B. Coefficent of Performance

The coefficient of performance (COP) is expressed as COP or coefficient of performance which defined as Refrigeration Effect= (h_1-h_4) kJ/kg
Compressor Work= (h_2-h_1) kJ/kg.

$$COP = \frac{\text{Refrigeration effect}}{\text{Compressor work}}$$

C. Select Definitions

Frost-free (FF) Refrigerator:

A Domestic refrigerator appliance in which all frozen food storage space is cooled by a frost-free system. Unfrozen food storage space may or may not be cooled by a frost- free system but all storage spaces in the appliance whether frozen or unfrozen are automatically defrosted with automatic disposal of water.

In Frost Free refrigerator
1. Cooling is provided by forced air circulation.
2. The system is automatically operated to prevent permanent formation of frost on all refrigerated surfaces and no ice or frost accumulates on stored food.

D. Direct Cool (DC) Refrigerator

These are the refrigerators with or without crisper, ice making or frozen food storage compartments and are NOT cooled by internal forced air circulation. Cooling is primarily obtained by natural convection only. However some products may have fan to avoid internal condensation but not to claim as frost free.

- **Total Gross Volume** is the sum of gross volumes for all compartments in a refrigerating appliance.
- **Gross Volume** - Measured volume enclosed within a compartment. While determining gross volume, internal fittings like shelves, removable partitions, containers, evaporator, thermostat & internal light housings are believed as not in place. Volume occupied by the barrier air ducts not considered.
- **Total Storage Volume** – the sum of the storage volumes for all compartments in a refrigerating appliance.
- **Storage Volume** – gross volume of a compartment minus the volumes of components & spaces recognized as being unusable for food storage. When the storage volume is determined, internal fittings like shelves, removable partitions, containers, evaporator, thermostat & internal housings are believed to be in place.

E. Level of label depends on type of refrigerator (Frost-free or Direct Cool), storage volume of the refrigerator and the annual energy use as tested (as per BEE procedures).

Total Adjusted Volume is calculated based on a formula:

Frost-Free

Total Adjusted Volume (Vadj) = Fresh Food Vol+ 1.62* Freezer Vol.

Direct Cool

Total Adjusted Volume (Vadj) = Fresh Food Vol. + 1.31* Freezer Vol.

F. Energy Star Levels Calculation

Total tested energy consumption of a refrigerator

KWH = k * Vadj + c
Where
KWH = Annual Energy Use (kWh/year).
k = Constant Multiplier (kWh/liter/year)
Vadj = Adjusted Storage Volume (Liters)
c = Constant Fixed Allowance (KWH)

G. Star Rating Band

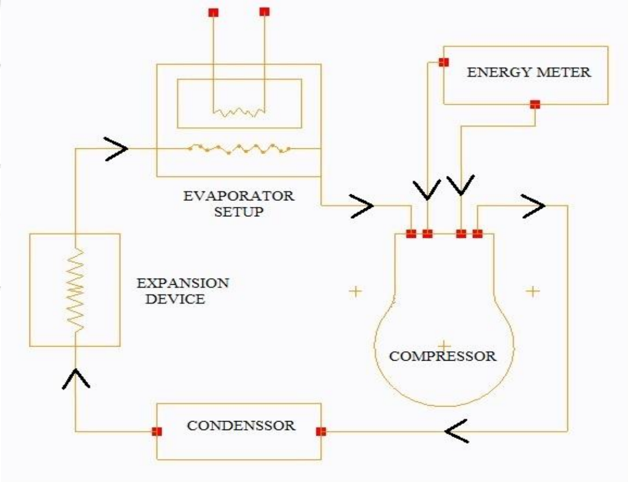
SRB nf *= knf * Vadj_tot_nf + cnf*
Where
knf = Constant Multiplier (kWh/Litre/Year)
Vadj_tot_nf = Total Adjusted Storage Volume for No Frost (Litre)
cnf = Constant Fixed Allowance (kWh/Year).

Bureau of Energy Efficiency (BEE) Labeled Direct Cool Refrigerators

Brand	Gross Volume, Liter	Storage Volume, Liter	Electricity Consumption Unit Per Year	Star Rating
B	180	174	265	5 Star
C	180	170	295	4 Star
B	180	174	305	4 Star
A	180	168	312	4 Star
D	180	169	405	3 Star

3. Design & Experimental Setup

In this chapter an experimental setup is designed to find the COP of the domestic vapour compression refrigeration system. The system will be about the size of a 180 L domestic refrigerator. The main objectives of the setup will be to keep the evaporator temperature constant during the experiment to explain in the aim of the present work. In this experimental R-600a is compared with the R-134a in a domestic refrigeration system.



4. Design & Experimental Setup Layout

The hermit sealed compressor, the air cool natural convection condenser and the capillary tube used for the setup are the same as for domestic refrigerator. The evaporators are placed in an insulated box which may be the use itself. The compressor is usually about 1/8th it's an approximate 100 watt. If the overall COP of the refrigerator is assumed unity at full load. The refrigerator effect will be 100watt.In the experimental setup. The cooling load may be provided by lamp bank. The load can be varied by with15

watt, 30 watt, 45watt in vapour compression cycles. In vapour compression refrigeration system the Coefficient of performance can be carried out at different load. The watt of lamp is calculated the experiment set up.
The experimental setup consists of following component:

1) The compressor usually sealed. The power to the compressor (watt) is measured by an energy meter disc type. And a stop watches. The thermostat is disconnected.
2) The condenser
3) The expansion device (capillary tube)
4) The evaporator
5) Lamp bank.

The evaporator lamp bank be placed is an insulated chamber the instrument

- Pressure gauge is fitted the suction and discharge of the compressor.
- Thermocouple is measured by temperature at various points in vapour compression refrigeration cycles.

5. Result and Discussion

Calculation of Cooling capacity, Power Consumption and Energy efficiency Ratio Using Refrigerant R134a (Tetrafluro ethane)

Cooling Capacity Calculation: Cooling capacity is measured in Watt.
1 Watt of Cooling Power =3.413 BTU/Hr
1 Ton =1200 BTU/Hr.

$$\text{Cooling Capacity} = \frac{\text{BTU/ Hr}}{3.413}$$

$$\text{Cooling Capacity} = \frac{365}{3.413}$$

Cooling Capacity = 107.03 Watt.

Energy Consumption Calculation:

1. Normal Working Hour of a Refrigerator in a day = 6 Hr/Day
2. Actual working of Compressor "Cut In & Cut Out" Condition is 70 % = 6 Hr * 70 % =4.2 Hr/Day Compressor runs time.
3. If the Electric Power Consumption of 180 Liter = 0.909 Unit/Day
4. If the Electric Power Consumption of 180 Liter = 332.Unit /Year.
5. If Rate Per Unit = Rs. 5/-
6. Electric Consumed Per Day =0.909 * 5 =Rs 4.545/-
7. Electric Consumed Per Month = 30 * 4.545 =Rs 136.35/-
8. Electric Consumed Per Year = 12 * 136.35 =Rs 1636/-

Energy Efficiency Ratio (EER):

$$\text{EER} = \frac{\text{Cooling Capacity}}{\text{Electric Power Consumption}}$$

$$\text{EER} = \frac{107.03}{0.909} = 117.74 \text{ (Four Star)}$$

Calculation of Cooling capacity, Power Consumption and Energy efficiency Ratio Using Refrigerant R600a (Isobutene)

Cooling Capacity Calculation

$$\text{Cooling Capacity} = \frac{485}{3.413}$$

Cooling Capacity = 142.10 Watt

Energy Consumption Calculation

1 Normal Working Hours of a Refrigerator in a day = 6 Hr/Day
2 Actual working of Compressor "Cut In & Cut Out" Condition is 70 % = 6 Hr * 70 % = 4.2 Hr/Day Compressor run time.
3 If the Electric Power Consumption of 180 Liter = 0.712 Unit/Day
4 If the Electric Power Consumption of 180 Liter = 260.Unit / Year
5 If Rate Per Unit = Rs. 5/-
6 Electric Consumed Per Day =0.712 * 5 =Rs 3.56/-
7 Electric Consumed Per Month = 30 * 3.56 =Rs 106.8/-
8 Electric Consumed Per Year = 12 * 106.8 =Rs 1281.6/-

Energy Efficiency Ratio (EER):

$$\text{EER} = \frac{142.10}{0.712}$$

=199.57 (Five Star).

6. Conclusion

Thus, on the basis of the above observation, it can be concluded that for two different types of refrigerant that is R134a (Tetrafluro ethane) & R 600 (Isobutene) can be used in domestic refrigerator. R600a (Isobutene) used in domestic refrigerators has good Coefficient of performance, less noise and less energy consumption. Following points are concluded:

- Energy Efficiency Ratio of R-600a is higher than R-134a.
- Experiment carried out using refrigerant R134a and R600a at in Domestic Refrigerator; it is found that cooling Capacity using Refrigerant 134a for constant refrigeration effect is 107.03. Whereas for same refrigeration effect the cooling Capacity using Refrigerant R600a is 142.10.
- Compressor energy consumption of domestic refrigerator decreased by 10-15% with using refrigerant R600a.
- Energy consumption under the test condition, when tested in accordance with relevant standard as R600a is 260 units per year whereas R134a is 332 units per year.

7. Future Scope

- If we are using refrigerant R600a (Isobutene) in Domestic refrigerator then it do not has any Global Warming Potential.

- The other remarkable feature includes Lower noise level in compressor and Less Refrigerant Quantity Charge.
- If we are using refrigerant R600a (Isobutene) in Domestic refrigerator Low Electric power Consumption and Economical.

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