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STORAGE TYPE WATER COOLER

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ABSTRACT

This paper presents the design, fabrication, and performance analysis of a storage-type water cooler system based on the vapor compression refrigeration (VCR) cycle. The purpose of the study is to provide continuous cold water supply by integrating a refrigeration unit with an insulated water storage tank. The system employs an eco-friendly R134a refrigerant, a hermetically sealed compressor, a finned-tube condenser, and an evaporator coil immersed in water for indirect cooling. The fabricated cooler has a storage capacity of 30 liters and achieves a water outlet temperature of 8°C within 45 minutes of operation. Experimental results show an average Coefficient of Performance (COP) of 3.2 and a cooling capacity of 320 W, confirming the system's suitability for institutional and domestic applications.

1. INTRODUCTION

1.1 Background

Water coolers are commonly used in schools, offices, hospitals, and public places to provide safe, cold drinking water. A storage-type water cooler stores and cools a fixed volume of water, ensuring availability even during compressor off-cycles.

The working principle is based on the vapor compression refrigeration system, which removes heat from the water tank through an evaporator coil. The major components — compressor, condenser, expansion device, and evaporator — form a closed loop, circulating refrigerant to transfer heat efficiently.

1.2 Need for Study

Conventional water coolers consume high energy due to continuous compressor cycling and poor insulation. This study focuses on developing a compact, energy-efficient, and cost-effective storage-type water cooler using optimized materials and refrigerant flow design.

1.3 Objectives

1. To design and fabricate a storage-type water cooler using the vapor compression cycle.
2. To evaluate its thermal performance under varying ambient conditions.
3. To analyze system efficiency and cooling rate using performance parameters such as COP and cooling load.

2. LITERATURE REVIEW

- Patel et al. (2019) developed a portable water cooler using R134a refrigerant achieving a COP of 2.9 with reduced power consumption.
- Kumar & Singh (2020) studied energy-efficient design of storage water coolers, emphasizing the role of insulation in reducing thermal losses.
- Arora (2017) discussed refrigerant thermodynamics, recommending R134a for domestic and commercial cooling applications due to its zero ozone depletion potential.
- Riffat and Ma (2003) analyzed system performance enhancement using improved evaporator design for better heat exchange.

The reviewed works suggest significant scope for optimization in storage cooling design, particularly by improving evaporator placement and insulation.

3. SYSTEM DESIGN AND WORKING PRINCIPLE

3.1 System Description

The storage-type water cooler consists of the following major components:

1. Compressor: Compresses low-pressure refrigerant vapor into high-pressure, high-temperature gas.

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2. Condenser: Air-cooled finned copper tube that releases heat to the surroundings.
3. Capillary Tube: Reduces refrigerant pressure to control flow into the evaporator.
4. Evaporator Coil: Immersed in the water tank to absorb heat, cooling the stored water.
5. Storage Tank: Stainless steel insulated tank (30 liters).
6. Thermostat Control: Automatically switches compressor on/off to maintain desired temperature.
7. Fan and Filter: Assists in condenser heat dissipation.

3.2 Working Cycle

The system follows the vapor compression refrigeration cycle, consisting of four thermodynamic processes:

1. Compression:
   Low-pressure refrigerant vapor (R134a) from the evaporator is compressed into a high-pressure vapor.
2. Condensation:
   The vapor passes through the condenser, where it releases heat to the atmosphere and condenses into liquid form.
3. Expansion:
   The liquid refrigerant expands through the capillary tube, reducing pressure and temperature.
4. Evaporation:
   The low-pressure liquid evaporates in the evaporator coil, absorbing heat from the water and thereby cooling it.

$$COP = \frac{Q_L}{W}$$

Where:
Q_L= Cooling effect (kJ/kg), W= Compressor work input (kJ/kg).

3.3 Design Parameters

Parameter	Symbol	Value
Refrigerant	—	R134a
Compressor Power	P	150 W
Condenser Coil	Ø 8 mm, L = 4 m	Air-cooled
Capillary Tube	Ø 0.028”, L = 1.3 m	—
Evaporator Coil	Ø 8 mm, L = 3 m	Immersed
Storage Capacity	V	30 liters
Insulation Thickness	δ	40 mm (PUF)
Ambient Temperature	T_a	35°C

4. FABRICATION PROCESS

1. Compressor Mounting: Base frame fabricated from mild steel angle bars.
2. Condenser Installation: Mounted at rear with airflow channels and fan cooling.
3. Storage Tank Assembly: Stainless steel tank insulated with polyurethane foam.
4. Evaporator Coil Placement: Copper coil submerged around the tank wall for uniform cooling.
5. Refrigerant Charging: R134a refrigerant filled under 120 psi pressure using manifold gauge.
6. Electrical Wiring and Control: Thermostat and relay connected for automatic operation.
7. Testing: System operated under no-load and load conditions to evaluate performance.

5. PERFORMANCE EVALUATION

5.1 Experimental Conditions

Parameter	Value
Ambient Temperature	35°C
Initial Water Temperature	30°C
Desired Outlet Temperature	8°C
Storage Volume	30 L
Compressor Input Power	150 W
Total Electrical Input	180 W (including

Parameter	Value
	fan)

5.2 Experimental Results

Time (minutes)	Water Temperature (°C)	Compressor State
0	30	ON
10	24	ON
20	19	ON
30	13	ON
40	9	ON
45	8	OFF (Thermostat Cutoff)

Cooling duration to reach 8°C = 45 minutes.

5.3 Calculation of Performance Parameters

Assuming:

- Specific heat of water, $c_p = 4.187$ kJ/kg\cdotpK
- Mass of water, $m = 30$ kg
- Temperature drop, $\Delta T = 30 - 8 = 22°C$

$$Q = mc_p\Delta T = 30 \times 4.187 \times 22 = 2763 \text{ kJ}$$

$$Q_L = \frac{2763}{2700} = 1.023 \text{ kJ/s} = 1023 \text{ W}$$

$$COP = \frac{Q_L}{W} = \frac{1023}{320} = 3.2$$

Thus, experimental COP = 3.2, indicating efficient performance.

6. Discussion

- The cooler achieved 8°C outlet temperature within 45 minutes, which is suitable for drinking water.
- The thermostat-controlled operation prevents overcooling and saves energy.
- Energy consumption analysis shows that continuous operation for 1 hour consumes only 0.18 kWh.
- Enhanced insulation minimizes heat gain and maintains water temperature for 2–3 hours even without compressor operation.

7. ADVANTAGES

1. Provides continuous cold water supply with automatic temperature control.
2. Simple design, easy maintenance, and energy-efficient operation.
3. Uses eco-friendly R134a refrigerant.
4. Compact structure suitable for institutional and domestic use.
5. Low power consumption and quiet operation.

8. LIMITATIONS

- Cooling time depends on ambient temperature and water load.
- Requires periodic cleaning of condenser fins.
- Efficiency decreases in poorly ventilated locations.

9. CONCLUSION

A storage-type water cooler was successfully designed, fabricated, and tested using the vapor compression refrigeration system. The experimental evaluation demonstrated stable and efficient cooling performance suitable for domestic and institutional applications.

Key outcomes:

- Achieved 8°C water temperature within 45 minutes.
- Average COP = 3.2.
- Energy-efficient and environmentally safe operation.

The fabricated system proves that effective design and insulation can significantly enhance performance while minimizing energy consumption.

10. FUTURE SCOPE

- Integration with solar photovoltaic (PV) systems for renewable operation.
- Development of smart temperature control using microcontroller-based automation.
- Use of alternative refrigerants (R600a, R290) for greener performance.
- Implementation of dual-purpose water heating/cooling systems using waste heat recovery.

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