Feasibility Study and Development of Refrigerator cum Air Conditioner

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Abstract- This paper is about our attempt to merge Domestic Refrigerator and Air conditioner into a combined system such that an ordinary man can have a sound sleep which automatically increases his working productivity for the next day.
Refrigerator has become a necessity of all households in 21st Century. As the country's GDP is 8 to 9% and is likely to be 10%, hence the standard of living of common man is bound to be better. In all metropolitan cities, environment degradation due to automobile & other factors is on the rise, therefore the requirement of air-conditioner has already been felt.
The motivation for the project comes from rising energy demands and hence its cost. As we all know that we are lacking of power resources, so this product will help us in tackling this problem as we are trying to make a personalized cooling system which will run at a very low cost that can be afforded by a common man.
In minimum construction, maintenance and running cost, this attempt is quite useful for domestic purpose so that our ultimate aim of the project that is those who cannot afford an Air Conditioner can have the comfort of Air Conditioner could be completed. Since all energy cost are on a rise, therefore this project is a way forward in realizing the economic as well as environmental demands. As it is said "the energy saved is the energy produced". On the other hand the common man can have the comfort of Air conditioner.

Index Terms- Affordable, Air Conditioner, Domestic Refrigerator, Productivity

I. INTRODUCTION

Refrigerator is ranked as one of the best innovations of the 20th century where Refrigerator explored in earlier of 20th century and Air-Conditioner is lately in that of 20th century. However it has become the prime necessity in 21st century .In over a span of three decades, there has been a surge in energy demands due to the everlasting population especially in India. This has led to increase in pollution and energy cost that cannot be affordedby poor men. The idea of this project explores the possibility of combining two units i.e. Refrigerator and Air-Conditioner into a single unit, such that the running cost becomes zero or almost negligible. The name of the device is termed as Refrigerator cum Air-Conditioner where both the Refrigerator and Air-Conditioner are working on the cost of only Refrigerator. This is how we are trying to make the environment and a common man comfortable. By this product a common man could have a sound sleep so that his productivity for the next day increases.
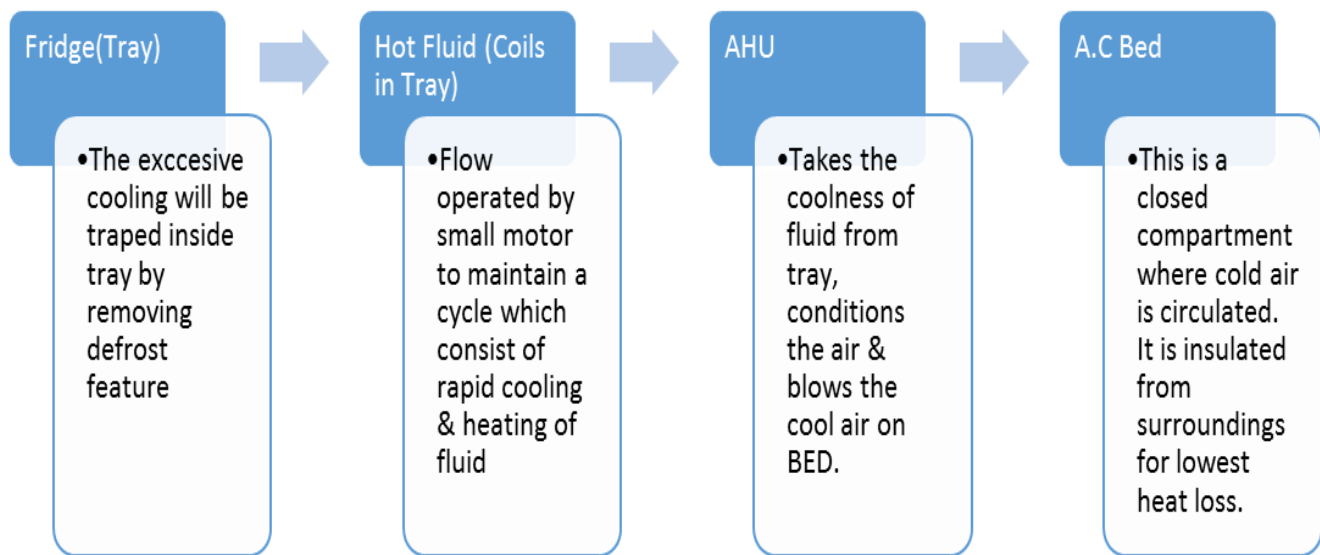
II. SYSTEM DESCRIPTION

Fridge(Tray)	Hot Fluid (Coils in Tray)	AHU	A.C Bed
•The exccesive cooling will be traped inside tray by removing defrost feature	•Flow operated by small motor to maintain a cycle which consist of rapid cooling & heating of fluid	•Takes the coolness of fluid from tray, conditions the air & blows the cool air on BED.	•This is a closed compartment where cold air is circulated. It is insulated from surroundings for lowest heat loss.

Figure 1: Block diagram of whole setup

Components
- Refrigerator with Closed Tray
  Refrigerator
  - *Compressor* = Reciprocating type hermitically sealed, 1/8 hp, 240 volt
  - *Refrigerant* = R-22/R-134a
  - *Throttle Valve* = Capillary tube, Dia – 1 mm, Length – 2 m
  - *Condenser* = Air cooled type, Copper tube, Diameter – 5 mm, No. of turns 7
- Copper Pipes (Coils)
- Air Handling Unit
- Low Power Pump
- A.C Bed

TRAY
In this research, dripping tray is been replaced by a closed tray.
A tray is like a closed compartment to use the extra cooling of freezer which is until wasted by defrosting feature of refrigerator. It will set beneath the freezer, where dripping tray is held. The area would be kept same as that of ordinary tray that can easily fit inside the fridge. Specific height is provided to the tray so that it shapes like a box, insulated from each side.
Now the working is simple, the excess coolness is passed inside the closed tray compartment where the conductive coils (Copper tubes) carrying the flowing fluid to be cooled is lying. As the fluid is under room temperature, the heat exchange will take place as a result of temperature gradient. This will cool down the fluid so that it can be employed as a coolant for Air Handling Unit.

AIR HANDLING UNIT
An (AHU) comprises of following components
1) Fans/Blowers – the purpose of fan is related to the movement of air. It may operate at a single speed or may offer different air speeds.
   Commonly used types of fans are –
   a) Constant air volume (CAV)
   b) Variable air volume(VAV)
2) Coils- coils carry the coolant. It is in the coils where heat exchange takes place. Heat exchange may occur in cross flow or counter flow fashion.
   Coolant used in the project is water and the material of which coils are made of is copper

3) Dampers – the fan in an AHU create a substantial vibration & duct system could transmit this noise to the occupants of the bed. To avoid this, vibration isolators are used between the fan & the rest of the (AHU).
4) Filters- air filtration is necessary as the air may comprise of dust particles or microbes. If large amount of dust & microbes are present they will make air unfit for breathing.
   For maintain air quality the filter has to regard to odour, dust, toxic gasses & bacteria.

AC BED
AC bed is made from a very light weight and high thermal resistivity **Polyurethane foam** having thermal conductivity of K=0.03 of dimensions 6' X 4'X 3'6"(L X B X H).the thickness of insulation is from 2cm-3cm.

III.   THEORY

A vapor compression cycle is used in most household refrigerators, refrigerator–freezers and freezers. In this cycle, a circulating refrigerant such as R134a enters a compressor as low-pressure vapor at or slightly above the temperature of the refrigerator interior.
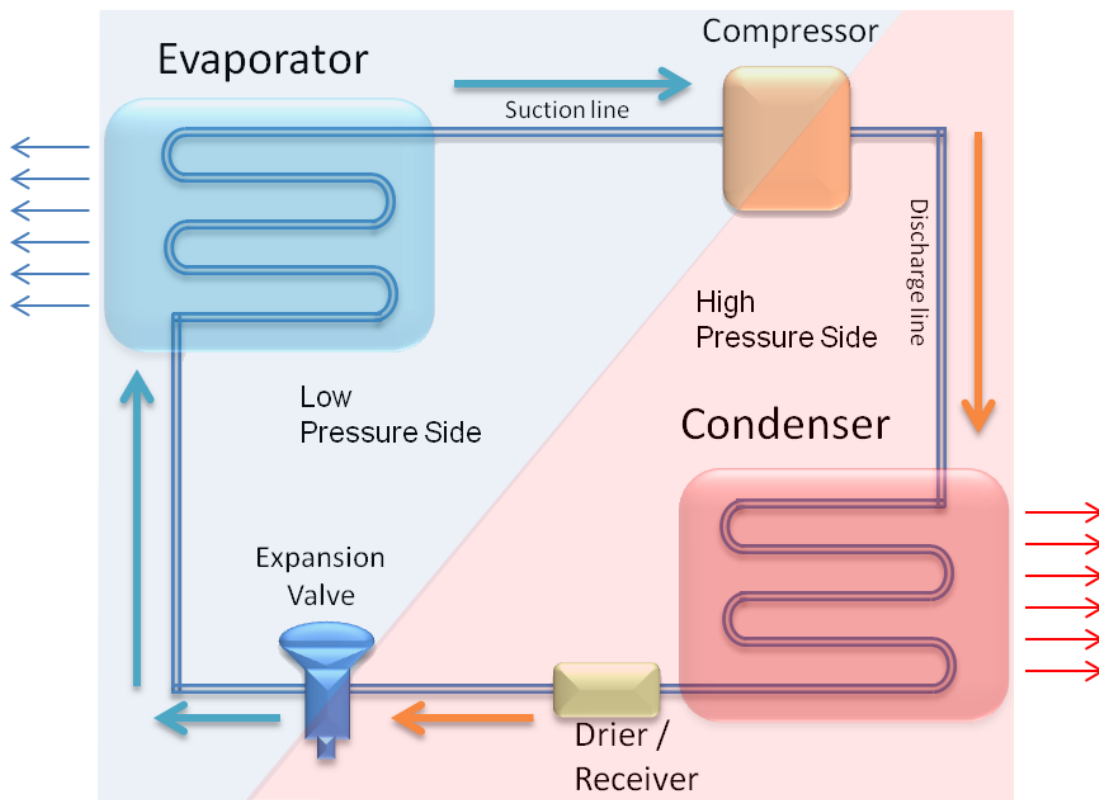

Figure 2: Vapor Compression (Referigeration) Plant-flow Diagram

The vapor is compressed and exits the **compressor** as high-pressure superheated vapor.

The superheated vapor travels under pressure through coils or tubes that make up the ***condenser***; the coils or tubes are passively cooled by exposure to air in the room. The condenser cools the vapor, which liquefies. As the refrigerant leaves the condenser, it is still under pressure but is now only slightly above room temperature.

This liquid refrigerant is forced through a **metering or throttling device**, also known as an expansion valve (essentially a pin-hole sized constriction in the tubing) to an area of much lower pressure. The sudden decrease in pressure results in explosive-like flash evaporation of a portion (typically about half) of the liquid. The latent heat absorbed by this flash evaporation is drawn mostly from adjacent still-liquid refrigerant, a phenomenon known as *auto-refrigeration*.

This cold and partially vaporized refrigerant continues through the coils or tubes of the **evaporator** unit. A fan blows air from the refrigerator or freezer compartment ("box air") across these coils or tubes and the refrigerant completely vaporizes, drawing further latent heat from the box air. This cooled air is returned to the refrigerator or freezer compartment, and so keeps the box air cold. Note that the cool air in the refrigerator or freezer is still warmer than the refrigerant in the evaporator. Refrigerant leaves the evaporator, now fully vaporized and slightly heated, and returns to the compressor inlet to continue the cycle. Domestic refrigerators are

extremely reliable because the moving parts and fluids are sealed from the atmosphere for life, with no possibility of leakage or contamination. In comparison, mechanically-driven refrigeration compressors, such as those in automobile air conditioning, inevitably leak fluid and lubricant past the shaft seals. This leads to a requirement for periodic recharging and, if ignored, possible compressor failure.
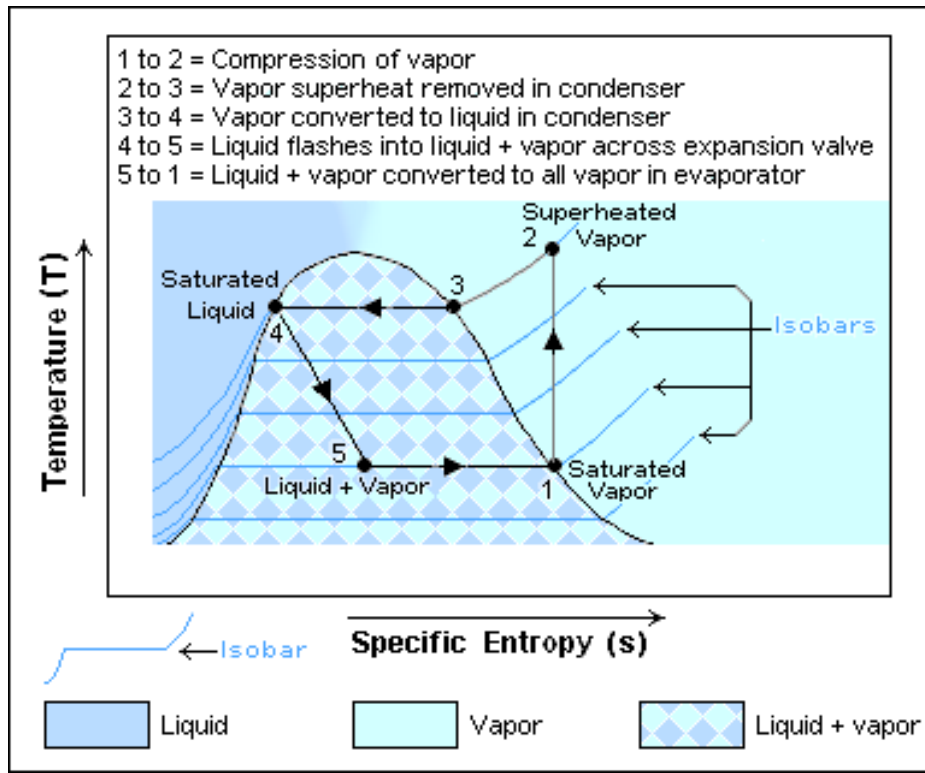

Figure 3: Vapor Compression (Referigeration) Temperature-entropy Diagram

Unit of refrigeration

Domestic & commercial refrigerators may be rated in kJ/s, or Btu/h of cooling. One British thermal unit is equal to about 1055 Joules. It is the amount of energy needed to cool or heat one pound (0.453 kg) of water by 1 deg. Fahrenheit. Commercial refrigerators in the US are mostly rated in tons of refrigeration, but elsewhere in kW. One ton of refrigeration can freeze one short ton of water at 0 deg. C in 24 hours i.e. 2000 pounds of ice at 144 BTUs per pound (heat of fusion of water) = 288000 BTUs

288000/24 = 12000 BTUs/hr. or one ton of refrigeration.

Now, an **air handling unit (AHU)** is device used to regulate & circulate air. It is a part of air conditioning system. They usually connect to duct ventilation system that distributes the conditioned air to the desired area.

AHU are of different types and sizes. They are used to offer cooling as well as heating purposes; also they can be just used to as a ventilation system to provide fresh air into office buildings.

Small AHU may comprise of only air filter, coils & blower & these are called *fan coil units*. A large air handler that contains 100% outside air & no recalculated air is known as *makeup air unit (MAU). An air handler for outdoor use, typically on rooftops is known as rooftop units* (RTU).

We allow the cool air to the AC Bed. An AC bed is a thermal insulating covering upon existing beds, like a mosquito net. This bed helps to maintain a certain temperature to make person comfortable so that he can relax better at night and become more productive on next day

IV.   MEASUREMENTS AND CALCULATIONS

Cooling capacity is directly related to size of area. 2 tons i.e. 48000 BTU/hr of AC is required to cool 2000 sq. feet home. Hence, 1500 BTU/hr is sufficient to cool 50 sq. (7*7) feet A.C Bed i.e. approximately 0.12 ton of refrigeration.

According to the heat exchange inside A.C Bed the corresponding cooling capacity is provided by tray. The cooling capacity can be varied by:-

- Changing dimensions (number of turns, diameter of pipe) of coils through which working fluid (water) flows.
- Controlling the flow rate of water, that is driven by pump.

Various thermal losses are involved in flowing fluid, whichis required to be minimized:-
- Convective & Conductive Losses, due to temperature gradient between surroundings & inside fluid.
- Frictional Losses.

Tray Technicalities:
- Temperature maintained inside tray: -10 to -15°C
- Working fluid used: Water
- Temperature of Working fluid :-
  - Before entering tray, T_{h1}: 45°C
  - After leaving tray, T_{h2}: 15°C(expected)
- Material for coils: Copper (Thermal Conductivity – 385-386 W/m.K)

Consider cross-flow heat exchange inside tray between refrigerant & working fluid.

Hence, Heat exchanged is, $Q = m_h c_h \Delta T$

Here, $m_h = mass\ flow\ rate\ of\ water\ (\frac{kg}{s})$

$c_h = specific\ heat\ of\ the\ water = 4.18\ kJ/kg^0C$

$\Delta T =$

$T_{h1} - T_{h2}$ (Temperate diff. of water before & after passing through tray)

$$Q = m_h * 4.18 * 30\ kW$$

A.C Bed Calculations

Measurements are done on two materials one is PVC strips and second is polyurethane form.

Table 1: Measurement for A.C Bed Insulation

Using PVC strips		Using polyurethane foam	
Thickness(δ)	Heat Rate(Q)	Thickness(δ)	Heat Rate(Q)
1 cm	2452 W	1 cm	383 W
2 cm	1216 W	2 cm	192 W
3 cm	810 W	3 cm	128 W

V. CONCLUSION

The refrigerator's defrost function is utilized to extract excessive coolness and is fed to an AHU to work like an Air conditioner which is used for personalized cooling. After this paper we conclude that a common man can have comfort of air conditioner at very low running cost or zero cost, which would prepare him for better productivity for the next day.

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