DESIGN AND DEVELOPMENT OF COOLING SYSTEM FOR FRUITS AND VEGETABLES

BY

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING. FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

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DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

18/1/11

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CERTIFICATION

This is to certify that the project entitled "Design and Development of Cooling System for fruits and vegetables " by Ibrahim, Aderemi Kozeem meets the regulation governing the award of degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

I dedicate this project work to Almighty Allah for His infinite mercy and to my parents for their tremendous support.

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ABSRACT

Fruits and vegetables preservation after harvest in order to retain the quality is quite tasking especially during the hot periods of the year. In this work a portable cooling and storage system was developed for fruits and vegetables in transit. The storage provides a periodic sprinkling of water on the fruits as practiced by the traditional fruit sellers on wheelbarrows. It has the capacity of storing 15.451kg of product. The performance tests showed that the average storage temperature of the inner chamber of the system was 28°C while the relative humidity of the chamber was 93.2%. The average weight of the samples of the vegetable products inside the system during the test period was fairly constant compared to those stored outside the system which shows signs of shrinkage and witting. The storage provides a better way of storing and preserving the products.

TABLE OF CONTENT

Chapter Two

Chapter Three

Chapter Four

Chapter Five

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Most farmers are faced with problems of distribution of farm produce from the farm to the market or consumers due to lack of good transportation and storage systems. Fifty percent of farm produce like fruits and vegetables are lost in transit from the farm to the consumers (Alebiowu, 1985). These leads to low return to the farmers resulting in less production of produce. The losses usually emanate from the inadequate facilities specially at the farm gate and distribution centres.

Fresh fruits and vegetables start to deteriorate immediately after harvest. The rate at which the farmers or sellers of these products exposed them to direct sunlight before getting to the final destination makes the product deteriorate faster and also reduce the nutritional value of the produce thereby reducing the shelf-life of the products. In most centers where fruits and vegetables are sold, the farmers/ traders sprinkle water on the fresh products to prevent them from losing moisture which usually results in shriveling of the products. It is thus desirable to have a simple system that will perform similar function.

Provision of cooling system can help in reducing the spoilage of fruits and vegetables in transit. Design and fabrication of a simple cold storage system for fruits and vegetables can greatly reduce losses.

1.2 Objectives of the Study

The objective of this project is to design and fabricate a simple cold storage system that can be used to store fruits and vegetables in transit with a view to reduce the incidence of shriveling.

1.3 Justification

The recognition of an increasing and worldwide demand for high quality in fruits and vegetables has grown in recent years. Unfortunately, these important commodities are highly perishable in their fresh forms, which results in scarcity during offseason resulting in exorbitant prices.

Since cooling is the process of removing heat from an enclosed space or from the farm product, therefore the development of the cooling system for fruits and vegetables can help the farmers in the preservation and storage of fruits and vegetables and also prevent such product from direct exposure to sunlight as is currently being practiced in most distribution centers in Nigeria.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Fruits and Vegetables

Fruits are important due to their carbohydrate and vitamins contribution to human diet. Most fruits contain large quantities of sugar and vitamins such as vitamins A and C which are lacking in other food items such as grains (Ndirika, 1992).

2.2 Methods of Fruits and Vegetables Storage

There are various methods or techniques that can be applied in storing fruits and vegetables which could be at low temperature, ambient temperature, in clay pot with jute bag at ambient temperature (Ndirika, 1992).

In storing at low temperatures to avoid frost damage, storage temperature should be about 1 to 4 degree Celsius(Ndirika, 1992).

2.3 Cooling System

It is highly advised to place harvested fruits and vegetables as soon as possible in a storage environment that is kept at the appropriate temperatures and to retain such temperatures thereafter. Different storage temperatures had been established for different products. These different temperatures need to be verified for each product, considering the degree of maturity, the variety, and the growing region of the produce. There are ranges of cooling techniques available (*Desruelles et al.,* 1997), including the following:

2.3.1 Air Cooling

Air-cooling requires the supply of cold fresh air (RH 85-90%) to bulk or packaged products. This system requires moderate investment. Controlling parameters are easy and the system is made up of separate modules. However the cooling process is very slow and not homogenous (Thomspon, 1987). In regions without access to electricity, very low-cost cold stores can be built which rely on evaporative cooling. Storage in pits or caves is a traditional means of taking advantage of the cool and more constant temperatures below ground. Night air can be used to lower the temperature of a well-insulated cold store, which is then sealed during the daytime (*Desruelles et al.,* 1997).

2.3.2 Forced Air Cooling

The simplest design is achieved by building parallel stacks of palletized cartons in a refrigerated cold room. The gap between the two parallel rows of pallets is closed with a cover. A small fan is placed at one end. The exhaust fan removes air from the enclosed space, so that the pressure falls. Cold air then flows through the ventilation slots in each carton. Advantages of forced-air cooling are its capital cost, its flexibility (cartons, bins, before or after packing) and lack of condensation. Forced-air cooling is more rapid than air-cooling but not as rapid as hydro-cooling or vacuum-cooling (*Desruelles et al.,* 1997).

2.3.3 Hydro Cooling

Hydro-cooling involves immersing the produce in cold water. The advantages of this method are speed, uniform cooling and no weight loss by dehydration. Disadvantages of the system include the need to dry the product surface after cooling and build-up or transmission of diseases in the hydro-cooling water. There are also problems with the requirement for a large quantity of clean water, disposing of waste water, heavy capital cost and the system is not applicable to all types of packaging especially cartons. This technique is used for small fruits or vegetables, leafy vegetables and pineapple. Another system which uses less water involves passing the produce through a cold mist at about 5° C (*Desruelles et al.,* 1997).

2.3.4 Vacuum Cooling

Vacuum-cooling is particularly effective for leafy greens. The products are placed in a chilled vacuum chamber and air is exhausted by a vacuum pump. When the pressure is low enough the water in the produce starts to evaporate and cools the tissue. Pre-cooled fruits and vegetables are then placed immediately into a cool room. The decrease in temperature is very rapid but this technique is capital-intensive (*Desruelles et al.,* 1997).

2.3.5 Evaporative Cooling Process

Evaporative cooling process is a constant heat process which can be analyzed by using a psychometric chart

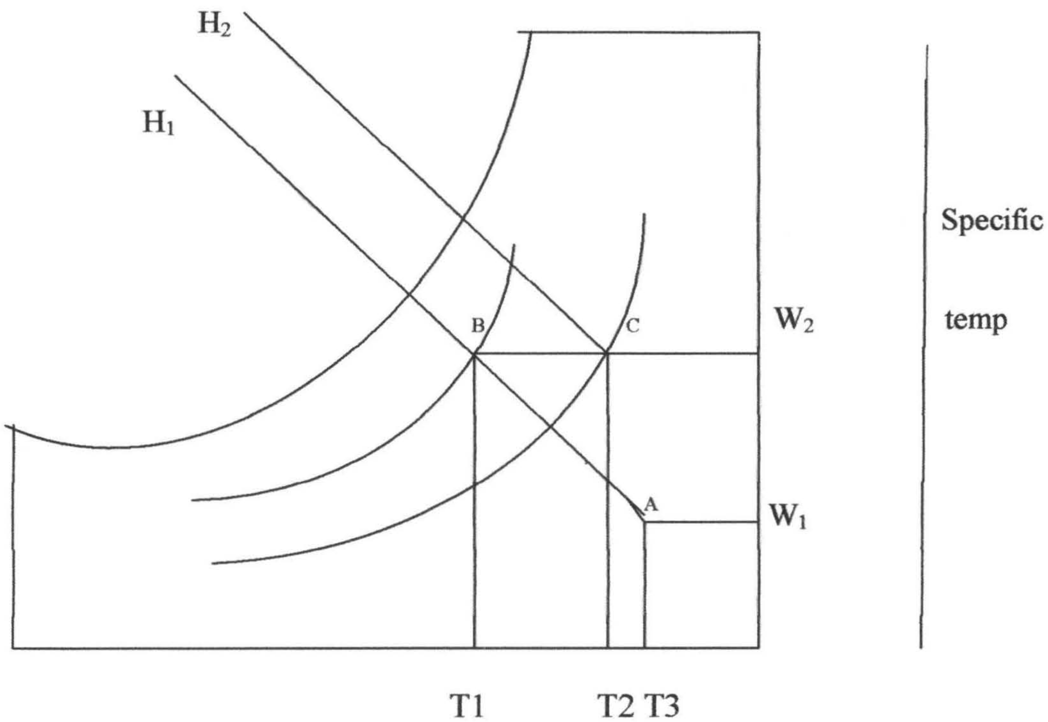

Figure 2.12 Psychometric chart of evaporative cooling system

Point A represent the condition of the air before it enters the cooler, which is normally indicated by its Dry bulb temperature, Wet bulb temperature or Relative humidity of the air.

The Dry bulb temperature of the air leaving the cooler $(DBoff)$ is obtained from the expression,

$$PE = \frac{\text{DBon} - \text{DBoff} \times 100}{\text{DBoff} - \text{WBon}}$$

Where,

PE = Percentage efficiency adiabatic of the cooler,

$DBon$ = Dry bulb temperature of air entering the cooler.

$DBoff$ = Dry bulb temperature of air leaving the cooler.

$WBon$ = Wet bulb temperature of air entering the cooler.

Note that the Wet bulb temperature (WB) of the air remains unchanged. Point B can be plotted as shown above combining $DBoff$ and $WBoff$ ($WBoff = WBon$).

The cooler must be considerably lower in temperature (DB) then the system air in order to hold the quantity of supply of air within reasonable units. For the purpose of the design, the condition of air at point B is generally assumed to be warmed up to 5°C. With this condition, point C is plotted at the intersection of the horizontal line from B with the vertical dry bulb temperature of the system condition (Norman, 1983).

2.4 Controlled Atmospheric Storage

A controlled atmosphere (CA) storage is one in which the oxygen level is reduced and the carbon dioxide level is increased during product storage. Such controlled atmosphere lowers the respiration level and thus extend the storage life of some products. Proper oxygen and carbon dioxide level for the product and storage temperature may double the normal Refrigerated storage life of the product (Woolich, 1997). Controlled atmosphere storage must be tightly sealed to maintain the desired atmospheric conditions. Doors, joints of construction and all construction should be gas tight. To reduce the gas diffusion through the walls, a plastic liner is frequently used. A plastic lung, and plastic bag external but connected, is used to allow the gas to extend or contract without collapsing the storage walls.

Numerous fruits are stored under controlled atmosphere storage among which are apples, pears and cherries primarily for sales as fresh fruits. The use of controlled atmosphere storage is increasing in popularity among growers of fruits and vegetables varieties for fresh market because added flexibility in marketing is possible with the longer potential storage period (Goldburg, 1987).

Controlled temperature storage is a common method of storage for some fruits prior to freezing. In principle, a controlled atmosphere high in carbon dioxide and low in oxygen content slows down the rate of respiration, which may extend shelf life of any respiring fruit during storage. Due to the fact that these fruits do not ripen appreciably after picking, most fruits are picked as near to eating-ripe maturity as possible(Shachtman, 2000).

2.5 Hypobaric Storage

Hypobaric storage is a refrigerated storage in which commodities are maintained under low pressure, high relative humidity conditions. Other terms used for this type of storage are sub atmospheric pressure storage, low pressure storage and vacuum storage.(Goldburg, 1987).

2.6 Refrigeration

Refrigeration is defined as the elimination of heat from a material at a temperature higher than the temperature of its surroundings. The mechanism of refrigeration is a freezing process and freezing storage involves the thermodynamic aspect of freezing (Anderson, 1992). According to the second law of thermodynamic, heat only flow from higher to lower temperatures. Therefore, in order to raise the heat from a lower to a higher temperature level, expenditure of work is needed. The aim of industrial refrigeration process is to eliminate heat from low temperature points towards points with higher temperature. For this reason, either closed mechanical refrigeration fluids circulate, or open cryogenic systems with liquid nitrogen (LIN) or carbon dioxide (CO_2), are commonly used by the food industry (Stoecker and Jones, 1982).

The main element in a closed mechanical refrigeration system are the condenser, compressor, evaporator and the expansion valve. The refrigerants, hydro chlorofluorocarbon (HCFC) and ammonia are examples of the refrigerants used in these types of mechanical refrigeration systems (Andrew *et al.*, 2003).

2.7 Freezing Point

The effect of freezing, frozen storage, and thawing on fruit quality has been investigated over several decades. Today frozen fruits constitute a large and important food group (Skrede, 1996). The quality demanded in frozen fruits products is mostly based on the intended used of the product. If the fruit is to be eaten without any further processing after thawing, texture characteristics are more important when compared to use as a raw material in other industries. In general, conventional methods of freezing tend to destroy the turgidity of living cells in fruit tissues. Compare to vegetables, fruits do not have a fibrous structure that can resist this destructive effect. In addition, fruits to be frozen are harvested in a fully ripe state and are soft in texture. On the contrary, a great number of vegetables are frozen in an immature state (Boyle *et* *al.,*1977). Fruits have delicate flavors that are easily damaged or changed by heat, indicating they are best eaten when raw and decrease in quality in processing. In the same way, attractive colour is important for frozen fruits. Chemical treatments or additives are often used to inactivate the deteriorative enzymes in fruits. Therefore, proper processing is essential for all steps involved, from harvesting to packaging and distribution (Skrede, 1996).

2.8 Production and Harvesting

The characteristics of raw materials are primary importance in determining the quality of the frozen product. These characteristics include several factors such as genetic makeup, climate of the growing area, type of fertilization, and maturity of harvest (Boyle *et al.,* 1977).

The ability to withstand rough handling, resistance to virus disease, molds, uniformity in ripening, and yield are some of the important characteristics of fruits to be considered in production. The use of mechanical harvesting generally causes bruising of fruits and results in rapid deterioration. In contrast, hand picking provides gentler handling and sorting of fruits. However in most cases, it is non-economical compared to mechanical harvesting due to high labour cost (Boyle *et al.,* 1977).

As a result, harvesting of fruit at an optimum level for commercial use is difficult. Simple tests like pressure tests are applied to determine when a fruit has reached optimum maturity for harvest. Colour is also one of the characteristics used to determining maturity since increase maturation causes a darker colour in fruits. A combination of colour and pressure tests is a better way to assess maturity level for harvesting (Skrede, 1996).

In summary most of these methods and systems of cooling and storing of fruits and vegetables are capital intensive and cannot easily be affordable by the peasant farmers and handlers of these products, hence there is a need to explore other simpler means using the easily available materials.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Design methodology

The following are principles used for the design and development of the cooling system for fruits in transit.

3.2 Design consideration

The design of the cooling system is concerned with attaining an appropriate temperature and relative humidity for the system so as to keep the fruits and vegetables fresh.

3.3 Description of the machine

The cooling system is made of aluminum in rectangular box shape with a length of 500mm, breath of 500mm and height of 1100mm. The rectangular box is then lagged with a length, breath and height of 50mm, 25mm and 50mm respectively. A rock wool material is used to lag the system so as to reduce the amount of heat produced within the system.

The system is then divided into three compartments separated with perforated trays, each of which is fixed with a perforated pipes where the fruits and vegetables will be placed. The pipes are 220mm apart from one another. The trays are also separated 220mm from one another.

The pumping machine has power of 0.5hp with frequency of 50hz and velocity of 220V and a model number of MKP.60 and also has a thermal protector. The door of the cooling system is made up of transparent glass.

3.4 Material required

The materials that make up the system include water pump, reservoir, perforated pipes, tubes, tray, aluminum sheet, transparent glass, rock wool, wheel, net, handle, tomatoe, spinach and alfalfa.

3.5 Component design

3.5.1 Pipe design

The pressure drop due to frictional resistance to flow in pipe was calculated using Manning equation and Darcy formula as given below:

$$Pf = 0.0929 \times 10^{-2} \mathrm{FLWVm}^3$$

Where

Pf-Pressure drop, F-Coefficient of friction, L-Length of pipe, W-Specific weight of fluid, V-Velocity, m- mass of water

$$\mathrm{m} = \frac{(4\mathrm{q})^{1/2}}{cdv}$$

d = Pipe diameter, q=flow rate of arm$^{3/s}$(61.25×10^2 m/s), v=air velocity (15.83m/s)

Substituting into equation, the pressure is given as

$$Pf = \frac{0.092 \times 10 \times 0.6 \times 3.28 \times 0.08 \times 48.252}{3.0}$$

$$= 9.4592 \times 10^{-3}$$

$$= 2367.5\ N/m^2$$

Total pressure loss in the pipe for water transport is given by the relationship(Kumar, 2006),

where, P= Total pressure loss, Pm= Measured pressure, Ps=standard pressure, Pf= Pressure drop.

$$P = Pm + Ps + Pf$$

$$= 0.234 + 0.424 + 9.45$$

In Pascal or N/m^2

$$= 10.128$$

$$= 99.38\ N/m^2$$

3.5.2 Design of the main cooling chamber capacity

The volume of the cooling chamber can be mathematically represented as;

$$V = L \times B \times H$$

Where, V= Volume

L= Length,50cm

B= Breadth,50cm

H= Height,110cm

$$V = 50cm \times 50cm \times 110cm$$

$$= 275000cm^3$$

$$= 0.275m^3$$

3.5.3 Design of each layer

The volume of each layer can be calculated mathematically as

$$V = L \times B \times H$$

Where,L-50cm, B-50cm, H-22cm

$$= 50cm \times 50cm \times 22cm$$

$$= 55000cm^3$$

$$V = 0.055m^3$$

For the three layers, the total volume;

$$V = 0.055\text{m}^3 \times 3$$

$$= 0.165\text{m}^3$$

3.5.4 Bulk density

The bulk density of tomatoes was determined experimentally by weight volume method under natural filling condition, in order to estimate the theoretical capacity of the system.

$25.75kg$ of green tomatoes occupied a volume of $2.75 \times 10^{-1}m^3$ of a standard container. The bulk density can therefore be calculated as

$$Db = \frac{\text{Ms}}{\text{Vs}}$$

Where,

Db = Bulk density (kg/m^3), Ms = Mass of samples (tomatoes)(kg), Vs = Volume occupied by the samples (m^3)

$$\therefore Db = \frac{25.75 \text{ kg}}{2.75 \times 10^{-1}\text{m}^3}$$

$$Db = 93.64kg/m^3$$

3.5.5 Cooling system capacity

The volume of one tomato can be calculated as,

$$V = \frac{4}{3}\pi r^3$$

Where V= Volume

r = radius, 0.24cm

π= 3.142

$$V = \frac{4}{3} \times 3.142 \times (0.24\text{cm})^3$$

$$= 1.33 \times 3.142 \times 0.013824\text{cm}^3$$

$$= 0.0577686cm^3$$

$$V = 0.000579m^3$$

Assuming 285 tomatoes are to be stored, the total volume (TV) is

$$TV = 0.000579 \times 285$$

$$TV = 0.165m^3$$

The total volume is $1.65 \times 10^{-1}m^3$

Therefore, the capacity of the system is

$$C = Db \times Vs$$

Where C-Capacity, kg, Db-bulk density, 93.64kg/m^3, Vs-Volume, 1.65×10^{-1}m^3

$$C = 93.64 \times 1.65 \times 10^{-1}$$

$$C = 15.451\ kg$$

3.5.6 Reservoir size

The volume of the reservoir can be represented mathematically as

$$V = L \times B \times H$$

Where, L- Length, 28cm

H-Height, 30cm

B-Breadth, 28cm

$$V = 28cm \times 28cm \times 30cm$$

$$= 23520cm^3$$

$$= 0.0235m^3$$

3.5.7 Pump selection

According to Olukoya (1998), in the pump selection, there are two essential qualities which the pump must be required of, and some restriction on the pump selection which may be present which are;

i) Minimum operating efficiency, ii) Pump speed, iii) Type of pump, iv) Static lift, v) Noise level, vi) Space available for pump and type of pump.

All these will influence the type of pump chosen. The specification given is the flow rate and operation head, usually referred to as duty required, and the first step is to know the pump speed.

From the specification of the pump, the capacity of the pump selected is 0.5hp (0.37kW) with a given voltage of 220V. The plug diameter of 2.5mm, frequency of 50hz, revolution of 2850rpm.

3.5.8 Analysis of the cooling required

3.5.8.1 Analysis of the cooling system

The efficiency of the cooling system was analysed using the relationship (Norman, 1983)

$$PE = \frac{\mathrm{DBon} - \mathrm{DBoff} \times 100}{\mathrm{DBon} - \mathrm{WBon}}$$

Where

PE = Percentage efficiency adiabatic of the cooler,

$DBon$ =dry bulb temperature of air entering the cooler,

$DBoff$ =Dry bulb temperature of air leaving the cooler,

$WBon$ =Wet bulb temperature of air entering the cooler,

This cooling system is designed for 90% efficiency. Cooling system is satisfactory only in areas where Dry bulb temperature is excess of 32.22°C combine with Wet bulb lower than 23.89°C (Norman, 1983).

The condition stated above suits that of the tropics, therefore the following data gotten from the school metrological station for so many years can be used for the design.

1)Dry bulb temperature DBT= $28°C - 34°C$

2) Wet bulb temperature WBT= $18°C - 19°C$

3) Relative Humidity(mean)= 73%.

For the purpose of the design the dry bulb temperature and wet bulb temperature that was used are 30°C and 19°C respectively.

The condition of air as it leaves the cooler can be predicted using the equation above

Where Percentage Efficiency adiabatic= $80\%= 0.8$

$DBon = 31°C, WBon = 19°C$

Substituting the value of dry bulb temperature leaving the cooler is

$$0.8 = \frac{31 - \text{DBoff}}{31 - 19}$$

$$0.8(31 - 19) = 31 - DBoff$$

$$9.6 = 31 - DBoff$$

$$DBoff = 21.4°C$$

Therefore,

$DBoff = 21.4°C, WBoff = 19°C$

With the help of Psychometrics chart analysis of system-air, sensible heat absorbed by the evaporated cooled air is seen in the figure below,

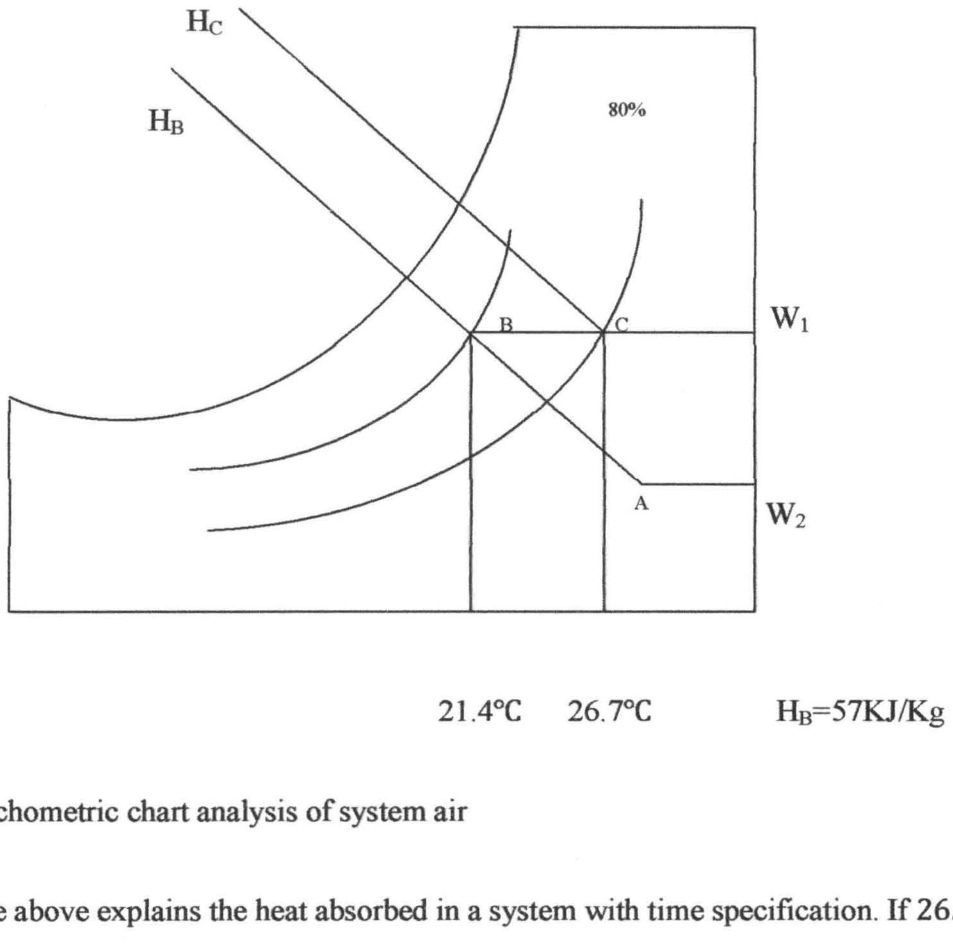

Figure 3.1 Psychometric chart analysis of system air

The figure above explains the heat absorbed in a system with time specification. If 26.7°C of dry bulb temperature is adopted as an acceptable space temperature.

$H_C = 60\ KJ/Kg$

R_C=Relative humidity at point C = 68%

The heat absorbed from the system air per kg of cool air calculated is given by

$$Hs = Hc - H_B$$

$$= 60 - 57 = 33KJ/Kg$$

The total amount of heat per hour which 1000cfm (0.47194m^3/s) of air through the cooler can absorb under the design condition is

$$H = \frac{Q}{\text{SpVol}}$$

Where,

H= Heat, Q= Quantity of air required, Hs= Sensible heat, and Sp= Specific volume

From the figure of air at condition A,

$$Specific\ volume, Sp = 0.275m^3/\text{Kg}$$

$$H = \frac{0.47194 \times 3}{0.275}$$

$$= 5.1484364KJ/sec$$

$$= 308.90618KJ/min$$

$$= 18534.371KJ/hour$$

From figure of air at condition A,

Specific volume= $0.275m^3/\text{Kg}$

At condition (A)=0.0084KJ/Kg of dry air(W1)

At condition (C)=0.0148KJ/Kg of dry air (W2)

The amount of water used is given by

$$AW = \frac{\mathrm{Q} \times \mathrm{W2} - \mathrm{W1}}{\text{specific vol}}$$

$$= \frac{0.47194 \times 0.0148 - 0.0084}{0.275}$$

$$= 5.1465 \times 10^{-3}\mathrm{Kg/s}$$

$$= 0.3088\mathrm{Kg/min}$$

$$= 18.5274 Kg/hour$$

Note that

$$1gal = 3.782Kg$$

Therefore for 18.5274 Kg, the amount of gallon of water is

$$= \frac{18.5274}{3.782}$$

$$= 4.899\mathrm{gal/hr}$$

Therefore 4.899gallons of water will be used in the project for the cooling of the fruits and vegetables.

3.5.8.2 Quantity of heat released

The quantity of heat released during cooling may be calculated approximately according to Gyorgy and Elsevier (1986) using the equation,

$$q = (\frac{C}{\propto F^1})qo\left[\frac{4\Delta\theta}{(\Delta\theta + 1) + \left(\frac{1}{b}\right)\left(2 - \frac{1}{\Delta\theta}\right)}\right](e^{b\theta 1} - e^{b\theta 2})$$

Where,

q = Quantity of heat released, (KJ), F^1 = Surface area of 1Kg of material,=0.019m^2, $\Delta\theta$ = Change in temperature,=10 °C, α = Heat coefficient,=16.74 KJm^{-2}h^{-1}c^{-1}, C = Product specific heat,=18534.7 KJKg^{-1}h^{-1}, θ_1=Initial temperature,=28 ^{0}C, θ_2 = Final temperature,=18 ^{0}C, q_0 & b = Constants =0.039 & 0.067.

$$q = \left(\frac{18534}{16.74 \times 0.019}\right)0.039\left[\frac{4 \times 10}{(10 + 1) + \left(\frac{1}{0.067}\right)\left(2 - \frac{1}{10}\right)}\right](e^{0.067\times 28} - e^{0.067\times 18})$$

$$q = 58283.019 \times 0.039 \times 0.8518 \times 3.1872$$

$$q = 6170.972KJ$$

3.5.8.3 Flow rate

The appropriate flow rate equation for the heat transfer is preserved by Newton-Rikhman law of cooling as

$$Q = hA(ts - tf)$$

Where,

Q = Heat flow rate, W, A = Area = $0.019m^2$, ts = Surface temperature = 28^0C, tf = fluid temperature = 18^0C, h = heat transfer= 6170.972KJ

$$Q = 6170.972 \times 0.019(28°C - 18°C)$$

$$Q = 1172.485W$$

3.6 Performance Test

A performance test was carried out on the system as follows; The designed and fabricated system was subjected to some performance test after assembling. First the water pump was switched on and water was pumped from the reservoir and circulated through the tubes to the perforated pipes which sprinkles the water on the chamber. After the empty test runs, some vegetables, spinach, tomato and alfalfa were harvested fresh in the early hours of the morning and stored in the system. Before storage some observation were made on the texture and colour of the samples. The relative humidity of the chamber and the surrounding was measured.

Water was then sprinkled at interval of 2hrs on the products while the same observation on texture and colour were carried out during the storage period. Some other samples of the vegetables were stored in the open in laboratory as control.

CHAPTER FOUR

4.0 Results and discussion

4.1 Results

The results of the measured physical parameter of fruits and vegetables in the developed cooling system (controlled sample) compared with the uncontrolled samples outside the system are shown in tables 4.1, 4.2, and 4.3 below;

Table 4.1:Results of the measured parameters on spinach stored in the system

Period	Relative Humidity (%)		Color		Texture		Defect	
(day)	Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled	uncontrolled	Controlled	Uncontrolled
1st	94	82	Light green	Light green	Turgid	Turgid	Nil	Nil
2nd	95	86	Light green	Light green	Turgid	Turgid	Nil	Nil
3rd	92	81	Light green	Dark green	Turgid	Wilting	Nil	Shriveling

Table 4.2: Results of the measured parameters on tomato stored in the system

Period	Relative Humidity (%)		Color		Texture		Defect	
(day)	Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled	uncontrolled	Controlled	Uncontrolled
1st	94	82	Light red	Light red	Hard	Hard	Nil	Nil
2nd	95	86	Light red	Light red	Hard	Soft	Nil	Nil
3rd	92	81	Light red	Yellowish red	Hard	Very soft	Nil	Decay

Table 4.3: Results of the measured parameter on alfalfa stored in the system

Period	Relative Humidity (%)		Color		Texture		Defect	
	Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled	uncontrolled	Controlled	Uncontrolled
1	94	82	Light green	Light green	Turgid	Turgid	Nil	Nil
2	95	86	Light green	Light green	Turgid	Turgid	Nil	Nil
3	92	81	Light green	Dark green	Turgid	Wilting	Nil	Shriveling

The average relative humidity inside the cooling system is,

$$= \frac{94 + 95 + 92}{3}$$

$$= 93.2\%$$

While the average relative humidity of the environment is,

$$= \frac{82 + 86 + 81}{3}$$

$$= 83\%$$

4.2 Discussion of result

The designed cooling system was fabricated and subjected to some performance tests. The water sprinkling ability of the system was very uniform over the entire chamber. This actually eliminates the energy usually expected by the handlings of the fruits and vegetables using the wheel barrow system.

The results showed that the average relative humidity obtained inside the chambers during the test period was 93.2% compared to the average relative humidity of the environment which was 83%. This relative humidity helps in reducing the rate of water lost in the produce thus preventing shrinkage and shriveling which normally results in unattractive appearance of the fresh vegetables.

The results of the observation, made on the three vegetables stored using the system are as shown in tables 4.1, 4.2, and 4.3. The results showed that the samples of vegetables stored in the cooling system remained fresh throughout the duration of storage while the uncontrolled samples showed signs of wilting and shriveling at the end of the second day.

CHAPTER FIVE

5.0 Conclusion and recommendation

5.1 Conclusion

After the design and development of the cooling system for fruits and vegetables was finished, test was carried out in the system using tomatoes, spinach and alfalfa.

From the experiment carried out in the system, it showed that 93.2% relative humidity was attained in the system to maintain the fruits and vegetables in their fresh form while 83% relative humidity was attained in the environment. The standard relative humidity required is 90-95% (Source: Industrial standard ASM, ASME, IEEE, ISO,APO) 2010, which implies that the system is effective enough for the purpose it was meant for. The observation during the test shows that shriveling and wilting takes place in the uncontrolled environment rapidly.

5.2 Recommendation

The following recommendations should be put in place to improve this cooling system,

1. An automatic switch should be connected to the water pump to regulate the flow of water in the system.
2. A 1Hp water pump should be used for effective spray of water.
3. The orifices of the discharge should be directed towards the inside of the system to avoid water from splashing outside the system.

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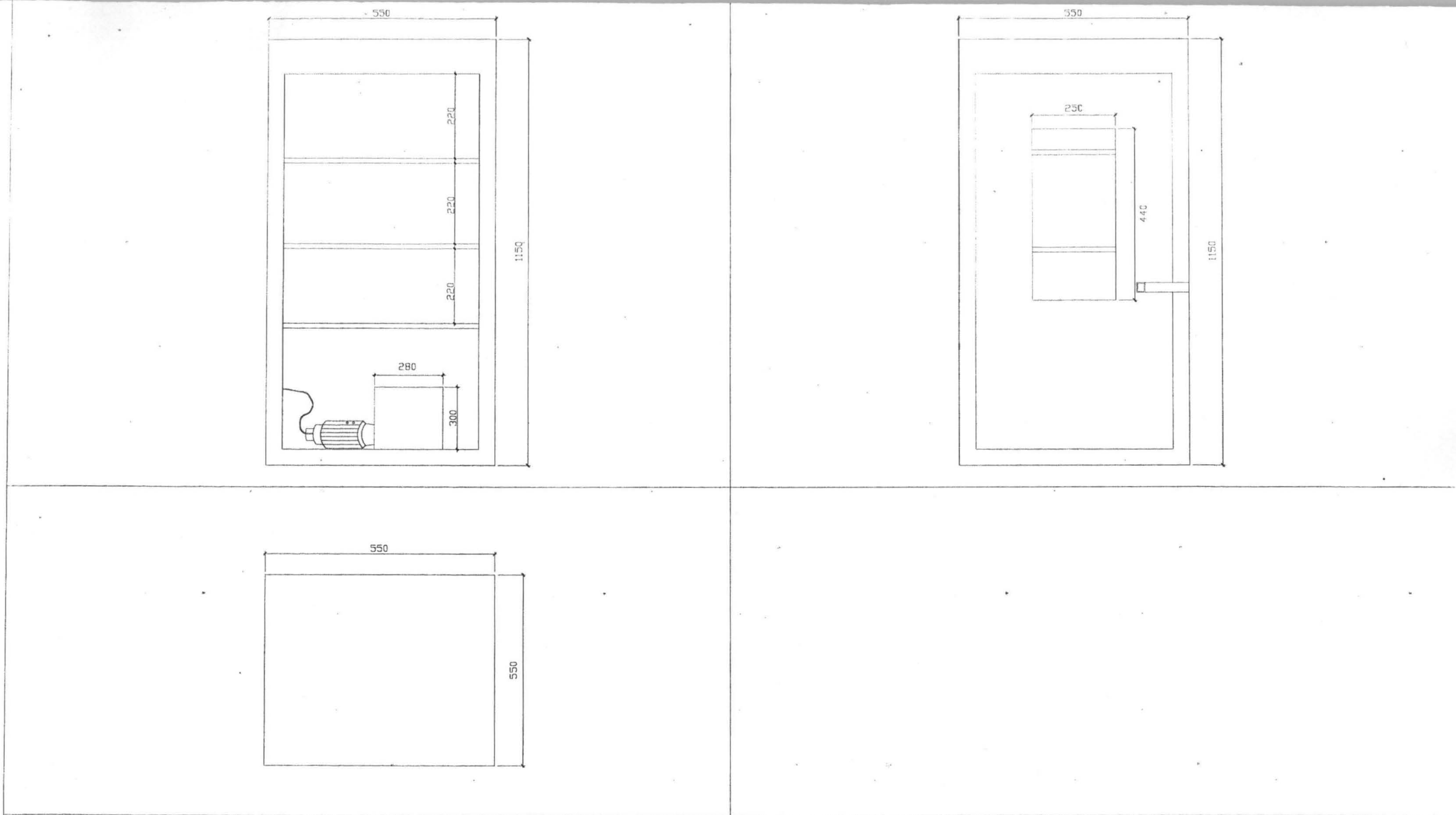
APPENDIX

Table 4.4: Material cost

S/NO	MATERIALS	QUANTITY	AMOUNT	PRICE
1	Pumping machine	1	9000	9000
2	Tray	3	400	1200
3	Pipe	1	450	450
4	Net	2	500	1000
5	Aluminum sheet	4	3000	12000
6	Handle	2	200	400
7	Wheel	4	150	600
8	Transparent glass	1	700	700
9	Punctured pipe	1	600	600
10	Rockwool	3	600	1800
11	Rivet pin	65	5	325
12	Latchet	1	40	40
13	Padlock	1	85	85
			TOTAL	28200



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	FINAL YEAR PROJECT	ORTHOGRAPHIC VIEW OF COOLING SYSTEM	CHECKED BY:	ENGR. P.A. IDAH
			APPROVED BY:	ENGR. P.A. IDAH
			DATE:	JANUARY 2011
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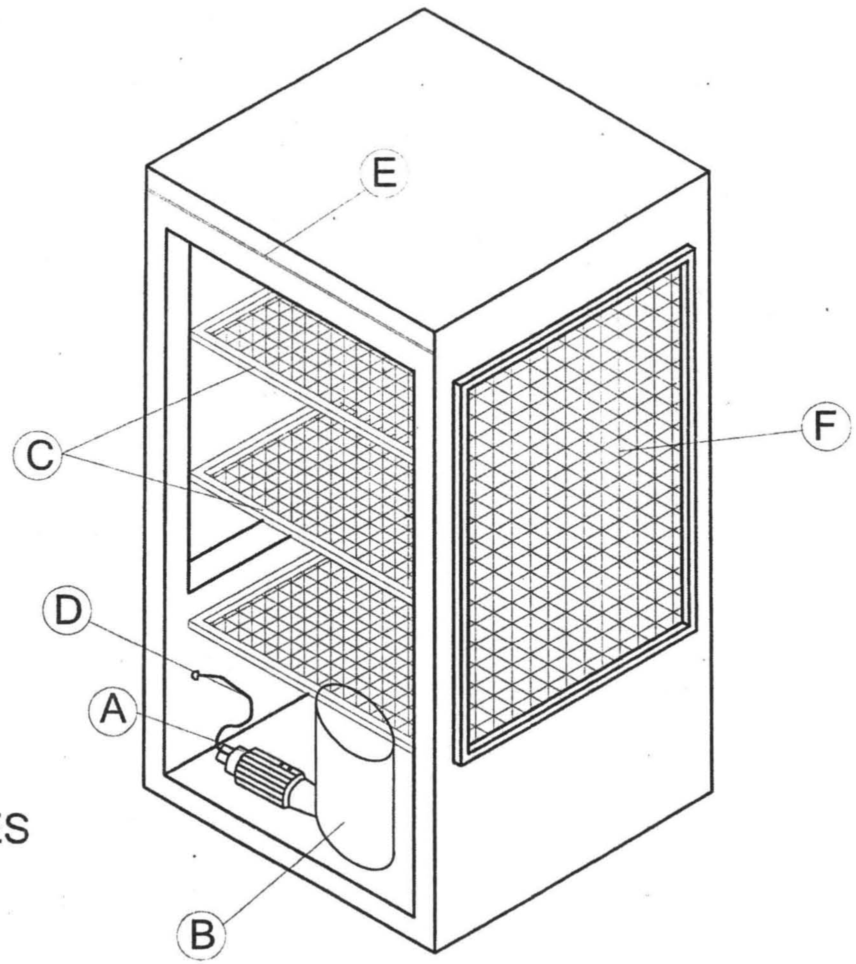

A = WATER PUMP

B = RESERVIOR

C = TRAY

D = PIPE

E = PUNCTURED PIPES

F = NET

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA.	PROJECT:	TITLE:	DESIGNED BY:	IBRAHIM ADEREMI . K.
	FINAL YEAR PROJECT	ISOMETRIC VIEW OF COOLING SYSTEM	CHECKED BY:	DR. ENGR. P.A. IDAH
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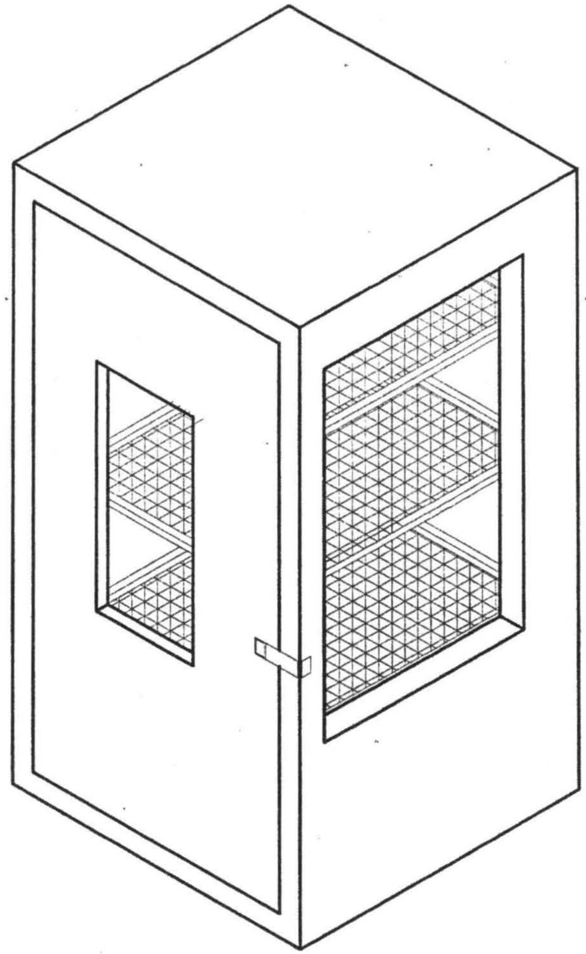

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	FINAL YEAR PROJECT	ISOMETRIC VIEW OF COOLING SYSTEM	CHECKED BY:	DR. ENGR. P.A. IDAH
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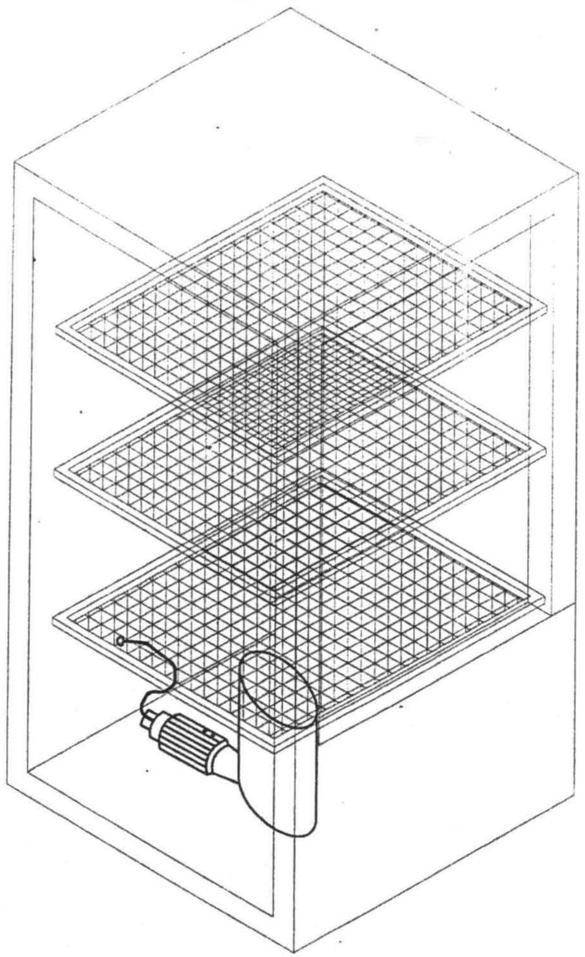

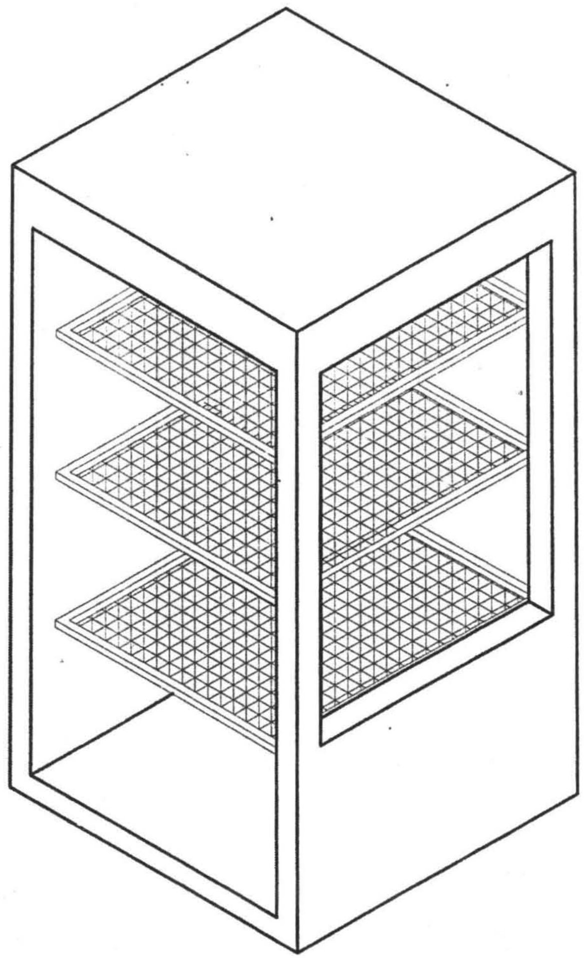

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA.	PROJECT:	TITLE:	DESIGNED BY:	IBRAHIM ADEREMI . K.
	FINAL YEAR PROJECT	SCHEMATIC ISOMETRIC VIEW OF COOLING SYSTEM	CHECKED BY:	DR. ENGR. P.A. IDAH
			APPROVED BY:	DR. ENGR. P.A. IDAH
			DATE:	DECEMBER 2010
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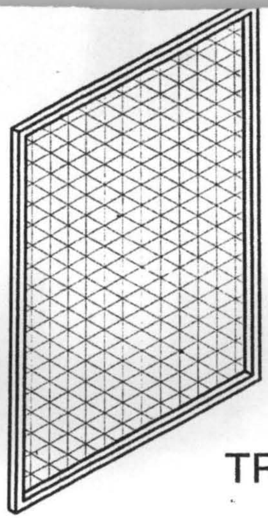

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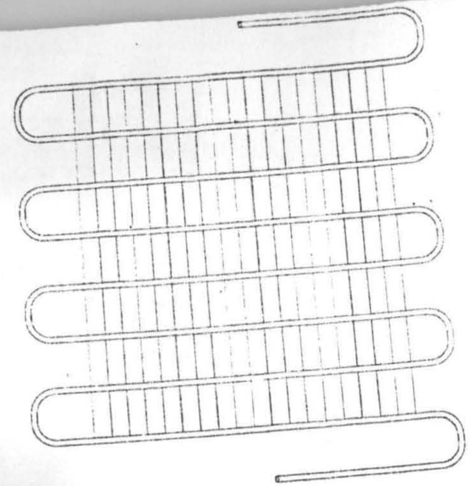
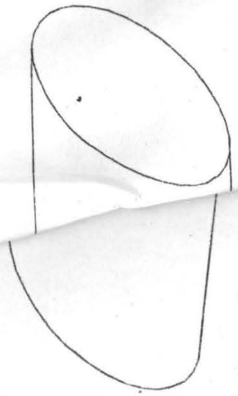
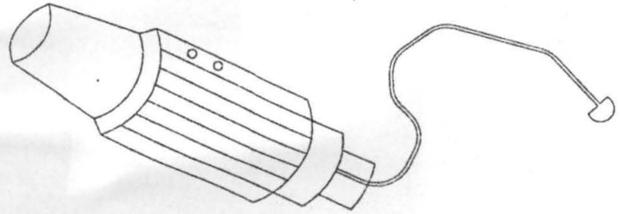


PIPE



RESERVOIR



WATER PUMP

RAL
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OLOGY

PROJECT:	TITLE:	DESIGNED BY:	IBRAHIM ADEREMI . K.
FINAL YEAR PROJECT	COMPONENT OF COOLING SYSTEM	CHECKED BY:	DR. ENGR. P.A. IDAH
		APPROVED BY:	DR. ENGR. P.A. IDAH
		DATE:	DECEMBER 2010