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Design and Construction of Split Unit Air Conditioner

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ABSTRACT

This project study is applicable to the field of heating, ventilation and air conditioning. The design and construction of a split unit air conditioner was carried out to achieve a suitable comfort in an office environment. After a study of existing air-conditioners and survey for availability of materials, the design concept of the split unit air-conditioner was achieved. And the following standard part were estimated as; compressor power rating 2.5hp, condenser power 8KW, evaporator power 5.85KW and power rating of blower as 120watts. And with a working fluid of refrigerant R410A which is weak compared to refrigerant R22 but less hazardous to the environment. The split unit air conditioner was tested for conformance to specification and it was satisfactory.

Keywords: *Design, construction, air conditioner, compressor power rating, refrigerant*

INTRODUCTION

Air conditioning is the process of altering the properties of air (primarily humidity and temperature) to favorable conditions, typically with the aim of distributing the conditioned air to an occupied space is to improve comfort. In the most general sense, air conditioning can refer to any form of technology humidification, de-humidification, heating, cooling, cleaning, ventilation, or air movement that modifies the condition of air [1-3]. In general, the air conditioner is a device that lowers the air temperature. The cooling is most done using a simple refrigeration cycle, but sometimes the evaporation is used, commonly for the comfort of cooling in buildings and motor vehicles [4-5]. In construction, a complete system of heating, ventilation and air conditioning is referred to as "HVAC" [6]. Air conditioning can also be provided by the simple process called free cooling which uses pumps to circulate a coolant (typically or a glycol mix) from a cold source, which in turn acts as a heat sink for the energy that is removed from the cooled space [7].

Generally, air conditioner can be classified into [8-9]; window unit air-conditioners, central unit air-conditioner, and split unit air-conditioner. In this air conditioner, all the component, namely; the compressor, condenser, expansion valve evaporator and cooling coil are enclosed in a single box. Window unit air conditioners are installed in an open window. The interior air is cooled as a fan blows it over the evaporator. On the exterior the heat drawn from the interior is dissipated into the environment as a second fan blows outside air over the condenser. A large house or building may have several such units, allowing each room to be cooled separately.

The central unit air conditioning unit is for cooling big building houses, offices, entire hotels, cinema hall, and factory etc. If the whole building is to be air condition, HVAC engineers find that putting individual units in each of the room is very expensive initially as well in the long run. The central air conditioning unit is comprises of huge compressor that has the capacity to produce hundreds of tons of air conditioning. The split unit air conditioning system comprises of two parts the outdoor unit and indoor unit. The outdoor unit, fitted outside the room, house component like the compressor, condenser, and the expansion valve. The indoor unit comprises the evaporator, and cooling fan. In the split system, one does not have to make any slot in the wall of the room.

However, considering the fact that Nigeria is located in a tropical region which is characterized by excessive high temperature and highly humid, it became necessary to develop a mechanical system which can help to reduce the hot the ambient temperature within a confined space for human comfort. In this research work, we carried out the design and construction of split unit air conditioner.

MATERIALS AND METHOD

The split unit air conditioner consist of two assemble units separated from each other, but interconnected by refrigerating piping. The two units are:

- Indoor unit
- Outdoor unit

Table1. *Outdoor and Indoor Unit Components*

SN	Outdoor Unit
1	Compressor
2	Condenser
3	Fan
4	Fan motor
5	Capillary tube
6	Grill
7	Motor mounting bracket
8	Cabinet
9	Capillary

Table2. *Indoor Unit Components*

SN	Indoor unit
1	Evaporator
2	Blower
3	Blower motor
4	Blower mounting bracket
5	Electronic control unit
6	Cabinet
7	Air filter
8	Fins or louvers(vertical and horizontal)
9	Display
10	Infared signal receiver
11	Remote controller
12	Air

Design Specification

Given consideration to constraints imposed by costs of material and availability, construction difficulties, operating conditions and design limits; the following design specification listed in Table 3 were made.

Table3. *Design specification*

S/N	Specification	Description/Dimensions
1.	Room size	5.2m x 4.6m x 2.7m
2.	A/C unit type	Ductless mini-split type
3.	A/C rating	2.0 horse power
4.	Compressor type	Variable frequency drive (VFD)
5.	User control	Wireless remote control
6.	Weight	Indoor unit:9kg Outdoor unit:38kg
7.	Dimensions	Width x height x depth Indoor unit: 0.79m x 0.25m x 0.28m Outdoor unit:0.78m x 0.55m x 0.290m
8.	Power input	220-240v 50hz A.C
9.	Space conditions	Indoor unit: 20oc dry bulb temperature Outdoor unit: 30oc dry bulb temperature
10.	Special feature	Self-diagnostic function
11.	Refrigerant	R410a (CHCLF3)
12.	Copper pipe	0.00635m and 0.0127m

Design Consideration

Air-conditioning system design is governed by either thermal comfort condition or special requirement for material or processes. This air condition is basically design for office application or residential application, thus only thermal comfort if considered. Hence, small function in temperature and humidity are tolerated. The outdoor and indoor surface heat transfer coefficient was considered to be 22.7w/m^{2}K and 7.42w/m^{2}K respectively

Design Calculation

The calculation of cooling load is a very vital factor in determining the appropriate air conditioner. The cooling load is defined as the rate at which heat is removed from the conditioned space in order to maintain a constant air space temperature.

The cooling loads consist of the following:

- Heat gain through the building wall
- Heat gain through the ceiling
- Heat gain through the window
- Heat gain through door
- Heat gain due to air infiltration
- Internal heat gain due to equipment in
- building space.

Calculation of Areas in Building Space

Height of wall

Height of windows

Height of doors

Area of Glass Window (AGW)

$$AGW = L_w \times H_w \qquad (1)$$

where,

Lw =Length of window= 1.3m

Hw = Heigth of window =1.4m

AGW = Area of glass window

Area of Door

$$D_D = D_L \times D_H \quad (2)$$

where,

D_D = Area of door

D_L = Length of door = 0.78m

D_H = Height of door =2.1m

Area of concrete wall

$$W_A = W_L \times W_H$$

where,

W_A =Area of wall

W_L = Length of wall in (m)

W_H = Heigth of wall = 2.7m

Calculation of Area of Concrete Wall

Table 4 shows the calculated area of concrete wall

Table4. *Calculated Area of Concrete Wall*

Wall dimension	Length of Wall (m)	Height of wall (m)	Area of wall (m^2)
AB	5.2	2.7	14 04
BC	4.6	2.7	12.42
CD	1.8	2.7	4.84
DE	0.6	2.7	1.62
EF	1.6	2.7	4.32
GH	1.8	2.7	4.86
$\sum WA = 42.12m^2$			

* FG =ED and BC = HA

Overall Heat Transfer Co-efficient

$$OHT = 1/(\frac{1}{ho} + \frac{xw}{kw} + \frac{1}{h1}) \quad (3)$$

OHT = overall heat transfer co-efficient of building space and wall

Ho = outdoor surface heat transfer coefficient

hi = Indoor surface heat transfer coefficient

xw = Thickness of concrete wall

kw = Thermal conductivity of concrete wall and ceiling

Heat Gain through Concrete Wall

$$HGCW = OHT \times TACW \times \Delta T \quad (5)$$

where,

OHT = Overall heat transfer coefficient

TACW = total area of concrete wall

ΔT = outside and inside temperature difference

Estimation of Internal Heat Gain

The internal heat gain are due to occupants such as light, appliances, and equipment within the air-condition space.

Table5. *Internal Heat Gain Computations*

Heat gain by occupant =115W	Number of average occupant = 4	Total heat from occupant =115 x 4 = 460W
Heat gain by light(bulb) 60watts	Number of light bulb =2	Total heat from light = 60 x 2 =120W
Heat gain from appliances	Cpu =55W Monitor =55W Printer =440W	Total heat from appliance = 55+55+440 = 550W
Total internal heat gain = 1130W		

Estimation of Heat Gain due to Air Inflation

Using the air change method, heat load due to air changes and other infiltration is estimated by $Q_i = BV_C\Delta T$ (6)

where,

Q_i = heat gain to air infiltration

B = Density of air

V_C = Rate of air infiltration/change

ΔT = Air temperature difference

Table6. *Heat Load Analysis*

S/N	Heat gain type	Q (W)
1.	Heat gain through concrete wall	1604.8
2.	Heat gain through concrete ceiling	947.9
3.	Heat gain through door	87.41
4.	Heat gain through glass window	1537.8
5.	Internal heat gain	1130
6.	Heat gain through air infiltration	14.7
Total heat load = $\sum Q$ = 5322.61		

Estimation of Coefficient of Performance of the System (COP)

Considering 39^{0}C and -15^{0}C as the condenser and evaporator temperature respectively; using refrigerant $R_{410a.}$ The T-S of the process is shown in Fig. 1.

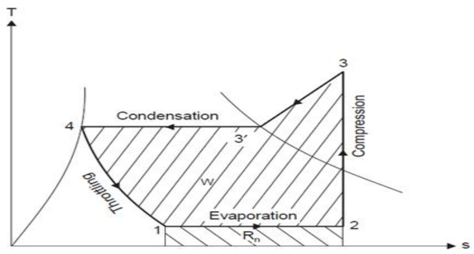

Fig1. *T-S diagram of refrigeration cycle*

Calculation for Mass Flow Rate

$Q_{T} = m(h_1 - h_4)$ (7)

where,

Q_T = Refrigeration capacity or evaporator

m = Refrigerant mass flow rate

h_1 = Enthalpy of refrigerant at inlet to compressor

h_4 = Enthalpy of refrigerant at inlet to evaporator

Calculation for Compressor Power

$Compressor\ rating\ (Wo) = m(h_2 - h_1)$ (8)

Calculation of Heat Rejected By Condenser

$Q_C = m(h_2 - h_1)$ (9)

where,

Q_C = Heat removed by condenser

m = Refrigerant mass flow rate

h_2 = Enthalpy of refrigerant at inlet to condenser

h_3 = Enthalpy of refrigerant at outlet of condenser

Volume of Air Flow

If the time taken for cold air from the external surface of the evaporator to fill the cooling space of a given capacity, then the maximum air flow is given as;

$Q = \frac{\text{volume}}{\text{time}}$ (10)

Capacity of the humidity (mass of water) removed per hour

$M_a = (w_1 - w_2)$ (11)

Latent Heat Removed From the Air (LH)

Latent heat removed from air (LH) = $M_a(h_1\text{-}h_3)$ (12)

Sensible Heat Removed From the Air (SH)

Sensible heat removed from the air (SH) = $M_a(h_3\text{-}h_2)$ (13)

Sensible Heat Factor (SHF) Of the System

SHF = = $\frac{SH}{\text{SH} + \text{LH}}$ (14)

Material Requirements and Selection

This section of the project involves detail and proper consideration of material properties, availability and likely limitations they may impose on the design. The main goal of material selection is to minimize cost while meeting a design performance goal; hence, material selection is fundamental to the design success. In material selection, certain requirements are put into consideration. These include:

- Economic requirement
- Availability requirement
- Service requirement
- Fabrication requirement

Economic Requirement

Under economic requirement, the cost of a material including cost of manufacture and assembly is taken into consideration. Also, it is important to note that the vital criteria should not be the initial cost of material, but the life cycle cost or cost effectiveness. It is usually more cost effective to collect a material that will produce an extended life of the product.

Availability Requirements

The availability of material as well as spares plays an important role in material selection. It will reduce the total cost of the project

Service Requirement

Under service requirement, consideration is given to physical mechanical, thermal, electrical properties etc., of a material in order to determine its functionality for selection. Other important consideration in service requirements are operational environment, and servicing requirements such as;

Physical properties: These include colour,specific weight,density, lustre etc.

Mechanical properties: These tensile strenghth, hardness ,ductility,impact strength, wear resistance etc.

Thermal properties: These include thermal expansion, thermal cinductivity, thermal stress, thermal resistance etc.

Electrical properties: These include conductivity, resistivity etc.

Fabrication Requirement

Fabrication requirement give consideration to materials properties which gives an indication of the suitability of a material for construction of a product. Material properties which are considered under fabrication requirements are:

- Rigidity
- Flexibility
- Ductility
- Malleability
- Machinability
- Weldability

Material Selection

Having considered the factors stated above and the design purpose, various materials were selected. The materials are highlighted below:

Table7. *Material Selection*

S/N	Components	Materials	Description
1.	Refrigerant	R410a (Monochlorodifluoro methane)	Its latent heat at -15^{0}C is 218kj/kg It has a boiling piont of -40.8^{0}C It has a moleculer weight of 86.5 It has an oxygen depleting potential (ODP) of 0.05 Its evaporator and condenser pressure at standard ton of refrigeration are 2.9 bar and 11.9 bar respectively
2.	Cabinet	Galvanized steel	High resistance to corrosion Good tensile strength Possesses good ductility
3.	Refrigerant tubing (indoor-outdoor connection)	Soft copper tubing and aluminium fins	high resistance to corrotion It is ductile It is non-magnetic material It can be easily bent and joined together.
4.	Air filter	Cellulose fibre and frame	Cellulose fibre possesses a high dust resistance The wire frame possesses a rigid surface for attaching fibre
5.	Capillary tube	Fixed length copper tubing	Its small diameter enable pressure drop. It produces a pressure proportional to its length and inversly proportional to its inner diameter
6.	Fan (indoor unit)	Drum type cross- flow fan	It produces efficient air flow at high pressure It produces an air flow tranversely across the impeller, moving pass the blade time It uses an impeller unit forward curved blades It has a lond length relatively to its diameter It is suitable for application where laminar flow is considerable in order to reduce noise.
7.	Fan(outdoor unit)	Propeller type axial flow fan	It is suitable for handling large air volume It produces a flow of air in a direction parallel to the axis of rotation.
8.	Compressor	Hermetically sealed reciprocating compressor	It consist of a motor and compressor coupled together by a common shaft inside a welded steel dome. It is powered by electricity In this type of compressor it is difficult to access the compressor and motor assembly. It is suitable for application requiring small displacement volumes and high condensing pressure.

Fabrication Procedure

Under this section the installation of various components that comprise the air-conditioning unit will be discusses. Various considerations during this procedure are:

- Provision of an easy means of draining away condensed water.
- Utilization of a wall surface that is not subject to vibration for the indoor unit.
- Proximity of an appropriate electric socket
- Avoidance of exposure of the A.C unit to direct sunlight.

Installation of the Mounting Plate

Using a level, the mounting plate was placed in a perfect square position vertically and horizontally.

- Using a drill, 32mm deep holes were drilled in the wall to fix the mounting plate.
- Plastic anchors were inserted into the holes and the mounting plate was fixed using the tapping screws.

Mounting of the Indoor Unit

After completing the above, the indoor unit was mounted onto the upper part of the mounting plate. The lower part of the indoor unit was then pressed tightly against the mounting plate.

Outdoor and Indoor Unit Assembly

Drilling for Wall Piping

- Considering the position of the mounting plate, a drill was utilized to drill a hole in the wall for the piping. The drilling was done such that the hole sloped towards the exterior.
- Also, a flexible flange was installed through the hole the keep it intact and clean.

Electrical Connections

- Having selected wire size suitable to the electrical power input and safety requirements, the cable wires were connected to the screw terminals.
- A plug connection was made available and an efficient earthing connection was ensured.

Refrigerant Piping Connection

- Firstly, the piping was run in the direction of the wall hole. Then, the copper pipes, drain pipes and power cables were bound together with a tape.
- The pipe cap of the indoor unit connection pipe was removed and a flare nut was inserted to create a flange at the extreme and of the connection pipe.
- The flare nut was screwed to the indoor unit coupling and the connections were tightened using two wrenches.

Bleeding the Refrigerant Circuit

- Having connected the indoor an outdoor units, air and humidity were bled from the refrigerant circuit using a vacuum; as explained below;
- The cap from the outdoor unit service port was removed
- The vacuum pump 1ose was connected to the service port
- The vacuum pump was operated until an absolute vacuum of 10mHg was reached
- The vacuum pump was stopped and the joints were checked for leaks using liquid soap.

Piping Insulation and Protection

The piping connection was covered using an insulating material. The piping was then inserted to the plastic slots fixed to the wall.

RESULTS AND DISCUSSION

The performance test results are shown in Table 8. The AC was tested in airtight apartment to avoid leakage. The duration of the test lasted for three hours. The temperature of the room before testing was 26^{o}C and 18^{o}C after testing.

Table8. *Performance Test Result Analysis*

S/N	Description	Observed Quantity/Quality
1.	Room features	Air tight
2.	Duration of Test	Three hours
3.	Temperature of room before test	26^{o}C
4.	Temperature of room after test	18^{o}C
5.	Numbers of persons in the room	Four
6.	Relative humidity before test	70%
7.	Relative humidity after test	55%
8.	Position of regulator	High cool
9.	Room size	6.4m x 4.6m x 2.7m
10	Other items in the room	Table, Chairs, Computer, Photocopy Machine

The indoor and outdoor components of the conditioning unit are interconnected to achieve control of ambient conditions of a space to suite user requirements. In the interior, air is cooled by means of a fan which blows it over the evaporator. At the exterior, air is heated as a seconds fan blows it over the condenser. Thus, a cycle is formed which draws heat from the room and discharge to the environment. The process which makes up the air conditioning cycle comprises the following. The fan powered by electric motor forces air into the indoor unit through an inlet grill located above the evaporator unit. The air in the unit passes through a filter media which removes dust from pother allergens. The cleaned air then passes through the surface of the evaporator coils where it is cooled to user requirement.

Finally, the fan forces the cooled air through the indoor unit louvers into the room. It was observed that the outdoor unit powered by electric motor was able forces outside air into the condensing unit through the side grill. The air in the unit is blown over the surface of the condensing coils and extracts heat from the high temperature refrigerant. The heated air leaves through the front grill and the process is continuously repeated.

For efficient use of the AC, the following maintenance procedures are required;

- Compressors repair should be carried out only when it is ensured that the other parts of the system are trouble free.
- Minor repairs of the system can ordinarily be made without removing the compressor.
- When the compressor is worn out considerably, it gives out a lot of noise; this means that the main bearing journals are worn out. In such a case, it is better to use a new or reprocessed/rebuilt compressor than to attempt to repair.

The following procedures were followed to check the efficiency of the compressor.

- Back seat the suction and discharge service value and then remove the plug.
- Attach a pressure guage to the discharge service value and a compound guage to the suction valve guage port.
- Start the compressor and throttle the discharge valve until pressure head of 9 bars is maintained.
- Close the system valve slowly and when it is completely closed, note the vacuum guage.
- Check the discharge valve leakage only after the compressor has been running long enough with the suction valve closed to remove any refrigerant which may be in the crankcase.
- Replace or repair both the suction and discharge valve if found defective.
- In the compressor, if there are loose or broken parts, replace the entire unit.

The maintenance that may be caries out on the condenser is mainly that of de-scaling. The de-scaling of a condenser should be carried out only when it is firmly ascertained that there is a considerable scaling in the condenser. The scale formation prevents heat transfer from the refrigerant to the water and thereby results in high discharge pressure which affects the performance of the equipment immensely.

The following procedure is adopted to de-scale the condenser;

- Drain out the water from condenser after isolating it from rest of the water line.
- Connect these suctions of the pump with separate tank by rubber hose and discharge the pump to condenser water inlet with suitable connectors and rubber hose.
- Connect the condenser line back to the tank. Fill the tank with the raw water. Start the pump and circulate the water for about ten minutes through the condenser and make sure that water does not leak from any of the joint hose e.t.c. Make sure that adequate water is available in the plant room for cleaning the condenser after acid circulation.
- Add acid to the tank water at 1:6 ratios. Circulate the solution for 6-8 hours and drain out the acid thereafter. Flush the system with fresh water. Then circulate washing soda in the tank for half an hour flush the system with fresh water once again.

When air is cooled below its dew point temperature (at 100% RH), it gives up the moisture and deposit on the nearest cooler surface (the evaporator). When the temperature of the evaporator falls below 0^oC, the moisture deposit on the surface of the evaporator freezes and form a coating of frost. If this frost is not removed periodically, it acts as an insulator and retards the heat transfer rate between the air and the evaporator which causes the compressor to run at a lower suction pressure. Also frost decreases the capacity and efficiency of the system. The process of removing the frost formed on the surface of the evaporator by melting it is called defrosting. Several methods are used in defrosting an evaporated but the manual defrosting method can be used in this system, where frost is allowed to melt off. This is the easiest and simplest for defrosting.

However, purging or removing of air from the evaporator and lines can also help in the maintenance of the evaporator and even the system at large. Through there are different method used to remove air from the evaporator, but the one recommended for this project is the method that makes use of a separate vacuum pump to purge or remove the air.

The following procedure should were followed to purge the system;

- Close the suction valve and remove the gauge port plug.
- Screw a pipe flare connector into the gauge port and connect to the vacuum pump which is then connected to compound gauge and valves between the gauge and the pump.

- Start the vacuum pump and open the suction valve half way. Run the pump till highest vacuum is obtained.
- Close the valve and open the pump. Air evacuation with be satisfactory if vacuum gets maintained.

The isometric view of the AC is shown in Figure 2.

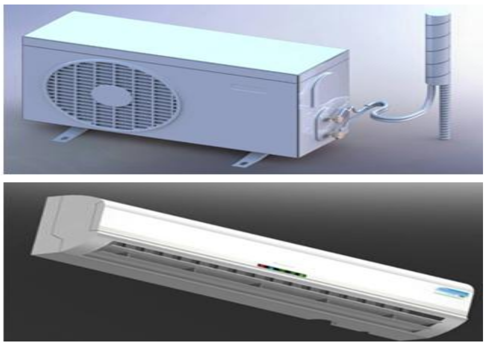

Fig1. *Isometric Model View of Air conditioner Split Unit AC*

Conclusion

The design and installation of the various components of the air-conditioning split unit were successfully carried out. The cooling can be varied over wide range of user requirement. During the testing phase, no defect was observed. The desires temperature and humidity levels were maintained constituently against a range of varying outdoor temperature. However, the major challenge during the installation was the establishment of the link between the indoor and the outdoor unit.

Recommendation

The air conditioner split unit is basically design to modify the condition of air within a single room or office so as to obtain thermal comfort. We therefore recommended that further design studies should emphasize on split unit-air conditioning units with an ability to cool several rooms within a building. This is because, the present air conditioner split unit does not adapt flexibility of cooling more than one room, due to ozone depletion and greenhouse effect cause by the presence of chlorine and fluorine in refrigerant, we also recommend that for subsequent studies, emphasis should be placed on the type of refrigerant used in air conditioners.

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