Original Research Article

APPRAISING OF AIR CONDITIONAL SYSTEM CONDENSATE DISCHARGE RATE IN SOUTHWEST, NIGERIA

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ABSTRACT

Aims: The aim of this research is to ascertain the condensate discharge rate from a split air conditional system with a view to channeling the condensate into a storage tank for other useful purposes.
Study Design: Quantitative study. Relevant data on condensate discharge rate was collected.
Place and Duration of Study: Department of Mechanical Engineering, The Federal University of Technology, Akure, Ondo State, Nigeria, between 16th to the 22nd of November, 2015.
Methodology: The method used consists of data collection and readings such as outdoor dry bulb temperature, dew point temperatures, relative humidity, and condensate volume. It features the calculation of air conditioning load estimation, data analysis, and cost analysis of integrating condensate collection which is essential for the completion of this study.
Results: The study discovered that about three thousand four hundred and eight-six (3,486) litres of condensate are being wasted on a weekly basis within the School of Engineering and Engineering Technology, The Federal University of Technology, Akure. This figure indicates the amount of reclaimed water source that is not in use.
Conclusion: The study has shown that the imbalance in water supply and demand currently experienced at School of Engineering and Engineering Technology building can be managed effectively if condensate water is properly collected. The condensate collected should be channelled by gravity flow through 32mm PVC pipes into a 5,000 Litres storage tank within the building and a Duty/Assist 2Hp Booster pump is to be installed to transfer the condensate into the existing plumbing works to the restrooms and laboratory for good use.

Keywords: Air-conditional System, Cooling Load Estimation, Reclaim Water, Condensate Discharge.

1. INTRODUCTION

Air conditioning can be referred as the process of simultaneous control of temperature, humidity, cleanliness and air motion for the comfort of human beings, animals or for the proper attainment of some industrial or scientific process [1]. The by-product of the simultaneous cooling in the air-conditioning system is the condensed water which is formed from moisture in the air. Therefore, condensate from air conditional is classified under the definition of alternative on-site sources of water such as rainwater to bolster water and decrease energy dissipated by town water operations [2]. The most efficient and vital use of condensate harvested from commercial or industrial buildings includes; toilet flushing, irrigation, ornamental water features, and process water, such as that used in manufacturing and makeup water in cooling towers.

It was reported by [3] that high temperature and humidity during summer months contribute greatly to condensate production amounting to 6 to 7 ml/s/1000 m² of the cooled area of buildings. The weather in Ondo State, Southwest, Nigeria is characterised by maximum daytime temperatures which rarely exceed 34 ^{o}c and low as 22 ^{o}c, a mean annual relative humidity of about 80 % [4]. Therefore, this makes it a good fit for condensate water recovery. Unfortunately, most buildings in Nigeria allows the condensate to typically drained away to an open ground as waste, which is an abundant source of reclaimed water. Hence, this paper aims to appraise the condensed water collected from a split-type air-conditioning system in a Nigerian office space.

2. LITERATURE REVIEW

Many types of research have been identified to determine the advantages of condensate recovery system in different places of the world. This study investigates some of this source of these condensate recovery system and the importance. [5] have found a modelling approach for determining condensate collection for an Institutional Building in Doha, Qatar. Results indicated that as the dew point temperature increased, the corresponding condensate of 660,000 gallons of water was captured from the condensate drains of the six hundred installed tons of air conditioning on a large commercial building in a location with one fourty days of dew point temperatures above 60°F. [6] reiterated the means of using the air-conditioning condensate as an added source of water. The results revealed that the enormous cost of implementing a condensate collecting system is still acceptable for buildings with high fresh air percentage. It was further observed that weather condition and space occupancy impact the volume of condensate generated. [7] presented a study of condensate modelling system for high performing buildings. The objective of the work was to develop a modelling system to estimate the amount of condensate from an air-conditional unit on an existing building. Some of the readings collected in the research work include; outdoor temperature, dew point and relative humidity of the fresh air and inside air conditional unit. The result showed that the total amount of condensate collected was 171,793 gallons during the summer season with 3.5 gallons per hour. [8] founded a modelling prediction technique for an outdoor air-conditional unit with energy recovery, while using annual daily readings of average temperature and humidity data. The analysis of the result indicated that the condensate production from the case study building's large dedicated outdoor air-conditional unit can completely supplement the annual daily water closet and urinal water demand with 6.12 x $I0^{6}$ L of excess, which could be used to supplement landscape irrigation system. [9] research study revealed that the design of HVAC systems in a sustainable laboratory facility will assist in high amounts of condensate recovery. The author revealed that utilizing weather data information in a newly built laboratory in Atlanta, and an estimated cooling load, the appraised condensate collection from the cooling coils exceeded 3028330 L every year.

3. METHODOLOGY

This study approached the subject of condensate collection with three specific purposes. It started with the development of a technique to identify the total volume of condensate collected using correlations with weather data. The next stage involves evaluating the method associated with a typical condensate collection system. Finally, the result collected was analysed for generalizations regarding environments where condensate collection would be recommended for the economic and environmental impact perspective.

3.1 Materials

A split type air-conditional unit (2500 W), graduated measuring cylinder (500 ml), thermo-hygrometer, collector (25 litres) and drainpipe (using 25 mm PVC adaptor)

3.2 Selection of environment and condensate measurement

The study was carried out in an office space within the School of Engineering and Engineering Technology, Federal University of Technology, Akure, Ondo State, Nigeria. The hourly values of dry bulb temperatures and relative humidity with operating conditions of the air handling unit give the typical condensate rate for each hour. The condensate produced for each specific hour was added to compute the condensate for that specific day. Precautions taken to enhance accuracy in measurement of condensate includes, calibration of the thermo-hygrometer apparatus used for the study to avoid errors associated with dry bulb temperature and relative humidity readings. The condensate collector was constantly checked to verify that there are no leaks. Although this study only looked at an office space within the school of engineering building, developing correlations between the amount of condensate and weather data parameters allows the results and conclusions to be applicable anywhere. The first step toward achieving this goal was to check if the correlation can be derived for the amount of condensate collection with respect to a readily available weather data parameter. The office space can accommodate at least four people and its volume was 33.8 m^3. Figure 1 shows the room plan of the office space.

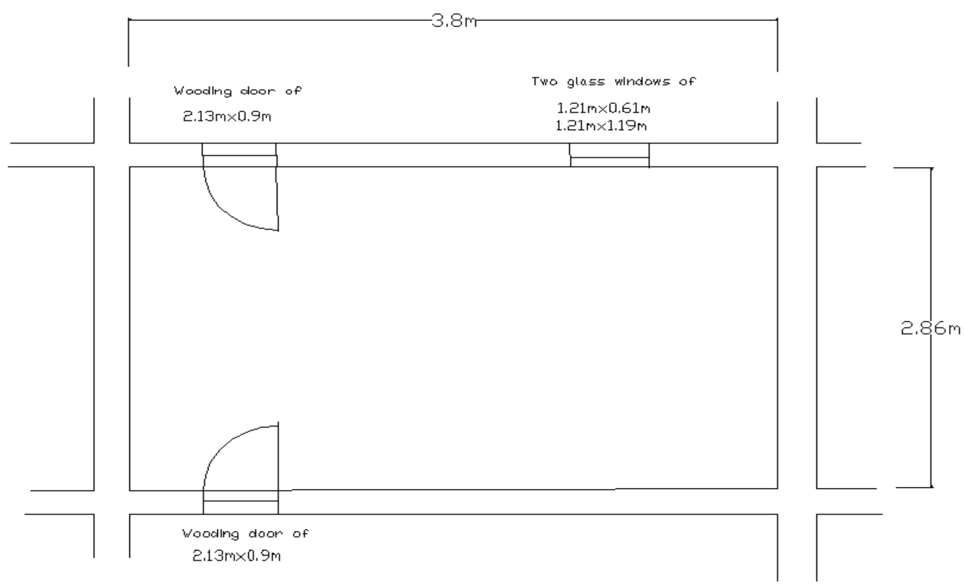

Fig 1. Room plan of the office space

3.3 Sizing and Installation of the Split Air-Conditioning System

According to [10], the occupancy activity impacts the fresh air ratio which may differ from 100% fresh air in operations like a kitchen, laundry room, and electrical room (where there is a presence of a pure sensible load). To calculate the cooling load of a building's volume, the effect of heat stored in the mass of the building has made it difficult due to its thermal inertia to heat response. Therefore, the sizing of the air conditional system for room conditioning should start with the theory of air conditioning load estimation in buildings and analysis of heat transfer in a typical sample of building construction in Akure. In order to achieve this, the Cooling Load temperature difference (CLTD) and Glass Load Factor (GLF) approach were developed by ASHRAE. Therefore, the conductive transfer across the wall surfaces or roof is defined in the form;

- **Roof Construction**
  Conventional roof-attic-ceiling combination U = 0.28 W/(m^2K)

- **Wall Construction**
  Brick, insulation, brick wall U = 0.34 W/(m^2K)
  Partition wall U = 0. 4 W/(m^2K)

- **Doors**
  Wood, solid core U = 1.82 W/(m2·K)

- **Windows**
  Clear louver-pane glass in metal frames
  3mm thick. U = 2.84 W/(m2·K)
  The window glass has a 600 mm overhang at the top.
  Assume closed, medium-color Venetian blinds.

- **Outdoor Design Conditions**
  A temperature of 33°C dry bulb with a 13 K daily range
  Relative humidity ratio of 0.0136 kg vapour/kg dry air (23.7 °C wet bulb)

- **Indoor Design conditions**
  A temperature of 22 °C dry bulb
  Relative humidity ratio of 55%

- **Occupancy**
  Four persons

- **Appliances and lights**
  110 W for the light fittings and 150% for the appliances in the office
  From the sensible, latent and total cooling load!

- **Heat gains**
  For walls, roof, and doors
  Q = U. A. (CLTD) (1)
  Where,
  U = coefficient of heat transfer W/(m^2k); A = area of surface, m^2,
  CLTD = Cooling Load Temperature Difference, K

- For Walls
  $Q = 0.34\times33.8\times14$
  $Q = 161$ W

- For Partition
  $Q = U.\ A.\ (CLTD)$
  $Q = 0.4\times33.8\times4$
  $Q = 54$ W

- For Roof
  $Q = U.\ A.\ (CLTD)$
  $Q = 0.28\times10.86\times27$
  $Q = 82$ W

- For Doors (Two numbers)
  $Q = 2\ (U.\ A.\ (CLTD))$
  $Q = 2\ (1.82\times1.17\times14)$
  $Q = 60$ W

- For Window – considering the overhang louver and curtain (H=2m)
  $Q = 2(A.\ (GLF))$ (2)
  Where GLF = glass load factor; A = area of surface, m^2,
  $Q = 2\ (1.416\times141)$
  $Q = 399$ W

- For Occupancy
  $Q = 67\ Wn$ (3)
  Wn = no of persons
  $Q = 67\times4$
  $Q = 268$ W

- Volumetric airflow rate for summer sensible heat
  $\dot{V} = ACH.\ V.\ 1000/3600$ (4)
  $\dot{V}$ = Volumetric airflow rate l/s; V = Volume of room m^3
  ACH = Summer air change rate l/h
  $V= 0.5\times33.8\times1000/3600$
  $V = 4.69$ l/s

- Infiltration
  $Q = 1.2.\ \dot{V}.\ \Delta t$ (5)
  Where Δt = Outside and inside design temperature respectively (^oC)
  Where $\dot{V}$ = Volumetric airflow rate l/s
  $Q = 1.2\times4.69\times(33-22)$
  $Q = 62$ W

- Total Heat Gain (6)
  Q = Latent heat + sensible heat
  Qtotal= 1303W

3.4 Cost Estimate

This is the overview of the cost of materials needed for installing piping fittings, accessories and electrical connectors in condensate collection. The estimated cost of integrating condensate collection to existing plumbing works of toilet and laboratory in the engineering building of the Federal University of Technology, Akure is shown in Table 1.

Table 1. Cost analysis of integrating condensate collection to existing engineering building

S/N	Materials Description	Specifications	Quantity	Unit Cost (~~N~~)	Total Cost (~~N~~)
1	GPee Storage Tank with all necessary accessories	5000 L	1	70,000.00	70,000.00
2	Lowara Booster Water Pump (Duty/Assist)	2 Hp, 20 L/min	1 set	210,000.00	210,000.00
3	Electrical Installation and control panel	lot			75,000.00
4	Plumbing Work and Piping Fittings	32 mm PVC			50,000.00
5	Contingencies				100,000.00
	TOTAL				₦505,000.00

4. Results and Discussion

This project collected condensate data for a period of 1 week in November 2015. After the problem with continuous power failure was corrected, data collection really started on November 16th, 2015. The results presented here cover a week period from the 16th to the 22nd of November, 2015. The concurring outdoor dry bulb temperature, relative humidity, and dew point temperatures during this period were also recorded. During this period, condensate collection varied from almost no quantity to what appears to be highest for the 100% outdoor air unit. The split air conditioning unit serves only the office under study and it is a one fan unit with provisions for outside air, return air and nominal cooling capacity of 2500 W. The average outdoor temperature and humidity during this period ranges from 52 ^{o}C – 68 % and 26 ^{o}C – 31 %. The result in Table 2 showed that a total of 42.03 Litres of condensate was harvestable between the time periods from the split air conditioning unit serving the office under study. The result collated also indicated that the figure could rise to as much as 3,486 L a week if the entire 83 numbers of split air conditioning unit serving laboratory and offices within the building are functioning. This figure indicates the amount of reusable water source that is not in use. The total volume of condensate harvested within the school of engineering and engineering technology building will be vital in complementing the primary water source such as watering of the landscape area, the source of water in the toilets and rinsing laboratory apparatus. The summary of the condensate collected for seven days is shown in Table 1.

Table 2. Showing the evaluation of condensate collection for five days

DAY	TIME		Average Relative Humidity (%)	Average Temperature (˚C)	Average Dew Point (˚C)	Condensate Collected (Litres)
	From	To				
16/11/2015	8:00am	4:00pm	57%	26	23	6.17
17/11/2015	8:00am	4:00pm	68%	29	21	6.85
18/11/2015	8:00am	4:00pm	52%	29	21	4.74
19/11/2015	8:00am	4:00pm	59%	30	22	5.83
20/11/2015	8:00am	4:00pm	64%	29	21	5.91
21/11/2015	8:00am	4:00pm	65%	29	21	6.25
22/11/2015	8:00am	4:00pm	60%	31	23	6.28
				Total Condensate Collected in SEET (x 1 nos of A/C Unit)		42.03 L
				Net Total for 83 no's of A/C unit Installed & Functioning		3,486 L

It was also observed in Table 2 that as the average relative humidity increased, there was a corresponding increase in the amount of condensate collected. Thus, the greater the relative humidity at a given temperature, the greater volume of the condensate formed and vice versa. The result agrees with the works of Lawrence *et al.* (2009) and Johnson (2008) who found that high relative humidity with corresponding dry bulb outdoor temperature and dew point gives rise to high volume of condensate that will be collected from an air conditioning system. Finally, as the temperature rises during the daytime (26 ˚C - 31 ˚C), the relative humidity for the corresponding time decreases (72 % - 53 %) and It can be said that the temperature is generally inversely proportional to the relative humidity.

5. Conclusion

The aim of the study is to apply recent techniques in appraising condensate collection potential and to determine if condensate collection would be recommended for the main water source. The application of reclaimed water source such as collected condensate is one approach for reducing long-term potable water consumption. The imbalance in the water supply and demand currently experienced at SEET building can be managed effectively if the condensate water is properly collected. Water and energy are conjoint and hence it is essential that building operators and industry leaders understand that water conservation is as important as energy conservation. The study discovered that about three thousand four hundred and eighty-six (3,486) litres of condensate are being wasted on a weekly basis within the School of Engineering and Engineering Technology, FUTA. Therefore, the condensate collected should be channelled by gravity flow through 32mm PVC pipes into a 5,000 Liters storage tank within the SEET building and a Duty/Assist 2Hp Booster pump is to be installed to transfer the condensate into the existing plumbing works to the restrooms and laboratory for good use.

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