Performance study of window-type air conditioning unit using R-407C as an alternative refrigerant

By

Abdallah K. O Herz

Supervisor

Mohammed A. al-Sa'ad

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LIST OF CONTENTS

LIST OF TABLES

ABREVIATIVE

ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers.
CFC	Chlorofluorocarbon
COP	Coefficient of Performance
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
ODP	Ozone Depletion Potential
ppm	Part per million

INTRODUCTION

REFREGERANTS are the working fluids in refrigeration, air conditioning, and heat pump systems. They absorb heat from one area and reject into another, usually through evaporation and condensation, respectively. These phase changes occur both in absorption and mechanical vapor compression systems, but they do not occur in systems operating on a gas cycle using a fluid such as air. The design of the refrigeration equipment depends strongly on the properties of the selected refrigerant.

Chlorofluorocarbons (CFCs like R-12, R-11, etc) and hydrochlorofluorocarbons (HCFCs like R-22) are currently used extensively in air conditioning and refrigeration. They possess most of the characteristics required, such as thermal and chemical stability, non-toxicity, non-flammability, and low cost. Despite these advantages, Montreal protocol of 1987 and the European community regulation called for the phasing out of Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) by the end of 20^{th} century because of their effect on the stratospheric ozone layer.

One of the most common chlorofluorocarbon (CFCs) refrigerants used in refrigeration and air conditioning is dichlorodifluoromethane (R-12), which is marketed under the trade name of Freon-12. It was first used in household refrigerators more than sixty years ago. The industry had optimized the design of vapor compression systems based on this refrigerant to provide an enviable balance of thermal and chemical stability. In accordance to Montreal protocol of 1987, dichlorodifluoromethane (R-12) must be totally phased out by the year 2000. A refrigerant which will be a suitable alternative for

R-12 must have acceptable thermodynamic and physical properties, compatibility with materials, lower ozone depletion potential, lower potential source of global warming, and high stability.

1.1 Ozone Depletion Potential and Global Warming

The molecules of (CFCs) and (HCFCs) contain carbon and halogens chlorine and fluorine. Once in the upper atmosphere, the molecules break down and release chlorine, which destroys ozone (ozone depletion), where this layer absorbs most of the harmful ultraviolet radiation. The depletion in ozone layer will permit the ultraviolet radiation to reach the earth.

In the lower atmosphere, these molecules absorb infrared radiation, which may contribute to the warming of the earth, (the global warming problem), green house effect, and so, climate changes.

1.2 Alternative Refrigerants

Since the phasing out of (CFCs) and (HCFCs) is essential and only a matter of time, it is a vital matter to find environmental safe alternatives that could replace these refrigerants. Efforts were directed towards finding new refrigerants that possess suitable properties, and at the same time do not contain atoms, which acts to deplete the ozone layer.

Recently the literature described physical and thermodynamic properties of a promising and environmentally acceptable alternative namely tetrafluoroethane (R-134a). R-134a is an aerosol propellant containing no chlorine atoms; and as such; fall completely outside concerns about stratospheric ozone destruction by Chlorofluorocarbons and hydrochlorofluorocarbons. It has an ozone depletion potential of zero and very small global warming potential compared to (CFCs) and (HCFCs). The thermodynamic and physical properties coupled with their non-toxicity, make this refrigerant very efficient and safe replacement for R-12.

1.3 The Importance of This Work

Refrigerants have become essential to many activities, including storage, transport and distribution of food, conservation of medical products and various industrial processes.

This work will concentrate on calculating thermodynamic properties of the two refrigerant R-12 and R-134a using computer algorithms. The performance study of the two refrigerants will be considered for Mass Flow Rate, Discharge Temperature, Power Consumption, Refrigeration Capacity, Heat Rejection Rate and Coefficient of Performance. The range of temperature used will be changed between –20 ^{o}C to 0 ^{o}C for the evaporator, and between 30 ^{o}C to 50 ^{o}C for the condenser.

The effect of superheating and subcooling for the standard cycle to refrigerant R-134a will be considered with condensing temperature of 40 ^{o}C. And the effect of isentropic efficiency on the coefficient of performance for the actual cycle will be considered with different values of condensing temperatures.

LITERATURE SURVEY

The depletion of ozone layer, the warming of the earth and many other destructive effects of the CFCs, HCFCs led to the holding of Montreal conference in 1987. The conference request to phase out the usage of CFCs and HCFCs. Governmental organization, scientists and researches all over the world, raced for finding alternative to the harmful CFCs, HCFCs, with minimum changes to the design of the existing units.

Many papers had been published within the last few years and considered the destructive effect of the CFCs on environment, and the importance of phasing out their production. Studies were carried on various refrigerant alternatives, concerning their properties (physical and thermodynamic) and system performance (experimentally and theoretically). The reported works were divided into experimental and theoretical work.

2.1 Experimental Works.

Carpenter, (1991) presented a brief outline of ICI developmental work on the new range of ester oils suitable for use with alternative refrigerants. He described the simple procedure developed to enable the refrigeration industry to convert from R-12 to R-134a. Also, he described the flushing procedure and the determination of residual mineral- oil contents. He concluded that R-134a and ester lubricants could be retrofitted into many of the existing refrigeration and air-conditioning systems currently running on R-12.

Bansal, Dutto, and Hivet, (1991) presented the performance characteristics of R-134a in an industrial (water to water) heat - pump test facility at Electricite de France with a twin-screw compressor. They studied the performance of R-134a in terms of performance parameters of the compressor (e.g its volumetric and isentropic efficiencies) and of the heat – pump system (e.g coefficient of performance and volumetric heating capacity). Also, they studied the influence of degree of superheat on the miscibility of R-134a with ester oil and on the viscosity of the oil-refrigerant mixture for various discharge pressures. They gave some advantages of R-134a use, such as; it is environmentally benign and possesses good properties.

Preisegger and Henrici, (1992) summarized the requirements for a suitable replacement for R-12. They described the criteria leading to the selection of R-134a, the developmental efforts that have been made and the results of this process. Also, they described chemical properties, material compatibility and thermodynamic properties of R-134a. Because of different chemistry in comparison with CFC refrigerants, special requirements for suitable compressor lubricants and system cleanliness are mentioned. These requirements are tolerable residues of oily and fatty impurities in tubes, evaporators, condensers and compressors remaining from the manufacturing processes. The reason of this is to avoid problems that could occur if these impurities are dissolved in refrigerant or lubricant and distributed in the system.

Devotta and Gopicand, (1992) presented the performance of R-134a as compared to R-22, R-152a, and R-134. The study included the pressure ratio, specific compressor displacement, coefficient of performance, and shaft power per ton of refrigeration. They also, presented a discussion of the practical implications of the choice of the alternatives to R-12.They concluded that the refrigeration effect is highest using R-12, while R-134a and R-152a would perform closer to R-12. They concluded that some major modifications have to be incorporated when replacing R-12 by R-134a and R-152a.

Magee, et al (1992) presented vapor pressure measurements for R- 134a with a temperature range between (180 K to 350 K) by using a static cell. Temperatures were measured with platinum resistance thermometer. Pressures were measured with calibrated oscillating quartz crystal pressure transducer. The experimental vapor pressure data was plotted in a graph and it was fitted in a polynomial equation.

Zoubi, (1998) examined a locally manufactured domestic refrigerator using R-134a as an alternative to R-12. He did not change or modify any design of the used refrigerator components. He concluded that R-134a gives a good performance as replacement to R-12 in domestic refrigerators. He obtained coefficients of performance up to 6.1. This was obtained at an evaporative temperature T_e of 5 °C and a condensing temperature T_c of 47 °C, and ambient temperature T_a of 29 °C.

Obeidat, (2000), studied the performance of A/C spilt unit working on R-134a. He found that R-134a gives low COP at different conditions compared to R-22, so he recommended that R-134a is not a suitable replacement for R-22.

Abu-jari, (2001) examined a chest freezer using R-407c as an alternative to R-12. He did not change or modify any design of the used freezer components. He concluded that R-407c is not recommended as alternative to R-12 in domestic refrigerators. He obtained coefficients of performance up to 7.51. This was obtained at an evaporative temperature T_e of –4.7°C and a condensing temperature T_c of 39 °C, and ambient temperature T_a of 22.5 °C.

2.2 Theoretical Works.

Cleland (1988) proposed empirical equations for predicting energy consumption of all refrigerants. These equations for calculating energy used in industrial and commercial refrigeration systems. The equations contain empirical constants, isentropic efficiency, heat load in the evaporator and the fractional vaporization occurring in the expansion valve.

Huber, et al (1992) presented new correlations for the thermodynamic properties of R-134a and a classical equation for the molar Helmholtz energy with temperature and density as the independent variables. The coefficients for the correlation represented the thermodynamic surface of R-134a were determined by using the Schmidt-Wagner equation of state.

Huber (1992) suggested that, the simple corresponding states for pure fluids was developed for spherically symmetric molecules whose intermolecular properties are conformal and this is a limited class of materials that places severe restrictions on the applicability of the model, especially for refrigerant which are generally non-spherical and polar.

Cleland (1992) presented coefficients that extend previously published polynomial curve-fit equations for thermodynamic properties of refrigerant R-134a. The data set that had been used was taken from published data by the international institute of refrigeration, which proved to be at least as accurate as any other data. Cleland had presented a set of equations within the range of temperature between -40 ^oC to 70 ^oC.

Preisegger, et al (1992) described thermodynamic properties to refrigerant R-134a for the isentropic exponent and the sonic velocity. The isentropic exponent as a function of temperature and pressure for a pressure range between 1.0 to 22 bar, and temperature range between -20 ^oC to 150 ^oC. The isentropic exponent in that range is 1.3, which is 2.5 % lower than that of R-12. The sonic velocity as a function of pressure and temperature for the pressure range between 1.0 to 6.0 bar, and temperature range between –20 ^oC to 100 ^oC, the values were 7-8 % higher than those of R-12.

Huber, at al (1994) developed a predictive corresponding state model for thermophysical properties of pure refrigerants and refrigerant mixture. They discussed the mathematical details, implementation and application of the extended corresponding states model to the equilibrium properties of refrigerants.

Chen, et al (1998) presented a computer program for producing logarithmic pressure-enthalpy diagrams for alternative refrigerants. The computer program contained two blocks, the data-generating block and the plot program block.

THERMODYNAMIC PROPERTIES AND CYCLE CALCULATIONS

3.1 Thermodynamic Properties

The data set, which is used to produce the properties equations, is available in the ASHRAE handbook. The data set is considered as accurate as any of other source, the range of saturated tempe[rature was taken from –30 °C to 65 °C and it was divided into three specific ranges, (–30 °C to 0 °C), (0°C to 50 °C) and (50 °C to 65 °C). Three pressure ranges were taken for superheated properties, (0.1 MPa to 0.45 MPa) , (0.45 MPa to 1.6 MPa) , (1.6 MPa to 2 MPa).

Microsoft Excel software was used to generate equations of saturation properties as function of saturation temperature of sixth degree polynomial type. SPSS software was used to generate superheated properties as function of pressure and temperature of third degree.

3.2 Equations of saturation properties

3.2.1 Refrigerant R-134a:

The saturated equation is expressed by the following equation,

$$Z = A_0+A_1 (T)+A_2 (T)^2+ A_3 (T)^3+ A_4 (T)^4+ A_5 (T)^5+ A_6 (T)^6 \qquad (3.1)$$

Where, z is any variable shown in the table (3.1). T in °C, within the range of applicability from –30 °C to 0 °C. The values of coefficients in equation (3.1) are shown in table (3.1)

The largest difference in the value of saturated pressure compared with the tabulated data was (0.006%), and (0.025%) for the saturated vapor specific volume, and (0.005%) for the saturated liquid enthalpy, and (0.002%) for the saturated vapor enthalpy, and (0.05%) for the saturated vapor entropy.

Table (3.1) coefficients for equation (3.1)

T (–30 °C to 0 °C)	P_{sat} (kPa)	v_g (m^3/kg)	h_f (kJ/kg)	h_g (kJ/kg)	s_g (kJ/kg.K)
A_0	292.693	0.0693	200.007	398.663	1.727
A_1	10.610	-0.0024	1.344	0.5706	-6.055E-4
A_2	0.148	5.383E-5	0.0032	-0.0034	-1.176E-6
A_3	0.0013	-4.045E-7	1.5721E-4	-1.92E-4	-6.452E-7
A_4	5.342E-6	4.1140E-8	6.026E-6	-6.768E-6	-2.144E-8
A_5	6.503E-8	7.469E-10	1.113E-7	-1.171E-7	-3.868E-10
A_6	4.818E-10	1.322E-11	7.715E3-10	-7.721E-10	-2.618E-12

For temperature values of (0 °C to 50 °C), the values of coefficients in equation (3.1) are shown in table (3.2). The largest difference in the value of saturated pressure compared with the tabulated data was (0.012%), and (0.125%) for the saturated vapor specific volume, and (0.014%) for the saturated liquid enthalpy, and (0.007%) for the saturated vapor enthalpy, and (0.003%) for the saturated vapor entropy.

Table (3.2) coefficients for equation (3.1)

T (0 °C to 50 °C)	P_{sat} (kPa)	v_g (m^3/kg)	h_f (kJ/kg)	h_g (kJ/kg)	s_g (kJ/kg.K)
A_0	292.69	0.0693	200	398.663	1.727
A_1	10.631	-0.0024	1.337	0.5706	-5.887E-4
A_2	0.142	5.166E-5	0.0015	-0.0034	1.265E-5
A_3	0.0013	-9.082E-7	1.90E-5	-1.92E-4	-5.385E-7

A_4	-1.737E-5	1.4002E-8	-4.431E-7	-6.768E-6	1.742E-8
A_5	3.558E-7	-1.591E-10	1.169E-8	-1.171E-7	-2.976E-10
A_6	-2.493E-9	8.715E-13	-8.972E-11	-7.721E-10	1.894E-12

For temperature values of (50 °C to 65 °C), the values of coefficients in equation (3.1) are shown in table (3.3). The largest difference in the value of saturated pressure compared with the tabulated data was (0.004%), and (0.05%) for the saturated vapor specific volume, and (0.005%) for the saturated liquid enthalpy, and (0.06%) for the saturated vapor enthalpy, and (0.004%) for the saturated vapor entropy.

Table (3.3) coefficients for equation (3.1)

T (50 °C to 65 °C)	P_{sat} (kPa)	v_g (m^3/kg)	h_f (kJ/kg)	h_g (kJ/kg)	s_g (kJ/kg.K)
A_0	0.0094	6.095E-7	0.004	0.0074	3.104E-5
A_1	0.186	1.202E-5	0.081	0.146	6.125E-4
A_2	2.208	1.426E-4	0.961	1.736	0.007
A_3	-0.079	-7.2283E-6	-0.041	-0.077	-3.25E-4
A_4	0.0014	1.449E-7	7.792E-4	0.0014	6.121E-6
A_5	-1.21E-5	-1.339E-9	-6.896E-6	-1.287E-5	-5.43E-8
A_6	4.051E-8	4.762E-12	2.381E-8	4.446E-8	1.877E-10

3.2.2 Refrigerant R-12:

The saturated equation is expressed by the following equation,

$$Z = A_0+A_1 (T)+A_2 (T)^2+ A_3 (T)^3+ A_4 (T)^4+ A_5 (T)^5+ A_6 (T)^6 \quad (3.2)$$

Where, z is any variable shown in the table (3.4). T in °C, within the range of applicability from –30 °C to 0 °C. The values of

coefficients in equation (3.2) are shown in table (3.4).The largest difference in the value of saturated pressure compared with the tabulated data was (0.012%), and (0.03%) for the saturated vapor specific volume, and (0.01%) for the saturated liquid enthalpy, and (0.006%) for the saturated vapor enthalpy, and (0.08%) for the saturated vapor entropy.

Table (3.4) coefficients for equation (3.2)

T (–30 °C to 0 °C)	P_{sat} (kPa)	v_g (m^3/kg)	h_f (kJ/kg)	h_g (kJ/kg)	s_g (kJ/kg.K)
A_0	308.620	0.055	36.051	187.519	0.6964
A_1	10.150	-0.0017	0.923	0.41981	-0.00048
A_2	0.1270	0.00003	0.0005	-0.0021	5.705E-06
A_3	7150.68E-07	-4.071E-07	-4.62E-06	-0.00007	-2.276E-08
A_4	-9023.38E-10	5.497E-09	2.31E-07	2.034E-06	-9.951E-10
A_5	-1631.52E-10	-3.641E-10	2.56E-08	2.215E-07	-7.492E-11
A_6	-2685.55E-12	-5.035E-12	4.67E-10	3.955E-09	-1.087E-12

For temperature values of (0 °C to 50 °C), the values of coefficients in equation (3.2) are shown in table (3.5). The largest difference in the value of saturated pressure compared with the tabulated data was (0.03%), and (0.2%) for the saturated vapor specific volume, and (0.04%) for the saturated liquid enthalpy, and (0.08%) for the saturated vapor enthalpy, and (0.04%) for the saturated vapor entropy.

Table (3.5) coefficients for equation (3.2)

T (0 °C to 50 °C)	P_{sat} (kPa)	v_g (m^3/kg)	h_f (kJ/kg)	h_g (kJ/kg)	s_g (kJ/kg.K)
A_0	308.59	0.055	36.075	187.526	0.6964
A_1	10.159	-0.0017	0.9239	0.4277	-0.00049
A_2	0.1214	0.00003	0.00032	-0.0004	6.513E-06
A_3	108.8E-06	-5.006E-07	0.00004	-0.000011	-2.07E-07
A_4	-172.3E-08	6.028E-09	-1.4277-06	-4.701E-07	7.468E-09
A_5	358.7E-10	-5.108E-11	2.499E-08	1.974E-08	-1.445E-10
A_6	-266.6E-12	2.153E-13	-1.570E-10	-2.065E-10	1.017E-12

For temperature values of (50 °C to 65 °C), the values of coefficients in equation (3.2) are shown in table (3.6). The largest difference in the value of saturated pressure compared with the tabulated data was (0.06%), and (0.08%) for the saturated vapor specific volume, and (0.009%) for the saturated liquid enthalpy, and (0.02) for the saturated vapor enthalpy, and (0.003) for the saturated vapor entropy.

Table (3.6) coefficients for equation (3.2)

T (50 °C to 65°C)	P_{sat} (kPa)	v_g (m^3/kg)	h_f (kJ/kg)	h_g (kJ/kg)	s_g (kJ/kg.K)
A_0	208563.85	-0.00026	225.346	-121.112	0.4001
A_1	-20824.99	0.0039	-15.789	29.002	0.0258
A_2	866.62	-0.00021	0.6101	-1.0930	-0.0009
A_3	-19.17	5.032E-06	-0.01174	0.0220	0.000018
A_4	0.238	-6.467E-08	0.000126	-0.0002	-2.048E-07
A_5	-1573.5E-06	4.350E-10	-7.180E-07	1.478E-06	1.187E-09
A_6	4322.5E-09	-1.206E-12	1.692E-09	-3.641E-09	-2.878E-12

3.3 Equations of superheated properties

3.3.1 Refrigerant R-134a

The superheated equation is expressed by the following equation,

$$Z=A_o+A_1(t)+A_2(t)^2+A_3(p)+A_4(p)^2+A_5(p)(t)+A_6(p)(t)^2+A_7(t)(p)^2+A_8(p)^3+A_9(t)^3 \qquad (3.3)$$

Where, z is any variable shown in the table (3.7). T in (°C), P in (MPa), within the range of applicability (-20 °C<T<50 °C), and pressure values (0.1 MPa to 0.45 MPa), The values of coefficients in equation (3.3) are shown in table (3.7). The largest difference in the value of superheated enthalpy compared with the tabulated data was (0.5%), and (0.2%) for the superheated entropy, and (0.12%) for the superheated specific volume.

Table (3.7) coefficient for equation (3.3)

P (0.1 to 0.45) MPa	*h* (kJ/kg)	*s* (kJ/kg.K)	*v* (m^3/kg)
A_0	406.10	1.925	0.4649
A_1	0.785	0.002	0.0014
A_2	0.0008	-2.289E-06	-5.832E-07
A_3	-22.67	-1.1921	-3.371
A_4	-8.480	2.3982	9.8584
A_5	0.2737	0.0014	-0.0065
A_6	-0.003	-0.000014	3.125E-07
A_7	0.2558	0.00022	0.0092
A_8	-3.9813	-2.1854	-10.088
A_9	5.303E-06	3.4271E-08	2.413E-09

For temperature values of (20 ^{o}C<T<90 ^{o}C) and pressure values of (0.45 MPa to 1.6 MPa), The values of coefficients in equation (3.3) are shown in table (3.8). The largest difference in the value of superheated enthalpy compared with the tabulated data was (0.6%), and (0.1%) for the superheated entropy, and (0.4%) for the superheated specific volume.

Table (3.8) coefficient for equation (3.3)

P (0.45 to 1.6) MPa	*h* (kJ/kg)	*s* (kJ/kg.K)	*v* (m^3/kg)
A_0	393.71	1.818	0.1028
A_1	0.631	0.0034	0.00035
A_2	0.001	-6.1001E-6	-5.335E-07
A_3	48.403	-0.4179	-0.19088
A_4	-93.561	0.23169	0.13730
A_5	0.3994	3.81086E-4	-0.00027
A_6	-0.0021	-1.6681E-6	-3.219E-07
A_7	0.1196	1.2622E-4	0.00011
A_8	26.2707	-0.063	-0.03580
A_9	4.06578E-6	1.297E-8	2.558E-09

For temperature values of (70 ^{o}C<T<110 ^{o}C) and pressure values of (1.6 MPa to 2.0 MPa), The values of coefficients in equation (3.3) are shown in table (3.9). The largest difference in the value of superheated enthalpy compared with the tabulated data was (0.1%), and (0.4%) for the superheated entropy, and (0.5%) for the superheated specific volume.

Table (3.9) coefficient for equation (3.3)

P (1.6 to 2.0) MPa	*h* (kJ/kg)	*s* (kJ/kg.K)	*v* (m^3/kg)
A_0	403.501	1.687	0.04574
A_1	1.179	0.004	0.00022
A_2	-0.0033	-1.36E-5	-1.301E-06
A_3	-39.205	-0.173	-0.0479
A_4	-2.9186	0.0052	0.0163
A_5	0.38909	9.8590E-4	0.000014
A_6	-0.0013	-3.318E-6	-7.135E-07
A_7	0.0289	7.0583E-5	0.000028
A_8	-0.281	-0.0014	-0.00257
A_9	1.209E-5	3.45864E-8	8.472E-09

3.3.2 Refrigerant R-12

The superheated equation is expressed by the following equation,

$$Z=A_o+A_1(t)+A_2(t)^2+A_3(p)+A_4(p)^2+A_5(p)(t)+A_6(p)(t)^2+A_7(t)(p)^2+A_8(p)^3+A_9(t)^3 \qquad (3.4)$$

Where, z is any variable shown in the table (3.10). T in (°C), P in (MPa), within the range of applicability (-20 °C<T<50 °C), and pressure values (0.1 MPa to 0.45 MPa), The values of coefficients in equation (3.4) are shown in table (3.10). The largest difference in the value of superheated enthalpy compared with the tabulated data was (0.8%), and (0.7%) for the superheated entropy.

Table (3.10) coefficient for equation (3.4)

P (0.1 to 0.45) MPa	*h* (kJ/kg)	*s* (kJ/kg.K)
A_0	193.530	0.883
A_1	0.5744	0.002
A_2	0.0021	3.358E-06
A_3	-22.46	-1.2036
A_4	70.196	2.8283

A_5	-0.396	-0.0012
A_6	-0.021	-0.00008
A_7	3.410	0.0121
A_8	-219.719	-3.0297
A_9	0.000042	1.779E-07

For temperature values of (20 °C<T<70 °C) and pressure values of (0.45 MPa to 1.6 MPa), The values of coefficients in equation (3.4) are shown in table (3.11). The largest difference in the value of superheated enthalpy compared with the tabulated data was (0.6%), and (0.3%) for the superheated entropy, and (0.9%) for the superheated specific volume.

Table (3.11) coefficient for equation (3.4)

P (0.45 to 1.6) MPa	*h* (kJ/kg)	*s* (kJ/kg.K)	*v* (m^3/kg)
A_0	193.590	0.772	0.09713
A_1	0.5909	0.0021	0.00037
A_2	0.00016	-3.105E-06	-6.596E-07
A_3	-18.8461	-0.2941	-0.19738
A_4	-3.65492	0.1259	0.15589
A_5	0.19685	0.00061	-0.00038
A_6	-0.00061	-1.746E-06	5.480E-08
A_7	0.0161	0.00002	0.000149
A_8	0.0686	-0.0304	-0.0435
A_9	5.579E-07	4.172E-09	2.116E-09

For temperature values of (70 °C<T<110 °C) and pressure values of (1.6 MPa to 2.0 MPa), The values of coefficients in equation (3.4) are shown in table (3.12). The largest difference in the value of superheated enthalpy compared with the tabulated data was (0.4%), and (0.7%) for the superheated entropy, and (0.6%) for the superheated specific volume.

Table (3.12) coefficient for equation (3.4)

P (1.6 to 2) MPa	*h* (kJ/kg)	*s* (kJ/kg.K)	*v* (m^3/kg)
A_0	192.345	0.7163	0.0399
A_1	0.67691	0.0024	0.00015
A_2	-0.0016	-9.687E-06	-6.360E-07
A_3	-21.111	-0.174	-0.04104
A_4	-5.758	0.0158	0.01436
A_5	0.31046	0.001	-2.635E-06
A_6	-0.0023	-7.207E-06	-4.041E-07
A_7	0.09405	0.00023	0.000019
A_8	-1.0924	-0.006354305	-0.00222
A_9	0.000016	5.46040E-08	3.958E-09

3.4 Cycle Calculations

Theoretical analyses were used to predict the performance of the vapor compression cycle. These analyses require a complete set of refrigerant's thermodynamic properties.

The theoretical refrigeration cycle is composed of four idealized thermodynamic processes. On the other hand, the actual refrigeration cycle deviates from the ideal cycle primarily because of pressure drops associated with fluid flow and heat transfer to or from the surroundings.

For actual cycle the vapor entering the compressor will probably be superheated. During the compression process there are irreversibilities and heat transfer either to or from the surroundings, depending on the temperature of the refrigerant and the surroundings.

Pressure drops occur everywhere in the system except in the compression process.

The working fluid is not a pure refrigerant but a mixture of refrigerant and oil.

These deviations from a theoretical cycle cause irreversibility within the system. And each irreversibility requires additional power into the compressor

3 .4.1 Theoretical Vapor-Compression Cycle, (Standard Cycle)

This cycle, shown in Figure (3.1), consists of an isentropic compression, isobaric heat transfer in both heat exchangers and irreversible, adiabatic expansion.

The states in Figure (3.1) correspond to:

State 1:saturated vapor, evaporator outlet, and compressor inlet.

State 2:superheated vapor, compressor outlet, and condenser inlet.

State 3: saturated liquid refrigerant, condenser outlet, and expansion device inlet.

State 4:expansion device outlet, evaporator inlet.

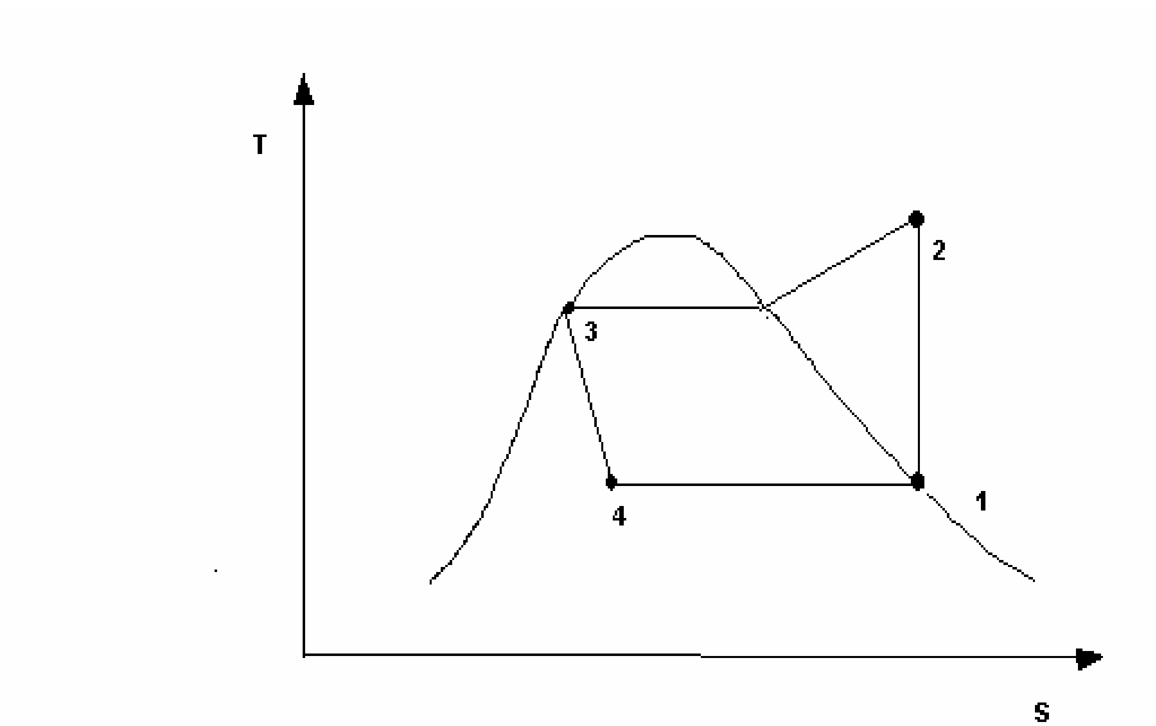

Figure (3.1) theoretical vapor compression cycle, temperature-entropy diagram

3.4.1-a) Calculation of Volume and Mass Flow Rate.

Volume flow rate can be calculated based on a specific characteristics of a given compressor, therefore to calculate volume flow rate one needs to know the compressor characteristics i.e. speed of the motor (rpm), displacement (V).

The following equation gives the volume flow rate as a function of motor speed (rpm), displacement of the compressor (V), and the volumetric efficiency η_v :

$$\dot{Q} = (rpm)(V)(\eta_v)(10^{-6}/60) \tag{3.5}$$

Where (V) in (cm^3), and $\dot{Q}$ (m^3/s), and η_v can be found from the following equation (Stoker and Jones,1987)

$$\eta_v = 1- m\,[(v_1/ v_2)-1] \tag{3.6}$$

Where v_1 , v_2 are the saturated and superheated specific volume for the inlet and outlet of the compressor in (m^3/kg) at state 1 and 2, respectively, as shown in Figure (3.1) ,and m is the percent clearance which is constant for a given compressor.

The mass flow rate of a refrigerant can be calculated using the following equation:

$$\dot{m} = \dot{Q} / v_1 \tag{3.7}$$

Where (v_1) is the saturated vapor specific volume at point (1) shown in Fig (3.1)

3.4.1-b) Isentropic compressor power.

The compressor power $\dot{W}_{comp}$ (kW), is the change in the enthalpy in process (1-2) multiplied by the mass flow rate.

$$\dot{W}_{comp} = \dot{m}\,(h_2-h_1) \tag{3.8}$$

Where h_1, h_2 are the saturated vapor and superheated enthalpies at state (1) and (2), respectively.

3.4.1-c) Refrigeration capacity.

The refrigeration capacity $\dot{Q}_{ref}$ (kW), is the heat transferred in process (4-1) multiplied by the mass flow rate.

$$\dot{Q}_{ref} = \dot{m}\ (h_1-h_4) \tag{3.9}$$

Where h_4 is the enthalpy at state (4), which is equal to h_3 at state (3) since the expansion process (3-4) occurs at constant enthalpy.

3.4.1-d) Heat rejection rate.

The heat rejection rate $\dot{Q}_{rej}$ (kW), is the heat transferred in process (2-3) multiplied by the mass flow rate.

$$\dot{Q}_{rej} = \dot{m}\ (h_2-h_3)\ = \dot{W}_{comp} + \dot{Q}_{ref} \tag{3.10}$$

Where h_2, h_3 are the superheated and saturated enthalpy at state (2) and state (3).

3.4.1-e) Coefficient of performance.

It is the ratio between refrigeration capacity to the compression work.

$$COP =(\dot{Q}_{ref} / \dot{W}_{comp}) = (h_1-h_4)/ (h_2-h_1) \tag{3.11}$$

3.4.2 Actual Vapor-Compression Cycle

As shown in Fig. (3.2) the actual vapor-compression cycle differs from the theoretical cycle as follows:

1.The refrigerant leaves the evaporator as superheated vapor.

2. The refrigerant leaves the condenser as subcooled liquid.

3. Irreversibility of the compression processes.

These states corresponds to:

State 1:saturated vapor in the evaporator.

State 2:superheated vapor, inlet to the compressor.

State 3:superheated vapor, exit from the compressor.

State 3i:superheated vapor after the isentropic compression process.

State 4:saturated liquid, in the condenser.

State 5:subcooled liquid, outlet from the condenser, and inlet to the adiabatic expansion device.

State 6:expansion device outlet, evaporator inlet.

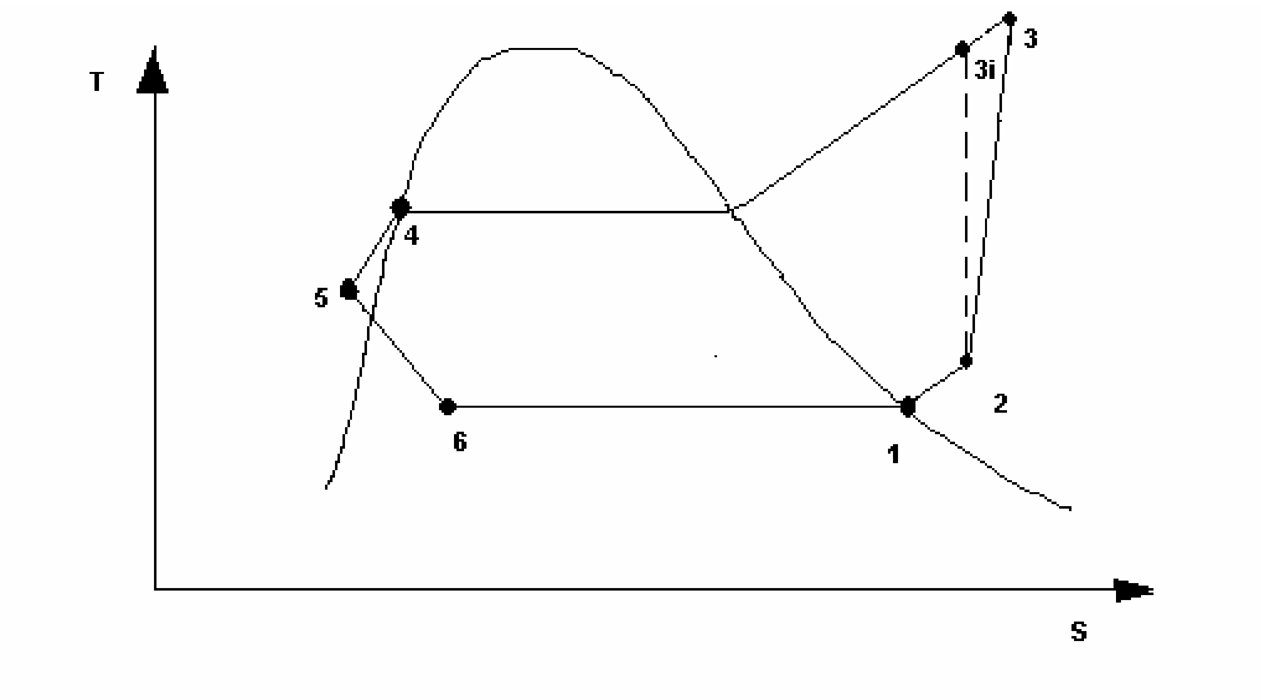

Figure (3.2) Actual vapor compression cycle, temperature-entropy diagram

3.4.2-a) Calculation of Volume and Mass Flow Rate.

$$\dot{Q} = (rpm)(V)(\eta_v)(10^{-6}/60) \quad (3.12)$$

Where (V) in (cm^3), and $\dot{Q}$ in (m^3/s)

$$\eta_v = 1 - m\,[(v_2/v_3) - 1] \quad (3.13)$$

Where v_2 , v_3 are the superheated specific volume for the inlet and outlet of the compressor in (m^3/kg) at state 2 and 3, respectively.

The mass flow rate of a refrigerant can be calculated using the following equation:

$$\dot{m} = \dot{Q} / v_2 \tag{3.14}$$

Where (v_2) is the superheated vapor specific volume at state (2).

3.4.2-b) Superheated and subcooling temperatures.

$$T_2 = T_1 + \Delta_{superheating} \tag{3.15}$$

Where T_2, T1 are the superheated temperature at outlet of the evaporator and the saturated vapor temperature in the evaporator, at state 2 and 1 respectively, $\Delta_{superheating}$ is the degree of superheat.

$$T_5 = T_4 - \Delta_{subcooling} \tag{3.16}$$

Where T_5, T_4 are the subcooled temperature at the outlet of the condenser and the saturated liquid temperature in the condenser, at state 6 and 5 respectively, and $\Delta_{subcooling}$ is the degree of subcooling.

3.4.2-c) Enthalpy at inlet and outlet compressor.

The enthalpy at the inlet of compressor h_2 is calculated according to the suction temperature (T_2) at state (2).

The enthalpy of refrigerant after compression h_3 is expressed as follows:

$$h_3 = h_2 + [h_{3i} - h_2] / \eta_{isent} \tag{3.17}$$

Where η_{isent} is the isentropic efficiency for the compressor.

3.4.2-d) compressor power.

$$\dot{W}_{comp} = \dot{m} (h_3 - h_2) \tag{3.18}$$

3.4.2-e) refrigeration capacity.

$$\dot{Q}_{ref} = \dot{m}\ (h_2-h_6) \tag{3.19}$$

3.4.2-f) heat rejection rate.

$$\dot{Q}_{rej} = \dot{m}\ (h_3-h_5) = \dot{W}_{comp} + \dot{Q}_{ref} \tag{3.20}$$

3.4.2-g) coefficient of performance.

$$COP = (\dot{Q}_{ref} / \dot{W}_{comp}) = (h_2-h_6)/(h_3-h_2) \tag{3.21}$$

3.5 Computer Algorithm.

The computer algorithm was written using programming language Matlab 6.1. The algorithm is listed in Appendix A and the following is a brief description of the program:

3.5.1) **Flow Chart of the main Algorithm.**

The flow chart of the main computer algorithm is shown in Fig (3.3), which includes the following:

- Input data:

-Specifying refrigerant type (R-134a, R-12).

-Specifying evaporator and condenser temperature.

- Data processing:

-Calculation of the saturation pressure, saturation specific volume, entropy and enthalpy for both liquid and vapor states and calculation of discharge conditions (exit temperature and exit enthalpy).

-Specifying compressor characteristics (revolution per minute, displacement, percent clearance) and isentropic efficiency for the actual cycle.

-Input the value of superheating and subcooling degree for the actual cycle.

-Calculation of volume and mass flow rates.

-Calculation of Compressor discharge temperature, Compressor work, Refrigeration capacity, Heat rejection rate and Coefficient of performance.

3.5.2) Flow Chart of the Subroutines used in the main Algorithm:

Subroutines R-12, R-134a are used to calculate the saturation and superheat properties values of each refrigerant. The flow chart of these subroutines is shown in Figure (3.4), the procedure for them as follows:

-Calculating evaporating and condensing pressures

-Compressor inlet temperatures, enthalpies, entropies, and specific volume for both actual and theoretical cycles

-Calculating isentropic compressor exit temperature using successive iteration.

-Calculating compressor exit enthalpy and specific volume, for theoretical cycle, compressor discharge enthalpy and specific volume for the inlet and exit of the compressor depending on isentropic efficiency for actual cycles.

-Subroutine mass is used to calculate volume flow rate of the refrigerant and the flow chart of this subroutine is shown in Figure (3.5)

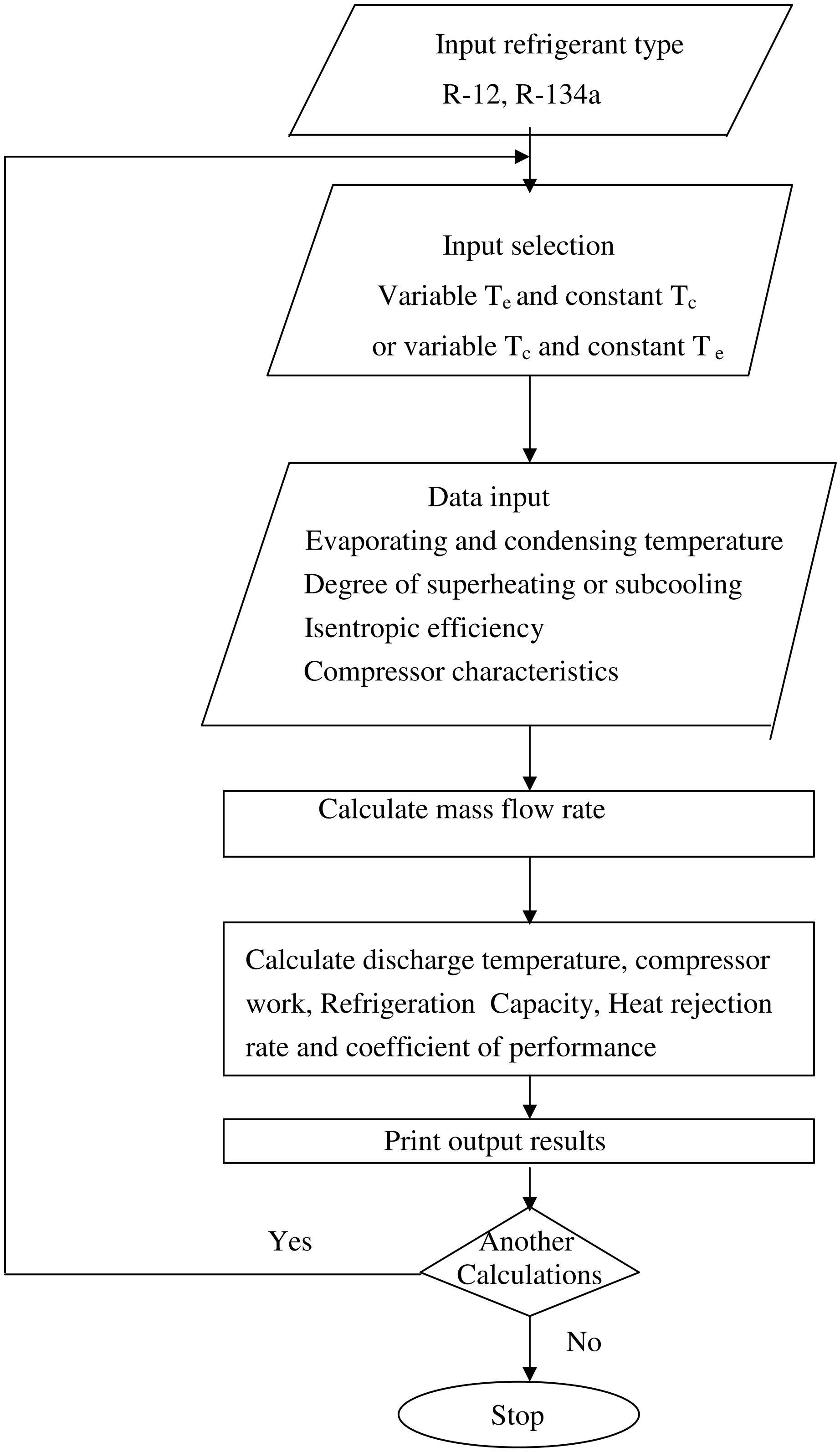

Figure (3.3) Main program flow chart

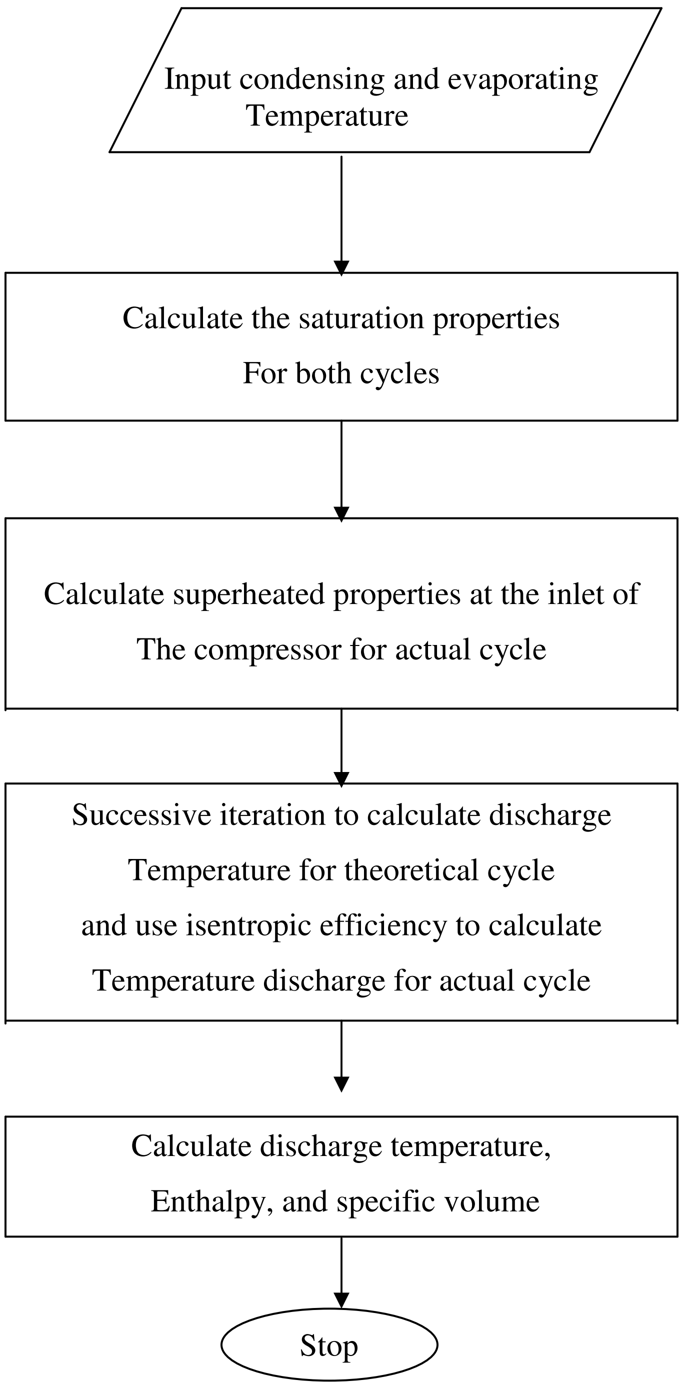

Figure (3.4) Subroutine flow chart for saturated and superheated properties

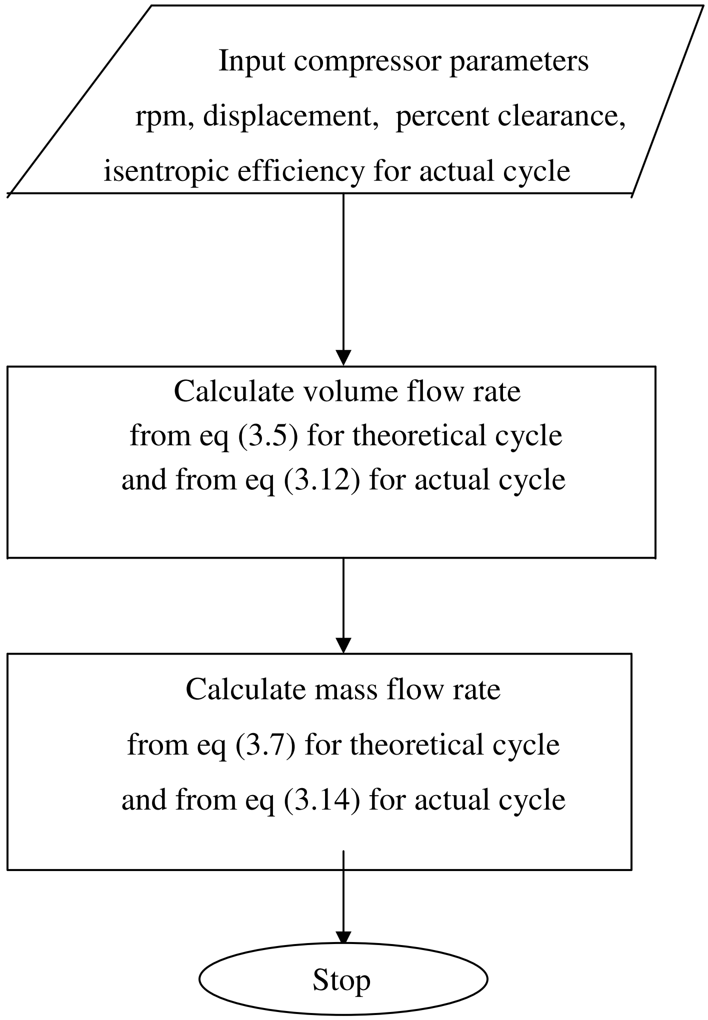

Figure (3.5) Subroutine flow chart for mass flow rate

3.6 Specifications of the freezer used in this research

- Trade mark	ABDIN
-Gross Capacity	200L
-Freezer storage capacity	200L
-Power rating	186 Watt
-Motor Power	179 Watt
-Nominal current	1.5 A
-Nominal frequency	50 Hz
-Nominal voltage	230 volts
-Capillary tube diameter	0.8 mm
-Capillary tube length	3.15 m

3.6.1 compressor specifications

-Compressor design	Reciprocating (hermetically-sealed)
-Compressor displacement size	12cc
-Speed (rpm)	1600
-Percent clearance	3

RESULTS AND DISCUSSION

The results of the temperature variations are presented in this chapter graphically for both refrigerants (R-134a and R-12). The temperature variations for the evaporator are from –20 °C to 0 °C and from 30 °C to 50 °C for the condenser. Numerical values are presented at the end of Appendix B for the same temperatures variation.

In this chapter the effect of the variation of the evaporator and condenser temperatures on the performance parameters is considered. These parameters include the mass flow rate, compressor discharge temperature, refrigeration capacity, compressor work, heat rejection rate, and coefficient of performance. There effects are presented for both refrigerants R-134a and R-12.

The effect of superheating and subcooling is considered for the refrigerant (R-134a). Comparison between standard cycle and ideal cycle with superheating and subcooling is considered also for this refrigerant. The effect of isentropic efficiency on the coefficient of performance is presented for the actual cycle.

4.1 Variation of the performance parameters with condensing and evaporating temperatures for standard cycle.

4.1.1 Mass flow rate

The variations of the mass flow rate with the evaporating temperature for both refrigerants are shown in Figures (4.1 and 4.2). As it is shown the mass flow rate increases with the increase of the evaporating temperature at constant condenser temperature. It is known that the mass flow rate is directly proportional to the volumetric efficiency and is inversely proportional to the specific volume at the inlet of the compressor. Thus as T_e increases, the specific volume decreases, leading to a higher volumetric efficiency. And the increase of the evaporating temperature will increase the evaporating pressure, which finally leads to a larger expansion valve opening and more flow rate.

The variations of the mass flow rate with the condensing temperature for both refrigerants are shown in Figures (4.13 and 4.14). The Figures show a slight decrease in the mass flow rate that occurs due to increasing T_c, which decrease the volumetric efficiency due to the decrease in specific volume at the exit of the compressor. While the specific volume at the compressor inlet remains constant.

4.1.2 Compressor discharge temperature

The variations of the compressor discharge temperature with the evaporating temperature are presented in Figures (4.3 and 4.4) for the two refrigerants. It is exhibited from those Figures that, for constant condensing temperature, increasing the evaporating temperature will contribute to decreasing the exit temperature of the compressor. The increase of condensing pressure will reduce the difference between evaporating and condensing pressures, thus the amount of superheat decreases.

Variations of the compressor discharge temperature with the condensing temperature are presented in Figures (4.15 and 4.16) for the two refrigerants. It is exhibited from those Figures that for constant evaporating temperature, increasing the condensing temperature will contribute to increase the exit temperature of the compressor. The increasing of condensing pressure will increase the difference between evaporating pressure and condensing pressure. Thus the amount of superheat will increase. High temperature at the exit of compressor could result in oil breakdown, which cause excessive wear or reducing life of discharge valves and overheating of compressor. So condensing temperature should be controlled to achieve certain compressor exit temperature.

4.1.3 Compressor power

The variations of the isentropic compressor work with the evaporating temperature are presented in Figures (4.5 and 4.6) for the two refrigerants. It is exhibited from those Figures that, for constant condensing temperature the isentropic compressor work increases with increasing the evaporating temperature. It is known that the work depends on the mass flow rate and the difference between the enthalpy at inlet and outlet of the compressor. Thus increasing T_e will increase the mass flow rate and will decrease enthalpy difference, but at low evaporating temperature it seems that the effect of the mass flow rate is prevailing which explains the increase in the compressor work.

The variations of the isentropic compressor work with the condensing temperature are presented in Figures (4.17 and 4.18) for the two refrigerants. It is shown that as T_c increases for constant T_e the compressor power will increase. Increasing T_c contribute to increase the enthalpy difference and a slight decrease in mass flow rate.

4.1.4 Heat rejection rate

The variations of the heat rejection rate with the evaporating temperature are presented in Figures (4.7 and 4.8) for the two refrigerants. It is exhibited from those Figures that, as T_e increases for constant values of T_c, the heat rejection rate increase. At the same manner in compressor work, the increase in mass flow rate is more than the decrease in the enthalpy difference (the outlet enthalpy of the compressor and the inlet enthalpy of the condenser).

The variations of the heat rejection rate with the condensing temperature are presented in Figures (4.19 and 4.20) for the two refrigerants. As T_c increases for constant T_e, heat rejection rate will decreases, this is because the decreasing in mass flow rate and the decrease in the enthalpy difference. This decreasing in enthalpy difference due to the increase in the saturated liquid enthalpy at the exit of the condenser which is more than the increase in the superheated enthalpy at the inlet of the condenser.

4.1.5 Refrigeration capacity

The variations of the refrigeration capacity with the evaporating temperature are presented in Figures (4.9 and 4.10) for the two refrigerants. It is exhibited from those Figures that, for constant condensing temperature, increasing the evaporating temperature will contribute to increase the refrigeration capacity. This is because the increase of the mass flow rate and the saturated vapor enthalpy while the saturated liquid enthalpy is constant for a certain T_c. Thus the enthalpy difference will increase, this causes increase in refrigeration capacity.

The variations of the refrigeration capacity with the condensing temperature are presented in Figures (4.21 and 4.22) for the two refrigerants. It is exhibited from those Figures that, for constant evaporating temperature, the increasing of condensing temperature will decrease the refrigeration capacity. This is because the slight decreasing in mass flow rate, and the increasing in the condenser temperature will increase the saturated liquid enthalpy at that condenser outlet. Which is lead to decrease the enthalpy difference a cross the evaporator.

4.1.6 Coefficient of performance

The variations of the coefficient of performance with the evaporating temperature are presented in Figures (4.11 and 4.12) for the two refrigerants. It is exhibited from those Figures that, as the evaporating temperature increases, for constant condensing temperature, the coefficient of performance increases. This is caused by increase in the enthalpy difference across the evaporator, and decrease in the enthalpy difference a cross the compressor.

The variations of the coefficient of performance with the condensing temperature are presented in Figures (4.23 and 4.24) for the two refrigerants. It is exhibited from those Figures that, the coefficient of performance decreases as T_c increases at constant T_e, which is due to the decrease in enthalpy difference across the evaporator and the increase in the enthalpy difference across the compressor.

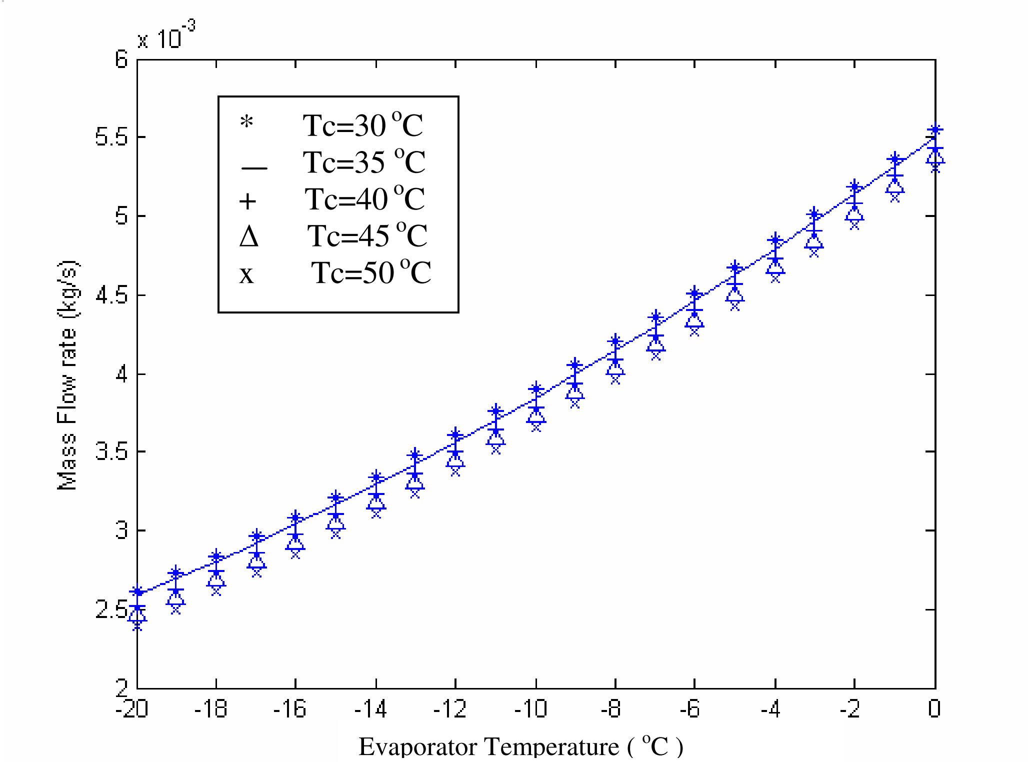

Figure (4.1) Mass flow rate versus evaporating temperatures with different values of condensing temperatures for refrigerant R-12

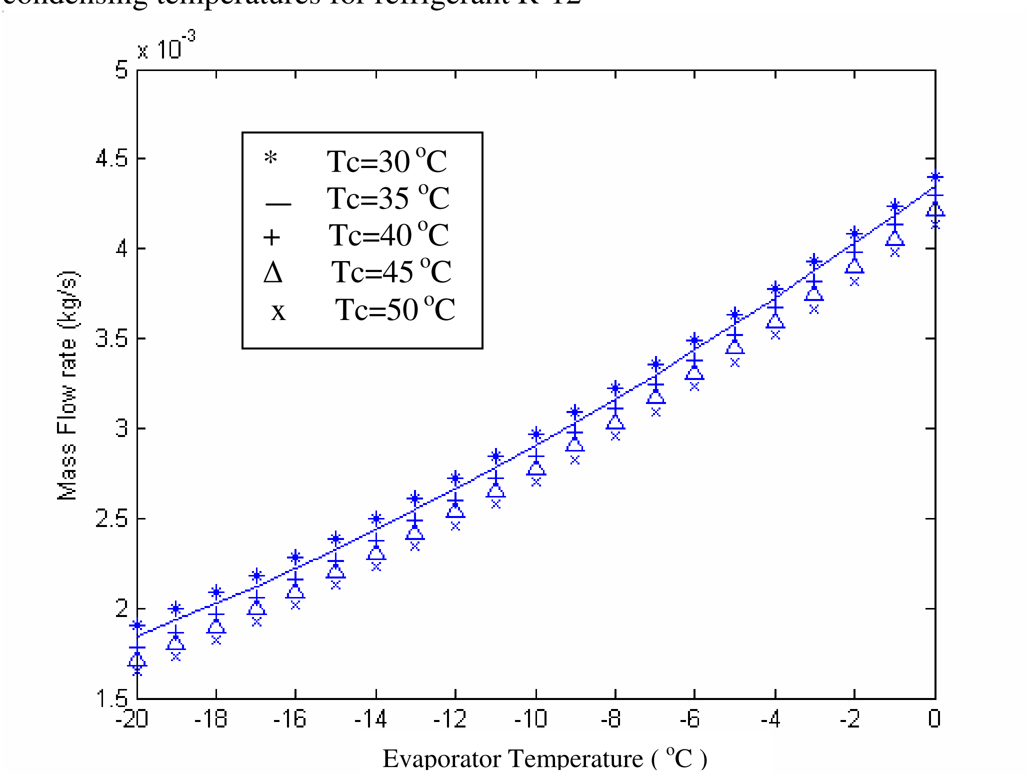

Figure (4.2) Mass flow rate versus evaporating temperatures with different values of condensing temperatures for refrigerant R-134a

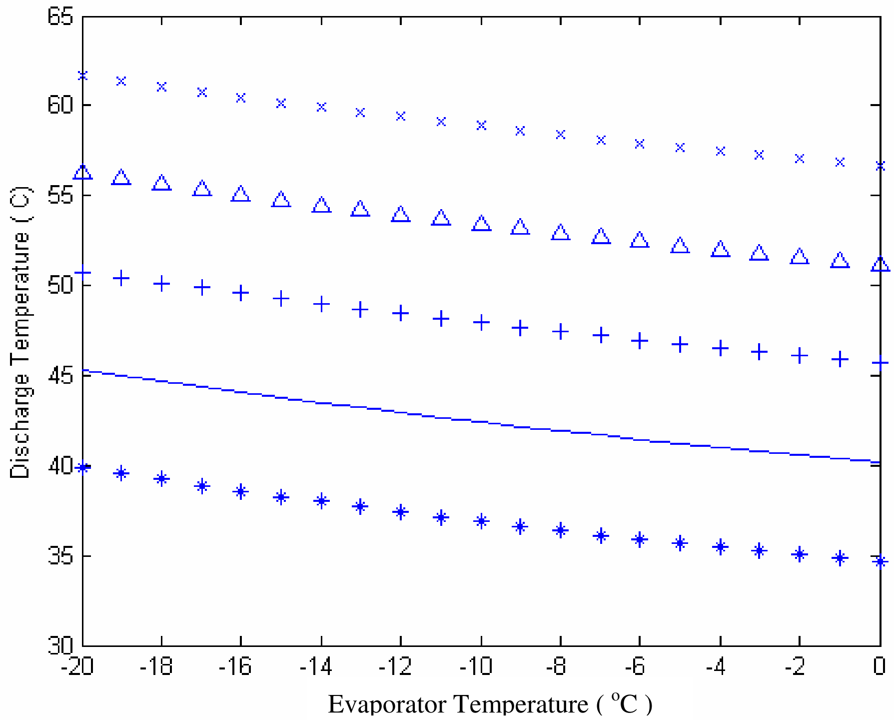

Figure (4.3) Discharge Temperature versus evaporating temperatures with different values of condensing temperatures for refrigerant R-12

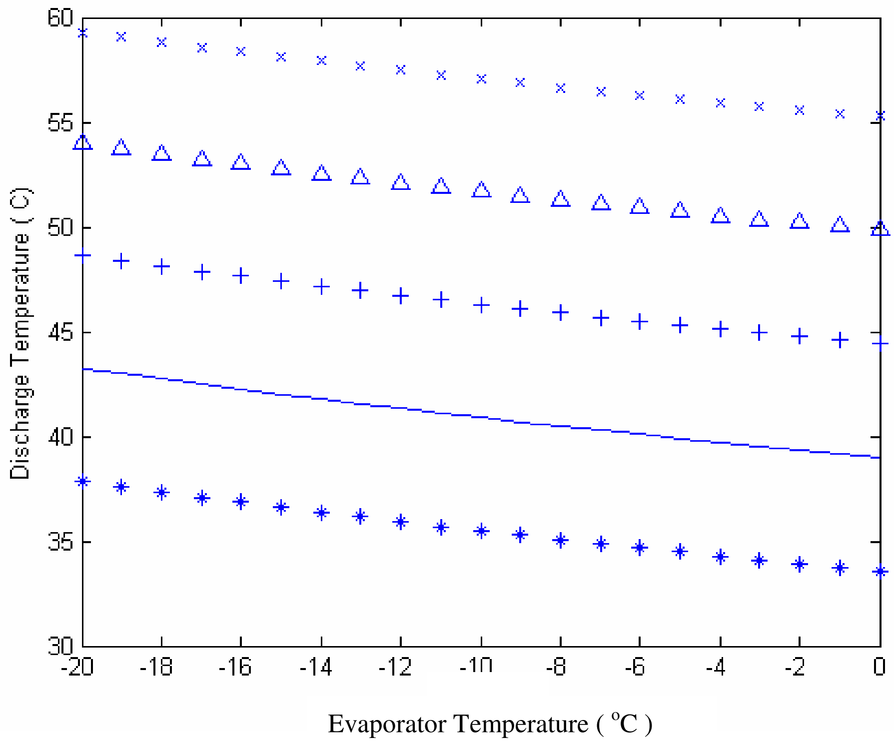

Figure (4.4) Discharge Temperature versus evaporating temperatures with different values of condensing temperatures for refrigerant R-134a

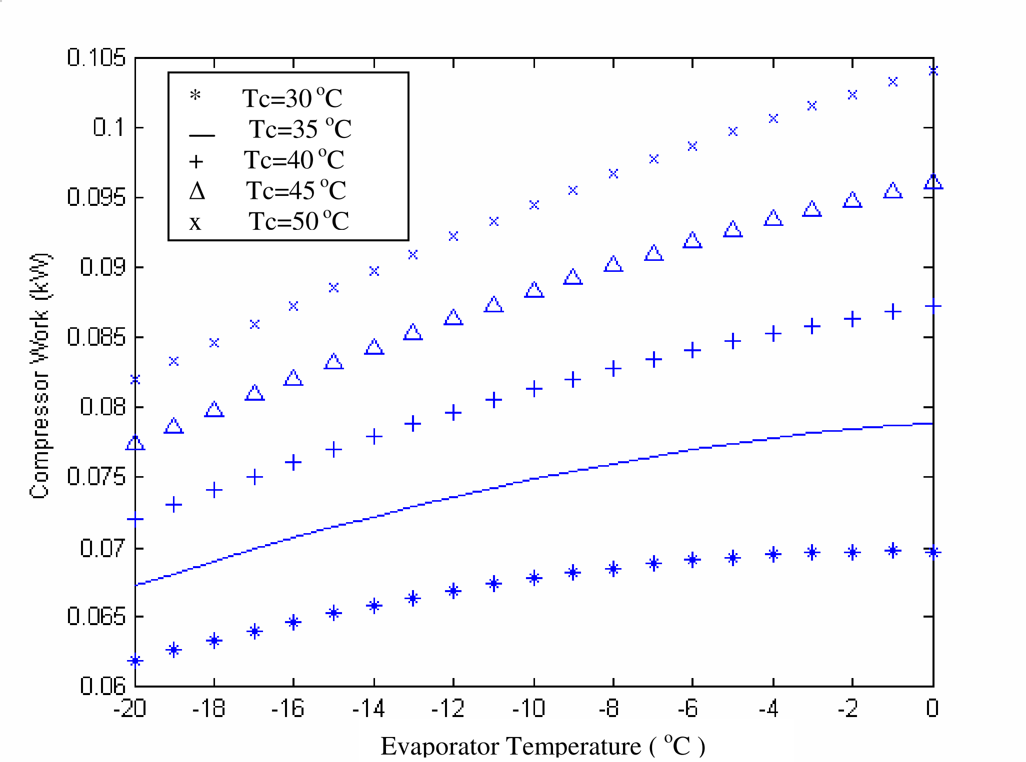

Figure (4.5) Compressor work versus evaporating temperatures with different values of condensing temperatures for refrigerant R-12

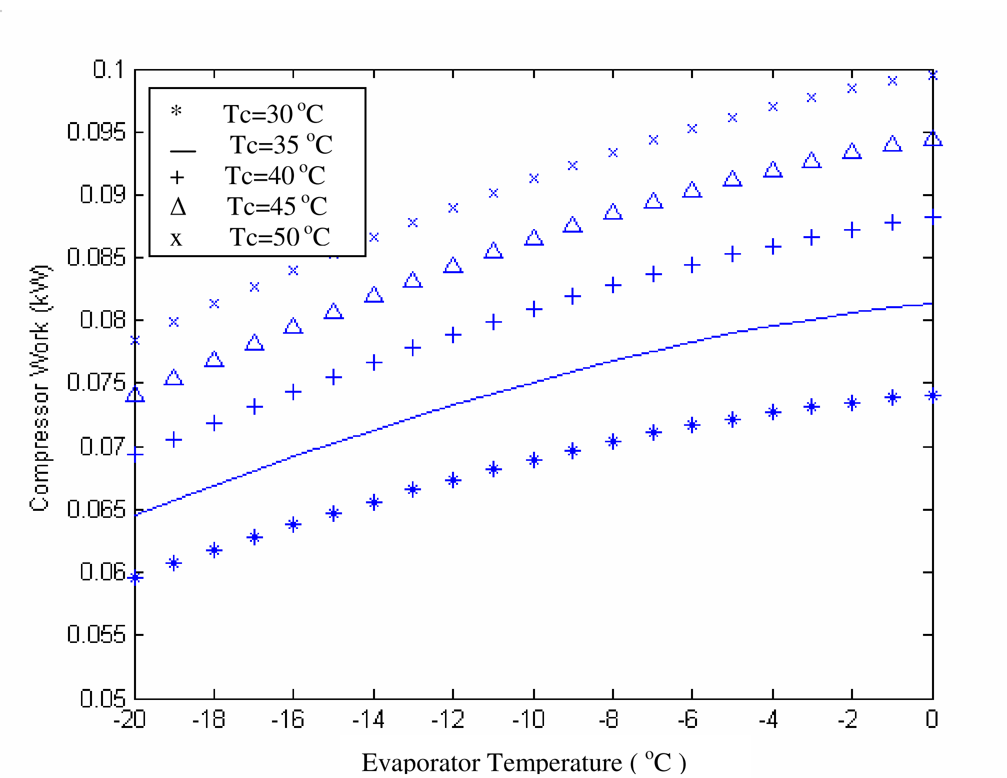

Figure (4.6) Compressor work versus evaporating temperatures with different values of condensing temperatures for refrigerant R-134a

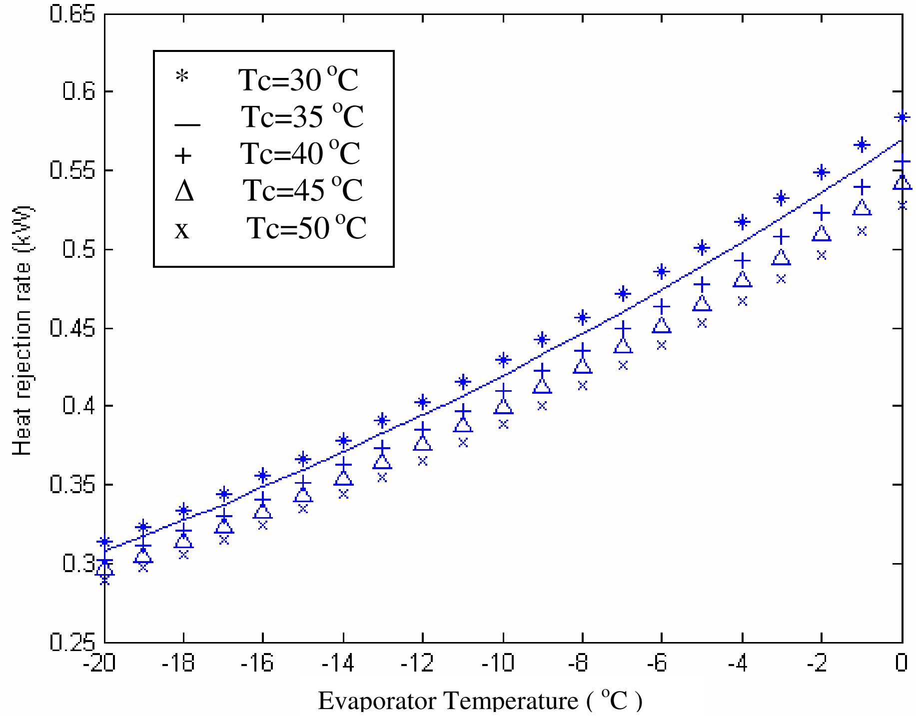

Figure (4.7) Heat rejection rate versus evaporating temperatures with different values of condensing temperatures for refrigerant R-12

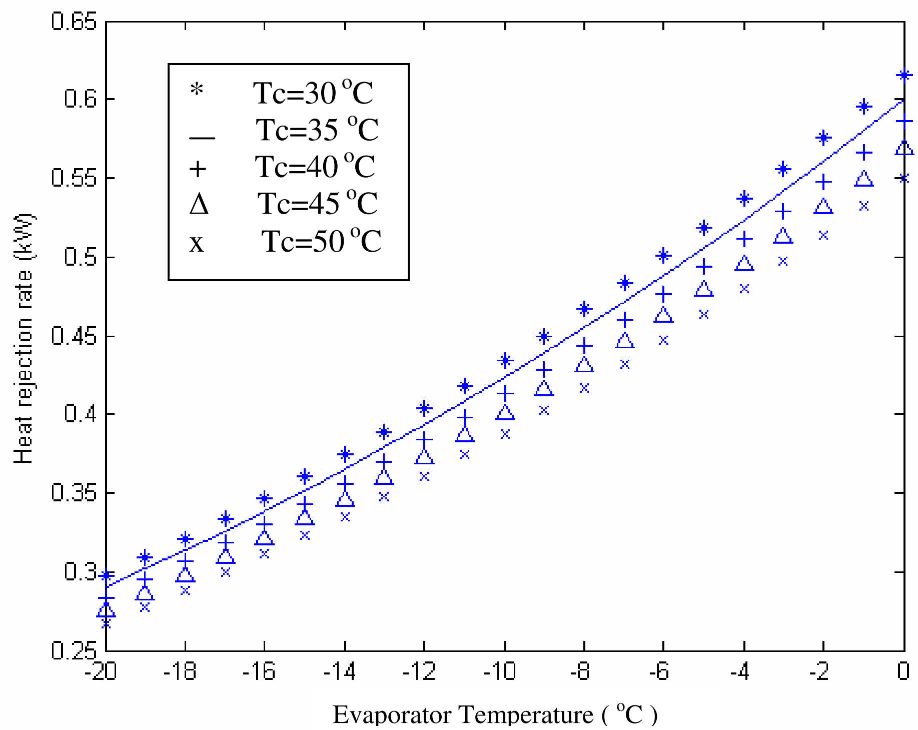

Figure (4.8) Heat rejection rate versus evaporating temperatures with different values of condensing temperatures for refrigerant R-134a

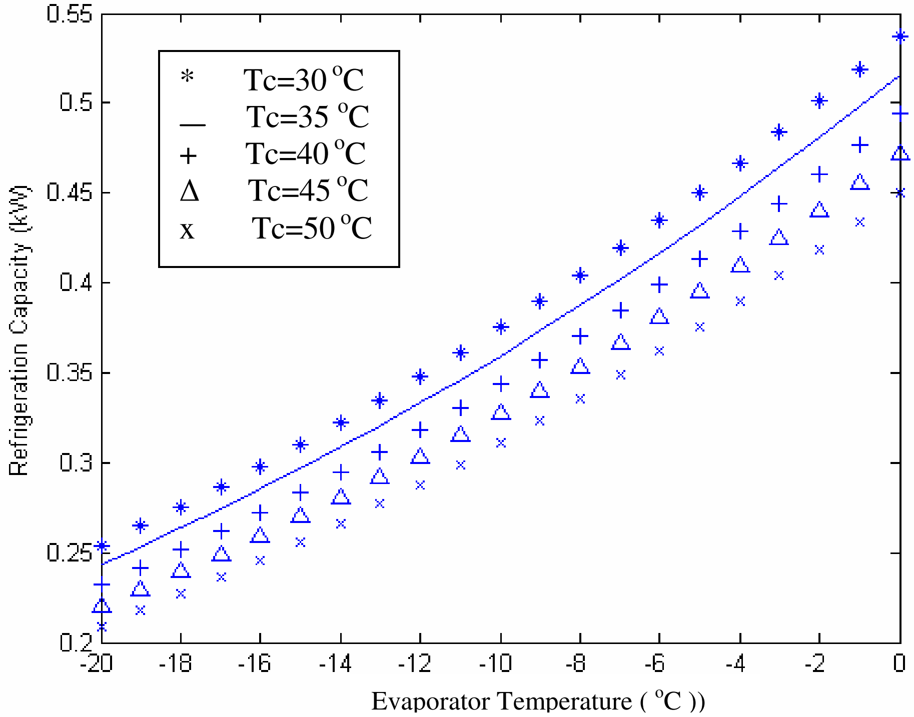

Figure (4.9) Refrigeration capacity versus evaporating temperatures with different values of condensing temperatures for refrigerant R-12

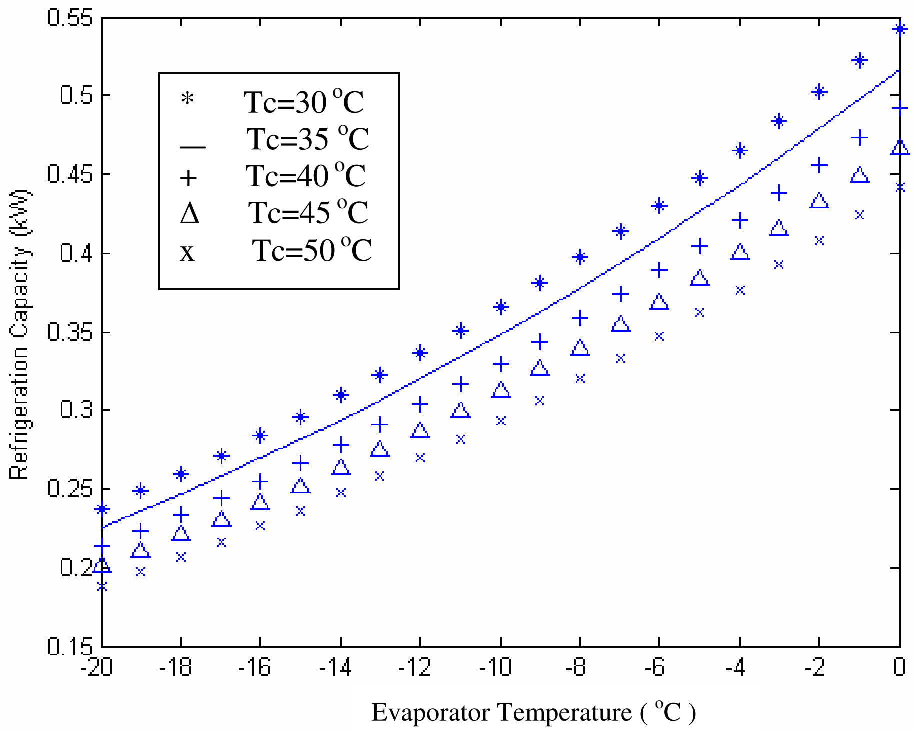

Figure (4.10) Refrigeration capacity versus evaporating temperatures with different values of condensing temperatures for refrigerant R-134a

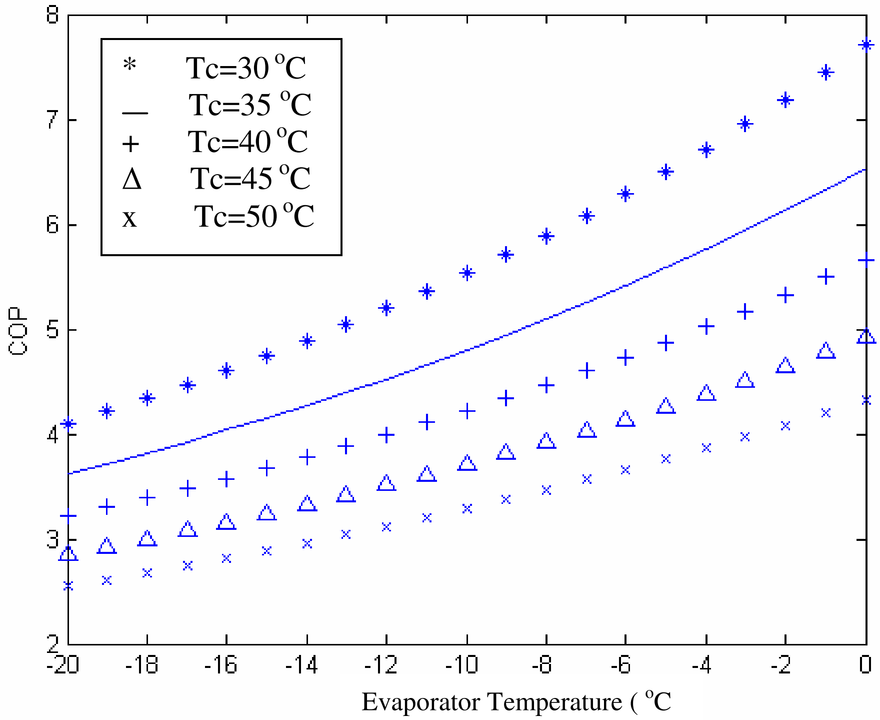

Figure (4.11) Coefficient of performance versus evaporating temperatures with different values of condensing temperatures for refrigerant R-12

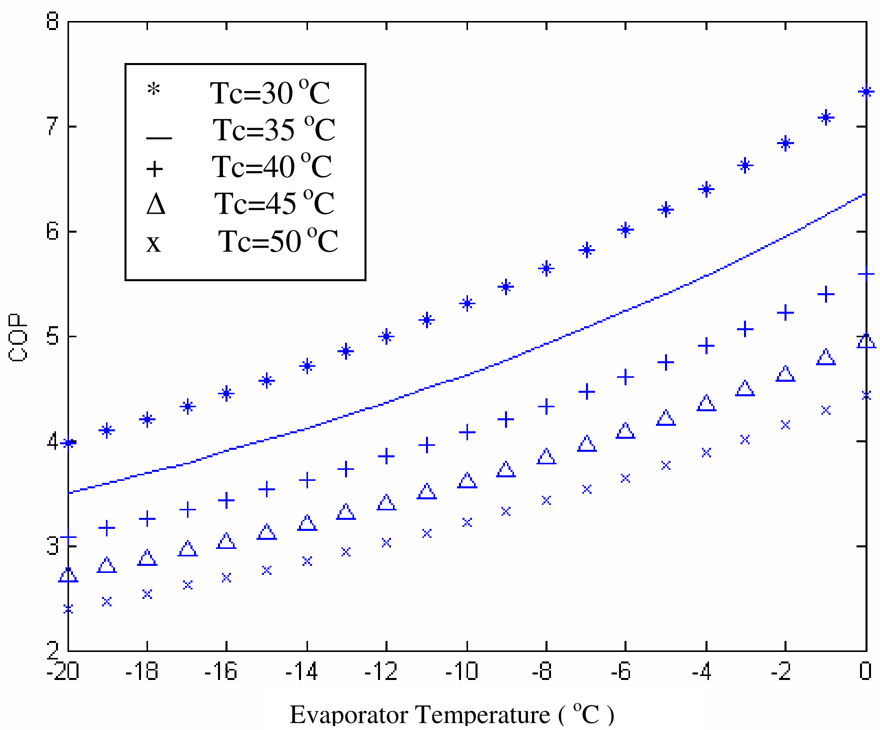

Figure (4.12) Coefficient of performance versus evaporating temperatures with different values of condensing temperatures for refrigerant R-134a

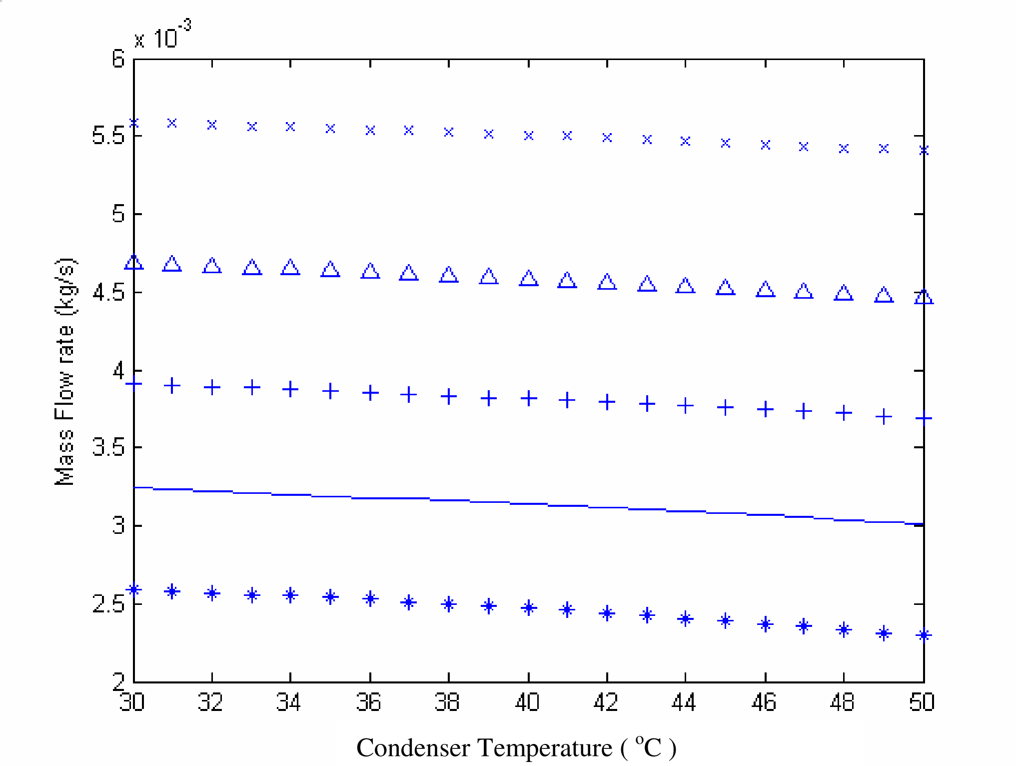

Figure (4.13) Mass flow rate versus condensing temperatures with different values of evaporating temperatures for refrigerant R-12

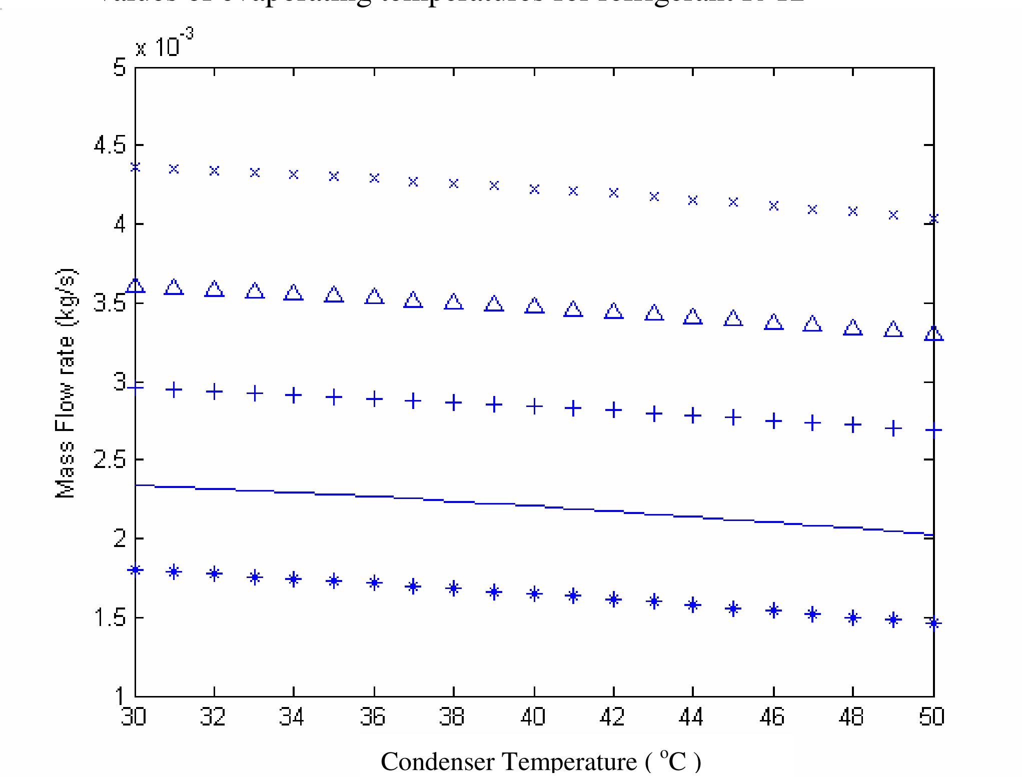

Figure (4.14) Mass flow rate versus condensing temperatures with different values of evaporating temperatures for refrigerant R-134a

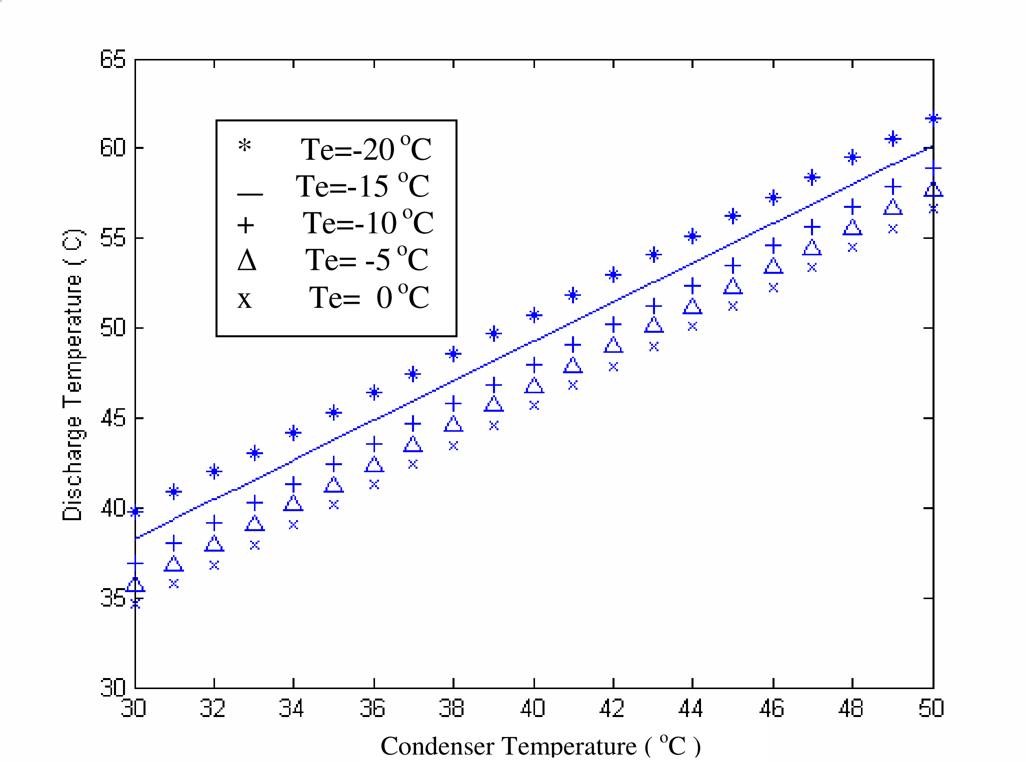

Figure (4.15) Discharge Temperature condensing temperatures with different values of evaporating temperatures for refrigerant R-12

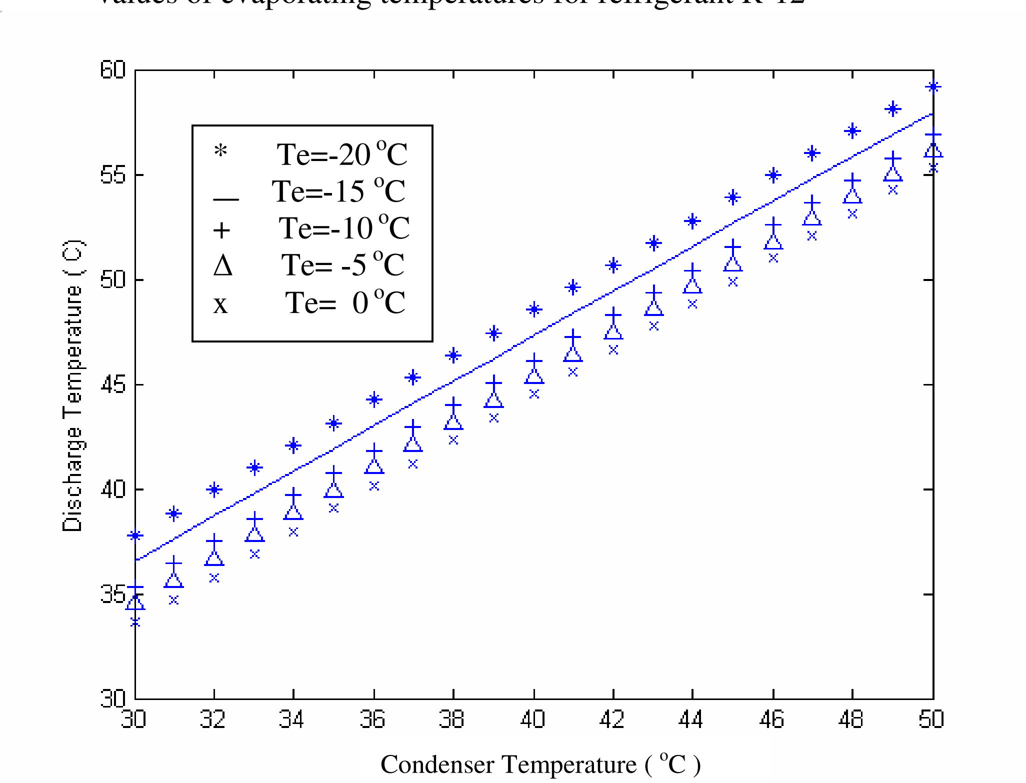

Figure (4.16) Discharge Temperature versus condensing temperatures with different values of evaporating temperatures for refrigerant R-134a

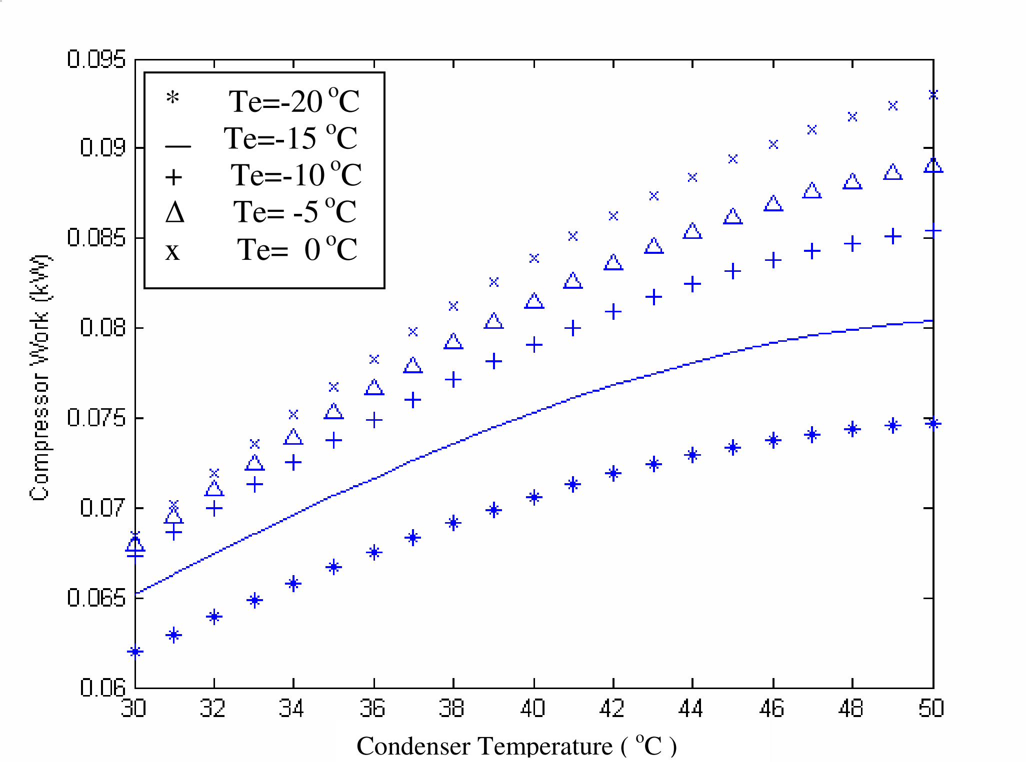

Figure (4.17) Compressor work versus condensing temperatures with different values of evaporating temperatures for refrigerant R-12

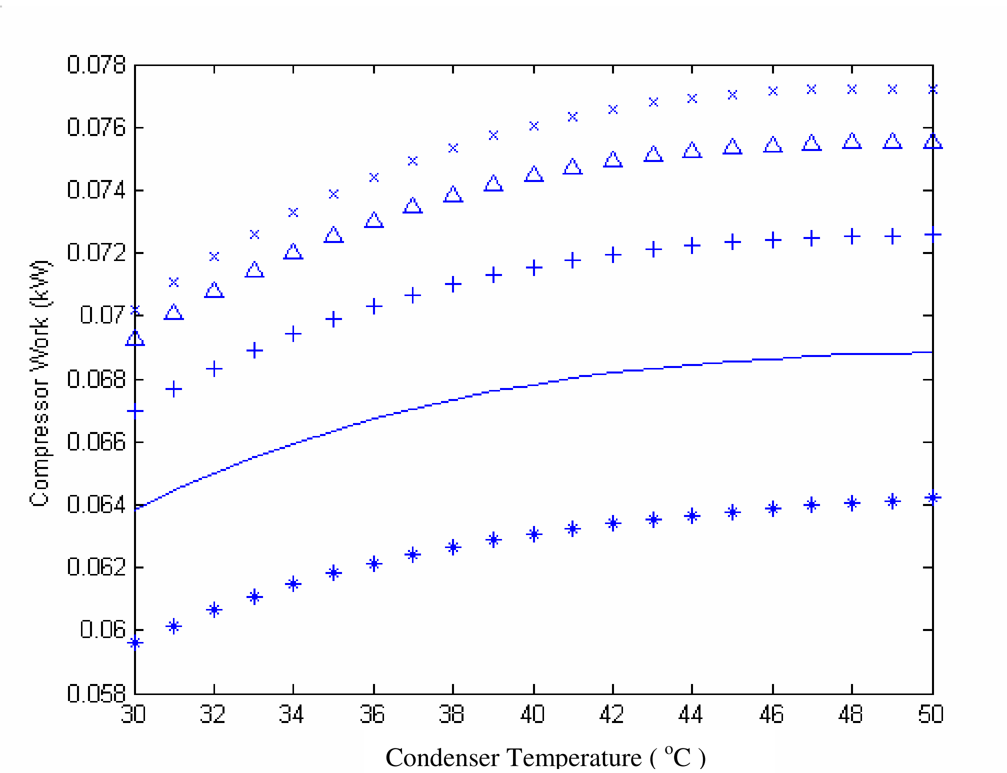

Figure (4.18) Compressor work versus condensing temperatures with different values of evaporating temperatures for refrigerant R-134a

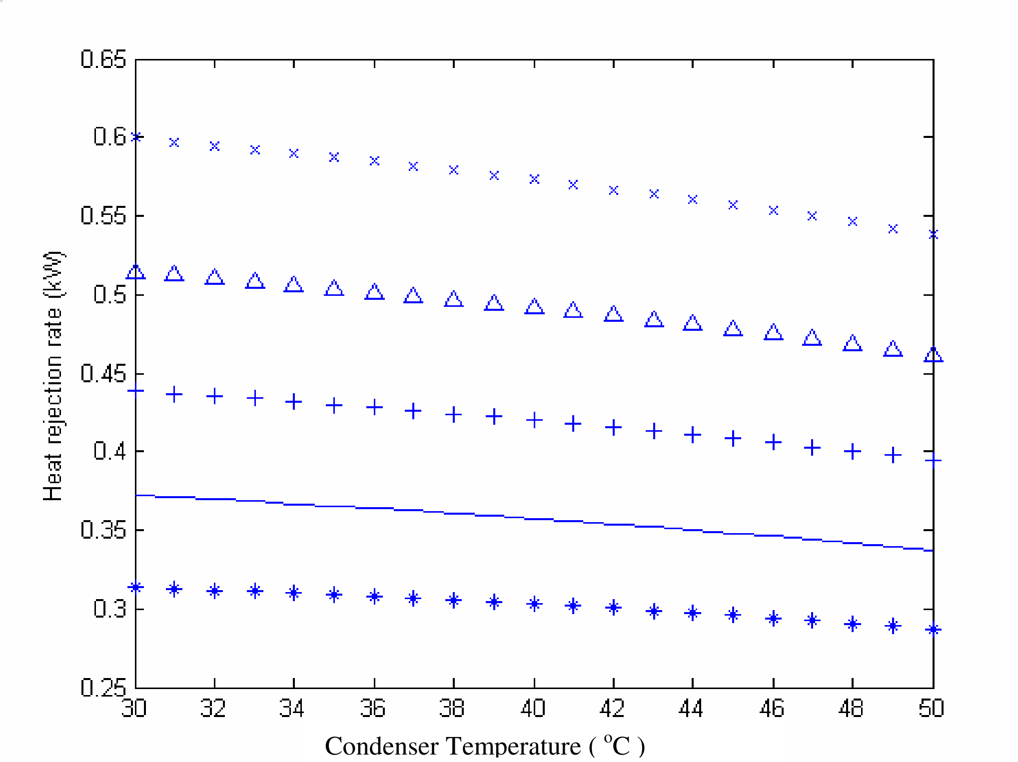

Figure (4.19) Heat rejection rate versus condensing temperatures with different values of evaporating temperatures for refrigerant R-12

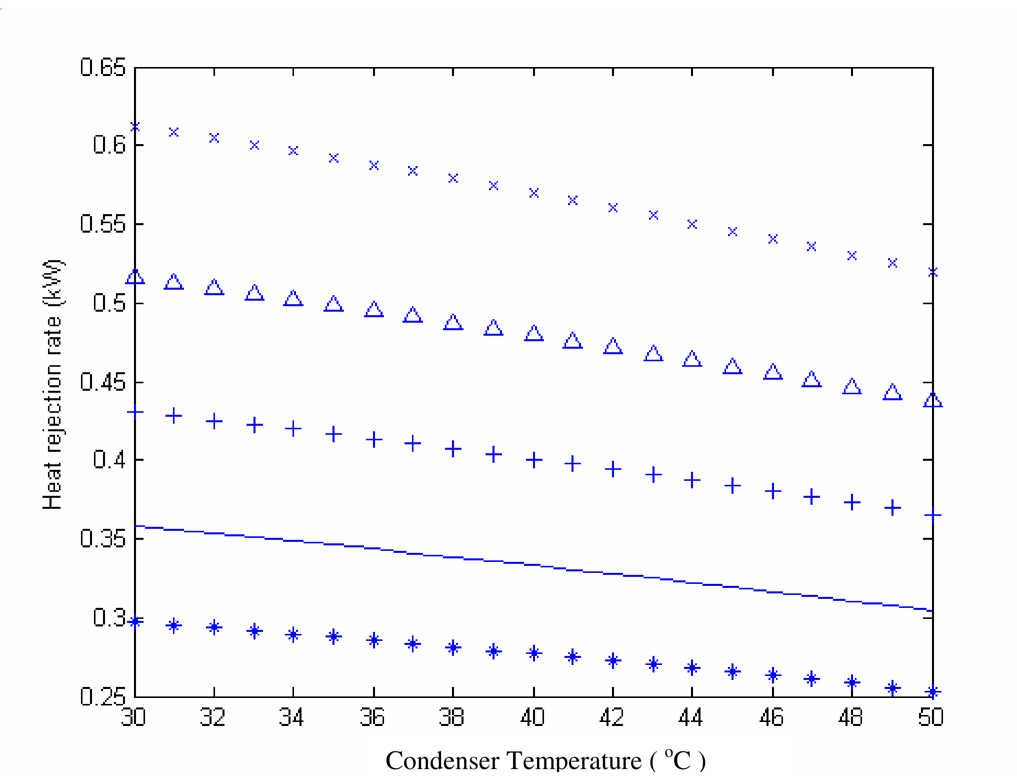

Figure (4.20) Heat rejection rate versus condensing temperatures with different values of evaporating temperatures for refrigerant R-134a

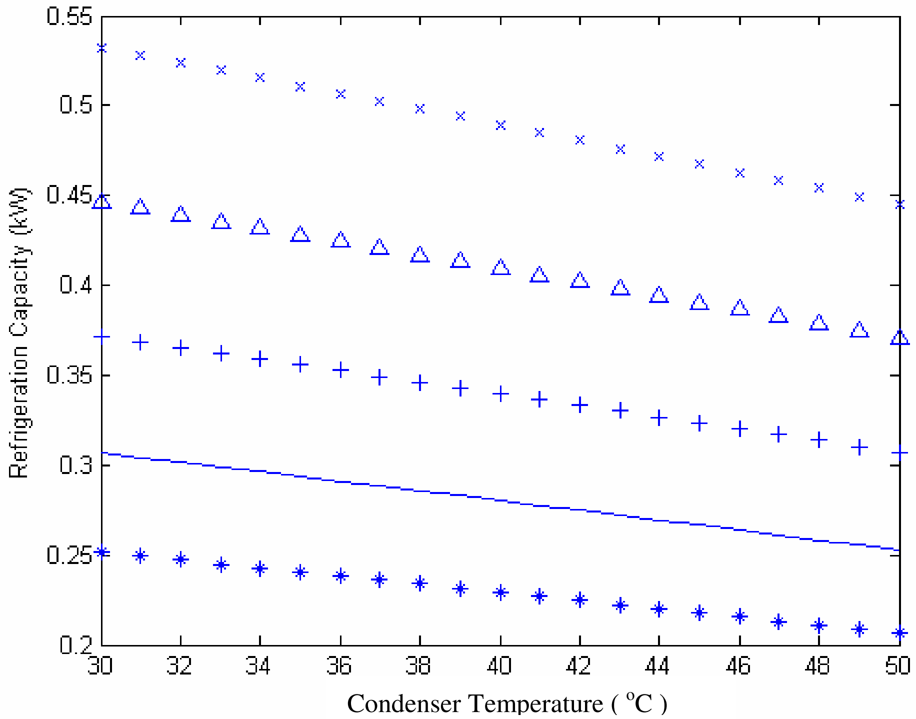

Figure (4.21) Refrigeration capacity versus condensing temperatures with different values of evaporating temperatures for refrigerant R-12

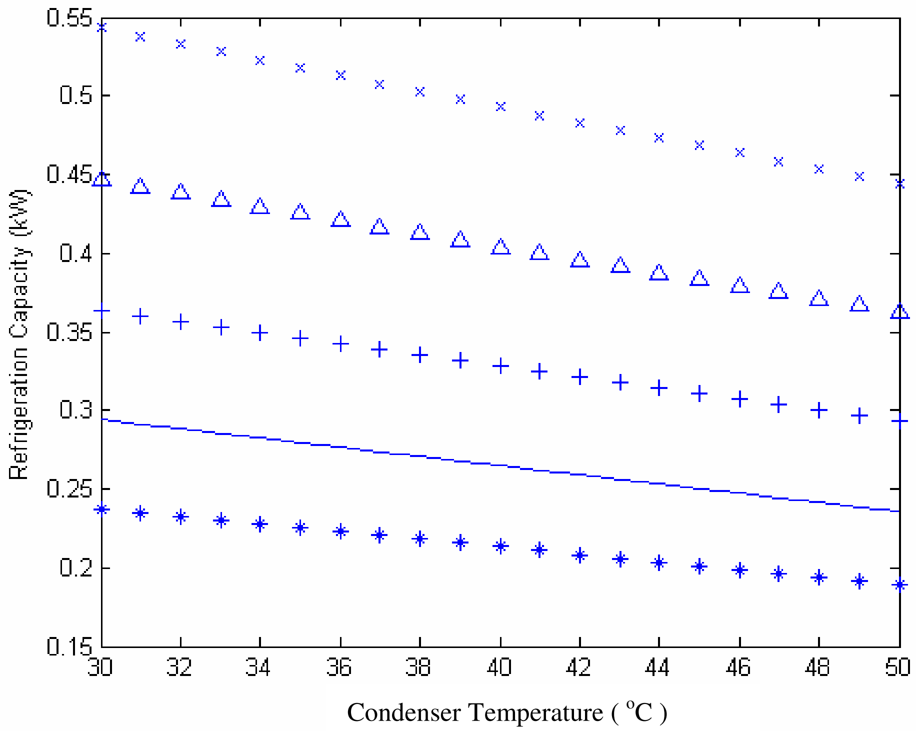

Figure (4.22) Refrigeration capacity versus condensing temperatures with different values of evaporating temperatures for refrigerant R-134a

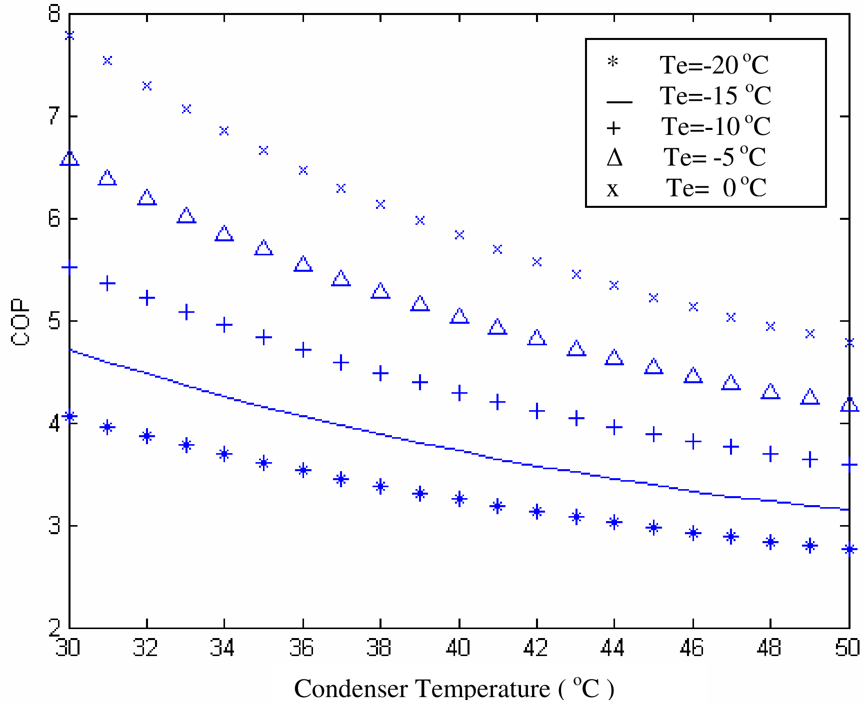

Figure (4.23) Coefficient of performance versus condensing temperatures with different values of evaporating temperatures for refrigerant R-12

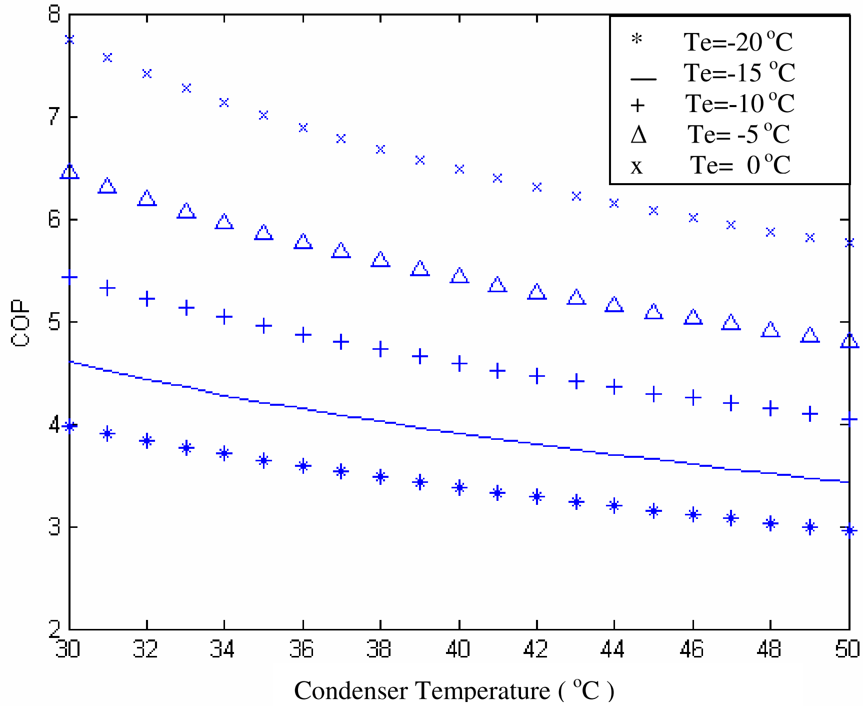

Figure (4.24) Coefficient of performance versus condensing temperatures with different values of evaporating temperatures for refrigerant R-134a

4.2 Comparison of the performance parameters between refrigerants R-134a, and R-12.

The comparison between the performance parameters of the two refrigerants will be considered for the standard cycle. These parameters include the compressor power, refrigeration capacity and the coefficient of performance. The comparison will be considered for a range of evaporating temperature between –20 ^{o}C to 0 ^{o}C, and with different values of condenser temperature (30 ^{o}C, 35 ^{o}C, 40 ^{o}C, 45 ^{o}C, 50 ^{o}C) .

4.2.1 Compressor power

The comparisons of the compressor work between the two refrigerants R-12, and R-134a, are shown in Figures (4.25) through (4.27). Figure (4.25) presents the compressor work against the evaporating temperature at a condensing temperature of 30 ^{o}C. It is shown that R-12 has the higher values of the compressor work for the evaporating temperatures range from (-20 ^{o}C to -14 ^{o}C), which is about (3.87% to 0.45%). While at higher degree of evaporating temperature, R-134a has higher values of compressor work, which reached (5.9%). For condensing temperature of 35 ^{o}C. It is observed that R-12 has higher values of the compressor work for the evaporating temperature range from (-20 ^{o}C to -11 ^{o}C), which is about (3.86% to 0.13%). While at higher degree of evaporating temperature, R-134a has higher values of the compressor work, which reached (3.07%).

Figure (4.26) presents the compressor work against the evaporating temperature at a condensing temperature of 40 ^{o}C. It is shown that R-12 has higher values of the compressor work for the evaporating temperature range from (-20 ^{o}C to -8 ^{o}C), which is about (3.88% to 0%). While at higher degree of evaporating temperature, R-134a has higher values of the compressor work, which reached (1.02%)

Figure (4.27) presents the compressor work against the evaporating temperature at a condensing temperature of 45 ^{o}C and 50 ^{o}C. It is shown that refrigerant R-12 has higher values of the compressor work, which is about (4.26% to 1.76%), for a condensing temperature of 45 ^{o}C, and between (4.26% to 4.32%) for a condensing temperature of 45 ^{o}C.

4.2.2 Refrigeration capacity

The comparisons of the refrigeration capacity between the two refrigerants R-12, and R-134a, are shown in Figures (4.28) through (4.30). Figure (4.30) presents the refrigeration capacity against the evaporating temperature at a condensing temperature of 30 ^{o}C and 40 ^{o}C. It is shown that R-12 has the higher values of the refrigeration capacity for the evaporating temperature range from (-20 ^{o}C to -3 ^{o}C), which is about (6.57% to 0.02%). While at higher degree of evaporating temperature, R-134a has higher values of the refrigeration capacity, which reached (0.96%) for a condensing temperature of 30 ^{o}C.

For a condensing temperature of 35 ^{o}C. It is observed that R-12 has the higher values of the refrigeration capacity for the evaporating temperature range from (-20 ^{o}C to -1 ^{o}C), which is about (7.28% to 0.06%). While at higher degree of evaporating temperature, R-134a has higher values of the refrigeration capacity, which reached (0.27%).

For a condensing temperature of 40 ^{o}C. It is observed that R-12 has higher values of the refrigeration capacity, which is about (7.98% to 0.4%). Figure (4.29) presents the refrigeration capacity against the evaporating temperature at a condensing temperature of 45 °C. It is shown that refrigerant R-12 has higher values of the refrigeration capacity, which is about (8.8% to 1.12%).

Figure (4.30) presents the refrigeration capacity against the evaporating temperature at a condensing temperature of 50 °C. It is shown that refrigerant R-12 has higher values of the refrigeration capacity, which is about (9.77% to 1.9%).

4.2.3 Coefficient of performance

The comparisons of the coefficient of performance between the two refrigerants R-12, and R-134a, are shown in Figures (4.31) through (4.34). Figure (4.31) presents the coefficient of performance against the evaporating temperature at a condensing temperature of 30 °C. It is shown that R-12 has higher values of COP for the evaporating temperature range from (-20 °C to 0 °C), which is about (1.97% to 4.05%). For a condensing temperature of 35 °C. It is observed that R-12 also has higher values of COP, which is about (2.4% to 1.8%).

Figure (4.32) presents the coefficient of performance against the evaporating temperature at a condensing temperature of 40 °C. It is shown that R-12 has higher values of COP, which is about (3.38% to 0.47%). Figure (4.33) presents the coefficient of performance against the evaporating temperature at a condensing temperature of 45 °C. It is shown that R-12 has higher values of COP for the evaporating temperature range from (-20 °C to -5 °C), which is about (3.74% to 0.23%). While at higher degree of evaporating temperature, R-134a has the higher value of COP, which reached (1.59%).

Figure (4.34) presents the coefficient of performance against the evaporating temperature at a condensing temperature of 50 ^{o}C. It is shown that R-12 has the higher values of COP for the evaporating temperature range from (-20 ^{o}C to -6 ^{o}C) which is about (4.73% to 0.355%). While at higher degree of evaporating temperature, R-134a has the higher value of COP, which reached (3.47%).

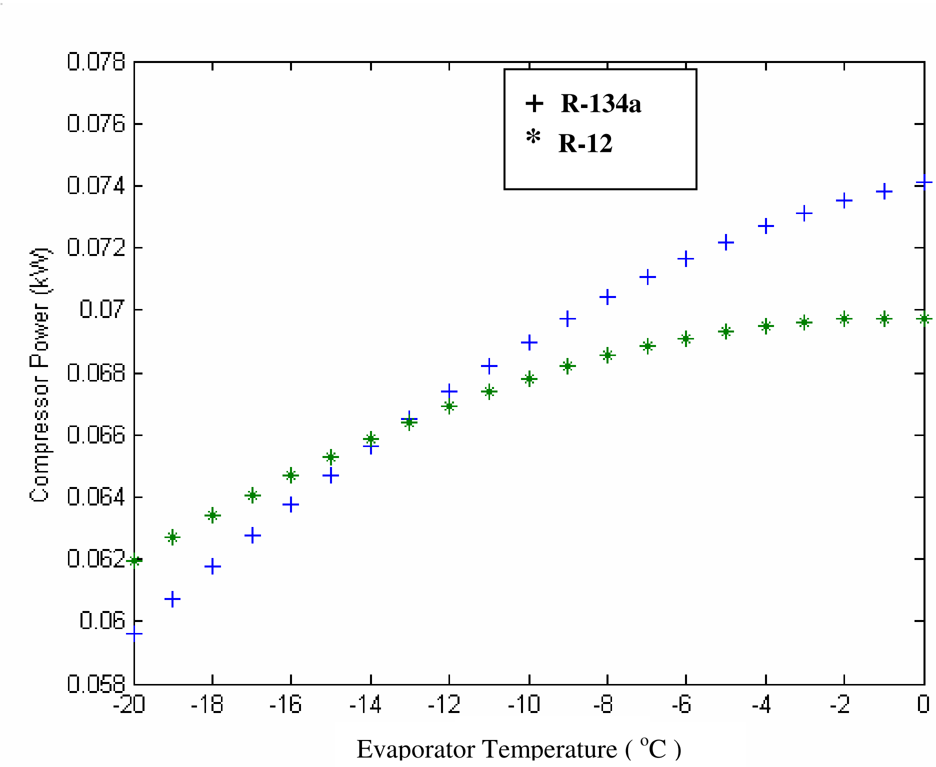

Figure (4.25) Compressor power versus evaporating temperature with condensing temperature of (30 ^{o}C)

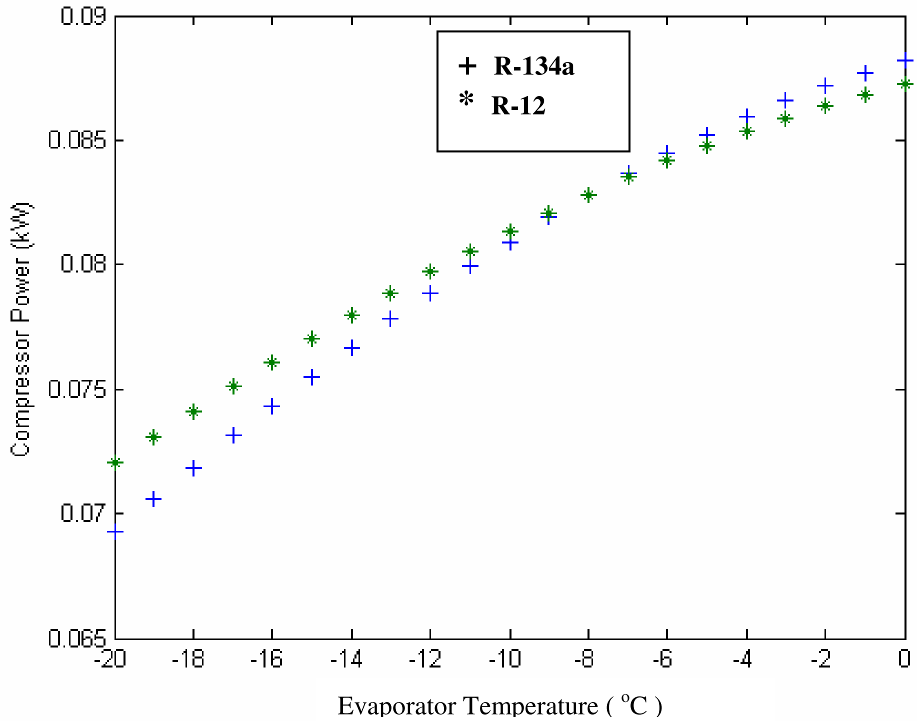

Figure (4.26) Compressor power versus evaporating temperature with condensing temperature of (40 °C)

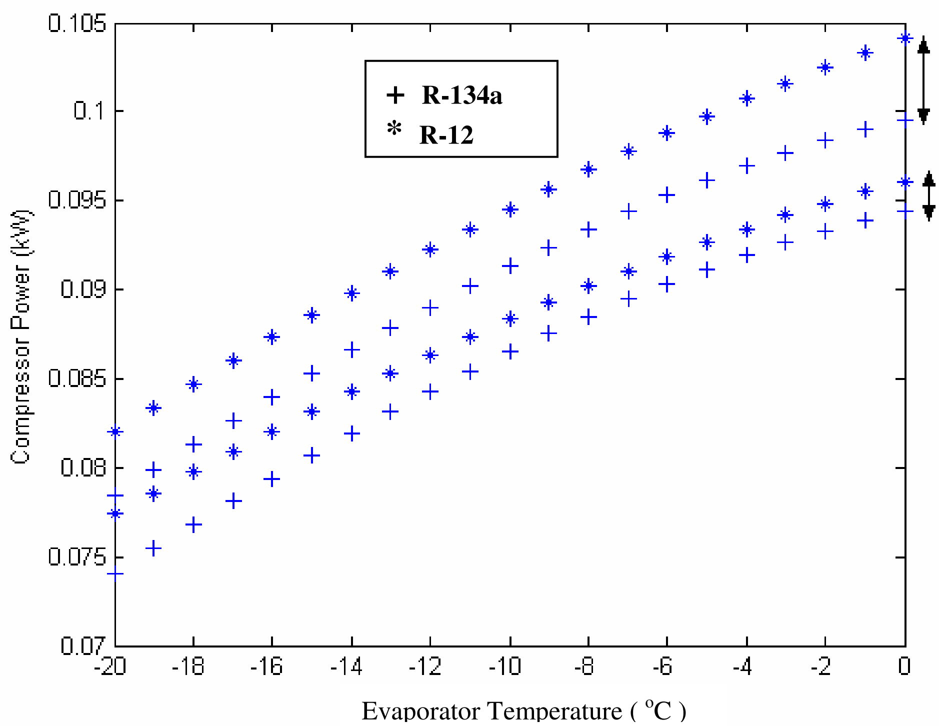

Figure (4.27) Compressor power versus evaporating temperature with condensing temperature of (45 °C) and (50 °C).

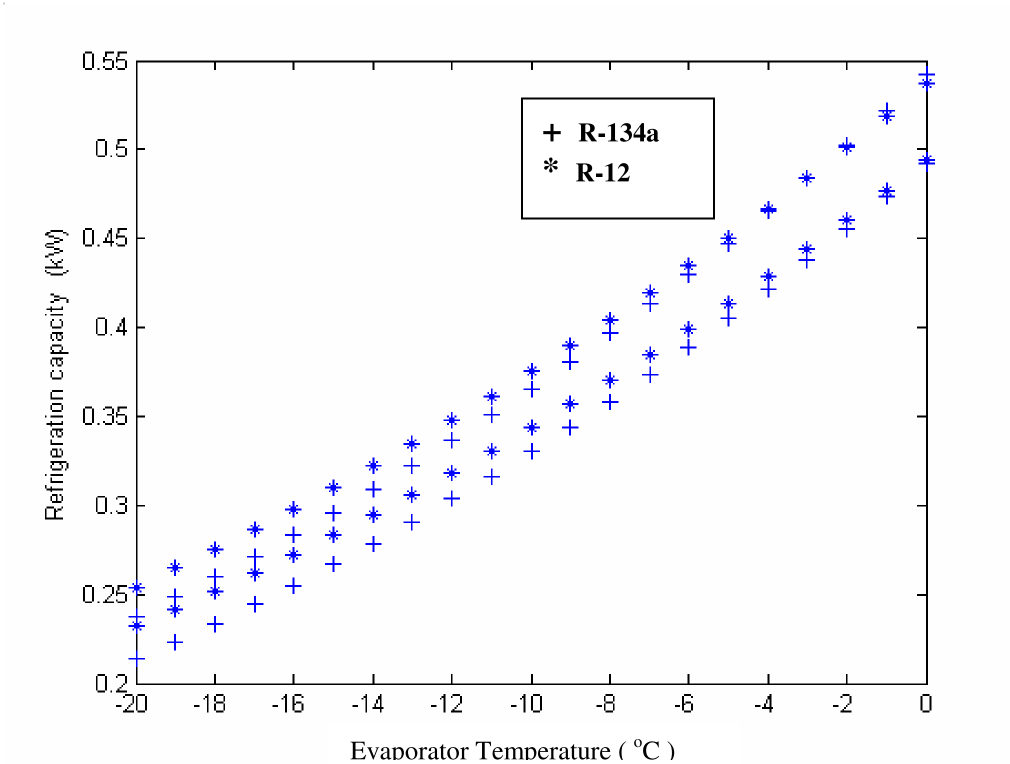

Figure (4.28) Refrigeration capacity versus evaporating temperature with condensing temperature of (30 °C), and (40 °C).

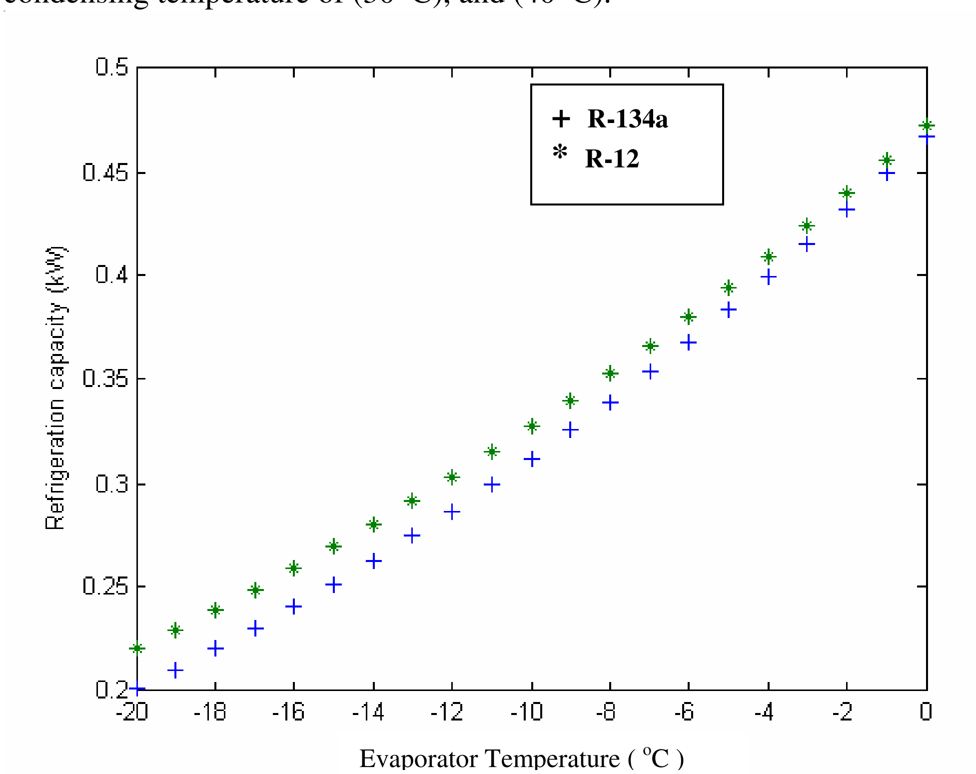

Figure (4.29) Refrigeration capacity versus evaporating temperature with condensing temperature of (45 °C)

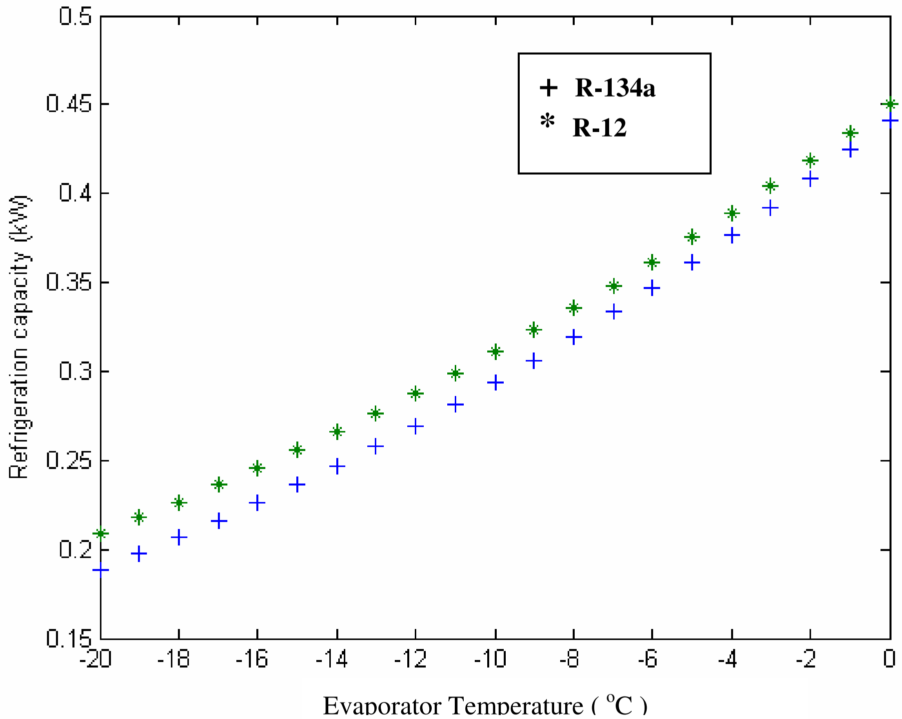

Figure (4.30) Refrigeration capacity versus evaporating temperature with condensing temperature of (50 °C)

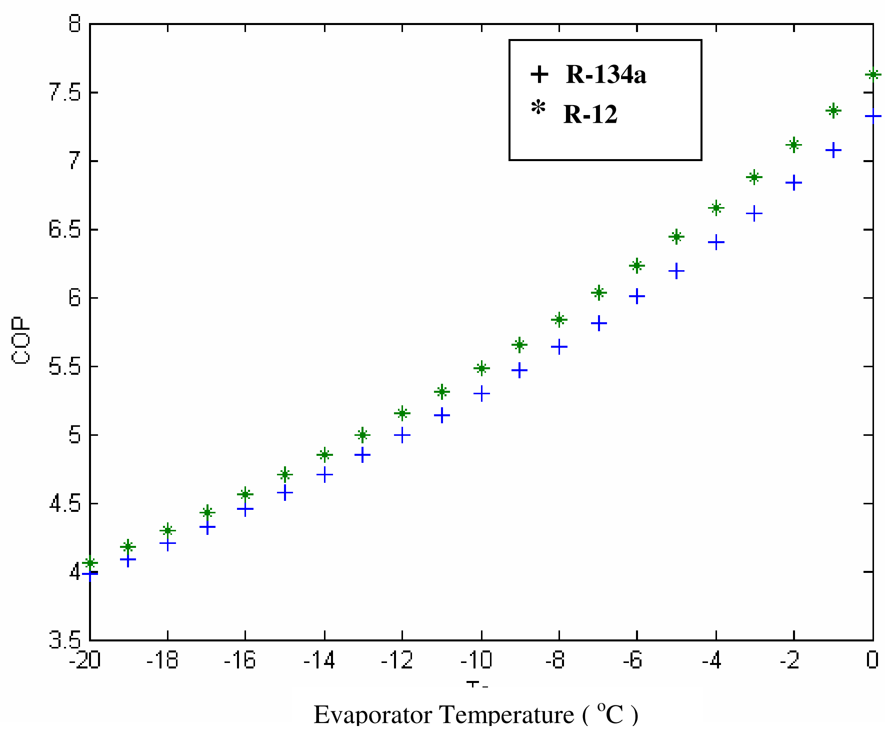

Figure (4.31) Coefficient of performance versus evaporating temperature with condensing temperature of (30 °C)

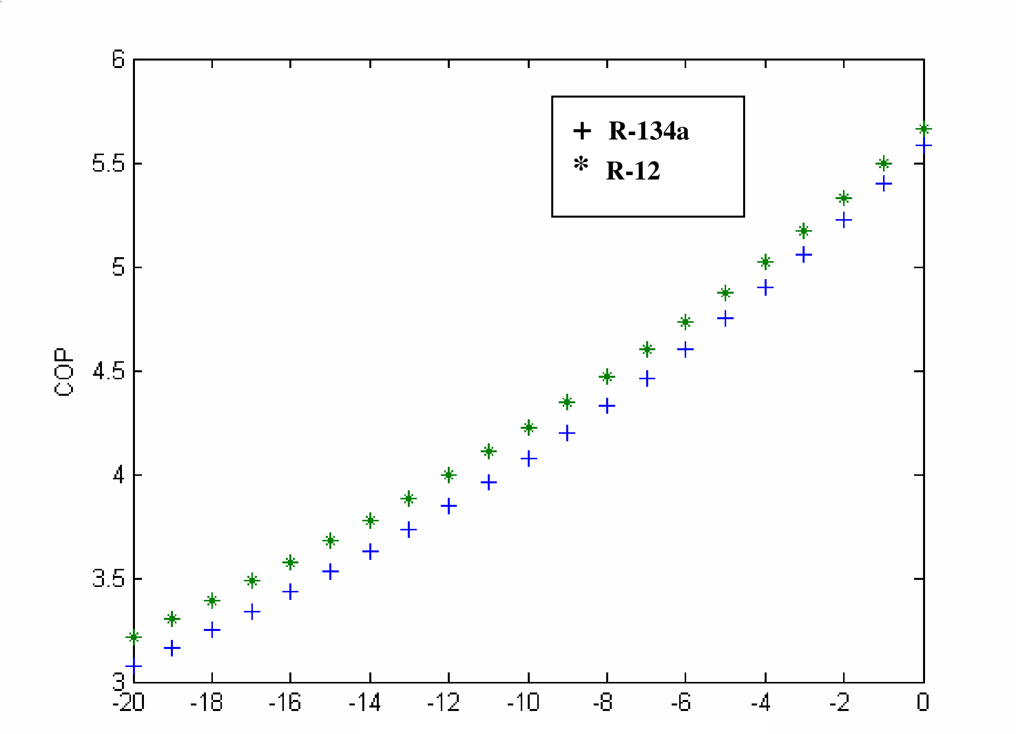

Figure (4.32) Coefficient of performance versus evaporating temperature with condensing temperature of (40 °C)

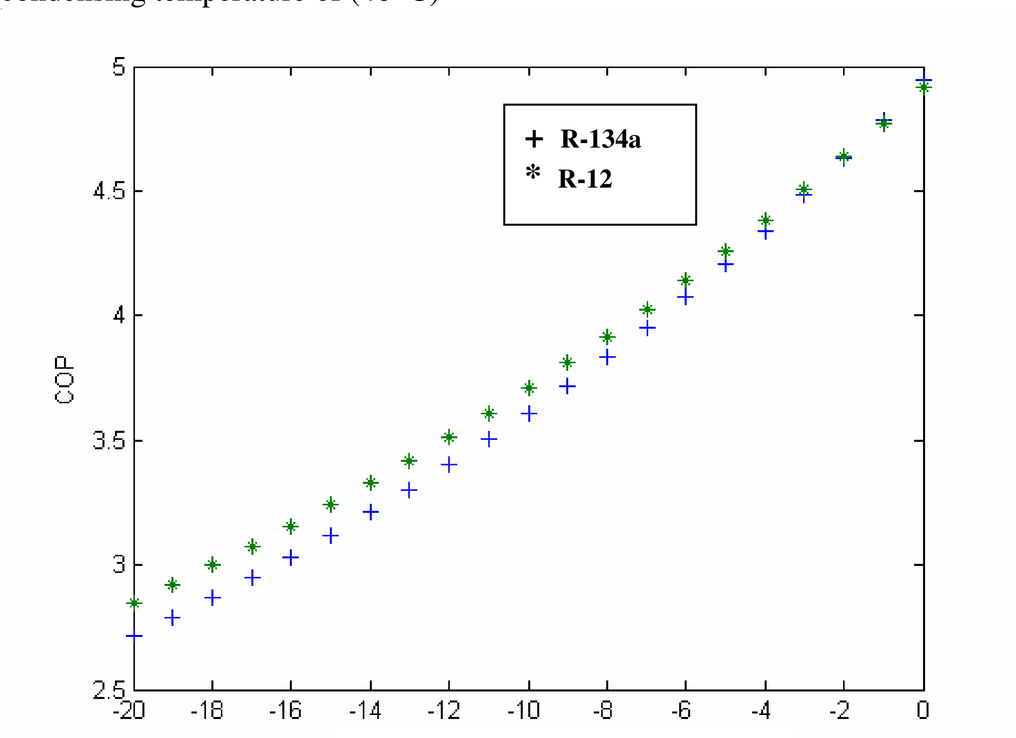

Figure (4.33) Coefficient of performance versus evaporating temperature with condensing temperature of (45 °C)

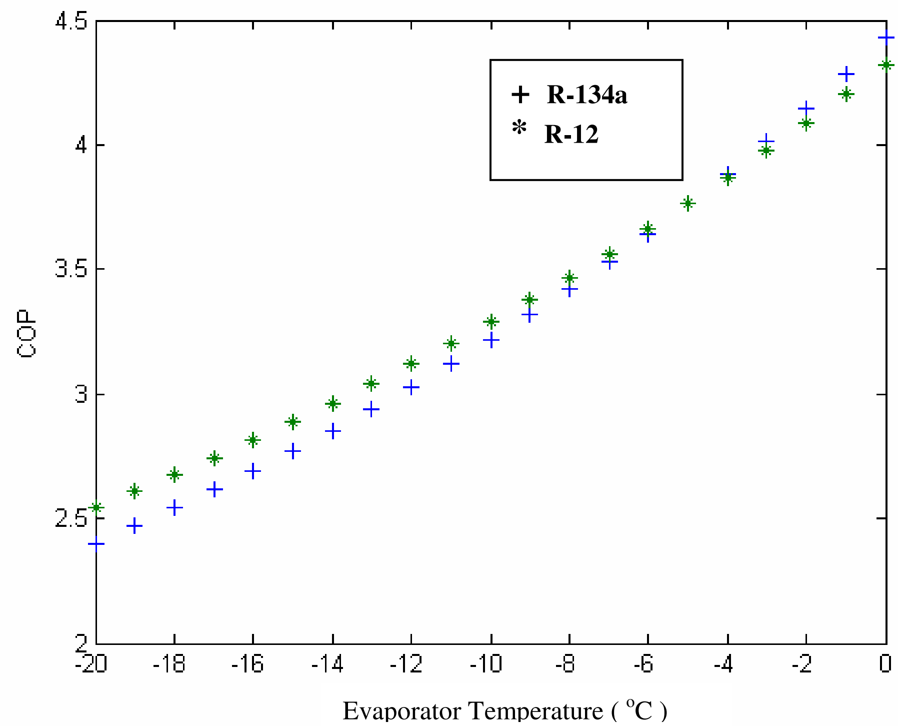

Figure (4.34) Coefficient of performance versus evaporating temperature with condensing temperature of (50 °C)

4.3 Comparisons between (standard cycle) and (ideal cycle with superheating and subcooling) for R-134a.

The ideal cycle with superheating and subcooling differs from the standard cycle by the superheating at the inlet of the compressor, and the subcooling at the outlet of the condenser. The comparison will give the effect of superheating and subcooling on the refrigeration standard cycle. The range of evaporating temperature changes between (–20 °C to 0 °C), with a constant condensing temperature of (40 °C). The comparasion will include Mass flow rate, Discharge temperature, Compressor work, Heat rejection rate, Refrigeration capacity, and Coefficient of performance. The degree of superheating and subcooling was selected to be (5 degrees).

4.3.1 Mass flow rate

Figure (4.40) presents the mass flow rate against the evaporating temperature at a condensing temperature of 40 ^{o}C. It is shown that the mass flow for (standard cycle) is higher than (the ideal cycle with superheating and subcooling) which, is about (5.5% to 2.3%). It is known that, the specific volume at the inlet of the compressor will increase, as Te increase, which leads to decrease the mass flow rate.

4.3.2 Compressor discharge temperature

Figure (4.41) presents the compressor discharge temperature against the evaporating temperature at a condensing temperature of 40 ^{o}C. It is shown that the discharge temperature for (standard cycle) is less than (the ideal cycle with superheating and subcooling) by (8.93%). The increasing of the inlet temperature of the compressor will increase the exit temperature of the compressor.

4.3.3 Compressor power

Figure (4.42) presents the compressor work against the evaporating temperature at a condensing temperature of 40 ^{o}C. It is shown that compressor work for (standard cycle) is less than (the ideal cycle with superheating and subcooling), which is about (1.29% to 1.34%). The increasing in the enthalpy difference (at the outlet and inlet of the compressor) is more than the slight decrease of the mass flow rate, which leads to increase the compressor work.

4.3.4 Heat rejection rate

Figure (4.43) presents the heat rejection rate against the evaporating temperature at a condensing temperature of 40 ^{o}C. It is shown that the heat rejection rate for (standard cycle) is less than the (ideal cycle with superheating and subcooling), which is about (4.13% to 4.54%). The increasing in the outlet enthalpy at the compressor, and the decreasing in the outlet enthalpy at the condenser, will increase the enthalpy difference across the condenser. This increasing obscures the slight decreasing in the mass flow rate, which leads to increase the heat rejection rate.

4.3.5 Refrigeration capacity

Figure (4.44) presents the refrigeration capacity against the evaporating temperature at a condensing temperature of 40 ^{o}C. It is shown that the refrigeration capacity for (standard cycle) is less than (the ideal cycle with superheating and subcooling), which is about (5.24% to 5.21%). The increasing in the inlet enthalpy at the compressor, and the decreasing in the outlet enthalpy at the condenser, will increase the enthalpy difference across the evaporator. This increasing obscures the slight decreasing in the mass flow rate, which leads to increase the refrigeration capacity.

4.3.6 Coefficient of performance

Figure (4.45) presents the coefficient of performance against the evaporating temperature at a condensing temperature of 40 °C. It is shown that the coefficient of performance for (standard cycle) is less than the (ideal cycle with superheating and subcooling) by (4.63%). The increasing in the refrigeration capacity is more than the increasing in the compressor work, which leads to increase the coefficient of performance.

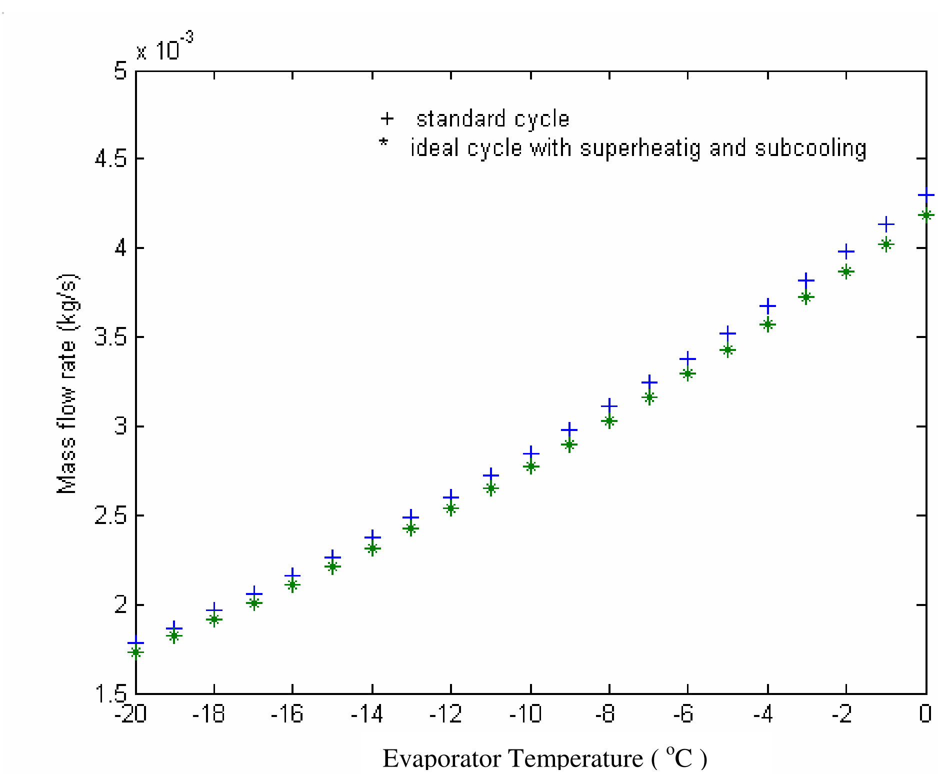

Figure (4.35) Mass flow rate versus evaporating temperature with condensing temperature of (40 °C)

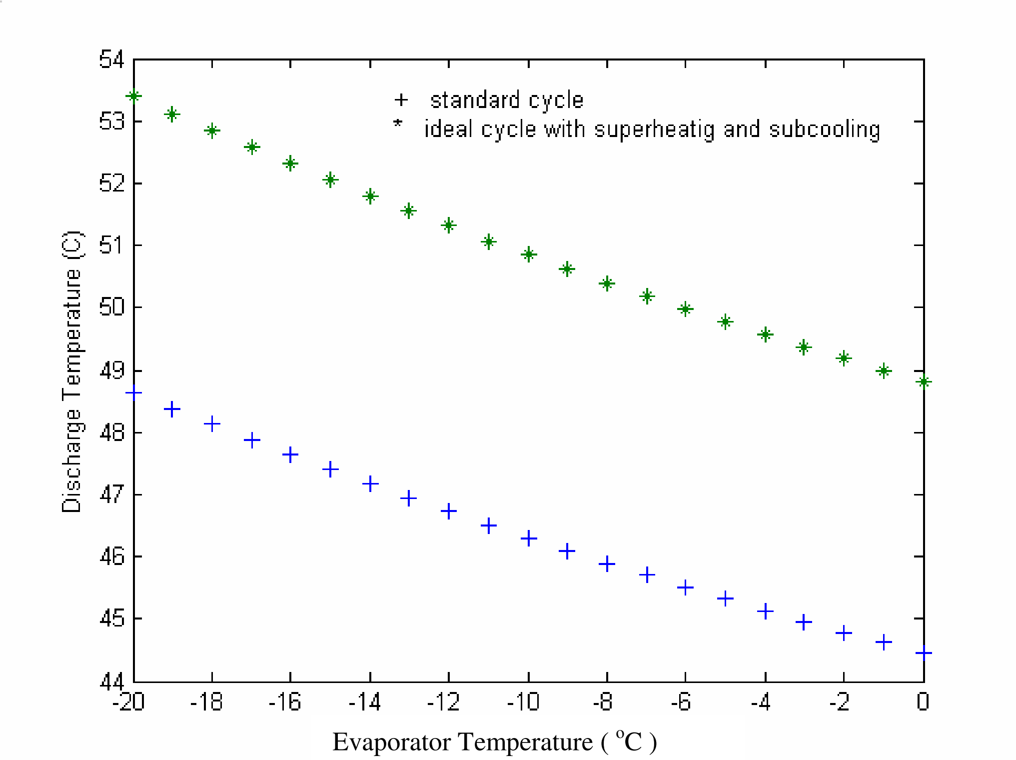

Figure (4.36) Discharge temperature versus evaporating temperature with condensing temperature of (40 °C).

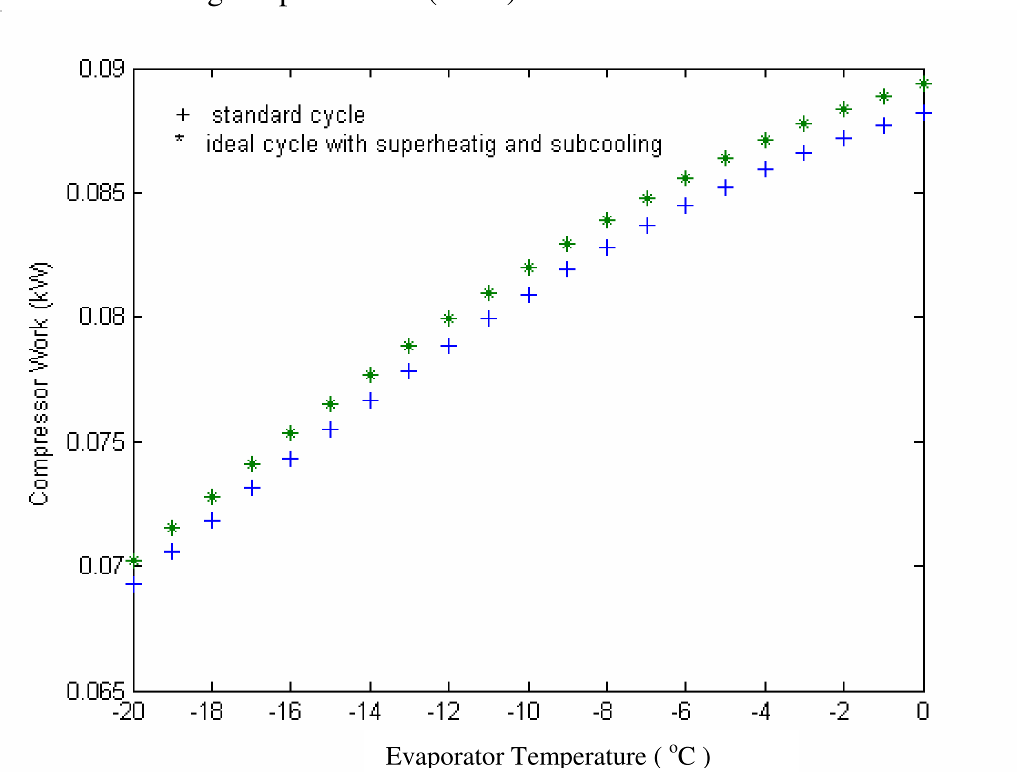

Figure (4.37) Compressor power versus evaporating temperature with condensing temperature of (40 °C)

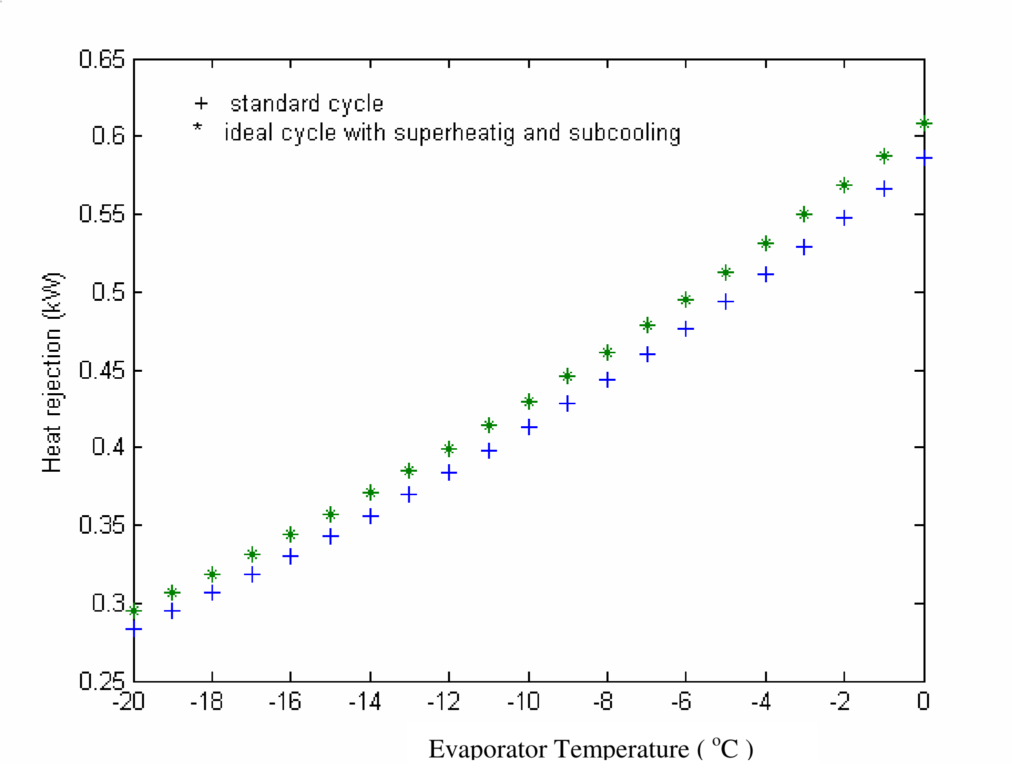

Figure (4.38) Heat rejection rate versus evaporating temperature with condensing temperature of (40 °C)

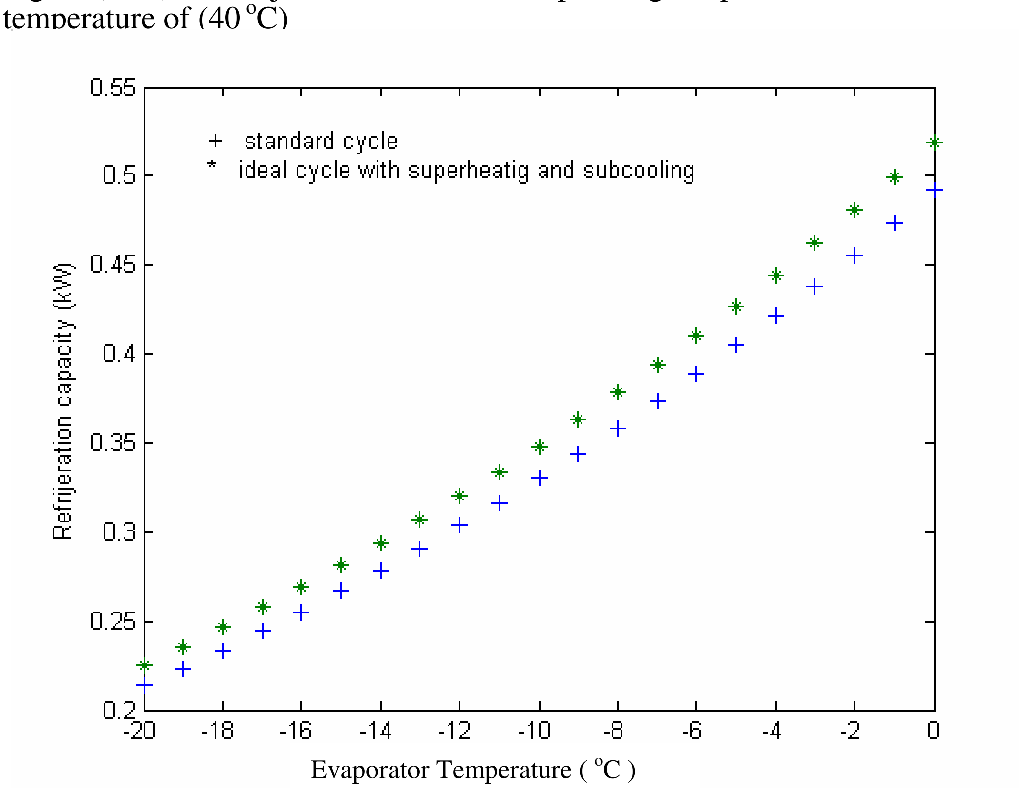

Figure (4.39) Refrigeration capacity versus evaporating temperature with condensing temperature of (40 °C)

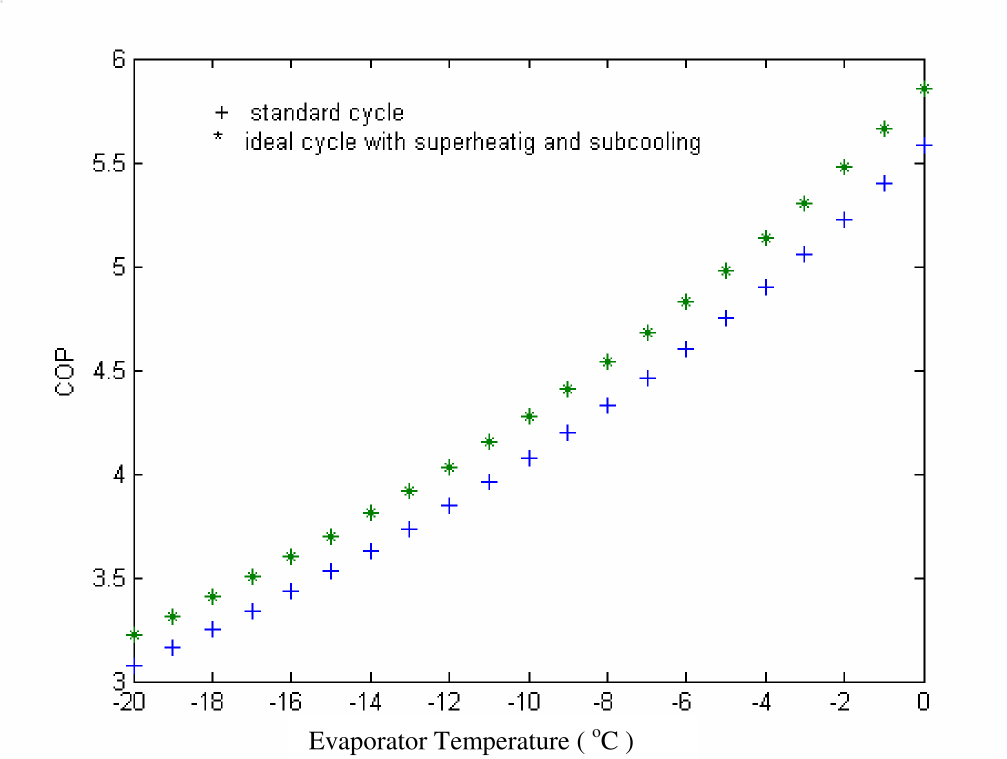

Figure (4.40) Coefficient of performance versus evaporating temperature with condensing temperature of (40 °C)

4.4 The effect of isentropic efficiency on the actual cycle for R-134a

The actual refrigeration cycle deviates from the ideal cycle because of pressure drops associated with fluid flow and heat transfer to or from the surrounding. During the compression process there are irreversibilities and heat transfer.

The effect of the isentropic efficiency will consider to the coefficient of performance with two different values (85% and 90%). This range of the isentropic efficiency was selected because; most of the isentropic efficiency seems likely to occur in. The value of superheating and subcooling was selected to be (5 degrees).

Figures (4.46) and (4.47) present the coefficient of performance against the evaporating temperature with different values of condensing temperature for an isentropic efficiency of (85%) and (90%), respectively. Figure (4.48) presents the coefficient of performance against the evaporating temperature at a condensing temperature of 40 ^{o}C. It is shown that the coefficient of performance for isentropic efficiency of (85%) is less than the coefficient of performance for isentropic efficiency of (90%), by (5.7%). The increasing in the isentropic efficiency will increase the coefficient of performance, because, the compression process approaches to the isentropic compression.

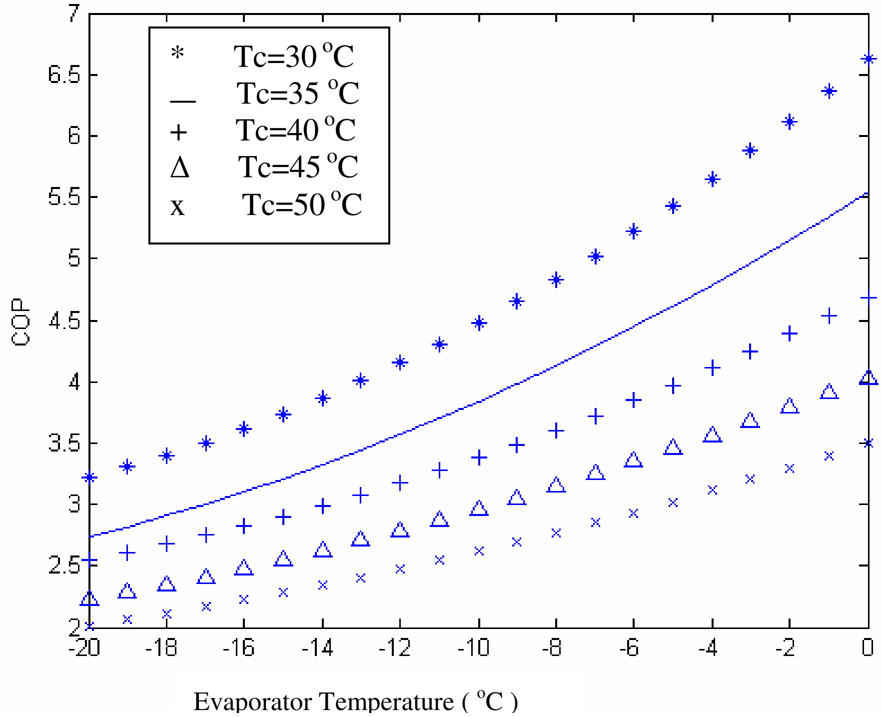

Figure (4.41) Coefficient of performance versus evaporating temperature with different values of condensing temperatures for isentropic efficiency of (0.85%)

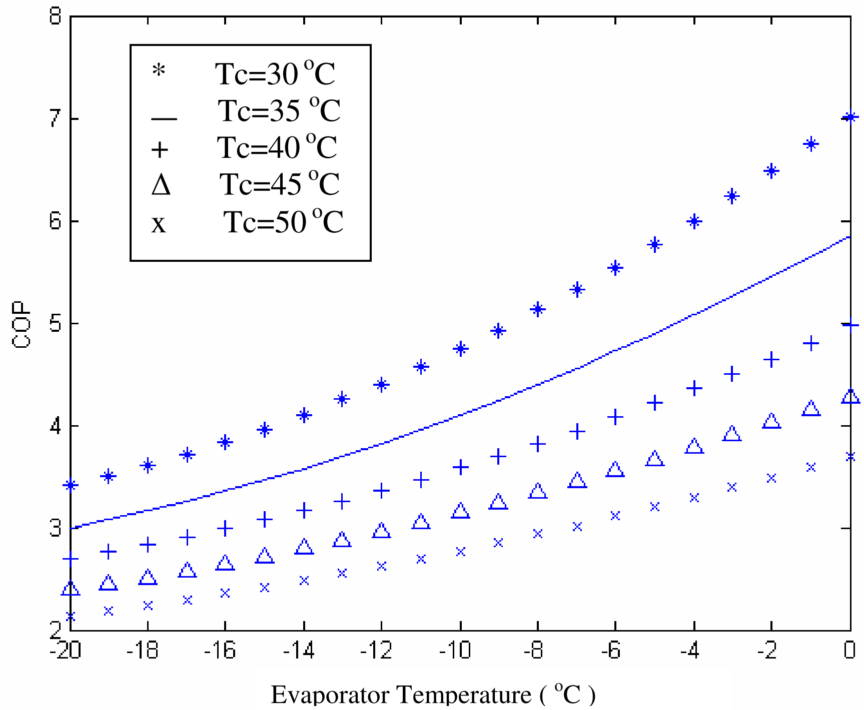

Figure (4.42) Coefficient of performance versus evaporating temperature with different values of condensing temperatures for isentropic efficiency of (0.90%)

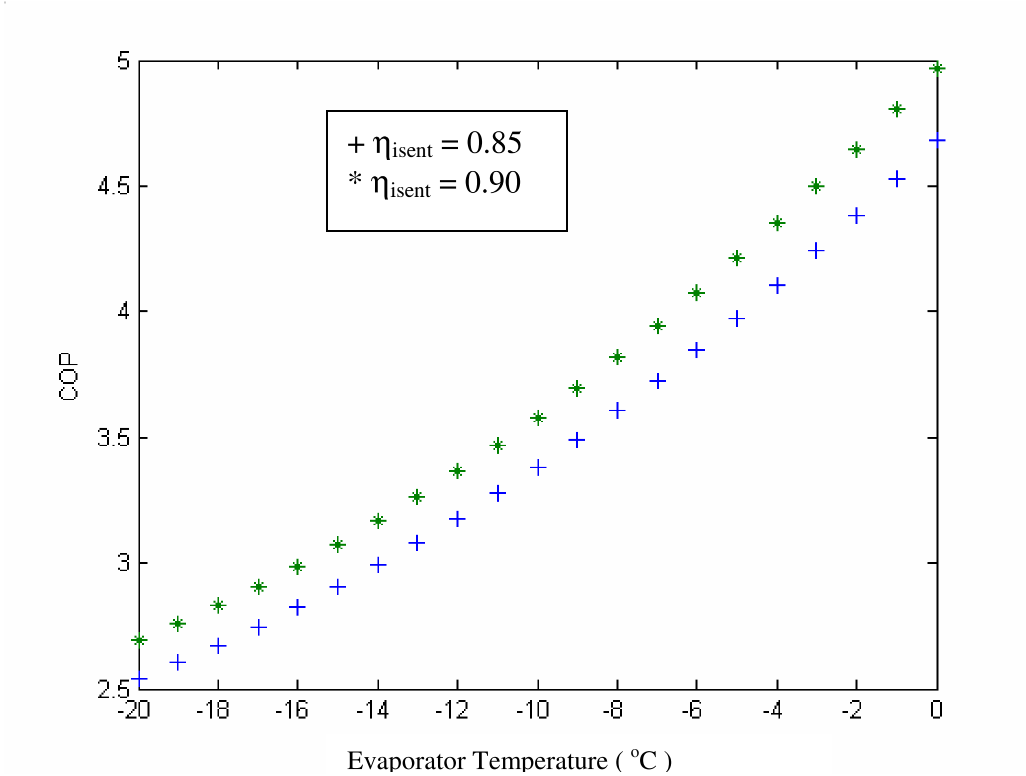

Figure (4.43) Coefficient of performance versus evaporating temperature with condensing temperatures of (40 ^{o}C)

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This research covers a theoretical performance study of a chest freezer working by (R-134a) replacing (R-12) using computer simulation method. A computer algorithm was developed to study the performance of vapor compression cycles. The following conclusions were deduced:

1. A full set of reasonable performance curves were presented for the chest freezer, using theoretical and actual cycle's analysis. A comparison between the two refrigerants was made to study the performance parameter. And these parameters were selected to be compressor work, refrigeration capacity and coefficient of performance for different values of Te and at Tc of (40 ^{o}C).

2. The performance study for the two refrigerants shows that R-134a is a suitable alternative for R-12. R-134a has lower values of the compressor work for low evaporating temperatures and high condensing temperature. R-134a has lower values of the refrigeration capacity for low evaporating temperatures and high condensing temperature.

3. Results of the system performance for the coefficient of performance indicate that R-12 has higher values of coefficient of performance for low evaporating temperatures and low condensing temperature. The maximum percent of the COP for R-134a is about (3.46%), which is at evaporating temperature of (0 ^{o}C) and at condensing temperature of (50 ^{o}C).

4. Comparison between the standard cycle and the ideal cycle with superheating and subcooling indicates the effect of superheating and subcooling on the vapor compression cycle for R-134a. The degree of superheating and subcooling was selected to be (5 degrees), which decrease the mass flow about (5.5% to 2.3%), while increase the discharge temperature by (8.93%). The degree of increasing for the compressor work was (1.29% to 1.34%), and for the heat rejection rate by (4.13% to 4.54%). For refrigeration capacity the range of increasing is (5.24% to 5.21%), and for the COP by (4.63%).

5. The actual cycle was constructed with two different values of isentropic efficiency (85% and 90%), and (5 degrees) of superheating and subcooling. The use of isentropic efficiency of (90%) instead of (85%) would increase the COP by (5.7%) at Tc of (40 ^{o}C).

5.2 Recommendations

1.Other researches are recommended, to study the performance of refrigerant R-134a with wider range of evaporating and condenser temperatures.

2. Experimental researches are recommended at the same chest freezer, working with R-134a, and compare it with the results observed in this research.

3. Experimental researches are recommended on refrigerant R-134a, for different design and environment conditions.

4. More researches are recommended on other promising and environmentally safe alternatives refrigerants, to phase out the use of CFCs and HCFCs.

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APENDIX A

COMPUTER PROGRAM CODE

This program is used to calculate the performance parameters for
The two refrigerants (R-134a, R-12) with different values of evaporating
Temperature and constant Condensing temperature to standard cycle

```
% parameters for refrigerant type and condenser temperature

choice1=input('Enter the Refrigerant type(For R-134a,Enter 1, For R-12,Enter 2)');
choice2=input('Enter the value of Condenser Temperature ');
z=choice1;
tc=choice2;

% parameters for compressor specification

choice3=input('Enter the value of Copressor volume(cm^3)');
choice4=input('Enter the value of Copressor speed(rpm)');
choice5=input('Enter the value of percent clearance of the compressor');
volume=choice3;
rpm=choice4;
m=choice5;

% /for loop to calculate performance parameters for evaporator temperature rang
```

```
% Te @(-20 to 0)

j=1;
tc(j)=tc;
for i=1:1:21
te(i)=i-21;
if te(i)<0
        if z = =1
 % /coefficients for R-134a (saturated properties) for temperature rang (-30 to 0)

p0=292.693037523621;p1=10.610259447499;p2=0.1488564683;p3=0.0013490988;
p4=5.342272654349E-6;p5=6.503495536157E-8;p6=4.818788559386E-10;
vg0=0.069352943773;vg1=-0.002413926336;vg2=5.383298321884E-5;
vg3=-4.045533257187E-7;vg4=4.114063907716E-8;vg5=7.46930759941E-10;
vg6=1.322790297005E-11;hl0=200.007454280755;hl1=1.344677404993;
hl2=0.0032662;hl3=1.572136529997E-4;hl4=6.02648443244E-6;
hl5=1.113546594816E-7;hl6=7.715564627762E3-10;hv0=398.663556819857;
hv1=0.570646273102;hv2=-0.003424016025;hv3=-1.9204893362E-4;
hv4=-6.768862516299E-6;hv5=-1.171936079183E-7;hv6=-7.721556194004E-10;
sv0=1.727280906458;sv1=-6.055363989535E-4;sv2=-1.17629024685E-6;
sv3=-6.452087221055E-7;sv4=-2.144685874898E-8;sv5=-3.868602731387E-10;
sv6=-2.61880612857E-12;

        else
 % /coefficients for R-12(saturated properties) for temperature (-30 to 0)

p0=308.620011;p1=10.150172;p2=0.127044;p3=7150.68E-07;p4=-9023.38E-10;
p5=-1631.52E-10;p6=-2685.55E-12;vg0=0.055396954;vg1=-0.001728015;
vg2=0.000034779;vg3=-4.07106E-07;vg4=5.49766E-09;vg5=-3.64122E-10;
vg6=-5.03502E-12;hl0=36.051171652;hl1=0.923815150;hl2=.000551833;
hl3=-4.62536E-06;hl4=2.31746E-07;hl5=2.56659E-08;hl6=4.67642E-10;
hv0=187.51917037;hv1=0.419819456;hv2=-0.002172069;hv3=-0.000077522;
hv4=2.03443E-06;hv5=2.21595E-07;hv6=3.95550E-09;sv0=0.696485979;
sv1=-.000485848;sv2=5.70544E-06;sv3=-2.27637E-08;sv4=-9.95112E-10;
sv5=-7.49224E-11;sv6=-1.08763E-12;
        end;
end;

 % evaporator pressure / <pe>
 pe(i)=p0+p1*te(i)+p2*te(i)^2+p3*te(i)^3+p4*te(i)^4+p5*te(i)^5+
 p6*te(i)^6;

 % saturated specific volume / <vge>
 vge(i)=vg0+vg1*te(i)+vg2*te(i)^2+vg3*te(i)^3+vg4*te(i)^4+vg5*te(i)^5+
 vg6*te(i)^6;
```

```
% saturated vapor entropy / <sve>
sve(i)=sv0+sv1*te(i)+sv2*te(i)^2+sv3*te(i)^3+sv4*te(i)^4+sv5*te(i)^5+
sv6*te(i)^6;

% saturated vapor enthalpy / <hve>
hve(i)=hv0+hv1*te(i)+hv2*te(i)^2+hv3*te(i)^3+hv4*te(i)^4+hv5*te(i)^5+
hv6*te(i)^6;

if 0<=tc(j)<50
      if z= =1
% /coefficients for R-134a (saturated properties) for temperature (0 to 50)

p0=292.69;p1=10.631269064422;p2=0.142371277847;p3=0.001390806101;
p4=-1.737144223464E-5;p5=3.55832371212E-7;p6=-2.493344811091E-9;
hl0=200;hl1=1.337089623185;hl2=0.001505552037;hl3=1.9002319027E-5;
hl4=-4.431829552188E-7;hl5=1.169882394051E-8; hl6=-8.972027202483E-11;
hl6=-8.972027202483E-11;


else
% /coefficients for R-12 (saturated properties) for temperature (0 to 50)

p0=308.597960;p1=10.159738;p2=.121430;p3=1088.88E-06;p4=-1723.37E-08;
p5=3588.75E-10;p6=-2667.63E-12; hl0=36.075849732;hl1=0.923972779;
hl2=0.000322651;hl3=0.000043351;hl4=-1.42775E-06;hl5=2.49966E-08;
hl6=-1.57011E-10;
      end;
% condenser pressure / <pc>
pc(j)=p0+p1*tc(j)+p2*tc(j)^2+p3*tc(j)^3+p4*tc(j)^4+p5*tc(j)^5+p6*tc(j)^6;
% saturated liquid enthalpy / <hlc>
hlc(j)=hl0+hl1*tc(j)+hl2*tc(j)^2+hl3*tc(j)^3+hl4*tc(j)^4+hl5*tc(j)^5+
hl6*tc(j)^6;
end;
if tc(j)>=50
      if z= =1
% coefficients for R-134a (saturated properties) for temperature (50 to 65)
p0=0.009431479019;p1=0.186114774355;p2=2.208235180766;p3=-0.0798852;
p4=0.001429519563;p5=-1.214126408644E-5;p6=4.051703368833E-8;
hl0=0.004108561398;hl1=0.081069145692;hl2=0.961643401735;
hl3=-0.041791903899;hl4=7.792845463046E-4;
hl5=-6.896931677655E-6;hl6=2.381863128416E-8;
       else
% coefficients for R-12 (saturated properties) for temperature (50 to 65)
p0=208563.85646;p1=-20824.99208;p2=866.629635;p3=-19.174128;p4=0.238126;
p5=-1573.53E-06;p6=4322.51E-09; hl0=225.34627079; hl1=-15.78998039;
hl2=0.610119699; hl3=-.011740489;hl4=.000126286; hl5=-7.18007E-07;
```

```
hl6=1.69264E-09;

      end;
 % condenser pressure / <pc>
pc(j)=p0+p1*tc(j)+p2*tc(j)^2+p3*tc(j)^3+p4*tc(j)^4+p5*tc(j)^5+p6*tc(j)^6;
% saturated liquid enthalpy / <hlc>
hlc(j)=hl0+hl1*tc(j)+hl2*tc(j)^2+hl3*tc(j)^3+hl4*tc(j)^4+hl5*tc(j)^5+
hl6*tc(j)^6;
end;

% subroutine for successive iteration to calculate superheated properties
texit=tc(j);
pc(j)=(pc(j))/1000;
es=100;
while es>=0.001
texit=texit+0.1;


  if z= =1
         if pc(j)<=1.6
% coefficients for R-134a (superheated properties) for pressure (0.45 to 1.6)

   hs0=393.71514987747;hs1=0.631562054942;hs2=.001012731335;
   hs3=48.4037463446;hs4=93.561362134923;hs5=0.399416037639;
   hs6=-0.002153119302;hs7=0.119637677522;hs8=26.270732371395;
   ss1=0.003448785754;hs9=4.065788832803E-6;ss0=1.818206741717;
   ss2=-6.100134813307E-6;ss3=-0.417935876886;ss4=0.2316956927;
   ss5=3.810867768081E-4;ss6=-1.668144774746E-6;ss7=1.262263902671E-4;
   sss8=-0.063997096241;ss9=1.297263303724E-8;vs0=0.102814300;
   vs1=0.000355162;vs2=-5.33536E-07;vs3=-0.190884376;
   vs4=0.137301329;vs5=-0.000274709;vs6=-3.21917E-07;vs7=0.000116651;
   vs8=-0.035802822;vs9=2.55860E-09;
         else
% coefficients for R-134a (superheated properties)for pressure (1.6 to 2.0)

   hs0=403.501922449796;hs1=1.179069902512;hs2=-0.003335903393;
   hs3=-39.2059147;hs4=-2.918688574172;hs5=0.3890950562;hs6=-0.00131251;
   hs7=0.028904010528;hs8=-0.281608335764;hs9=1.209975622134E-5;
   ss0=1.687362195776;ss1=0.0041072391;ss2=-1.366351773059E-5;
   ss3=-0.173702848269;ss4=0.005232137;ss5=9.8590656479E-4;
   ss6=-3.3180493211E-6;ss7=7.0583806568E-5;ss8=-0.0014679587;
   ss9=3.4586489019E-8;vs0=.045751251;vs1=.000220731;vs2=-1.30163E-06;
   vs3=-.047910906;vs4=.016331553;vs5=.000014835;vs6=-7.13511E-07;
   vs7=.000028050;vs8=-.002574831;vs9=8.47205E-09;
         end;
else
```

```
% coefficients for R-12 (superheated properties) for pressure (0.45 to 1.6)
        if pc(j)<=1.6
  hs0=193.59019708;hs1=.590981522;hs2=.000166806;
  hs3=-18.84617121;hs4=-3.654927754;hs5=.196854505;
  hs6=-.000611503  ;hs7=.016111774;hs8=.068680175; hs9=5.57929E-07;
  ss0=.772081735;ss1=.002176459; ss2=-3.10514E-06; ss3=-.294159474;
  ss4=0.125976829;ss5=.000610016; ss6=-1.74606E-06;ss7=.000021231;
  ss8=-.030434861;ss9=4.17294E-09;vs0=.097135680;vs1=.000374399;
  vs2=-6.59681E-07;vs3=-.197383526;vs4=.155892611;vs5=-.000381048;
  vs6=5.48007E-08;vs7=.000149904;vs8=-.043581874;vs9=2.11647E-09;
        else
% coefficients for R-12 (superheated properties) for pressure (1.6 to 2)

  hs0=192.34540069;hs1=0.676918431;hs2=-0.001681216;hs3=-21.11160073;
  hs4=-5.7588906;hs5=0.310465859;hs6=-0.002398521;hs7=0.094054479;
  hs8=-1.092479642;hs9=0.000015973;ss0=0.716347078;ss1=0.002426483;
  ss2=-9.68738E-06;ss3=-0.174858709;ss4=0.015857160;ss5=0.001062781;
  ss6=-7.20792E-06;ss7=0.000232049;ss8=-0.006354305;ss9=5.46040E-08;
  vs0=.039922023;vs1=.000157449;vs2=-6.36031E-07;vs3=-.041049398;
  vs4=.014368707;vs5=-2.63559E-06;vs6=-4.04195E-07 ;vs7=.000019463;
  vs8=-.002222563;vs9=3.95805E-09;
        end
 sSuper(i)=ss0+ss1*texit+ss2*texit^2+ss3*pc(j)+ss4*pc(j)^2+ss5*texit*
 pc(j)+ss6*pc(j)*texit^2+ss7*texit*pc(j)^2+ss8*pc(j)^3+ss9*texit^3;
 es=abs(sSuper(i)-sve(i));
 end;
 % superheated enthalpy/ <hsuper> @ compressor exit
 hSuper(i)=hs0+hs1*texit+hs2*texit^2+hs3*pc(j)+hs4*pc(j)^2+hs5*texit*
 pc(j)+hs6*pc(j)*texit^2+hs7*texit*pc(j)^2+hs8*pc(j)^3+hs9*texit^3;
 % superheated specific volume / <vsuper> @ compressor exit
 vSuper(i)=vs0+vs1*texit+vs2*texit^2+vs3*pc(j)+vs4*pc(j)^2+vs5*texit*
 pc(j)+vs6*pc(j)*texit^2+vs7*texit*pc(j)^2+vs8*pc(j)^3+vs9*texit^3;
 end

 %subrotine to calculate volume flow rate
 voleff(i)=1-m*((vge(i)/vSuper(i))-1);
 dsp(i)=(volume*rpm*voleff(i))*(0.000001/60);
 % mass flow rate calculation
 mf(i)=dsp(i)/vge(i);

 %discharge temperature / <texit>
 texit(i)=texit;

 %Refrigeration capacity / <Qref>
 Qref(i)=mf(i)*(hve(i)-hlc(j));
```

```
  %Heat rejection rate / <Qrej>
  Qrej(i)=mf(i)*(hSuper(i)-hlc(j));

  %Compressor work / <w>
  w(i)=mf(i)*(hSuper(i)-hve(i));

  %Coefficient of performance
  cop(i)=Qref(i)/w(i);

  end;
plot(te,cop,'*')
gtext('coeficient of performance for R-12 @ Tc=40',z)
xlabel('Te')
ylabel('COP')
```

```
% This program is used to compare the performance parameters for
% The two refrigerants (R-134a, R-12) with different values of evaporating
%Temperature and constant condensing temperature to standard cycle

choice1=input('Enter the value of Condenser Temperature ');
choice2=input('Enter the value of Compressor volume(cm^3)');
choice3=input('Enter the value of Compressor speed(rpm)');
choice4=input('Enter the value of percent clearance of the compressor');
tc=choice1;
volume=choice2;
rpm=choice3;
m=choice4;
 j=1;
 tc(j)=tc;
 for i=1:1:21
 te(i)=i-21;

 if te(i)<0
 %for R-134a
 p0=292.693037523621;p1=10.610259447499;p2=0.1488564683;p3=0.0013490988;
 p4=5.342272654349E-6;p5=6.503495536157E-8;p6=4.818788559386E-10;
 vg0=0.069352943773;vg1=-0.002413926336;vg2=5.383298321884E-5;
 vg3=-4.045533257187E-7;vg4=4.114063907716E-8;vg5=7.46930759941E-10;
 vg6=1.322790297005E-11;hl0=200.007454280755;hl1=1.344677404993;
 hl2=0.0032662;hl3=1.572136529997E-4;hl4=6.02648443244E-6;
 hl5=1.113546594816E-7;hl6=7.715564627762E3-10;hv0=398.663556819857;
 hv1=0.570646273102;hv2=-0.003424016025;hv3=-1.9204893362E-4;
 hv4=-6.768862516299E-6;hv5=-1.171936079183E-7;hv6=-7.721556194004E-10;
```

```
sv0=1.727280906458;sv1=-6.055363989535E-4;sv2=-1.17629024685E-6;
sv3=-6.452087221055E-7;sv4=-2.144685874898E-8;sv5=-3.868602731387E-10;
sv6=-2.61880612857E-12;
 pe134(i)=p0+p1*te(i)+p2*te(i)^2+p3*te(i)^3+p4*te(i)^4+p5*te(i)^5+
 p6*te(i)^6;
 vge134(i)=vg0+vg1*te(i)+vg2*te(i)^2+vg3*te(i)^3+vg4*te(i)^4+
 vg5*te(i)^5+vg6*te(i)^6;
 sve134(i)=sv0+sv1*te(i)+sv2*te(i)^2+sv3*te(i)^3+sv4*te(i)^4+
 sv5*te(i)^5+sv6*te(i)^6;
 hve134(i)=hv0+hv1*te(i)+hv2*te(i)^2+hv3*te(i)^3+hv4*te(i)^4+
 hv5*te(i)^5+hv6*te(i)^6;

% for R-12
     p0=308.620011;p1=10.150172;p2=0.127044;p3=7150.68E-07;p4=-9023.38E-
10;
p5=-1631.52E-10;p6=-2685.55E-12;vg0=0.055396954;vg1=-0.001728015;
vg2=0.000034779;vg3=-4.07106E-07;vg4=5.49766E-09;vg5=-3.64122E-10;
vg6=-5.03502E-12;hl0=36.051171652;hl1=0.923815150;hl2=.000551833;
hl3=-4.62536E-06;hl4=2.31746E-07;hl5=2.56659E-08;hl6=4.67642E-10;
hv0=187.51917037;hv1=0.419819456;hv2=-0.002172069;hv3=-0.000077522;
hv4=2.03443E-06;hv5=2.21595E-07;hv6=3.95550E-09;sv0=0.696485979;
sv1=-.000485848;sv2=5.70544E-06;sv3=-2.27637E-08;sv4=-9.95112E-10;
sv5=-7.49224E-11;sv6=-1.08763E-12;


 pe12(i)=p0+p1*te(i)+p2*te(i)^2+p3*te(i)^3+p4*te(i)^4+p5*te(i)^5+
 p6*te(i)^6;
 vge12(i)=vg0+vg1*te(i)+vg2*te(i)^2+vg3*te(i)^3+vg4*te(i)^4+
 vg5*te(i)^5+vg6*te(i)^6;
 sve12(i)=sv0+sv1*te(i)+sv2*te(i)^2+sv3*te(i)^3+sv4*te(i)^4+
 sv5*te(i)^5+sv6*te(i)^6;
 hve12(i)=hv0+hv1*te(i)+hv2*te(i)^2+hv3*te(i)^3+hv4*te(i)^4+
 hv5*te(i)^5+hv6*te(i)^6;
 end;

if 0<=tc(i)<50
%for R-134a
p0=292.69;p1=10.631269064422;p2=0.142371277847;p3=0.001390806101;
p4=-1.737144223464E-5;p5=3.55832371212E-7;p6=-2.493344811091E-9;
hl0=200;hl1=1.337089623185;hl2=0.001505552037;hl3=1.9002319027E-5;
hl4=-4.431829552188E-7;hl5=1.169882394051E-8; hl6=-8.972027202483E-11;
hl6=-8.972027202483E-11;

 pc134(j)=p0+p1*tc(j)+p2*tc(j)^2+p3*tc(j)^3+p4*tc(j)^4+p5*tc(j)^5+p6*tc(j)^6;
 hlc134(j)=hl0+hl1*tc(j)+hl2*tc(j)^2+hl3*tc(j)^3+hl4*tc(j)^4+hl5*tc(j)^5+
 hl6*tc(j)^6;
```

```
%for R-12
p0=308.597960;p1=10.159738;p2=.121430;p3=1088.88E-06;p4=-1723.37E-08;
 p5=3588.75E-10;p6=-2667.63E-12; hl0=36.075849732;hl1=0.923972779;
 hl2=0.000322651;hl3=0.000043351;hl4=-1.42775E-06;hl5=2.49966E-08;
 hl6=-1.57011E-10;

 pc12(j)=p0+p1*tc(j)+p2*tc(j)^2+p3*tc(j)^3+p4*tc(j)^4+p5*tc(j)^5+p6*tc(j)^6;
 hlc12(j)=hl0+hl1*tc(j)+hl2*tc(j)^2+hl3*tc(j)^3+hl4*tc(j)^4+hl5*tc(j)^5+
 hl6*tc(j)^6;
end;

if tc(i)>=50

 %for R-134a
 p0=0.009431479019;p1=0.186114774355;p2=2.208235180766;p3=-0.0798852;
 p4=0.001429519563;p5=-1.214126408644E-5;p6=4.051703368833E-8;
 hl0=0.004108561398;hl1=0.081069145692;hl2=0.961643401735;
 hl3=-0.041791903899;hl4=7.792845463046E-4;
 hl5=-6.896931677655E-6;hl6=2.381863128416E-8;

 pc134(j)=p0+p1*tc(j)+p2*tc(j)^2+p3*tc(j)^3+p4*tc(j)^4+p5*tc(j)^5+p6*tc(j)^6;
 hlc134(j)=hl0+hl1*tc(j)+hl2*tc(j)^2+hl3*tc(j)^3+hl4*tc(j)^4+hl5*tc(j)^5+
 hl6*tc(j)^6;
 %for R-12
 p0=208563.85646;p1=-20824.99208;p2=866.629635;p3=-19.174128;p4=0.238126;
 p5=-1573.53E-06;p6=4322.51E-09; hl0=225.34627079; hl1=-15.78998039;
 hl2=0.610119699; hl3=-.011740489;hl4=.000126286; hl5=-7.18007E-07;
 hl6=1.69264E-09;

 pc12(j)=p0+p1*tc(j)+p2*tc(j)^2+p3*tc(j)^3+p4*tc(j)^4+p5*tc(j)^5+p6*tc(j)^6;
 hlc12(j)=hl0+hl1*tc(j)+hl2*tc(j)^2+hl3*tc(j)^3+hl4*tc(j)^4+hl5*tc(j)^5+
 hl6*tc(j)^6;
 end;

 texit=tc(j);
 pc12(j)=(pc12(j))/1000;
 pc134(j)=(pc134(j))/1000;
 es=100;
 while es>=0.001
 texit=texit+0.1;
          if pc134(j)<=1.6
    %for R-134a
    hs0=393.71514987747;hs1=0.631562054942;hs2=.001012731335;
    hs3=48.4037463446;hs4=93.561362134923;hs5=0.399416037639;
    hs6=-0.002153119302;hs7=0.119637677522;hs8=26.270732371395;
```

```
 ss1=0.003448785754;hs9=4.065788832803E-6;ss0=1.818206741717;
 ss2=-6.100134813307E-6;ss3=-0.417935876886;ss4=0.2316956927;
 ss5=3.810867768081E-4;s6=-1.668144774746E-6;ss7=1.262263902671E-4;
 sss8=-0.063997096241;ss9=1.297263303724E-8;vs0=0.102814300;
 vs1=0.000355162;vs2=-5.33536E-07;vs3=-0.190884376;
 vs4=0.137301329;vs5=-0.000274709;vs6=-3.21917E-07;vs7=0.000116651;
 vs8=-0.035802822;vs9=2.55860E-09;
      else
 hs0=403.501922449796;hs1=1.179069902512;hs2=-0.003335903393;
 hs3=-39.2059147;hs4=-2.918688574172;hs5=0.3890950562;hs6=-0.00131251;
 hs7=0.028904010528;hs8=-0.281608335764;hs9=1.209975622134E-5;
 ss0=1.687362195776;ss1=0.0041072391;ss2=-1.366351773059E-5;
 ss3=-0.173702848269;ss4=0.005232137;ss5=9.8590656479E-4;
 ss6=-3.3180493211E-6;ss7=7.0583806568E-5;ss8=-0.0014679587;
 ss9=3.4586489019E-8;vs0=.045751251;vs1=.000220731;vs2=-1.30163E-06;
 vs3=-.047910906;vs4=.016331553;vs5=.000014835;vs6=-7.13511E-07;
 vs7=.000028050;vs8=-.002574831;vs9=8.47205E-09;
       end;
sSuper134(i)=ss0+ss1*texit+ss2*texit^2+ss3*pc134(j)+ss4*pc134(j)^2+
ss5*texit*pc134(j)+ss6*pc134(j)*texit^2+ss7*texit*pc134(j)^2+
ss8*pc134(j)^3+ss9*texit^3;
es=abs(sSuper134(i)-sve134(i));
end;
hSuper134(i)=hs0+hs1*texit+hs2*texit^2+hs3*pc134(j)+hs4*pc134(j)^2+
hs5*texit*pc134(j)+hs6*pc134(j)*texit^2+hs7*texit*pc134(j)^2+
hs8*pc134(j)^3+hs9*texit^3;
vSuper134(i)=vs0+vs1*texit+vs2*texit^2+vs3*pc134(j)+vs4*pc134(j)^2+
vs5*texit*pc134(j)+vs6*pc134(j)*texit^2+vs7*texit*pc134(j)^2+vs8*
pc134(j)^3+vs9*texit^3;
texit134(i)=texit;

texit=tc(j);
es=100;
while es>=0.001
texit=texit+0.1;
 % for R-12
        if pc12(j)<=1.6
 hs0=193.59019708;hs1=.590981522;hs2=.000166806;
 hs3=-18.84617121;hs4=-3.654927754;hs5=.196854505;
 hs6=-.000611503  ;hs7=.016111774;hs8=.068680175; hs9=5.57929E-07;
 ss0=.772081735;ss1=.002176459; ss2=-3.10514E-06; ss3=-.294159474;
 ss4=0.125976829;ss5=.000610016; ss6=-1.74606E-06;ss7=.000021231;
 ss8=-.030434861;ss9=4.17294E-09;vs0=.097135680;vs1=.000374399;
 vs2=-6.59681E-07;vs3=-.197383526;vs4=.155892611;vs5=-.000381048;
 vs6=5.48007E-08;vs7=.000149904;vs8=-.043581874;vs9=2.11647E-09;
        else
```

```
 hs0=192.34540069;hs1=0.676918431;hs2=-0.001681216;hs3=-21.11160073;
 hs4=-5.7588906;hs5=0.310465859;hs6=-0.002398521;hs7=0.094054479;
 hs8=-1.092479642;hs9=0.000015973;ss0=0.716347078;ss1=0.002426483;
 ss2=-9.68738E-06;ss3=-0.174858709;ss4=0.015857160;ss5=0.001062781;
 ss6=-7.20792E-06;ss7=0.000232049;ss8=-0.006354305;ss9=5.46040E-08;
 vs0=.039922023;vs1=.000157449;vs2=-6.36031E-07;vs3=-.041049398;
 vs4=.014368707;vs5=-2.63559E-06;vs6=-4.04195E-07 ;vs7=.000019463;
 vs8=-.002222563;vs9=3.95805E-09;
        end
 end;
sSuper12(i)=ss0+ss1*texit+ss2*texit^2+ss3*pc12(j)+ss4*pc12(j)^2+
ss5*texit*pc12(j)+ss6*pc12(j)*texit^2+ss7*texit*pc12(j)^2+ss8*
pc12(j)^3+ss9*texit^3;
es=abs(sSuper12(i)-sve12(i));
end;
hSuper12(i)=hs0+hs1*texit+hs2*texit^2+hs3*pc12(j)+hs4*pc12(j)^2+hs5*
texit*pc12(j)+hs6*pc12(j)*texit^2+hs7*texit*pc12(j)^2+hs8*pc12(j)^3+
hs9*texit^3;
vSuper12(i)=vs0+vs1*texit+vs2*texit^2+vs3*pc12(j)+vs4*pc12(j)^2+
vs5*texit*pc12(j)+vs6*pc12(j)*texit^2+vs7*texit*pc12(j)^2+vs8*pc12(j)^3+
vs9*texit^3;texit12(i)=texit;

voleff134(i)=1-m*((vge134(i)/vSuper134(i))-1);
dsp134(i)=(volume*rpm*voleff134(i)*0.000001/60);
mf134(i)=dsp134(i)/vge134(i);

voleff12(i)=1-m*((vge12(i)/vSuper12(i))-1);
dsp12(i)=(volume*rpm*voleff12(i)*0.000001/60);
mf12(i)=dsp12(i)/vge12(i);

Qref134(i)=mf134(i)*(hve134(i)-hlc134(j));
Qrej134(i)=mf134(i)*(hSuper134(i)-hlc134(j));
w134(i)=mf134(i)*(hSuper134(i)-hve134(i));
cop134(i)=Qref134(i)/w134(i);

Qref12(i)=mf12(i)*(hve12(i)-hlc12(j));
Qrej12(i)=mf12(i)*(hSuper12(i)-hlc12(j));
w12(i)=mf12(i)*(hSuper12(i)-hve12(i));
cop12(i)=Qref12(i)/w12(i);
end;

plot(te,cop134,'+',te,cop12,'*')
xlabel('Te')
ylabel('COP')
gtext('coeficient of performance for R-134a(+) R-12 (*) @ Tc=')
```

This program is used to compare the performance parameters for refrigerant (R-134a) between 'standard cycle' and 'ideal cycle with superheated and subcoolig' for different values of evaporating temperature and constant condensing temperature

```
choice1=input('Enter the value of Condenser Temperature ');
choice2=input('Enter the value of Compressor volume(cm^3)');
choice3=input('Enter the value of Compressor speed(rpm)');
choice4=input('Enter the value of percent clearance of the compressor');
choice5=input('Enter the degree of superheating');
choice6=input('Enter the degree of subcooling');

tc=choice1;
volume=choice2;
rpm=choice3;
m=choice4;
ds=choice5;
dc=choice6;
 j =1;
 tc(j)=tc;
 for i=1:1:21
 te(i)=i-21;
 ds(i)=te(i)+ds;
 dc(j)=tc(j)-dc;

 if te(i)<0
 p0=292.693037523621;p1=10.610259447499;p2=0.1488564683;p3=0.0013490988;
 p4=5.342272654349E-6;p5=6.503495536157E-8;p6=4.818788559386E-10;
 vg0=0.069352943773;vg1=-0.002413926336;vg2=5.383298321884E-5;
 vg3=-4.045533257187E-7;vg4=4.114063907716E-8;vg5=7.46930759941E-10;
 vg6=1.322790297005E-11;hl0=200.007454280755;hl1=1.344677404993;
 hl2=0.0032662;hl3=1.572136529997E-4;hl4=6.02648443244E-6;
 hl5=1.113546594816E-7;hl6=7.715564627762E3-10;hv0=398.663556819857;
 hv1=0.570646273102;hv2=-0.003424016025;hv3=-1.9204893362E-4;
 hv4=-6.768862516299E-6;hv5=-1.171936079183E-7;hv6=-7.721556194004E-10;
 sv0=1.727280906458;sv1=-6.055363989535E-4;sv2=-1.17629024685E-6;
 sv3=-6.452087221055E-7;sv4=-2.144685874898E-8;sv5=-3.868602731387E-10;
 sv6=-2.61880612857E-12;

  pe(i)=p0+p1*te(i)+p2*te(i)^2+p3*te(i)^3+p4*te(i)^4+p5*te(i)^5+
  p6*te(i)^6;
  vge(i)=vg0+vg1*te(i)+vg2*te(i)^2+vg3*te(i)^3+vg4*te(i)^4+vg5*te(i)^5+
  vg6*te(i)^6;
  sve(i)=sv0+sv1*te(i)+sv2*te(i)^2+sv3*te(i)^3+sv4*te(i)^4+sv5*te(i)^5+
  sv6*te(i)^6;
  hve(i)=hv0+hv1*te(i)+hv2*te(i)^2+hv3*te(i)^3+hv4*te(i)^4+hv5*te(i)^5+
```

```
 hv6*te(i)^6;

end;
if 0<=tc(i)<50

p0=292.69;p1=10.631269064422;p2=0.142371277847;p3=0.001390806101;
p4=-1.737144223464E-5;p5=3.55832371212E-7;p6=-2.493344811091E-9;
hl0=200;hl1=1.337089623185;hl2=0.001505552037;hl3=1.9002319027E-5;
hl4=-4.431829552188E-7;hl5=1.169882394051E-8; hl6=-8.972027202483E-11;
hl6=-8.972027202483E-11;
 % condenser pressure / <pc>
 pc(j)=p0+p1*tc(j)+p2*tc(j)^2+p3*tc(j)^3+p4*tc(j)^4+p5*tc(j)^5+p6*tc(j)^6;
 % saturated liquid enthalpy / <hlc>
 hlc(j)=hl0+hl1*tc(j)+hl2*tc(j)^2+hl3*tc(j)^3+hl4*tc(j)^4+hl5*tc(j)^5+
 hl6*tc(j)^6;
 hlcs(j)=hl0+hl1* dc(j)+hl2*dc(j)^2+hl3*dc(j)^3+hl4*dc(j)^4+hl5*dc(j)^5+
 hl6* dc(j)^6;

end;


if tc(i)>=50
 p0=0.009431479019;p1=0.186114774355;p2=2.208235180766;p3=-0.0798852;
 p4=0.001429519563;p5=-1.214126408644E-5;p6=4.051703368833E-8;
 hl0=0.004108561398;hl1=0.081069145692;hl2=0.961643401735;
 hl3=-0.041791903899;hl4=7.792845463046E-4;
 hl5=-6.896931677655E-6;hl6=2.381863128416E-8;

 pc(j)=p0+p1*tc(j)+p2*tc(j)^2+p3*tc(j)^3+p4*tc(j)^4+p5*tc(j)^5+p6*tc(j)^6;
 % saturated liquid enthalpy / <hlc>
 hlc(j)=hl0+hl1*tc(j)+hl2*tc(j)^2+hl3*tc(j)^3+hl4*tc(j)^4+hl5*tc(j)^5+
 hl6*tc(j)^6;
 hlcs(j)=hl0+hl1* dc(j)+hl2*dc(j)^2+hl3*dc(j)^3+hl4*dc(j)^4+hl5*dc(j)^5+
 hl6* dc(j)^6;
end;
 end;
 texit=tc(j);
 pc(j)=(pc(j))/1000;
 es=100;
 while es>=0.001
 texit=texit+0.1;
       if pc (j)<=1.6
   hs0=393.71514987747;hs1=0.631562054942;hs2=.001012731335;
   hs3=48.4037463446;hs4=93.561362134923;hs5=0.399416037639;
   hs6=-0.002153119302;hs7=0.119637677522;hs8=26.270732371395;
   ss1=0.003448785754;hs9=4.065788832803E-6;ss0=1.818206741717;
```

```
 ss2=-6.100134813307E-6;ss3=-0.417935876886;ss4=0.2316956927;
 ss5=3.810867768081E-4;s6=-1.668144774746E-6;ss7=1.262263902671E-4;
 sss8=-0.063997096241;ss9=1.297263303724E-8;vs0=0.102814300;
 vs1=0.000355162;vs2=-5.33536E-07;vs3=-0.190884376;
 vs4=0.137301329;vs5=-0.000274709;vs6=-3.21917E-07;vs7=0.000116651;
 vs8=-0.035802822;vs9=2.55860E-09;
        else
 hs0=403.501922449796;hs1=1.179069902512;hs2=-0.003335903393;
 hs3=-39.2059147;hs4=-2.918688574172;hs5=0.3890950562;hs6=-0.00131251;
 hs7=0.028904010528;hs8=-0.281608335764;hs9=1.209975622134E-5;
 ss0=1.687362195776;ss1=0.0041072391;ss2=-1.366351773059E-5;
 ss3=-0.173702848269;ss4=0.005232137;ss5=9.8590656479E-4;
 ss6=-3.3180493211E-6;ss7=7.0583806568E-5;ss8=-0.0014679587;
 ss9=3.4586489019E-8;vs0=.045751251;vs1=.000220731;vs2=-1.30163E-06;
 vs3=-.047910906;vs4=.016331553;vs5=.000014835;vs6=-7.13511E-07;
 vs7=.000028050;vs8=-.002574831;vs9=8.47205E-09;
        end;
sSuper(i)=ss0+ss1*texit+ss2*texit^2+ss3*pc(j)+ss4*pc(j)^2+ss5*
texit*pc(j)+ss6*pc(j)*texit^2+ss7*texit*pc(j)^2+ss8*pc(j)^3+ss9*texit^3;
es=abs(sSuper(i)-sve(i));
end;
hSuper(i)=hs0+hs1*texit+hs2*texit^2+hs3*pc(j)+hs4*pc(j)^2+
hs5*texit*pc(j)+hs6*pc(j)*texit^2+hs7*texit*pc(j)^2+hs8*pc(j)^3+hs9*texit^3;
                vSuper(i)=vs0+vs1*texit+vs2*texit^2+vs3*pc(j)+vs4*pc(j)^2+vs5*

      texit*pc(j)+

      vs6*pc(j)*texit^2+vs7*texit*pc(j)^2+vs8*pc(j)^3+vs9*texit^3;

texit(i)=texit;
%for p<0.4
hves0=406.10061018;hves1=0.785236203;hves2=0.000867213;
hves3=-22.67291654;hves4=-8.480875379;hves5=0.273702088;
hves6=-0.003289619;hves7=0.255804635;hves8=-3.981356817;
hves9=5.30370E-06;svs0=1.925304384;svs1=0.002808138;
svs2=-2.28946E-06;svs3=-1.192196804;svs4=2.398248374;svs5=0.001492391;
svs6=-0.000014960;svs7=0.000225748;svs8=-2.185430343;svs9=3.42710E-08;
ves0=.464963968;ves1=.001443962;ves2=-5.83257E-07;ves3=-3.371041682;
ves4=9.858480005;ves5=-.006584752;ves6=3.12592E-07;ves7=.009291367;
ves8=-10.08875120;ves9=2.41333E-09;

svs(i)=svs0+svs1*ds(i)+svs2*ds(i)^2+svs3*pe(i)+svs4*pe(i)^2+
svs5*ds(i)*pe(i)+svs6*pe(i)*ds(i)^2+svs7*ds(i)*pe(i)^2+svs8*
pe(i)^3+svs9*ds(i)^3;
hves(i)=hves0+hves1*ds(i)+hves2*ds(i)^2+hves3*pe(i)+hves4*
pe(i)^2+hves5*ds(i)*pe(i)+hves6*pe(i)*ds(i)^2+hves7*
ds(i)*pe(i)^2+hves8*pe(i)^3+hves9*ds(i)^3;
ves(i)=ves0+ves1*ds(i)+ves2*ds(i)^2+ves3*pe(i)+ves4*pe(i)^2+
```

```
ves5*ds(i)*pe(i)+ves6*pe(i)*ds(i)^2+ves7*ds(i)*pe(i)^2+ves8*
pe(i)^3+ves9*ds(i)^3;

texit=tc(j);
es=100;
while es>=0.001
texit=texit+.1;
       if pc(j)<=1.6
 hs0=393.71514987747;hs1=0.631562054942;hs2=.001012731335;
 hs3=48.4037463446;hs4=93.561362134923;hs5=0.399416037639;
 hs6=-0.002153119302;hs7=0.119637677522;hs8=26.270732371395;
 ss1=0.003448785754;hs9=4.065788832803E-6;ss0=1.818206741717;
 ss2=-6.100134813307E-6;ss3=-0.417935876886;ss4=0.2316956927;
 ss5=3.810867768081E-4;s6=-1.668144774746E-6;ss7=1.262263902671E-4;
 sss8=-0.063997096241;ss9=1.297263303724E-8;vs0=0.102814300;
 vs1=0.000355162;vs2=-5.33536E-07;vs3=-0.190884376;
 vs4=0.137301329;vs5=-0.000274709;vs6=-3.21917E-07;vs7=0.000116651;
 vs8=-0.035802822;vs9=2.55860E-09;
        else
 hs0=403.501922449796;hs1=1.179069902512;hs2=-0.003335903393;
 hs3=-39.2059147;hs4=-2.918688574172;hs5=0.3890950562;hs6=-0.00131251;
 hs7=0.028904010528;hs8=-0.281608335764;hs9=1.209975622134E-5;
 ss0=1.687362195776;ss1=0.0041072391;ss2=-1.366351773059E-5;
 ss3=-0.173702848269;ss4=0.005232137;ss5=9.8590656479E-4;
 ss6=-3.3180493211E-6;ss7=7.0583806568E-5;ss8=-0.0014679587;
 ss9=3.4586489019E-8;vs0=.045751251;vs1=.000220731;vs2=-1.30163E-06;
 vs3=-.047910906;vs4=.016331553;vs5=.000014835;vs6=-7.13511E-07;
 vs7=.000028050;vs8=-.002574831;vs9=8.47205E-09;
        end;
sSupers(i)=ss0+ss1*texit+ss2*texit^2+ss3*pc(j)+ss4*pc(j)^2+
ss5*texit*pc(j)+ss6*pc(j)*texit^2+ss7*texit*pc(j)^2+ss8*
pc(j)^3+ss9*texit^3;
es=abs(sSupers(i)-svs(i));
end;
hSupers(i)=hs0+hs1*texit+hs2*texit^2+hs3*pc(j)+hs4*pc(j)^2+
hs5*texit*pc(j)+hs6*pc(j)*texit^2+hs7*texit*pc(j)^2+hs8*
pc(j)^3+hs9*texit^3;
vSupers(i)=vs0+vs1*texit+vs2*texit^2+vs3*pc(j)+vs4*pc(j)^2+
vs5*texit*pc(j)+vs6*pc(j)*texit^2+vs7*texit*pc(j)^2+vs8*
pc(j)^3+vs9*texit^3;
texits(i)=texit;

voleff(i)=1-m*((vge(i)/vSuper(i))-1);
dsp(i)=(volume*rpm*voleff(i)*0.000001/60);
mf(i)=dsp(i)/vge(i);
```

```
    voleffs(i)=1-m*((ves(i)/vSupers(i))-1);
    dsps(i)=(volume*rpm*voleffs(i)*0.000001/60);
    mfs(i)=dsps(i)/ves(i);

   Qref(i)=mf(i)*(hve(i)-hlc(j));
   Qrej(i)=mf(i)*(hSuper(j)-hlc(j));
   w(i)=mf(i)*(hSuper(j)-hve(i));
   cop(i)=Qref(i)/w(i);

   Qrefs(i)=mfs(i)*(hves(i)-hlcs(j));
   Qrejs(i)=mfs(i)*(hSupers(i)-hlcs(j));
   ws(i)=mfs(i)*(hSupers(i)-hves(i));
   cops(i)=Qrefs(i)/ws(i);
 end;
 plot(te,cop,'.',te,cops)
 xlabel('Te')
ylabel('COP')
gtext(standard cycle(+) ,ideal cycle with superheating and subcooling (*) @ Tc=')
```

This program is used to calculate the performance parameters for refrigerant (R-134a) for actual cycle with different values of evaporating temperature and constant condensing temperature

```
choice1=input('Enter the value of Condenser Temperature ');
choice2=input('Enter the value of Compressor volume(cm^3)');
choice3=input('Enter the value of Compressor speed(rpm)');
choice4=input('Enter the value of percent clearance of the compressor');
choice5=input('Enter the degree of superheating');
choice6=input('Enter the degree of subcooling');
choice7=input('Enter the value of isentropic efficiency');

tc=choice1;
volume=choice2;
rpm=choice3;
m=choice4;
ds=choice5;
dc=choice6;
iseneff=choice7;
 j =1;
 tc(j)=tc;
 for i=1:1:21
 te(i)=i-21;
 ds(i)=te(i)+ds;
 dc(j)=tc(j)-dc;

 if te(i)<0
```

```
p0=292.693037523621;p1=10.610259447499;p2=0.1488564683;p3=0.0013490988;
p4=5.342272654349E-6;p5=6.503495536157E-8;p6=4.818788559386E-10;
vg0=0.069352943773;vg1=-0.002413926336;vg2=5.383298321884E-5;
vg3=-4.045533257187E-7;vg4=4.114063907716E-8;vg5=7.46930759941E-10;
vg6=1.322790297005E-11;hl0=200.007454280755;hl1=1.344677404993;
hl2=0.0032662;hl3=1.572136529997E-4;hl4=6.02648443244E-6;
hl5=1.113546594816E-7;hl6=7.715564627762E3-10;hv0=398.663556819857;
hv1=0.570646273102;hv2=-0.003424016025;hv3=-1.9204893362E-4;
hv4=-6.768862516299E-6;hv5=-1.171936079183E-7;hv6=-7.721556194004E-10;
sv0=1.727280906458;sv1=-6.055363989535E-4;sv2=-1.17629024685E-6;
sv3=-6.452087221055E-7;sv4=-2.144685874898E-8;sv5=-3.868602731387E-10;
sv6=-2.61880612857E-12;

 pe(i)=p0+p1*te(i)+p2*te(i)^2+p3*te(i)^3+p4*te(i)^4+p5*te(i)^5+
 p6*te(i)^6;




end;
if 0<=tc(i)<50

p0=292.69;p1=10.631269064422;p2=0.142371277847;p3=0.001390806101;
p4=-1.737144223464E-5;p5=3.55832371212E-7;p6=-2.493344811091E-9;
hl0=200;hl1=1.337089623185;hl2=0.001505552037;hl3=1.9002319027E-5;
hl4=-4.431829552188E-7;hl5=1.169882394051E-8; hl6=-8.972027202483E-11;
hl6=-8.972027202483E-11;
 % condenser pressure / <pc>
 pc(j)=p0+p1*tc(j)+p2*tc(j)^2+p3*tc(j)^3+p4*tc(j)^4+p5*tc(j)^5+p6*tc(j)^6;
 % saturated liquid enthalpy / <hlc>
 hlcs(j)=hl0+hl1* dc(j)+hl2*dc(j)^2+hl3*dc(j)^3+hl4*dc(j)^4+hl5*dc(j)^5+
 hl6* dc(j)^6;
 end;
        if tc(i)>=50
 p0=0.009431479019;p1=0.186114774355;p2=2.208235180766;p3=-0.0798852;
 p4=0.001429519563;p5=-1.214126408644E-5;p6=4.051703368833E-8;
 hl0=0.004108561398;hl1=0.081069145692;hl2=0.961643401735;
 hl3=-0.041791903899;hl4=7.792845463046E-4;
 hl5=-6.896931677655E-6;hl6=2.381863128416E-8;
 pc(j)=p0+p1*tc(j)+p2*tc(j)^2+p3*tc(j)^3+p4*tc(j)^4+p5*tc(j)^5+p6*tc(j)^6;
 hlcs(j)=hl0+hl1* dc(j)+hl2*dc(j)^2+hl3*dc(j)^3+hl4*dc(j)^4+hl5*dc(j)^5+
 hl6* dc(j)^6;
end;
 end;

    %for p<0.4
```

```
hves0=406.10061018;hves1=0.785236203;hves2=0.000867213;
hves3=-22.67291654;hves4=-8.480875379;hves5=0.273702088;
hves6=-0.003289619;hves7=0.255804635;hves8=-3.981356817;
hves9=5.30370E-06;svs0=1.925304384;svs1=0.002808138;
svs2=-2.28946E-06;svs3=-1.192196804;svs4=2.398248374;svs5=0.001492391;
svs6=-0.000014960;svs7=0.000225748;svs8=-2.185430343;svs9=3.42710E-08;
ves0=.464963968;ves1=.001443962;ves2=-5.83257E-07;ves3=-3.371041682;
ves4=9.858480005;ves5=-.006584752;ves6=3.12592E-07;ves7=.009291367;
ves8=-10.08875120;ves9=2.41333E-09;

svs(i)=svs0+svs1*ds(i)+svs2*ds(i)^2+svs3*pe(i)+svs4*pe(i)^2+
svs5*ds(i)*pe(i)+svs6*pe(i)*ds(i)^2+svs7*ds(i)*pe(i)^2+svs8*
pe(i)^3+svs9*ds(i)^3;

hves(i)=hves0+hves1*ds(i)+hves2*ds(i)^2+hves3*pe(i)+hves4*
pe(i)^2+hves5*ds(i)*pe(i)+hves6*pe(i)*ds(i)^2+hves7*
ds(i)*pe(i)^2+hves8*pe(i)^3+hves9*ds(i)^3;

ves(i)=ves0+ves1*ds(i)+ves2*ds(i)^2+ves3*pe(i)+ves4*pe(i)^2+
ves5*ds(i)*pe(i)+ves6*pe(i)*ds(i)^2+ves7*ds(i)*pe(i)^2+ves8*
pe(i)^3+ves9*ds(i)^3;

texit=tc(j);
es=100;
while es>=0.001
texit=texit+0.1;

    if pc(j)<=1.6
 hs0=393.71514987747;hs1=0.631562054942;hs2=.001012731335;
 hs3=48.4037463446;hs4=93.561362134923;hs5=0.399416037639;
 hs6=-0.002153119302;hs7=0.119637677522;hs8=26.270732371395;
 ss1=0.003448785754;hs9=4.065788832803E-6;ss0=1.818206741717;
 ss2=-6.100134813307E-6;ss3=-0.417935876886;ss4=0.2316956927;
 ss5=3.810867768081E-4;s6=-1.668144774746E-6;ss7=1.262263902671E-4;
 sss8=-0.063997096241;ss9=1.297263303724E-8;vs0=0.102814300;
 vs1=0.000355162;vs2=-5.33536E-07;vs3=-0.190884376;
 vs4=0.137301329;vs5=-0.000274709;vs6=-3.21917E-07;vs7=0.000116651;
 vs8=-0.035802822;vs9=2.55860E-09;
     else
 hs0=403.501922449796;hs1=1.179069902512;hs2=-0.003335903393;
 hs3=-39.2059147;hs4=-2.918688574172;hs5=0.3890950562;hs6=-0.00131251;
 hs7=0.028904010528;hs8=-0.281608335764;hs9=1.209975622134E-5;
 ss0=1.687362195776;ss1=0.0041072391;ss2=-1.366351773059E-5;
 ss3=-0.173702848269;ss4=0.005232137;ss5=9.8590656479E-4;
 ss6=-3.3180493211E-6;ss7=7.0583806568E-5;ss8=-0.0014679587;
```

```
ss9=3.4586489019E-8;vs0=.045751251;vs1=.000220731;vs2=-1.30163E-06;
vs3=-.047910906;vs4=.016331553;vs5=.000014835;vs6=-7.13511E-07;
vs7=.000028050;vs8=-.002574831;vs9=8.47205E-09;
      end;

   sSupers(i)=ss0+ss1*texit+ss2*texit^2+ss3*pc(j)+ss4*pc(j)^2+
   ss5*texit*pc(j)+ss6*pc(j)*texit^2+ss7*texit*pc(j)^2+ss8*
   pc(j)^3+ss9*texit^3;

   es=abs(sSupers(i)-svs(i));
   end;

   hSupers(i)=phs0+hs1*texit+hs2*texit^2+hs3*pc(j)+hs4*pc(j)^2+
   hs5*texit*pc(j)+hs6*pc(j)*texit^2+hs7*texit*pc(j)^2+hs8*
   pc(j)^3+hs9*texit^3;

   vSupers(i)=vs0+vs1*texit+vs2*texit^2+vs3*pc(j)+vs4*pc(j)^2+
   vs5*texit*pc(j)+vs6*pc(j)*texit^2+vs7*texit*pc(j)^2+vs8*
   pc(j)^3+vs9*texit^3;
   hSupers2(i)= hves(i)+( hSupers(i)- hves(i))/iseneff;

   texits(i)=texit;
   voleffs(i)=1-m*((ves(i)/vSupers(i))-1);
   dsps(i)=(volume*rpm*voleffs(i)*0.000001/60);
   mfs(i)=dsps(i)/ves(i);

  Qrefs(i)=mfs(i)*(hves(i)-hlcs(j));
  Qrejs(i)=mfs(i)*(hSupers2(i)-hlcs(j));
  ws(i)=mfs(i)*(hSupers2(i)-hves(i));

  cops(i)=Qrefs(i)/ws(i);

end;

plot(te,cop)
xlabel('Te')
ylabel('COP')
gtext(coefficient of performance for actual cycle  @ Tc=')
```

APENDIX B
RESULTS TABELS

Table (B.1) Mass flow rate (kg/s) for R-12 with different values of Tc for Standard cycle

Table (B.2) Mass flow rate (kg/s) for R-134a with different values of Tc for Standard cycle

Te °C	**Tc** = 30 °C	**Tc** = 35 °C	**Tc** = 40 °C	**Tc** = 45 °C	**Tc** = 50 °C
-20	0.0026	0.0026	0.0025	0.0025	0.0024
-19	0.0027	0.0027	0.0026	0.0026	0.0025
-18	0.0028	0.0028	0.0027	0.0027	0.0026
-17	0.003	0.0029	0.0029	0.0028	0.0027
-16	0.0031	0.003	0.003	0.0029	0.0029
-15	0.0032	0.0032	0.0031	0.003	0.003
-14	0.0033	0.0033	0.0032	0.0032	0.0031
-13	0.0035	0.0034	0.0034	0.0033	0.0032
-12	0.0036	0.0036	0.0035	0.0034	0.0034
-11	0.0038	0.0037	0.0036	0.0036	0.0035
-10	0.0039	0.0038	0.0038	0.0037	0.0037
-9	0.004	0.004	0.0039	0.0039	0.0038
-8	0.0042	0.0041	0.0041	0.004	0.004
-7	0.0044	0.0043	0.0042	0.0042	0.0041
-6	0.0045	0.0045	0.0044	0.0043	0.0043
-5	0.0047	0.0046	0.0046	0.0045	0.0044
-4	0.0048	0.0048	0.0047	0.0047	0.0046
-3	0.005	0.005	0.0049	0.0048	0.0048
-2	0.0052	0.0051	0.0051	0.005	0.0049
-1	0.0054	0.0053	0.0053	0.0052	0.0051
0	0.0055	0.0055	0.0054	0.0054	0.0053

Te °C	**Tc** = 30 °C	**Tc** = 35 °C	**Tc** = 40 °C	**Tc** = 45 °C	**Tc** = 50 °C
-20	0.0019	0.0018	0.0018	0.0017	0.0016
-19	0.002	0.0019	0.0019	0.0018	0.0017
-18	0.0021	0.002	0.002	0.0019	0.0018
-17	0.0022	0.0021	0.0021	0.002	0.0019
-16	0.0023	0.0022	0.0022	0.0021	0.002
-15	0.0024	0.0023	0.0023	0.0022	0.0021
-14	0.0025	0.0024	0.0024	0.0023	0.0022

-13	0.0026	0.0025	0.0025	0.0024	0.0023
-12	0.0027	0.0027	0.0026	0.0025	0.0025
-11	0.0028	0.0028	0.0027	0.0027	0.0026
-10	0.003	0.0029	0.0028	0.0028	0.0027
-9	0.0031	0.003	0.003	0.0029	0.0028
-8	0.0032	0.0032	0.0031	0.003	0.003
-7	0.0034	0.0033	0.0032	0.0032	0.0031
-6	0.0035	0.0034	0.0034	0.0033	0.0032
-5	0.0036	0.0036	0.0035	0.0035	0.0034
-4	0.0038	0.0037	0.0037	0.0036	0.0035
-3	0.0039	0.0039	0.0038	0.0037	0.0037
-2	0.0041	0.004	0.004	0.0039	0.0038
-1	0.0042	0.0042	0.0041	0.0041	0.004
0	0.0044	0.0043	0.0043	0.0042	0.0041

Table (B.3) Discharge temperature for R-12 with different values of Tc for Standard cycle

Te °C	**Tc** = 30 °C	**Tc** = 35 °C	**Tc** = 40 °C	**Tc** = 45 °C	**Tc** = 50 °C
-20	39.884	45.278	50.77	56.202	61.66
-19	39.5477	44.967	50.4604	55.8947	61.3539
-18	39.2192	44.6618	50.1566	55.5932	61.0536
-17	38.8985	44.3624	49.8586	55.2975	60.7591
-16	38.5856	44.0688	49.5664	55.0076	60.4704
-15	38.2805	43.781	49.28	54.7235	60.1875
-14	37.9832	43.499	48.9994	54.4452	59.9104
-13	37.6937	43.2228	48.7246	54.1727	59.6391

-12	37.412	42.9524	48.4556	53.906	59.3736
-11	37.1381	42.6878	48.1924	53.6451	59.1139
-10	36.872	42.429	47.935	53.39	58.86
-9	36.6137	42.176	47.6834	53.1407	58.6119
-8	36.3632	41.9288	47.4376	52.8972	58.3696
-7	36.1205	41.6874	47.1976	52.6595	58.1331
-6	35.8856	41.4518	46.9634	52.4276	57.9024
-5	35.6585	41.222	46.735	52.2015	57.6775
-4	35.4392	40.998	46.5124	51.9812	57.4584
-3	35.2277	40.7798	46.2956	51.7667	57.2451
-2	35.024	40.5674	46.0846	51.558	57.0376
-1	34.8281	40.3608	45.8794	51.3551	56.8359
0	34.64	40.16	45.68	51.158	56.64

Table (B.4) Discharge temperature (^oC) for R-134a with different values of Tc for Standard cycle

Te ^oC	**Tc** = 30 ^oC	**Tc** = 35 ^oC	**Tc** = 40 ^oC	**Tc** = 45 ^oC	**Tc** = 50 ^oC
-20	37.86	43.243	48.629	53.968	59.296
-19	37.6007	42.9865	48.3746	53.7168	59.0512
-18	37.3462	42.7348	48.125	53.4704	58.811
-17	37.0965	42.4879	47.8802	53.2288	58.5754
-16	36.8516	42.2458	47.6402	52.992	58.3444
-15	36.6115	42.0085	47.405	52.76	58.118
-14	36.3762	41.776	47.1746	52.5328	57.8962

-13	36.1457	41.5483	46.949	52.3104	57.679
-12	35.92	41.3254	46.7282	52.0928	57.4664
-11	35.6991	41.1073	46.5122	51.88	57.2584
-10	35.483	40.894	46.301	51.672	57.055
-9	35.2717	40.6855	46.0946	51.4688	56.8562
-8	35.0652	40.4818	45.893	51.2704	56.662
-7	34.8635	40.2829	45.6962	51.0768	56.4724
-6	34.6666	40.0888	45.5042	50.888	56.2874
-5	34.4745	39.8995	45.317	50.704	56.107
-4	34.2872	39.715	45.1346	50.5248	55.9312
-3	34.1047	39.5353	44.957	50.3504	55.76
-2	33.927	39.3604	44.7842	50.1808	55.5934
-1	33.7541	39.1903	44.6162	50.016	55.4314
0	33.586	39.025	44.453	49.856	55.274

Table (B.5) Compressor work (kW) for R-12 with different values of Tc for Standard cycle

Te °C	**Tc** = 30 °C	**Tc** = 35 °C	**Tc** = 40 °C	**Tc** = 45 °C	**Tc** = 50 °C
-20	0.062	0.0672	0.0721	0.0774	0.082
-19	0.0627	0.0681	0.0731	0.0786	0.0834
-18	0.0634	0.069	0.0741	0.0798	0.0847
-17	0.0641	0.0699	0.0751	0.0809	0.086
-16	0.0647	0.0707	0.0761	0.0821	0.0873
-15	0.0653	0.0715	0.0771	0.0832	0.0886
-14	0.0659	0.0722	0.078	0.0843	0.0898

-13	0.0664	0.073	0.0789	0.0853	0.091
-12	0.0669	0.0736	0.0797	0.0864	0.0922
-11	0.0674	0.0743	0.0805	0.0874	0.0934
-10	0.0678	0.0749	0.0813	0.0883	0.0945
-9	0.0682	0.0755	0.0821	0.0893	0.0957
-8	0.0685	0.076	0.0828	0.0902	0.0967
-7	0.0688	0.0766	0.0835	0.091	0.0978
-6	0.0691	0.077	0.0842	0.0919	0.0988
-5	0.0693	0.0774	0.0848	0.0927	0.0998
-4	0.0695	0.0778	0.0854	0.0934	0.1007
-3	0.0696	0.0782	0.0859	0.0942	0.1016
-2	0.0697	0.0785	0.0864	0.0948	0.1025
-1	0.0697	0.0787	0.0868	0.0955	0.1033
0	0.0697	0.0789	0.0873	0.0961	0.1041

Table (B.6) Compressor work (kW) for R-134a with different values of Tc for Standard cycle

Te ^{o}C	**Tc** = 30 ^{o}C	**Tc** = 35 ^{o}C	**Tc** = 40 ^{o}C	**Tc** = 45 ^{o}C	**Tc** = 50 ^{o}C
-20	0.0596	0.0646	0.0693	0.0741	0.0785
-19	0.0607	0.0657	0.0706	0.0754	0.0799
-18	0.0617	0.0669	0.0719	0.0768	0.0813
-17	0.0628	0.068	0.0731	0.0781	0.0827
-16	0.0637	0.0692	0.0743	0.0794	0.084
-15	0.0647	0.0702	0.0755	0.0807	0.0853
-14	0.0656	0.0713	0.0767	0.0819	0.0866
-13	0.0665	0.0723	0.0778	0.0831	0.0878
-12	0.0674	0.0733	0.0789	0.0843	0.089

-11	0.0682	0.0742	0.0799	0.0854	0.0902
-10	0.069	0.0751	0.0809	0.0865	0.0913
-9	0.0697	0.076	0.0819	0.0875	0.0924
-8	0.0704	0.0768	0.0828	0.0885	0.0934
-7	0.0711	0.0776	0.0837	0.0895	0.0944
-6	0.0717	0.0783	0.0845	0.0903	0.0953
-5	0.0722	0.0789	0.0852	0.0912	0.0962
-4	0.0727	0.0796	0.086	0.0919	0.097
-3	0.0731	0.0801	0.0866	0.0927	0.0977
-2	0.0735	0.0806	0.0872	0.0933	0.0984
-1	0.0738	0.0811	0.0877	0.0939	0.099
0	0.0741	0.0814	0.0882	0.0944	0.0996

Table (B.7) Heat rejection rate (kW) for R-12 with different values of Tc for Standard cycle

Te ^oC	**Tc** = 30 ^oC	**Tc** = 35 ^oC	**Tc** = 40 ^oC	**Tc** = 45 ^oC	**Tc** = 50 ^oC
-20	0.3136	0.3079	0.3016	0.2957	0.2888
-19	0.3247	0.3188	0.3122	0.306	0.2988
-18	0.3361	0.3299	0.3231	0.3166	0.3091
-17	0.3478	0.3414	0.3342	0.3275	0.3197
-16	0.3598	0.3532	0.3457	0.3387	0.3306
-15	0.3722	0.3653	0.3575	0.3502	0.3418
-14	0.3849	0.3777	0.3697	0.362	0.3533

-13	0.398	0.3905	0.3821	0.3741	0.3651
-12	0.4114	0.4036	0.3949	0.3866	0.3772
-11	0.4251	0.417	0.408	0.3994	0.3897
-10	0.4392	0.4308	0.4215	0.4125	0.4024
-9	0.4537	0.445	0.4353	0.4259	0.4155
-8	0.4686	0.4595	0.4495	0.4397	0.429
-7	0.4838	0.4744	0.464	0.4539	0.4428
-6	0.4994	0.4897	0.4789	0.4684	0.4569
-5	0.5155	0.5053	0.4942	0.4833	0.4714
-4	0.5319	0.5214	0.5099	0.4986	0.4863
-3	0.5487	0.5378	0.5259	0.5143	0.5015
-2	0.5659	0.5547	0.5424	0.5303	0.5171
-1	0.5836	0.572	0.5592	0.5468	0.5331
0	0.6017	0.5897	0.5765	0.5636	0.5495

Table (B.8) Heat rejection rate (kW) for R-134a with different values of Tc for Standard cycle

Te °C	**Tc** = 30 °C	**Tc** = 35 °C	**Tc** = 40 °C	**Tc** = 45 °C	**Tc** = 50 °C
-20	0.297	0.29	0.2826	0.2751	0.2669
-19	0.309	0.3016	0.2938	0.2859	0.2772
-18	0.3214	0.3135	0.3053	0.297	0.2879
-17	0.3341	0.3259	0.3172	0.3084	0.2988
-16	0.3473	0.3386	0.3295	0.3202	0.3101
-15	0.3608	0.3516	0.3421	0.3324	0.3218
-14	0.3747	0.3651	0.3551	0.3449	0.3337
-13	0.3891	0.379	0.3685	0.3577	0.346

-12	0.4039	0.3933	0.3823	0.371	0.3587
-11	0.4191	0.408	0.3964	0.3846	0.3718
-10	0.4347	0.4231	0.411	0.3986	0.3852
-9	0.4508	0.4386	0.426	0.413	0.3989
-8	0.4673	0.4546	0.4413	0.4278	0.4131
-7	0.4843	0.471	0.4572	0.443	0.4276
-6	0.5017	0.4878	0.4734	0.4586	0.4426
-5	0.5196	0.5051	0.4901	0.4746	0.4579
-4	0.538	0.5229	0.5072	0.4911	0.4737
-3	0.5569	0.5411	0.5248	0.508	0.4898
-2	0.5762	0.5598	0.5428	0.5253	0.5064
-1	0.5961	0.579	0.5613	0.5431	0.5234

Table (B.9) Refrigeration capacity (kW) for R-12 with different values of Tc for Standard cycle

Te °C	**Tc** = 30 °C	**Tc** = 35 °C	**Tc** = 40 °C	**Tc** = 45 °C	**Tc** = 50 °C
-20	0.2541	0.2431	0.2318	0.2204	0.2088
-19	0.2646	0.2531	0.2415	0.2296	0.2176
-18	0.2754	0.2635	0.2514	0.2392	0.2267
-17	0.2866	0.2742	0.2617	0.2490	0.2360
-16	0.2981	0.2853	0.2723	0.2592	0.2457
-15	0.3100	0.2967	0.2833	0.2697	0.2558

-14	0.3222	0.3085	0.2946	0.2805	0.2661
-13	0.3349	0.3207	0.3063	0.2917	0.2768
-12	0.3479	0.3332	0.3183	0.3032	0.2878
-11	0.3613	0.3461	0.3307	0.3151	0.2992
-10	0.3751	0.3594	0.3435	0.3274	0.3110
-9	0.3894	0.3732	0.3567	0.3400	0.3231
-8	0.4040	0.3873	0.3703	0.3531	0.3356
-7	0.4191	0.4018	0.3843	0.3665	0.3484
-6	0.4346	0.4168	0.3987	0.3803	0.3617
-5	0.4506	0.4322	0.4135	0.3946	0.3754
-4	0.4670	0.4480	0.4287	0.4092	0.3894
-3	0.4839	0.4643	0.4444	0.4243	0.4039
-2	0.5012	0.4810	0.4605	0.4398	0.4188
-1	0.5190	0.4982	0.4771	0.4558	0.4341
0	0.5372	0.5158	0.4941	0.4722	0.4499

Table (B.10) Refrigeration capacity (kW) for R-134a with different values of Tc for Standard cycle

Te °C	**Tc** = 30 °C	**Tc** = 35 °C	**Tc** = 40 °C	**Tc** = 45 °C	**Tc** = 50 °C
-20	0.2374	0.2254	0.2133	0.201	0.1884
-19	0.2483	0.2358	0.2232	0.2104	0.1973
-18	0.2596	0.2466	0.2335	0.2202	0.2066
-17	0.2714	0.2578	0.2441	0.2303	0.2162
-16	0.2835	0.2694	0.2552	0.2408	0.2261

-15	0.2961	0.2814	0.2666	0.2517	0.2364
-14	0.3091	0.2938	0.2784	0.2629	0.2471
-13	0.3226	0.3067	0.2907	0.2746	0.2582
-12	0.3365	0.32	0.3034	0.2867	0.2697
-11	0.3509	0.3337	0.3165	0.2992	0.2816
-10	0.3657	0.3479	0.3301	0.3121	0.2938
-9	0.3811	0.3626	0.3441	0.3255	0.3066
-8	0.3969	0.3778	0.3585	0.3393	0.3197
-7	0.4132	0.3934	0.3735	0.3535	0.3333
-6	0.4301	0.4095	0.3889	0.3683	0.3473
-5	0.4474	0.4262	0.4048	0.3835	0.3618
-4	0.4653	0.4433	0.4213	0.3992	0.3767
-3	0.4838	0.461	0.4382	0.4153	0.3921
-2	0.5027	0.4792	0.4556	0.432	0.408
-1	0.5223	0.4979	0.4736	0.4492	0.4244
0	0.5424	0.5172	0.4921	0.4669	0.4413

Table (B.11) Coefficient of performance for R-12 with different values of Tc for Standard cycle

Te °C	**Tc** = 30 °C	**Tc** = 35 °C	**Tc** = 40 °C	**Tc** = 45 °C	**Tc** = 50 °C
-20	4.0609	3.5787	3.1859	2.8202	2.5199
-19	4.1788	3.6774	3.2706	2.893	2.5833
-18	4.3013	3.7799	3.3583	2.9683	2.6488
-17	4.4288	3.8861	3.449	3.0461	2.7165
-16	4.5613	3.9963	3.543	3.1265	2.7863
-15	4.6991	4.1106	3.6403	3.2097	2.8585

-14	4.8425	4.2292	3.741	3.2957	2.933
-13	4.9917	4.3523	3.8454	3.3846	3.01
-12	5.1471	4.4801	3.9534	3.4766	3.0895
-11	5.3088	4.6127	4.0654	3.5717	3.1717
-10	5.4774	4.7505	4.1814	3.6701	3.2565
-9	5.653	4.8937	4.3016	3.7719	3.3442
-8	5.8362	5.0424	4.4262	3.8772	3.4349
-7	6.0272	5.197	4.5554	3.9862	3.5285
-6	6.2266	5.3577	4.6894	4.099	3.6253
-5	6.4348	5.5249	4.8284	4.2158	3.7253
-4	6.6523	5.6989	4.9725	4.3367	3.8288
-3	6.8798	5.88	5.1222	4.4619	3.9357
-2	7.1177	6.0687	5.2776	4.5915	4.0463
-1	7.3668	6.2653	5.439	4.7259	4.1607
0	7.6278	6.4703	5.6067	4.8652	4.2791

Table (B.12) Coefficient of performance for R-134a with different values of Tc for Standard cycle

Te °C	**Tc** = 30 °C	**Tc** = 35 °C	**Tc** = 40 °C	**Tc** = 45 °C	**Tc** = 50 °C
-20	3.9808	3.4924	3.078	2.7146	2.4008
-19	4.0908	3.5875	3.1617	2.7897	2.4698
-18	4.2051	3.6862	3.2487	2.8676	2.5412
-17	4.3239	3.7888	3.3389	2.9484	2.6153
-16	4.4474	3.8954	3.4326	3.0323	2.6921

-15	4.5759	4.0062	3.53	3.1194	2.7717
-14	4.7096	4.1214	3.6313	3.2098	2.8544
-13	4.8487	4.2413	3.7365	3.3038	2.9402
-12	4.9936	4.366	3.8459	3.4015	3.0293
-11	5.1446	4.4958	3.9597	3.5031	3.122
-10	5.3018	4.631	4.0782	3.6087	3.2183
-9	5.4659	4.7718	4.2015	3.7187	3.3184
-8	5.637	4.9185	4.33	3.8331	3.4227
-7	5.8156	5.0716	4.4638	3.9523	3.5312
-6	6.0022	5.2312	4.6034	4.0765	3.6442
-5	6.1972	5.3979	4.749	4.206	3.762
-4	6.4011	5.572	4.9009	4.3411	3.8848
-3	6.6146	5.7539	5.0595	4.4821	4.013
-2	6.8383	5.9442	5.2253	4.6293	4.1468
-1	7.0727	6.1434	5.3986	4.7832	4.2866
0	7.3187	6.3521	5.58	4.9441	4.4327

Table (B.13) Mass flow rate (kg/s) for R-12 with different values of Te for Standard cycle

Tc °C	**Te** = -20 °C	**Te** = -15 °C	**Te** = -10 °C	**Te** =-5 °C	**Te** = 0 °C
30	0.0026	0.0032	0.0039	0.0047	0.0055
31	0.0026	0.0032	0.0039	0.0047	0.0055
32	0.0026	0.0032	0.0039	0.0047	0.0055
33	0.0026	0.0032	0.0039	0.0047	0.0055
34	0.0026	0.0032	0.0039	0.0046	0.0055
35	0.0026	0.0032	0.0038	0.0046	0.0055

36	0.0025	0.0032	0.0038	0.0046	0.0055
37	0.0025	0.0032	0.0038	0.0046	0.0055
38	0.0025	0.0032	0.0038	0.0046	0.0055
39	0.0025	0.0031	0.0038	0.0046	0.0055
40	0.0025	0.0031	0.0038	0.0046	0.0054
41	0.0025	0.0031	0.0038	0.0046	0.0054
42	0.0025	0.0031	0.0038	0.0046	0.0054
43	0.0025	0.0031	0.0038	0.0045	0.0054
44	0.0025	0.0031	0.0038	0.0045	0.0054
45	0.0025	0.0030	0.0037	0.0045	0.0054
46	0.0024	0.0030	0.0037	0.0045	0.0054
47	0.0024	0.0030	0.0037	0.0044	0.0053
48	0.0024	0.0030	0.0037	0.0044	0.0053
49	0.0024	0.0030	0.0037	0.0044	0.0053
50	0.0024	0.0030	0.0037	0.0044	0.0053

Table (B.14) Mass flow rate (kg/s) for R-134a with different values of Te for Standard cycle

Tc °C	**Te** = -20 °C	**Te** = -15 °C	**Te** = -10 °C	**Te** =-5 °C	**Te** = 0 °C
30	0.0019	0.0024	0.003	0.0036	0.0044
31	0.0019	0.0024	0.0029	0.0036	0.0044
32	0.0019	0.0024	0.0029	0.0036	0.0044
33	0.0019	0.0024	0.0029	0.0036	0.0044
34	0.0018	0.0023	0.0029	0.0036	0.0044
35	0.0018	0.0023	0.0029	0.0036	0.0043

36	0.0018	0.0023	0.0029	0.0036	0.0043
37	0.0018	0.0023	0.0029	0.0036	0.0043
38	0.0018	0.0023	0.0029	0.0036	0.0043
39	0.0018	0.0023	0.0029	0.0035	0.0043
40	0.0018	0.0023	0.0028	0.0035	0.0043
41	0.0017	0.0022	0.0028	0.0035	0.0042
42	0.0017	0.0022	0.0028	0.0035	0.0042
43	0.0017	0.0022	0.0028	0.0035	0.0042
44	0.0017	0.0022	0.0028	0.0035	0.0042
45	0.0017	0.0022	0.0028	0.0035	0.0042
46	0.0016	0.002	0.0028	0.0034	0.0041
47	0.0016	0.002	0.0027	0.0034	0.0041
48	0.0016	0.002	0.0027	0.0034	0.0041
49	0.0016	0.002	0.0027	0.0034	0.0041
50	0.0016	0.0021	0.0027	0.0034	0.0041

Table (B.15) Discharge temperature (°C) for R-12 with different values of Te for Standard cycle

Tc °C	**Te** = -20 °C	**Te** = -15 °C	**Te** = -10 °C	**Te** =-5 °C	**Te** = 0 °C
30	39.884	38.2805	36.872	35.6585	34.64
31	40.8776	39.3396	38.0293	36.8237	35.7357
32	41.982	40.446	39.139	37.9325	36.8465
33	43.0852	41.5512	40.2477	39.0403	37.9563
34	44.1872	42.6552	41.3554	40.1471	39.0651

35	45.278	43.781	42.429	41.222	40.16
36	46.3876	44.8596	43.5678	42.3577	41.2797
37	47.486	45.96	44.6725	43.4615	42.3855
38	48.5832	47.0592	45.7762	44.5643	43.4903
39	49.6792	48.1572	46.8789	45.6661	44.5941
40	50.77	49.28	47.935	46.735	45.68
41	51.8676	50.3496	49.0813	47.8667	46.7987
42	52.96	51.444	50.181	48.9655	47.8995
43	54.0512	52.5372	51.2797	50.0633	48.9993
44	55.1412	53.6292	52.3774	51.1601	50.0981
45	56.202	54.7235	53.39	52.2015	51.158
46	57.3176	55.8096	54.5698	53.3507	52.2927
47	58.404	56.898	55.6645	54.4445	53.3885
48	59.4892	57.9852	56.7582	55.5373	54.4833
49	60.5732	59.0712	57.8509	56.6291	55.5771
50	61.66	60.1875	58.86	57.6775	56.64

Table (B.16) Discharge temperature (^oC) for R-134a with different values of Te for Standard cycle

Tc ^oC	**Te** = -20 ^oC	**Te** = -15 ^oC	**Te** = -10 ^oC	**Te** =-5 ^oC	**Te** = 0 ^oC
30	37.86	36.6115	35.483	34.4745	33.586
31	38.8451	37.6191	36.4263	35.558	34.7
32	39.9215	38.6962	37.5066	36.6403	35.7876
33	40.9973	39.7727	38.5863	37.7222	36.8748
34	42.0725	40.8486	39.6654	38.8037	37.9616
35	43.243	42.0085	40.894	39.8995	39.025

36	44.2211	42.9986	41.8218	40.9655	40.134
37	45.2945	44.0727	42.8991	42.0458	41.2196
38	46.3673	45.1462	43.9758	43.1257	42.3048
39	47.4395	46.2191	45.0519	44.2052	43.3896
40	48.629	47.405	46.301	45.317	44.453
41	49.5821	48.3631	47.2023	46.363	45.558
42	50.6525	49.4342	48.2766	47.4413	46.6416
43	51.7223	50.5047	49.3503	48.5192	47.7248
44	52.7915	51.5746	50.4234	49.5967	48.8076
45	53.968	52.76	51.672	50.704	49.856
46	54.9281	53.7126	52.5678	51.7505	50.972
47	55.9955	54.7807	53.6391	52.8268	52.0536
48	57.0623	55.8482	54.7098	53.9027	53.1348
49	58.1285	56.9151	55.7799	54.9782	54.2156
50	59.296	58.118	57.055	56.107	55.274

Table (B.17) Compressor work (kW) for R-12 with different values of Te for Standard cycle

Tc °C	**Te** = -20 °C	**Te** = -15 °C	**Te** = -10 °C	**Te** =-5 °C	**Te** = 0 °C
30	0.062	0.0653	0.0678	0.0693	0.0697
31	0.0629	0.0663	0.0687	0.0698	0.0702
32	0.0639	0.0674	0.07	0.071	0.0719
33	0.0648	0.0685	0.0713	0.0725	0.0736
34	0.0658	0.0696	0.0725	0.0739	0.0752
35	0.0672	0.0715	0.0749	0.0774	0.0789

36	0.0675	0.0717	0.0761	0.0776	0.0791
37	0.0683	0.0726	0.077	0.0779	0.0798
38	0.0691	0.0736	0.0775	0.0791	0.0812
39	0.0699	0.0744	0.0781	0.0803	0.0826
40	0.0721	0.0771	0.0813	0.0883	0.0945
41	0.073	0.0772	0.0821	0.0885	0.0948
42	0.0741	0.0773	0.0823	0.0887	0.0951
43	0.0752	0.0775	0.0825	0.09	0.0956
44	0.0763	0.0781	0.0827	0.0918	0.0959
45	0.0774	0.0832	0.0883	0.0927	0.0961
46	0.0778	0.0839	0.0889	0.0932	0.0968
47	0.0781	0.0842	0.0891	0.0948	0.0974
48	0.079	0.0863	0.0899	0.0956	0.098
49	0.0796	0.0877	0.0921	0.0978	0.0992
50	0.082	0.0886	0.0945	0.0998	0.1041

Table (B.18) Compressor work (kW) for R-134a with different values of Te for Standard cycle

Tc ^{o}**C**	**Te** = -20 ^{o}C	**Te** = -15 ^{o}C	**Te** = -10 ^{o}C	**Te** =-5 ^{o}C	**Te** = 0 ^{o}C
30	0.0596	0.0647	0.069	0.0722	0.0741
31	0.0602	0.0651	0.0715	0.0735	0.0752
32	0.0606	0.0658	0.0726	0.0754	0.0763
33	0.0611	0.0661	0.0737	0.0768	0.0775
34	0.0615	0.0668	0.0743	0.0772	0.0779

35	0.0646	0.0702	0.0751	0.0789	0.0814
36	0.0652	0.0667	0.0762	0.081	0.0832
37	0.0667	0.067	0.0774	0.0823	0.0849
38	0.0675	0.0673	0.0782	0.0841	0.086
39	0.0684	0.0676	0.0791	0.0748	0.0878
40	0.0693	0.0755	0.0809	0.0852	0.0882
41	0.071	0.0762	0.0812	0.0861	0.0891
42	0.0723	0.0769	0.0824	0.0868	0.091
43	0.0734	0.0771	0.0838	0.0871	0.0928
44	0.0738	0.0775	0.085	0.0885	0.0937
45	0.0741	0.0807	0.0865	0.0912	0.0944
46	0.0751	0.0812	0.0871	0.0924	0.0952
47	0.0758	0.0823	0.0876	0.0938	0.0963
48	0.0764	0.0835	0.0882	0.0945	0.0974
49	0.0773	0.0841	0.0892	0.0958	0.0981
50	0.0785	0.0853	0.0913	0.0962	0.0996

Table (B.19) Heat rejection rate (kW) for R-12 with different values of Te for Standard cycle

Tc ^{o}C	**Te** = -20 ^{o}C	**Te** = -15 ^{o}C	**Te** = -10 ^{o}C	**Te** =-5 ^{o}C	**Te** = 0 ^{o}C
30	0.3136	0.3722	0.4392	0.5155	0.6017
31	0.3127	0.3708	0.4371	0.5123	0.5973
32	0.3118	0.3695	0.4354	0.5103	0.5949
33	0.3109	0.3682	0.4337	0.5081	0.5924
34	0.3099	0.3668	0.4319	0.506	0.5898

35	0.3079	0.3653	0.4308	0.5053	0.5897
36	0.3078	0.364	0.4282	0.5015	0.5845
37	0.3067	0.3624	0.4263	0.4991	0.5817
38	0.3056	0.3609	0.4243	0.4967	0.5789
39	0.3044	0.3592	0.4222	0.4942	0.576
40	0.3016	0.3575	0.4215	0.4942	0.5765
41	0.3014	0.3558	0.4179	0.489	0.5699
42	0.3004	0.354	0.4156	0.4863	0.5668
43	0.299	0.3521	0.4133	0.4835	0.5635
44	0.2975	0.3511	0.4109	0.4806	0.5602
45	0.2957	0.3502	0.4125	0.4833	0.5636
46	0.2943	0.346	0.4058	0.4746	0.5533
47	0.2926	0.344	0.4031	0.4715	0.5497
48	0.2908	0.343	0.4004	0.4683	0.546
49	0.289	0.3401	0.3975	0.4649	0.5422
50	0.2888	0.3418	0.4024	0.4714	0.5495

Table (B.20) Heat rejection rate (kW) for R-134a with different values of Te for Standard cycle

Tc °C	**Te** = -20 °C	**Te** = -15 °C	**Te** = -10 °C	**Te** =-5 °C	**Te** = 0 °C
30	0.297	0.3608	0.4347	0.5196	0.5961
31	0.2952	0.3557	0.4282	0.5124	0.595
32	0.2934	0.3534	0.4254	0.509	0.594
33	0.2915	0.352	0.4247	0.5076	0.587
34	0.2911	0.3519	0.4239	0.5061	0.581

35	0.29	0.3516	0.4231	0.5051	0.579
36	0.2855	0.349	0.4136	0.4948	0.571
37	0.284	0.3487	0.4125	0.493	0.564
38	0.2835	0.345	0.412	0.4925	0.562
39	0.283	0.343	0.4118	0.492	0.561
40	0.2826	0.3421	0.411	0.4901	0.5613
41	0.281	0.341	0.409	0.4755	0.559
42	0.279	0.339	0.399	0.4715	0.551
43	0.277	0.336	0.398	0.4674	0.549
44	0.276	0.335	0.3988	0.4746	0.547
45	0.2751	0.3324	0.3986	0.4597	0.5455
46	0.273	0.3318	0.399	0.459	0.5405
47	0.2701	0.33	0.387	0.4587	0.5355
48	0.268	0.3289	0.3865	0.4584	0.5303
49	0.2675	0.324	0.3859	0.4481	0.5252
50	0.267	0.320	0.3841	0.4521	0.5211

Table (B.21) Refrigeration capacity (kW) for R-12 with different values of Te for Standard cycle

Tc °C	**Te** = -20 °C	**Te** = -15 °C	**Te** = -10 °C	**Te** =-5 °C	**Te** = 0 °C
30	0.2541	0.3100	0.3751	0.4506	0.5372
31	0.2494	0.3043	0.3683	0.4427	0.5283
32	0.2472	0.3017	0.3651	0.439	0.524
33	0.245	0.299	0.362	0.4353	0.5197
34	0.2438	0.297	0.3599	0.4326	0.5164

35	0.2431	0.2967	0.3594	0.4322	0.5158
36	0.2383	0.291	0.3525	0.4242	0.5068
37	0.2361	0.2884	0.3494	0.4205	0.5024
38	0.2338	0.2857	0.3462	0.4167	0.4981
39	0.2326	0.284	0.345	0.414	0.4957
40	0.2318	0.2833	0.3435	0.4135	0.4941
41	0.2271	0.2776	0.3366	0.4054	0.485
42	0.2248	0.2748	0.3333	0.4017	0.4806
43	0.2225	0.2721	0.3301	0.3979	0.4762
44	0.2212	0.2699	0.3298	0.3951	0.4737
45	0.2204	0.2697	0.3274	0.3946	0.4722
46	0.2156	0.2638	0.3203	0.3864	0.4628
47	0.2133	0.2611	0.317	0.3825	0.4584
48	0.2109	0.2583	0.3137	0.3787	0.4539
49	0.209	0.2565	0.3124	0.3778	0.450
50	0.2088	0.2558	0.3110	0.3754	0.4499

Table (B.22) Refrigeration capacity (kW) for R-134a with different values of Te for Standard cycle

Tc °C	**Te** = -20 °C	**Te** = -15 °C	**Te** = -10 °C	**Te** =-5 °C	**Te** = 0 °C
30	0.2374	0.2961	0.3657	0.4474	0.5424
31	0.235	0.2911	0.3603	0.442	0.5382
32	0.2325	0.2882	0.3567	0.4377	0.533

33	0.2301	0.2852	0.3531	0.4334	0.5279
34	0.2277	0.2823	0.3495	0.4292	0.5229
35	0.2254	0.2814	0.3479	0.4262	0.5172
36	0.2229	0.2764	0.3424	0.4206	0.5128
37	0.2205	0.2735	0.3389	0.4164	0.5078
38	0.2181	0.2705	0.3353	0.4122	0.5028
39	0.2157	0.2676	0.3318	0.408	0.4978
40	0.2133	0.2666	0.3301	0.4048	0.4921
41	0.2109	0.2618	0.3248	0.3996	0.4879
42	0.2085	0.2589	0.3213	0.3955	0.483
43	0.2061	0.256	0.3179	0.3913	0.4781
44	0.2037	0.2532	0.3144	0.3872	0.4732
45	0.201	0.2517	0.3121	0.3835	0.4669
46	0.1989	0.2474	0.3075	0.379	0.4635
47	0.1965	0.2446	0.3041	0.3749	0.4586
48	0.1941	0.2417	0.3006	0.3708	0.4538
49	0.1917	0.2388	0.2972	0.3667	0.449
50	0.1884	0.2364	0.2938	0.3618	0.4443

Table (B.23) Coefficient of performance for R-12 with different values of Te for Standard cycle

Tc ^{o}C	**Te** = -20 ^{o}C	**Te** = -15 ^{o}C	**Te** = -10 ^{o}C	**Te** =-5 ^{o}C	**Te** = 0 ^{o}C
30	4.0609	4.6991	5.4774	6.4348	7.6278
31	3.9625	4.5909	5.3634	6.3685	7.5291
32	3.8681	4.4746	5.2179	6.1824	7.2902
33	3.7778	4.3636	5.0799	6.0068	7.0661

34	3.6913	4.2579	4.9489	5.8411	6.8558
35	3.5787	4.1106	4.7505	5.5249	6.4703
36	3.5297	4.0614	4.707	5.5368	6.451
37	3.4543	3.9702	4.5954	5.3973	6.2981
38	3.3824	3.8835	4.4895	5.2655	6.1339
39	3.3138	3.8011	4.3893	5.141	5.9795
40	3.1859	3.6403	4.1814	4.8284	5.6067
41	3.1866	3.6486	4.162	4.8126	5.985
42	3.1277	3.5782	4.1194	4.8079	5.5687
43	3.0719	3.5116	4.039	4.7092	5.4477
44	3.019	3.3486	3.8632	4.4162	5.3339
45	2.8202	3.2097	3.6701	4.2158	4.8652
46	2.811	3.104	3.534	4.155	4.766
47	2.752	2.987	3.447	3.958	4.656
48	2.701	2.921	3.327	3.868	4.488
49	2.6482	2.886	3.299	3.797	4.356
50	2.5199	2.8585	3.2565	3.7253	4.2791

Table (B.24) Coefficient of performance for R-134a with different values of Te for Standard cycle

Tc ^oC	**Te** = -20 ^oC	**Te** = -15 ^oC	**Te** = -10 ^oC	**Te** =-5 ^oC	**Te** = 0 ^oC
30	3.9808	4.5759	5.3018	6.1972	7.3187
31	3.9057	4.5181	5.289	6.0102	7.1712
32	3.8349	4.4341	5.2213	5.8897	6.8158
33	3.7681	4.355	5.1258	5.7642	6.6709

34	3.6047	4.2803	5.0358	5.5551	6.4354
35	3.4924	4.0062	4.631	5.3979	6.1521
36	3.4872	3.965	4.5708	4.9886	5.8895
37	3.3323	3.886	4.4949	4.8688	5.7777
38	3.2798	3.746	4.3227	4.8004	5.6924
39	3.1292	3.664	4.2541	4.799	5.6008
40	3.078	3.530	4.0782	4.749	5.580
41	2.986	3.4499	3.965	4.6489	5.4905
42	2.885	3.398	3.821	4.5784	5.3063
43	2.801	3.2878	3.789	4.411	5.2262
44	2.799	3.201	3.722	4.3464	5.15
45	2.7146	3.1194	3.6087	4.206	4.9441
46	2.6937	2.9052	3.5459	4.0245	4.8076
47	2.609	2.8897	3.495	3.9667	4.7409
48	2.5895	2.8014	3.3452	3.8807	4.6767
49	2.4873	2.799	3.2965	3.8063	4.5149
50	2.4008	2.7717	3.2183	3.762	4.4327

Table (B.25) Comparison between R-12 & R-134a with different values of Tc for Compressor work to Standard cycle

Te °C	Tc = 30 °C		Tc = 35 °C		Tc = 40 °C		Tc = 45 °C		Tc = 50 °C	
	R-12	R-134a	R-12	R-134a	R-12	R-134a	R-12	R-134a	R-12	R-134a
-20	0.062	0.0596	0.0672	0.0646	0.0721	0.0693	0.0774	0.0741	0.082	0.0785
-19	0.0627	0.0607	0.0681	0.0657	0.0731	0.0706	0.0786	0.0754	0.0834	0.0799
-18	0.0634	0.0617	0.069	0.0669	0.0741	0.0719	0.0798	0.0768	0.0847	0.0813
-17	0.0641	0.0628	0.0699	0.068	0.0751	0.0731	0.0809	0.0781	0.086	0.0827

-16	0.0647	0.0637	0.0707	0.0692	0.0761	0.0743	0.0821	0.0794	0.0873	0.084
-15	0.0653	0.0647	0.0715	0.0702	0.0771	0.0755	0.0832	0.0807	0.0886	0.0853
-14	0.0659	0.0656	0.0722	0.0713	0.078	0.0767	0.0843	0.0819	0.0898	0.0866
-13	0.0664	0.0665	0.073	0.0723	0.0789	0.0778	0.0853	0.0831	0.091	0.0878
-12	0.0669	0.0674	0.0736	0.0733	0.0797	0.0789	0.0864	0.0843	0.0922	0.089
-11	0.0674	0.0682	0.0743	0.0742	0.0805	0.0799	0.0874	0.0854	0.0934	0.0902
-10	0.0678	0.069	0.0749	0.0751	0.0813	0.0809	0.0883	0.0865	0.0945	0.0913
-9	0.0682	0.0697	0.0755	0.076	0.0821	0.0819	0.0893	0.0875	0.0957	0.0924
-8	0.0685	0.0704	0.076	0.0768	0.0828	0.0828	0.0902	0.0885	0.0967	0.0934
-7	0.0688	0.0711	0.0766	0.0776	0.0835	0.0837	0.091	0.0895	0.0978	0.0944
-6	0.0691	0.0717	0.077	0.0783	0.0842	0.0845	0.0919	0.0903	0.0988	0.0953
-5	0.0693	0.0722	0.0774	0.0789	0.0848	0.0852	0.0927	0.0912	0.0998	0.0962
-4	0.0695	0.0727	0.0778	0.0796	0.0854	0.086	0.0934	0.0919	0.1007	0.097
-3	0.0696	0.0731	0.0782	0.0801	0.0859	0.0866	0.0942	0.0927	0.1016	0.0977
-2	0.0697	0.0735	0.0785	0.0806	0.0864	0.0872	0.0948	0.0933	0.1025	0.0984
-1	0.0697	0.0738	0.0787	0.0811	0.0868	0.0877	0.0955	0.0939	0.1033	0.099
0	0.0697	0.0741	0.0789	0.0814	0.0873	0.0882	0.0961	0.0944	0.1041	0.0996

Table (B.26) Comparison between R-12 & R-134a with different values of Tc for Refrigeration capacity to Standard cycle

Te °C	**Tc** = 30 °C		**Tc** = 35 °C		**Tc** = 40 °C		**Tc** = 45 °C		**Tc** = 50 °C	
	R-12	R-134a	R-12	R-134a	R-12	R-134a	R-12	R-134a	R-12	R-134a
-20	0.2541	0.2374	0.2431	0.2254	0.2318	0.2133	0.2204	0.201	0.2088	0.1884
-19	0.2646	0.2483	0.2531	0.2358	0.2415	0.2232	0.2296	0.2104	0.2176	0.1973
-18	0.2754	0.2596	0.2635	0.2466	0.2514	0.2335	0.2392	0.2202	0.2267	0.2066
-17	0.2866	0.2714	0.2742	0.2578	0.2617	0.2441	0.2490	0.2303	0.2360	0.2162

-16	0.2981	0.2835	0.2853	0.2694	0.2723	0.2552	0.2592	0.2408	0.2457	0.2261
-15	0.3100	0.2961	0.2967	0.2814	0.2833	0.2666	0.2697	0.2517	0.2558	0.2364
-14	0.3222	0.3091	0.3085	0.2938	0.2946	0.2784	0.2805	0.2629	0.2661	0.2471
-13	0.3349	0.3226	0.3207	0.3067	0.3063	0.2907	0.2917	0.2746	0.2768	0.2582
-12	0.3479	0.3365	0.3332	0.32	0.3183	0.3034	0.3032	0.2867	0.2878	0.2697
-11	0.3613	0.3509	0.3461	0.3337	0.3307	0.3165	0.3151	0.2992	0.2992	0.2816
-10	0.3751	0.3657	0.3594	0.3479	0.3435	0.3301	0.3274	0.3121	0.3110	0.2938
-9	0.3894	0.3811	0.3732	0.3626	0.3567	0.3441	0.3400	0.3255	0.3231	0.3066
-8	0.4040	0.3969	0.3873	0.3778	0.3703	0.3585	0.3531	0.3393	0.3356	0.3197
-7	0.4191	0.4132	0.4018	0.3934	0.3843	0.3735	0.3665	0.3535	0.3484	0.3333
-6	0.4346	0.4301	0.4168	0.4095	0.3987	0.3889	0.3803	0.3683	0.3617	0.3473
-5	0.4506	0.4474	0.4322	0.4262	0.4135	0.4048	0.3946	0.3835	0.3754	0.3618
-4	0.4670	0.4653	0.4480	0.4433	0.4287	0.4213	0.4092	0.3992	0.3894	0.3767
-3	0.4839	0.4838	0.4643	0.461	0.4444	0.4382	0.4243	0.4153	0.4039	0.3921
-2	0.5012	0.5027	0.4810	0.4792	0.4605	0.4556	0.4398	0.432	0.4188	0.408
-1	0.5190	0.5223	0.4982	0.4979	0.4771	0.4736	0.4558	0.4492	0.4341	0.4244
0	0.5372	0.5424	0.5158	0.5172	0.4941	0.4921	0.4722	0.4669	0.4499	0.4413

Table (B.27) Comparison between R-12 & R-134a with different values of Tc for Coefficient of performance to Standard cycle

Te °C	**Tc** = 30 °C		**Tc** = 35 °C		**Tc** = 40 °C		**Tc** = 45 °C		**Tc** = 50 °C	
	R-12	R-134a	R-12	R-134a	R-12	R-134a	R-12	R-134a	R-12	R-134a
-20	4.0609	3.9808	3.5787	3.4924	3.1859	3.078	2.8202	2.7146	2.5199	2.4008
-19	4.1788	4.0908	3.6774	3.5875	3.2706	3.1617	2.893	2.7897	2.5833	2.4698
-18	4.3013	4.2051	3.7799	3.6862	3.3583	3.2487	2.9683	2.8676	2.6488	2.5412
-17	4.4288	4.3239	3.8861	3.7888	3.449	3.3389	3.0461	2.9484	2.7165	2.6153

-16	4.5613	4.4474	3.9963	3.8954	3.543	3.4326	3.1265	3.0323	2.7863	2.6921
-15	4.6991	4.5759	4.1106	4.0062	3.6403	3.53	3.2097	3.1194	2.8585	2.7717
-14	4.8425	4.7096	4.2292	4.1214	3.741	3.6313	3.2957	3.2098	2.933	2.8544
-13	4.9917	4.8487	4.3523	4.2413	3.8454	3.7365	3.3846	3.3038	3.01	2.9402
-12	5.1471	4.9936	4.4801	4.366	3.9534	3.8459	3.4766	3.4015	3.0895	3.0293
-11	5.3088	5.1446	4.6127	4.4958	4.0654	3.9597	3.5717	3.5031	3.1717	3.122
-10	5.4774	5.3018	4.7505	4.631	4.1814	4.0782	3.6701	3.6087	3.2565	3.2183
-9	5.653	5.4659	4.8937	4.7718	4.3016	4.2015	3.7719	3.7187	3.3442	3.3184
-8	5.8362	5.637	5.0424	4.9185	4.4262	4.33	3.8772	3.8331	3.4349	3.4227
-7	6.0272	5.8156	5.197	5.0716	4.5554	4.4638	3.9862	3.9523	3.5285	3.5312
-6	6.2266	6.0022	5.3577	5.2312	4.6894	4.6034	4.099	4.0765	3.6253	3.6442
-5	6.4348	6.1972	5.5249	5.3979	4.8284	4.749	4.2158	4.206	3.7253	3.762
-4	6.6523	6.4011	5.6989	5.572	4.9725	4.9009	4.3367	4.3411	3.8288	3.8848
-3	6.8798	6.6146	5.88	5.7539	5.1222	5.0595	4.4619	4.4821	3.9357	4.013
-2	7.1177	6.8383	6.0687	5.9442	5.2776	5.2253	4.5915	4.6293	4.0463	4.1468
-1	7.3668	7.0727	6.2653	6.1434	5.439	5.3986	4.7259	4.7832	4.1607	4.2866
0	7.6278	7.3187	6.4703	6.3521	5.6067	5.58	4.8652	4.9441	4.2791	4.4327

Table (B.28) Comparison between “standard cycle” & “ideal cycle with superheating and subcooling” with Tc (40 ^{o}C) for (Mf, T_{exit}, W_{comp})

Te ^{o}C	**Mf (kg/s)**		**Discharge temperature (^{o}C)**		**Compressor work (kW)**	
	Standard cycle	Ideal cycle with Superheating & Subcooling	Standard cycle	Ideal cycle with Superheating & Subcooling	Standard cycle	Ideal cycle with Superheating & Subcooling
-20	0.0018	0.0017	48.6290	53.4000	0.0693	0.0702
-19	0.0019	0.0018	48.3746	53.1206	0.0706	0.0715
-18	0.0020	0.0019	48.1250	52.8466	0.0719	0.0728

-17	0.0021	0.0020	47.8802	52.5777	0.0731	0.0741
-16	0.0022	0.0021	47.6402	52.3142	0.0743	0.0753
-15	0.0023	0.0022	47.4050	52.0559	0.0755	0.0765
-14	0.0024	0.0023	47.1746	51.8029	0.0767	0.0777
-13	0.0025	0.0024	46.9490	51.5552	0.0778	0.0788
-12	0.0026	0.0025	46.7282	51.3127	0.0789	0.0799
-11	0.0027	0.0027	46.5122	51.0755	0.0799	0.0810
-10	0.0028	0.0028	46.3010	50.8436	0.0809	0.0820
-9	0.0030	0.0029	46.0946	50.6169	0.0819	0.0830
-8	0.0031	0.0030	45.8930	50.3956	0.0828	0.0839
-7	0.0032	0.0032	45.6962	50.1795	0.0837	0.0848
-6	0.0034	0.0033	45.5042	49.9686	0.0845	0.0856
-5	0.0035	0.0034	45.3170	49.7631	0.0852	0.0864
-4	0.0037	0.0036	45.1346	49.5628	0.0860	0.0871
-3	0.0038	0.0037	44.9570	49.3677	0.0866	0.0877
-2	0.0040	0.0039	44.7842	49.1780	0.0872	0.0883
-1	0.0041	0.0040	44.6162	48.9935	0.0877	0.0889
0	0.0043	0.0042	44.4530	48.8143	0.0882	0.0894

Table (B.29) Comparison between "standard cycle" & "ideal cycle with superheating and subcooling" with Tc (40 °C) for (Qrej, Q_{ref}, COP)

Te °C	**Qrej (kW)**		**Qref (kW)**		**COP**	
	Standard cycle	Ideal cycle with Superheating & Subcooling	Standard cycle	Ideal cycle with Superheating & Subcooling	Standard cycle	Ideal cycle with Superheating & Subcooling
-20	0.2826	0.2948	0.2133	0.2251	3.0780	3.2277
-19	0.2938	0.3065	0.2232	0.2355	3.1617	3.3155
-18	0.3053	0.3186	0.2335	0.2463	3.2487	3.4066
-17	0.3172	0.3311	0.2441	0.2576	3.3389	3.5012

-16	0.3295	0.3440	0.2552	0.2692	3.4326	3.5995
-15	0.3421	0.3573	0.2666	0.2813	3.5300	3.7017
-14	0.3551	0.3709	0.2784	0.2938	3.6313	3.8078
-13	0.3685	0.3850	0.2907	0.3067	3.7365	3.9181
-12	0.3823	0.3995	0.3034	0.3201	3.8459	4.0329
-11	0.3964	0.4143	0.3165	0.3339	3.9597	4.1522
-10	0.4110	0.4297	0.3301	0.3482	4.0782	4.2765
-9	0.4260	0.4454	0.3441	0.3630	4.2015	4.4058
-8	0.4413	0.4616	0.3585	0.3783	4.3300	4.5405
-7	0.4572	0.4782	0.3735	0.3941	4.4638	4.6809
-6	0.4734	0.4953	0.3889	0.4103	4.6034	4.8272
-5	0.4901	0.5129	0.4048	0.4271	4.7490	4.9798
-4	0.5072	0.5309	0.4213	0.4444	4.9009	5.1391
-3	0.5248	0.5494	0.4382	0.4623	5.0595	5.3055
-2	0.5428	0.5684	0.4556	0.4807	5.2253	5.4793
-1	0.5613	0.5879	0.4736	0.4997	5.3986	5.6611
0	0.5803	0.6079	0.4921	0.5192	5.5800	5.8513

Table (B.30) Coefficient of performance for R-134a with different values of Tc for Actual cycle with isentropic efficiency of (0.85)

Te °C	**Tc** = 30 °C	**Tc** = 35 °C	**Tc** = 40 °C	**Tc** = 45 °C	**Tc** = 50 °C
-20	3.2238	2.7347	2.5426	2.2249	2.0145
-19	3.3082	2.818	2.6058	2.2829	2.0621
-18	3.4016	2.9073	2.6736	2.3443	2.1125
-17	3.504	3.0026	2.746	2.4091	2.1657
-16	3.6154	3.1039	2.823	2.4773	2.2217
-15	3.7358	3.2112	2.9046	2.5489	2.2805

-14	3.8652	3.3245	2.9908	2.6239	2.3421
-13	4.0036	3.4438	3.0816	2.7023	2.4065
-12	4.151	3.5691	3.177	2.7841	2.4737
-11	4.3074	3.7004	3.277	2.8693	2.5437
-10	4.4728	3.8377	3.3816	2.9579	2.6165
-9	4.6472	3.981	3.4908	3.0499	2.6921
-8	4.8306	4.1303	3.6046	3.1453	2.7705
-7	5.023	4.2856	3.723	3.2441	2.8517
-6	5.2244	4.4469	3.846	3.3463	2.9357
-5	5.4348	4.6142	3.9736	3.4519	3.0225
-4	5.6542	4.7875	4.1058	3.5609	3.1121
-3	5.8826	4.9668	4.2426	3.6733	3.2045
-2	6.12	5.1521	4.384	3.7891	3.2997
-1	6.3664	5.3434	4.53	3.9083	3.3977
0	6.6218	5.5407	4.6806	4.0309	3.4985

Table (B.31) Coefficient of performance for R-134a with different values of Tc for Actual cycle with isentropic efficiency of (0.90)

Te °C	**Tc** = 30 °C	**Tc** = 35 °C	**Tc** = 40 °C	**Tc** = 45 °C	**Tc** = 50 °C
-20	3.4137	2.9996	2.6956	2.3872	2.1382
-19	3.5045	3.0796	2.7616	2.4456	2.1878
-18	3.6047	3.1662	2.8326	2.5078	2.2404
-17	3.7143	3.2594	2.9086	2.5738	2.2960
-16	3.8333	3.3592	2.9896	2.6436	2.3546
-15	3.9617	3.4656	3.0756	2.7172	2.4162
-14	4.0995	3.5786	3.1666	2.7946	2.4808
-13	4.2467	3.6982	3.2626	2.8758	2.5484
-12	4.4033	3.8244	3.3636	2.9608	2.6190
-11	4.5693	3.9572	3.4696	3.0496	2.6926
-10	4.7447	4.0966	3.5806	3.1422	2.7692
-9	4.9295	4.2426	3.6966	3.2386	2.8488
-8	5.1237	4.3952	3.8176	3.3388	2.9314
-7	5.3273	4.5544	3.9436	3.4428	3.0170
-6	5.5403	4.7202	4.0746	3.5506	3.1056
-5	5.7627	4.8926	4.2106	3.6622	3.1972
-4	5.9945	5.0716	4.3516	3.7776	3.2918
-3	6.2357	5.2572	4.4976	3.8968	3.3894
-2	6.4863	5.4494	4.6486	4.0198	3.4900
-1	6.7463	5.6482	4.8046	4.1466	3.5936
0	7.0157	5.8536	4.9656	4.2772	3.7002