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Research Paper

Design, Fabrication, and Performance Evaluation of a Petrol-Driven Refrigerating System for Effective Vaccine Storage in Remote Areas

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Abstract— Refrigeration, encompassing diverse methods of heat removal, plays a pivotal role in modern industrial and domestic applications. Among these methods, the vapour-compression system stands as the most widely employed technique due to its efficiency and versatility. This study centers on the comprehensive design, fabrication, and performance evaluation of a novel refrigerating system driven by a Gx 160 petrol engine, seamlessly integrating Nissan Micra AC components.

The devised refrigerating system attains a notable weight of 982N, indicative of its robust construction, coupled with an impressive COPmax (Coefficient of Performance at maximum efficiency) value of 12.2. This exceptional COPmax underscores the system's adeptness at transforming energy input into effective cooling output. Operating within a temperature range of 31°C to 8°C, the system demonstrates its aptitude in preserving vaccines, substances pivotal in stimulating antibody production for disease protection in humans and animals.

Crucially, the petrol-driven engine powering the system exhibits an efficient fuel consumption rate, utilizing a mere 0.8 litters of petrol during an 18.35-minute cooling cycle to reach the target temperature of 8°C. The results of this study unveil the potential of this petrol-driven refrigerating system as a viable solution for remote areas lacking reliable power grids, facilitating efficient vaccine preservation and contributing to enhanced healthcare outcomes.

Overall, this research underscores the synergy between innovative design, meticulous fabrication, and rigorous performance assessment in creating effective refrigeration solutions. The system's robust characteristics, efficient cooling, and eco-friendly fuel consumption hold promise for a wide spectrum of applications beyond vaccine storage, impacting diverse sectors requiring dependable and energy-efficient refrigeration solutions.

Keywords— Refrigeration, Heat Removal, Vapor-Compression System, Design, Fabrication, Vaccine Preservation, Innovative design

1. Introduction

Refrigeration is characterized as a process involving the extraction of heat. This involves removing heat from a contained environment or object in order to reduce temperatures. Within industrialized nations and affluent sectors of developing regions, refrigeration predominantly serves the purpose of preserving food items at reduced temperatures, effectively impeding the detrimental effects caused by bacteria, yeast, and mold. This technique allows many perishable goods to undergo freezing, enabling their extended storage for months or even years, with minimal compromise to nutritional content, flavour, or appearance.

In a broader sense, refrigeration, also referred to as air conditioning, encompasses the full control over temperature, humidity, air filtration, and air dispersion to conform to the conditioned space's environmental requirements.[1].

The refrigeration system, which essentially includes the movement of heat from one site to another, is critical to the operation of a cold room. The vapour-compression system is the most common technique of refrigeration, and it is widely used in large cold storage systems such as industrial chillers. The condenser, compressor, evaporator, and expansion valve are crucial components of a simple refrigeration system.

i. Condenser:

The process of condensation transforms gas into a liquid state. Its principal function is to transform the refrigerant gas taken from the evaporator by the compressor into a liquid state. Heat is transmitted from the condenser to the surrounding air once condensation begins, provided the temperature of the condensation exceeds that of the environment. The high-pressure vapour within the condenser is cooled, converting it to a liquid refrigerant form with some heat retained. The liquid refrigerant flows from the condenser to an air channel.

ii. Compressor:
The compressor uses the suction line to draw low pressure and low temperature vapour from the evaporator. The vapour undergoes a compression in this stage and elevate its temperature as it is drawn. The primary purpose is to increase the temperature and pressure of the vapour, which will transform it from a low temperature to a high temperature vapour. The compressor discharges the vapour into the discharge line

iii. Evaporator:
An evaporator serves the purpose of converting any liquid substance into a gas state, with concurrent heat absorption. This process involves the heat transmission from a cold region to a heating system using a liquid refrigerant. Under low pressure, the liquid refrigerant boils in the evaporator. The liquid refrigerant temperature should be lower than the temperature of the things being chilled so as to allow for efficient heat transfer. Following the transfer, the compressor uses a suction line to suck liquid refrigerant from the evaporator, causing the refrigerant to evaporate as it exits the coil of evaporator.

iv. Expansion Unit or Valve:
Situated commonly before the evaporator and positioned at the terminus of the liquid line, the expansion valve is encountered by the condensed liquid refrigerant. By reducing the pressure of the refrigerant, its temperature drops to a level below atmospheric conditions. This refrigerant in liquid form is subsequently directed into the evaporator for further processing [2-3].

1.1 The Problem Statemen

Vaccination plays a pivotal role in safeguarding the health of individuals and animals against diseases by stimulating the production of antibodies, proteins that combat infections. The practice of vaccination holds immense significance in disease prevention within the realm of public health. Proper storage of vaccines, particularly in rural and remote regions, emerges as a critical concern.

Vaccines necessitate consistent and controlled temperature conditions to retain their potency, typically requiring storage temperatures between 0°C and 8°C. However, the challenge arises in areas devoid of access to a national power grid, where maintaining the requisite temperature for vaccine storage can be daunting. In such contexts, vaccines often need to be transported from distant storehouses to the utilization point, incurring potential complications and risks during transit.

The efficacy of disease prevention through vaccination hinges on the ability of the region to uphold optimal storage conditions for vaccines. In this context, regions equipped with dependable vaccine storage capabilities can more effectively mitigate disease outbreaks.

For locations where a centralized power grid is unavailable, reliance on distributed generation sources becomes imperative. This scenario has prompted the initiation of the present research work, which focuses on the design, fabrication, and performance assessment of a refrigerating system powered by petrol engine. The primary aim is to establish a sustainable and efficient solution for refrigeration in remote areas, enhancing the preservation of vaccine efficacy and bolstering disease prevention efforts.

1.2 Aim and Objective

This project aim is to develop a petrol engine refrigeration system using a vapor compression cycle.
This study objective is as follows:
1. To design a vapor compression refrigeration system.
2. To fabricate a vapor compression refrigeration system
3. To evaluate the performance of a vapor compression refrigerating system

1.3 Scope of the Study

The goal of this work is to design, build, and test the performance of a cooling system powered by a petrol engine. This refrigeration system draws inspiration from components of the Micra car air-conditioning system, notably the condenser, compressor, and evaporator. The comprehensive study was conducted within the premises of The Polytechnic, Ibadan, and was designed to cater to the stringent temperature requirements for vaccine preservation, maintaining a range of 0 to 8 degrees Celsius. The undertaking encompasses the intricate interplay of engineering, refrigeration technology, and sustainable power sources, culminating in a solution that bridges the vital gap in vaccine storage within remote and challenging environments.

1.4 Contribution to Knowledge

This innovative design presents a multitude of favorable economic implications, notably encompassing enhanced availability, superior functionality, and more. Consequently, it establishes a noteworthy comparative cost advantage over imported alternatives. Significantly, this project work addresses the paramount needs of medicine and food preservation, a critical consideration in both urban and rural settings, particularly in regions with limited medical access.
Moreover, this undertaking holds the potential to evolve into a promising entrepreneurial avenue, serving as a lucrative fabrication-for-sale enterprise. Beyond its commercial potential, this project is poised to catalyse local and technology transfer initiatives. By synergizing vehicle air conditioning components with internal combustion engines, the project contributes to technological fusion in a hitherto untapped domain. An additional rewarding outcome is the creation of substantial employment opportunities, thereby enhancing both economic prosperity and local expertise.

2. Related Work

Refrigeration is a crucial process in contemporary industrial and household settings, serving a vital role in maintaining desired temperature levels for various applications. Among the various methods utilized, the vapor-compression system stands out as the most commonly employed technique due to its efficiency and adaptability. This literature review explores the existing body of research, highlighting significant contributions from multiple scholars in the refrigeration systems field.

In a study, a mini solar-powered refrigerator was successfully used for cooling with no greenhouse gas emissions. It consisted of a Peltier module, heat sink, charge controller, solar panel, battery, microcontroller kit, and more [4].
In another study a thermoelectric type refrigeration system was design and constructed, the system consisted of 12 Peltier modules, 5 DC fans, a fridge, and a freezer compartment. The Peltier modules were used to cool the compartments of the refrigerator, which were powered by an AC outlet. The system consumed 57 W of electrical power. After 2 hours of testing, the system was found to have a COP of 81.85%, and the temperatures inside the compartments ranged from 6.9℃ to -5.3℃ [5].

In a separate study, a single-cylinder four-stroke straight-injection engine with a modified automotive vapor compression system was used for cooling. The analysis revealed acceptable system operation across various speeds and loads, with fuel consumption and torque showing dependence on engine speed [6]. Another researcher concentrated on the design and development of a refrigeration system powered by an 80cc internal combustion petrol engine. Their experiments confirmed the feasibility of the concept for both traction and non-traction applications of the engine, demonstrating its potential versatility [7].

Additionally, a study investigated a vapor compression refrigeration system with an elliptical-shaped evaporator coil. Their research highlighted how altering the evaporator's shape and incorporating extended surfaces could enhance heat transfer efficiency. The elliptical design resulted in a 1.5% increase in COP due to improved refrigeration effect and reduced compressor work and heat absorption [8].

In a different research work, mesoscale vapor compression refrigeration cycle was develop by scientist utilizing R134A refrigerants in the form of VCRC. Their research yielded a COP value of 3.34, demonstrating the system's effectiveness in heat dissipation and cooling, suitable for specific applications [9].

Furthermore, explored a mesoscale VCRC utilizing R-134A and other refrigerants. Their research provided insights into how the choice of refrigerant impacted COP values and offered comparisons of various compressor types. Their findings contributed to our understanding of the design parameters necessary for specific evaporator heat loads [10]. Another approach involved the development of a car air-conditioning system utilizing exhaust gas and vapor absorption refrigeration (VAR) technology. Their research showcased the feasibility of harnessing waste heat from vehicle exhaust gases to power the VAR system, eliminating the need for an internal combustion engine and compressor. This approach not only reduced costs but also minimized system maintenance [11]. Moreover, a comprehensive study encompassed the design of all components of a refrigeration system, resulting in a miniature CPU cooling unit. By using R-134A refrigerant, the system achieved efficient heat dissipation and demonstrated the feasibility of employing an electric motor-driven isentropic compressor. The study also highlighted the potential for linear vapor compression compressor that doesn't use pistons, and a COP value of 3.0 was obtained [12].

In conclusion, these scholarly contributions underscore the depth of research in refrigeration systems. From improving efficiency and reducing fuel consumption to exploring alternative energy sources and innovative component designs, these studies exemplify the ongoing commitment to advancing refrigeration technology. The collective findings offer valuable insights and creative solutions with broad applications beyond traditional refrigeration, shaping the future of this critical field.

In this paper, we present our unique design, fabrication, and performance evaluation of a petrol-driven refrigeration system, which utilizes a component from a car air-conditioning system to achieve refrigeration. The compressor is powered by a petrol engine, enabling the system to achieve a cooling temperature range of 0-8°C. Detailed descriptions of the materials and methods employed in this study are provided in the following section, along with the results obtained.

3. Materials and Methods

3.1 Materials
The material used for this project were purchased from local markets located in Ibadan and Lagos. These items include a GX 160 petrol engine, a Micra car alternator, mild steel 50x50x5mm angle iron, a 75A-12V battery, a pulley, a caster wheel, a freezer compartment or casing, a Micra car compressor, an evaporator, a dryer/expansion valve, a condenser, and a fan.

3.2 Equipment/tools
The tools and equipment used in this research include an electric arc welding machine, cutting machine, grinding machine, drilling machine, measuring tape, plier cutting, and 50kva generator.

3.3 Design consideration
In designing the refrigerating system for preserving vaccines, several factors were taken into consideration. These factors include production cost, availability of petrol fuel, flexibility in fabrication, maintenance requirements, durability, cost of materials, and availability of fabrication tools and equipment. The design was tailored to meet specific requirements for materials and processes.

3.4 CAD modelling and Virtual prototyping
We employed CAD software to create a comprehensive 3D model of our proposed design, which we then divided into sub-components to ease fabrication and assembly. Through multiple iterations, we meticulously refined the geometry, dimensions, and functionality of the model. By utilizing

virtual prototyping, we were able to simulate the behaviour and interactions of various components under different conditions, allowing us to identify any potential issues and optimize all opportunities. The general layout and profile of the refrigerating system (See Figure 1 and Figure 2) consist of a two-blower motor (fan), petrol engine, alternator and base, compressor, evaporator, condenser, expansion valve, and freezer compartment.

3.5 Design specifications

The specification of our novel refrigeration system is shown in table 1

Table 1: The specification of our refrigeration system

Items	Specifications	Items	Specifications
Freezer Compartment:	- Height: 780mm - Breadth: 520mm - Width: 580mm – Mass: 6kg	**Petrol engine (Gx160):**	Type of engine: Single 4 stroke cylinder, OHV petrol engine, Cylinder inclined at 25 degrees with shaft horizontal - Type of cylinder sleeve: Cast iron - Stroke by bore: 45mm x68mm - Compression ratio: 9.0:1 - Net power: 3.6 kW (4.8 HP) / 3600 rpm - Continuous rated power: 2.5 kW (3.4 HP) / 3000 rpm, 2.9 kW (3.9 HP) / 3600 rpm - Maximum Net torque- 10.3 Nm / 1.05 kgfm / 2500 rpm - System ignition is transistorized - Capacity of the fuel tanks -3.1L - The capacity of the engine oil tank: 0.6 Liter - Dimensions (L x W x H): 312 x 362 x 346 mm - The engine have 15.1 kg dry weight
Compressor:	- Type: DKV-08 Nissan compressor - Horsepower: 5h.p - Discharge pressure: 7 bars - Cooling method: Air cooled - Material: Mild steel - Speed: 1500-2000 rpm - Flow rate: 0-20 cubic feet per minute (CFM) - Mass: 8kg CFM means cubic feet per minute, which indicates the amount of air that a compressor can produce at a given pressure level. Compressors with higher CFM ratings are suitable for larger applications as they can provide more air.	**Battery:**	- Core length: 151 mm - Core width: 65 mm - Core depth: 94 mm - Weight of battery: 14 kg - Battery main current: 12 volts - Alternative charge current: 75 A
The alternator:	- Weight: 4.5 kg - System main current: 12 volts - Alternative charge current: 65.0 A - Type: Nissan Mitsubishi - Model No: CA1652IR LRA03075 112457 23173	**The condenser fan:**	- Gross Weight: 3 kg - Model: condenser cooling fan Nissan Micra 1.0 petrol automatic
The evaporator:	-Cooling fin material: Aluminium - Core length: 212 mm - Core width: 240 mm - Core depth: 60 mm - Weight: 1.3 kg	**The condenser:**	- Cooling fins material: Aluminum - Height: 494 mm - Width: 435 mm - Thickness: 17 mm - Type: Nissan Micra comes with a dryer - Weight: 13.5 kg

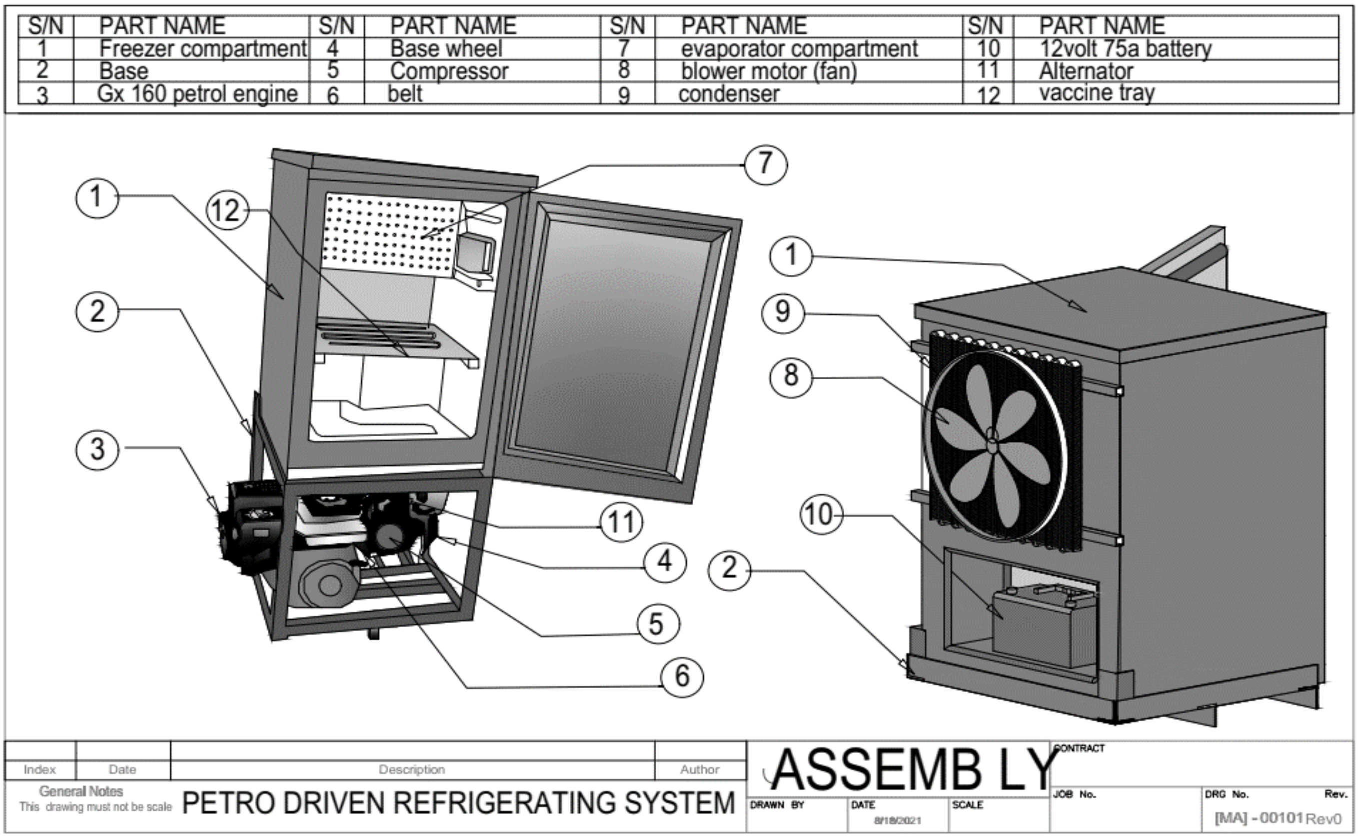
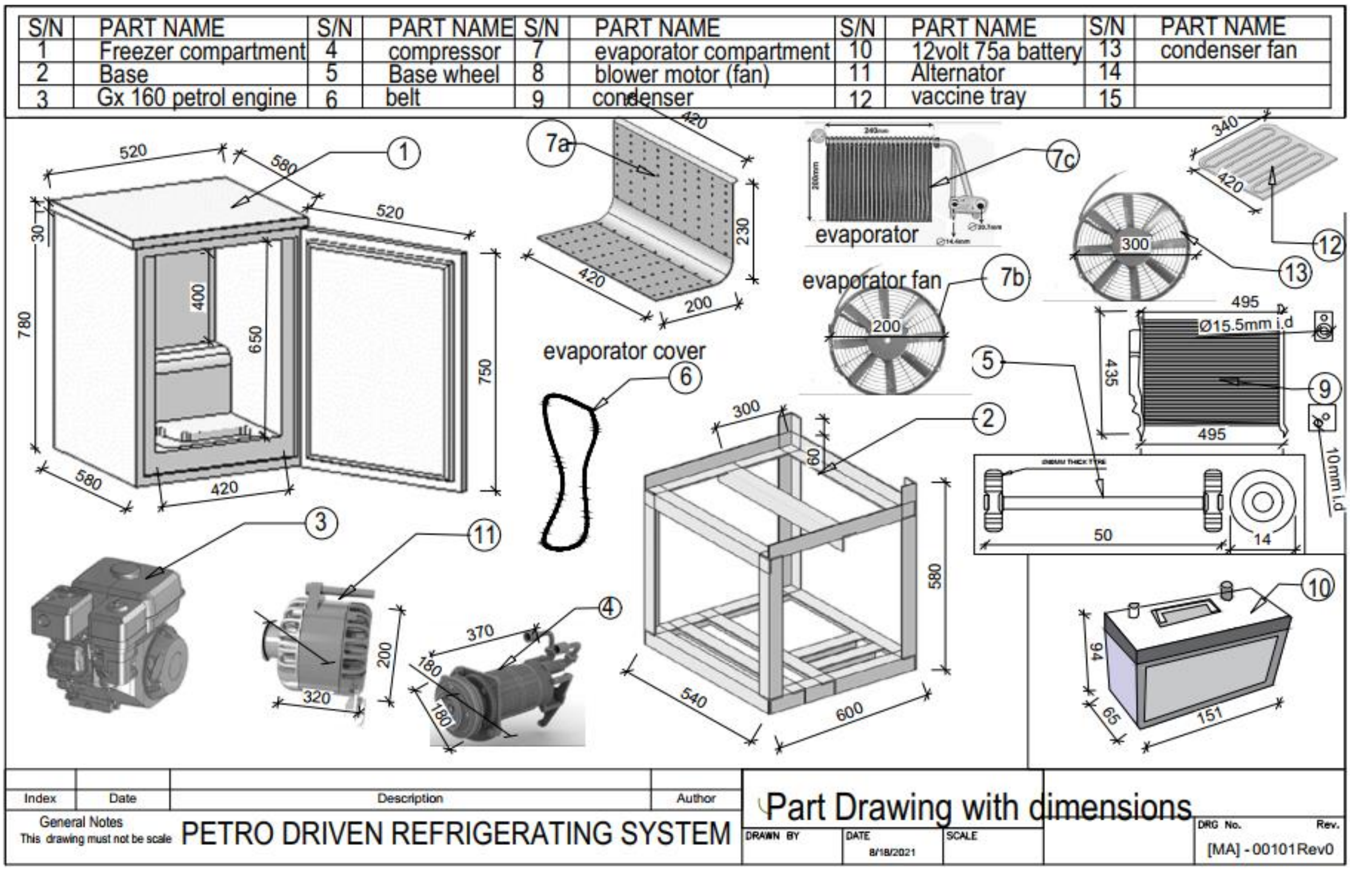


Figure 1. CAD modeling of the prototype



Fugure 2. Design Drawing Showing Varuous Component of the Refrigeration system

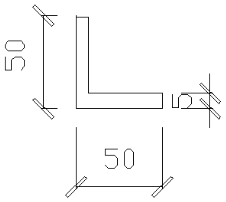
3.6 Design calculation

The base calculation

The weight of the base stand can be determined by multiplying the specific weight of the mild steel 50x50x5mm RSEA (Angle iron) by the total length used in the construction of the base.

The specific weight of mild steel angle iron

Area of the cross-section of 50x50x 5m angle iron



A = (50mm x5mm) + (45mm x5mm)

= 250mm^2 +225mm^2

= 475mm^2 = 0.000475m^2

The area of the cross-section of mild steel 50x5mm equal angle iron is 0.000475m^2

$$\text{Density} = \frac{\text{Mass in Kg}}{\text{Volume}} \quad \textbf{(1)}$$

$$\text{Density} = \frac{\text{Mass per one min}}{\text{Area}} \quad \textbf{(2)}$$

Density of mild steel = 7850kg/m^3

Area of mild steel angle iron section = 0.000475m^2

A specific mass of angle iron = Density of mild steel x Area of section

= 7850kg/m^3 x 0.000475m^2

= 3.72875kg/m

The total length of the angle obtained from the design drawing for the base construction

= (540 x 7) mm + (600 x 4) mm + (580x2) mm + (520x2) mm

= 3780mm + 2400mm + 1160mm + 1040mm

= 8380mm

= 8.38m

$$Tm = Ms \times Lt \quad \textbf{(3)}$$

Where Tm is the total mass of base

Ms is the specific mass of the base and Lt is the total length of the base

= 3.72875kg/m^3 x 8.38m

=31.246506kg = 31.25kg

Total weight of the system

Mass of compressor =8kg

Mass of evaporator = 1.3kg

Mass of freezer compartment = 6kg

Mass of alternator =4.5kg

Mass of petrol engine = 15.1 kg

Mass of condenser = 13.5kg

Mass of condenser fan =3kg

Mass of evaporator fan = 1.5kg

Mass of battery = 14kg

Total weight of the system = 8kg +1.3kg + 6kg + 4.5kg + 15.1kg + 13.5kg + 3kg + 1.5kg + 14kg + 31.25kg = 98.15kg

Hence, the weight of the system is approximate 982N

The maximum Co-efficient of performance of the refrigerating system

The overall heat has been extracted from the refrigerating space/room and delivered to the outside air.

The compressor devours power from the 12volt battery and heat energy also becomes thermal energy in the outside air.

$$\text{The COPmax} = \frac{\mathbf{T_{room}}}{\mathbf{T_{outside} - T_{room}}} = \frac{\mathbf{T_L}}{\mathbf{T_H - T_L}} \quad \textbf{-(4)}$$

$T_H = 31^o$c

$T_L = 8^o$c

$$COP_{max} = \frac{281}{304 - 281} = \frac{281}{23} = 12.2$$

The ideal maximum coefficient of performance of the refrigerating system is 12.2

3.7 Fabrication Process:

1. The Base: Eight pieces of steel angle iron were cut to various lengths: four 540mm, two 600mm, and two 580mm. Two additional pieces measuring 350mm were also cut and welded to serve as reinforcement. An electric arc welding machine was used to weld these pieces together to form the base. The compressor and alternator were installed in a vertical alignment, with the alternator being mounted on the first platform of the base. Additionally, tires purchased from the local market were welded to the bottom of the base. The joints were properly grounded to check for holes in the welding and to correct them. Finally, the base was primed with red oxide and painted with grey paint to prevent corrosion. See Figure 3.

2. Gx 160 Petrol Engine: The Gx 160 petrol engine was chosen for its affordability and availability in the market. It was installed on the first platform of the base to drive the system compressor and alternator with a belt.

3. The Alternator: The alternator plays a critical role in transforming the mechanical energy generated by the gasoline engine into electrical energy. As the engine operates, a drive belt on a pulley linked to the alternator propels it forward. The alternator rotor shaft, set in motion by this pulley, spins the magnets around the coil. This process yields a voltage range of 131/2 to 15 volts, which exceeds the capacity of typical 12-volt batteries. When the engine is on, the alternator continuously recharges the battery. It is mounted on the base at a specific distance away and in vertical alignment with the compressor. see

4. The Compressor: The Micra compressor was chosen for its affordability and availability. It takes in and pumps out the refrigerant. When the compressor starts working, its job is to pressurize or compress the refrigerant. As the pressure increases, so does the temperature of the refrigerant. It then flows in a gaseous state through a pipe or hose to the condenser, where it is high-pressure and high-temperature. The compressor is placed on the base and aligned with the alternator for the belt to drive them both together with the engine.

5. The Condenser and Evaporator: The refrigeration process relies heavily on the condenser, which is responsible for converting high-temperature and high-pressure refrigerant from gas to liquid at the same temperature. In this specific system, the condenser is located outside the freezer compartment, which was purchased from a local market in Ibadan and mounted on a 20x20x1.6mm SHS welded at the back of the freezer casing. Thanks to the compressor-incorporated fan, heat is expelled from the condensing environment. The Micra condenser was chosen due to its affordability and availability. Equally important to the refrigeration system is the evaporator. A Micra car evaporator was selected based on its thermal properties, cost, and availability. The evaporator is placed inside the freezer compartment and covered with an evaporator cover. Its function is to receive low-pressure liquid from the expansion valve.

3.8 Assembly and Testing

To produce the final product, the assembly process involves the combination of several fabricated components. Here is the methodology used for the assembly:

1. Component Inspection: Prior to assembly, each fabricated component undergoes a thorough inspection to ensure its dimensional accuracy and surface quality.
2. Alignment and Fixturing: Components are properly aligned using a spirit level, level bulb, and square to ensure they fit correctly.
3. Joining Methods: The assembly employs a combination of joining methods such as welding, adhesive bonding, and mechanical fastening. These methods are selected based on their compatibility with the chosen materials.
4. Quality Control: Quality control checks are conducted at different points during the assembly process to validate the assembly's integrity and conformity with design specifications. The assembly is made up of various components, including the evaporator, blower motor, cover, condenser and fan, dryer, alternator, 12v battery, petrol engine, base, freezer compartment, base tire, vaccine tray, and refrigerant.

Figure 3.The base and Gx Petrol Engine Installation

Figure 4. Installion of Compressor and Alternator

Figure 5. Aligning the Compressor, Alternator and Engine

Figure 6. Assembly of the condenser in the freezer compartment

Figure 7. Assembly of the evaporator inside the freezer compartment

Figure 8. Assembly of the evaoporator and the blower motor fan

Testing and Validation

After assembly the system underwent testing**,** once the engine is in motion, it powers both the compressor and alternator simultaneously. The compressor, being the primary component of the system, receives low-pressure refrigerant gas, R-132 is used in this case and compresses it into high-temperature, high-pressure gas. This gas then flows out of the compressor's outlet and into the condenser, where it is changed into a liquid. The high-pressure liquid then passes through the receiver/dryer, which filters out any moisture that may have contaminated the refrigerant. The filtered liquid then flows through the expansion valve, allowing it to expand and become low-pressure liquid.

This low-pressure liquid then goes directly into the evaporator, where it boils and transforms into high-pressure gas, absorbing heat in the process. This cools the wall of the evaporator, and the blower motor, which is integrated with the compressor, pushes the cold air into the refrigerated space. The low-pressure gas returns to the compressor for another cycle. A small temperature bulb is located at the evaporator's outlet, continuously adjusting the refrigerant flow through the expansion valve and into the evaporator based on the evaporator temperature and pressure.

The evaporator outlet temperature is utilized to regulate the expansion valve, setting the maximum operating pressure at the evaporator outlet. The refrigerant then flows through the low-side service port, and as it is added, the pressure on the low side rises until it reaches its maximum operating pressure, which is typically 35psi. A thermostat built into the system controls the temperature of the room or refrigerated space. It stops the compressor from operating when the minimum temperature is reached.

4. Result and Discussion

4.1 Experimental Results

We present the experimental results obtained from our constructed petrol engine refrigerating system in this sect. Our primary objective was to determine the time required to cool the temperature of a given space to 8°C using the system. To conduct this experiment, we employed a thermometer and a stopwatch to record the necessary data

4.1.1 Initial Room Temperature

Before starting the engine, we measured the room temperature to be 31°C.

4.1.2 Cooling Process

Upon starting the engine, it initiated the cooling process by driving the belt at a constant revolution speed of 2500 RPM. This process was monitored closely, and the following results were observed:

- The engine took 18.35 minutes to lower the room temperature from the initial 31°C to the target temperature of 8°C.

- During this cooling period, 0.8 liters of fuel was consumed.

- The cooling rate of the refrigeration system was established by plotting a graph of temperature against time. It was observed that the room temperature decreases with respect to time and was linear as shown below in Figure 9.

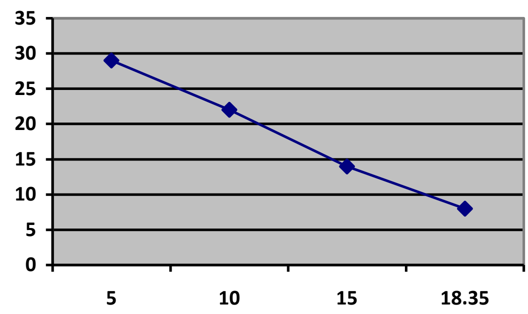


Figure 9. Cooling temperature against time

4.1.3 Return to Ambient Temperature

Following the cooling process, we further investigated the time required for the system to return to the ambient room temperature of 31°C after the engine was turned off. Our findings revealed an average time of 12 hours and 35 minutes for the system to return to this temperature.

Figure 9. A typical picture of the thermometer reading during testing

Figure 10. A typical picture of the constructed petrol driven refrigeration system

4.2 Discussion

The experimental results presented above demonstrate the efficiency and performance of the petrol engine refrigerating system. The key findings and their implications are discussed below:

4.2.1 Rapid Cooling

Our system demonstrated its ability to rapidly cool the space from 31°C to 8°C in just 18.35 minutes. This efficient cooling time suggests that the system has the potential to quickly lower temperatures in controlled environments, making it suitable for various applications, such as refrigeration in automobiles or small-scale cooling needs.

4.2.2 Fuel Consumption

During the cooling process, the system consumed only 0.8 liters of fuel. This fuel efficiency is a crucial factor, especially for applications where minimizing energy consumption is essential. Lower fuel consumption not only reduces operational costs but also has environmental benefits by lowering carbon emissions.

4.2.3 Return to Ambient Temperature

The system's ability to return to the ambient room temperature of 31°C within an average time of 12 hours and 35 minutes after the engine was turned off highlights its temperature regulation capabilities. This feature is crucial in scenarios where maintaining a stable temperature is critical, such as in refrigerated storage or transport.

In summary, results show that the built petrol engine cooling system has promising performance when it comes to efficient cooling, fuel consumption, and temperature control.

Further optimization and fine-tuning of the system could potentially enhance its capabilities, making it a valuable asset in various cooling and refrigeration applications. Future work should focus on optimizing the system for specific use cases and exploring its potential for broader commercial and industrial applications.

5. Conclusion and Future Scope

In this study, we have successfully designed and constructed a refrigerating system utilizing Nissan micro car AC components, powered by a Gx 160 petrol engine. Our investigation into the system's performance has yielded valuable insights, which form the basis for our conclusion and recommendations.

The COP of the refrigerating system was determined to be 12.2. This signifies an efficient utilization of energy for cooling purposes, highlighting the system's effectiveness in maintaining low temperatures. It is worth noting that achieving a high COP is crucial in applications like vaccine storage, where precise temperature control is essential.

Furthermore, the experimental results revealed that it takes approximately 18.35 minutes for the system to cool the vaccine room to 8°C, demonstrating a rapid cooling capability. However, the system requires 12 hours and 35 minutes to return the room temperature to its initial state. This

extended time for temperature recovery is an area that warrants further investigation and optimization.
In terms of fuel consumption, the system utilized 0.8 liters of petrol during the 18.35-minute cooling cycle. This information is vital for assessing the operational costs of the system and for potential improvements in fuel efficiency.

One noteworthy aspect that emerged from our study is the manual starting of the engine, which requires manpower. The engine's weight, measured at 982N, signifies the need for careful consideration regarding the ease of engine initiation. This aspect is crucial for ensuring the practicality and user-friendliness of the system.

Recommendations for Further Investigation and Design Enhancement
Based on our findings, we recommend the following areas for further investigation and design enhancement:

Engine Starting Mechanism: Given the manual starting process and the weight of the engine, it is advisable to explore automated or more user-friendly starting mechanisms. This can enhance the system's usability and reduce the physical strain on operators.

Temperature Recovery Time: The prolonged 12-hour and 35-minute temperature recovery time is a concern, especially in scenarios where rapid temperature stabilization is critical. Investigating methods to reduce this recovery time without compromising system efficiency is essential.

Fuel Efficiency Optimization: Consider researching and implementing techniques to improve fuel efficiency, which can lead to reduced operational costs and environmental benefits. This might involve adjusting engine settings, optimizing component performance, or exploring alternative refrigerants.

Long-term Reliability: Assess the long-term reliability and durability of the system, especially in continuous operation. Investigate potential wear and tear issues and develop maintenance protocols to ensure system longevity.

Energy Source Diversification: Explore the possibility of incorporating alternative energy sources, such as renewable energy or hybrid systems, to reduce dependency on fossil fuels and enhance sustainability.

In conclusion, our study has provided valuable insights into the performance of the refrigerating system constructed using Nissan micro car AC components and a Gx 160 petrol engine. By addressing the recommended areas of investigation and design enhancement, we can further optimize the system's efficiency, usability, and sustainability, making it a valuable asset for various applications, including vaccine storage and beyond. Continued research and development in this field hold the potential to revolutionize refrigeration technology and contribute to a more sustainable future.

Data Availability
If additional data not covered in this study is required by the reader, they are welcome to request it from the corresponding author via the provided contact information. Please note that certain data may not be publicly released due to privacy policies and confidentiality constraints.

Conflict of Interest
The author affirms that there are no conflicts of interest to disclose.

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None

Authors' Contributions
All authors revised and approved the final manuscript.

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Appendix: Project Cost

S/N	MATERIAL DESCRIPTIONS	QTY	UNIT	AMOUNT
1	Gx 160 petrol Engine	1	Pcs	N70,000
2	Freezer Compartment	1	Pcs	N15,000
3	Compressor and construction	1	pcs	N50,000
4	Belt	1	Pcs	N4,000
5	Condenser with dryer	1	Pcs	N35,900
6	Condenser fan	1	Pcs	N10,000
7	Evaporator	1	pcs	N45,000
8	Evaporator fan	1	pcs	N7,000
9	Refrigerant (R-134a)			N8,000
10	Bolt and Nut	30	Pcs	N15,000
11	Paint	4	Liters	N12,000
12	50x5mm RSEA	2	Length	N16,000
13	Two leg Tyre	1	Pair	N6,000
14	Fuel	5	Liters	N9,000
15	Engine oil	2	liters	N3,000
16	Electrode	1	Pack	N4,800
17	Alternator and accessories	1	pcs	N45,000
18	Battery	1	pcs	N17,500
19	Transportation			N15,000
		TOTAL		N388,200

Labor cost = 10% of material cost
=10% of N388,200= N38,820
Miscellaneous = 5% of material cost
= 5% of = N19,410
Total cost = labor cost + Material cost + Miscellaneous = N38,820+ N388,200 +19,410= N446430

AUTHORS PROFILE

Ojo Benson earned his bachelor degree Mechanical Engineering Manufacturing, from The Polytechnic, Ibadan in 2020. He is currently working as Mechanical Site Engineer for Metal Berg Manufacturing Limited. His main research work focuses on Smart Manufacturing, Sustainable and Advance Manufacturing, Joining and Fabrication, Material Development, Computational Mechanics, Human centered design, Process Optimization, Dynamic System & Control, Quality, and Precision engineering

