Refrigerant Piping for Split-Type Airconditioning System: Software Automation

Josef Vill S. Villanueva
NORSU, Kagawasan Ave., Dumaguete City, Negros Oriental
Corresponding Author Email: josefvill_v@yahoo.com

ABSTRACT

Correct line sizing is important in the design of refrigerant piping system as it helps minimize the pressure losses which cause inefficiency of the refrigeration system. Toward this end, the study developed refrigeration piping software which serves as a tool and guide for the proper design of refrigerant piping system. This windows-based program is easy to use and is equipped with different features which will help the designer in actual installation of split type air conditioning unit.

The objectives of this study is to create simulation software for designing refrigerant piping system which will determine the minimum pipe size required to deliver refrigerant between the compressor/condenser and evaporator within specified pressure loss limits. This study also establishes the relation between the design parameters of the refrigerant piping system and pressure loss limits. The equation used in computing system capacity is based on empirical equation. ASHRAE equations were also used in solving temperature drop and pressure drop. The programming language used in is Visual Basic Software or known as VB programming language.

The result of the study provides engineers the essential parameters for designing refrigerant piping system. It helps the designer visualize the different refrigerant piping layout with its corresponding pressure losses. The results of pressure losses of this software are closely the same with the pressure drop using Darcy's equation.

KEYWORDS: Pressure Drop, Temperature Drop, programming language, pipe size, ACU

1. INTRODUCTION

Good piping practices are essential to guarantee a long life and minimal maintenance[1]. First of all, a good system begins with a proper planning. According to refrigerant piping guide by McQuay International correct line sizing is imperative to improve the performance of the system.

Undersized lines will result in high pressure drops, diminished capacity, and increased power requirements. An oversized suction line will lead to poor oil return (as oil and refrigerant do not mix) and premature compressor change outs. Of the major sections of pipe, the suction line is the most critical to size properly. Generally, the suction line is sized for a minimum pressure drop through the line and a minimum velocity in order to ensure good oil return to the compressor[2]. McQuay international piping guide further stated that incorrectly sizing the suction line can lead to oil return problems or a reduction in the system's capacity. It is also important to correctly size the discharge and liquid lines. However, in this study the compressor and condenser are in one package therefore there no need to design the discharge line pipe. In the liquid line, pressure drop should be minimized to avoid refrigerant flashing. In addition, oversized liquid line is discouraged because it will significantly increase the system refrigerant charge[1]. This, in turn, affects the oil charge.

In order to make it easier in designing refrigerant piping system, there are several state of the art programs have been developed such as E20-II, Techni-Solve Line Size 1.1.30, Elite Software HVAC Tools program and SavarelRefrigerat Pipe Sizing[3].

However, the cost of these programs is one of the drawbacks why most educational institution and industries have difficulty in acquiring the said software.

2. MATERIALS AND METHODS

2.1 Method

The equation used in computing system capacity is based on empirical equation as shown in eq. 1.

The computation of temperature drop and pressure drop are based on ASHRAE formulas which are shown in eq. 3 and eq. 4[4]. Formulas of refrigerant effect, mass flow rate, volume flow rate and velocity of refrigerant are shown in eq. 1 – eq. 4[5]

System Capacity = $\frac{L\ x\ w\ x\ 500}{12000}$ tons of refrigeration

eq.1

Where: L = length of the room
W = width of the room

$$\Delta T_{actual} = \Delta T_{table}\left[\frac{actual\ length}{table\ length}\right]\left[\frac{actual\ capacity}{table\ capacity}\right]^{1.8}$$

eq. 2

$$\text{PressureDropactual} = \text{PressureDroptable}\left[\frac{\Delta T_{actual}}{\Delta T_{table}}\right] \quad eq.3$$

Refrigerating Effect = $(h_1 - h_4)$ eq. 4

Where: $h_4 = h_f$ = saturated liquid enthalpy
$h_1 = h_g$ = saturated vapor enthalpy

$$m = \frac{kW\ of\ refrigeration}{(h_1 - h_4)} \quad eq.5$$

Where: m = mass flow rate of refrigerant

$$Q = m\nu \quad eq.6$$

where: Q = volume flow rate of refrigerant
v = specific volume of refrigerant

$$V = \frac{m\upsilon}{A} \quad eq.7$$

where: V = velocity of refrigerant
A = cross sectional area of the pipe

2.2 Programming Language

This project used Visual Basic Software or known as VB programming language. Visual Basic was one of the first systems that made it practical to write programs for the Windows operating system. This was possible because VB included software tools to automatically create the detailed programming required by Windows. These software tools not only create Windows programs, they also take full advantage of the graphical way that Windows works by letting programmers "draw" their systems with a mouse on the computer. Visual Basic is distinctly different language providing powerful features such as graphical user interface (GUI), event handling, object oriented feature, error handling and structured programming.[6]

2.3 Simulation Scheme

Writing a Visual Basic program requires development steps. The following lists outline these steps:

1. Come up with a program concept and sketch out on paper how it might look on the screen.
2. Create the program using Visual Basic’s toolbox and editor
3. Save the program to disk
4. Run the program and see how it works
5. Fix programming errors
6. Go back to step 2

The three basic programming steps in creating a Visual Basic program:

1. Design the Graphical User Interface (GUI) for the proposed simulation platform.
2. Develop the source code which enables the program to produce the desired output for simulation.
3. Compile the program into an executable file, thus creating a standalone application that can run without the need to be loaded into the Visual Basic.

2.4 Flow of Study

The Windows-based Refrigerant Piping system program consists of three windows; Main Window, Input Window and Output Window. The flow chart in figure below shows the events that take place in each window. The details of the flow of events are explained in the proceeding paragraphs.

- Main Window

This window displays the selection of different refrigerants specifically, R-22, R-134a, R-407 and R-410. Selection of refrigerant is the primary step in the design of refrigerant piping system.

- Input Window

This window will open after the refrigerant is selected. This window displays different parameters to be inputted. Primary parameters are the length, width and height of the room. Location of the compressor/condenser and evaporator is also required. The program will test if the values inputted of primary parameters are within the limits value. If the inputted value does not satisfy the condition the program will display an error message and will ask to input another value that is within the limits. If the inputted value satisfies the condition, it will ask the other known design parameters of suction line, and liquid line. Known design parameters are condenser temperature, evaporator temperature and temperature drop. Calculation of the unknown design parameters will follow after all known design parameters are inputted.

- Output Window

The calculated value of the design parameters will be displayed on the Output Window of the user interface. The output parameters of suction and liquid line are horizontal line size, vertical riser size, total temperature drop, total pressure drop and total equivalent length. The system capacity is also displayed. Visualization of the piping layout will also be displayed in the Output Window.

2.5 Manual Computation of Refrigerant Piping Design

Computation shown below is an example of manually designing a refrigerant piping system. The data are just assumptions to a certain situation. The computation of cooling load is just based on rule of thumb.

Given Data:

Type of Refrigerant: R22
Room Dimension;
Length = 7 m
Width = 6.5 m
Height = 4 m

Location of compressor/condenser;
Coordinate: x = 1 m
y = 1m
Location of evaporator;
Coordinate: x = 5 m
y = 3m

Condenser Temperature = 40^{0}C
Evaporator Temperature = -5^{0}C
Design Temperature drop = 0.04 K/m

Note: The value of design temperature drop is taken from refrigerant line sizing. Other values of design temperature drop are 0.02 K/m and 0.01 K/m[7].

Solution:

System Capacity = $\frac{L\ x\ w\ x\ 500}{12000}$ tons of refrigeration

= $\frac{7x6.5x500}{12000}$

= 1.8958 tons of refrigeration

= 1.8958 tons $\left(\frac{211 \, kJ/\min}{1 ton}\right)\left(\frac{1\min}{60\sec}\right)$

= 6.67 kW of refrigeration

From table R22 Refrigerant line sizing; @-5^{0}C, 0.04 k/m and 6.67 kW of refrigeration
Liquid Line Size = 12mm
Suction Line Size = 22 mm

Computation of equivalent length
Liquid Line:

$$\Delta x = 4m$$
$$\Delta z = 2m$$

From appendix 2 page55 table equivalent length for fittings:
At 12mm diameter 90^0 long radius = 0.3 m
Filter drier = 3.45 m

Liquid Line Equivalent length = 4m + 2m + 0.3(2) + 3.45 = 10.05 m

Suction Line:

$$\Delta x = 4m$$
$$\Delta z = 2m$$

From appendix 2 page55 table of equivalent length for fittings;
At 22mm diameter 90^0 long radius = 0.4 m
Suction Line Equivalent length = 4m + 2m + 0.4(2) = 6.8m

Computation of temperature drop and pressure drop

Liquid Line:

$$\Delta T_{actual} = \Delta T_{table}\left[\frac{actual\ length}{table\ length}\right]\left[\frac{actual\ capacity}{table\ capacity}\right]^{1.8}$$

Actual Length = Equivalent Length = 10.05m
Table Length = 30.4878m
Actual Capacity = System Capacity = 6.67 kW

ΔT_{table} = 0.02 K/m

At 12mm diam. And 0.02 K/m; Table Capacity = 11.24 kW

ΔT_{actual} = 0.02 $\left[\frac{10.05}{30.4878}\right]\left[\frac{6.67}{11.24}\right]^{1.8}$
= 2.57 x 10^{-30}C

Pressure Drop$_{actual}$ = Pressure Drop$_{table}$ $\left[\frac{\Delta T_{actual}}{\Delta T_{table}}\right]$

From table R22 Pressure Drop$_{table}$ = 0.749 kPa

Pressure Drop$_{actual}$ = 0.749kPa $\left[\frac{2.57x10^{-3}}{0.02}\right]$
= 0.095 kPa

Pressure Drop from the riser = riser height x refrigerant pressure drop/m
From table; refrigerant pressure drop of R22 = 11.31 kPa/m
Pressure Drop from the riser = 2m x 11.31kPa/m
= 22.62 kPa
Total pressure drop = Pressure Drop$_{actual}$ + Pressure Drop from the riser
= 0.095 kPa + 22.62 kPa
= 22.71 kPa

Suction Line:

$$\Delta T_{actual} = \Delta T_{table}\left[\frac{actual\ length}{table\ length}\right]\left[\frac{actual\ capacity}{table\ capacity}\right]^{1.8}$$

Actual Length = Equivalent Length = 6.8m
Table Length = 30.4878m
Actual Capacity = System Capacity = 6.67 kW

ΔT_{table} = 0.04 K/m

At 22mm diam. And 0.02 K/m; Table Capacity = 7.51 kW

ΔT_{actual} = 0.04 $\left[\frac{6.8}{30.4878}\right]\left[\frac{6.67}{7.51}\right]^{1.8}$
= 7.2 x 10^{-30}C

Pressure Drop$_{actual}$ = Pressure Drop$_{table}$ $\left[\frac{\Delta T_{actual}}{\Delta T_{table}}\right]$

From table R22 Pressure Drop$_{table}$ = 0.572 kPa

Pressure Drop$_{actual}$ = 0.572kPa $\left[\frac{7.2x10^{-3}}{0.04}\right]$
= 0.103 kPa

Refrigerating Effect = ($h_1 - h_4$)
At -5^{0}C, h_1 = 403.16 kJ/kg (see appendix 3 page 66)
At 40^{0}C, h_4 = 249.65 kJ/kg (see appendix 3 page 66)
Ref. Effect = 403.16 kJ/kg - 249.65 kJ/kg
= 153.51 kJ/kg
kW of refrigeration = m ($h_1 - h_4$)

m = $\frac{kW\ of\ refrigeration}{(h_1 - h_4)}$

= $\frac{6.67\, kJ/s}{153.51\, kJ/kg}$

m = 0.04345 kg/s

Refrigerant Velocity at Suction Line:
Q = AV
Q = m υ
V = $\frac{m\upsilon}{A}$

υ_g @ -5^{0}C = 0.0552915 m^3/kg

A = $\frac{\pi}{4}(D)^2 = \frac{\pi}{4}\left(\frac{22}{1000}\right)^2$
= 3.88x10^{-4} m^2

$$= \frac{0.04345\,{}^{kg}/_{s}\left(0.55291\,{}^{m^3}/_{kg}\right)}{3.88x10^{-4}\,m^2}$$

= 6.1917 m/s

Refrigerant Velocity at Liquid Line:

Q = AV

Q = m υ

$$V = \frac{m\upsilon}{A}$$

υ_f @ 40^{0}C = 0.00088611 m^3/kg (see appendix 3 page 66)

$$A = \frac{\pi}{4}(D)^2 = \frac{\pi}{4}\left(\frac{12}{1000}\right)^2$$

= 1.13097x10^{-4} m^2

$$V = \frac{0.04345\,{}^{kg}/_{s}\left(0.00088611\,{}^{m^3}/_{kg}\right)}{1.13097x10^{-4}\,m^2}$$

= 0.3404 m/s

3. RESULTS AND DISCUSSIONS

3.1 Refrigerant Piping Software

3.1.1 Software Features

It is User Friendly

In designing refrigerant piping system the process is long and tiring as can be seen in the previous chapter. This software eliminates or minimizes the manual manipulation. The software uses visual basic and is much more user friendly like other windows applications. The main window of the design simulation software is shown in figure 1.

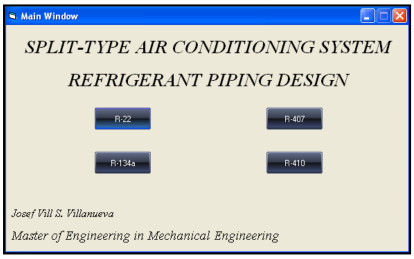

Figure 1. Main window

Requires few input parameters

The software requires few input parameters as shown in figure 12a and 12b. These are room dimension, location of ACU, condenser temperature, evaporator temperature and design temperature drop.

In Room Dimension frame as shown in Figure 2a, you are required to input the length, width and height of the room. The location of installation will be also inputted. Only SI units are being used.

The Input Design Data shown in Figure 2b display the location of compressor/condenser and evaporator. The designer should input the coordinates for the location of evaporator and compressor/ condenser. Also in this frame the condenser temperature, evaporator temperature and design pressure drop are being inputted.

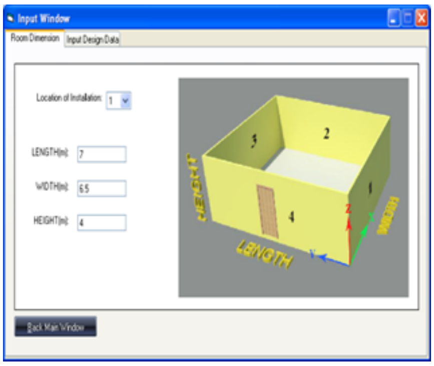

Figure 2 (a) Room dimension

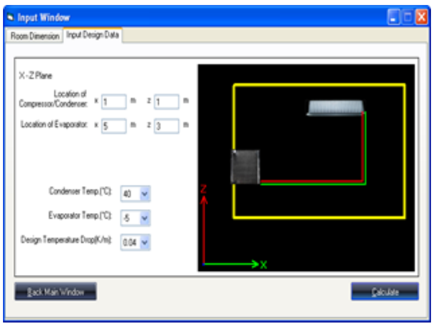

Figure 2b Unit Location

Calculates essential design parameters

The software calculates all necessary parameters which are essential in designing refrigerant piping system as shown in figure 3a. In this figure, the frame displays the pipe size, temperature drop, pressure drop and equivalent length of suction and liquid line. System capacity is displayed in this frame.

Provides Visualization

The software provides a visualization of the ACU as shown in figure 3b. The frame shows the layout of the refrigerant piping. Refrigerating Effect, mass flow rate and velocity are also displayed in this frame.

Provides bill of materials

The software provides bill of materials as shown in figure 3c. The designer will be the one to input the price of each material. The labor cost is assumed to be 40% of the material cost.

A back, save and print icon are provided in this Output Window frame. If back icon is click it will go back to the previous window to edit some of the entry. The designer has also the option to save or print the results of the Output Window before closing.

The refrigerant piping design software is 1.1MB in size. It can be operated in all windows operating system by simply copying it to a computer and executing it.

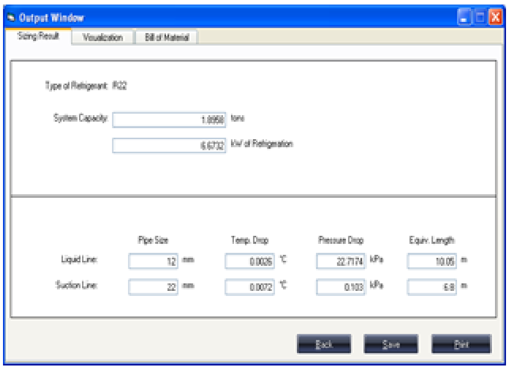

Figure 3(a) Sizing Results

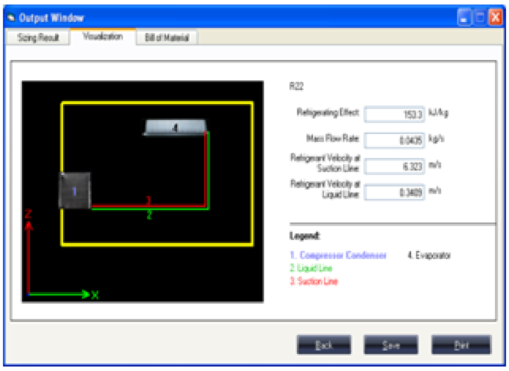

Figure 3 (c) Bill of Materials

3.2 Testing on capabilities and limitations of the refrigerant piping software

The simulation software is only limited to 7.5 tons of refrigeration and it used for a split type air conditioning unit. The first step upon using this software is to select the type of refrigerant. After selection of refrigerant, room dimension frame will appear which will require the length, width and height to be inputted before you can input the design parameters. If it happened that you forgot to input the room dimension, error display will appear as shown in figure 4.

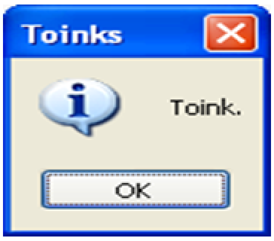

Figure 4. Error Display

If the design area exceeds 7.5 tons of refrigeration, then error display will appear as shown in figure 5. The frame will just display the tons of refrigeration but it will not give any results of the design parameters.

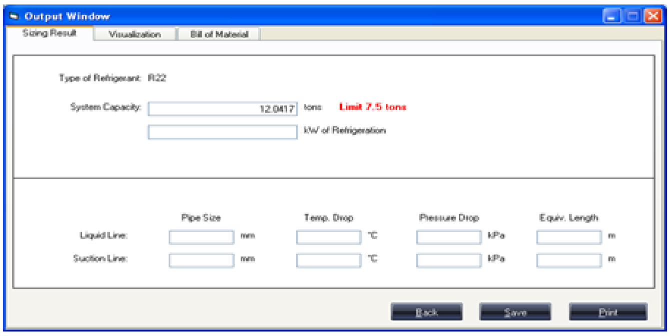

Figure 5. Display on exceeds capacity

In piping layout, the designer can place the location of compressor/condenser and evaporator anywhere in the design area by simply using the coordinate system or by using the mouse and drag it anywhere the designer want to place while maintaining some other parameters. Figure 6a-6d shows the different locations of compressor/condenser and evaporator.

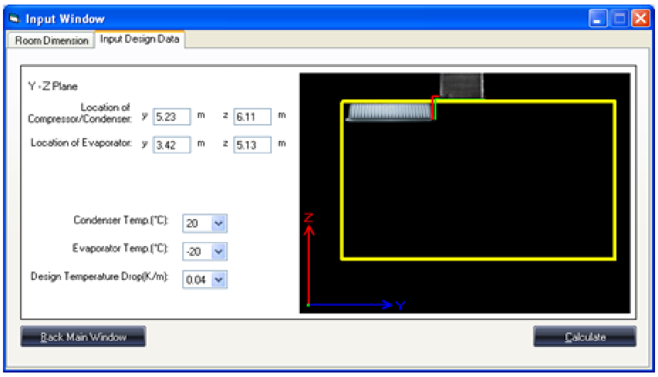

Figure 6a Sample location of ACU

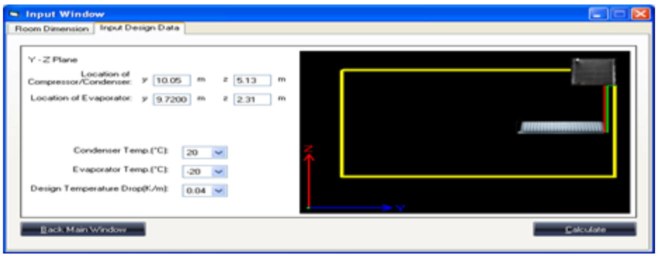

Figure 6b. Sample location of ACU

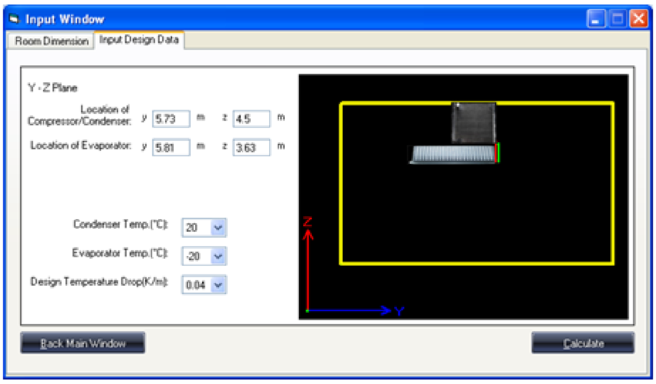

Figure 6c. Sample location of ACU

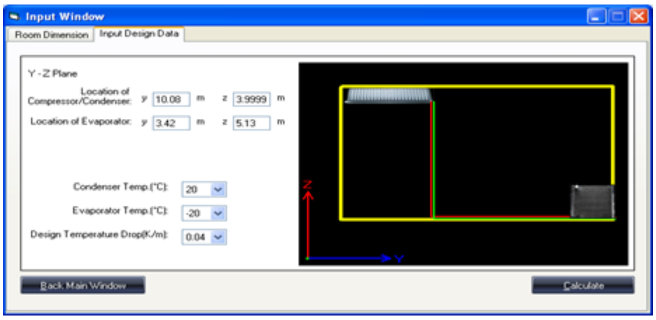

Figure 6d. Sample location of ACU

3.3 Result comparison on pressure losses: software versus Darcy's equation

Test was conducted in computing pressure losses in the suction side of the refrigerant piping system using the refrigerant piping software and by using the formula in Darcy's equation. In the computation, the location of condenser/compress and evaporator are fixed. Refrigerant 22 is being used. The refrigeration capacity is increased from 1 ton to 7 tons. The detailed in computation is shown in Appendix 1. The results of the computation are shown in figure 7.

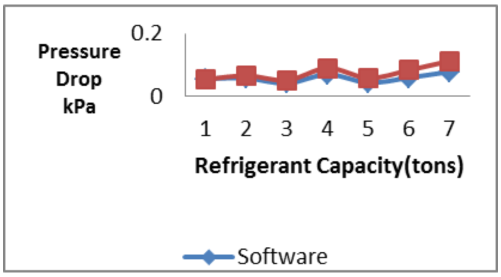

Figure 7. Suction pressure loss

The graph shows that the pressure drop using Darcy's equation is higher than the refrigerant piping software. The smallest difference is found in 1 ton capacity, while the highest difference of pressure drop is found in 7 tons capacity. It was found out that the refrigerant piping software is more conservative than Darcy's Equation. In this case, Darcy's Equation is assumes to be a single laminar flow. The obtain data from the software specifically velocity, length and diameter are being used in Darcy's Equation[8]. The graph also shows that the difference in results to the Darcy Weisbach and software increases with the tonnage. This is because as the tonnage increases, velocity of refrigerant also increases and velocity has great effect in solving the pressure loss using Darcy's Weisbach equation.

3.4 Test of software on the actual installation of refrigerant piping system

The software was tested in actual installation of split-type air conditioning unit. The venue of the test was in Ramar Cooling System as shown below in figure 8.

Figure 8. Venue of the test

The test was conducted in their office and the room dimension is 5m x 5m x 4.5m. The locations of compressor/condenser, evaporator and piping are shown in figure 9-12.

Figure 9. Room Location

Figure 10. Location of evaporator

Figure 11. Location of piping

Figure 12. Location of compressor/condenser

Software was then used and the results are shown in Figure 13-16. The system capacity was found out to be 1.0417 tons and the total cost of installation is P 32,243.24. Pipe sizes were found to be 12 mm for liquid line and 22 mm for suction line. Other details of results can be found in the figures stated.

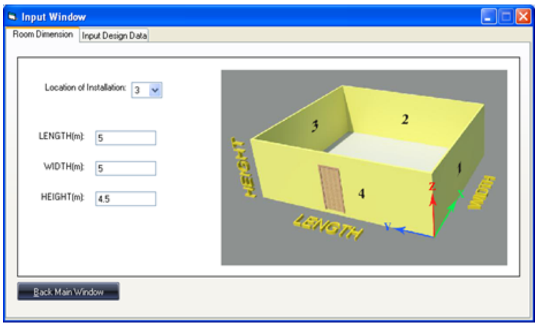

Figure 13. Room dimension

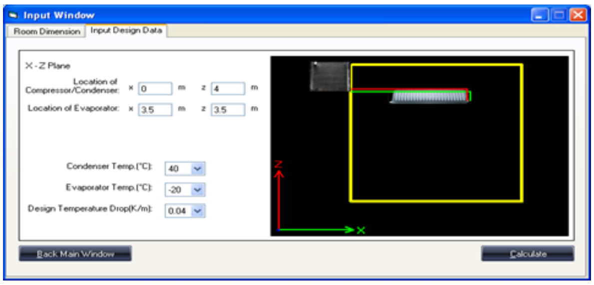

Figure 14. Input design data

Figure 15. Bill of materials

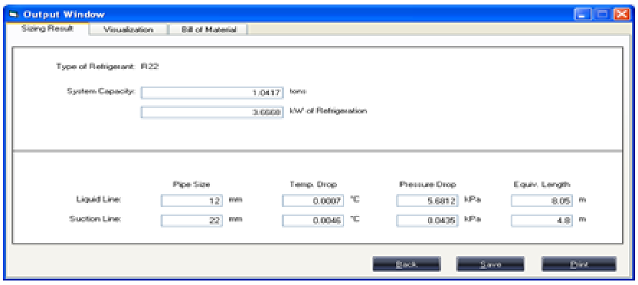

Figure 6. Sizing results

The result of the software was 1.0417 tons which is almost equal to the actual installed split-type aircon unit that has a capacity of 12,000 Btu/hr (1 ton).

Figure 17. Actual capacity of installed ACU

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The results of pressure drop of this software are closely the same with the pressure drop using Darcy's equation as can be seen in figure 7. Since the software uses the ASHRAE formula in solving the pressure drop, therefore the result is reliable.

In addition, this refrigerant piping software provides the engineers the essential parameters for designing refrigerant piping system. It helps the designer visualize the different refrigerant piping layout with its corresponding pressure losses. The software also provides the bill of material which helps the designer estimate how much will be the cost of installation of a split type air conditioning unit. This software eliminates the tiresome calculations and improves the performance of the designer during the designing process by reducing the designing time.

4.2 Recommendations

The creation of this simulation software was successfully developed based on the original objectives of this study. The study was able to illustrate a method where design strategies originate from computer simulation. However, due to time constrain and some other factors, the refrigeration capacity is only limited to 7.5 tons, visualization is also limited to two dimensional layout and the design is only concentrated on one room. It would be better that the following suggestions will be carried out as future studies.

1. Increase the refrigeration capacity so that the simulation software will not only be limited to 7.5 tons.
2. Improve the visualization into three dimensional drawing to have a proper view of the piping layouts.

REFERENCES

[1] www.mcquay.com

[2] www.coolit.co.za/linesize

[3] www.saravel.com

[4] www.ashrae.org

[5] Stoecker, W. and Jones, J. (1997). Refrigeration and air conditioning2nd edition. New York: McGraw-Hill.

[6] Mansfield,R.(1993].Visual Basic for Windows.second edition.Manila:Global Publishing

[7] www.refrigerati.co/doc.sat_table/R22.pdf

[8] Daugherty, R. L., Finnermore E. J., and Franzini J. (1989). *Fluid mechanics with engineering applications*. Phillipines: McGraw-Hill Book Company.