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Versatile Refrigerator

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Abstract: ***Energy can neither be created nor be destroyed, it can be transformed from one form to another. This another form of energy is left unused causing "waste". Meaning this energy is wasted in various forms like heat, mass, sound, electricity etc. This project moves ahead with this criteria of recovering waste heat energy which is being rejected from the sytem.Hence, the goal of the project is to save this consumption of electricity by using versatile refrigerator concept. This project has created a new design of refrigerator, which provides pleasant chill and warm water. In this refrigerator the wasted energy is used to obtain warm & chill water, their temperatures are 42.1°C and 16.8°C. This reading was achieved from 5 lit attached reservoirs on versatile refrigerator .It avoids the electric consumption of water dispenser in home. Further to which this project will also maintain same COP of the refrigerator with the recommended blend refrigerant propane & isobutane.***

Keywords: Blend refrigerant, Waste energy recovery, Electric Consumption, COP

1. Introduction

The problem we could found now a days the electricity consumption is high in day to day life. So we are reducing that electricity from water dispenser. It used for producing hot and cold drinking water it consumes 1.9 Kwh/day with timer and 2.8 Kwh/day without timer. But the refrigerator is used in all home for cooling purpose and to store vegetables for maintaining freshness. So refrigerator is available in every home, it consumes 17.4 kwh/day. This versatile refrigerator can save this water dispenser electricity by redesigning its refrigerator tubes.

1.1. Selection Criteria for Refrigerator & Refrigerant

1.1.1 Low Annual Energy Use & Size Matters

American Council for an Energy Efficient Economy (ACEEE), it recommends that you consider models that use at least 30% less electricity than that required by federal law. These products will meet the 2014 federal standard and may qualify for rebates—check with your local utility. Refrigerators under 25 cubic feet should meet the needs of most households. The models over 25 cubic feet use significantly more energy. If you are thinking about purchasing such a large unit, you may want to reconsider. A smaller unit may well meet your household's needs.

1.1.2 Environmental & Thermal Factors

- **Ozone Depletion Potential (ODP):** According to the Montreal protocol, the ODP of refrigerants should be zero, i.e., they should be non-ozone depleting substances. Refrigerants having non-zero ODP have either already been phased out (E.g. R 11, R 12) or will be phased-out in near-future (e.g. R22). Since ODP depends mainly on the presence of chlorine or bromine in the molecules, refrigerants having either chlorine (i.e., CFCs and HCFCs) or bromine cannot be used under the new regulations.
- **Global Warming Potential (GWP)**: Refrigerants should have as low a GWP value as possible to minimize the problem of global warming. Refrigerants with Zero ODP but a high value of GWP (e.g. R134a) are likely to be regulated in future.
- **Total Equivalent Warming Index (TEWI):** The factor TEWI considers both direct (due to release into atmosphere) and indirect (through energy consumption) contributions of refrigerants to global warming. Naturally, refrigerants with as a Low a value of TEWI are preferable from global warming point of view.
- **Toxicity:** Ideally, refrigerants used in a refrigeration system should be nontoxic. However, all fluids other than air can be called as toxic as they will cause suffocation when their concentration is large enough. Thus toxicity is a relative 10 term, which becomes meaningful only when the degree of concentration and time of exposure required to produce harmful effects are specified. Some fluids are toxic even in small concentrations. Some fluids are mildly toxic, i.e., they are dangerous only when the concentration is large and duration of exposure is long. Some refrigerants such as CFCs and HCFCs are non-toxic when mixed with air in normal condition. However, when they come in contact with an open flame or an electrical heating Element, they decompose forming highly toxic.
- **Flammability:** The refrigerants should preferably be non-flammable and nonexplosive.For flammable refrigerants special precautions should be taken to avoid accidents.

1.1.3 Safety Criteria

Under safety criteria, we consider the toxicity, flammability, action on perishable food and formation of explosive compound on exposure to air. An ideal refrigerant should be non-toxic, non-flammable, have no effect on food products and should not react with atmospheric air. No refrigerant satisfy these criteria fully. We can therefore, group refrigerants into different sub-groups based on their flammability and toxicity levels.

2. Objective

The main objective of this project are mentioned below,

- To make a small tanks on top of a versatile refrigerator.
- Performance Test conditions of refrigerator on running after all arrangements are over.
- Maintain refrigerator cycle on versatile refrigerator.
- Performance check for electricity consumption and co-efficient of performance

3. Refrigerant

The working agent in a refrigerating system that absorbs carries or releases heat from the place to be cooled or refrigerated can be termed as a refrigerant. This heat transfer generally takes place through a phase change of the refrigerant. A more complete definition of a refrigerant could be given as follows:

"Refrigerant is the fluid used for heat transfer in a refrigerating system that absorbs heat during evaporation from the region of low temperature and pressure, and releases heat during condensation at a region of higher temperature and pressure."

3.1 Primary and Secondary Refrigerants

Fluids suitable for refrigeration purposes can be classified into primary and secondary refrigerants. Primary refrigerants are those fluids, which are used directly as working fluids, for example in vapor compression and vapor absorption refrigeration systems. When used in compression or absorption systems, these fluids provide refrigeration by undergoing a phase change process in the evaporator. As the name implies, secondary refrigerants are those liquids, Which are used for transporting thermal energy from one location to other. Secondary refrigerants are also known under the name brines or anti freezes. Of course, if the operating temperatures are above 0oC, then pure water can also be used as secondary refrigerant, for example in large air conditioning systems. Antifreezes or brines are used when refrigeration is required at sub-zero temperatures. Unlike primary refrigerants, the secondary refrigerants do not Under go phase change as they transport energy from one location to other. An important property of a secondary refrigerant is its freezing point. Generally, the freezing point of brine will be lower than the freezing point of its constituents.

The temperature at which freezing of brine takes place it depends on its concentration. The concentration at which a lowest temperature can be reached without solidification is called as eutectic point. The commonly used secondary Refrigerants are the solutions of water and ethylene glycol, propylene glycol or calcium chloride. These solutions are known under the general name of brines. In this project attention is focused on primary refrigerants used mainly in vapor compression refrigeration systems. As discussed earlier, in an absorption refrigeration system, a refrigerant and absorbent combination is used as the working fluid.

3.2 Hydrocarbons

Hydrocarbon refrigerants have excellent environmental, thermodynamic, and thermo-physical properties, however they are highly flammable. As a result of these factors, hydrocarbons are the molecular basis for the halocarbon refrigerants wherein some or all of the hydrogen atoms have been replaced by halogens such as chlorine, fluorine, and bromine which reduce flammability but can cause unwelcome effects on the environment. Hydrocarbon refrigerants provide a range of boiling points with applicability from cryogenics to air conditioning. In the past hydrocarbon refrigerants have had limited applications Primarily within the petrochemical industry to provide industrial chilling and process refrigeration. With the phase out of the CFCs, hydrocarbon refrigerants are entering into new arenas. The hydrocarbons most commonly used as refrigerants are:

Methane R-50, Ethane R-170, Propane R-290, Butane R-600, Isobutane R-600a, Ethylene R-1150, Propylene R-1270.

In Versatile refrigerator we use a blend refrigerant that combines Isobutane (50%) and propane (50%).Their performance to be,

Isobutane, also known as methyl propane, is an isomer of butane. It is the simplest alkane with a tertiary carbon. Concerns with depletion of the ozone layer by Freon gases have led to increased use of isobutane as a gas for refrigeration systems, especially in domestic refrigerators and freezers, and as a propellant in aerosol sprays. When used as a refrigerant or a propellant, isobutane is also known as R-600a. Some portable camp stoves use a mixture of isobutane with propane, usually 50:50.Isobutane is used as a feedstock in the petrochemical industry, for example in the synthesis of isooctane. Propane is a three-carbon alkane with the molecular formula C_3H_8, normally a gas, but compressible to a transportable liquid. A by-product of natural gas Processing and petroleum refining, it is commonly used as a fuel for engines, oxy-gas torches, barbecues, portable stoves, and residential central heating. Propane is one of a group of liquefied petroleum gases (LPG gases). The others include butane, propylene, butadiene, butylene, isobutylene and Mixtures thereof. Propane containing too much propene (also called propylene) is not suited for most vehicle fuels. HD-5 is a specification which establishes a maximum concentration of 5% propene in propane. Propane and other LP gas specifications are established in ASTM D-1835. All propane fuels include an odorant, almost always ethanethiol, so that people can easily smell the gas in case of a leak. Propane as HD-5 was originally intended for use as vehicle fuel.
HD-5 is currently being used in all propane applications.

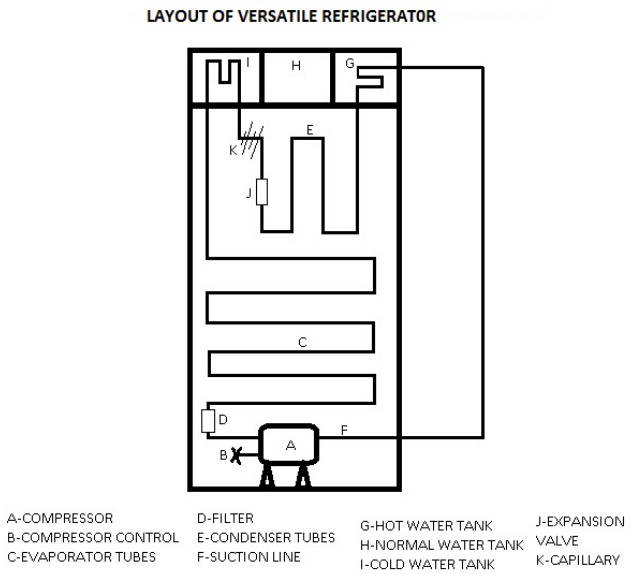
4. Water Dispenser

An instant hot water dispenser, or "boiling water tap," is an appliance that dispenses water at about 94 °C (201 °F) (near-boiling). There are hot-only and hot and cool water models, and the water may be filtered as well as heated. Instant hot water dispensers became popular in the 1970s. Water dispenser is a system used to make the hot water and cold water in a single set up with the electricity consumption. The problem we found there power consumption should be used so that there is also used in two set ups one is switch timer and another one is without timer. So cost wise it takes some initial amount to set up the dispenser. For that purpose we reduce that cost, electricity and space requirement in home appliance.

4.1 Water Dispenser Specification

Dimensions: 13”W*15”D*38”H
Floor: 28”
Drip tray: 7.5”
Heating: 180˚F
Cooling: 37-50˚F
Voltage: 115VAC
Power required: 600W (maximum)

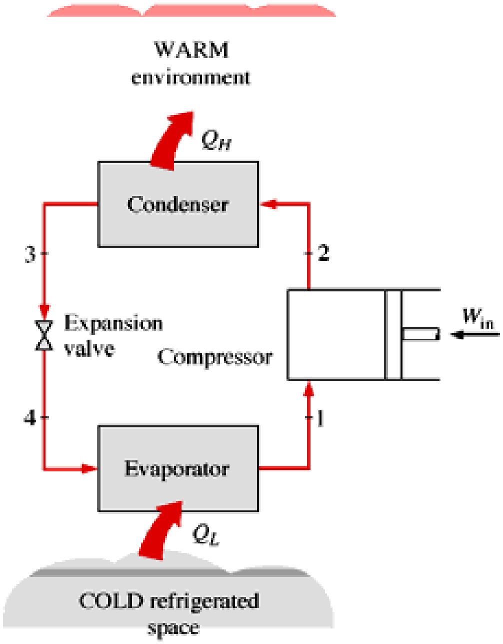
5. Versatile Refrigerator



5.1. Working Cycle Of Versarile Refrigerator

A refrigerator doesn't actually create cold. It removes heat. Cold is the absence of heat, and the complete absence of heat is considered absolute zero, which is −459.67°F −273.15°C.

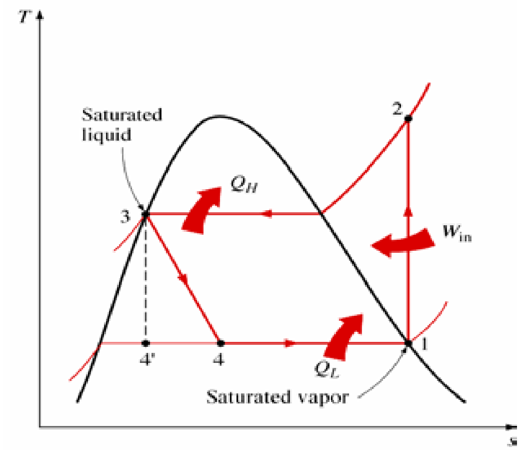
As the refrigerant pushed through a sealed system of tubing by the refrigerator's compressor it moves from a very thin capillary tube into the larger tubing of the evaporator. As this happens the pressure of the refrigerant is greatly reduced causing it to boil at a lower temperature, greatly increasing its ability to absorb the warm air within the freezer compartment.



Inside the freezer, a fan circulates air over the cool tubing and the refrigerant absorbs the heat from the freezer's warmer air. Just like wind moving from a high-pressure zone into a low-pressure zone to equalize, heat will move toward cooler areas to try to equalize. Equality cannot be achieved because the now warm gas continues through the system to the condenser. As the heated gas flows through the condenser coils on the back or under the refrigerator, the heat within the gas leaves in favor of the cooler air in the room, and the cycle starts again. If you prefer to just think of the fan blowing cold air into the appliance that's fine; but technically, the heat is being pumped out rather than cold being pumped in.

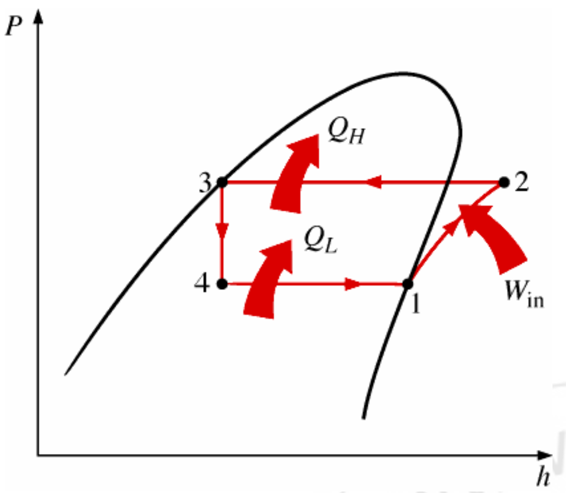
The cold air that is generated in the freezer passes through vents (the air diffuser) to the refrigerator compartment. A thermostat or cold control in the refrigerator activates the compressor whenever the temperature rises above the set point. In some newer models there is a separate cooling coil for the freezer and the refrigerator and thus two temperature controls.

5.2 T-S Diagram of Versatile Refrigerator



Process 1-2 Isentropic Compression Process
Process 2-3 P = const. Heat Rejection Process
Process 3-4 Expansion under Throttling Process, h = const
Process 4-1 P = const. Heat Addition Process

5.3 P-H Diagram of Refrigeration Cycle



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Process 3-4 Expansion under Throttling Process, h = const
Process 4-1 P = const. Heat Addition Process

5.4. Performance of Versatile Refrigerator

As we know that our refrigerator is designed to provide hot and cold water in upper tank along with the refrigeration process in interior. Now it's the time to check it performance and efficiency. For measuring its performance we had decided to take the performance reading of hot water, cold water and freezer .for checking performance of our design we decided to take temperature reading of hot water, cold water and freezer. Measuring of temperature is done by fixing of digital thermometer in each chamber i.e. hot and cold water chamber and in freezer.

Before taking the performance record first we allowed our refrigerator to run ideal for 1hr. then after that we started noticing the temperature of each chambers and freezer .after one hour of running ideal condition ,we got the temperature reading 38.4◦c of hot water,29◦c of cold water and the -9.6◦c of freezer. Besides this we also took reading of energy meter to check energy consumption. Then again after one hour we took the second reading which showed the temperature of hot water chamber as 41◦c, cold water chamber as 27.7◦c and freezer temperature as -16.4◦c. again after one hour we took the 3rd reading of hot water chamber temperature which was 41◦c, cold water temperature was 25.3◦c and freezer temperature -14.7◦c.same way we did for 4th reading after one hour and get temperature for hot water chamber 42◦c, cold water chamber 24.2◦c and freezer temperature -19.3◦c. then finally we took the 5th reading after one hour which showed hot chamber temperature as 42.1◦c, cold chamber temperature as 22.7◦c and freezer temperature as-20◦c.
Thus from this five temperature reading of hot water chamber, cold water chamber and freezer we have calculated its efficiency. We had seen from the reading that the hot water chamber temperature goes on increasing hour by hour but after reaching 42◦c its shows only slight increase in its temperature. The hot water obtained from this chamber suitably hot enough for drinking.

In case of cold water chamber, its temperature reading decrease slowly 1.5 to 1.3◦c from 29◦c to 22.7◦c every hour .the water in cold water chamber is pleasant and cold enough for drinking. Drinking the water of this cold temperature will not affect the body. As compared to temperature of cold water which is taken from the refrigerator inside, the cold water obtained in cold water chamber is more suitable for drinking .It also healthy for human.

Now moving on to freezer we get to know that the temperature decreases from -9.6◦c to -20◦c within five hours. This makes the refrigerator to work properly and hence there will not be any problem in its original function of refrigeration process. Besides this it's more useful for us to have household refrigerator with this much additional features.

6. Problems Faced In Experimentation

As we all know Problems are the key to success, it's because of problems only which give birth to solutions, this shows we to face too many problems for making our design perfect.

For making the design perfect we tried many new ideas and while developing this ideas in practical problems were happened. As our project is mainly concerned with hot and cold water, so more effects were put to increase temperature of hot water chamber and decrease the temperature of cold water chamber. First we made connection in such a way that the condenser duct is given directly from compressor to hot water chamber and after coming out of it, it is usually connected to condenser line. Then from condenser line to drier, and from the drier capillary tube was connected and then to the evaporator tube, first this evaporator tube is passed through the cold water chamber .after coming out of it again one capillary tube was connected which was given to the freezer then it is finally connected to evaporator duct and finally this duct was connected to compressor.

In this design the problem which we faced was that, that the performance of the refrigerator was decreased .the cooling effect which we was getting inside the refrigerator was decreased but hot water chamber temperature was good enough it reached 42◦c to overcome this problem we made slight modification in our design, in this we made connection in such a way that the condenser duct is given directly from compressor to hot water chamber and after coming out of it, it is connected to usual condenser line. Then from condenser line to drier, and from the drier capillary tube was connected this capillary tube was given to the freezer which then connected to the evaporator duct, then while coming out of the refrigerator this evaporated duct was connected to another capillary tube and this capillary is connected to another evaporated duct which is further extended to the cold water chamber and then from the cold water chamber this evaporated duct Is finally extended and connected to compressor. In this design the problem which we faced was that, that the water in cold water chamber become freeze totally (it became ice), not only the chamber but there was ice formation in evaporator duct line also. Here also the hot water chamber was good enough it reached 42◦c

Thus to overcome this we again made the modification in our design , in this we made connection in such a way that the condenser duct is given directly from compressor to hot water chamber and after coming out of it, it is connected to usual condenser line. Then from condenser line to drier, and from the drier capillary tube was connected this capillary tube was given to the freezer which then connected to the evaporator duct, then while coming out of the refrigerator this evaporated duct is further extended to the cold water chamber and then from the cold water chamber this evaporated duct Is finally extended and connected to compressor. In this we used only one capillary tube, thus it made our design final. Finally here we got the cold water chamber temperature good and suitable enough for drinking purpose. The temperature of cold water temperature in this design was reached to22.7◦c in 5 hrs. running conditions of refrigerator here also the hot water chamber was good enough it reached 42◦c .

7. Performance of Versatile Refrigerator

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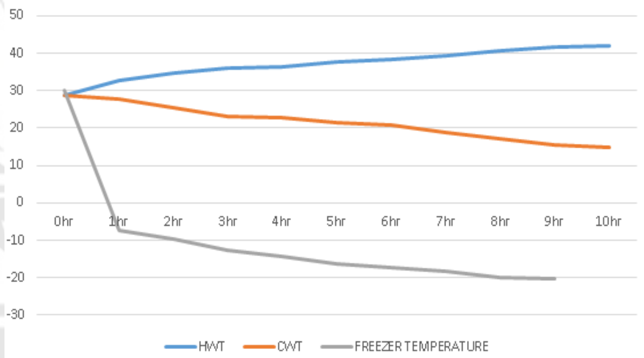
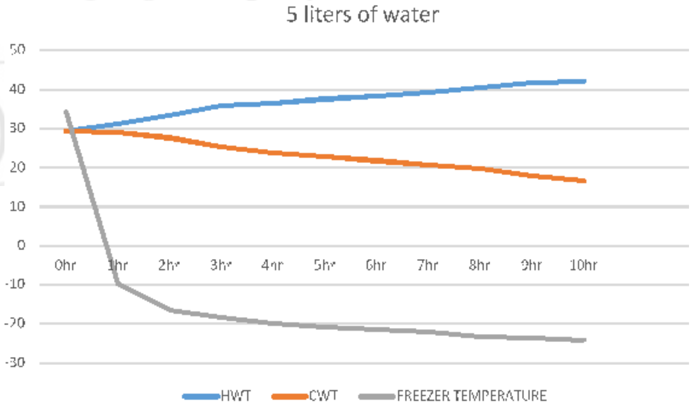
7.1.1 For 3 Liters of Water in Tanks at 29.8 C ATM Condition With Out Cut Off



7.1.2 For 5 Liters Of Water In Tanks At 33.6 C ATM Condition With Out Cut Off



7.1.3 For 5 Liters Water With Cut Off (After 12 Hr Running Condition At 32.9 C ATM Temperature)

Cut off no./Initial temperature	Hot water temperature(42.1 c)	Cold water temperature(16.3 c)	Freezer temperature (-25 c)
1st cut off(1 hour)	Off temperature-44.7 On temperature-42.9	Off temperature-16.5 On temperature-17.9	Off temperature- -24 On temperature- 1.7
2nd cut off(21 min)	Off temperature-47.3 On temperature-46.8	Off temperature-17.7 On temperature-18.2	Off temperature- -22 On temperature- -0.6
3rd cut off(30 min)	Off temperature-48.6 On temperature-47.6	Off temperature-18.3 On temperature-18.8	Off temperature- -21 On temperature- -0.2

7.2 Calculation

In this refrigerator, the refrigerant used is a mixture of is obutane and propane (50% each)

Operating temperature:
Condenser temperature: 40°C
Evaporator temperature:-20°

At t_0=-20°C
1h=541.49 KJ/Kg
S1=2.3836KJ/Kg K

At t_K=40°C
h3 =301.01 KJ/Kg
hg =615.90 KJ/Kg
S_g= 2.3584KJ/Kg K
C_P=2.0018 KJ/Kg K

Isentropic process: $S_1=S_2$
$S_2= S_g + C_P \ln(T_2/T_1)$
$2.3836=2.3584+2.0018 \ln (T_2/313)$
Discharge temperature, T_2=316.96 K

$h_2=h_g+ C_P (T_2- T_1)$
=615.90+2.0018(316.96-313)
=623.827 KJ/Kg

Refrigeration effect, Q =h1-h3
=541.49-301.01
=240.48 KJ/Kg

Specific work, W = h2-h1
=623.827-541.49
=82.337 KJ/Kg

Coefficient of performance, COP= Q/W
= 240.48/82.337
= 2.920

Mass flow rate, M=211/Q
=211/240.48
=0.8774Kg/min (TR)

Horse power per ton of refrigeration,
HP/TR= 4.761/COP
=4.761/2.920
=1.63047
= 1.2 kW

8. Result

Finally our project is completed, which mainly deal with waste heat recovery system i.e. producing hot and cold water in household refrigerator has showed a bench mark. As we know that in our project we used a household refrigerator in which we made a various modification in its design to get the perfect output. This project is an ecofriendly project which mainly looks after energy saving and health concern of human beings. As we all know drinking cold water at temperature of 7 to 10◦c will affect our health causing various diseases .Hence this project is done to overcome this problem as well as to utilize the waste heat energy emitted through the condenser. In this project the cold water made for drinking purpose is 19◦c which is cold and pleasant enough for drinking.

We had also utilized this waste heat to heat the water, thus also producing warm water at a temperature of 42◦c. Initially we too faced many problems in designing this refrigerator but finally the 3rd design has fulfilled our expectation. This project has created a new era in refrigeration field and this showed the emerging engineers that there is a lot of scope in this in field. And it is expected to bring more changes in this refrigeration system for the development of the country and the world.

9. List of Symbols, Abbreviations and Nomenclature

HFC	Hydro-fluorocarbon
HFO	Hydro fluoro-olefins
HC	Hydro carbons
HCFC	Hydro Chloro fluoro carbon
CFC	Chlorofluorocarbon
ANSI	National Standard Institute
ASTM	American Society for Testing and Materials
R 22	Chlorodifluoromethane
R 717	Ammonia
R 290	Propane
R 600a	Isobutane
PSAT	Saturated Pressure
Hg	Enthalpy of saturated vapour
Cp	Specific heat of vapour
Sg	Specific entropy of saturated vapour
h1	Enthalpy of vapour
h2	Discharge Enthalpy
h3	Enthalpy of vapour
HR/TR	Horse power per ton of refrigeration

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