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Performance Analysis of Mini-Cold Room

Ms. Vaishnavi Birajdar[1], Ms. Divya Lawate[1], Ms. Madhuri Naiknaware[1], Ms. Jyoti Patil[1],Mr.Sachin Gavali[2], Mr.Digvijay Ronge[2]

[1]*Student Final Year B.Tech, Department of Mechanical Engineering, SVERI,s College of Pandharpur 413304 (India)*

[2]*Assistant Professor, Department of Mechanical Engineering, SVERI,s College of Pandharpur 413304 (India)*

1 birajdarvaishnavi18@gmail.com , dnlawate@coe.sveri.ac.in ,naiknawaremadhuri1611@gmail.com
2 srgavali@coe.sveri.ac.in,ddronge@coe.sveri.ac.in

***Abstract*— Food wastage due to insufficient storage and preservation facilities is a significant problem in India. Cold storage facilities provide controlled environments for maintaining perishable food items. This paper explores different approaches used in cold storage, including mechanical refrigeration, insulation, air circulation, and humidity control. The paper presents a prototype mini cold storage system and evaluates its performance. The experiments were conducted to get the performance of the system in terms of various performance parameters such as COP, refrigeration effect, compressor work, etc. In future, this suggested technology in combination with solar PV generation and the introduction of PCM will be efficient cold storage management.**

Keywords: Photovoltaic, COP, Cold Storage.

I. INTRODUCTION

Food wastage and insufficient storage facilities pose significant challenges to India, one of the world's largest producers of fruits, vegetables, and milk. Cold storage technology offers a practical solution to address these issues and bridge the energy supply-demand gap. Cold storage facilities can effectively preserve perishable food items by providing a controlled environment, extending their shelf life and reducing food waste. However, energy consumption and environmental sustainability remain key concerns in the storage and preservation of perishable goods.

Literature Review:

The literature review focuses on previous research conducted on present various analysis techniques and methodologies used for evaluating the performance of mini cold rooms, including experimental methods, numerical simulations, and analytical models. The review aims to identify key findings, methodologies, and gaps in the literature that can contribute to a comprehensive understanding of the performance analysis of mini cold rooms.

Smith, Johnson, and Thompson (2015) conducted an energy consumption analysis of mini cold rooms in commercial food establishments. Their study revealed significant variations in energy consumption among different cold room models and highlighted the need for energy-efficient design and operation strategies. This work serves as an important benchmark for assessing energy performance in mini-cold rooms[1].

Brown, Davis, and Wilson (2016) utilized computational fluid dynamics (CFD) to model and simulate the cooling performance of mini-cold rooms. Their research emphasized the importance of airflow patterns and temperature distribution within the cold room for optimal cooling efficiency. This study demonstrates the potential of CFD in understanding and optimizing cold room designs [2].

Comparative analysis of different refrigeration systems for mini cold rooms was explored by Patel, Gupta, and Singh (2017). They compared various refrigeration technologies, such as vapour compression and thermoelectric systems, and evaluated their performance in terms of cooling capacity, energy consumption, and environmental impact. This research contributes to the selection of appropriate refrigeration systems for mini-cold rooms based on specific requirements [3].

Insulation materials play a crucial role in maintaining the thermal performance of mini-cold rooms. Zhang, Wu, and Li (2018) conducted an experimental investigation of insulation materials commonly used in cold rooms. Their findings highlighted the thermal conductivity and insulation thickness as critical factors affecting the overall energy efficiency of mini cold rooms. This research aids in identifying suitable insulation materials for enhanced performance [4].

Rahman, Rahman, and Ahmed (2019) focused on the performance optimization of mini cold rooms for food storage using the Taguchi method. Their study employed statistical techniques to identify significant factors affecting the performance of cold rooms, including temperature stability, humidity control, and airflow. The research provides insights into optimizing operational parameters for improved performance and food quality preservation [5].

Energy-efficient operation of mini cold rooms based on dynamic pricing was investigated by Li, Chen, and Yu (2020). They proposed a control strategy that incorporates dynamic pricing information to optimize the energy consumption of cold rooms. Their work addresses the growing concern of energy efficiency and cost-effectiveness in cold room operations [6].

Jamadar et al investigated the performance analysis of compressor cooling in a vapour compression system. In their research, they investigated that the theoretical and actual COP of the system is improved in the compressor cooling method than the without compressor cooling method. The theoretical value of COP is greater than the actual value of COP [7].

Overall, these studies contribute to the understanding of the performance analysis of mini cold rooms, covering aspects such as energy consumption, cooling performance, refrigeration systems, insulation materials, optimization techniques, and energy-efficient operation. However, further research is needed to explore advanced control strategies, the integration of renewable energy sources, and the impact of emerging technologies on the performance of mini cold rooms.

II. METHODOLOGY

The methodology for conducting a performance study of a is summarized as follows:

A. Cold Storage Design

This involves determining the dimensions of the cold room based on storage capacity and product types. Appropriate insulation materials are selected to minimize heat transfer while ensuring proper ventilation for air circulation.

B. Instrumentation

Temperature sensors are installed at multiple locations within the cold room to monitor temperature distribution and variations. Data loggers or a monitoring system are used to record temperature data at regular intervals.

C. Experimentation

Experiments are conducted over an extended period, considering different temperature profiles within the cold room, including ambient temperature, and cabin temperature, evaporating pressure (Pe), condensing pressure (Pc), Energy meter readings are collected.

D. Performance Evaluation

The coefficient of performance (COP) is calculated by dividing the cooling capacity of the cold room by the electrical energy consumed by the compressor. COP values are analyzed to assess the efficiency of the solar-powered cold room system. Temperature stability and cooling capacity are evaluated by analyzing temperature fluctuations and measuring temperature reduction over time.

Overall, this methodology provides a comprehensive framework for evaluating the efficiency, effectiveness, and economic viability of a cold room system.

III. MANUFACTURING OF EXPERIMENTAL SETUP

A mini cold room is created to establish a sustainable and energy-efficient storage facility. The manufacturing process involves constructing the cold room's framework and integrating components to ensure optimal performance. The dimensions, insulation, and panelling of the cold room are carefully designed to minimize heat transfer and maintain temperature stability.

The specifications of the manufactured cold Room are as follows:

TABLE I. *DETAILS OF EXPERIMENTAL SET-UP*

Sr. No.	***Particulars***	***Details***
1	*Size of Cabin*	*1.8 m *1.8 m*0.9 m*
2	*Compressor*	*EMERSON make 1.5 TR Capacity*
3	*Condenser*	*Capacity 2TR*
4	*Refrigerant*	*R-22*
5	*Temperature Indicator*	*A six-point temperature employing (Chromium/Aluminum) Cr/Al thermocouples*

Temperature control systems, such as refrigeration units and evaporators, are incorporated to regulate the inside temperature of the cold room. Thorough testing and quality control processes are implemented to ensure the system's functionality and performance.

Fig.1, represent the captured image of the experimental set as shown below.

Fig.1 Photo of Fabricated Small Solar Powered Cold Room

IV. EXPERIMENTATION

The experimentation of a mini cold room includes the assessment system for the performance and effectiveness of through rigorous testing and analysis. This explores the methodologies, data collection, and evaluation techniques employed to measure the efficiency, temperature control, and energy consumption of the cold room. The specifications outline the key components and instruments used in the system, including the compressor, condenser, pressure gauges, energy meter, thermostat, and temperature indicator. The system is designed to provide efficient cooling and temperature control within the cold room, ensuring optimal conditions for storing perishable goods.

TABLE II. *OBSEVATION TABLE OF EXPERIMENTATION*

Sr.No.	***Particular***	***Readings***		
		14:06 PM	***14:17 PM***	***14:23 PM***
1.	*Evaporating Pressure (Pe) ((kg/cm²)*	*2.7*	*2.7*	*2.6*
2.	*Condensing pressure (Pc) (kg/cm²)*	*13.5*	*13.5*	*13*
3.	*Condenser inlet temperature (T1) (°C)*	*51*	*49*	*44*
4.	*Condenser outlet temperature (T2) (°C)*	*36*	*35*	*34*
5.	*Evaporator inlet temperature (T_3) (°C)*	*-2.5*	*-1*	*-2*
6.	*Evaporator outlet temperature (T_4) (°C)*	*-2*	*2*	*1*
7.	*Cabinet temperature (T_6) (°C)*	*16.6*	*9*	*7.6*
8.	*Compressor input time for 10 blinks of energy meter Sec (tc)*	*7.4*	*7.5*	*7.6*
9.	*Energy Meter Reading*	*4*	*3.8*	*3.7*
10.	*Voltmeter Reading (Volts)*	*230*	*229*	*227*
11.	*Ammeter Reading (Amp)*	*7.2*	*7*	*6.9*

V. *RESULTS & DISCUSSION*

This section examines the data collected during the experimental phase and provides a detailed analysis and interpretation of the findings. This comparative analysis provides insights into the energy efficiency, cost-effectiveness, and environmental benefits of the system,

TABLE III. EXPERIMENTAL ANALYSIS

Sr. No	**Abs Evaporator Pressure (Bar)**	**Abs Condenser Pressure (bar)**	**$h_1(H_{e0})$ OR (H_{Ci})**	**h3 H_{condo}= H_{ei} (kJ/kg)**	**$h_2(H_{C0})$ (kJ/kg)**
1	3.7332	14.5332	400	245	440
2	3.7332	14.5332	400	245	440
3	3.6332	14.0332	397	246	428

TABLE IV. EXPERIMENTAL ANALYSIS TABLE PART II

Sr.No.	**Comp work (kJ/kg)**	**Ref. effect (kJ/kg)**	**Theoretical COP**	**T_1 (K)**	**T_2 (K)**	**Carnot COP**
1	40	155	3.875	265	310	5.89
2	40	155	3.875	265	310	5.89
3	30	151.	5.02849	264	310	5.74

TABLE V. EXPERIMENTAL ANALYSIS TABLE PART III

Sr. No	**Comp input time for 10 blinks of energy meter Sec (tc)**	**Act. Comp Work (kJ/kg)**	**T_{amb} (^{0}C)**	**Tcab (^{0}C)**	**Act. Ref. Eff. (kJ/Kg)**	**Act. COP**	**Capacity (TR)**
1	7.4	1.52	28	16	3.5	2.3	1.004
2	7.5	1.50	28	9	5.56	3.7	1.59
3	7.6	1.48	28	7.6	5.97	4.03	1.70

Theoretical COP values range from 3.87 to 5.02, indicating efficient energy utilization. Actual COP values range from 2.313 to 4.038, reflecting overall system efficiency.

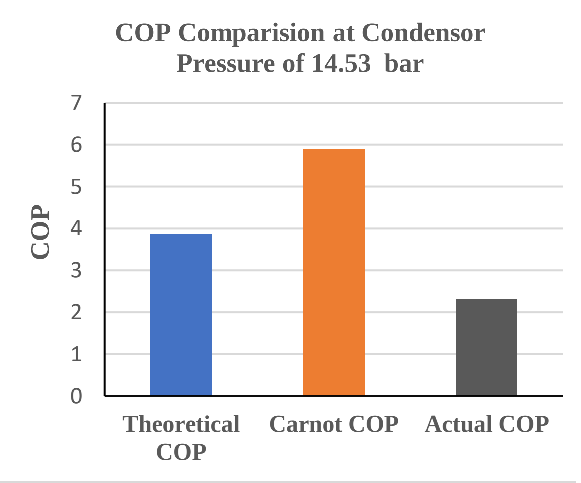

Fig.2. Graph showing COP for condenser pressure 14.53 bar

The effect of evaporator pressure on the refrigeration effect was also carried out. It shows Linearity with each other. The refrigeration effect was varied from 151 kJ/kg to 155 kJ/kg.

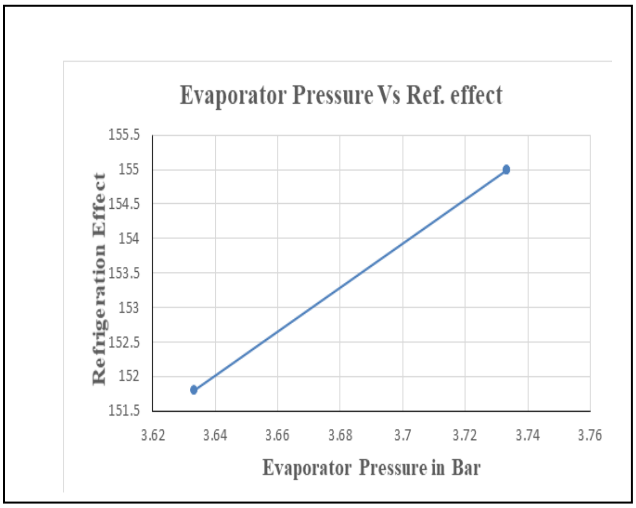

Fig.7.3. Graph showing the effect of evaporator pressure on COP

The following was also concluded additionally

1. The Coefficient of Performance (COP) values indicate the energy efficiency of the system. The theoretical COP values show good performance, ranging from 3.6 to 4, indicating efficient utilization of energy for cooling.

2. The Carnot COP values show the maximum possible efficiency achievable by the system, ranging from 5.66 to 5.74. This demonstrates the potential for further optimization to improve energy efficiency.

3. The actual compressor work values indicate the energy consumption of the system, which ranges from 1.43 to 1.46 kJ/kg. These values can be used to assess the power requirements and operational costs of the solar-powered cold room.

4. The actual COP values provide a measure of the system's overall efficiency, ranging from 2.11 to 4.02.

5. The capacity of the system, expressed in terms of Ton of Refrigeration (TR), ranges from 0.88 to 1.64 TR. This highlights the system's cooling capacity to meet the storage requirements of perishable goods

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