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Simulation of Air Conditioning System for Substitute of Refrigerant R-22 by Using Refrigerant R407C and R410A

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ABSTRACT

Energy demand has gradually augmented through all sectors, i.e. industry, residential, commercial, and agriculture over the previous few decades, and it is anticipated to carry on to grow. India's per capita power consumption stands at 30% of the average of the world. The energy system of India is mainly based on the consumption of coal for energy generation, oil for industry and transport, and biomass for heating and cooking for housing. Any optimization of energy use, apart from cost-saving, will have a positive impact on the degrading of the environment.

Refrigerant R22, R407C, and R410A have been simulated by CoolPack software to find the alternative refrigerant in place of R22 because Refrigerant R22 has ozone-depleting potential. Refrigerant R407C and R410A have zero ozone-depleting potential and mostly similar performance characteristics to R22. Firstly simulation is done with CoolPack software using a constant condensing temperature of 50 °C and variation of evaporator temperature from -15 °C to 10°C then next stage, simulation is done using a constant evaporator temperature of 0°C and variation of condensing temperature from 30°C to 65°C. It is found by simulation; that refrigerant R407C has higher COP and lower power consumption compared with refrigerant R410A. Hence R407C is the better alternative refrigerant for R22 compared with refrigerant R410A.

KEYWORDS: Coefficient of performance, Energy saving, ozone-depleting potential, global warming potential, Air Conditioning System.

1. INTRODUCTION

Refrigerants are the operational fluids in air conditioners and refrigeration units. There are many refrigerants available in the market. Therefore it is desirable to know which of the refrigerants is best suited for a particular system working under a given condition. A toxic refrigerant is one that is injurious to human beings if subjected to a given length of time. From this point of view, refrigerants are grouped according to the time during which a man is subjected to such gas without having a fatal effect. A toxic refrigerant is not permitted for air conditioning, food preservation, etc., with the coil directly lying in the conditioned space. If such refrigerants are to be used, an indirect system is permitted [1].

Montreal Protocol (MP) specified control actions for the decrease and finally the phase-out of ozone-depleting matters in September 1987. Montreal Protocol planned phase-out of controlled substances. According to MP, Non-Article 5 (developed) nations; CFCs were phased out by 1996 and in Article 5 nations by 2010. As per the Copenhagen amendments to the Montreal Protocol, HCFCs were also counted in as controlled substances for the total worldwide phase-out by 2040. According to the Kyoto protocol, the use of substances possessing high GWP has to be banned from the everlasting perception. This shows that searching for a different refrigerant, which has zero ODP and also has a low GWP. R22 refrigerant is used in air conditioning, bottle coolers deep freezers, and heat pumps.

An alternative of R22 is R407C and R410A falls under this category as per ASHRAE handbook 2010. These refrigerants contain hydrogen, carbon, and fluorine. Hence they do not have any ozone-depleting chlorine. Also having no ozone-depleting components, they generally have an even lower GWP than HCFCs [2]. R-410A is now the prominent alternative for HCFC-22 for new apparatus. R-407C is another alternative for HCFC-22 and can be used in retrofits in addition to new equipment [3].

Table 1.1 Properties of refrigerants [4]

S.N	Refrigerant Number	ODPs	$GWP_{100}s$
1	R-22	0.055	1810
2	R-407C	0	1800
3	R-410A	0	2100

Table 1.1 as per the latest scientific assessment, Calm and Hourahan (2007) reported ODPs and $GWP_{100}s$ for refrigerant R-22, R-407C, and R-410A.

2. BACKGROUND STUDY:

Previously a number of related works were reported by many researchers. Some of the important are listed below.

S. Devotta et al. (2001) compared some refrigerants as alternatives to R-22 for the air conditioner, which has only, zero ODP. They selected R-407C as another refrigerant for R-22, [5]. Chen (2008) simulated and compared R410A and R22 refrigerants in air conditioners. R410A has zero ODP so it can be used for the replacement of R-22 in the future. It is found that R410A can reduce the global warming impact. He compared EER, cooling capacity, the annual energy Consumption of air conditioners, and the GWP [6].

Chakravarth and Kumar (2012) experimentally investigated a different refrigerant for R22 in the air conditioner. They tested three types of refrigerants. As per the Montreal Protocol, R22 will be banned after 2030. It is necessary to find alternate refrigerants in place of the R22 refrigerant. Alternate refrigerants should have less ODP and GWP. They selected R407C and R407A for the alternate refrigerants. They found that R407A has 2% lower power consumption compared to R22 [7]

Venkataiah and Rao (2013) performed a simulation analysis of the various refrigerants on CoolPack software. It is found that R410A can be selected as a similar refrigerant to substitute R22 in air conditioners, as its displacement volume is much lower, and also discharge temperatures are lower as compared to R22. It is found that R410A selected the best refrigerant in place of R-22[8].

S. S. Jadhav and K. V. Mali (2015) evaluated R410A refrigerant as an alternative for R22 in the air-conditioners. R410A has zero ODP, with blends of refrigerant. At the same saturated temperatures, refrigerant R410A works at higher pressure. Results show that COP increased 6 % by using R410A compared with R22 [9].

Roy et al. (2017) carried out a simulation for the refrigerants R404A, R152a, and R600a using CoolpPacK software for vapour compression refrigeration system performance. Condenser temperature is taken from 25°C to - 45°C and evaporator temperature is taken from 0°C to -20°C for simulation. COP, Energy consumption, and mass flow rate of refrigerants were computed. Results show that power consumption increased and COP of the refrigeration system decreases with reducing evaporator temperature [10]. Abdulqadir et al. (2019) experimentally investigated an air conditioner using R-22 and R-407C refrigerants. They compared the experimental results for the refrigerant R22 and R407C in the same working condition. It is found that the COP of R22 is higher compared to R407C. They concluded to R407C can be an alternate refrigerant for R22[11].

Bharathi Raja et al. (2020) experimentally analyzed vapour compression refrigeration systems using hydrocarbon refrigerant, R407A, and R22. Results show that R407A is an efficient refrigerant compared to R22 and hydrocarbon refrigerants. Hydrocarbons consume less power compared to R22, and R407A [12].

3. SIMULATION BY COOLPACK SOFTWARE WITH REFRIGERANTS R22, R407C, AND R410A:-

Montreal Protocol (MP) specified control actions for the decrease and finally the phase-out of ozone-depleting matters in September 1987. According to the Kyoto protocol, the use of substances having high GWP has to be banned from the long-term perspective. This shows that searching for a different refrigerant that has a zero ODP and also has a low GWP. Hence wide research is being on across the world to find a possible alternative to R22.

An alternative of R22 is R407C and R410A falls under this category as per ASHRAE handbook 2010. R407C and R410A refrigerants have Hydrogen, Carbon, and Fluorine. Hence they do not have any ozone-depleting Chlorine. Also having no ozone-depleting components, they generally have an even lower GWP than HCFCs.

A simulation of the air conditioning system is done using CoolPack simulation software. In this simulation work following assumptions are made:

Compressor isentropic efficiency = 0.7

Degree of subcooling, = 10

Degree of superheating= 5

Cooling capacity= 5.275 KW

Pressure drop in evaporator and suction line=0

Heat loss from compressor =0 %

No suction gas heat exchanger =0

Simulation is done using a constant condensing temperature of 50 °C and a variation of evaporator temperature from -15 °C to 10°C.

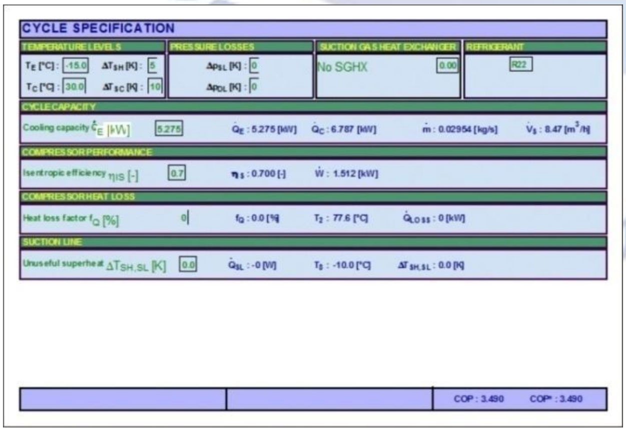

Figure 1. Simulation of an air conditioner using evaporative temperature is -15 °C and condenser temperature is 30 °C for R-22 refrigerant

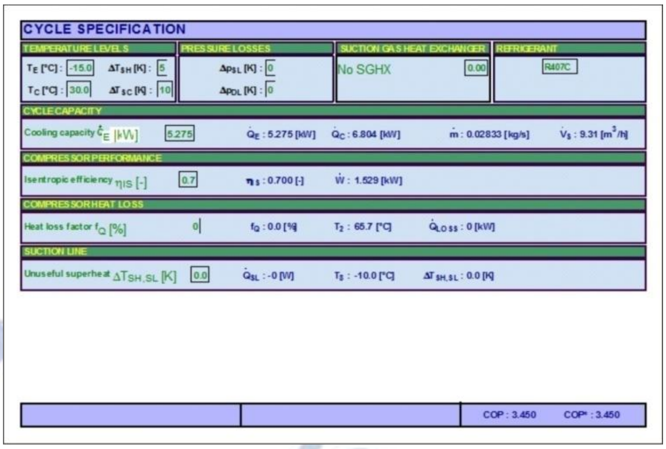

Figure 2. Simulation of an air conditioners using evaporative temperature is -15 °C and condenser temperature is 30 °C for R407C refrigerant

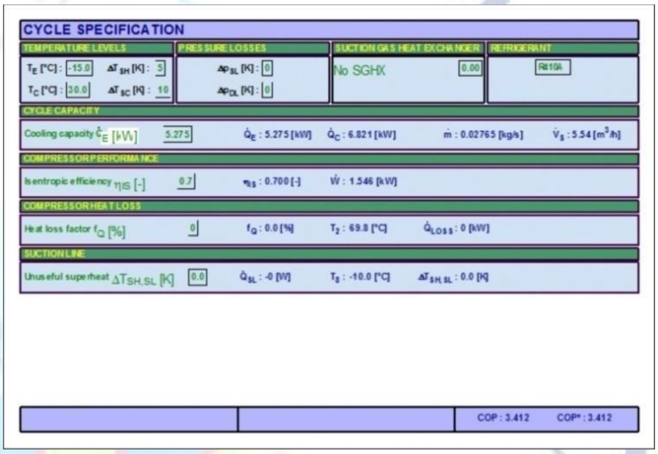

Figure 3. Simulation of an air conditioners using evaporative temperature is -15 °C and condenser temperature is 30 °C for R410A refrigerant

4. RESULTS AND DISCUSSION

The influence of different system parameters such as COP, power consumption, and pressure ratio for the constant condenser temperature (50°C), different evaporator temperatures (-15 °C to 10°C) and constant evaporator temperature (0°C), and different condensing temperatures (30 °C to 65°C) of refrigerants R22, R407C, and R410A for air conditioners showed in tabular as well as in graphical form to find the alternate refrigerant in place of R22, which is obtained from the CoolPack simulation software.

IV(A) Simulated results and discussion

The performance parameters at constant condenser temperature (50°C) and different evaporator temperatures (-15 °C to 10°C) of refrigerants R22, R407C, and R410A for air conditioner.

Table 4.1 Variation of COP for constant condenser

temperature (50°C) and different evaporator temperatures (-15 °C to 10°C) of refrigerants R22, R407C, and R410A**

S.N	Tc (°C)	T_E (°C)	COP		
			R22	R407C	R410A
1	50	-15	2.156	2.053	2.007
2	50	-10	2.433	2.322	2.267
3	50	-5	2.761	2.64	2.577
4	50	0	3.156	3.022	2.951
5	50	5	3.642	3.49	3.41
6	50	10	4.251	4.075	3.986

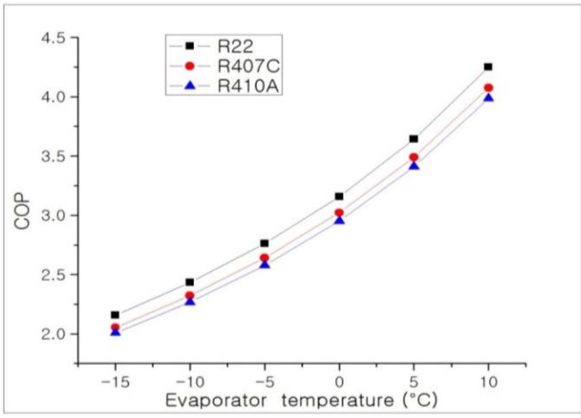

Figure 4. Variation of COP for refrigerants R22, R407C, and R410A with variation of evaporator temperature

Figure 4 shows COP increases with increases in evaporator temperature for refrigerants R22, R407C, and R410A. It is found that R22 has a higher COP than R407C and R410A, but R407C has a higher COP compared with R410A for the same operating conditions.

Sr. No.	Tc (°C)	T_E (°C)	P_2/P_1		
			R22	R407C	R410A
1	50	-15	6.57	7.504	6.361
2	50	-10	5.483	6.192	5.337
3	50	-5	4.61	5.153	4.509
4	50	0	3.904	4.321	3.835
5	50	5	3.327	3.648	3.282
6	50	10	2.854	3.1	2.825

Table 4.2 Variation of power consumption for constant condenser temperature (50°C) and different evaporator temperatures (-15 °C to 10°C) of refrigerants R22, R407C, and R410A

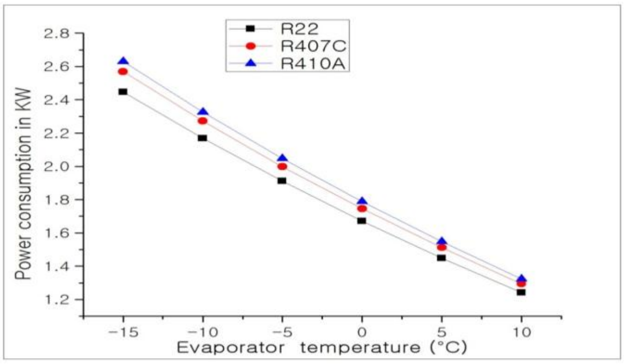

Figure 5. Variation of power consumption for refrigerants R22, R407C, and R410A with variation of evaporator temperature

Figure 5 shows power consumption decreases with increases in evaporator temperature for refrigerants R22, R407C, and R410A, due to a decrease in pressure ratio. It is found that R22 has lower power consumption than R407C and R410A, but R407C has lower power consumption compared with R410A for the same operating conditions.

Table 4.3 Variation of pressure ratio for refrigerants R22, R407C and R410A with variation of evaporator temperature

Sr. No.	Tc (°C)	T_E (°C)	W(KW)		
			R22	R407C	R410A
1	50	-15	2.446	2.569	2.629
2	50	-10	2.169	2.272	2.326
3	50	-5	1.911	1.998	2.047
4	50	0	1.671	1.746	1.788
5	50	5	1.449	1.512	1.547
6	50	10	1.241	1.294	1.323

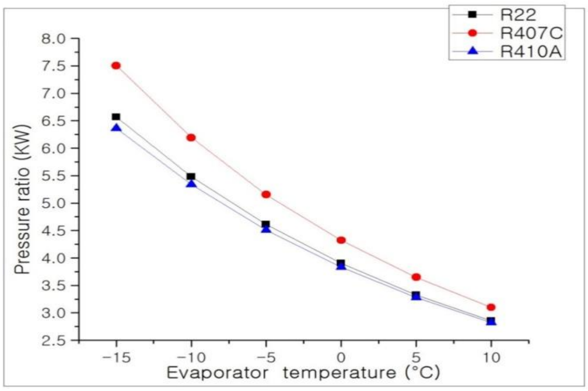

Figure 6. Variation of pressure ratio for refrigerants R22, R407C and R410A with variation of evaporator temperature

Figure 6 shows the pressure ratio decreases with increases in evaporator temperature for refrigerants R22, R407C, and R410A. It is found that R22 has a higher pressure ratio than R410A and lower than R407C for the same operating conditions.

IV(B) Simulated results and discussion The performance parameters at constant evaporator temperature and different condensing temperatures of refrigerants R22, R407C, and R410A

S. N	T_E (°C)	Tc (°C)	W(KW)		
			R22	R22	R22
1	0	30	0.9018	0.9018	0.9018
2	0	35	1.077	1.077	1.077
3	0	40	1.263	1.263	1.263
4	0	45	1.46	1.46	1.46
5	0	50	1.671	1.671	1.671
6	0	55	1.899	1.899	1.899
7	0	60	2.147	2.147	2.147
8	0	65	2.419	2.419	2.419

Table 4.4 Variation of COP for constant evaporator temperature and different condensing temperatures of refrigerants R22, R407C and R410A

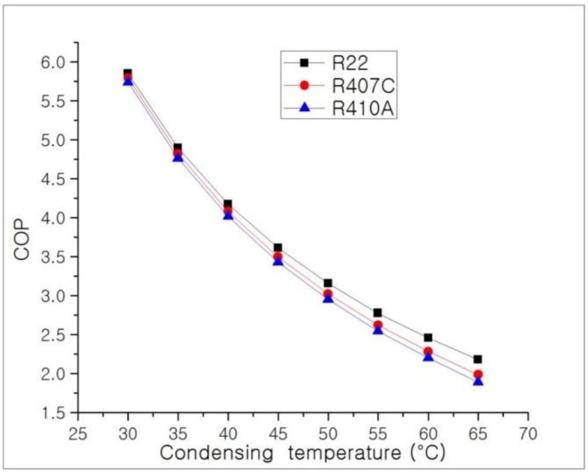

Figure 7. variation of COP for refrigerants R22, R407C and R410A

Figure 7 shows COP decreases with increases in condensing temperature for refrigerants R22, R407C, and R410A, due to an increase in the pressure ratio of a compressor. It is found that R22 has a higher COP than R407C and R410A, but R407C has a higher COP compared with R410A for the same operating conditions.

Table 4.5 Variations of power consumption for constant evaporator temperature and different condensing temperatures of refrigerants R22, R407C and R410A

S.N	T_E (°C)	Tc (°C)	COP		
			R22	R407C	R410A
1	0	30	5.85	5.795	5.739
2	0	35	4.897	4.821	4.761
3	0	40	4.177	4.082	4.018
4	0	45	3.613	3.498	3.43
5	0	50	3.156	3.022	2.951
6	0	55	2.777	2.624	2.548
7	0	60	2.457	2.284	2.2
8	0	65	2.18	1.987	1.89

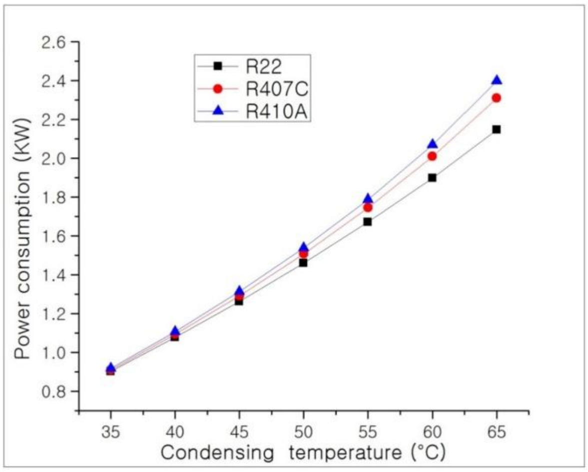

Figure 8. Variation of power consumption for refrigerants R22, R407C, and R410A

Figure 8 shows power consumption increases with increases in condensing temperature for refrigerants R22, R407C, and R410A, due to an increase in pressure ratio by a compressor. It is found that R22 has lower power consumption than R407C and R410A, but R407C has lower power consumption compared with R410A for the same operating conditions.

Table 4.6 Variation of pressure ratio for constant evaporator temperature and different condensing temperatures of refrigerants R22, R407C and R410A

Sr. No.	T_E (°C)	T_C (°C)	P_2/P_1		
			R22	R407C	R410A
1	0	30	2.395	2.536	2.356
2	0	35	2.723	2.913	2.675
3	0	40	3.082	3.334	3.027
4	0	45	3.475	3.802	3.413
5	0	50	3.904	4.321	3.835
6	0	55	4.37	4.895	4.297
7	0	60	4.877	5.528	4.802
8	0	65	5.427	6.224	5.351

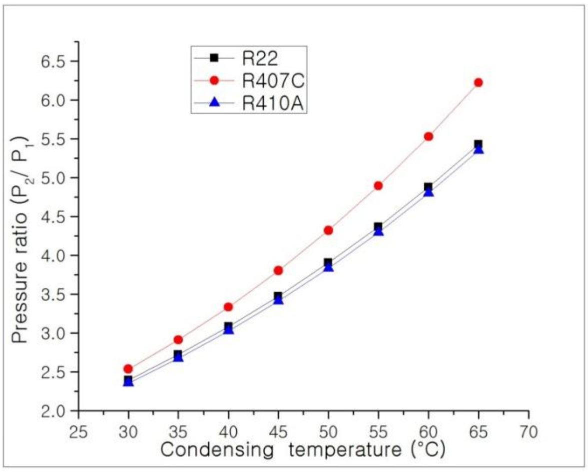

Figure 9. Variation of pressure ratio for refrigerants R22, R407C and R410A

Figure 9 shows the pressure ratio increases with increases in condensing temperature for refrigerants R22, R407C, and R410A. It is found that R22 has a higher pressure ratio than R410A but is lower than R407C for the same operating conditions.

5. CONCLUSIONS:

Simulation has been done using refrigerants R22, R407C, and R410A to find the alternate refrigerant in place of R22, due to its ozone-depleting potential. Because Refrigerant R407C and R410A have zero ozone-depleting potential. Simulation is done using a constant condensing temperature of 50 °C and a variation of evaporator temperature from -15 °C to 10°C and then the secondary simulation is done using a constant evaporator temperature of 0°C and a variation of condensing temperature from 30°C to 65°C. Simulation by CoolPack software with refrigerants R22, R407C, and R410A has shown the following conclusions:

- R22 has a higher COP than R407C and R410A, but R407C has a higher COP compared with R410A for the same operating conditions.
- R22 has lower power consumption than R407C and R410A, but R407C has lower power consumption compared with R410A for the same operating conditions.
- R22 has a higher pressure ratio than R410A and lower than R407C for the same operating conditions.
- It is found by simulation, that refrigerant R407C has higher COP and lower power consumption compared with refrigerant R410A.So R407C is the better alternative refrigerant for R22.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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