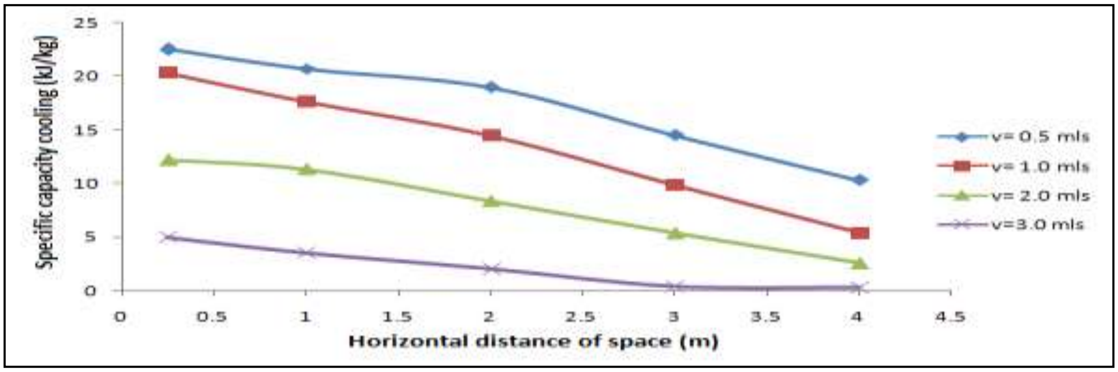

Fig.(4-11) Effect of inlet air velocity on specific capacity cooling in space

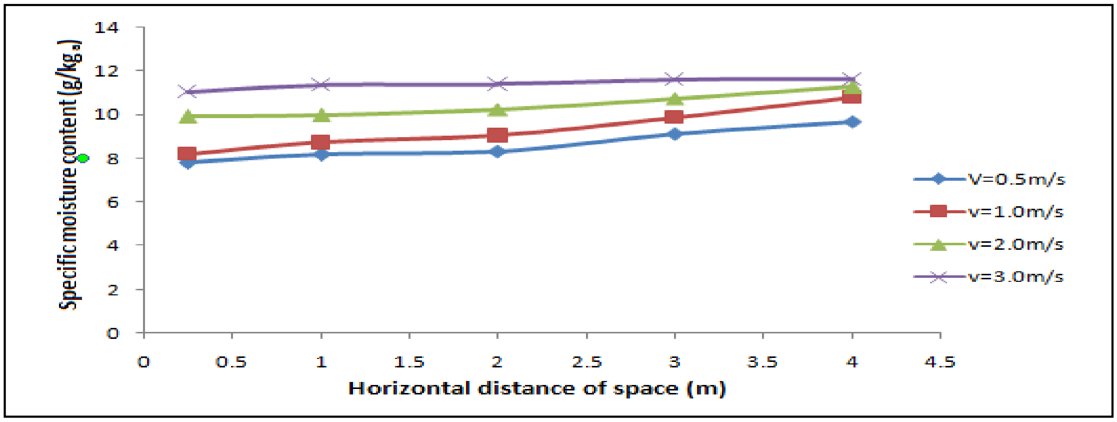

Fig.(4-12) Effect of inlet air velocity on specific moisture content in space

Air conditioner Performance under different water temperature:

Use cooling water at different temperatures to study the impact on the performance of the system. Fig.(4-13) illustrates the effect of water temperature (Tw)on temperature of supply air in space. It can be seen that the temperature of supply air in space decreases with decreasing water temperature, due to increase in heat transfer and dehumidify. At water temperature is (7.8˚C), the maximum (ΔDBT) is (12.8˚C), while its value is (8˚C) at (Tw=18˚C). The maximum wet-bulb effectiveness decreased from (93.4% to 58.4%) at increasing water temperature (see fig. 4-14), and maximum dew point effectiveness decreased from (66.6% to 37.91%) (see fig. 4-15). The maximum relative humidity increased from 51.6% to 42.8% (see fig. 4-16). The maximum cooling capacity increased from (16.12kJ/kg to 9. 1kJ/kg) (see fig. 4-17). The maximum specific moisture content decreases from (9.29g/kg$_a$ to 8.08g/kg$_a$) at inlet (Tw=7.8˚C) and from (9.29g/kg$_a$ to 8.96g/kg$_a$) at inlet (Tw=18˚C),(see fig.4-18).

Table 3: Operational conditions at different water temperature.

Inlet air condition	DBT ˚C	R.H. %	WBT ˚C	DP ˚C	h kJ/kg	W g/kg$_a$
	34	28	20.3	12.9	58.1	9.29
water temperature ˚C	Case1	Case2	Case3			
	7.8	12.6	18			

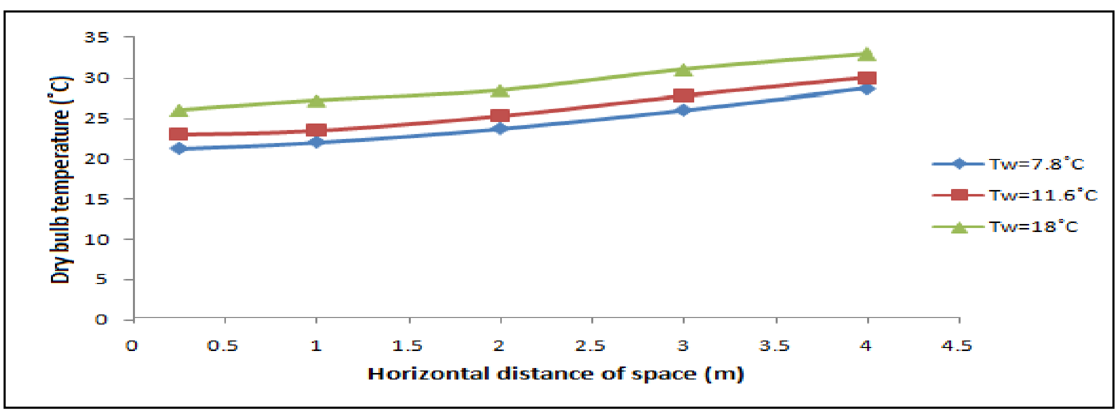

Fig.(4-13) Effect of water temperature on supply temperature in space

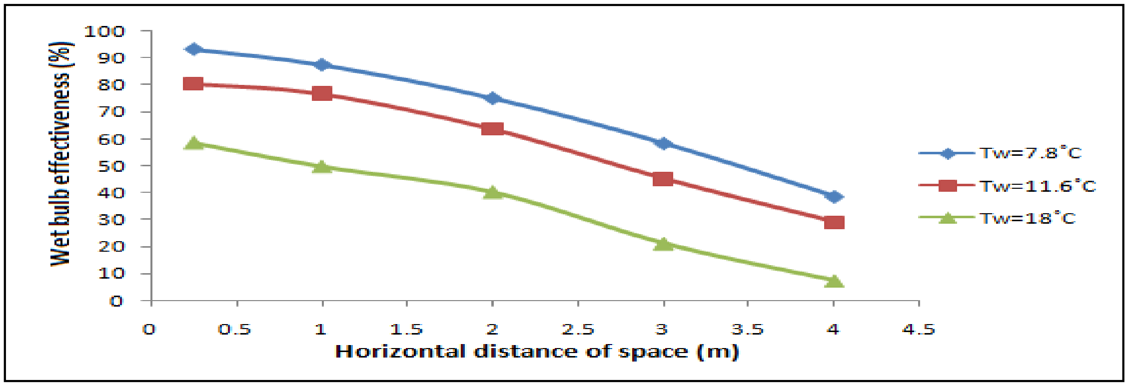

Fig.(4-14) Effect of water temperature on wet bulb effectiveness in space

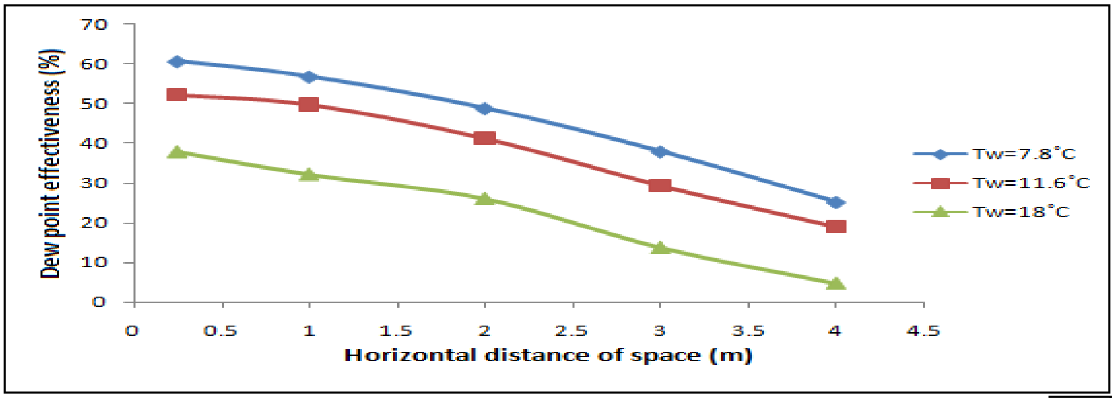

Fig.(4-15) Effect of water temperature on dew point effectiveness in space

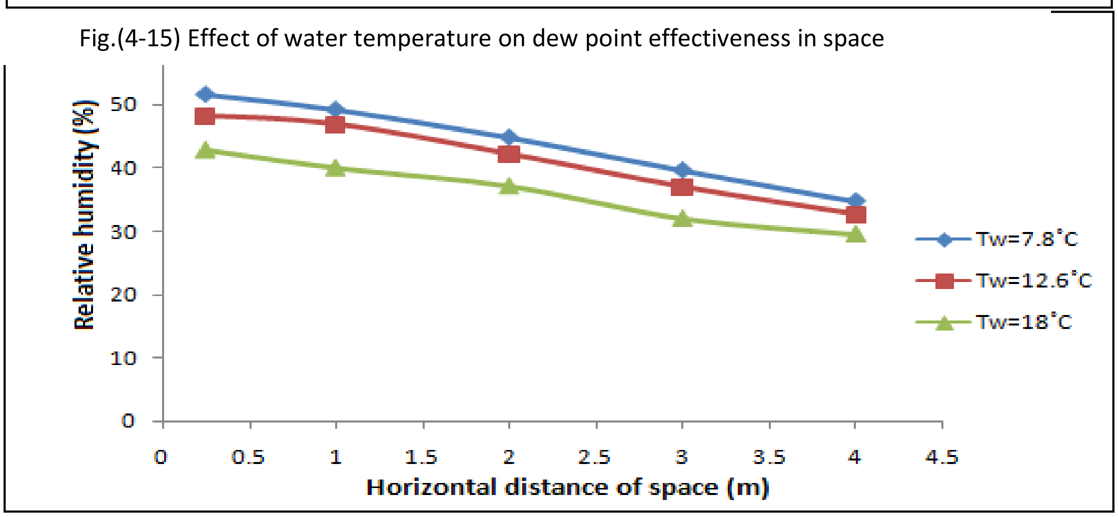

Fig.(4-16) Effect of water temperature on relative humidity in space

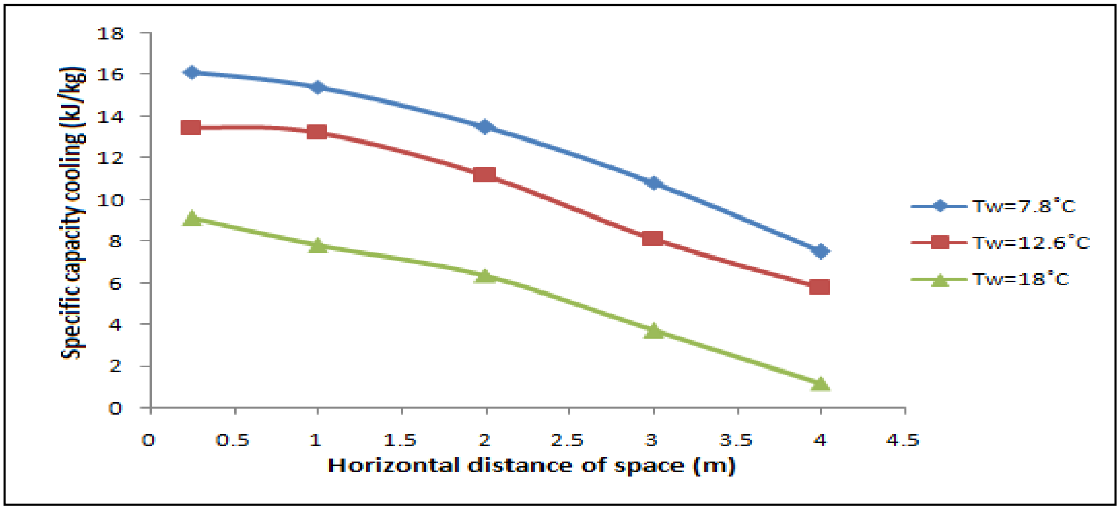

Fig.(4-17) Effect of water temperature on specific capacity cooling in space

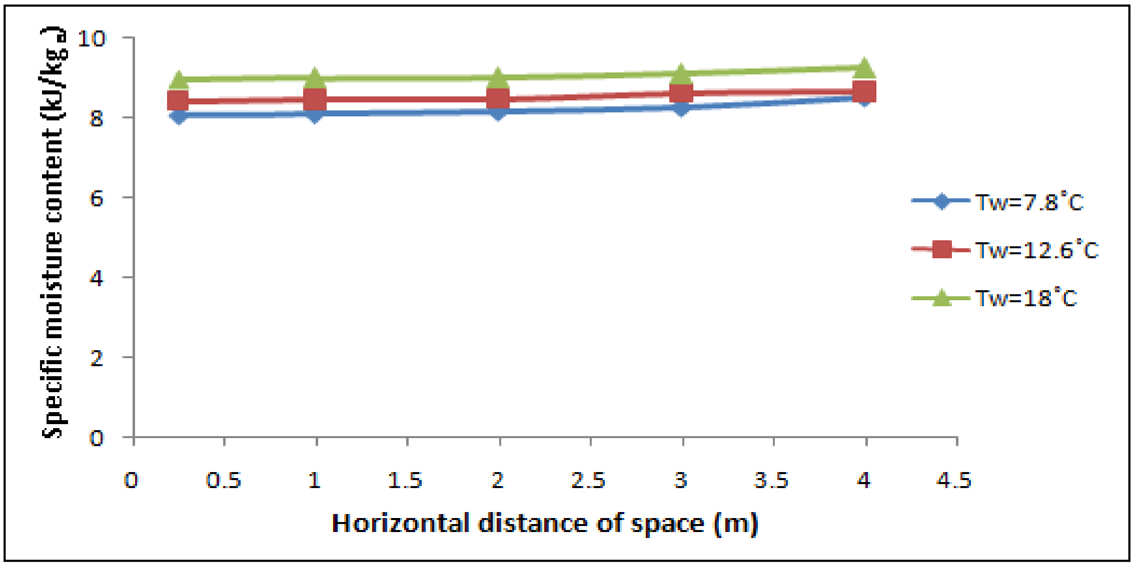

Fig.(4-18) Effect of water temperature on specific moisture content in space

Comparison between presented operating system and conventional systems:

Table (4) contains results comparison between new system data and other conventional air conditioning systems under the given conditions. Results show that the current system more efficient than evaporative air cooler in terms of reducing the temperature and the electrical energy consumption, while refrigeration systems are more efficient in reducing temperature but energy consumption 10.5 times more than the current system.

Table 4: Comparison between new system and other conventional air conditioning systems.

System type	Inlet DBT(˚C)	Inlet RH(%)	Out DBT (˚C)	Elect. Consumption(A)
New system	38.7	31	24.5	0.9
Evap. air cooler	38.7	31	29	2.2
Ref. system (18000BTU)	38.7	31	17.3	9.6

CONCLUSION

Study is conducted to verify the performance of a simple air conditioning system and study the effect of the factors affecting the performance of the system and compare performance with other air conditioning systems. The whole work paper can be summarized as follows.

The inlet (DBT) of air varies from (34˚C to 41˚C) leads to the increase in (ΔDBT) from (12.8˚C to 16.7˚C) and specific cooling capacity from (16.12 kJ/kg to 25.84 kJ/kg). Effect of air velocity is passive on (ΔDBT), specific cooling capacity and other properties. The increase in air velocity leads to the decrease in (ΔDBT) from (12.5˚C to 3.4˚C) and specific cooling capacity from (22.55 kJ/kg to 4.96 kJ/kg). The decrease in water temperature leads to increase in (ΔDBT). At water temperature is (7.8˚C), (ΔDBT) is (12.54˚C), while at water temperature is (18˚C), (ΔDBT) is (7.9˚C). Has been compare performance evaluation of system with other systems in terms of (ΔDBT) and energy consumption. the current system more efficient than evaporative air cooler in terms of reducing the temperature and the electrical energy consumption, while refrigeration systems are more efficient in reducing temperature but energy consumption 10.5 times more than the current system.

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