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WOODEN REFRIGERATION SYSTEM

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ABSTRACT

Wood is a porous and fibrous structural tissue found in the stems and roots of trees and other woody plants. It is an organic material, a natural composite of cellulose fibers that are strong in tension and embedded in a matrix of lignin that resists compression. Wood is sometimes the secondary xylem in the stems of trees, or it is more broadly to include the same type of tissue elsewhere such as in the roots of trees or shrubs. In a living tree it performs a support function, enabling woody plants themselves.to grow large or to stand up by themselves. *Refrigeration* is a process of removing heat from a low-temperature reservoir and transferring it to a high-temperature reservoir. The work of heat transfer is traditionally driven by mechanical means, but can also be driven by heat, magnetism, electricity, laser, or other means. A refrigeration system with an insulator case is an energy efficient system that reduces the energy loss in a system through convention and conduction. The insulating materials considered are locally available woods, wallboard, fiberglass and cork. The scope of this project are to design and test local wood thermal conductivity for insulation materials. The thermal conductivity of the insulating materials was tested and recorded while a comparison of the literature material with the least thermal conductivity wood was used for the casing of the refrigerator unit. The refrigeration temperature of -1^0C to -5^0C will be maintained for a long time thereby retaining the temperature for a long duration even after a long period

of power outage. All the local woods tensile property was tested using tensile machine to achieve structural stability and at the same time maintain the refrigeration temperature of -1 ^{0}C – 5^0 C. Software was used in designing of the system. Design is a process, an activity, and not only the results of that activity.

KEYWORDS: Seasoned Wood, Thermal Conductivity, Insulator, Fiberglass, Refrigeration Cycle.

I. INTRODUCTION

Wood has been used for thousands of years for fuel, as a construction material, for making tools and weapons, furniture and paper, and as a feedstock for the production of purified cellulose and its derivatives, such as cellophane and cellulose acetate. Refrigeration is a process of removing heat from a low-temperature reservoir and transferring it to a high-temperature reservoir. The work of heat transfer is traditionally driven by mechanical means, but can also be driven by heat, magnetism, electricity, laser, or other means. Refrigeration has many applications, including, but not limited to: household refrigerators, industrial freezers, cryogenics, and air conditioning. Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible, but are otherwise similar to air conditioning units. Refrigeration has had a large impact on industry, lifestyle, agriculture, and settlement patterns. The idea of preserving food dates back to at least the ancient Roman and Chinese empires. However, mechanical refrigeration technology has rapidly evolved in the last century, There has been considerable study and debate about the potential negative environmental and health impacts of refrigerating systems with aluminum case. Refrigeration works by removing heat from a product and transferring that heat to the outside air. An energy efficient system contains both a heat and air barrier. For an effective thermal barrier, proper installation of quality insulation product is core. The wood and wood base materials have many applications in areas that require good insulating properties; their low thermal conductivity and good strength make them perfect for constructions and fabrications of Refrigerators, beer barrels and cars etc. (Kollmann and Cote 1965, Ward 1960). The insulation material considered in this project for an optimum performance is fiberglass with ply of timber coatings and seasoned Woods.

Woods are generally regarded as poor conductor of heat and are then used as insulators. We shall consider a typical wood with its three main directions of longitudinal, radial and tangential directions. The grain direction is parallel to the longitudinal axis, although most

wood properties differ in each of these axes. The thermal conductivity of wood varies with the direction of heat flow with respect to the grain, specific gravity, defect, and also with the moisture content in wood and temperature (Maclean 1941). Thermal conductivity is referred to as a transport property, and provides an indication of the rate at which energy is transferred by the diffusion process. It depends on the physical structure of matter, atom and molecule, which is related to the state of the matter (Incropera & Dewitt, 1981).

The thermal conductivity of wood is usually measured by the steady state method, which usually requires some time for wood sample to reach equilibrium temperature. If the wood sample contains high moisture content, it will take a fairly long time for the moisture distribution in wood to reach the equilibrium state. It is therefore advisable to dry woods very well before carrying out a heat test on them. Theoretical understanding of the wood thermal conductivity will help in predicting the change of properties with extended range of moisture content.

There are almost 20% or more losses due to improper insulation. Health hazard associated with improper insulation like electrocution and ozone depletion potential. This project will address the recurrent issue of energy losses due to poor insulation. The thermal conductivity of many of our locally available woods will be determined. Traditionally, the design field has been identified with particular end products, e.g., mechanical design, electrical design, ship design. In these fields, design work is largely based on specific techniques to foster certain product characteristics and principles.

II. LITERATURE REVIEW

Hard and Soft Woods

It is common to classify wood as either softwood or hardwood. The wood from conifers (e.g. pine) is called softwood, and the wood from dicotyledons (usually broad-leaved trees, (e.g. oak) is called hardwood. These names are a bit misleading, as hardwoods are not necessarily hard, and softwoods are not necessarily soft. The well-known balsa (a hardwood) is actually softer than any commercial softwood. Conversely, some softwoods (e.g. yew) are harder than many hardwoods. There is a strong relationship between the properties of wood and the properties of the particular tree that yielded it. The density of wood varies with species. The density of a wood correlates with its strength (mechanical properties). For example, mahogany is a medium-dense hardwood that is excellent for fine furniture crafting, whereas

balsa is light, making it useful for model building. One of the densest woods is black ironwood.

People have used wood for thousands of years for many purposes, including as a fuel or as a construction material for making houses, tools, weapons, furniture, packaging, artworks, and paper. Known constructions using wood date back ten thousand years. Buildings like the European Neolithic long house were made primarily of wood. The seasonal harvesting of snow and ice is an ancient practice estimated to have begun earlier than 1000 B.C. A Chinese collection of lyrics from this time period known as the Shijing, describes religious ceremonies for filling and emptying ice cellars. However, little is known about the construction of these ice cellars or what the ice was used for. The next ancient society to harvest ice may have been the Jews according to the book of Proverbs, which reads, "As the cold of snow in the time of harvest, so is a faithful messenger to them who sent him." Historians have interpreted this to mean that the Jews used ice to cool beverages rather than to preserve food. Other ancient cultures such as the Greeks and the Romans dug large snow pits insulated with grass, chaff, or branches of trees as cold storage. Like the Jews, the Greeks and Romans did not use ice and snow to preserve food, but primarily as a means to cool beverages. The Egyptians also developed methods to cool beverages, but in lieu of using ice to cool water, the Egyptians cooled water by putting boiling water in shallow earthen jars and placing them on the roofs of their houses at night. CAD (computer-aided design) has its roots in interactive computer graphics. Before the CAD era, engineering drawings were prepared manually on paper using pencils and drafting instruments on a drafting table. The advent of interactive computer Graphics replaced the drafting table with a computer monitor and the pencil with an input device such as a light pen or mouse. Instead of using physical drafting instruments, software commands and icons on the computer display are used. The drawing can be created, modified, copied, and transformed using the software tools. At the time, CAD stood for computer-aided drafting. Three-dimensional CAD systems were developed in the 1960s.

In review of refrigeration literature, it is very interesting since every aspect of it, the availability of refrigerants, the prime-movers and the developments in compressors and the methods of refrigeration all are a part of it. A refrigeration system utilizes work supplied by an electric motor to transfer heat from a space to be cooled to a high temperature sink (place to be heated). Low temperature boiling fluids called refrigerants absorb thermal energy to get vaporized in the evaporator causing a cooling effect in the region being cooled. The operating

temperature and the coefficient of performance are of importance in comparing these two parametric cooling systems. An evaluation using energy and exergy analyses which are based on first and second law of thermodynamics will be applied. Refrigeration as it is known these days is produced by artificial means. According to IIT Kharagpur in "history of Refrigerator" it seemed very difficult to make a clear demarcation between natural and artificial refrigeration, it is generally agreed that the history of artificial refrigeration began in the year 1755, when the Scottish professor William Cullen made the first refrigerating machine, which could produce a small quantity of ice in the laboratory. Based on the working principle, refrigeration systems can be classified as vapour compression systems, vapour absorption systems, gas cycle systems etc.

- **Evaporator:** the purpose of the evaporator is to remove unwanted heat from the product, via the liquid refrigerant.
- **Compressor:** the purpose of the compressor is to draw the low- temperature, low pressure vapour from the evaporator via the suction line.
- **Condenser:** The purpose of the condenser is to extract heat from the refrigerant to the outside air.
- **Expansion valve:** within the refrigeration system, the expansion valve is located at the end of the liquid line, before the evaporator
- **Refrigerants:** the type used will depend on the capabilities of the system and the temperatures that have to be achieved during refrigeration. Wooden refrigeration system incorporated the refrigeration cycle

In laboratory setting, heat flux is exceedingly different to control. Thus, at the atomic level, there are no simple, correct expressions for thermal conductivity. Atomically, the thermal conductivity of a system is determined by how atoms composing the system interact. There are two different approaches for calculating the thermal conductivity of a system.

The first approach employs the Green-Kubo relations. Although this employs analytic expressions which in principle can be solved, in order to calculate the thermal conductivity of a dense fluid or solid using this relation requires the use of molecular dynamics computer simulation.

The second approach is based upon the relaxation time approach. Due to the unharmonicity within the crystal potential, the phonons in the system are known to scatter. There are three main mechanisms for scattering:

- Boundary scattering, a phonon hitting the boundary of a system,
- Mass defect scattering, a phonon hitting an impurity within the system and scattering,
- Phonon-phonon scattering, a phonon breaking into two lower energy phonons or a phonon colliding with another phonon and merging into one higher energy phonon.

The function of insulation materials is to minimize the transport of heat through the construction. The heat transport can normally be divided in three parts; conduction through solid, conduction through gas phase and radiation through pores as shown in Insulators have a low coefficient of conductivity; they do not conduct heat well.

Insulators have a low coefficient of conductivity; they do not conduct heat well. Nonmetals, such as wood, textiles, and plastics, are usually poor conductors. Wood has average 0.1 $W/m^{o}k$, while wallboard 0.048 $W/m^{o}k$, cork 0.043 $W/m^{o}k$.

Wallboard is gypsum plasterboard used in the construction industry for finishing interior wall surfaces. It is made primary of gypsum (hydrous calcium sulphate) with a paper exterior liner, and other additives such as glue and binders. It has waterproofing materials and fire retardants.

III. METHODOLOGY

Design

In the design stage, drafting and computer graphics techniques are combined to produce models of different machines. Using a computer to perform the three steps 'art to part' process: Shown in Fig.1. The first two steps in this process are the use of sketching software to capture the initial design ideas and to produce accurate engineering drawings. The third step is rendering an accurate image of what the part will look like.

Materials

It is important that the materials and methods used to improve the performance of wood refrigerator are compatible with its performance. In calculating the thermal conductivity of Nigerian woods there is need to employ some instruments outside the test rig to ensure that all necessary information for the calculation is made available, those instruments are as follows – thermocouple, thermometer, Ammeter, voltmeter, Vernier caliper, the wood disc. Different wood sample were collected for test and their thermal conductivity were equally

calculated to achieve the most preferred Nigeria wood which should be used as insulator for a wooden refrigerator system.

A collection of twenty different woods that are readily available where collected from the timber shade comprising of both hard and soft woods and they were cut to sizes and subjected to the same temperature in the oven furnace at Standard organization of Nigeria (SON) Enugu.

A special effort was made to select specimens having different densities and different amounts of moisture within each species. Experiments were made on a number of species with the moisture content ranging from 0 (oven-dry) to that of wood in the green condition.

The specimens were cut to dimensions of approximately 60mm by 60mm and the thickness generally ranged from about 6mm to 18mm. Thickness measurements were made with a micrometer.

The equations for the thermal conductivity are as follows; the quantity of heat conducted through the specimen or sample (wood) is:

$$Q = \frac{KA(T_1 - T_2)}{X} \qquad (1)$$

Where X is the thickness of the sample and A is the cross-sectional area of the sample, T_1- T_2 is the temperature difference while the K is the thermal conductivity.

The rate of heat lost to the surrounding by the furnace is given as:

$$Q = m\,c\,(\frac{dT}{dt})T_2 \qquad (2)$$

Where m is the mass of the metallic disc in the furnace, c is the specific heat capacity of mild steel.

$\frac{dT}{dt}$ = rate of cooling at T_2

Comparing equations 1 and 2

$$m\,c\,(\frac{dT}{dt})T_2 = \frac{KA(T_1 - T_2)}{X}$$

$$k = \frac{m\,cX\,(\frac{dT}{dt})T_2}{A(T_1 - T_2)} \qquad (3)$$

$\lambda_{Total} = \lambda_{gas} + \lambda_{solid} + \lambda_{rad}$ (W/m.K) 4

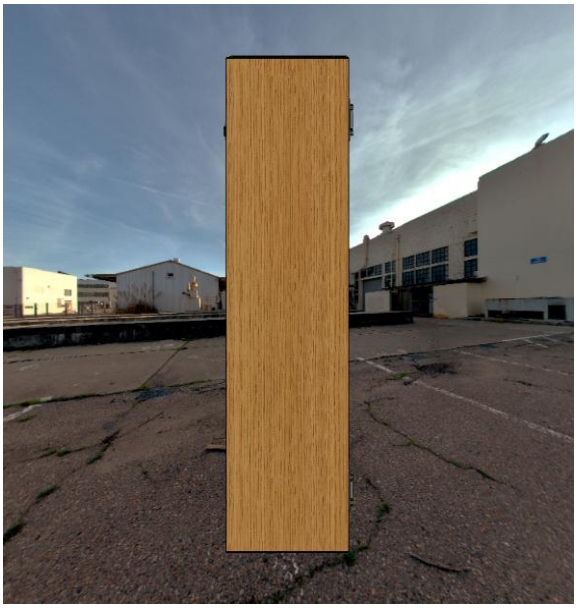
IV. RESULT

The thermal conductivity of eleven selected local wood in South East and a seasoned wood were carried out with the results as recorded in Table 1. below.

Table 1. Experimental Result

Wood (local name)	$T_1{}^oC$	$T_2{}^oC$	ΔT + 273 (Kelvin)	Mass (g)	Thermal Conductivity (W/m·K)
Meninar	27.30	98.50	344.20	59.59	0.0488
Agba white	28.40	97.80	342.40	44.52	0.0656
Meninar	27.50	87.20	332.70	62.52	0.0481
Ugba	27.60	90.60	336.00	53.44	0.0557
Agba Red	29.50	96.90	340.40	60.45	0.0486
Ukpaka	26.50	97.00	343.50	97.20	0.0300
Mahogany	31.20	205.40	447.20	15.79	0.1416
Marine board	30.70	207.25	449.55	67.77	0.0328
Oto	30.50	201.50	444.00	5.22	0.4315
Plywood	28.90	99.10	343.20	23.65	0.1232
Ngwu	32.00	205.00	446.00	23.48	0.0955
Marima	29.00	86.50	330.50	49.62	0.0610

The furnace maximum temperature was maintained at 250^{o}C with time of 1800 second under power rating of 1000watts. The result showed that selected local woods have relatively good thermal properties. The woods are finished with varnish and anti rot agents. The woods that have thermal conductivity ranging from 0.050 and below are considered for use as insulating materials. The woods are assembled as the structural frame work and at the same time the insulating materials like there are used as door. The lagging of the door was done using the cork or fiberglass.



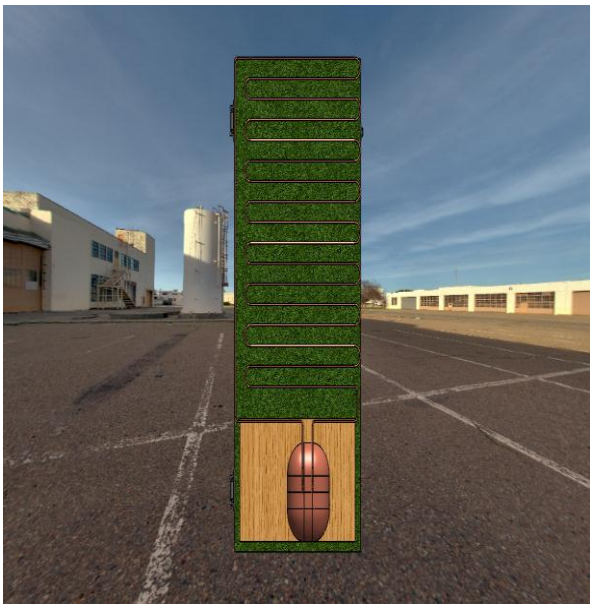


Fig. 1: The Views of Wooden Refrigerator.

In a refrigeration system, liquid refrigerant absorbs heat from the air when changing to a gas (boiling). Water boils at 100°C and cannot be used to cool when it changes from a liquid to a gas. Refrigerant gas should boil at a low temperature. R134a boils at -26°C and freezes at -101°C. Hydrocarbons like, Propane (R190), Butane (R600), Iso-butane (R600a), Propylene (R1270) etc. are generally used as refrigerant in refrigeration system because of their similar properties with R12 andR134a with its very low Global Warming Potential and zero Ozone Depletion Potential. The vapor compression refrigeration cycle is a common method for transferring heat from a low temperature to a high temperature. The figure 2. below show the principles of operation of a refrigeration cycle. Coefficient of performance (COP) of the refrigerator is defined as desired output per required input.

$$\text{COP} = \frac{\text{Desired output}}{\text{Required input}} = \frac{\text{Cooling effect}}{\text{Work input}} \qquad (5)$$

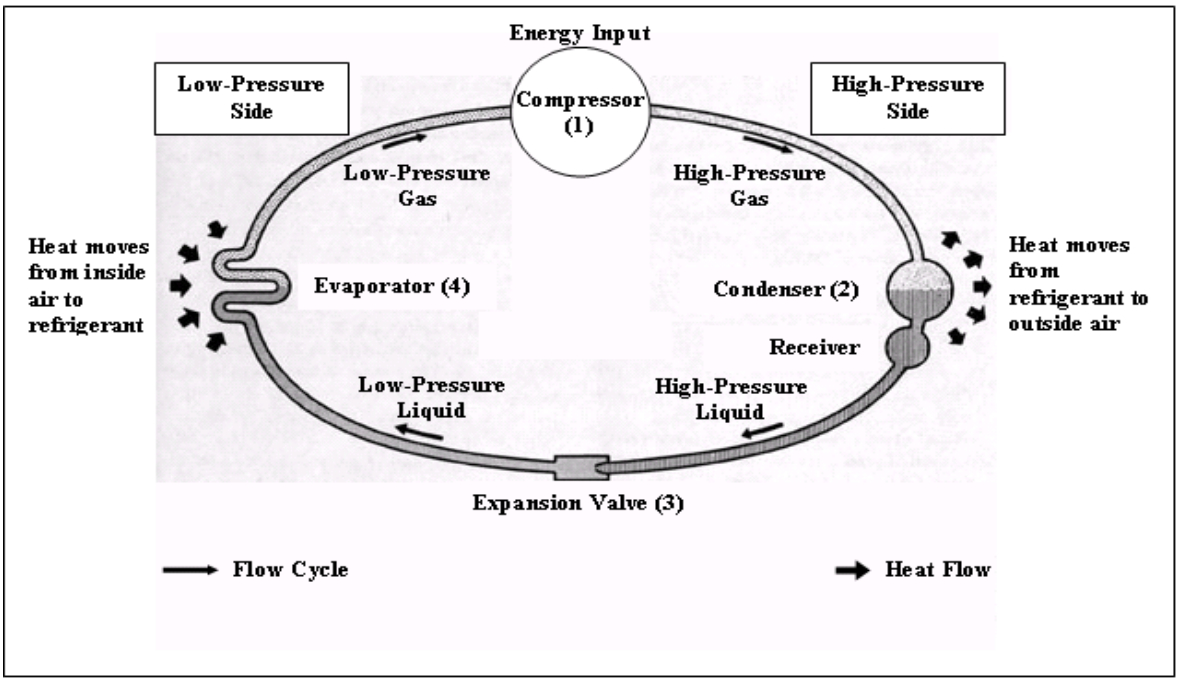


Figure 2: Refrigeration cycle.

V. CONCLUSION/RECOMMONDATION

CAD combines the characteristic of designer and computer that are best applicable made CAD such as popular design tool. CAD has allowed the designer to bypass much of the Manual drafting and analysis. Storing the food products at optimal temperature will help in keeping the food fresh for a long period. There are display refrigerators which can store the food products and display them also. It is an excellent tool for a successful business. Of all the inventions made in the 20th century, refrigeration was among those that altered the course of our everyday lives in a most tasteful way. Until this century wood was the single greatest material aid and comfort in every century of our lives. Depending on who starts counting where, the experts all disagree, the art and technique of using wood into countless forms of tools, heat, shelter, furniture, transportation, decoration, kitchen utensils, and every other thing imaginable; and some not. The first of everything; including the first submarine and airplane; were first made of wood. The refrigeration system which incorporated the use of wooden case as door and structural frame work was done to reduce the electrocuting effect of refrigeration system. The organic refrigerant of propane was still used because of low Global Warming potential and zero Ozone Depletion Potential associated. The result of the thermal conductivity of our local woods as contained proved that most of the wood samples tested gave a range of thermal conductivity which is acceptable for use in this project. We used Agba Red as the wood case for the refrigeration unit and its analysis will be published in the next work.

REFERENCES

1. J. D. MacLean, Heating, piping & air conditioning, Madison, Wis., June 1941; 13(6): 380-391.
2. James M. Calm, "The next generation of refrigerants Historical review, considerations, and outlook", International journal of refrigeration, 2008; 31: 1123-1133, USA.
3. A.R. Trott and T. Welch, Refrigeration and Air conditioning Third edition by Butterworth-Heinemann. Reed Educational and Professional Publishing Ltd., 2000.
4. Abhishek Kumar et al, "Design of Domestic refrigerator using Propylene (R1270) as refrigerant" International Journal of Latest Engineering and Management Research, 2017; 2: 14-18.
5. Horst H. Nimz, Uwe Schmitt, Eckart Schwab, Otto Wittmann, Franz Wolf "Wood" in Ullmann's Encyclopedia of Industrial Chemistry, Wiley-VCH, Weinheim, 2005; doi:10.1002/14356007.a28_305.
6. Search – APA – The Engineered Wood Association" (PDF). apawood.org. Archived (PDF) from the original on, 2006; June 27.
7. Neuburger, Albert. The technical arts and sciences of the ancients. London: Kegan Paul, 2003; 122. ISBN 0710307551.
8. "N.B. fossils show origins of wood". CBC.ca. August 12, 2011. Archived from the original on August 13, 2011. Retrieved August 12, 2011.
9. Horst H. Nimz, Uwe Schmitt, Eckart Schwab, Otto Wittmann, Franz Wolf "Wood" in Ullmann's Encyclopedia of Industrial Chemistry, Wiley-VCH, Weinheim, 2005. doi:10.1002/14356007.a28_305.
10. Hickey, M.; King, C. The Cambridge Illustrated Glossary of Botanical Terms. Cambridge University Press, 2001.
11. https://en.wikipedia.org/wiki/Wood.
12. https://www.google.com/search?q=refrigeration&ie=utf-8&oe=utf-8.
13. https://www.lifehack.org/443821/7-advantages-of-display-fridges-for-your-food-business.
14. http://www.startribune.com/how-refrigeration-changed-our-lives/248916161/.
15. http://www.kramers.org/whywood.html.
16. Engr.Rufus Ogbuka Chime et al. Design, Modeling, Application and Analysis of Bevel Gears Int. Journal of Engineering Research and Applications www.ijera.com ISSN: 2248-9622, April 2016; 6(4): (Part - 3), 44-52.