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Research Article

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Development of An Air- Conditioner with Cold Water Dispenser

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Abstract: This paper deals with the study of air conditioner and water dispenser system in a single unit. The aim of the paper is to develop a system which can provide cold water and air conditioning effect with the regular air conditioning system simultaneously. The design mainly consists of compressor, condenser, evaporators, expansion valves and other accessories including pressure gauges, and thermometers. Frame structure was constructed to give support to the entire system and to make it portable and transportable. The suction and discharge pipes of the condenser are joined with the tee fitting to obtain two flow lines. The two lines of suctions are joined with evaporator's coils of both air conditioner and water dispenser. This system comprises of air cycle and water cycle combined with a common compressor and condenser. The results and discussions of the analysis of the performance of the developed AC system over six sets of experimentations conducted with respect to the three thermal performance properties considered for the evaluation. The thermal performance properties utilized for the evaluation are work of compression (WoC), Refrigeration effect (RE) and coefficient of performance (COP). The results obtained were plotted in graphs. The refrigerant R-22 is charged into the compressor as working fluid for the system to bring about the various heating and cooling effects.

Keywords: Cold water, air-conditioning, work of compression, refrigeration effect, coefficient of performance

1. Introduction

From earlier times, the art of artificial cooling is employed in the preservation of the perishable such as milk, food, drinks, medicine etc. indoor air cooling has also been employed in order to provide humanitarian comfort and cool environment in industry applications. The application of cooling is employed in various fields. The two major methods employed for artificial cooling are refrigeration and air conditioning (Ramachandra et. al, 2017).

At present in the market, the technology advancement has the separate form of the water cooler and air conditioner. They work on the same principle. The standard of people has improved and this makes many people to install these two equipment in their homes, offices and many more. The most disadvantages and concerns of scientists are that they consume more electrical energy than any other appliances in the homes and this is a great concern to researchers. The attractive point of this project is that it can provide these facilities in compact way with lesser electrical consumption in a single unit (Sunil et. al, 2018).

The purpose of water cooler is to make two in one equipment at constant temperature irrespective of ambient temperature. The air conditioning with water dispenser system is designed to provide a comfortable living or working environment within a specific area by controlling the surrounding at a suitable range of temperature, relative humidity, air circulation and purity of the air. The air conditioners alongside with electric heater and water cooler are generally used in residential and commercial buildings (Sunil et. al, 2018).

Refrigeration is defined as the process to achieve and keep an enclosed space at a temperature lower than its surrounding's temperature. This is done by continuous extraction of heat from the enclosed space where the temperature is below that of the surrounding environment. Nowadays refrigeration is indispensable in our daily lives. It is used in the preservation of perishable foods and keeps the food fresh in a suitable condition.

Air conditioning and refrigeration system consume significant amount of energy in buildings and in industries. The energy consumed in these systems is sensitive to load changes, seasonal variations, operation and maintenance, ambient conditions etc. hence the performance evaluation will have to take into account all these factors. For centralized air conditioning systems, the air flow at the air handling unit (AHU) can be measured with an anemometer. The dry bulb and wet bulb temperatures can be measured at the AHU inlet and outlet. The data can be used along with a psychometric chart to determine the enthalpy (heat content of air at the AHU inlet and outlet (Ramachandra et. al, 2017).

The air conditioning units which work on the principle of vapour compression system consists of compressor, condenser, expansion valve and evaporator. A refrigerant is a working medium in the refrigeration system. The cycle with sub – cooling and superheating of refrigerant is more advantageous to increase the refrigerating effect which leads to increase the coefficient of performance and reduce the mass flow of refrigerant hence the compressor work reduces. Condenser in the air conditioning units designed to remove heat absorbed by the refrigerant in the evaporator and heat of compression added by the compressor (Satich et.al, 2018). This is achieved by transferring heat from the refrigerant vapour discharged by the compressor to some external cooling medium, usually water or air. In the condenser, the pressure is maintained constant, but the temperature is constant only during the removal of latent heat from the refrigerant i.e. only in the considering portion.

2. Literature Survey

Scientists all over the world are in search of new and renewable energy source, one option is to develop energy storage devices which are as important as developing new sources of energy. The air conditioning along with cold water dispenser can operate in various modes. They were focused on to solve the air conditioning drip water problem.

The concept of air cooling intrigued the great American inventor and statesman Benjamin Franklin, who in 1758 conducted experiments with evaporation and alcohol to attain freezing temperatures.

Meckler, 1920 proposed a two – stage solid desiccant air conditioning system, integrated with a heating ventilation and air conditioning (HVAC) system. An energy exchange was employed to pre cool and pre dehumidify the process air by exchanging sensible and latent heat with return air from conditioned space without the addition of external heat or regeneration. The air conditioning is one of the most important inventions of modern times – cooling homes, businesses, and systems that are critical to the world. The air conditioning along with water dispenser can operate in various modes which are water heating, water cooling, space heating, etc. (Ashish and Subhrajyoti 2015)

Air conditioning actually has roots in second century China, where an inventor named Ding Huane crafted a manually powered rotary fan. In the year 1840s, Physician and inventor Dr. John Gorrie of Florida proposed the idea of cooling cities to relieve residents of the evils of high temperatures. Gorrie believed that cooling was the key to avoiding diseases like malaria but his rudimentary system for cooling hospital rooms required ice to be shipped to Florida from frozen lakes and streams in the northern United States. The idea of artificial cooling went stagnant for several years until Engineer Wills Carrier took a job that would result in the invention of the first modern electrical air conditioning unit.

In 1922, Carrier Engineering Corporation installed the first well – designed cooling system for theaters at metropolitan Theater in Los Angeles, which pump pumped cool air through higher vents for better humidity control and comfort throughout the building.

In 1929, Frigidaire introduced a new split – system room cooler to the market place that was small enough for home use and shaped like a radio cabinet.

Between 1930 and 1931, Thomas Midgley, Albert Henne and Robert McNary of General Motors Synthesized Chlorofluorocarbon (CFC) Coolants which became the world’s first non – flammable refrigerating fluids which substantially improve the safety of air conditioners.

In 1932, Schultz and Sherman produced an air conditioning unit that could be placed on a window ledge.

As a follow up to the concepts of Mechanical refrigeration established in earlier years, Willis Haviland Carrier’s system sent air through coils filled with cold water, cooling the air while at the same time removing moisture to control room humidity. In 1933, the carrier Air conditioning Company of America developed an air conditioner blower, mechanical controls and evaporator coil, and this device became the model in the growing U.S. market place for air cooling system. Today's air conditioners, while operating on the same fundamental science as Carrier's 1933 system, incorporate advancements in vapour compression, diagnostics and controls, electronic sensors, materials and energy efficiency.

In 1947, Engineer Henrry Galson went on to develop a more compact, inexpensive version of the window air conditioner and set up production lines for several manufacturers.

Emissions of condensed water of air conditioners in the run-time give rise to inconvenience and affect the environment, and the condensed water discharge to the outdoor is a waste of water resource. Thus the treatment of condensed water is a very practical problem. Mecler proposed a two-stage solid desiccant air conditioning system, integrated with a Heating Ventilation and Air Conditioning (HVAC) system. An energy ex-change was employed to pre - cool and pre - dehumidify the processed air by exchanging sensible and latent heat with return air from conditioned space without the addition of external heat or regeneration.

A lot of research was carried out on the solar air heater. Alvarez et al. described the development and testing of an efficient, single-glass air solar collector with an absorber plate made of recyclable aluminum cans (RAC). The maximum efficiency reached was 74%, which was very satisfactory for an air solar collector with an absorber plate made of recyclable aluminum cans. In addition to the obvious benefits and enjoyments of comfort cooling, air conditioner altered architectural design, allowing windowless office buildings and houses without porches.

Techarungyaisan, et al (2006) developed a steady state simulation model to predict the performance of a small split type air conditioner with integrated water heater. The mathematical model consists of sub - models of system components such as evaporator, condenser, compressor, capillary tube, receiver and water heater. The model was coded into a simulation program and used to predict system parameters of interest such as condenser exit air temperature, evaporator exit air temperature, heat rejecting in the condenser and cooling capacity of the system.

Bansal, et al (2012) presented a review of the next generation not – in – kind technologies to replace conventional vapour compression refrigeration technology for household applications. Such technologies are sought to provide energy savings or other environmental benefits for space conditioning, water heating and refrigeration for domestic use. These alternative technologies include: thermo acoustic refrigeration, thermoelectric refrigeration, thermo tunneling, magnetic refrigeration, Stirling cycle refrigeration, pulse tube refrigeration, Malone cycle refrigeration, absorption refrigeration, adsorption refrigeration and compressor driven metal hybrid heat pumps.

Fatouh and Kafafy (2006), worked on the possibility of using hydrocarbon mixtures as working fluids to replace R134a in domestic refrigerators and it has been evaluated through a simulation analysis. The performance characteristics of domestic refrigerators were predicted over a wide range of evaporation temperatures (3.5 - 100C) and condensation temperatures (40–600C) for various working fluids such as R134a, propane, commercial butane and propane/iso – butane/n – butane mixtures with various propane mass fractions.

Dasthagiri (2015) showed the need for a combine system in order to cool or freeze water with the help of refrigerator.

Himanshu (2014) developed a refrigerator cum air conditioner and the combined system of refrigerator with air conditioner.

Kongre et al (2013), analysed the testing and performance of air conditioner cum water dispenser. They introduced basic design principles and test analysis performed in the laboratory, comfort conditions and suitable coefficient of performance with respect to atmospheric condition without sacrificing the air conditioning output. They also published work on Design methodologies of air conditioner cum water dispenser

Joudi and Al – Amir (2014) used a finite difference model to simulate the capillary tube in split conditioners under high outdoor air temperatures. It was shown that the capillary chocking length increased with increasing outdoor air temperature. To enhance the system cooling capacity, the capillary tube and the suction line are usually placed together forming a counter flow heat exchanger (Dincer and Kanughi, 2010)

Dhunde et al, 2016 worked on the Experimental study of Modified Refrigerator cum air conditioning and water cooler system. They also worked the effective combined cooling with power reduction for refrigeration cum Air conditioner, air cooler and water cooler.

Poonia et al researched on the design and development of energy efficient multi utility desert cooler. They carried out the experimental investigation on their specially designed desert water cooler by using evaporating principle for Rajasthan where high dry bulb temperature and low humidity exist in summer season. The experimental setup was not only used for cooling of room, drinking cool water but also used for storing vegetables, medicines, foods for long time at lower temperature than outside temperature by separate attachment and separate drinking water tank with desert cooler.

Cabello, (2015) studied the influence of the evaporating pressure, condensing pressure and superheating degree of the vapour on the exegetic performance of a refrigeration plant using three different working fluids R134a, R407c and R22

Baskaaran and Matthews, (2012) achieved a comparison of vapour compression refrigeration system using ecofriendly refrigerants of low global warming potential. R600a had a slightly higher performance coefficient (COP) than R134a for the condensation temperature.

Bolaji, (2014) studied the performances of R152a, R161 and R1234yf with very low global warming potential were investigated theoretically as alternatives to R134a in vapour compression refrigeration systems. The results obtained showed that the saturation vapour pressures for R152a and R1234yf were very close to that of R134a, which indicates similar properties, while that of R161, between the temperatures range of -30 to 40ºc, deviated significantly by 49.2%. R152a emerged as the most energy efficient of the investigated refrigerants with average power per ton of refrigeration (PPTR) of 30.5% less than that of R134a. R152a and R161 exhibited higher volumetric refrigerating capacities (VRC) and coefficient of performance (COP) than R134a. The highest COP was obtained using R152a in the system with an average value of 43.5%higher than that of R134a while the average COPs for R161 and R1234yf are 4.8% higher and 7.1% lower respectively. Generally R152a performed better than the other two alternatives as R134a substitute in that it has similar saturation pressure as R134a, exhibited lowest PPTR, very high VRC and highest COP.

Vinay Vishwanah et al, has carried out experimental investigation of water dispenser system using air conditioning. The objective of the experiment was to provide cold water without affecting the performance of the air conditioner by combining the water cycle and air cycle so that heat is transferred from closed space i.e room to the outside and this waste heat was used to heat the water outside the room. This system can be easily installed at official building, mall where the large numbers of air condition system used.

Kongre, (2013) has published paper on Design methodologies of air conditioner cum water dispenser. This paper includes the design of evaporator, Condenser, capillary tube to run on both cycles i.e air and water.

Singh et al worked on the design and fabrication of three in one air conditioning. This paper deals with human comfort conditions and designed the setup such that the air conditioner, water cooler are needed for human comfort include in this single setup.

3. Methodology and Design Analysis

Figure 1 shows the schematic of the air conditioner with the water dispenser.

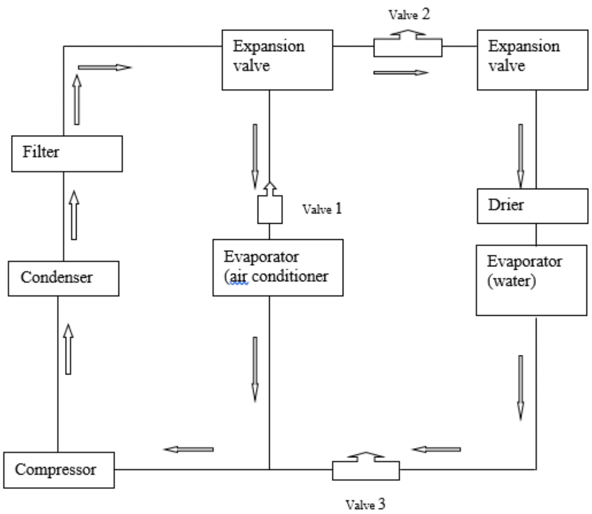

Figure 1: Schematic diagram of air conditioner with cold water dispenser

Design of Air-Conditioning with cold water dispensing System

The Test rig possesses the dual functions of space air-conditioning and water cooling. It is designed as a split-type unit.

The discharge pipe of condenser utilized a tee fitting to obtain two flow lines as shown in Figure 1. The two lines of discharges are joined with evaporator coils of both air conditioner and water cooler. Valves are placed at strategic positions to control the flow of refrigerant.

When the system is put on, the refrigerant flows to the two cycles (water cooler and air conditioner) simultaneously when the three valves are switched on. When the refrigerating effect of the air conditioner alone is desired, the valve 2 and valve 3 will be closed, but when both the water cooler and air conditioner are required to function simultaneously, the valves 1, 2 and 3 will be open to refrigerant movement.

Components Description

i. Frame

The frame is the main structure that supports the components mounted on it. It is made up of galvanized iron bar (Angle bar 40x40x4 mm) material welded together at different sections to give the set up a rigid support. Rollers (4tyres) are fixed at the base to allow mobility. The dimension of the frame is: length 30cm, width 14cm, height 60cm, number of wheels 4, plate of dimension 30cm x 12cm is used to mount the system on the frame.

ii. Compressor

Compressor is considered to be the hearth of the vapour compression refrigeration system. It pumps the refrigerant through the system and circulates it again and again in cycles continuously. It produces high pressure and hence high temperature to enable the refrigerant to reject its heat in the condenser. It also helps to produce low pressure in the evaporator to make the refrigerant to pick up maximum amount of heat from the space to be refrigerated.

Air conditioner compressor is used to remove the heat – laden vapour refrigerant from the evaporator of the air conditioning systems. In lay man term, the compressor compresses or squeezes the vapour into a smaller volume at high temperature.

iii. Condenser

The function of the condenser is to provide a heat transfer surface through which heat passes from the refrigerant to the condenser medium which is either water or air.

iv. Expansion valve

This device is to supply a proper amount of refrigerant to the evaporator after reducing its pressure considerably so that the refrigerant may take sufficient amount of heat from the refrigerated space during evaporation.

v. Water dispenser

This is the cold water chamber and has one of evaporator.

vi. Evaporator

Evaporator absorbs heat from the surrounding location or medium which is to be cooled by means of the refrigerant.

vii. Filter

This is incorporated in the liquid line between hot water chamber and capillary tube. It cleans the refrigerant and prevents it from clogging which may frost the liquid line.

viii. Fan and motor unit

Fan is used to facilitate the movement of air across the conditioned space.

Design Criteria

The following design criteria were considered in the cause of selecting components of HVAC equipment, according to Association of Heating Refrigeration and Air-conditioning Engibeers (ASHRAE, 1997; 2007); Trott and Welch, (2000); Grondzik, (2007); Ballamy (2004) and participants observation

- dimensions of the condition space are (L.B.H) 3600 x 4200 x 3000mm
- dimension of the external wall is 225 x 450 perforated block plastered on both sides with 25mm cement script
- Rated number of occupants is 3persons
- Ambient temperature 30 ºC
- Air velocity 0.2m/s
- Required conditioned space condition 26 ºc and 50 % relative humidity

 Volumteric efficiency of compressors range between 85 – 90 % (assuming 90 %)

Geometric positition of the office is 24o N latitude, (7.3070 oN, 5.1398 oE) accoding to FUTA hand book directory.

Standard Comfort Condition (for office)

Indoor type = 25 % DBT (77 ºF) 25ºC

Relative humidity = 50 %

Air movement = 30 fpm = 9.144 m/h

Design Analysis

For the air-conditioning system:

Equipment/materials considered within the conditioned space

 Occupant load per task (230W per person for seating and doing light work in the office)

 Bolb waltage, Wb (87W power rating)

 Balance factor, (BF) = 1.0

 Cooling load factor, CLF = 1.0

 Load factor (for fan is 0.4, desktop is 0.25 and printer is 0.25)

(ASHRAE, 1997; 2007);

Power Rating

The power rating (Q_{cp}) of the condensing unit required for circulating the working fluid (R22) for effective cooling of the conditioned space (Q_{ac}) and refrigeration of the water by the dispenser (Q_{disp}) can be obtained using the modified equation (6), according to Wang (2000); Ayodeji (2018)

$$Q_{cp} = Q_{AC} + Q_{disp} \quad (1)$$

Where, $Q_{ac} = Q_1 + Q_2 + \ldots\ldots\ldots\ldots\ldots + Q_8$

Q_1 = Occupant cooling load

Q_2 = Equipment cooling load (office equipment; desktop and printer)

Q_3 = lighting load

Q_4 = heat gain through glass

Q_5 = heat gain through solar radiation

Q_6 = heat gain through infiltration

Q_7 = heat gain through wall

Q_8 = heat gain through roof and ceiling

The estimated power rating of the water dispenser (Q_{tdisp}) is given by equation (14), according to Ballamy (2004); Ayodeji (2018)

$$Q_{tdisp\,(kW)} = \rho_w . V_w . c_w . [t_{avw} - t_{dw}] \frac{t_d}{3600}$$

Volumetric Efficiemcy of Compressor

The volumetric Efficiemcy of the compressor used for the project is given as follows

Volumetric efficiency of compressor $\eta_v = \frac{v_s}{v_d}$ (2)

Where V_s = specific volume of the compressor at suction point

V_d =specific volume at discharge point

= clearance factor (ε) is 0.09

According to Ayodeji et al (2018), the volumetric efficiency can be re-written as

$$\eta_v = \frac{v_s}{v_d} = 1 + \varepsilon(1 - \frac{v_s}{v_d}) \quad (3)$$

and the refrigeration mass flow rate as

$$m_r = 1 + \varepsilon(1 - \frac{v_s}{v_d}).\frac{Pd}{Vs} \quad (4)$$

For a condensing unit with a piston displacement (p_d of 41.8cm^3/rev, equation (3) can be rewitten as

$$= 10^{-6}\{1 + \varepsilon(1 - \frac{v_s}{v_d})\}\left(\frac{41.8}{Vs}\right) \quad (5)$$

Table 1: cooling load of condensing unit

S./No.	Cooling load	Equation No.	Equation , Q =	Parameters	Calculated Values (W)
1	Occupant	1		3 Persons	690
2	Office equipment	2	$\frac{power\ rating}{motor\ eff}\ x\ load\ factor$		209.39
3	Lighting	3	3.4wbfclf	1	163.13
4	Glass	4	$UACLTD_C$		106.64
5	Solar radiation	5	$UACLTD_C$		369.79
6	Infiltration	6	$Q_{ws} + Q_{wd}$		140.80
7	Wall	7	$UA(t_0 - t_1)$	4	344.87
8	Roof and ceiling	8	$UACLTD_C$		295.10
9	Q_{AC}	9	$Q_1 + Q_2 + \ldots\ldots\ldots\ldots\ldots + Q_8$		2319.72
10	Q_{DISP}	10	$\rho_w.V_w.c_w.[t_{avw} - t_{dw}]\frac{t_d}{3600}$		82.53
11	$Q_{Compressor}$	11	$Q_{AC} + Q_{DISP}$		2402.239945

Considering the estimated cooling load and the rated capacity of the condensing unit of 2402.24watts. The specification of the compressor used for this project, (as infered from "SAMSUNG" Air Conditioner Operation Design Manual), are as follows:

(i) Capacity (cool) = 9000Btu/h (2.6374kW)
(ii) Voltage = 220 – 240 v/50hz
(iii) Current = 4.6A
(iv) Power = 980W
(v) Pressure (high line) = 3.2 or 0.69Mpa
(vi) +Refrigerant = R22
(vii) Charging mass = 530g
(viii) Model number = UR5A250JHDEM

$$M_r = 10^{-6}\{1 + \varepsilon(1-\frac{v_s}{v_d})\}\ x\ \frac{41.8}{v_s} \tag{6}$$

V_s = specific volume of the refrigirant at suction which is the inverse of the density of the refrigerant.

$$V_s = \frac{1}{density}$$

Using the thermo physical properties of refrigerants table, density is 1250.45 kg/m^3

M_r = 0.0568kg/s

4. Results and Discussion

This section presents the results and discussions of the analysis of the performance of the developed system over the sets of the experimentations conducted with respect to the three (3) thermal performance properties considered for the evaluation. The thermal performance properties utilized for the evaluation are: work of compression (WoC), refrigeration effect (RE) and coefficient of performance (COP).

Tables 2-9 present results of the experimental data obtained during the experimentations and the analyses Figures 8-15 present the plots of the variations of the thermal performance properties utilized for evaluating the performance of the developed system with time

The test rig shows the working of portable air conditioner - water dispenser unit that utilizes R22, as its working fluid, to satisfy the needs for providing cold water along with air conditioning of an office space simultaneously. The unit can be installed and utilized in houses, schools offices etc, to serve these purposes

In the process of taking readings, high and low pressure gauges were placed at appropriate places to measure pressure level at suction and discharge of compressor, condenser and evaporators. Temperature data logger was used to measure the temperature at various points

The work of compressor was noted to be reducing with increase in time of operation when the AC was operated alone while the work of compressor was seen increasing relatively with time when the water cooler was added to the condensing unit and they work simultaneously.

The refrigerating effect of the system decreases slightly with increase in time when AC was operated alone while it was seen increasing with time when water cooler was operated with the AC.

The coefficient of performance of the system when the AC was operated alone was seen increasing slightly with increase in time while it was observed a decrease at the initial stage but later showed increase with increase in time when the water cooler was operated simultaneously with the AC.

It was observed that throughout the experimentations, the work of compressor of the test rig when used as air conditioner alone was greater than when used as combined air conditioner – water dispenser. This progressive reduction in the work of compression of the rig when used for the dual function lies in that the temperature of the water in the dispenser is less than the conditioned space temperature (30ºC) and as a result, the temperature of the refrigerant leaving the air condition is reduced by the temperature of water in the dispenser and this accounted for the reduction in the pressure ratio of the compressor and work of compression i.e. the refrigerant which its elevated in temperature gets colder a bit when it get contact with cold water in the water dispenser.

More so, the refrigerating effect of the rig when used as air conditioner is greater than when used to achieve the dual functions. This can be attributed to the fact that during the entire process, the system is hot – pulled and it accounted for the continuous prolong operation of the system and continuous circulation of the refrigerant round the rig so as to attain its design condition obstinate in the case when the rig used simultaneously to achieve the dual functions. The cold water in the water dispenser tended to set a local condensing medium for the refrigerant by cooling it below the temperature it attained in the air conditioner before it enters the suction line of the compressor as such the temperature lift of the refrigerant in the compressor when used to achieve the dual function is lower than when used alone. The temperature difference of refrigerant in the air conditioner alone is greater than when it is used for the dual functions.

Finally, the progressive increase in the coefficient of performance of the rig when used as an air conditioner alone can be attributed to its reduction in WOC and increase in RE. This agrees with the findings of Tomczyk (2016); Dirk (2016); Ayodeji etal (2018); that COP of a system increases or improve when its RE increases and WOC decreses.

At the compressor inlet surface suction temperature of 9ºC, the refrigerant temperature can be determine by the equation

$$T_1 = \frac{Mhln^{r2}/_{r1}}{2\pi k} + T2 \quad (7)$$

Where M_r is mass flow rate of the refrigerant

r_2 is outside radius of the capillary tube = 3mm

r_1 is inside radius of the capillary tube = 2.5mm

h is h_{gf} = change in enthalpy

K is thermal conductivity of copper

T_2 is suction surface temperature.

But $M_r = 10^{-3}\{1 + \varepsilon(1-\frac{Vs}{Vd})\} \text{ x } \frac{41.8}{Vs}$

ε = constant = 0.09, v_s = 0.0007997m^3/kg, v_d = 0.029925 m^3/kg

subtituting the value in the equation, mass flow rate = 56.847 g/s or 0.0568 kg/s

Performance evaluations of the Test Rig

The evaluations of the Test rig were done in sequence when it was used:

(i) alone to air-conditioning an office as captured in the scope of the research, and

(ii) simultaneously to air-conditioning and office space and to powering a water dispenser

Work done by the compressor when only AC is operated

The work done per kg of refrigerant by the compressor is given by equation (37) (Akusu, 2010)

$$W = h_1 - h_2 \quad (8)$$

where, W is work input to the compressor (kJ/kg);

h_1 is enthalpy in kJ/kg at the delivery of the evaporator;

h_2 is enthalpy in kJ/kg at the entrance of the condenser at the compressor inlet temperature of 9ºC

$h_1 = 197.31kJ/kg$

$h_2 = 191.95kJ/kg$

Refrigerating Effect when AC is operated alone

The cooling effect produced by a refrigerating system in a given time is known as refrigerating effect. It is expressed as KJ/s or KJ/min

Refrigeration is expressed in terms of ton of refrigeration abbreviated as TR. A ton of refrigeration may be defined as the amount of refrigeration effect produced by the uniform metering of one tone of ice from and at 0ºC in 24hours

Since the latent heat of ice is 335kJ/kg, therefore, one ton of refrigeration,

1TR = 1000 × 336Kj in 24hours

$$= \frac{1000 \times 335}{24 \times 60}$$

= 232.6kJ/min

The refrigerating effect is calculated using equation (9) (Akusu, 2010)

$$R_E = h_1 - h_4 \quad (9)$$

Effectiveness of Evaporator (ε) when AC is operated alone

$$\varepsilon = \frac{(mc_p(T_i - T_o)}{mc_p(T_I - T_w)} \quad (10)$$

$$(\frac{T_i - T_o}{T_i - T_w})$$

where, m= mass flow rate of refrigerant in kg/sec

Tci = Evaporator inlet temperature = 24ºC

Tco = Evaporator outlet temperature =15.4ºC

Tw = Temperature of water = 14ºC

Cp = Specific heat at constant pressure =2.47 kJ/kg K

$$\varepsilon = (\frac{T_i - T_o}{T_i - T_w})$$

ε = 0.86 = 86%

Coefficient of Performance (C.O.P) when AC is operated alone

$$C.O.P = \frac{h_1 - h_4}{h_1 - h_2} \quad (11)$$

Where, h_1 = Enthalpy at inlet of compressor in kJ/kg

H_2 = Enthalpy at outlet of compressor in kJ/kg

H_4 = Enthalpy at outlet of evaporator in kJ/kg

h1 = 197.31kJ/kg

h2 = 191.95kJ/kg

$h_3 = h_4 = 183.37kJ/kg$

$$C.O.P_1 = \frac{h_1 - h_4}{h_1 - h_2}$$

Work done by the compressor when both AC and water dispenser were operated together

The work done per kg of refrigerant by the compressor is given by equation (12) (Akusu, 2010)

$$W = h_1 - h_2 \quad (12)$$

where, W is work input to the compressor (kJ/kg);

h_1 is enthalpy in kJ/kg at the delivery of the evaporator;

h_2 is enthalpy in kJ/kg at the entrance of the condenser

Refrigerating Effect when both AC and water dispenser were operated

The cooling effect produced by a refrigerating system in a given time is known as refrigerating effect. It is expressed as KJ/s or KJ/min. A ton of refrigeration may be defined as the amount of refrigeration effect produced by the uniform metering of one tone of ice from and at 0ºC in 24hours

Since the latent heat of ice is 335kJ/kg, therefore, one ton of refrigeration,

1TR = 1000 × 336Kj in 24hours

$$= \frac{1000 \times 335}{24 \times 60}$$

= 232.6kJ/min

The refrigerating effect is calculated using equation (18) (Akusu, 2010)

RE = $h_1 - h_4$

Coefficient of Performance (C.O.P) when AC and water dispenser were operated simultaneously

$$C.O.P = \frac{h_{1-}h_4}{h_1 - h_2}$$

Where, h_1 = Enthalpy at inlet of compressor in KJ/Kg

H_2 = Enthalpy at outlet of compressor in KJ/Kg

H_4 = Enthalpy at outlet of evaporator in KJ/Kg

Variations of air temperature (ºC) and pressure (Bar) for compressor when AC and water dispenser are operated simultaneously

Table 3 and presents the summary of the experimental data obtained with the instrumentations attached to the test rig when used air-conditioning an office space and supplying cold water via a water dispensing unit.

Table 3: readings obtained when AC and water dispenser were operated simultaneously

Time (min)	Compressor Temperature (ºC)		AC Evaporator Temperature (ºC)		Dispenser Water		Compressor Pressure (bar)
	Inlet	Outlet	Outlet	Inlet	Temp.(ºC)	Pressure (bar)	
0	30	30.0	30	30	30	24	25
30	12	15.0	12	24	10	24	25
60	10	14.0	8.5	23	7.0	24	25
90	7.6	10.0	7.2	22	5.7	24	25
120	2.1	3.9	3.6	21	2.4	24	25
150	0	1.8	2.9	21	0.0	24	25
180	0	0.8	1.8	18	0.0	24	25

Variations of Evaporator temperature (ºC), pressure (Bar) and enthalpy (kJ/kg) when AC and water dispenser were operated

Table 4: evaporate readings with corresponding enthalpy.

Time (min)	Evaporator temp. (ºC)	Evaporator Pressure (bar)	Enthalpy, h_1 (kJ/kg)	Enthalpy, 2 (kJ/kg)
0	30	24	177.24	177.24
30	12	24	194.66	192.445
60	8.5	24	196.44	192.86
90	7.2	24	198.414	196.44
120	3.6	24	203.147	201.473
150	2.0	24	204.87	202.496
180	1.8	24	204.87	204.218

Table 5 presents summary of the thermal performance properties utilized for evaluating the performance of the test rig when used alone as an air-conditioning system whilst Table 6 presents when used to perform the dual functions (combined air conditioning –water dispensing nit)

Table 5: Summary of the thermal performance of Test rig as an Air-conditioning unit

Time (ºC)	Work of compressor(kJ/kg)	Refrigerating effect (kJ/kg)	Coefficient of performance
30	5.36	13.94	2.60
60	4.44	13.70	3.08
90	3.89	13.18	3.39
120	3.87	13.15	3.40
150	3.61	12.44	3.45

Table 6: Summary of the thermal performance of Test rig as combined air-conditioning-water dispensing unit

Time (°C)	Work of compressor(kJ/kg) (AC + DISP)	Refrigerating effect (kJ/kg) (AC + DISP)	Coefficient of performance (AC + DISP)
30	2.22	11.29	5.10
60	3.58	12.14	3.39
90	3.93	13.07	3.32
120	4.97	16.84	3.40
150	3.29	18.56	5.64

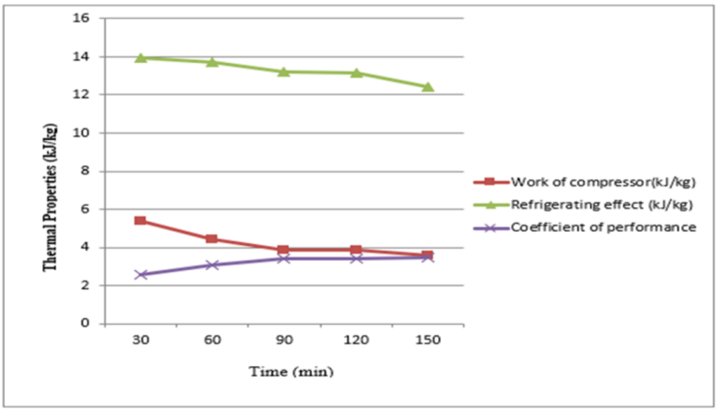

Figure 2: graph of Work of compressor, refrigerating effect and coefficient of performance with time when AC was operated alone

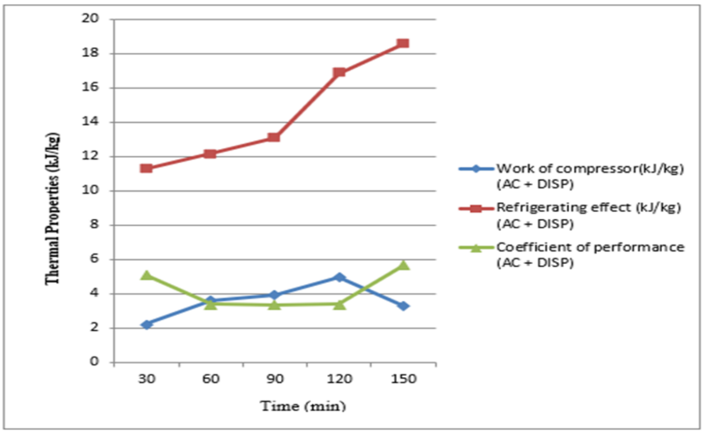

Figure 3: graph of Work of compressor, refrigerating effect and coefficient of performance with time when AC and water dispenser were operated simultaneously

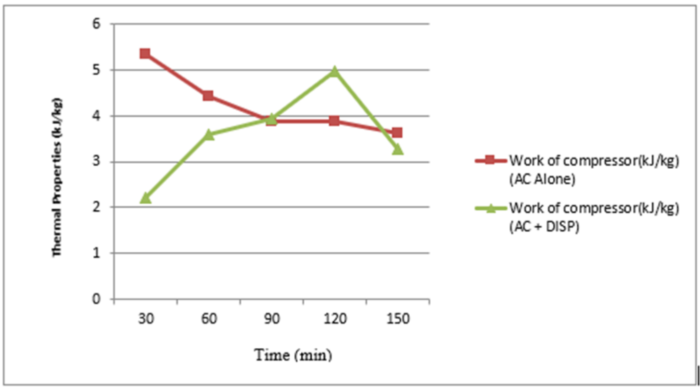

Figure 4: Work of compressors against time

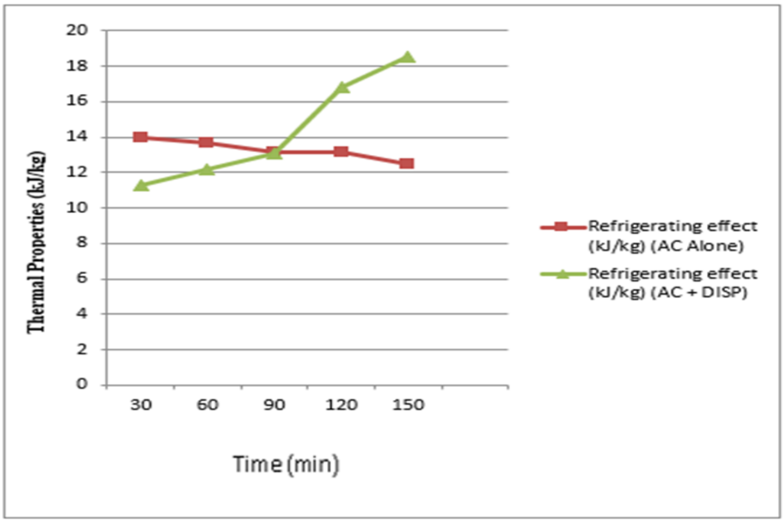

Figure 5: Refrigeration effects against time

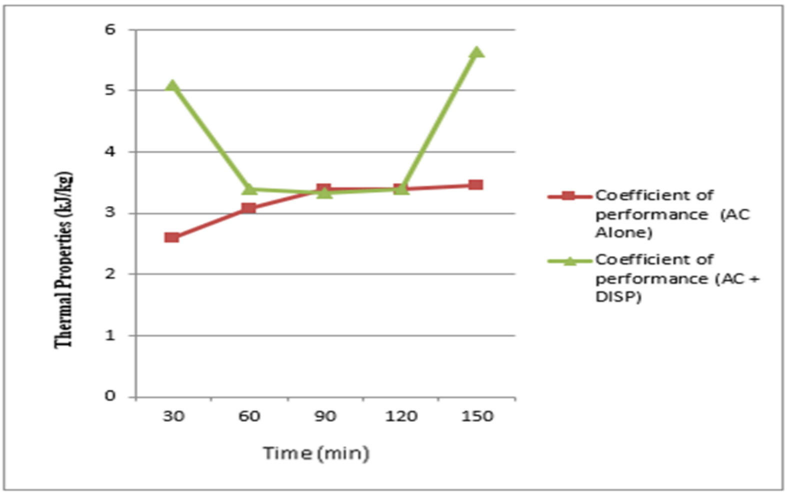

Figure 6: Coefficient of performance against time

5. Conclusion

The research focused on the development and performance evaluation of a combined air conditioner-water dispensing unit. It was developed to meet the thermal requirements of the occupant. The developed system comprises, basically a 1.5 hp split air-conditioning unit and 0,5 hp water dispensing unit utilizes a 2.0 hp condensing unit, industrial type thermostatic expansion valve, and uses R22 as the working fluid.

Air conditioner with water dispenser was developed for an office space (3600 mm x 4200mm x 2400mm) and cooling of water for meeting the thermal comfort requirement of the occupant.

The properties of cool water and cool air were obtained in one unit; this research has been able to develop an air conditioning system incorporated with a water cooler. Hence, it eliminates the separate use of an air conditioner and water cooler as the purposes are served in a same unit. This research can increase human comfort as cold water can be available simultaneously with cold air in a single phase (socket) minimizing consumption of electricity, decreases global warming potential.

The refrigerating effect and the work of compressor was decreasing with time when the AC was working alone but the values of the refrigerating effect and the work of compressor increases when the AC and the Water dispenser were both operated simultaneously.

When AC was operated alone, the COP of the condensing unit increases with time with the average COP of 3.184 but when the AC and the water dispenser were in use together simultaneously, the COP of the system decreases initially and slightly increase after some hour of operation with average COP of 4.16.

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