MECHANICAL ENGINEERING DEPARTMENT

MBB 4012

FINAL YEAR PROJECT II

PROGRESS REPORT

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PROPOSED TITLE : PERFORMANCE STUDY OF THE SOLAR-POWERED ABSORPTIVE REFRIGERATION PROCESS

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ABSTRACT

Fossil fuels that are currently used as energy sources are of limited quantity and also have negative environmental impacts. Currently, air conditioning systems that are based on vapor compression principle are primary electricity consumers. From this perspective, if another source of electricity that can be used by these systems is available, we can be less dependent to fossil fuels in terms of power generation. Thus, Solar powered absorptive refrigeration cooling systems as a green cold production technology is the best alternative. Therefore, a comprehensive literature review on absorption based refrigeration and air conditioning systems that are powered by solar energy will be explored in this research project.

Chapter 1 will introduce the background of the project. The problem statement of this project will also be stated to address the main purpose and significance of conducting this research project. Besides that, the objective of this research project will also be included and the scope of study as well.

A detailed literature review will be discussed in Chapter 2. In this chapter, the concept and basic understanding of the project is shown. This chapter is divided into 3 sections, which are solar power, air conditioning, and the complete system to power up the air condition using the solar power.

Finally in the last chapter, a clear overview of the whole project will be given through research methodology, the experimental approach and procedures as well as the key milestones that will be presented.

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CHAPTER 1 PROJECT BACKGROUND

1.1 Background Study

The sun is known to supply the world with a permanent and abundant clean energy source in the form of solar radiation. The amount of solar radiation intercepted by the earth's surface is 82×10^{15} W which is much higher compared to the annual global energy use [1]. Realizing this, researches have been widely done in recent years producing many promising technologies in order to extract the sun's energy. One of these important technologies is the solar refrigeration systems which employ either absorption or adsorption technologies.

The peaks of requirements in cold coincide most of the time with the availability of the solar radiation making the development of solar refrigeration technologies to be the worldwide focal point for concern [2]. Solar refrigeration has the potential to improve the life quality for people who live in areas where there is insufficient source of electricity. Moreover, the solar cooling technology can reduce the environmental impact raised by conventional air-conditioning systems which is ozone depletion problem caused by the utilization of chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) in them. Thermally powered absorption refrigeration system has gained considerable interest in recent years [3]. Thermally powered absorption cooling and refrigeration systems have the advantages of being (i) compact, (ii) free or nearly free of moving parts (iii) efficiently driven by low temperature waste heat or renewable energy sources, and (iv) also free from environmentally-harmful substances as these systems can use natural or alternative refrigerants such as water [4,5] , ethanol [6,7] , methanol [8] , ammonia [9] , etc. In addition, no corrosion problems exist in adsorption systems.

1.2 Problem Statement

The current problem with existing absorption refrigeration process that makes it less popular than the vapour compression cycle is the low coefficient of performance of the absorption air conditioning process meaning more energy, input is needed by the system in order to cool a specific room. Besides that, the current global environment and energy problem, high demands exist for solar powered refrigeration to minimize carbon dioxide generation by the consumption of fossil fuels. Development of a solar air-conditioning system having high performance and reliability is demanded. Power consumption in buildings is on rise every year, resulting in a need to develop energy self-sufficient systems for buildings. Solar-assisted cooling seems to be potential substitute to conventional electrically driven refrigeration units from an environmental standpoint since it has beneficial effects in reducing CO_2emissions.

1.3 Objective

The objective of this study is to design a solar powered absorptive air conditioning system. Parameters that are included in this study includes the:

i. Cooling load of a specified room.

ii. Humidity requirement of specified room.

1.4 Scope of Studies

In this study, the main subject under investigation is a room with the following characteristics:

i. Rectangular room with 50% window area on only 1 side of wall and 1 door

ii. 30 occupants

iii. Electrical devices used in the room are computer, projector and lights

iv. Heat gain from outside is due to Malaysia's weather condition

CHAPTER 2 LITERATURE REVIEW

2.1 Solar Power

Solar power is the most abundant energy source available and also a free source of fuel. It is the most flexible and applicable renewable energy source [2]. The reason is, solar can be used for several function including heating, cooling and power generation. However, the solar power is not without any disadvantage. The biggest disadvantage is it requires sunlight that is only available during daylight. This means, it is not available during the night and overcast days. However this problem can be overcome by using an efficient thermal storage system that can continue producing power for a certain period of time even during the absence of sunlight. Compared to wind energy, the availability of solar power is more predictable as the cycle of sunlight can be easily predicted and it also plays an important role in designing a solar power generating system.

Solar energy collector is a major component of any solar power system that absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid (usually air, water, or oil) that flows through it. The energy collected is then transferred either directly to the hot water or space conditioning equipment or to a thermal energy storage tank from which can be drawn for use at night and/or cloudy days. Another type of collector is the photovoltaic cell that converts the photons from the sunlight straight to electricity.

Solar radiation can be converted into electrical energy directly, without any intermediate process at all, by the use of solar photovoltaic (PV) cells. These cells are usually fabricated as flat discs, up to a few inches in diameter. The advantages of this form of electricity generation, compared with thermal processes are considerable.

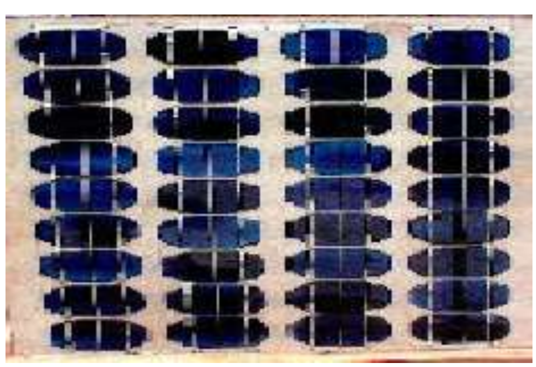

Figure 1 *Photovoltaic (PV) cell*

One of the advantages of the photovoltaic (PV) cells is there are no moving parts which means little maintenance is required. Besides that, the cells are reliable and long-lasting, with no harmful waste products and no discernible health hazard. The cells are usually made of silicon, which is one of earth's most abundant and cheap materials. The cells can be used on site in remote locations, such as the rural areas, buoys anchored at sea, or spacecraft in orbit.

These PV cells also have several disadvantages such as the cost of making them. Although the price has dropped greatly in the past two decades, it is still expensive when compared with other renewables or with fossil fuel sources such as coal or gas. Secondly, the manufacturing of photovoltaic cells takes quite a bit of electricity. It takes two to four years to generate enough electricity from photovoltaic cells to compensate for the original electricity used to make them. However the cells generally last 20 years or more.

2.2. Absorption Air Conditioning System

This section will describe the typical cycle in any absorption system. However the actual unit will contain additional refinements to increase efficiency of the system. Air-conditioner working on absorption principle varies from the conventional vapor compression principle is that the refrigerant is raised to a higher temperature and pressure by heating instead of by using a compressor which requires electrical power. This means that the components of each system are the same except that the compressor is replaced by a generator. The condenser and evaporator functions the same in absorption system as in vapor compression system.

A typical absorption system is illustrated in Figure 2 that is made up of upper vessel which contains absorber and evaporator and lower vessel which contains the condenser, generator and heat exchanger. This system is two different fluids to operate which is refrigerant and absorber. Some of the examples of refrigerant-absorbent pairs are:

- Ammonia-salt [18]
- Methylamine-salt [18]
- Alcohol-salt [18]
- Ammonia-organic solvent [18]
- Sulfur dioxide-organic solvents [18]

- Halogenated hydrocarbons-organic solvent [18]
- Water-alkali nitrate [18]
- Ammonia-water-salt [18]

This system begins its process by supplying the evaporator with the refrigerant by spraying it over a tube bundle containing water to be chilled by means of a refrigerant pump. The refrigerant absorbs heat from the water thus lowering the water's temperature and chilling it. This results in the refrigerant to evaporate and turns to vapor. The evaporator is maintained at low pressure in order to have a sufficiently low boiling temperature to produce the desired chilled water. Normally the pressure would be 0.25 Hg.

To maintain this desired pressure in the evaporator, the refrigerant vapor is drawn off as soon as it is produced. This is done by placing the absorber adjacent to the evaporator in the upper vessel as seen in Figure 2. The absorbent should have a very strong affinity for the refrigerant vapor thus taking the vapor into solution as it is produce. The absorbent is sprayed by the absorber pump to provide a large liquid surface as possible as it needs to contact the refrigerant's vapor in a one of process. The solution formed by the absorbent and refrigerant falls towards the absorber pan passing through a tube bundle which removes the heat from the solution and turns to its liquid state. This process is where the heat absorbed from the chilled water in the evaporator is rejected from the machine.

The absorption process continues as long as the air-conditioner is turn on. As it continues, the absorbent becomes more and more diluted and will lose its ability to absorb at the same rate the refrigerant vapor is produce. This requires the absorbent to be replenished with a strong solution. The absorbent-refrigerant solution produce in the previous process in the absorber pan drops down pipe 1 in Figure 2 and flows to the generator where it enters from one side of the heat exchanger. Inside the generator, the solution is heated by a low pressure steam or hot water where it is boiled and drives off the refrigerant vapor. The solution now becomes a strong absorbent again and flows out of the generator through another side of the heat exchanger. In the heat exchanger, the heated strong solution transfers its heat energy to the weak solution as it needs to lower its temperature before being able to do work. The weak solution on the other hand needs to be heated before it is concentrated in the generator. It is then mixed with and intermediate-strength solution in an ejector and then pumped back to the absorber to repeat the process.

The refrigerant vapor generated in the generator flows to the condenser where it is condensed by the same water used to cool the absorbent-refrigerant solution in the absorber. The condensed refrigerant is collected in the condenser pan and flows back into the evaporator as a result of pressure difference the two components to start the process again. This process is now complete and will continue in the presence of heat and maintained liquid flows.

By matching the absorber capacity with the chilling load, the system can be controlled. To control the absorber capacity, the absorbent-refrigerant solution concentration is modulated. It is done so by varying the amount of strong solution that leaves the generator. When less than full capacity is needed, weak solution is taken from the absorber pan and transferred to the ejector weir box where it will prevent the strong solution from flowing into the ejector. This is made possible by modulating valve in Figure 2 in bleed line 3 with respect to the leaving chilled water temperature.

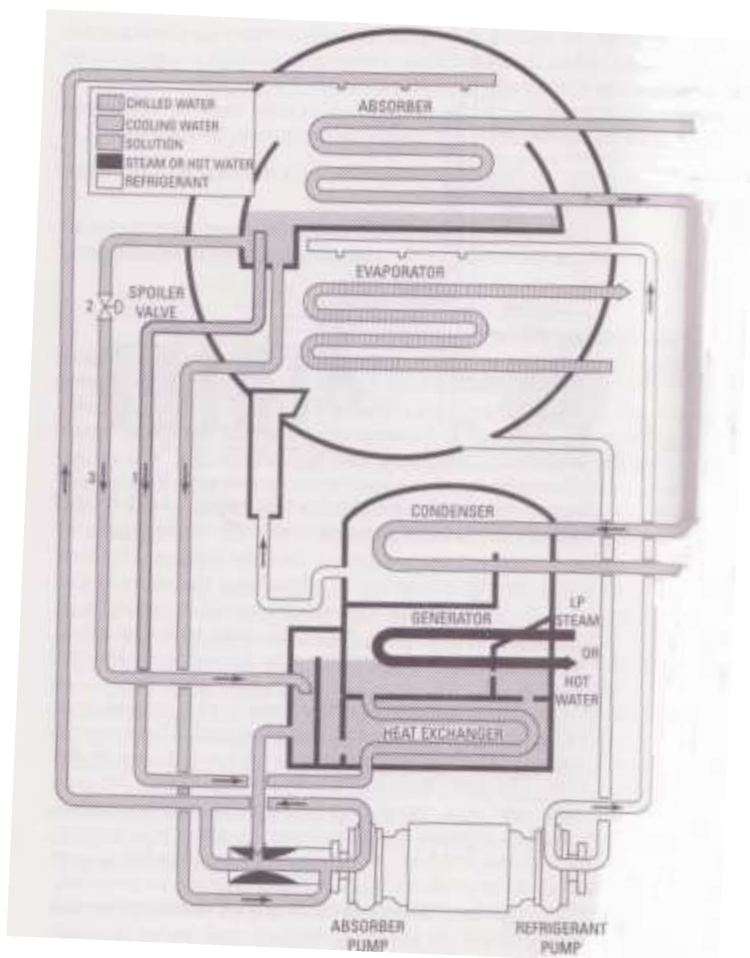

Figure 2 *Absorption cycle*

2.3. Solar Powered Absorption Air conditioning System

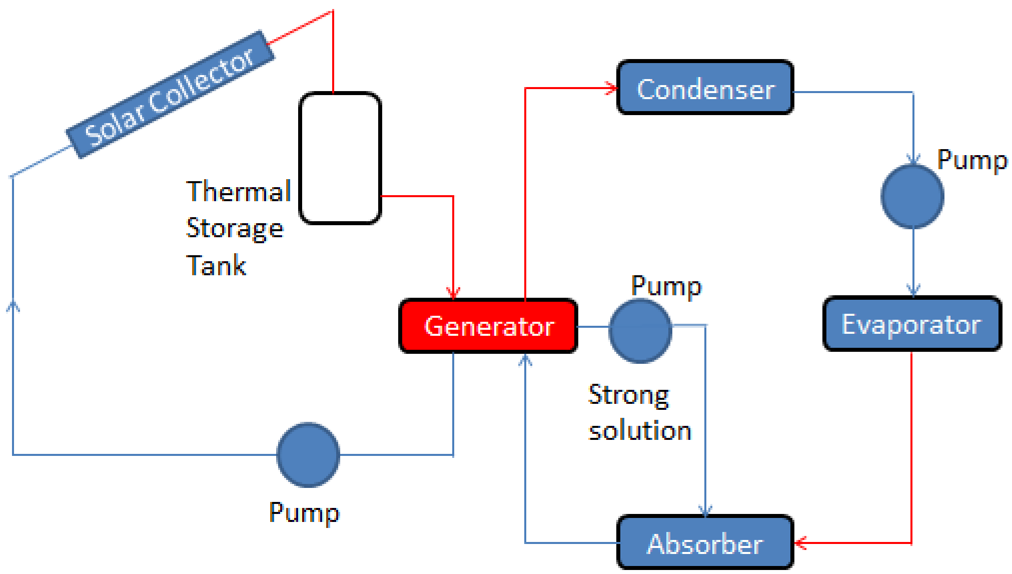

Figure 3 *Arrangement of the solar powered air conditioning unit*

Figure 3 above shows the configuration of absorption air-conditioning system with solar heating. As explained in section 2.2, the major difference between an absorption system and vapor-compression system is that the compression process in vapor compression is replaced by heat addition in the absorption system. This heat addition can be obtained by solar water heating. Water is heated in the solar collector and flows to the thermal storage tank where heated water is stored for use during the absence of sunlight. The heated water is then passed through the generator of the absorption system where it heats up the absorbent-refrigerant solution to separate the refrigerant from the solution. After heating up the solution, the water is then pumped back to the solar collector to begin the process again.

This system requires less electrical power compared to the vapor-compression which requires electrical power to run the compressor. The electrical power needed to operate the pumps in the system can also be produce by the solar collector. In this case a hybrid solar collector can be used whereby it converts solar energy into electricity and heat.

This type of collector is made up of a photovoltaic module and an absorber plate that acts as a heat removal device for the PV cells which is attached on the back of the PV module that cools the PV module. The heat collected by the absorber plate is used to heat up the water needed in the absorption system. Performance comparisons between hybrid PV collectors and conventional PV-only systems have also been conducted. All the results indicated that hybrid PVT systems can achieve increased energy conversion efficiency with potential cost benefits.

2.4 Cooling Load Calculations

The first step of calculation that is done in this project is the cooling load calculation for the room that is being used for this project. There are several steps that should be followed to make it easier and more systematic in calculating the cooling load of the room. The steps are:

1. Select indoor and outdoor design temperatures of the room.
2. Use architectural plans to measure dimensions of all of the room's surfaces and calculate the areas for these surfaces.
3. Select heat transfer coefficient for each elements or calculate from each individual's R-value
4. Calculate heat gains through walls, roof and floors for the room using Cooling Load Temperature Difference (CLTD).

$$Q = U \times A \times CLTD \text{ ------------------ } (1)$$

Where, Q = Sensible cooling load, Btu/hr

U = Overall heat transfer coefficient, BTU/hr-ft^2-F

A= Area, ft^2

CLTD = Cooling load temperature difference, F

5. Calculate heat gains through glasses.

$$Q = A \times GLF \text{ -------------------------- } (2)$$

Where, Q = Sensible cooling load, Btu/hr

A= Area, ft^2

GLF = Glass load factor, BTU/hr-ft^2

6. Calculate occupancy load

$$Q_s = q_s \times n \times CLF \text{ ----------------- (3)}$$

Where, $Q_s =$ Sensible cooling load, Btu/hr

q_s = Sensible heat gain per person, Btu/hr

n = Number of people

CLF = Cooling load factor for people

$$Q_l = q_l \times n \text{ -------------------------- (4)}$$

Where, Q_l = Latent cooling load, Btu/hr

q_l = Latent heat gain per person, Btu/hr

n= Number of people

The total occupancy cooling load is the summation of the sensible and latent cooling load.

7. Calculate appliance load.

The heat gain from equipment may sometimes be found directly from the manufacturer or the nameplate data. Some equipment produces both sensible and latent heat and he total heat gain from the equipment is the summation of the sensible and latent cooling load.

8. Calculated Infiltration load.

For this step, the quantity of air infiltrating into the room is first calculated using the equation :

$$CFM = ACH \times \frac{V}{60} \text{ ------------------- (5)}$$

Where, CFM = air infiltration rate into room, CFM

ACH = Number of air changes per hour

V = room volume, ft^3

TC = Temperature change between indoor and outdoor air, F

After calculating the air infiltration rate, the heat gain due to air infiltration is calculated using the equation:

$$Q = 1.1 \times CFM \times TC \text{ -------------- } (6)$$

Where, Q = Sensible cooling load, Btu/hr

CFM = air infiltration rate into room, CFM from equation 5.

TC = Temperature change between indoor and outdoor air, F

9. Calculate Ventilation load

$$Q = 1.1 \times CFM \times TC \text{ -------------- } (7)$$

Where, Q = Sensible cooling load, Btu/hr

CFM = air infiltration rate into room, CFM from equation 5.

TC = Temperature change between indoor and outdoor air, F

$$Q_l = 0.68 \times CFM \times (W_i{}' - W_o{}') \text{ -------------- } (8)$$

Where, Q_l = Latent cooling load, Btu/hr

CFM= Air infiltration rate ft^3/min

$W_i', W_o{}'$ = Higher (indoor) and lower (outdoor) humidity ratio,

dr w/lb d.a.

10. Add individual loads to find the sensible load for the room.

After calculating each cooling load, it will help to input the data into the table below so that none of the cooling load is left out in the calculation of the total cooling load.

Table 1 *Total Cooling Load*

Room Name	Meeting Room				
Plan size					
Wall	Direction	U	A	CLTD	Cooling Load
Roof/ceiling					
Floor					
Partition					
Door					
Windows	Direction			CLF	
Infiltration					
Ventilation					
People					
Appliances					
Total Cooling Load					

CHAPTER 3 METHODOLOGY

3.1 Research Methodology and Project Activities

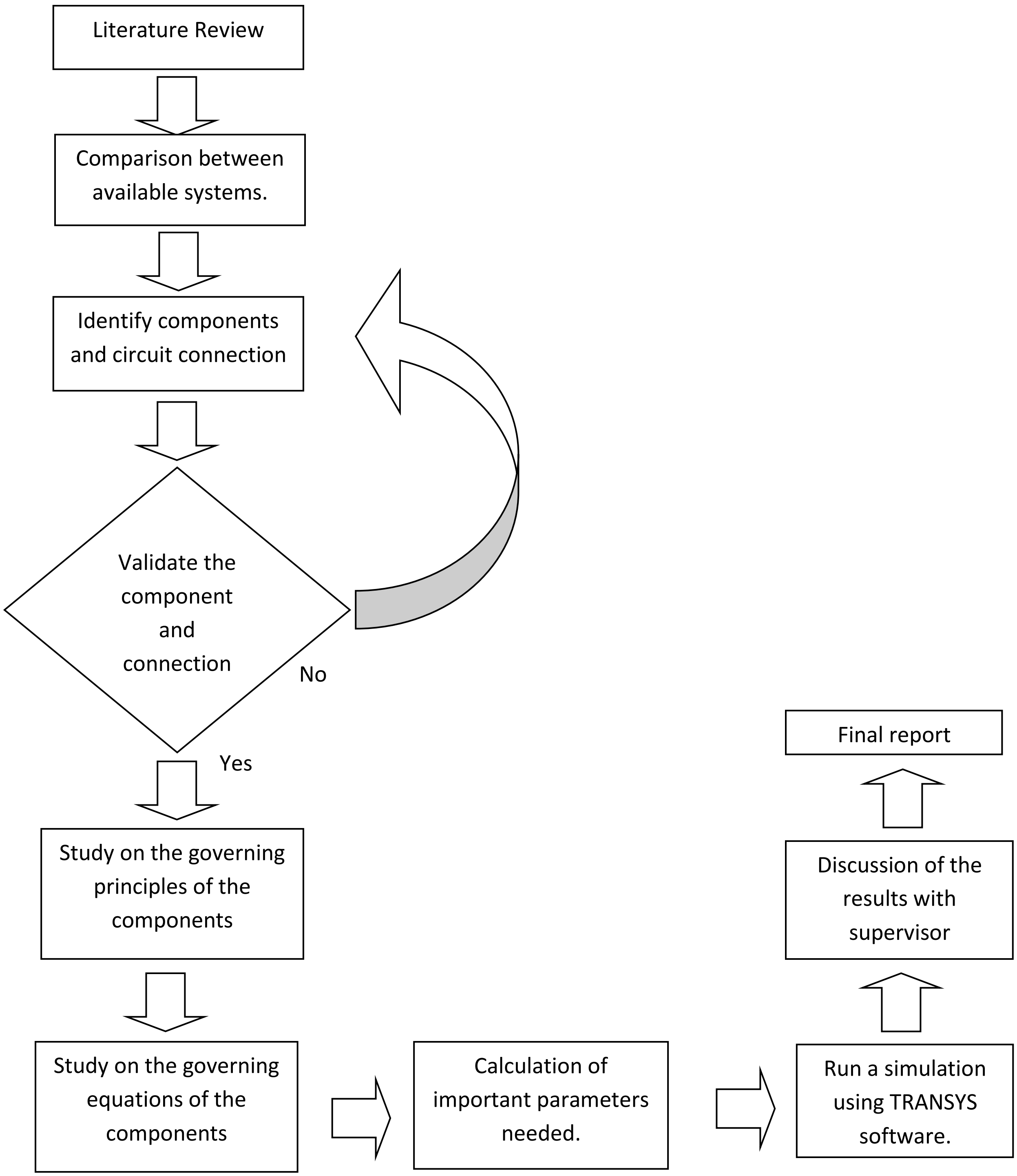

Figure 4 *Flow of project*

3.2 Key Milestones

Several key milestones for this research project must be achieved in order to meet the objective of this project:

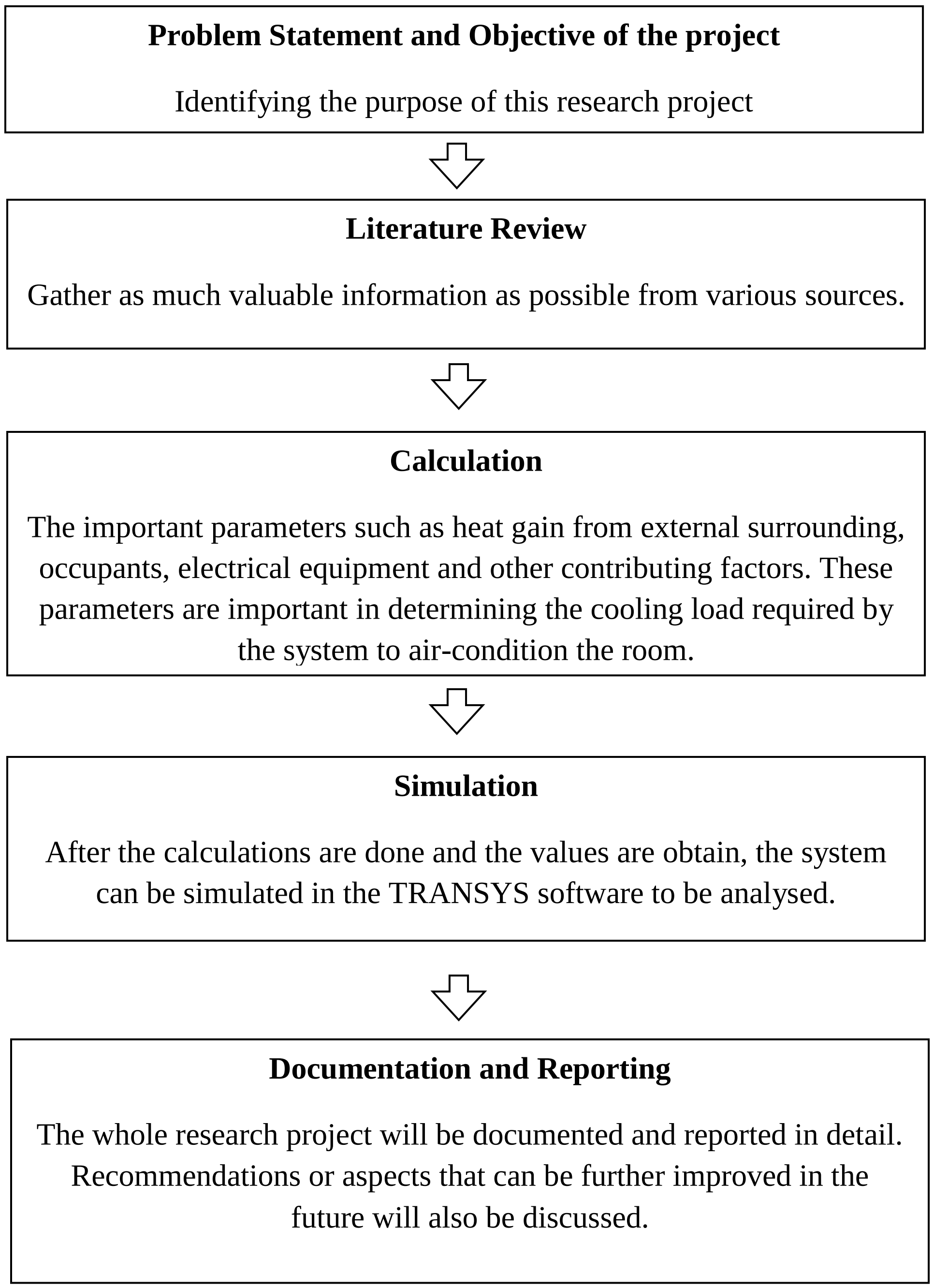

Figure 5 *Key Milestones*

3.3 Gant Chart

Table 2 *Gantt chart*

NO	DETAIL / WEEK	1	2	3	4	5	6	7	Mid-Semester Break	8	9	10	11	12	13	14
1	Selection of Project Title	■	■													
2	Preliminary Research Work and Literature Review			■	■	■	■									
3	Submission of Extended Proposal Defence						●									
4	Preparation for Oral Proposal Defence							■								
5	Oral Proposal Defence Presentation									■	■					
6	Detailed Literature Review									■	■	■	■	■		
7	Preparation of Interim Report			■	■	■	■	■		■	■	■	■	■		
8	Submission of Interim Draft Report														●	
9	Submission of Interim Final Report															●

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Calculation

Conduction through Exterior Structure

1) **Flat suspended-roof**

Roof Material: 1 in. wood 2 in insulation

Cooling Load Temperatore Difference (CLTD): 33F

Roof's U-value: $0.83 \frac{BTU}{h.ft^2.F}$

Area of Roof: $60.7\ m^2$

Table 3 *Corrected values of CLTD,* °F

Month	LM	Outside design dry bulb temperature, °F	Daily Temperature Range,°F	Average outside temperature, °F	Room Temperature ,°F										
					60.8	62.6	64.4	66.2	68	69.8	71.6	73.4	75.2	77	78.8
					Corrected values of CLTD, °F										
January	-2.5	87.8	11	82.3	45.0	43.2	41.4	39.6	37.8	36.0	34.2	32.4	30.6	28.8	27.0
February	-0.5	89.6	11	84.1	48.8	47.0	45.2	43.4	41.6	39.8	38.0	36.2	34.4	32.6	30.8
March	0.0	91.4	11	85.9	51.1	49.3	47.5	45.7	43.9	42.1	40.3	38.5	36.7	34.9	33.1
April	-1.5	91.4	11	85.9	49.6	47.8	46.0	44.2	42.4	40.6	38.8	37.0	35.2	33.4	31.6
May	-3.0	89.6	11	84.1	46.3	44.5	42.7	40.9	39.1	37.3	35.5	33.7	31.9	30.1	28.3
June	-3.5	89.6	11	84.1	45.8	44.0	42.2	40.4	38.6	36.8	35.0	33.2	31.4	29.6	27.8
July	-3.0	89.6	11	84.1	46.3	44.5	42.7	40.9	39.1	37.3	35.5	33.7	31.9	30.1	28.3
August	-1.5	89.6	11	84.1	47.8	46.0	44.2	42.4	40.6	38.8	37.0	35.2	33.4	31.6	29.8
September	0.0	87.8	11	82.3	47.5	45.7	43.9	42.1	40.3	38.5	36.7	34.9	33.1	31.3	29.5
October	-0.5	87.8	11	82.3	47.0	45.2	43.4	41.6	39.8	38.0	36.2	34.4	32.6	30.8	29.0
November	-2.5	87.8	11	82.3	45.0	43.2	41.4	39.6	37.8	36.0	34.2	32.4	30.6	28.8	27.0
December	-3.0	87.8	11	82.3	44.5	42.7	40.9	39.1	37.3	35.5	33.7	31.9	30.1	28.3	26.5

Table 4 *Cooling Load from conduction through roof*

Month	Room Temperature (Farenheit)										
	60.8	**62.6**	**64.4**	**66.2**	**68**	**69.8**	**71.6**	**73.4**	**75.2**	**77**	**78.8**
	Cooling Load (Q , BTU/Hr)										
January	2267.1	2176.5	2085.8	1995.1	1904.4	1813.7	1723.0	1632.3	1541.7	1451.0	1360.3
February	2458.6	2367.9	2277.2	2186.5	2095.9	2005.2	1914.5	1823.8	1733.1	1642.4	1551.7
March	2574.5	2483.8	2393.1	2302.4	2211.7	2121.0	2030.4	1939.7	1849.0	1758.3	1667.6
April	2498.9	2408.2	2317.5	2226.8	2136.2	2045.5	1954.8	1864.1	1773.4	1682.7	1592.0
May	2332.6	2242.0	2151.3	2060.6	1969.9	1879.2	1788.5	1697.8	1607.2	1516.5	1425.8
June	2307.5	2216.8	2126.1	2035.4	1944.7	1854.0	1763.3	1672.6	1582.0	1491.3	1400.6
July	2332.6	2242.0	2151.3	2060.6	1969.9	1879.2	1788.5	1697.8	1607.2	1516.5	1425.8
August	2408.2	2317.5	2226.8	2136.2	2045.5	1954.8	1864.1	1773.4	1682.8	1592.0	1501.4
September	2393.1	2302.4	2211.7	2121.0	2030.4	1939.7	1849.0	1758.3	1667.6	1576.9	1486.2
October	2367.9	2277.2	2186.5	2095.9	2005.2	1914.5	1823.8	1733.1	1642.4	1551.7	1461.0
November	2267.1	2176.5	2085.8	1995.1	1904.4	1813.7	1723.0	1632.3	1541.7	1451.0	1360.3
December	2242.0	2151.2	2060.6	1969.9	1879.2	1788.5	1697.8	1607.2	1516.5	1425.8	1335.1

2) Floor

Roof Material: 4 in. lightweight concrete

Cooling Load Temperature Difference (CLTD): 33F

Floor's U-value: $0.83 \frac{BTU}{h.ft^2.F}$

Area of Floor: 60.7 m^2

Table 5 *Corrected values of CLTD,* °F

Month	LM	Outside design dry bulb temperature, °F	Daily Temperature Range, °F	Average outside temperature, °F	Room Temperature, °F										
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March	0.0	91.4	11	85.9	57.1	55.3	53.5	51.7	49.9	48.1	46.3	44.5	42.7	40.9	39.1
April	-1.5	91.4	11	85.9	55.6	53.8	52.0	50.2	48.4	46.6	44.8	43.0	41.2	39.4	37.6
May	-3.0	89.6	11	84.1	52.3	50.5	48.7	46.9	45.1	43.3	41.5	39.7	37.9	36.1	34.3
June	-3.5	89.6	11	84.1	51.8	50.0	48.2	46.4	44.6	42.8	41.0	39.2	37.4	35.6	33.8
July	-3.0	89.6	11	84.1	52.3	50.5	48.7	46.9	45.1	43.3	41.5	39.7	37.9	36.1	34.3
August	-1.5	89.6	11	84.1	53.8	52.0	50.2	48.4	46.6	44.8	43.0	41.2	39.4	37.6	35.8
September	0.0	87.8	11	82.3	53.5	51.7	49.9	48.1	46.3	44.5	42.7	40.9	39.1	37.3	35.5
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November	-2.5	87.8	11	82.3	51.0	49.2	47.4	45.6	43.8	42.0	40.2	38.4	36.6	34.8	33.0
December	-3.0	87.8	11	82.3	50.5	48.7	46.9	45.1	43.3	41.5	39.7	37.9	36.1	34.3	32.5

Table 6 *Cooling Load from conduction through floor*

Month	Room Temperature , °F										
	60.8	**62.6**	**64.4**	**66.2**	**68**	**69.8**	**71.6**	**73.4**	**75.2**	**77**	**78.8**
	Cooling Load (Q , BTU/Hr)										
January	2569.4	2478.7	2388.1	2297.4	2206.7	2116.0	2025.3	1934.6	1843.9	1753.3	1662.6
February	2760.9	2670.2	2579.5	2488.8	2398.1	2307.5	2216.8	2126.1	2035.4	1944.7	1854.0
March	2876.8	2786.1	2695.4	2604.7	2514.0	2423.3	2332.6	2242.0	2151.3	2060.6	1969.9
April	2801.2	2710.5	2619.8	2529.1	2438.4	2347.8	2257.1	2166.4	2075.7	1985.0	1894.3
May	2634.9	2544.2	2453.6	2362.9	2272.2	2181.5	2090.8	2000.1	1909.4	1818.8	1728.1
June	2609.7	2519.1	2428.4	2337.7	2245.0	2156.3	2065.6	1975.0	1884.2	1793.6	1702.9
July	2634.9	2544.2	2453.6	2362.9	2272.2	2181.5	2090.8	2000.1	1909.4	1818.8	17281
August	2710.5	2619.8	2529.1	2438.4	2347.8	2257.1	2166.4	2075.7	1985.0	1894.3	1803.6
September	2695.4	2604.7	2514.0	2423.3	2332.6	2242.0	2151.3	2060.6	1969.9	1879.2	1788.5
October	2670.2	2579.5	2488.8	2398.1	2307.5	2216.8	2126.1	2035.4	1944.7	1854.0	1763.3
November	2569.4	2478.7	2388.1	2297.4	2206.7	2116.0	2025.3	1934.6	1843.9	1753.3	1662.6
December	2544.2	2453.6	2362.9	2272.2	2181.5	2090.8	2000.1	1909.4	1818.8	1728.1	1637.4

4.2 Results and Discussion

Calculation for conduction and radiation through glass is pending at the moment because of unavailable data needed which are the U-value and CLTD for glass and also the Maximum Solar Heat Gain Factor. Upon obtaining these data, the calculation of the heat conduction and radiation through glass walls can be calculated. In the meantime, calculation of the heat gain from internal sources will be done to proceed with the project.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

In conclusion, this research project is focusing on designing a solar powered absorptive refrigeration process through calculation and simulation in order to evaluate the coefficient of performance of the system as compared to the existing system.

For recommendations, future work in this area needs to be done in order to refine the potential of establishing the solar powered absorptive refrigeration process, as it is believed that it can be an alternative in the energy sector to reducing the dependence in fossil fuel. Furthermore, future analysis and research on this matter should be done to improve the system to make it more accepted by the market and explore the possibilities of the system to be used in many houses and buildings.

Thus, this research is another contribution to the energy sector itself, to be exploitable and acceptable by the local community and contributes to bringing forward the potential use of alternative energy in Malaysia.

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