Portable Air Conditioner Design for Fabrication

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***Abstract*—The increase in the demand of the domestic energy necessitates the developments of the innovative solutions in the area of heating, ventilation and air conditioning. This project presents a novel design of the Portable air conditioner for a domestic purpose. Unlike conventional air conditioning systems which are fixed and effect complete space, portable AC's can be moved and spot cooling can be achieved. This eliminates the need for higher capacities and multiple AC's. Design is carried out considering the mass production of AC's. An AC with vapour-compression refrigeration cycle is considered. Suitable sub-systems like compressor, evaporator, condenser etc. have been calculated. Performance of the AC after the fabrication will be evaluated experimentally.**

***Index Terms*—Computational fluid dynamics, portable ac, condenser, R22**

I. Introduction

Air conditioning systems are one of the most important products in contemporary world. They are vital in creating comfort living conditions. With the effect of global warming temperatures are rising, as a result air conditioner sales are increasing drastically every year. Various types of air conditioning systems are available in the market to cater the needs of different levels of air conditioning for homes, offices, industries, shopping malls etc.

Portable air conditioner is an innovative product originally derived from standard window air conditioner running on vapour compression refrigeration cycle. Standard window air conditioner or Split Air conditioner is limited to be used in room or inside a closed environment, once fixed it cannot be mobilized.

Portable air conditioner runs on vapour compression refrigeration cycle with rotary compressor. Unlike conventional air conditioners which run in a closed environment, portable air conditioners can be used in both closed environment and open environments like a retail outlet or a showroom or in any open hall with air conditioner focused on specific location. In addition to that portable air conditioner gives localized air conditioning effect which cannot be achieved with conventional type air conditioners.

In this paper the performance of a portable air conditioner based on vapour compression refrigeration cycle and running on R23 refrigerant has been evaluated. Various types of heat exchangers used in refrigeration and air-conditioning systems have been studied in detail.

A. Vapor Compression Refrigeration Systems

Vapour compression refrigeration systems are the most commonly used among all refrigeration systems. As the name implies, these systems belong to the general class of vapour cycles, wherein the working fluid (refrigerant) undergoes phase change at least during one process. In a vapour compression refrigeration system, refrigeration is obtained as the refrigerant evaporates at low temperatures. The input to the system is in the form of mechanical energy required to run the compressor. Hence these systems are also called as mechanical refrigeration systems.

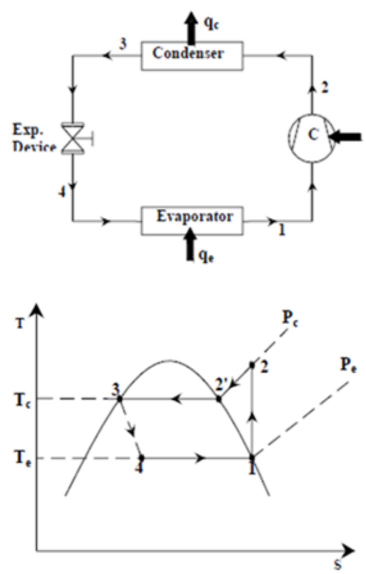

Fig. 1. Standard vapour compression refrigeration system component layout and T-S diagram

B. Standard Vapour Compression Refrigeration System (VCRS)

The Fig. 1, shows the schematic of a standard, saturated, single stage (SSS) vapour compression refrigeration system and the operating cycle on a T-s diagram. As shown in the figure the standard single stage, saturated vapour compression refrigeration system consists of the following four processes:

Process 1-2: Isentropic compression of saturated vapour in compressor

Process 2-3: Isobaric heat rejection in condenser

Process 3-4: Isenthalpic expansion of saturated liquid in expansion device
Process 4-1: Isobaric heat extraction in the evaporator

C. *Working of an Air Conditioner*

The Fig. 2, shows schematic of vapour compression cycle based refrigeration system. Components of an air-conditioner system:

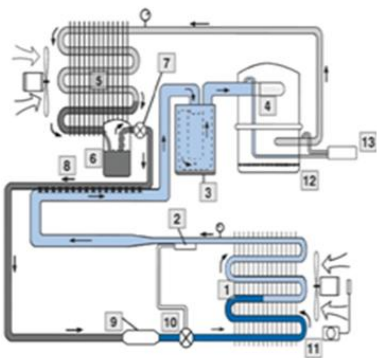

Fig. 2. Working of air conditioner

Condenser:

Condenser is an important component for any refrigeration system. In a typical refrigerant condenser, the refrigerant enters the condenser in a superheated state. It is first de-superheated and then condensed by rejecting heat to an external medium. The refrigerant may leave the condenser as a saturated or a sub-cooled liquid, depending upon the temperature of the external medium and design of the condenser. Shows the variation of refrigeration cycle on T-s diagram. In the figure, the heat rejection process is represented by 2-3’-3-4. The temperature profile of the external fluid, which is assumed to undergo only sensible heat transfer, is shown by dashed line. It can be seen that process 2-3’ is a de-superheating process, during which the refrigerant is cooled sensibly from a temperature T2 to the saturation temperature corresponding condensing pressure, T3’. Process 3’-3 is the condensation process, during which the temperature of the refrigerant remains constant as it undergoes a phase change process.

Classification of condensers:

Based on the external fluid, condensers can be classified as:

- Air cooled condensers
- Water cooled condensers, and
- Evaporative condensers

Air-cooled condensers:

As the name implies, in air-cooled condensers air is the external fluid, i.e., the refrigerant rejects heat to air flowing over the condenser. Air-cooled condensers can be further classified into natural convection type or forced convection type.

Natural convection type:

In natural convection type, heat transfer from the condenser is by buoyancy induced natural convection and radiation. Since the flow rate of air is small and the radiation heat transfer is also not very high, the combined heat transfer coefficient in these condensers is small. Hence these condensers are used for small capacity refrigeration systems like household refrigerators and freezers. The natural convection type condensers are either plate surface type or finned tube type. In plate surface type condensers used in small refrigerators and freezers, the refrigerant carrying tubes are attached to the outer walls of the refrigerator.

The finned type condensers are mounted either below the refrigerator at an angle or on the backside of the refrigerator. In case, it is mounted below, then the warm air rises up and to assist it an air envelope is formed by providing a jacket on backside of the refrigerator. The fin spacing is kept large to minimize the effect of fouling by dust and to allow air to flow freely with little resistance.

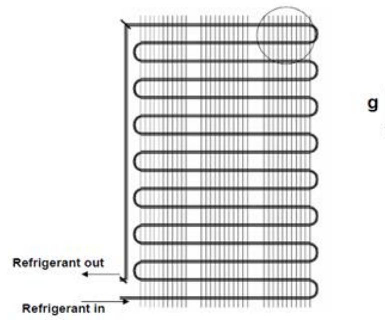

Fig. 3. Schematic of a wire-and-tube type condenser used in small refrigeration systems and & Forced convection, plate fin and tube type condenser

Forced convection type:

In forced convection type condensers, the circulation of air over the condenser surface is maintained by using a fan or a blower. These condensers normally use fins on air-side for good heat transfer. The fins can be either plate type or annular type. Forced convection type condensers are commonly used in window air conditioners, water coolers and packaged air conditioning plants.

The fins are usually of aluminum and tubes are made of copper. Holes of diameter slightly less than the tube diameter are punched in the plates and plates are slid over the tube bank. Then the copper tubes are pressurized which expands the tubes and makes a good thermal contact between the tube and fins. This process is also known as bulleting. For ammonia condensers mild steel tubes with mild steel fins are used. In this case the fins are either welded or galvanizing is done to make a good thermal contact between fin and tube.

Evaporator:

An evaporator, like condenser is also a heat exchanger. In an evaporator, the refrigerant boils or evaporates and in doing so absorbs heat from the substance being refrigerated. The name evaporator refers to the evaporation process occurring in the heat exchanger.

Classification

Natural and Forced Convection Type:

The evaporator may be classified as natural convection type or forced convection type. In forced convection type, a fan or a pump is used to circulate the fluid being refrigerated and make it flow over the heat transfer surface. In natural convection type, the fluid being cooled flows due to natural convection currents arising out of density difference caused by temperature difference.

Flooded and Dry Type:

The third classification is flooded type and dry type. Evaporator is said to be flooded type if liquid refrigerant covers the entire heat transfer surface.

Natural Convection type evaporator coils:

These are mainly used in domestic refrigerators and cold storages. When used in cold storages, long lengths of bare or finned pipes are mounted near the ceiling or along the high sidewalls of the cold storages. The advantages of such natural convection coils are that the coil takes no floor space and it also requires low maintenance cost. It can operate for long periods without defrosting the ice formed on it and it does not require special skill to fabricate it. Household refrigerators, display cases, walk-in-coolers, reach-in refrigerators and obviously large cold storages are few of its applications.

Shell-and-Tube Liquid Chillers:

The shell-and-tube type evaporators are very efficient and require minimum floor space and headspace, these are used for small and medium capacity refrigeration plants with capacity ranging from 2 TR to 350 TR.

Flooded Type Shell-and-Tube Evaporator:

Flooded type of shell and tube type liquid chiller where the liquid (usually brine or water) to be chilled flows through the tubes in double pass just like that in shell and tube condenser.

Shell-and-tube evaporators can be either single pass type or multipass type. In multipass type, the chilled liquid changes direction in the heads.

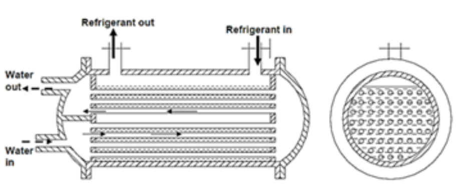

Fig. 4. Schematic of a flooded shell and tube evaporator

Plate Surface Evaporators:

These are also called bonded plate or roll-bond type evaporators. Two flat sheets of metal are embossed in such a manner that when these are welded together, the embossed portion of the two plates makes a passage for refrigerant to flow. This type is used in household refrigerators.

It provides an additional thermal storage capacity during off-cycle and load shedding to maintain a uniform temperature. These evaporators are commonly used in refrigerated trucks.

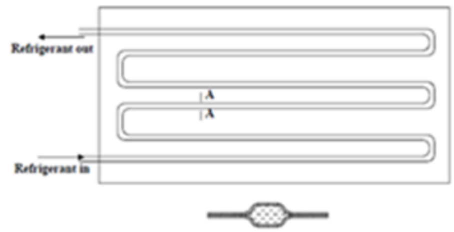

Fig. 5. Schematic of an embedded tube (roll bond), plate surface evaporator

Comparison of R22 and R134a

In the present analysis R-22 refrigerant is used as the working fluid. As, it is an ozone harming substance. An optional refrigerant which is ozone harm free refrigerant should be considered. Their comparison is given below.

Air conditioners, refrigerators and freezers rely on the circulation of a refrigerant--a chemical that can efficiently remove heat from the surroundings

R22 is an HCFC, While R134a Is an HFC like R12, which is the original ozone-depleting refrigerant, R22 is marketed under the brand name Freon, and it's one of the earliest CFC alternatives. Its chemical name is chlorodifluoromethane, and it belongs to a closely related class known as hydro-chloroflurocarbons (HCFCs). These refrigerants also contain chlorine that can potentially find its way into the upper atmosphere.

R134a belongs to another class of CFC alternatives, called hydrofluorocarbons (HFCs), that don't contain chlorine. Its chemical name is tetrafluoroethane. It isn't the only CFC alternative on the market, and it isn't the best.

- Using R134a in Systems Designed for R22
- R134a has a lower thermal conductivity than R22, so an R134a system needs a larger heat exchanger.
- A system circulating R134a needs a drier, because of the propensity of the refrigerant to absorb water.
- R134a swells the rubber components in the refrigeration system and causes leaks.
- R134a corrodes copper, so the system must include an additive to prevent it.
- R134a systems require special lubricating oils that are, on the whole, inferior to those used in an R22 system.

Coefficient of Performance of a System (COP):

As various performance parameters are expressed in terms of enthalpies, it is very convenient to use a pressure – enthalpy chart for property evaluation and performance analysis. The use of these charts was first suggested by Richard Mollier. A typical P-h chart, enthalpy is on the x-axis and pressure is on y-axis. The isotherms are almost vertical in the sub cooled region, horizontal in the two-phase region (for pure refrigerants) and slightly curved in the superheated region at high pressures, and again become almost vertical at low pressures. A typical P-h chart also shows constant specific volume lines (isochors) and constant entropy lines (isentropes) in the superheated region.

Using P-h charts one can easily find various performance parametersfrom known values of evaporator and condenser pressures.In addition to P-h and T-s charts one can also use thermodynamic property tables from solving problems related to various refrigeration cycles.

Calculation of COP for R22 as refrigerant:

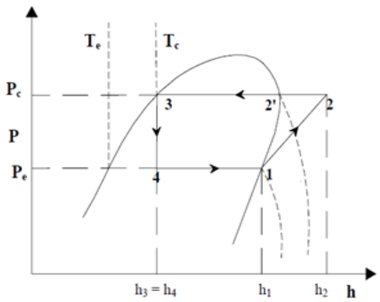

Fig. 6. Standard vapour compression refrigeration cycle on a P-h chart

P_c = 314.5 PSI = 2168.4Kn/m^2
P_e = 89.5 PSI = 617.08Kn/m^2
Refrigerant used = R22a
COP of system $=\frac{h_1-h_4}{h_2-h_1}$
h_1 = 401.5KJ/Kg (at 7^{o}C)
h_2 = 422.8KJ/Kg (at 60^{o}C)
h_3 = 302.3KJ/KgK (at 60^{o}C)
$h_4 = h_f + Xh_{fg}$ (X is dryness fraction)
$h_3 = h_4$
302.3 = 208.3 + X(199.2)
X = 0.311
h_4 = 302.3
COP = $\frac{401.5-302.3}{422.8-401.5}$ = 4.65
COP = 4.65

II. Conclusion

Detailed study of vapor compression refrigeration cycle has been presented along with classification of types of condensers and evaporators used in refrigeration and air conditioning systems. Coefficient of performance (COP) of the portable air conditioner running with R22 has been calculated and found to be 8.96.

Acknowledgement

Acknowledge Sreyas Institute of Engineering & Technology for R&AC lab facilities for psychometric testing of AC, Akella Systems Pvt. Ltd., for Assembling the prototype model and Uniscient Engineering Pvt. Ltd. For computational Fluid Dynamics work.

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