JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Performance Analysis of Heat Pump Air Conditioning System for Heating and Cooling

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Abstract -

Heat pumps are flexible devices that have gained significance as an energy-efficient alternative for both heating and cooling. Traditional heat pumps work in either heating or cooling mode, requiring the installation of separate systems for each season. The concept of simultaneous heating and cooling (SHC) using heat pumps, on the other hand, has emerged as a viable alternative to traditional HVAC systems. This study article seeks to give a complete evaluation of the most recent innovative techniques, developments, and issues linked with applying heat pumps. This study provides useful insights into the potential of SHC systems for improving energy efficiency and thermal comfort in buildings by investigating various system configurations, control tactics, and technology breakthroughs.

keywords :

SHC heat pump
HVAC System
Dual mode heat pump
Heat recovery heat pump
Simultaneous heating and cooling control

I. INTRODUCTION

In this work the development of System has been a focus of research for many years, with the goal of creating machines that can give the two system in one machine. This is going to give the cooling system and heating system in one machine.

Heat pumps are quite efficient equipment but the heat they produce form their renewable component varies only according to changes in in the temperature of the environment as they take input from atmosphere. Thermal solar collectors are the best source of heat on hot and sunny days but they are totally inefficient whenever there is no sun.

This project aims to develop There is need to develop those types of modified devices which consume less energy. The main objective of our project is to provide heating and cooling effect simultaneously in one device which can lead to less consumption of energy for the desired effect. Cooling device like refrigerator or freezer which provide cooling effect and it consumes more electricity as it sinks the high temperature exhaust in atmosphere and goes waste. If we need heating effect, we will have to use heat pump or any other electrical resistance heating system, these are the high electrical power consuming devices. If we need hot and cold water simultaneously we need two different device to meet our requirement, but use of two different devices for two different desiring effects will lead to high energy consumption, more space need and operating problems.

The increasing demand for thermal comfort in buildings, coupled with the need for energy efficiency, has driven the development of advanced heating and cooling technologies. Heat pumps have gained popularity due to their ability to extract heat from renewable sources such as the ambient air, ground, or water, and transfer it indoors for heating purposes. In cooling mode, heat pumps can reverse the cycle and remove heat from indoor spaces. While heat pumps are inherently more energy-efficient than conventional heating and cooling systems, the need for separate equipment for heating and cooling has limited their full potential.

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Fig. 1: Assembly of the system

II. CONCEPT OF HEAT PUMP SYSTEM

A heat pump system is a type of HVAC (Heating, Ventilation, and Air Conditioning) system that is designed to transfer heat from one location to another using the principles of thermodynamics. It operates based on the concept that heat naturally flows from warmer areas to cooler areas.

In a heat pump system, a refrigerant fluid is circulated through a closed loop. The system consists of four main components: an evaporator, a compressor, a condenser, and an expansion valve. Here's how the process works:

Evaporator: The refrigerant fluid absorbs heat from a low temperature source (such as outdoor air or the ground) and evaporates into a gas form.

Compressor: The compressor then increases the pressure and temperature of the refrigerant gas, which further enhances its heat-carrying capacity.

Condenser: The high-pressure, high-temperature refrigerant gas enters the condenser, where it releases heat to a higher temperature area (such as indoors for heating or outdoors for cooling). As the refrigerant releases heat, it condenses back into a liquid state.

Expansion Valve: The condensed liquid refrigerant passes through an expansion valve, which reduces its pressure and temperature, preparing it for the next cycle.

The process repeats cyclically, with the heat pump system continuously transferring heat from one location to another. In heating mode, the heat pump extracts heat from the outdoor air (even at low temperatures) and transfers it indoors, providing warmth. In cooling mode, the process is reversed, with the heat pump extracting heat from indoors and releasing it outdoors, providing a cooling effect.
Heat pump systems are known for their energy efficiency since they can deliver more heat or cooling energy compared to the electrical energy they consume. They are particularly effective in moderate climates and can provide both heating and cooling in a single system, offering year-round comfort.

III. COMPONENTS OF HVAC SYSTEM

parts of heat pump are similar to those of a refrigerator or an air conditioner, though they function in reverse. This is why heat pumps are sometimes called reverse refrigerators. The heat pump consists of four major components: a compressor, a condenser, an expansion valve ,and an evaporator. When it comes to refrigerators and air conditioners, the evaporator is most responsible for cooling or freezing, but for heat pumps, the condenser is most responsible for heating the room.

1. Compressor

A compressor is a mechanical device that increases the pressure of a gas by reducing its volume. An air compressor is a specific type of gas compressor. Compressors are similar to pumps: both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas.

We are using R-32 because it is a next generation refrigerant that efficiently carries heat and has lower environmental impact. Refrigerant is a medium for conveying heat. Air conditioners transfer heat while circulating refrigerant between the indoor and outdoor units.

R32 compressors are designed to work specifically with the R32 refrigerant, which offers improved environmental performance compared to other refrigerants. They play a vital role in heat pump and air conditioning systems, efficiently compressing R32 gas and facilitating the heat transfer process within the system.

Fig. 2: R-32 Compressor

Model	Displacement	Cooling	Power	COP	Capacitor	Compressor
No		Capacity				Height
	(cc)	W/Btu/hr	(W)	(W/W)	(uF/V)	(mm)
KSF180 S1VFPA	18.0	5535|18882	1265	4.38	40/370	314

Table no 1:Compressor's Specifications

2. Condenser

copper both heats up and cools down faster than aluminium. Hence, in terms of actual usage, copper condenser air conditioners provide faster cooling compared to those which have an aluminium condenser Copper has one major advantage over aluminium is its low specific heat. In real world usage, copper condenser AC's can offer faster cooling compared to aluminium .That's where features like Turbo cool, Power Cool, etc. come in

Fig. 3: Condenser

Material	Copper
Size	20 30
Tube Material	Copper
Fin Material	Aluminium
Colour	Silver

Capacity	Min - 1.5 Tr to 150 tr
Is it Customized	Customization
Corrosion Resistance	Yes
I Deal In	New Only
Minimum Order Quantity	10 Square Feet

Table no 2: Condenser's Specifications

3.Expansion Valve

A thermal expansion valve or thermostatic expansion valve is a component in vapor compression refrigeration and air conditioning systems that controls the amount of refrigerant released into the evaporator and is intended to regulate the super heat of the refrigerant that flows out of the evaporator to a steady value.

Fig. 4: Expansion Valve

3. Reversing Valve

A reversing valve is a type of valve and is a component in a heat pump, that changes the direction of refrigerant flow. By reversing the flow of refrigerant, the heat pump refrigeration cycle is changed from cooling to heating or vice versa. This allows a residence or facility to be heated and cooled by a single piece of equipment, by the same means, and with the same hardware. The reversing valve has two states, relaxed (unactuated) versus energized. The energized state is typically achieved by applying 24 volts AC, which is commonly used in HVAC equipment. The heat pump can be designed by the manufacturer to produce either cooling or heating with the reversing valve in the relaxed state. When the reversing valve is energized, it will produce the opposite transfer of heat from its relaxed state. For example, a reversing valve installed in such a way as to produce cooling when relaxed will produce heating when energized. Likewise, a reversing valve installed to produce heating when relaxed will produce cooling when energized.

Fig. 5: Reversing valve

IV. WOKING CYCLE

Heat pump uses the same principle of vapor compression refrigerant cycle and has the same basic components like a traditional air conditioner (compressor, condenser, evaporator, and expansion device), except that it can reverse the refrigeration cycle or in other words, swap the functions of the two heat ex changers (condenser and evaporator). Refer to the schematic below and note the application is reversed for heating mode. (Note the components are not reversed physically).

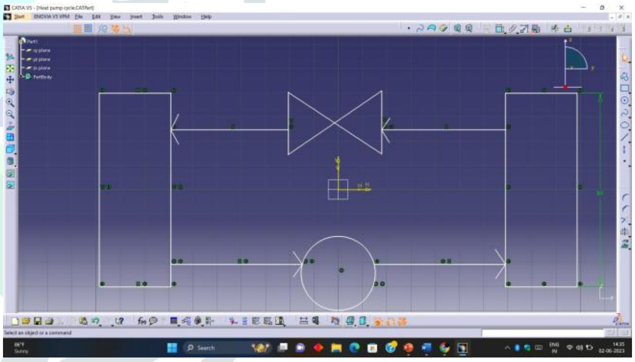


Fig 6: Heat Pump Cycle

Study of vapor compression refrigeration system

- Stage 1 – Outside heat ex changer picks up heat from the earth, ground water or air and transfers it to the refrigerant. The refrigerant gets evaporated and now enters the compressor.

- Stage 2 – The refrigerant, having now absorbed the environmental heat now enters the compressor and is compressed. The compressor increases the pressure of the refrigerant and also its heat content. This is the only part of the cycle where additional energy is required

- Stage 3 – The refrigerant gas now passes through the "indoor side" heat ex changer where it gives up its heat and turns back into a liquid.

- Stage 4 – In order to be able to start the cycle again, the refrigerant must be DE-pressurized, and so it is passed through an expansion valve, where it returns to a low-pressure liquid / gas mix and can begin to absorb heat from the air/earth/water again as it moves toward point 1.

VI HEATING AND COOLING LOAD OF HEAT PUMP

Coefficient of performance without heating element

COP without heating $= \frac{h1 - h3}{h'2 - h'1}$

Coefficient of performance with heating element

COP with heating $= x = \frac{h1 - h3}{h2 - h1}$

since,

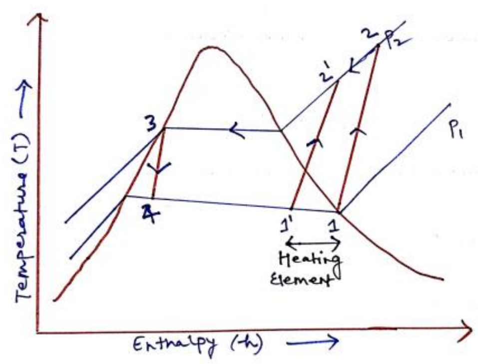
(Work done by compressor without heating element)>(Work done by compressor with heating element)

i.e. (h ′ 2 − h ′ 1)>(h2 − h1)

so,

COP with heating coil > COP without heating coil

Using Sub-cooling device between condenser and expansion device This is the process of cooling the refrigerant liquid below its condensing temperature at a given pressure. Subcooling is beneficial as it increases the refrigeration effect by reducing the throttling loss at no additional specific work input. Sub-cooling provides 100 percent refrigerant liquid to enter the expansion device, preventing vapour bubbles from impending the flow of refrigerant through the expansion valve. If the sub-cooling is caused by a heat transfer method external to the refrigeration cycle, the refrigerating effect of the system is increased, because the sub-cooled liquid



T-S Diagram with heating element

has less enthalpy than the saturated liquid. Sub-cooling is accomplished by refrigerating the liquid line of the system, using a higher temperature system. The state of the refrigerant entering the expansion device of conventional vapor compression cycles is usually assumed to be saturated liquid. However, liquid cooling below saturation reduces the throttling losses and potentially increases COP.

mathematical calculation:

- Coefficient of performance without sub-cooling

COP without sub-cooling $= x = \frac{h2-h1}{h3-h2}$

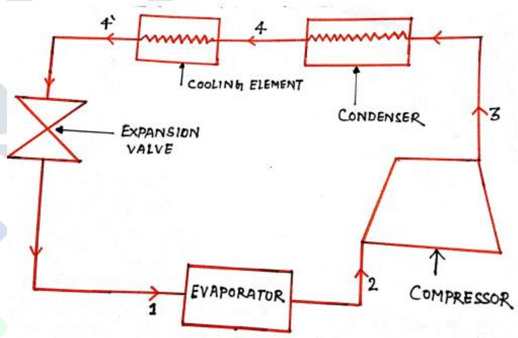
- Coefficient of performance with sub-cooling

COP with sub-cooling $= \frac{h'2-h'1}{h3-h2}$

since,

(Refrigerating effect with sub-cooling)>(Refrigerating effect without sub-cooling)

i.e. (h2 − h ′ 1) >(h2 − h1)



refrigeration system with sub-cooling device between condenser and expansion device

COP with sub-cooling > COP without sub-cooling

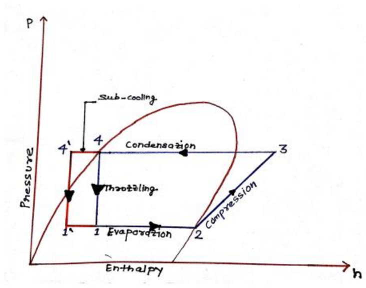
Heating Part Energy transfer to the hot water = Mass of water × specific heat capacity of water × temperature difference

Q = m × c × ΔT Here, Mass (m) = 2kg

Initial temperature of refrigerant flowing through evaporator (T1) = 21oC

Final temperature of refrigerant flowing through evaporator (T2) = 41oC

Temperature Difference (ΔT) = 20oC



T-S Diagram with sub-cooling Device

Specific Heat Capacity of water = 25KJ/Kg×K

Energy transfer to the hot water: Q = 2 × 25 × 20 = 1000KJ

Q Heating = 1000KJ

Time required to heat (t) = 30 min = 1800 sec.

Rate of heat transfer == $\frac{Energy\ Transfer}{Average\ Time\ Required} = \frac{1000\ \text{KJ}}{1800\ sec}$ = 0.555 KW

Cooling Part

Dimension of internal space of room = 15 feet x 20 feet

Volume of internal space of room = 8495053.98 cm3

Density of air = 1.225 Kg/m3

Specific Heat Capacity at constant volume = 0.718 KJ/Kg ×K

Mass (m) = Density of air× Volume of air

Final cooling chamber temperature = 8oC

Initial cooling chamber temperature = 27oC

Heat transfer internal space of room = Mass of air×specific heat of air at constant volume×temperature difference

Q = m × c × ΔT

Q = 0.019590 × 0.718 × 19 = 0.2672KJ

Q Cooling = 0.2672KJ Rate of Heat Transfer =$\frac{0.2672}{1800\ sec}$ = 1.4844 $\times 10^{-4}$KW

IV. CONCLUSION

In conclusion, the Assembling of the system we get to know the why the exact the component is using and connecting and assembling to the system how the existence of one component changes the whole air conditioning cycle.

We also to come to know how the electricity usage is getting less and hoe it is energy efficient and a system is energy efficient. With the current developing technologies in this field.

This research paper aims to contribute to the existing knowledge on simultaneous heating and cooling systems using heat pumps. By analysing different system configurations, control strategies, and technological innovations, it will provide a comprehensive overview of the current state-of-the-art. The findings of this study can serve as a valuable resource for researchers, engineers, and policymakers working towards developing more sustainable and energy-efficient heating and cooling solutions in the built environment.

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