Development and Evaluation of a Prototype Refrigerated Cooling Table for Conference Services

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Abstract

This paper presents the development and evaluation of a prototype refrigerated cooling table for conference services. The major components of the table are compressor, condenser, evaporator, capilary tube, thermostat and table metal wooden frame. The table uses vapour compression cycle based on the Evans-Perkins (reverse Rankine) cycle as its principle of operation. The evaporator has three cabinet ports. Plywood and square mild steel pipes are used for the construction of the table frame. The refrigerated cooling table successfully reduces temperature of beverages from 35°C to 15.5°C, 13°C and 11°C, when placed in a plastic, glass and stainless steel containers respectively. The refrigerated cooling table performs better when compared with a standard domestic refrigerator. The coefficient of performance using experimental values is 5.14 with a compressor power of 69.3W for three participants.

1. Introduction

Refrigeration, during the Stone Age era, was known to the ancient Egyptians and people of India who used evaporation to cool liquid in porous earthen jars exposed to dry night air and to the early Chinese, Greek and Romans who use natural ice or snow stored in underground pits for cooling wine and other delicacies. The technique of mechanical refrigeration began with the invention of machine for making artificial ice.

The first known artificial refrigeration was demonstrated by William Cullen at the University of Glasgow in 1748. Cullen let ethyl ether boil into partial vacuum; he did not however use the result to a practical purpose. In 1805, an American inventor, Oliver Evans designed the first refrigeration machine that used vapour instead of liquid. Evans never constructed his machine, but a similar one was built by an American physician, John Gorrie in 1844. Commercial refrigeration is believed to have been initiated by an American businessman, Alexander twinning in 1856. Shortly afterwards, an Australian, James Harrison examined the refrigerators used by Gorrie and Twinning and introduced vapour compression refrigeration to the brewing and meat packing industries. In 1884, Dr. John Gorrie designed the first commercial reciprocating refrigerating machine in the United States. The first hermetically sealed motor-compressor was developed by General Electric Company for domestic refrigerators and sold in 1924.

The most outstanding developments in refrigeration was achieved when two refrigeration engineers, Midgely and Hene discover a nontoxic, non-flammable, fluorinated hydrocarbon refrigerant family called Freon in 1931. The chlorofluorocarbons (CFCs), Refrigerant–11 and refrigerant–12, became widely adopted commercial products in reciprocating and centrifugal compressors [1, 2]. However, due to the depletion of the ozone layer, the introduction of hydrofluorocarbons (HFCs) is gradually gaining grounds due to its non-ozone depleting substances. HFC-134a is a synthetic substance and has emerged as an alternative to Freon-12 [1].

The applications of refrigeration include, but not limited to household (domestic) refrigerators, industrial freezers, cryogenics, air conditioning and heat pumps [3]. In developing tropical countries like Nigeria, the use of refrigeration as a domestic refrigerators are the most prevalent due to very high temperatures. Domestic refrigerators are use for chilling beverages at homes, offices, seminars, cocktail parties, general meetings, canteens and conferences. However, during general meetings and conferences where participants are expected to be seated for a very long time, the beverage served loses its heat to the environment, causing it to reduce its palatability. To make it chilled again, the beverages are returned to the refrigerator distant away from the participants and left for several minutes before returning it to the participants. This practice of taking beverages away from the participant in some cases opened is unhygienic and unsafe. To circumvent this problem, Mohammed *et al.* [4] designed an innovative refrigerated cooling table to be used for conference services.

This paper presents the development and evaluation of a portable cooling table for conference services. The table is another innovative use of the principle of refrigeration. It is a multipurpose table which fulfils the requirement of a domestic refrigerator for maintaining low temperature of beverages while being able to be used to carry out other activities like conventional meeting tables.

1.1 Description of Principal Components of the refrigerated Cooling Table

The principal components of a cooling table are the evaporator, compressor, condenser, filter dryer, expansion valve, thermostat and the table metal and wood frame.

The *Evaporator* is a heat exchanger which provides a heat transfer surface for the transfer of heat from the body (beverages) being cooled to the refrigerant. The evaporator of the refrigerated cooling table has three coil-shaped cabinets (Figure 3). The cabinet itself is a cylindrical shaped thin aluminium foil on which the beverage cup/bottle will be placed and is between the beverage and the evaporator coil. Each cabinet is covered with a well lagged rectangular wooden box. Polystyrene is the lagging material used between the evaporator coils and the plywood. Figure 1 shows the three wooden boxes serving as a cover to the lagging material. The bottom cover of each box is fitted with a drainage hole, to allow for the draining of water. The three boxes are protected from the participant by a plywood cover (Figure2). Beverages are inserted through the evaporator cover. The evaporator cover is made of a circular plywood material. It fitted with handle and lagged with a polystyrene material to prevent heat losses to the surrounding as shown in figures 2 and 3.

The *Compressor* is a hermetic sealed vapour compressor which serves as the engine of the refrigerated cooling table. The function of the compressor is to pump refrigerant from evaporator to a very high temperature and pressure to the condenser. Hermetic sealed compressor is a design whereby the motor and the compressor are sealed in the same housing. The advantages of this design are that it minimizes leakage of refrigerant and the motor is cooled by the suction vapour flowing through the motor windings. The result is a smaller and cheaper compressor/motor assembly. The compressor is fitted on two auxiliary square pipe members. A square area is created at the wooden back cover of the table to allow for proper ventilation of the compressor as shown in figures 1 and 3.

The *Condenser* is another heat exchanger which provides a surface through which heat is transferred from the high pressure, high temperature refrigerant vapour to the condensing media resulting in the refrigerant being condensed to liquid [5]. The condenser is place at the back of the table to reduce the effect of heat transfer to the participants (Figure 3). The expansion valve used is a capillary tube. It is a coiled length of fine tubing that has a very small orifice of 0.5 to 2.0mm in diameter. The tube is employed because of the prototype nature of the refrigerated cooling table. At the capillary tube, high pressure is dissipated in forcing the liquid refrigerant through the small orifice and in the process, some of the liquid flashes into vapour as the refrigerant flows through the tube. The tube also regulates the amount of refrigerant that is supplied to the evaporator [6].

The *Filter/Dryer* is fitted in the system illuminate the moisture that may freeze in the expansion valve, especially in a low temperature system, and impair capillary tube operation. The presence of moisture can wash the lubricating oil in the cylinder of the compressor, thereby affecting its performance. While foreign matters in the refrigeration system may cause damage to the capillary tube and compressor. The fitter/dryer contains a Silica gel which tends to remove the moisture and foreign matters from the refrigerating system [1].

The *Thermostat* is a temperature sensitive device actuated by effect of temperature change on expansion qualities of solids liquids and gases. The sensitive element may be single metal strip, which shortens or lengthens, a bimetallic strip, which distorts or bends, fluid which expands or contracts [7]. A bimetallic strip is employed in the refrigerated cooling table to regulate the temperature of the evaporator in order to prevent freezing of the beverages. It is a white regulator place at the back of table as shown in Figure 3.

The *Table metal and wooden frame* is made of ¼ square inch mild steel pipe and plywood respectively. The metal frame is covered with plywood. The compressor, condenser, evaporator, filter/dryer and thermostat are mounted on the metal frame of the refrigerated cooling table as shown in Figure 1 and Figure 3.

Figure 1. The refrigerated cooling table showing internal components

Figure 2. Front view of a complete prototype refrigerated Cooling Table

Figure 3. Back view showing condenser, compressor and thermostat of the cooling Table

1.2 Operations of the refrigerated cooling table

The operation of the refrigerated cooling table is based on vapour compression refrigeration system. In this system, refrigeration is obtained when the refrigerant evaporates at low temperatures. Mechanical energy is required to run the compressor. The vapour compression cycle is based on the Evans-Perkins cycle and generally called the reverse Rankine cycle. The repetitive transformation of liquid to vapour and vapour to liquid is the basis on which vapour compression cycle depends. The major components of the system are the compressor, condenser, filter/dryer, thermostat, capillary tube, suction heat exchanger and the evaporator. Figure 4 shows the schematic of the refrigerated cooling table. Figures 5(a) and 5(b) shows operating cycle based on reverse Rankine cycle vapour compression refrigeration system on a T-s and P-h diagrams respectively.

When the refrigerant undergoes the process of vaporization (process 5-6) and extracts the latent heat from the low temperature, low pressure heat source (beverages), a refrigeration effect is achieved. The low temperature, low pressure refrigerant vapour is then compressed isentropically in the compressor (process 1-2). The refrigerant pressure and temperature increases from T_1 and P_1 to T_2 and P_2 respectively during the compression process as shown in Figures 5(a) and 5(b). The refrigerant vapour then moves to the condenser. At the condenser, the high pressure, high temperature vapour refrigerant undergoes the process of condensation isobarically and rejects the heat of condensation to an external heat sink (process 2-3). As the refrigerant changes from vapour to liquid, the refrigerant temperature reduces from T_2 to T_3, while the pressure remains constant (Figures 5(a) and 5(b)). The high pressure liquid refrigerant passes through the filter/dryer and moisture and solid particles are trapped. The high pressure refrigerant then passes through the counter flow heat exchanger (Figure 5, process 3-4) where the warm refrigerant liquid from the condenser isobarically exchanges heat with the cool refrigerant vapour from the evaporator. The temperature of the refrigerant is further reduced from T_3 to T_4 while the pressure remains constant (process 3-4). The refrigerant then moves to the expansion valve (Figure 4). At the expansion valve (capillary tube), the high pressure liquid refrigerant undergoes isenthalpic expansion and regulates the flow of refrigerant to the evaporator. The refrigerant pressure and temperature reduces from T_4 and P_4 to T_5 and P_5 respectively as shown in Figures 5(a) and 5(b) (process 4-5). Due to the drop in pressure, some amount of liquid refrigerant flashes into vapour and the exit condition lies in the two-phase region as it enters into the evaporator. At the evaporator, because of the low pressure of refrigerant, it boils at low temperature extracting the heat of vaporization isobarically and isothermally from the beverages in the evaporator (process 5-6). The refrigerant pressure and temperature remains the same as shown in Figures 5(a) and 5(b) [6]. The heat absorbed from the beverages by the refrigerant in the evaporator causes the temperature of the beverages to drop, thereby providing effective cooling (refrigerating effect) of the cooling table. Finally, before the refrigerant enters into the compressor, the low pressure, low temperature refrigerant then passes through the counter flow heat exchanger (Figure 5, process 6-1) where the cool refrigerant vapour from the evaporator isobarically exchanges heat with the warm refrigerant liquid from the condenser.

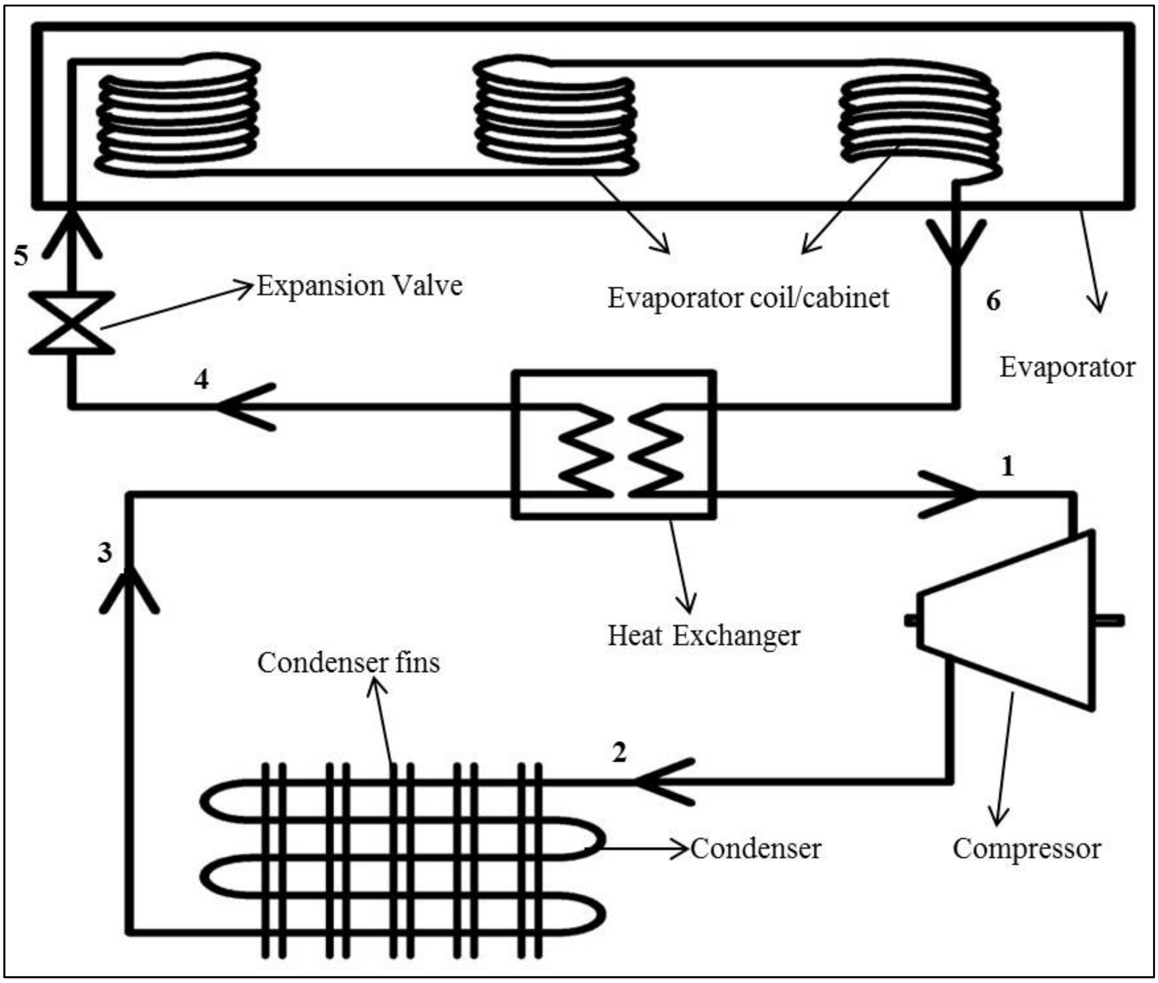

Figure 4. Schematic of the refrigerated components of the table

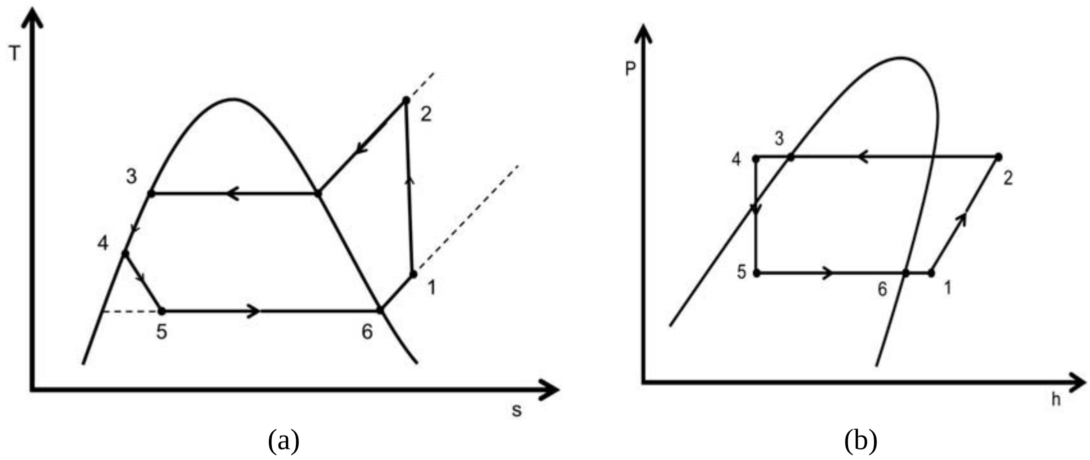

Figure 5. Flow Diagram for a Vapour compression Cycle, (a) P-h Diagram, (b) T-s Diagram.

2. Materials and Methods

The design of the evaporator, condenser and compressor of the refrigerated cooling table is given below. The material selections and evaluation procedure are also below.

2.1 Evaporator Design

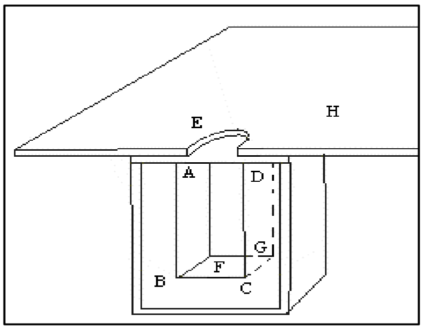

Figure 6. Diagram of Cooling Table Showing the Insulated Walls of a single port [4].

Evaporator load ($\dot{Q}_E$) which defines the rate at which heat is removed from the refrigerated space in order to attain and maintain the desired temperature consist of the usage load ($\dot{Q}_U$), the leakage load ($\dot{Q}_L$) and the supplementary load ($\dot{Q}_S$) as express in equation (1).

$$\dot{Q}_E = \dot{Q}_U + \dot{Q}_S + \dot{Q}_L \quad \textbf{(1)}$$

The rate of heat transfer through the surfaces (4 sides) of the evaporator cabinet (Figure 6), the base and the evaporator cabinet cover is defined as

$$\dot{Q}_E = \dot{m}c(T_2 - T_1) + \frac{3}{20}\dot{m}c(T_2 - T_1) + \left[\frac{4A_1\Delta T_1}{\left(\frac{x_1}{k_1}+\frac{x_2}{k_2}\right)} + \frac{A_2\Delta T_2}{\left(\frac{x_1}{k_1}+\frac{x_2}{k_2}\right)} + \frac{A_3\Delta T_3}{\left(\frac{x_3}{k_3}+\frac{x_6}{k_2}+\frac{x_7}{k_1}\right)}\right] \quad \textbf{(2)}$$

$$A_1 = ABxBC \quad \textbf{(3)}$$

$$A_2 = BCxCG \quad \textbf{(4)}$$

$$A_3 = \frac{\pi D^2}{4} \quad \textbf{(5)}$$

Where x_1, x_7 are polystyrene thickness; x_3 is *Formica* thickness; x_2, x_6 are the wood thickness; k_1 is the thermal conductivity of polystyrene; k_2 is the thermal conductivity of wood; k_3 is the thermal conductivity of Formica; ΔT is the change in temperature; U_1 is the heat transfer coefficient; A_1, A_2 & A_3 are the surface area of the respective lagging sides and the cabinet cover; D is the diameter of port; $\dot{Q}_C$ is the rate of heat transfer through cabinet cover.

The total length of the evaporator for a prototype refrigerated cooling table is given as;

$$L_T = nL + (n-1)L' = \frac{n\dot{Q}_E}{\pi D_i U \Delta T_f} + (n-1)L' \quad \textbf{(6)}$$

Where, L, L' and n are the length of coil for a single port, length of evaporator coil between two ports and number of ports respectively.

The volume of evaporator tube, V_e is given as

$$V_e = \frac{\pi D_i^2}{4} L_T \quad \textbf{(7)}$$

The cabinet volume of the three ports is express as.

$$V_c = \frac{n\pi D_c^2}{4} h \quad \textbf{(8)}$$

2.2 Condenser Design

Heat transferred through a fin, Q_f is given as

$$Q_f = \eta_f a_f h_o \Delta T_m \quad \textbf{(9)}$$

The number of fins, N_f required by the condenser is express as

$$N_f = \frac{\dot{Q}_{23}}{\dot{Q}_f} \qquad \textbf{(10)}$$

The length of finned condenser, L_f is

$$L_f = \frac{N_f \times w}{2} \qquad \textbf{(11)}$$

Volume of condenser tubing, V;

$$V = \pi D_i L \qquad \textbf{(12)}$$

Where, $\dot{Q}_{23}$ is the rate of heat rejected by the condenser; η_f is the fin efficiency; *w* is the condenser fin width; L is the length of tube.

2.3 Compressor Capacity

The capacity of the compressor for an adiabatic process is given as

$$\dot{w}_c = \dot{m}(h_2 - h_1) \qquad \textbf{(13)}$$

$$\dot{m} = \rho \dot{V}_s = \frac{\dot{V}_s}{v_1} \qquad \textbf{(14)}$$

Where, $\dot{w}_c$ is the rating of the compressor; $\dot{m}$ is the mass flow rate of the refrigerant; v_1 is the specific volume of refrigerant at compressor suction; ρ is the density of refrigerant; $\dot{V}_s$ is the compressor swept volume (m^3/s); h_1 is the enthalpy of refrigerant at compressor suction; h_2 is the enthalpy of refrigerant at inlet of the condenser.

2.4 Design Specifications

Table 1. Evaporator design calculation

Name	Abb	Values/Units
Area of side AB and BC	A_1	$0.0264m^2$
Area of side BC and CG	A_2	$0.0144m^2$
Area of cabinet port cover	A_3	0.00636
Rate of heat transfer through cabinet cover	$\dot{Q}_c$	0.3624W
Leakage load	$\dot{Q}_L$	3.762W
Usage load	$\dot{Q}_U$	13.93W
Supplementary load	$\dot{Q}_S$	2.09W
Evaporator load for a single port	$\dot{Q}_E$	19.78W
Refrigerating capacity	$\dot{Q}_r$	356.1W
Outside diameter of the evaporator tube	D_o	0.00635m
Inside diameter of the evaporator tube	D_i	0.00483m
Mean velocity of fluid	V	0.125m/s
Total length of evaporator coil	L_T	3.84m
Volume of evaporator tube	V_e	$7.026x10^{-5}m^3$

Table 2. Compressor design calculation

Name	Abb	Values/Units
Specific volume of refrigerant at compressor suction	v_1	$0.065m^3/kg$
Swept volume	$\dot{V}_s$	$1.946x10^{-4}m^3/s$
Rating of the compressor	$\dot{w}$	69.3W

Table 3. Condenser design calculation

Name	Abb	Values/Units
Length of condenser fins	L_f	43.5mm
Surface area of the fin	P_s	10mm
Cross sectional area of pipe	A	$2.25x10^{-6}m^2$
Fin index	m	$153.9m^{-1}$
Fin efficiency	η_f	0.1494
Heat transfer through a fin	Q_f	0.2306W
Rate of heat rejected by the condenser	$\dot{Q}_{23}$	425.39W
Number of fins	N_f	1845
Length of finned condenser tube	L_c	4.15m

2.5 Material selection

Material selection is the ability of the designer to choose the right type of material for the construction or fabrication of any engineering structure or components [2]. The key factors considered before choosing the materials used for the fabrication of the refrigerated cooling table are availability of materials, economic implications, fabrication requirements, service requirements and properties expected of the materials. Table 1 shows the materials used for the refrigerated cooling table.

Table 4. Material Selection

Parts	Materials	Reasons for selection
Table frame	Mild steel	High tensile strength, availability
Lagging material	Polystyrene	Lightness, low thermal conductivity, durability and low cost.
Table top and covers	Plywood	Low thermal conductivity, high resistance to electrical conductivity, low density and specific gravity and high resistance to chemical attack.
Cabinet	Aluminium foil	High thermal conductivity and resistance to corrosion.
Refrigerant	R-12	Availability, faint odor, non-flammability and the most widely used of all refrigerants, notably for commercial and domestic refrigeration.

2.6 Fabrication Procedure

The construction of the cooling table was carried out in the central workshop of the Department of Mechanical Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Minna, Nigeria. The procedures used for the fabrication of the refrigerated cooling table include cutting, shaping, turning, grinding, hammering, binding, drilling, sawing, bending, welding and painting. The development of the refrigerated cooling table has two stages; fabrication and assembly. The component fabricated includes; table frame, table top, formation of evaporation coil, fabrication of the cooling cabinet, construction of lagging and table covers. Evaporator, condenser, capillary tube, electric motor were assembled.

2.6.1 Construction

The material used for the fabrication of the table frame was a 254mm square pipe made of mild steel. It was marked, cut and welded at 2095mm (3pieces) x 645mm (2pieces) to form the top of the metal frame. The table stand was marked and cut at 523mm (4 pieces) and welded to the frame top. 8 auxiliary members of 2095mm (2 pieces), 503mm (2 pieces), 675mm (2 pieces) and 200mm (2 pieces) were marked, cut and welded to form the complete metal frame work. The welding was achieved by electric arc welding using filler rod and gauges 12 electrodes. A portable hand grinder was used for finishing of the joints after which holds were drilled on the frames using a hand-drilling machine for the purpose of mounting the plywood table top and covers.

The material used for the wooden part of the refrigerated cooling table was plywood of 19.05mm, 6.35mm and 12.7mm thick for the table top, covers (front, back and sides) and outer covers of evaporator lagging material respectively. The plywood was marked and cut at 2100mm x 650mm, 1955mm x 675mm, 2010mm x 675mm and 503mm x 680mm for table top, front, back and sides (2 pieces) covers respectively. A hand-drilling machine was used to drill holes at the edges of the covers for the purpose of mounting. The outer part of the evaporator was lagged by polystyrene, marflet and plywood. The polystyrene and plywood were formed into a hollow cuboid to give the required lagging for the evaporator cabinet, while the marflet is expected to lag the evaporator lines. The evaporator chambers were properly lagged (cover). The cabinet cover was made of Formica, ply-wood and polystyrene. These materials were cut into circular shapes to fit the diameter of the cabinet cover.

Formica material was then placed on top of the table to prevent heat transfer to any material being used on the table. The evaporator coil was made of 6.35mm diameter copper pipe. The evaporator was achieved by wounding round the evaporator coil on the evaporator cabinet and after the required number of turns was attained, it was extended to the next cabinet to form the evaporator chamber. The heat exchanger was achieved by bring together the low pressure, low temperature refrigerant coil in a counter-flow direction with the cool refrigerant vapour from the evaporator as shown in Figure 4 above.

2.6.2 Assembly

The evaporator cabinet which was made of aluminium foil was screwed to the under part of the tabletop directly under the ports. The evaporator coil was worn over the evaporator cabinet and it was held in place using clips. The lagging of the evaporator was made up of the lagging box and the flexible lagging hose. A drain hose was attached to the drain hole of the lagging box after which the lagging box was used to lag the evaporator cabinet and it was held to the table using holders. The flexible lagging hose was then used to lag the length of evaporator coil between the ports which was horizontal for ease of fabrication and also the suction line. The compressor, condenser, capillary tube, thermostat, filter/dryer were all mounted along the refrigeration cycle on the metal frame of the table.

2.7 Performance Evaluation and Testing Procedure

The refrigerated portable cooling table was painted and ready for testing. The vapour refrigerant was charged into the system to check for leaks. It was confirmed that there was no leaks. Vacuum pump was connected to the system through gauge manifold and the system was vacuumed. The vacuum pump was allowed to run for two hours before refrigerant was allowed to flow into the system. A small amount of R12 was charged into the system and it was purged to help clean out the system. The power supply circuit was then connected to the compressor.

The apparatus used to carry out the performance evaluation of the refrigerated cooling are the digital thermometer, stop watch and plastic, glass and stainless steel cups. Water was used as a sample for testing. The cooling table was switched on and after 15mins, the cabinet attained a temperature of 7^0C. This temperature was maintained throughout the experiment with the aid of a thermostat. The ambient temperature was 28^oC. 33cl of water was placed in a plastic cup and inserted into the evaporator cabinet of the cooling table. A digital thermometer was inserted into the water and the temperature recorded. The cabinet was closed. After 5mins, the cabinet was opened and the thermometer inserted into the water. The value obtained was recorded. The temperatures were measured after every 5mins interval for 60mins. A thermostat was used to regulate the temperature of the evaporator. The experiment was repeated using glass and stainless steel cup containers and the water temperature values were noted and recorded. The product temperature obtained at five minutes time interval for plastic, glass and stainless steel containers are shown in table 2.

In other to evaluate the performance of the refrigerated cooling table, the experiment was also carried out using standard domestic refrigerator located at Leeds, United Kingdom. The results obtained from the second experiment are also shown in table 5.

Table 5. Experimental Temperature result sheet (^{0}C).

Time (mins)		0	05	10	15	20	25	30	35	40	45	50	55	60
Plastic	Table	35	29.5	26	23	20	18.5	17	16	15.5	15.5	15	15	15
	Fridge	35	31.5	29.5	27	26.5	25.5	25	24	23.5	23	22.5	22	21.5
Glass	Table	35	28	23.5	19	17	15.5	14.5	13.5	13	12.5	12.5	12.5	12.5
	Fridge	35	30.5	28.5	26.5	25.5	24.5	23.5	23	22.5	22	21.5	21	20.5
Stainless Steel	Table	35	27	22	18	15	13	12.5	11.5	11	11	11	11	11
	Fridge	35	29	26	23	19	18.5	18	17.5	17	16.5	16	15.5	15

3. Results

The temperature obtained when liquid (water) was put inside a plastic, glass and stainless steel containers for the refrigerated cooling table and a domestic refrigerator were recorded. The graph of temperature against time for each container was also plotted as shown in Figures 7, 8 and 9.

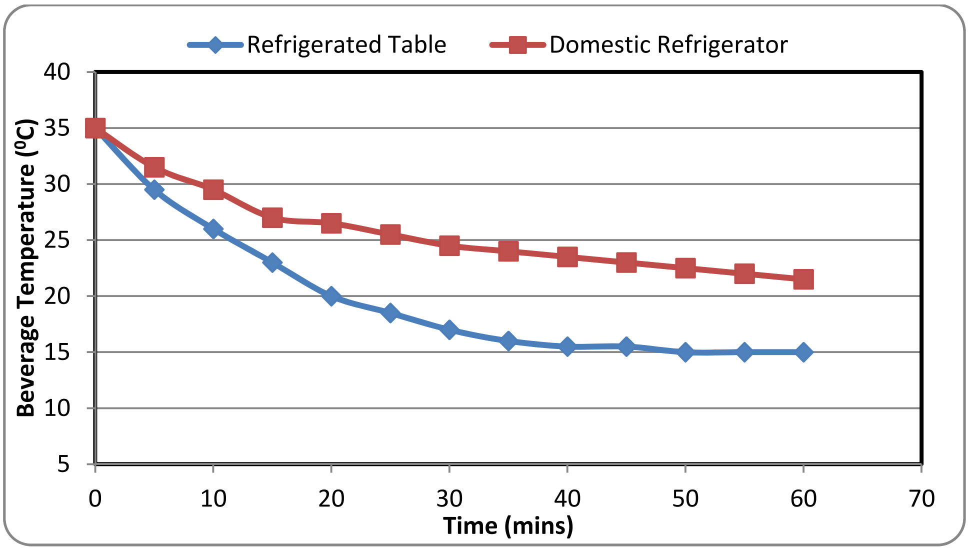

Figure 7. Plastic material

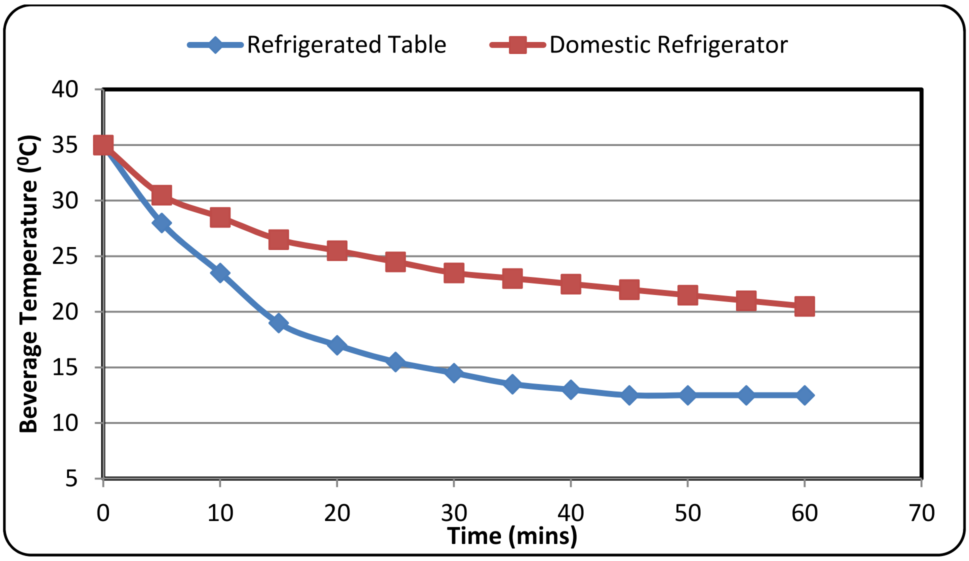

Figure 8. Glass material

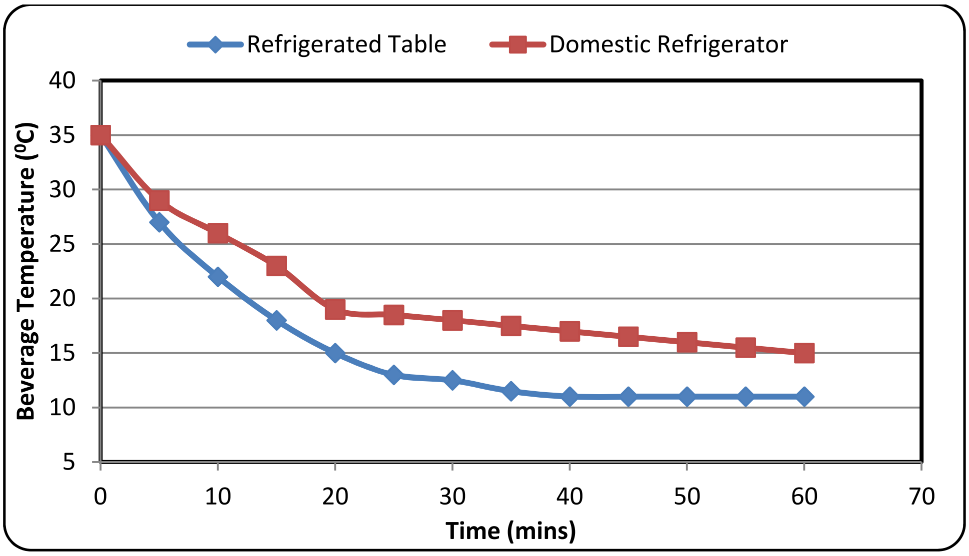

Figure 9. Stainless Steel material

4. Discussions

From the results, it can be seen that with a product temperature of 35°C, the refrigerated cooling table reduces the temperature to 15.5°C, 13°C and 11°C, when the water was placed in a plastic, glass and stainless steel containers respectively. The temperature of the cabinet was 7°C before each of the containers were placed inside the evaporator cabinet. The temperatures obtained show that the plastic container poses more resistance to heat transfer between the cabinet and the product when compared with glass and stainless steel containers. The stainless steel containers had the least resistance to heat transfer. Thermodynamically speaking, the thermal conductivity of stainless steel is higher than that of glass, and glass is higher than that of plastic as seen from the temperatures obtained. It can also be seen that after 40 minutes, the temperature of water in the stainless steel material stabilizes at 11°C, while that of glass material stabilizes after 45 minutes at 12.5°C and plastic material stabilizes after 50 minutes at 15°C. In comparison with a standard domestic refrigerator, the refrigerated cooling table performs better as shown in figures 7, 8 and 9. In all three materials used, the cooling table cools faster and maintain a stable temperature as desired for its purpose.

The saturated temperature of refrigerant in the evaporator was taken to be -5°C for calculation purpose while that of the condenser was 40°C. The enthalpy of the evaporator saturated vapour was read from tables to be 185.38kJ/kg. Linear interpolation was carried out to obtain the value of the enthalpy at the superheated vapour, subcooled liquid and wet vapour state to be 208.53kJ/kg, 66.45kJ/kg and 66.45kJ/kg respectively. These values were taken based on the assumption that the compression process is isentropic and the expansion process isenthalpic. The values obtained were used to calculate the coefficient of performance of the cooling table to be 5.14 and refrigerating effect was obtained to be 118.93kJ/kg. The compressor work for a three ports in the cooling table was 69.3W at a mass flow rate of 2.994 x 10^{-3}kg/s. The heat transfer through the wall of the refrigerating unit was analyzed and the value obtained was 59.35W. This shows that the cabinets were properly lagged to prevent heat loss.

5. Conclusion

A refrigerated cooling table was successfully fabricated using locally available materials. The coefficient of performance (COP) was 5.14 with a refrigerating effect of 118.93kJ/kg and a compressor power of 69.3W. The refrigerated cooling table shows that the temperature of beverages was successfully reduces to 11°C, 13°C and 15.5°C using a stainless steel, glass and plastic containers respectively in 40mins. The table perform better when compared with a standard domestic refrigerator.

Acknowledgement

The Authors will like to thank Mobil Producing Nigeria Unlimited and Surveyor Collins Ojonugwa Elaigu for jointly providing the funds for this research.

References

[1] Wang Shan K. Handbook on Air-Conditioning and Refrigeration, McGraw-Hill; 2001.
[2] A. Mohammed, A.E. Elaigu. Design, fabrication and testing of a cooling table for conference services. B.Eng. Thesis, Department of Mechanical Engineering, Federal University of Technology, Minna, Nigeria. 2004.
[3] Norman C. H. Modern Refrigeration Practice. 3rd Edition, Singapore McGraw-Hill; 1983.

[4] Mohammed A., Elaigu A.E., Hassan A.B., Adeniyi A.A. The design of a cooling table for conference services. *Elixir Mech. Engg*. 44 (2012): 7354-7358.
[5] Stoecker W. F., Jones J.W. Refrigeration and Air-Conditioning, 2nd Edition, London: McGraw- Hill; 1982.
[6] Stephen E.M. Standard Refrigeration and Air-Conditioning. 3rd Edition, New York: McGraw-Hill;1983.
[7] Cottel L. W., Olanrewaju S. Tropical Refrigeration and Air-Conditioning.1st Edition, Hong Kong: Longman; 1984.