CHAPTER – IV
RESULTS & DISCUSSION

To find the effect of particular parameter on the performance of the system, other parameters of system have been kept constant.

The parameters assumed for the computation of results are furnished below.

1. Low temperature circuit evaporating temperature, T_{E-LT} = -85°C.
2. Medium temperature circuit evaporating temperature, T_{E-MT} = -40°C.
3. High temperature circuit evaporating temperature, T_{E-HT} = 0°C.
4. High temperature circuit condensing temperature,. T_{C-HT} = 30°C.
5. Medium temperature circuit condensing temperature,. T_{Cas-IC} = 5°C.
6. Low temperature circuit condensing temperature, $T_{Cas-IIC}$ = -35°C
7. Temperature difference in cascade condenser, $(\Delta T)CC$ = 5°C.
8. Degree of superheating , $(\Delta T)sup$ = 0 °C in both HT and LT circuit.
9. Degree of sub cooling , $(\Delta T)_{sub}$ = 0 °C in both HT and LT circuit.
10. Isentropic efficiency, η_{isen}, = 0.85 in all HT,MT and LT compressor.
11. Effectiveness of cascade heat exchanger-I and II (ε_{cc}) = 1.
12. Mass flow rate of refrigerant is calculated of the low temperature at the first assuming the cooling capacity of the system 10 ton of refrigeration..

The parameters have been varied for the computations of results are furnished below.

1. The low temperature circuit evaporator temperature T_{E-LT} is varied from -88.8 °C to -75 °C.

2 The medium temperature circuit evaporator temperature T_{E-MT} is varied from -40 °C to -50 °C.

3 The high temperature circuit evaporator temperature T_{E-HT} is varied from 0 °C to -15 °C.

4. The high temperature circuit condensing temperature ($T_{C,HT}$) is varied from 30°C to 40 °C .

5. The cascade condenser temperature difference ΔT_{cc} is varied from 0°C to 15°C.

6. Low temperature circuit condensing temperature , $T_{Cas-IIC}$ is varied from -35°C to -25°C.

7. Degree of subcooling (ΔT)sub and Degree of superheating (ΔT)sup is maintained zero in all calculations.

4.1 EFFECT OF CONDENSER TEMPERATURE OF HIGH TEMPERATURE CIRCUIT ON OTHER SYSTEM PARAMETERS:

To find out the Effect of condenser temperature of High temperature circuit on other system parameters. We are keeping T_1 = 0^0C, T_5 = - 40^0C, T_7 = 5^0C, T_9 = - 85^0C and T_{11} = -35^0C.

When the condenser temperature of high temperature circuit (stage-I) varied from 30^0C to 40^0C, the variation in the power consumption in compressor- I, II & III is shown by figure 4.1.1. While the variation in total power consumption of system is shown by same figure. It is clear from the figure that the compressor work of stage-I increase by approximately 44% by the increasing condenser temperature from 30^0C to 40^0C. While the compressor work of stage-II and Stage -III are constant.

When the condenser temperature of high temperature circuit (stage-I) varied from 30^0C to 40^0C, the variation in the coefficient of performance of stage-I, stage-II, stage- III and overall coefficient of system shown by figure 4.1.2.

It is evident that COP of high temperature circuit reduces by 30.75% approximately due to increase of condenser temperature from 30^0C to 40^0C. While for the same condenser temperature rise the overall COP reduced by 9.68% approximately.

When the condenser temperature of high temperature circuit (stage-I) varied from 30^0C to 40^0C, the variation in the pressure ratio for compressor I, II and compressor III are shown by figure 4.1.3. It is clear from graph that due to variation in condenser temperature of high temperature circuit (stage-I), only the pressure ratio across the compressor -I increases when the compressor increases. While there is no change in the pressure ratio of compressor- II & III, due to the variation in condenser temperature of Stage - I from 30^0C to 40^0C.

When the condenser temperature of high temperature circuit (stage-I) varied from 30^0C to 40^0C, the variation in the specific volume (m^3/Kg) of the refrigerant at the inlet of compressor - I, II and III is zero (figure 4.1.4.) It is due to the fact that isobutene is completely saturated vapour at the inlet of compressor -I. Show the change in specific volume of isobutene is negligible in the temperature range from 30^0C to 40^0C. While the specific volume of propane and ethane at the inlet of compressor -II and III is same (constant) because there is no change in evaporator temperature in this set up.

When the condenser temperature of high temperature circuit (stage-I) varied from 30^0C to 40^0C, the variation in the mass flow rate (kg/min) through the compressors are shown by figure- 4.1.5. It is evident from figure that the mass flow rate in compressor-I increases by 4.0-4.5% the increase of 5^0C temperature in condenser of high temperature circuit.The mass flow rate in the circuit II and III remain same with the variation in condenser temperature of high temperature circuit.

When the condenser temperature of high temperature circuit (stage-I) varied from 30^0C to 40^0C, the variation in the cylinder bore size & stroke length increases due to the increased mass flow rate and constant specific volume of saturated vapour of isobutene. It is shown in the figure of 4.1.5. and table no. 4.3. So if the ambient temperatures increases, one should use the reciprocating compressor of bigger size to accommodate increase mass flow rate to give the same result, when running at the constant speed.

The overall Carnot efficiency (ideal) of system decreases from 71.16 to 69.66% with the increase in condenser temperature from 30^0C to 40^0C. The overall coefficient of performance of system deteriorates from 1.16 to 1.047 due to the condenser temperature increase from 30^0C to 40^0C.

The IInd law efficiency is 71.16% when the condenser temperature of stage-I is 30^0C. The IInd law efficiency decreases to 69.66 % when we increasethe temperature of condenser of HT circuit by 10^0C. This reduction in efficiency is due to increase in compressor were and decrease in refrigeration effect in high temperature circuit.

The $COP_{Carnot\ system}$ and $COP_{carnot,\ stage\text{-}I}$ decreases with the temperature rise in condenser temperature of condenser of HT circuit. The COPcarnot, Rate of exergy destruction and 2nd law efficiency of Stage-II and III remains constant with the increase of condenser temperature. The exergy destruction of the stage-I & system increase with the condenser temperature rise. (Fig. 4.1.7) The 2nd law efficiency of stage-I and full system decrease from 87.35% and 70.96% respectively to 80.64% and 69.66% with the increase from condenser temperatures from 30^0C to 40^0C (Fig. 4.1.6) and (Table 4.4)

The second law efficiency of vapour compression cycle is quite high. This is due to the fact, I assumed that ideal Carnot cycle which is reversible. In actual vapour compressor cycle, this involves internal irreversibility and external irreversibility. Internal irreversibility are due to throttling process and superheathorn. External irreversibilities occurs in condensation and evaporation process due to the finite temperature differences required for heat transfer.

4.2. EFFECT OF DECREASING OF EVAPORATOR TEMPERATURE IN HIGH TEMPERATURE CIRCUIT ON SYSTEM'S PARAMETERS.

The cascade heat exchange-I works as evaporator for high temperature circuit. To analyse effect of Effect of decreasing of evaporator temperature in high temperature circuit on system's parameters, we are keeping the $T_3 = 30^0C$, $T_5 = -40^0C$, $T_7 = 5^0C$, $T_9 = -85^0C$ and $T_{11} = -35^0C$ constant.

When the evaporator temperature of stage -I decreases, the compressor work (h_2-h_1) increases. But the compressor work of stage-II & stage- III remain constant. The increased work in stage - I is almost equal to the work increase due to the increase in condenser temperature. The change in work done on temperature with the variation in evaporator temperature is shown in figure 4.2.1.

The coefficient of performance of the system decreases by lowering the evaporator temperature. The COP of the high temperature circuit only decreases while other both COP of stage-II and stage -II remains constant. COP of stage-I is only responsible to decrease the system's overall coefficient of performance. It is illustrated in figure 4.2.2. The effect of on overall COP of systems due to the increase in condenser temperature or decrease in evaporator temperature of high temperature circuit is almost same. (See table 4.1)

The pressure of vapour refrigerant at the inlet of compressor decreases due to the decreasing the evaporator temperature of cascade heat exchanger -I. Due to lower pressure of isobutene at compressor-I inlet, the compressor ratio of high temperature circuit increases to maintain the same condenser temperature. So heavy compressor is requiring to get the same result. The change in pressure ratio with respect to evaporator temperature of HT circuit is shown in figure - 4.2.3.

By decreasing the evaporator temperature the specific volume of vapour refrigerant at compressor inlet increases. The reduction in evaporator temperature is in stage-I only, the specific volume of vapour refrigerant (propane and ethane) at the inlet of compressor of stage-II and stage III will remains constant. As evaporator temperature decreases, there is 3 to 4 % increase in specific volume of isobutene per degree of ^{0}C. The effect of evaporator temperature of HT circuit on specific volume of all refrigerant three circuit are shown in figure 4.2.4.

When there is a decrease in evaporator the mass flow rate of isobutene increases due to increase in specific volume at lower temperature. There is increase of approximately 2.5% in mass flow rate (Kg/min.) of isobutene per 5^{0}C drop in evaporator temperature. Since the evaporator temperature of circuit II and circuit III are constant therefore the mass flow rate of refrigerant through the circuit remain constant. It is illustrated by figure 4.2.5.

As mentioned above, due to increase mass flow rate of isobutene in circuit-I the dimensions of bore and stroke of reciprocating compressor increases as shown in table 4.3.

Due to lowering the evaporator temperature of Ist stage from 0^{0}C to -15^{0}C, 2nd law efficiency of Stage-I decreases from 87.35% to 81.43%, 2nd law efficiency of system decreases 70.96% to 60.66% and exergy destruction increases for stage-I from 0.9256 KW to 2.313 KW and for overall system from 8.8049 KW to 13.9495 KW. For Stage-II & Stage- III, 2nd law efficiency, exergy destruction and COP_{carnot} remains constant with the lowering of evaporator temperature. (fig. 4.2.6 and fig. 4.2.7).

4.3 EFFECT OF INCREASING CONDENSER TEMPERATURE OF MEDIUM TEMPERATURE CIRCUIT.

For the medium temperature circuit, cascade heat exchanger-I works as a condenser. To see the effect of variation in condenser temperature of CHE-I, the following parameter are being kept constant.

T_3 = 30^{0}C, T_1 = 0^{0}C, T_5 = -40^{0}C, T_9 = - 85^{0}C and T_{11} = -35^{0}C

The effect of increase in condenser temperature of CHE-I on the work done of compressors are shown in figure 4.3.1.It is evident from the table 4.1. and the figure 4.3.1 , the work done from compressor -I and compressor - II increased. The increase in work done by compressor-I is approximately 8.4% while in compressor-II is approximately 45% with respect to the increase of 15^0C temperature rise in condenser of medium temperature circuit.

The overall COP of the system decreases with the increase of condenser temperature CHE-I. It is shown by figure 4.3.2. The COP of medium temperature circuit decreases and the COP of high temperature circuit and low temperature circuit remains constant. The COP is the ratio of net refrigerant effect to work done on compressor. The temperature range of circuit-I and circuit -III are same, the COP of these circuit remains constant.

The effect of condenser temperature of stage-II (cascade heat exchanger-I) on pressure ratio to be developed by the compressor is show in figure 4.3.3.It is clear that the pressure ratio of stage-I (HT circuit) and stage-III (LT circuit) remains constant, while there is a rapid growth in pressure ratio of stage-II due to increase of condenser temperature of this stage.

Specific volume at compressor inlet of all refrigerant i.e. isobutene , propane and ethane circulated through the stages remains constants when there is a variation in condenser temperature on stage-II. Figure 4.3.4 shows the relation between specific volume of vapour refrigerant at compressor inlet to compressor of stage-II. The specific volume of vapour refrigerant at compressor inlet will very only when the evaporator temperature changes.

The effect of condenser temperature of stage-II (CHE-I) on the mass flow rate of refrigerant through the different circuits are shown by figure 4.3.5.It is evident from figure that the mass flow rate of medium temperature circuit and low temperature circuit increase with the increase of condenser temperature of stage-II(CHE-I). The ratio of increase of mass flow rate of propane and ethane through circuit II and circuit III are approximately one with the given set of parameters.

The bigger dimensions of reciprocating compressor of circuit -II and circuit-III required when the condenser temperature increase of stage-II. The required size of bore and stroke length of reciprocating compressor are shown in table 4.3.

By increasing condenser temperature of stage-II, the 2nd law efficiency of system and stage-II decreases, while 2nd law efficiency of stage-I and stage-III remains constant. The exergy destruction for stage-I, Stage-II & system increases with in increasing in condenser temperatures of CHE-I. (fig. 4.3.6 and Fig. 4.3.7) and (Table 4.4) The 2nd law efficiency of system decreases 75.12% to 64.53% and 2nd law efficiency of stage-II decreases 85.16% to 78.18%, while the exergy destruction for the system increases from 7.1224 KW to 12.052 KW when the condenser temperature of stage -II is increase from 0^0C to 15^0C.

4.4 EFFECT OF EVAPORATOR TEMPERATURE OF MEDIUM TEMPERATURE CIRCUIT (CASCADE HEAT EXCHANGER – II) ON SYSTEM PARAMETERS.

To analyse the system components performance on varying the T_7, keep the T_3=30°C, T_1=0°C, T_7=5°, T_9= -85° and T_{11}= -35°

On decreasing the evaporator temperature of CHE –II the work done on compressor – I & Compressor – II increases. The increase in work done on compressor – II is more than work done on Compressor – I. Since the work done in Stage – I & II increases and in Stage IIII remains constants. So, the total work done on system increases from 30.32 KW to 34.373 KW when the evaporator temp of CHE-II vary from -40°C to -50°C (Fig. 4.4.1)

When the evaporator temperature of stage – II i.e. (CHE-II) decreases the COP of circuit – I & circuit – II remains constant. When the evaporator temperatures of stage – II vary from -40°C to -50°C, the COP of stage II decreases from 4.284 to 3.221 and the overall cop of system decreases from 1.16 to 1.004 (Fig. 4.4.2)

When the evaporator temperature (T_5) of stage- II vary from -40°C to -50°C, the pressure ratio developed by compressor –I & III remains same. While the compressor – II should develop more pressure ratio for pumping propane refrigerant at same condenser temperature i.e. T_7=5°C. The pressure ratio of compressor – II at 40°C and 4.964 and at T_9 = -50°C (evaporator temp) and 7.824 (Fig. 4.4.3.)

When we decrease the evaporator temperature of stage – II from -40°C to -50°C, the specific volume of propane vapour at inlet of compressor – II increase from 0.3799m^3/kg to 0.5796$m^{3/}$kg. But with the same variation in T_5 the specific volume of refrigerant of high temperature circuit and low temperature circuit remains constant. (fig. 4.4.4.)

The mass flow rate of Isobutene and Propane increases in the H.T. Circuit and M.T. Circuit respectively on decrease in temperature of evaporator of M.T. circuit. The mass flow rate of Ethane, in low temperature circuit remains constant when there is any variation is evaporator temperature of MT circuit. At T_5= -40°C the mass flow rate is stage – I and stage – II is 12.302 kg/Min and 8.974 kg/min. When we decrease the T_5 to -50° the mass flow rate in stage – I increase to the value of 13.07 kg/min and in stage – II to 9.318 kg/min (fig. 4.4.5)

There is increase in mass flow rate in stage I and stage II and increase in specific volume of vapour at inlet of compressor – II at the decreasing of evaporator temperature of stage – II. To accommodate this increase mass flow rate, we should select the bigger compressor for stage – I and stage – II. Assuming the compressor are running at constant speed of 1000 RPM. The variation in cylinder bore and stroke length due to decreasing T_5 is shown in Table 4.3.

By lowering the evaporated temperatures from -40^0C to -50^0C of evaporator of stage-II, the $\eta_{II\text{- system}}$ & $\eta_{II\text{ stage-II}}$ decreases. From 70.96% to 62.58% & 82.73% to 79.44% respectively (Fig. 4.46). The exergy destruction for stage-I, II & system increase and for stage-III remains constant with lowering of T_5 (fig. 4.4.7) and (Table 4.4) The exergy destruction for the system increases from 8.8049 KW to 12.8623 KW with the lowering the evaporated temperatures from -40^0C to -50^0C of evaporator of stage-II.

4.5 EFFECT OF INCREASING CONDENSER TEMPERATURE OF STAGE – III (CHE-II) ON SYSTEM PARAMETERS.

For analysis of the effect of increasing of condenser temperature of low temperature circuit, we are keeping all other temperatures constant.

T_3=30°C, T_1=0°C, T_7=5°C, T_9=-85°C, T_5= -40°C

When we are increasing the condenser temperature of LT circuit, the increase in the work done on compressor I and II are very less, while the increase in work done on compressor – III is more, (i.e. 11.9995 KW to 15.38 KW) The total work done (W_I + W_{II} + W_{III}) increases from 30.32 KW to 35.02 KW on varying the condenser temperature of stage – III from -35°C to -25°C.

The COP of stage – III decreases and COP of stage – I and stage II remains constant, on varying the condenser temperature of stage – III. The COP of stage-III and overall COP of system is 2.931 and 1.16 respectively at T_{11}=-35°, while the COP of stage – III and overall COP of system i.e. 2.286 and 1.004 respectively at T_{11}= -25° where T_{11} is the condenser temperature of stage – III (low temperature circuit) (Fig. 4.5.2)

On increasing condenser temperature of stage – III, the pressure ratio of stage – I and stage –II remains constant. But the pressure ratio of compressor – III and increasing from 7.454 to 10.071 when the condenser temperature increase from -35°C to -25°C. It is evident from Fig. 4.5.3 that on increasing the condenser temperature of stage – III, we should use heavier compressor to meet the requirement.

The specific volume of refrigerant vapour at compressor's inlet remain same within the change in condenser temperature of stage – III while keeping the evaporator temperature of stage – III constant. It is shown in figure 4.5.4.

On increasing the condenser temperature of stage – III, the mass flow rate in all the three stage increases. This increase in mass flow rate of refrigerant in stage – III is due to the variation in temperature difference across CHE-II. Due to the increase in mass flow rate of LT circuit, the mass flow rate of HT circuit & MT circuit also increases. The value of mass flow rate through stage I, II and III is shown by figures 4.5.5 and table 4.3.

. If there is increase in mass flow rate through stages the reciprocating compressor should be selected of bigger size to accommodate the increased mass flow rate. To get the bore size and stroke length of compressors I, II and III it is assume that compressors are running at constant speed of 1000 RPM. The size of cylinder bore and stroke length of all three compressor on different at T_9 is shown in Table 4.3.

By increasing condenser temperature of stage-III (CHE-II) the $\eta_{II\ stage-III}$, and $\eta_{II\ system}$ decreases and II law efficiency for stage- I & II remains constant (fig. 4.5.6). The exergy destruction for stage-I, II, III and for system increase by increasing T_{11}. The $\eta_{IIstage-III}$ changes from 77.95 to 72.95% and $\eta_{II\ system}$ 70.96% to 61.41% when the condenser temperature change from -35^{0}C to -25^{0}C. The exergy destruction for stage-I change from 0.9256 KW to 0.992 KW for stage-II from 1.9018 KW to 2.0375 KW, for stage-III from 2.6449 KW to 4.1603 KW and Exergy destruction for full system increase from 8.8049 KW to 13.5412 KW. (Fig. 4.5.7 & Table 4.4)

4.6. EFFECT OF EVAPORATOR TEMPERATURE STAGE – III (L.T. CIRCUIT) ON SYSTEM PERAMETERS

To get the result of varying evaporator temperature of stage – III we are keeping T_3=30°C, T_1=0°C, T_7=5°, T_{11}= -35° and T_5= -40° constant.

When the evaporator temperature of low temperature circuit decreases, the work done by all compressor increases. In compressor I and II, it is mainly due to increased mass flow rate through HT & MT circuit. But the work done in compressor –III increases more compare to the other two compressors. In compressor-III, the increase in work done is more due to increased temperature difference across the stage – III. The total work done at -75° is 25.677 KW while the total work done at -88.5°C is 32.298 KW. The work done in individual compressor are shown in figure 4.6.1.

When the evaporator temperature of stage – III decreases the COP of circuit-III and overall COP decreases. But the COP of HT circuit & MT circuit remains constant due to fixed temperature differences across these stages. The COP of stage I, II and III and system are shown in figure 4.3.

When there is decrease in evaporate temperature of stage – III the pressure ratio of stage – III increase drastically. At the evaporator temperature of -75°, the pressure ratio of stage – III is 4.572, while at the evaporator temperature of -88.8°C, the pressure ratio of stage III is 9.111. There is no effect of the variation of evaporator temperature of stage – III on the pressure ratio required for stage – I and stage – II. (fig. 4.6.3)

. On decreasing the evaporator temperature of stage III, the specific volume of vapour refrigerant at compressor inlet increases for Ethane (low temperature state) and remains constant for stage I and stage II. The specific volume of vapour of refrigerant increases on lowering of evaporator temperature. From fig. 4.6.4 the specific volume of ethane at temperature -75° and -88.5° is 0.2592m_3/kg and 0.4919m^3/kg respectively.

On lowering the evaporator temperature of stage – II, the mass flow rate of refrigerant through stage I, II & III increases. This increment in mass flow rate of Ethane is due to increase in temperature difference across stage and increase specific volume of ethane at lower evaporator temperature. The mass flow rate of stage – I and II increases due to increase in mass flow rate in stage – III to meet the systems requirement, to accommodate the increased mass flow rate, the compressor of bigger size is required. The size of compressor for different evaporator temperature are shown in Table 4.3

The $\eta_{II\ stage\text{-}III}$ and $\eta_{II\ system}$ decrease from 81.76% to 76.37% and 72.59% to 70.23% when the evaporator temperature of stage III lowers from - 70^0C to -88.8^0C. The II law efficiency for stage-I & II remains constant at 87.35% and 82.73 at the above temperature variation of evaporator of stage-III. (fig. 4.6.6). The exergy destruction for all the three stages and system increases when the evaporator temperature falls. At T_9 = - 88.8 ^{0}C the $E_{x\text{-}dest}$ for stage-I, stage-II, stage-III and system is 0.9557 KW 1.9536 KW, 3.1735 KW and 9.6151 KW respectively. Where as at T_9 = -75^{0}C, exergy destruction for stage-I, stage - II, stage-III & system is 0.8612KW, 1.720 KW, 1.5615 KW and 7.038 KW respectively.

T_1 = 0 ^{0}C, T_5 = –40 ^{0}C , T_7= 5^{0}C, T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

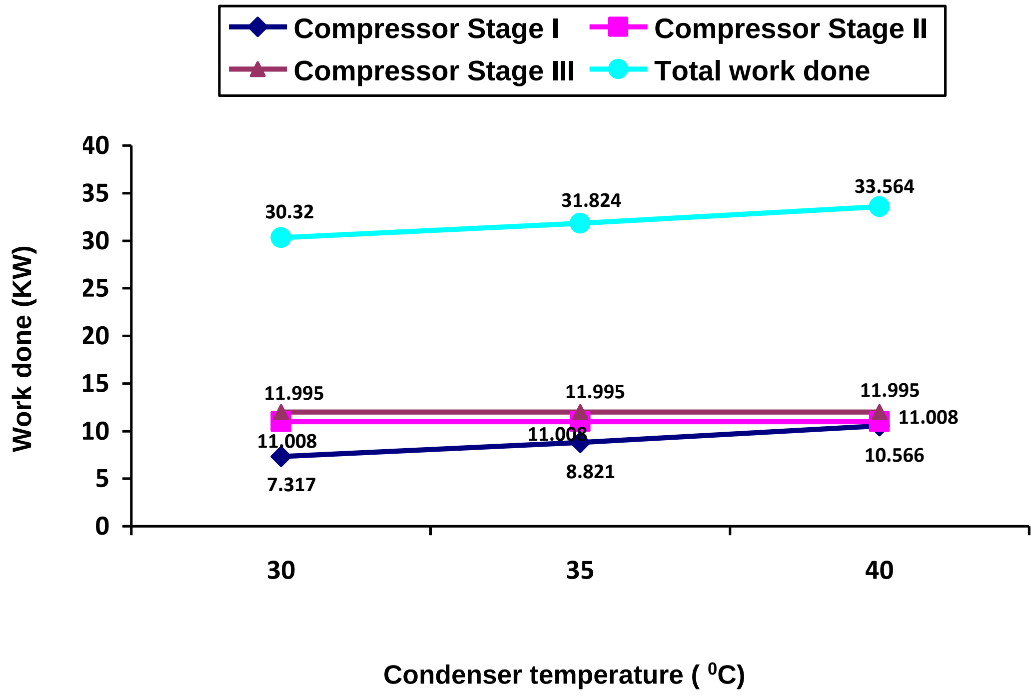


Fig. 4.1.1 : Effect of Condenser temperature on work done by Compressors

T_1 = 0 ^{0}C, T_5 = –40 ^{0}C , T_7= 5^{0}C, T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

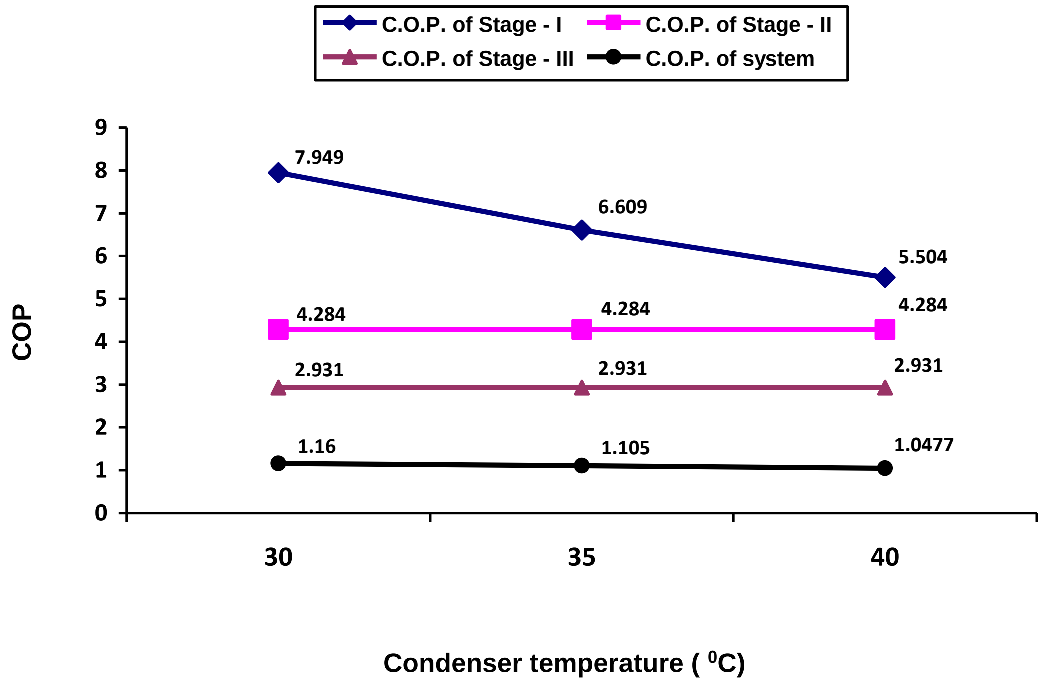


Fig. 4.1.2 : Effect of Condenser temperature on Coefficient of performance.

$T_1 = 0\ ^0C$, $T_5 = -40\ ^0C$, $T_7 = 5^0C$, $T_9 = -85^0C$, $T_{11} = -35^0C$ (Keeping all constant)

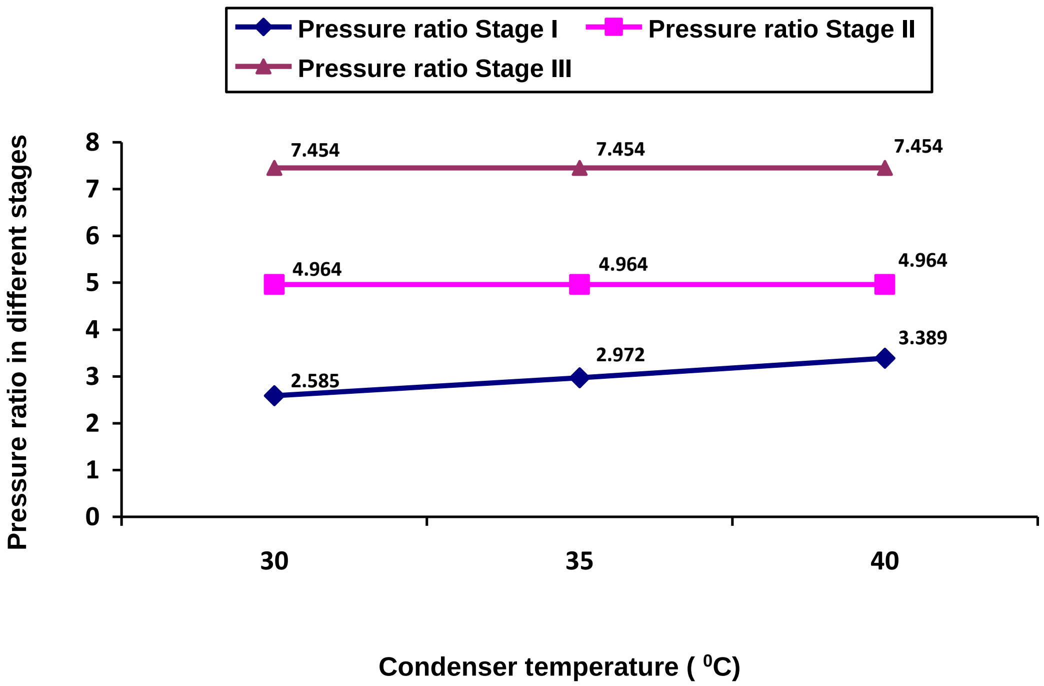


Fig. 4.1.3 : Effect of Condenser temperature on Pressure ratio of different stages.

$T_1 = 0\ ^0C$, $T_5 = -40\ ^0C$, $T_7 = 5^0C$, $T_9 = -85^0C$, $T_{11} = -35^0C$ (Keeping all constant)

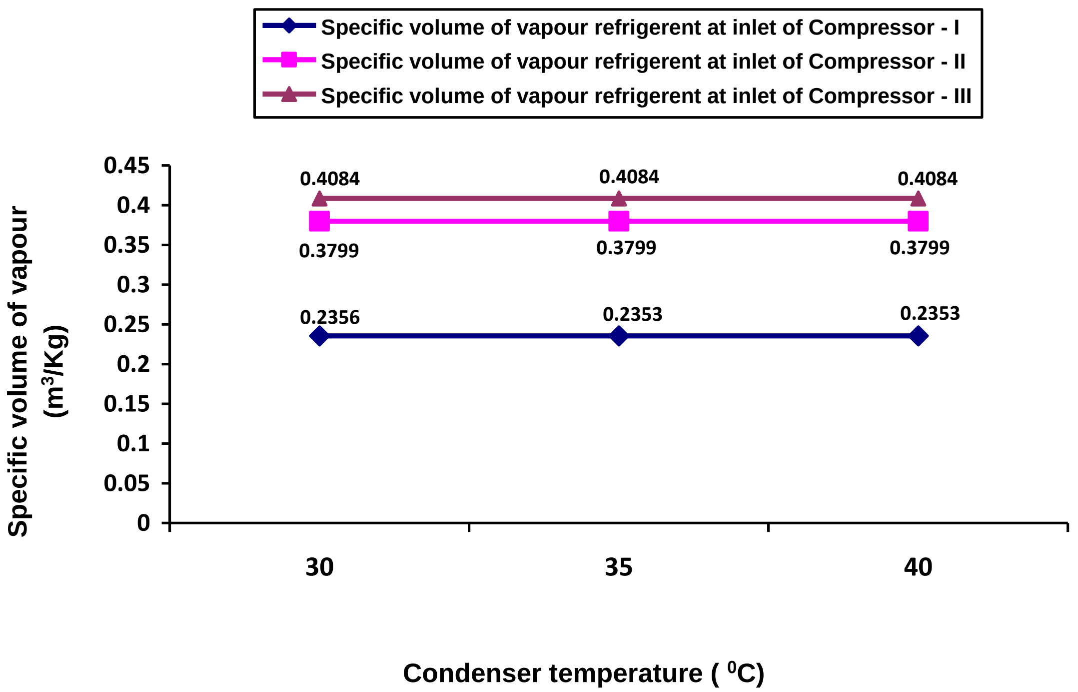


Fig. 4.1.4 : Effect of Condenser temperature on Specific Volume of vapour refrigerent at various compressor inlet.

$T_1 = 0\ ^0C$, $T_5 = -40\ ^0C$, $T_7 = 5^0C$, $T_9 = -85^0C$, $T_{11} = -35^0C$ (Keeping all constant)

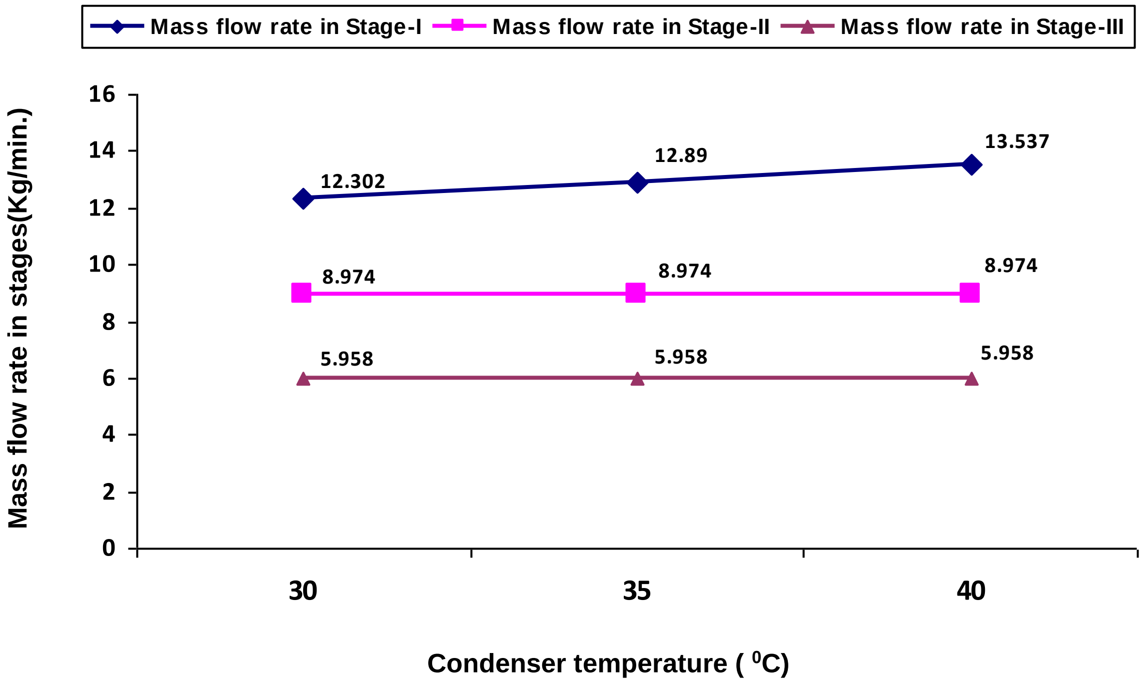


Fig. 4.1.5 : Effect of Condenser temperature on Mass flow rate in different stages.

$T_1 = 0\ ^0C$, $T_5 = -40\ ^0C$, $T_7 = 5^0C$, $T_9 = -85^0C$, $T_{11} = -35^0C$ (Keeping all constant)

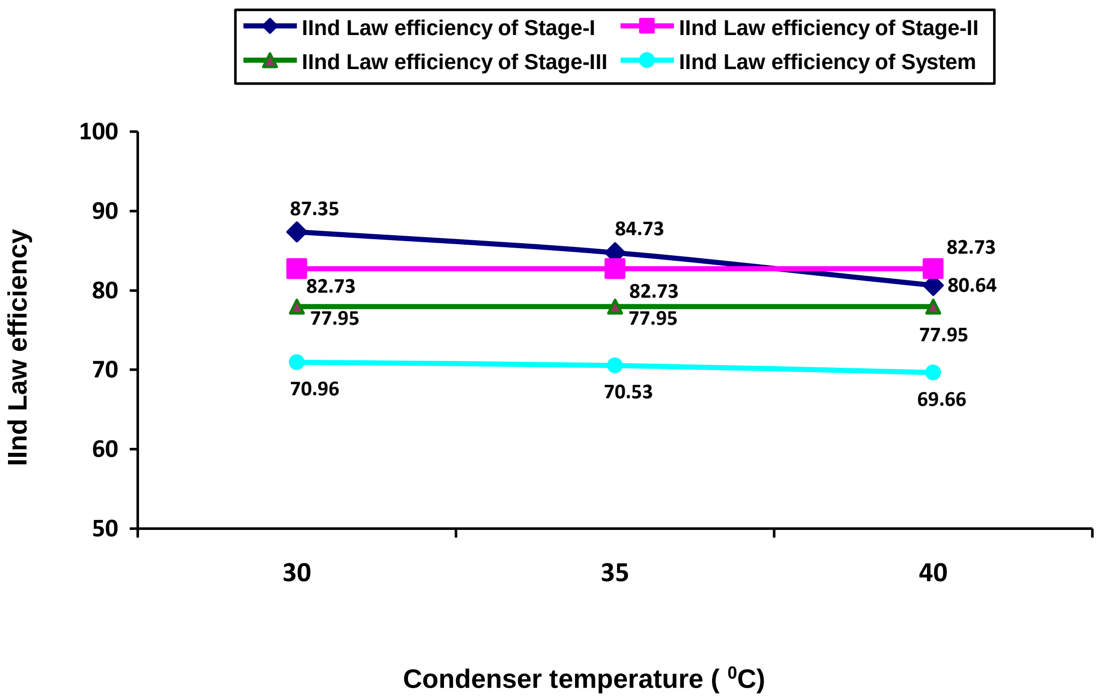


Fig. 4.1.6 : Effect of Condenser temperature on IInd Law efficiency of Stage-I, II, III & system.

$T_1 = 0\ ^0C$, $T_5 = -40\ ^0C$, $T_7 = 5^0C$, $T_9 = -85^0C$, $T_{11} = -35^0C$ (Keeping all constant)

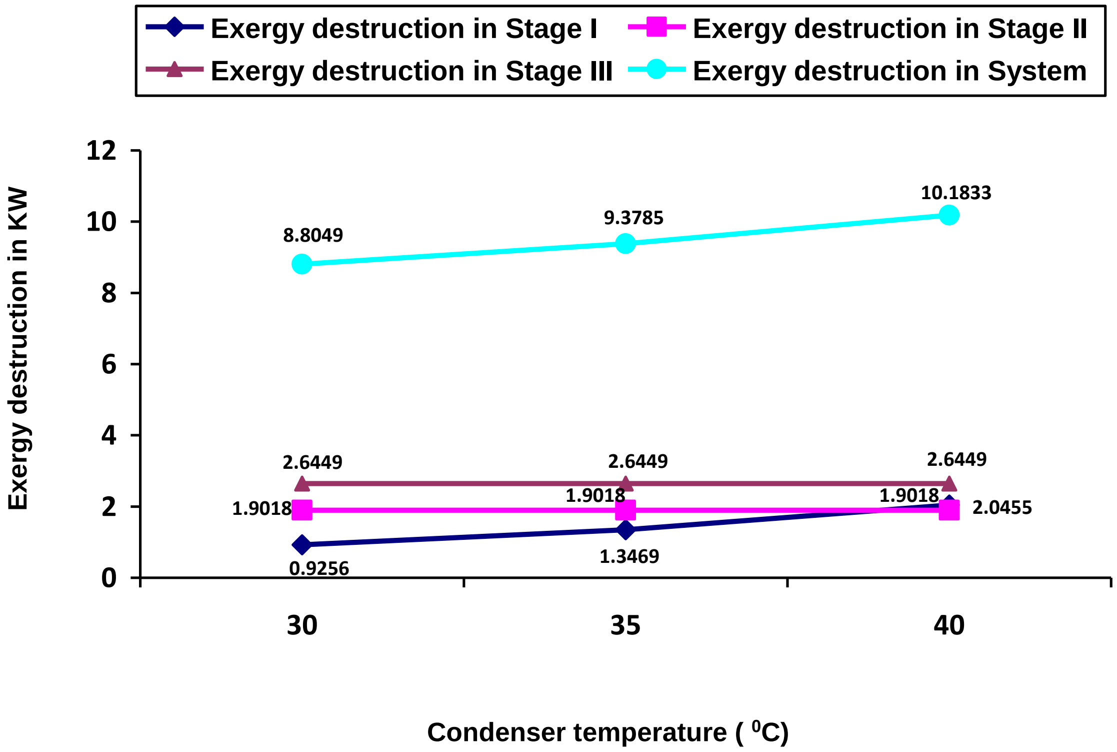


Fig. 4.1.7 : Effect of Condenser temperature on Exergy destruction of Stage-I, II, III & System.

T_3 = 30 ^{0}C, T_5 = –40 ^{0}C , T_7= 5^{0}C, T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

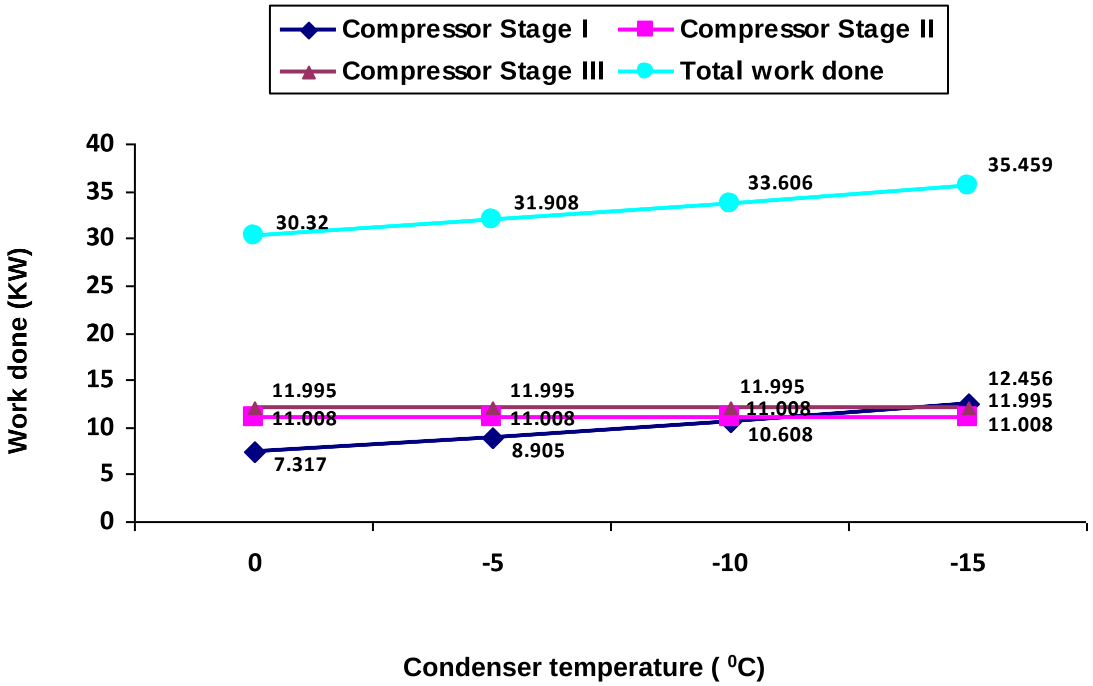


Fig. 4.2.1 : Effect of Evaporator temperature of High Temperature circuit (Cascade Heat Exchanger –I) on work done by Compressors

T_3 = 30 ^{0}C, T_5 = –40 ^{0}C , T_7= 5^{0}C, T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

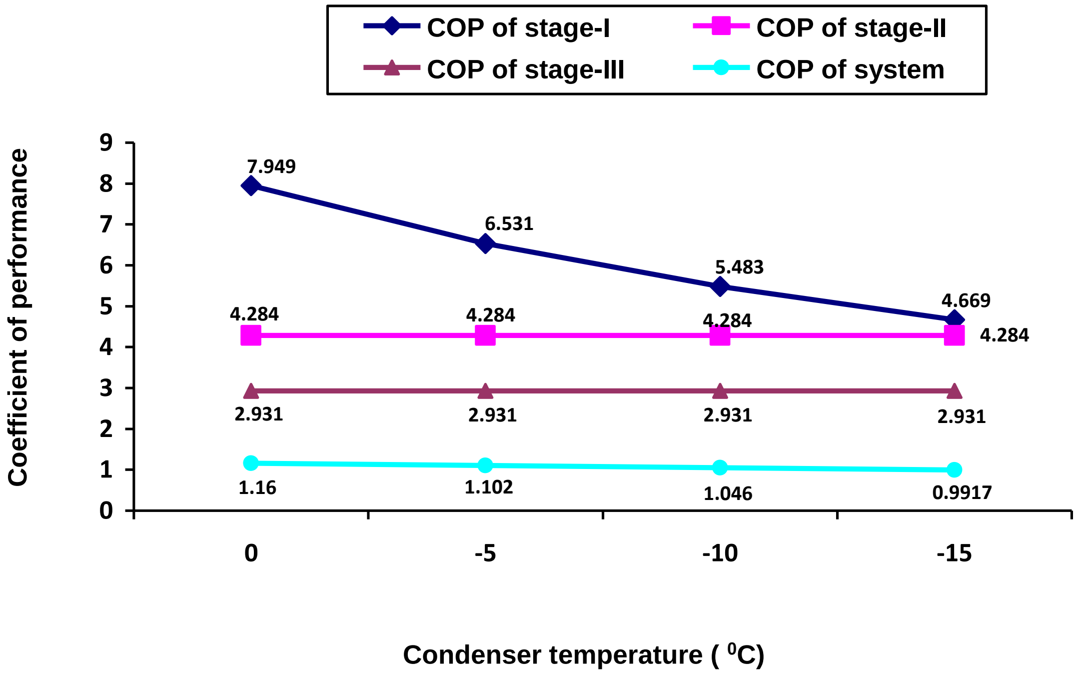


Fig. 4.2.2 : Effect of Evaporator temperature of High Temperature circuit (Cascade Heat Exchanger –I) on COP of stage-I,II,III & system.

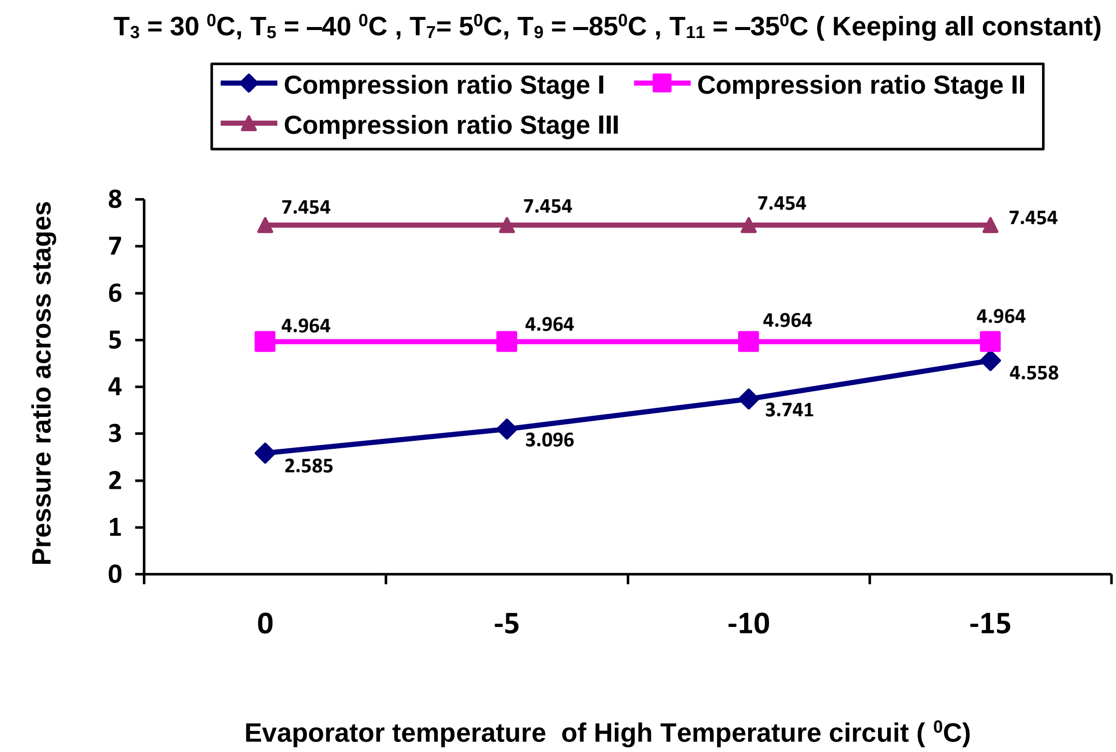


Fig. 4.2.3 : Effect of Evaporator temperature of High Temperature circuit (Cascade Heat Exchanger –I) on pressure ratio of Compressors.

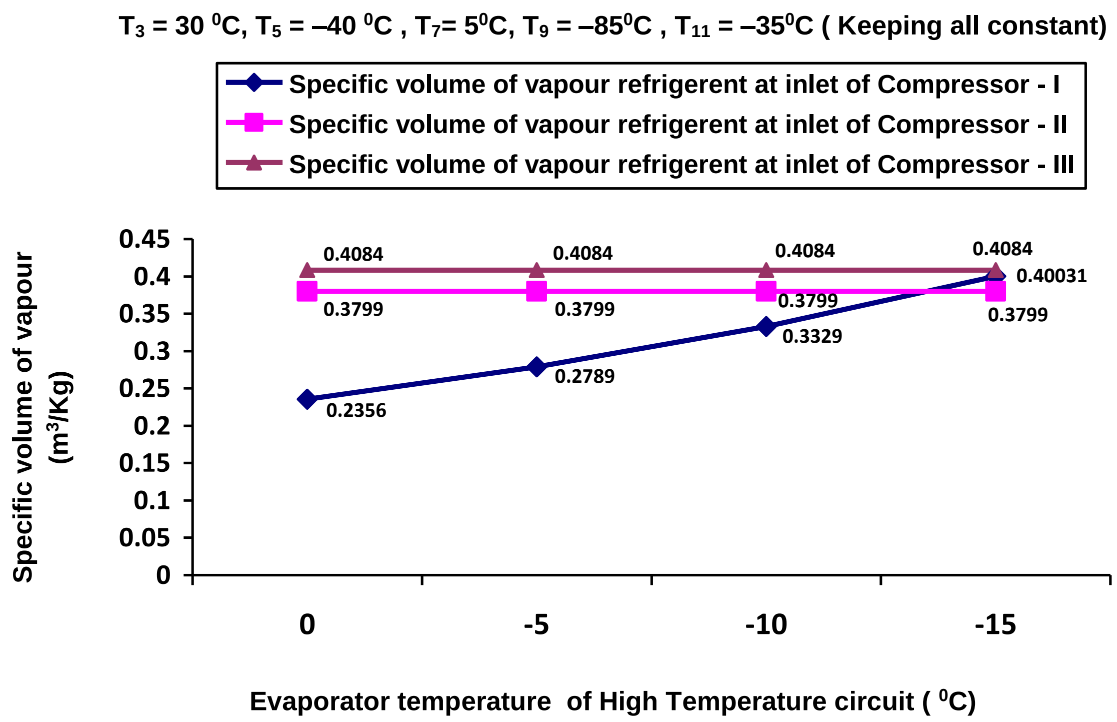


Fig. 4.2.4 : Effect of Evaporator temperature of High Temperature circuit (Cascade Heat Exchanger –I) on Specific Volume of vapour refrigerant at various compressor inlet.

T_3 = 30 ^{0}C, T_5 = –40 ^{0}C , T_7= 5^{0}C, T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

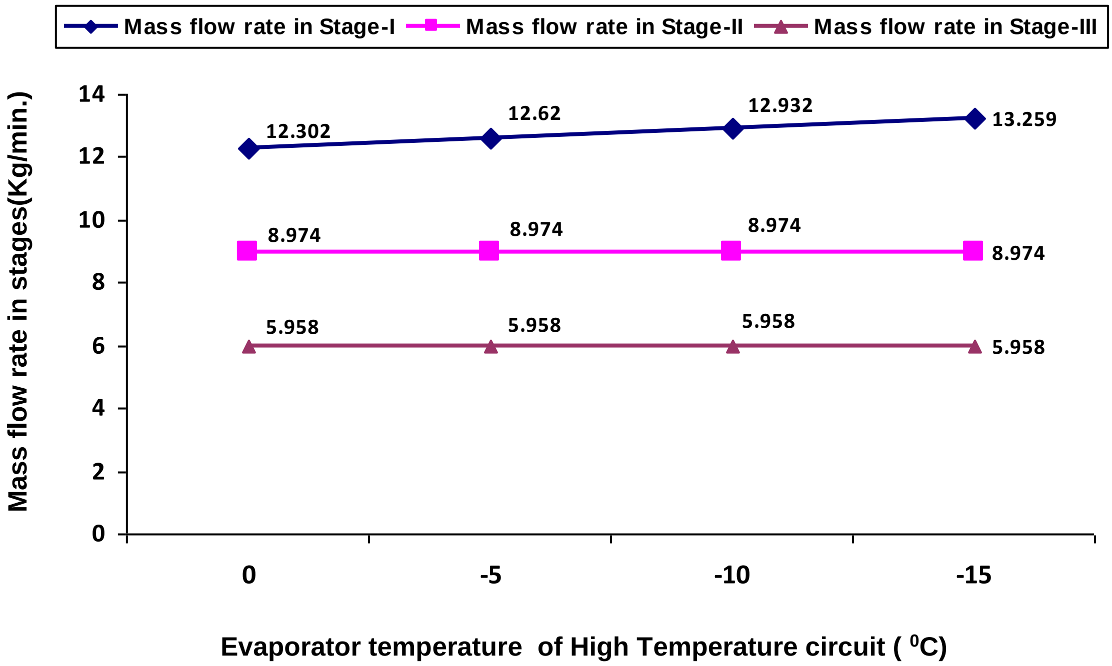


Fig. 4.2.5 : Effect of Evaporator temperature of High Temperature circuit (Cascade Heat Exchanger –I) on Mass flow rate in different stages.

T_3 = 30 ^{0}C, T_5 = –40 ^{0}C , T_7= 5^{0}C, T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

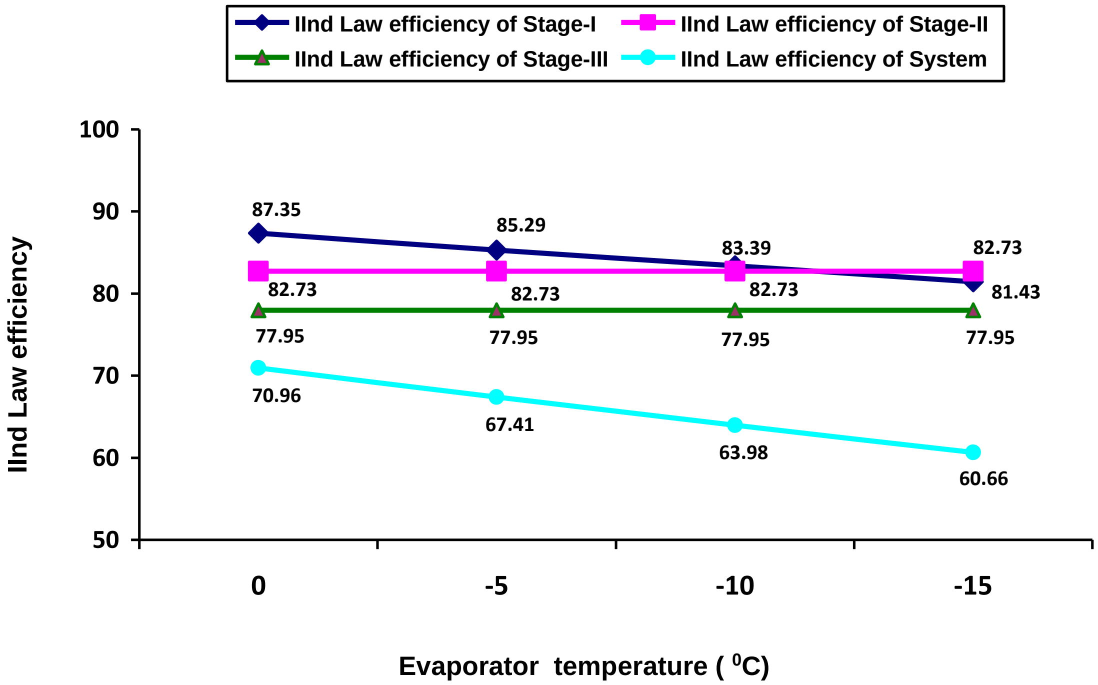


Fig. 4.2.6 : Effect of Evaporator temperature of High Temperature circuit (Cascade Heat Exchanger –I) on IInd Law efficiency of Stage-I, II, III & system.

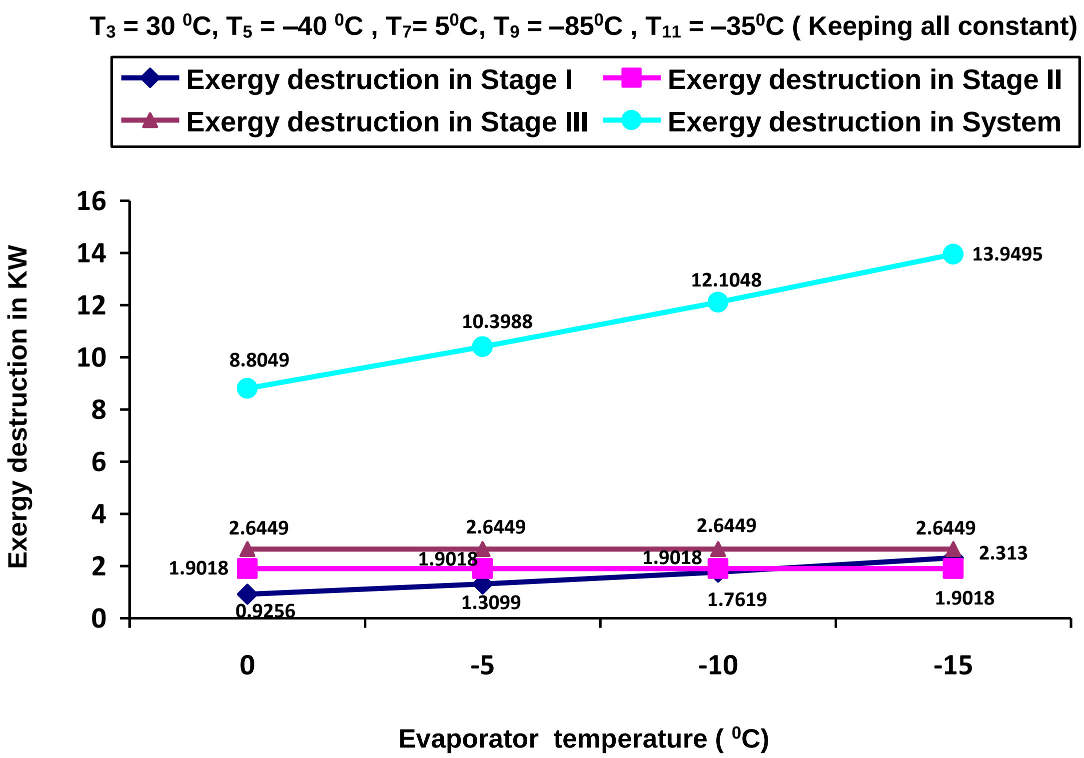


Fig. 4.2.7 : Effect of Evaporator temperature of High Temperature circuit (Cascade Heat Exchanger –I) on Exergy destruction of Stage-I, II, III & System.

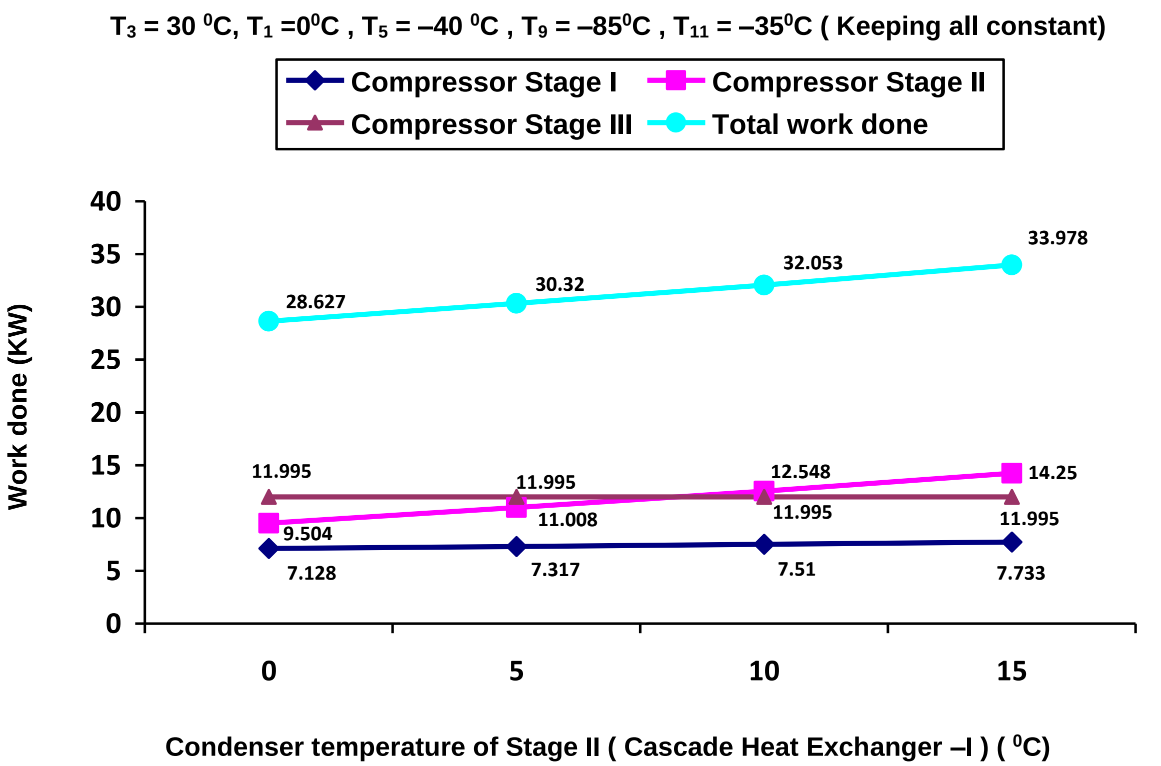


Fig. 4.3.1 : Effect of Condenser temperature of Stage – II (Cascade Heat Exchanger-I) on work done by Compressors.

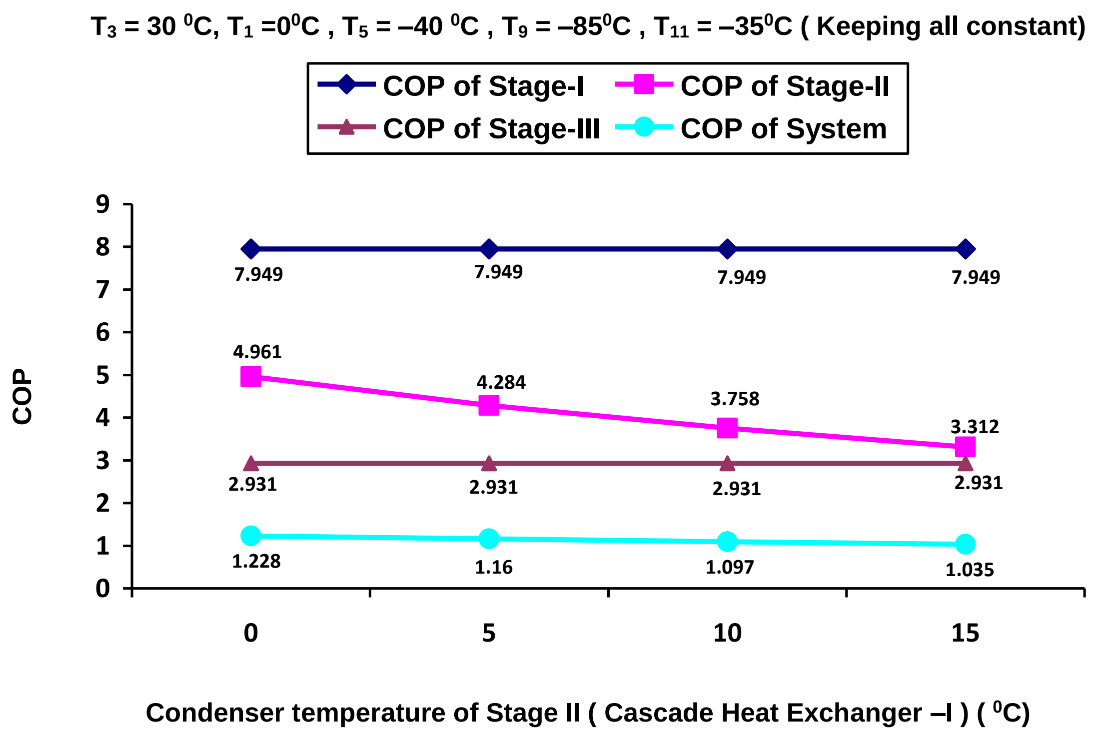


Fig. 4.3.2 : Effect of Condenser temperature of Stage – II (Cascade Heat Exchanger-I) on COP of Stage-I, II, III & system.

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_5 = –40 ^{0}C , T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

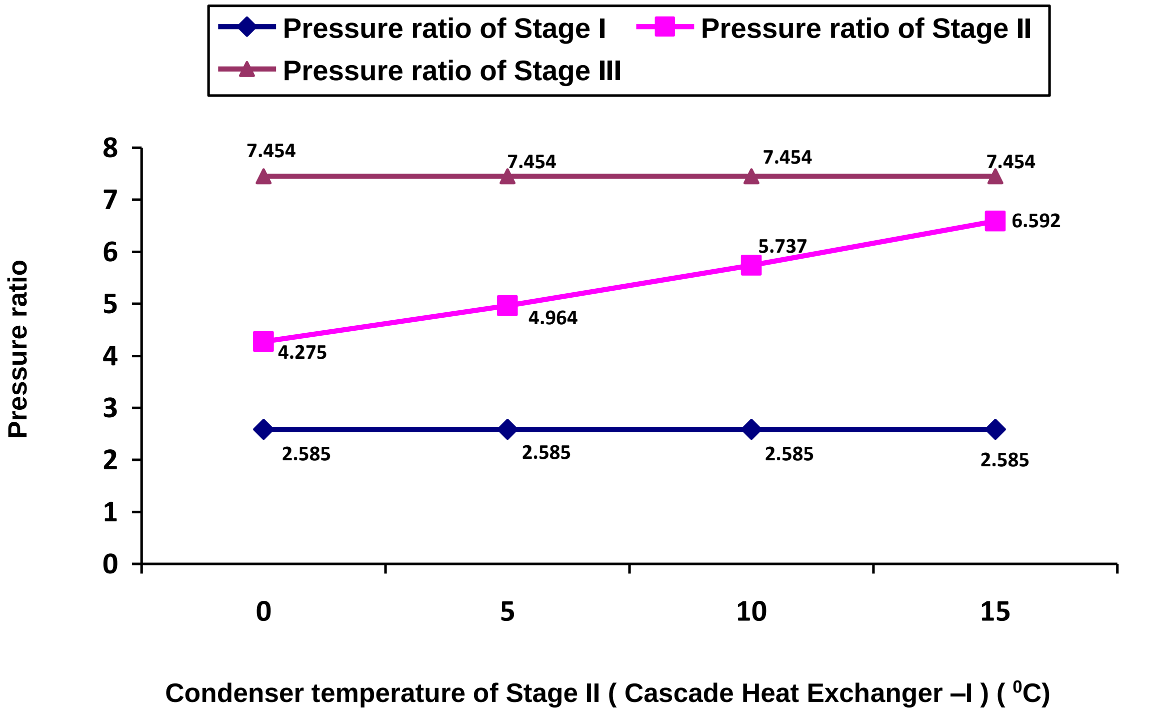


Fig. 4.3.3 : Effect of Condenser temperature of Stage – II (Cascade Heat Exchanger-I) on pressure ratio developed by Compressors.

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_5 = –40 ^{0}C , T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

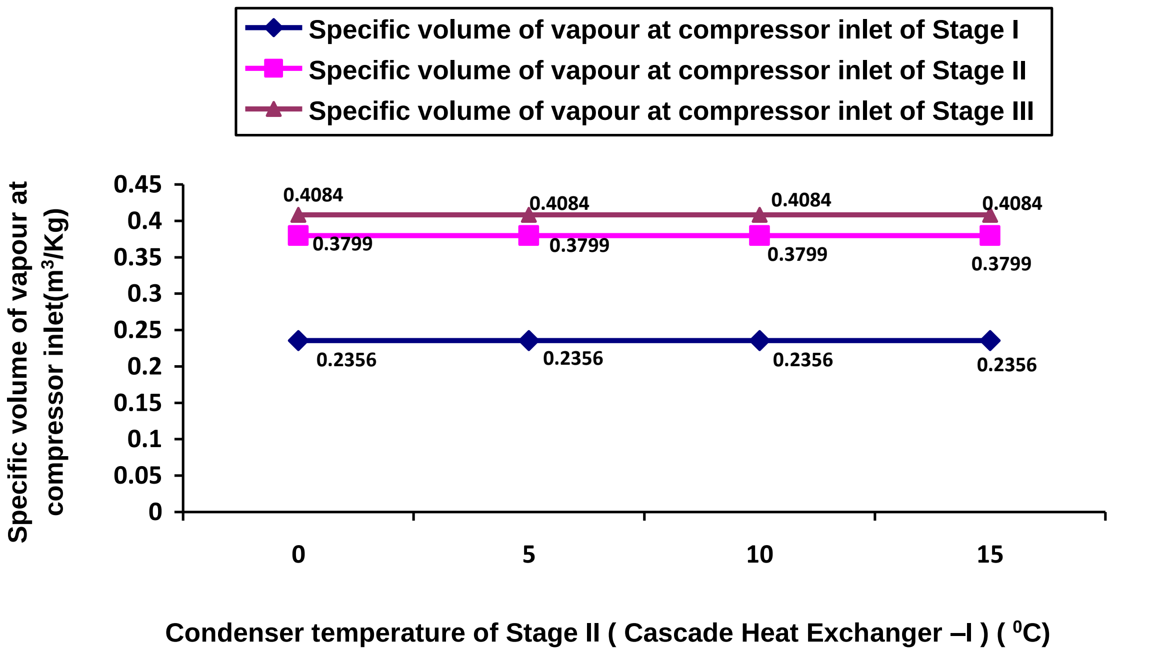


Fig. 4.3.4 : Effect of Condenser temperature of Stage – II (Cascade Heat Exchanger-I) on Specific volume of vapour at compressor inlet.

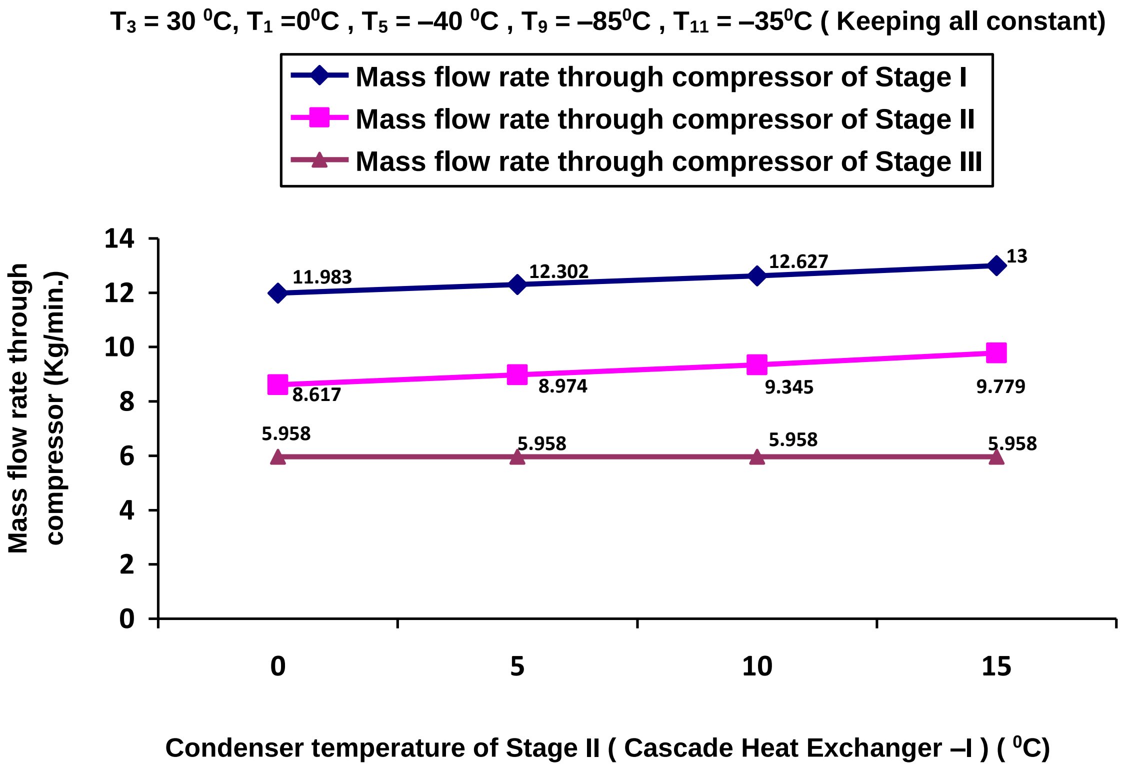


Fig. 4.3.5 : Effect of Condenser temperature of Stage – II (Cascade Heat Exchanger-I) on Mass flow rate at various stages.

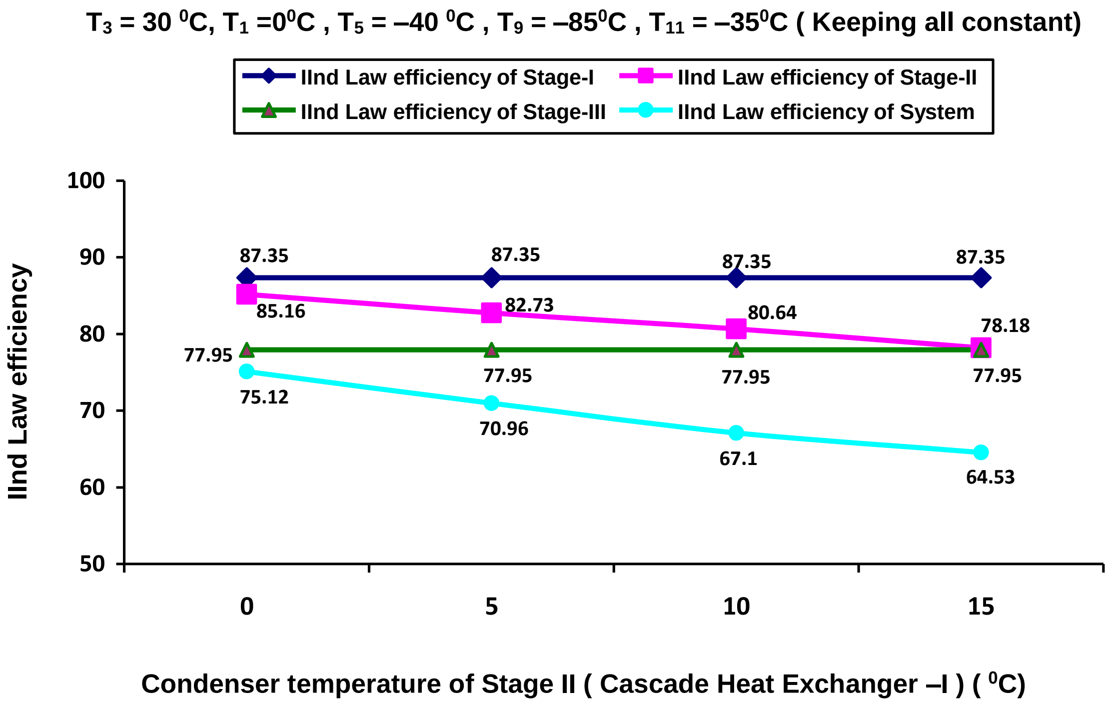


Fig. 4.3.6 : Effect of Condenser temperature of Stage – II (Cascade Heat Exchanger-I) on IInd Law efficiency of Stage-I, II, III & system.

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_5 = –40 ^{0}C , T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

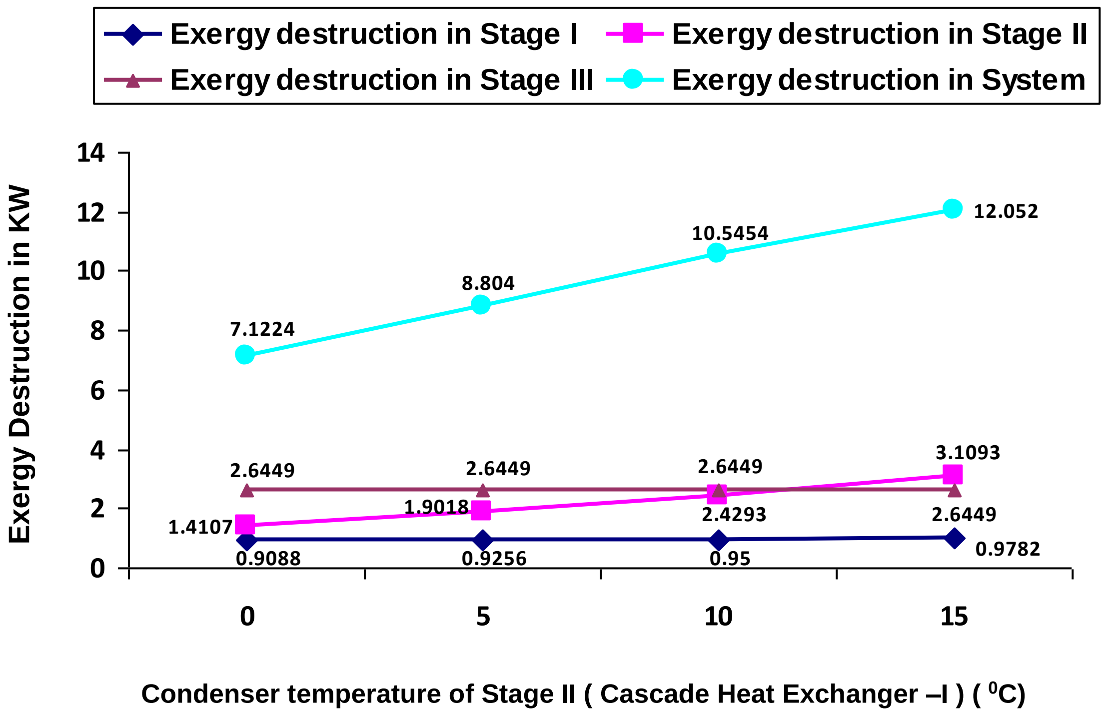


Fig. 4.3.7 : Effect of Condenser temperature of Stage – II (Cascade Heat Exchanger-I) on Exergy destruction of Stage-I, II, III & System.

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_7 = 5 ^{0}C , T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

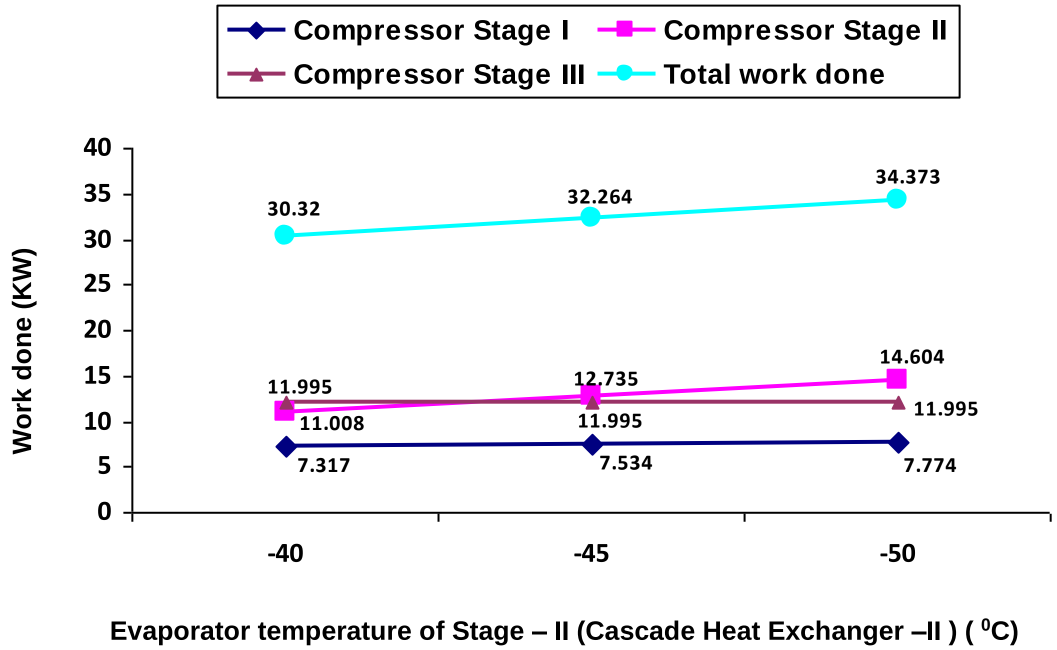


Fig. 4.4.1 : Effect of Evaporator temperature of Stage – II (Cascade Heat Exchanger-II) on compressors power.

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_7 = 5 ^{0}C , T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

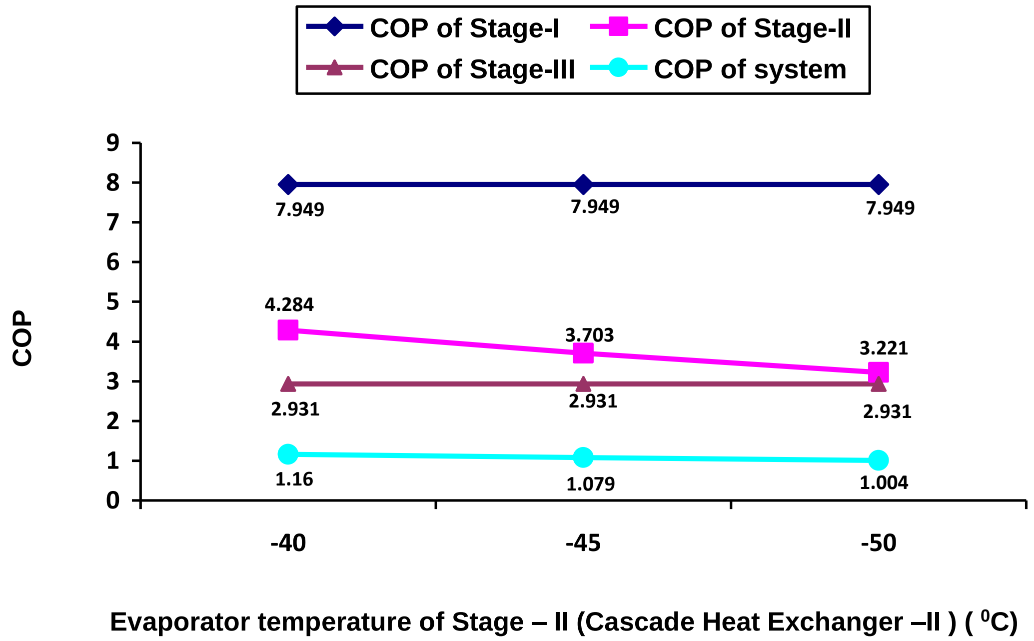


Fig. 4.4.2 : Effect of Evaporator temperature of Stage – II (Cascade Heat Exchanger-II) on COP of Stage-I, II, III & system.

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_7 = 5 ^{0}C , T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

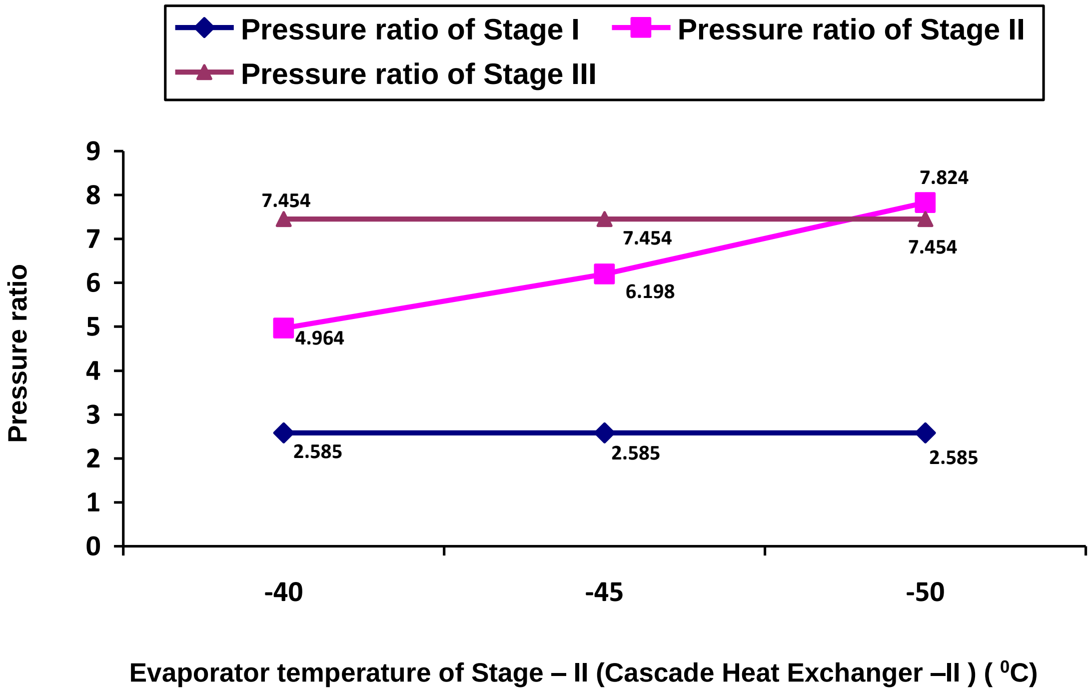


Fig. 4.4.3 : Effect of Evaporator temperature of Stage – II (Cascade Heat Exchanger-II) on compressor pressure ratio.

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_7 = 5 ^{0}C , T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

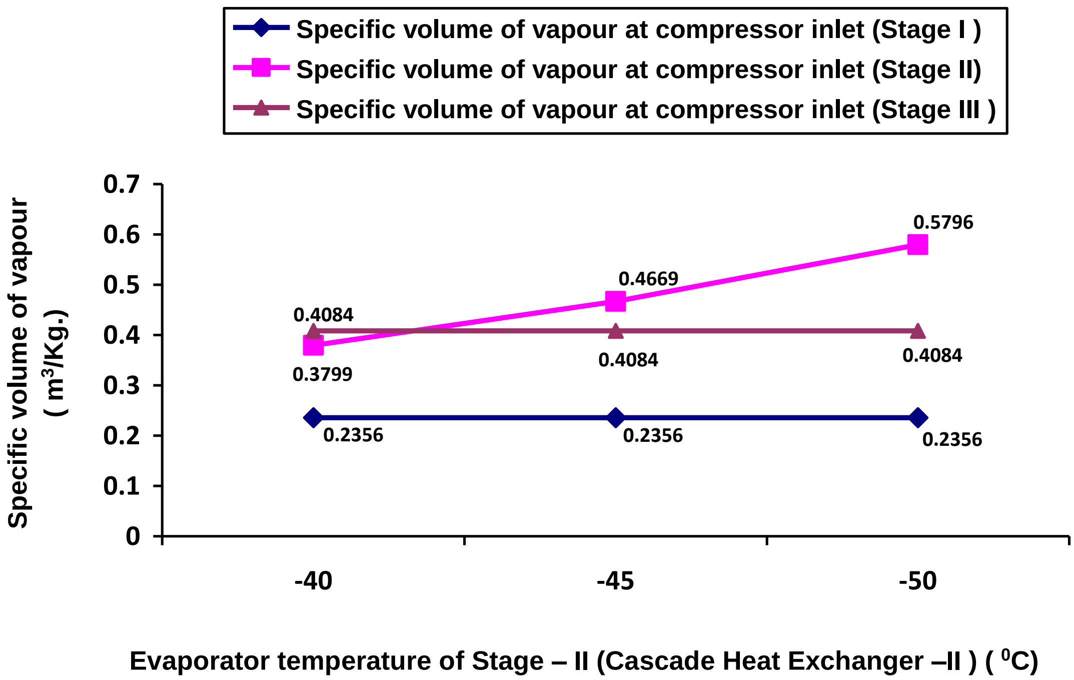


Fig. 4.4.4: Effect of Evaporator temperature of Stage – II (Cascade Heat Exchanger-II) on specific volume of vapour at compressor inlet.

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_7 = 5 ^{0}C , T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

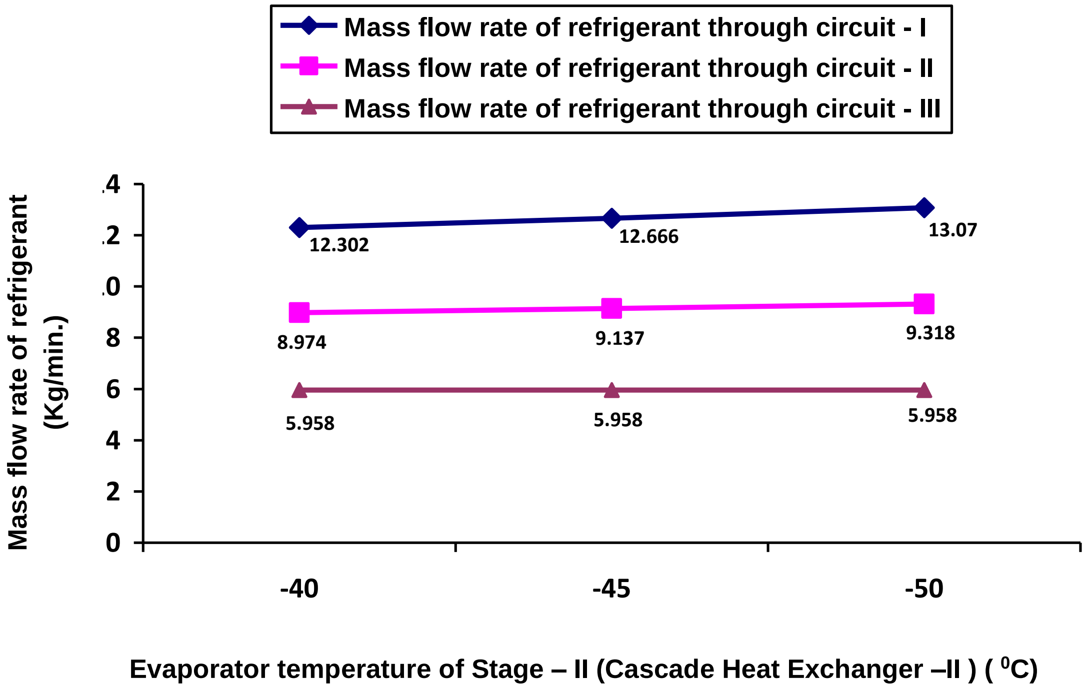


Fig. 4.4.5: Effect of Evaporator temperature of Stage – II (Cascade Heat Exchanger-II) on mass flow rate through various stages.

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_7 = 5 ^{0}C , T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

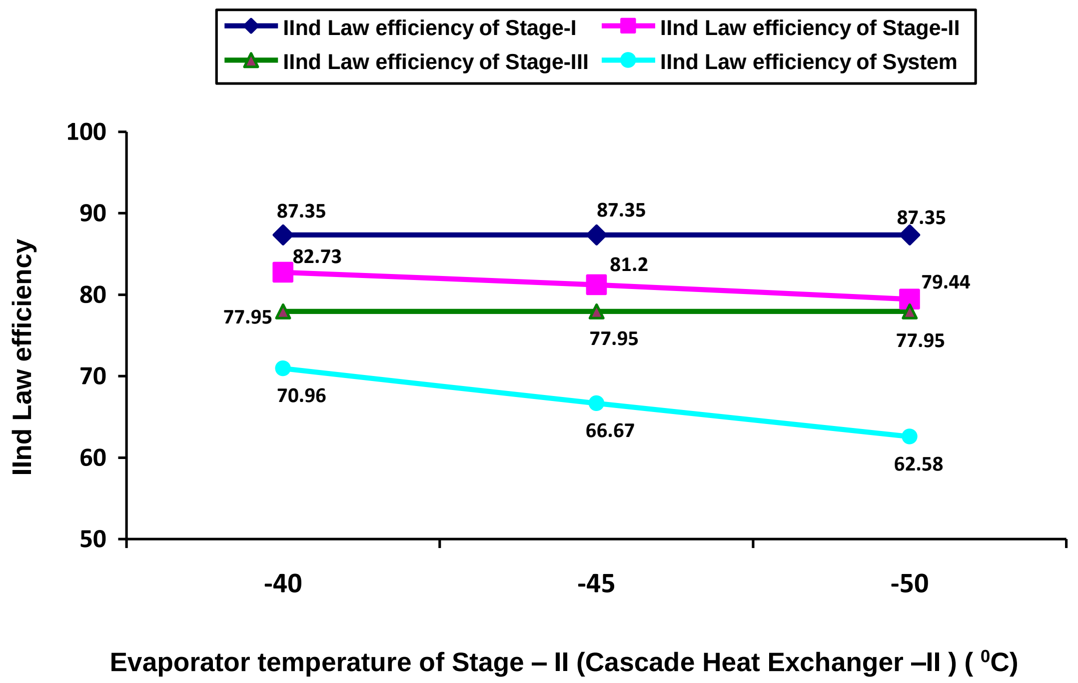


Fig. 4.4.6 : Effect of Evaporator temperature of Stage – II (Cascade Heat Exchanger-II) on IInd Law efficiency of Stage-I, II, III & system.

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_7 = 5 ^{0}C , T_9 = –85^{0}C , T_{11} = –35^{0}C (Keeping all constant)

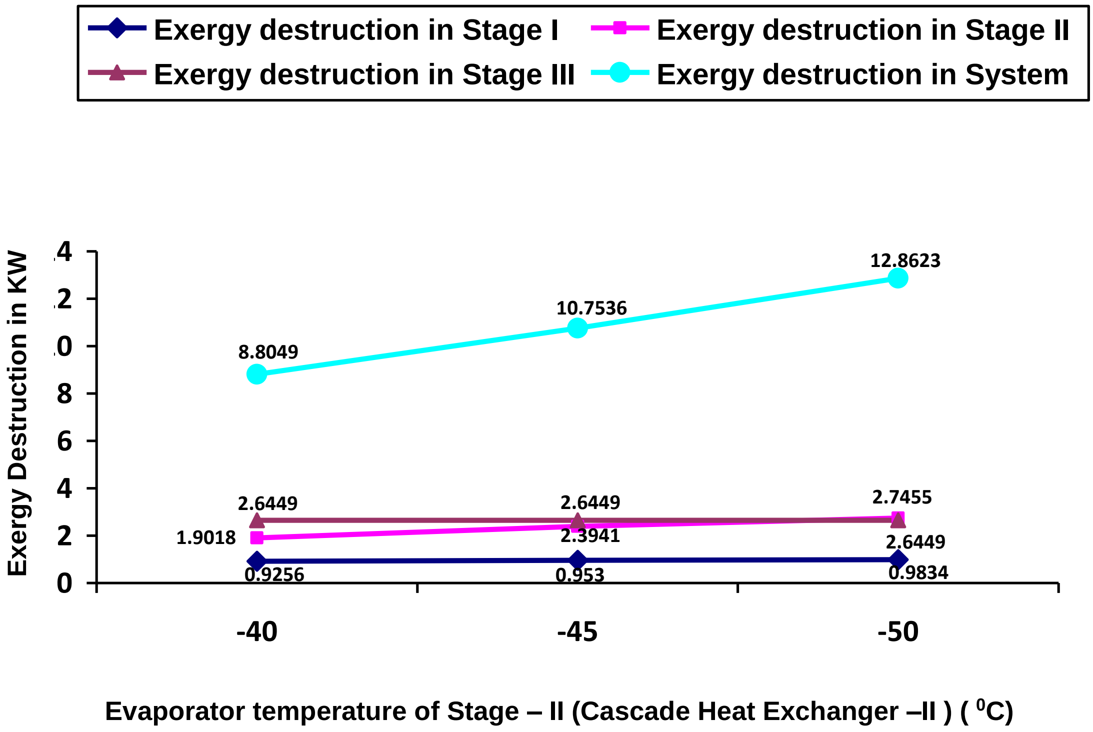
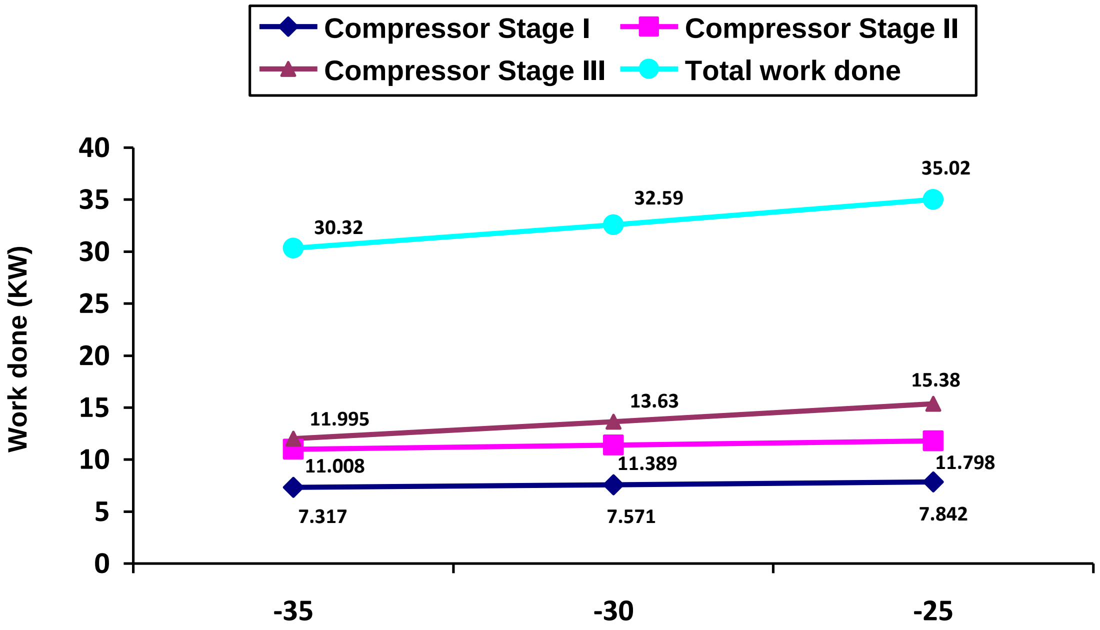


Fig. 4.4.7 : **Effect of Evaporator temperature of Stage – II (Cascade Heat Exchanger-II) on Exergy destruction of Stage-I, II, III & System.**

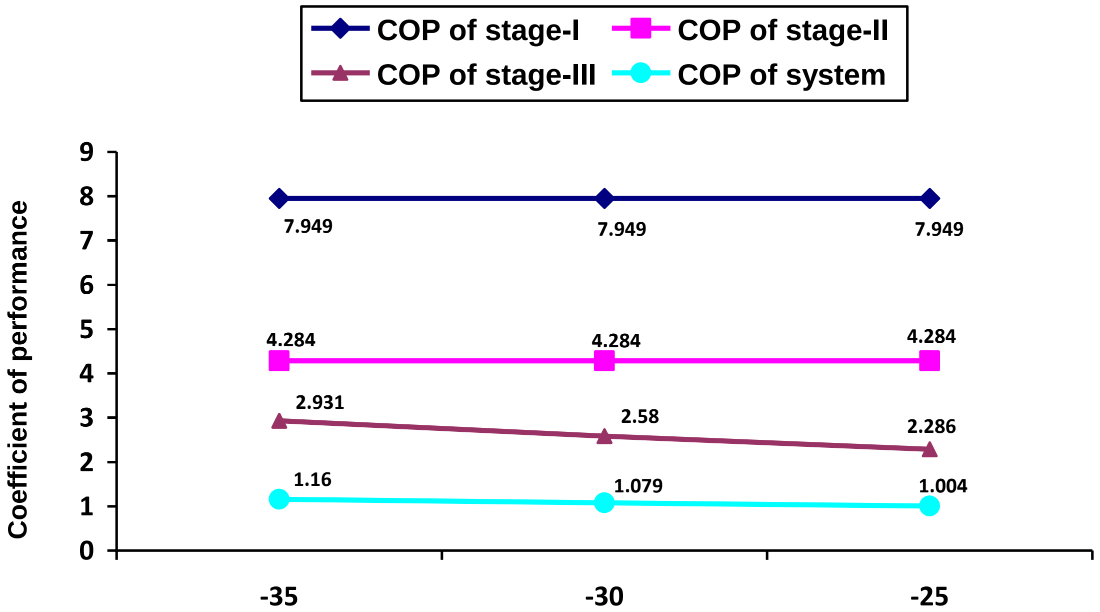
T_3 = 30 ^{0}C, T_1 =0^{0}C , T_7 = 5 ^{0}C , T_9 = –85^{0}C , T_5 = –40^{0}C (Keeping all constant)



Condenser temperature of stage –III (Cascade Heat Exchanger –II) (^{0}C)

Fig. 4.5.1 : Effect of Condenser temperature of stage- III on work done by Compressors

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_7 = 5 ^{0}C , T_9 = –85^{0}C , T_5 = –40^{0}C (Keeping all constant)



Condenser temperature of stage –III (Cascade Heat Exchanger –II) (^{0}C)

Fig. 4.5.2 : Effect of Condenser temperature of stage- III on coefficient of performance

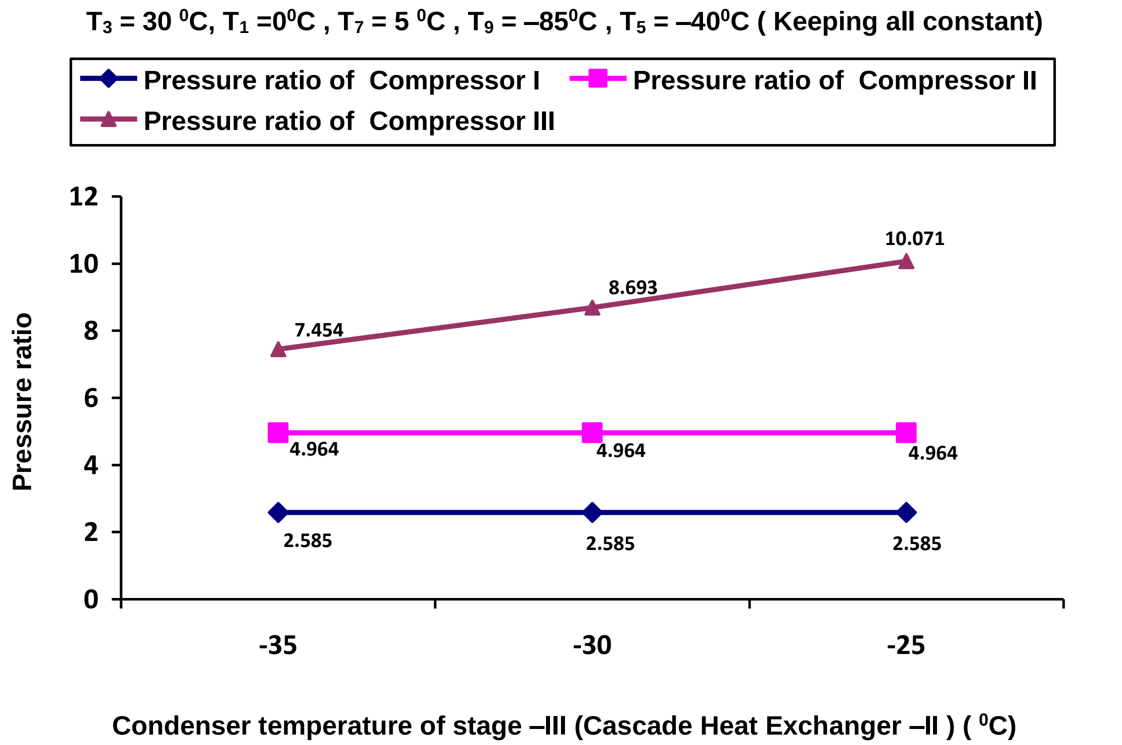


Fig. 4.5.3 : Effect of Condenser temperature of stage- III on pressure ratio developed by Compressors

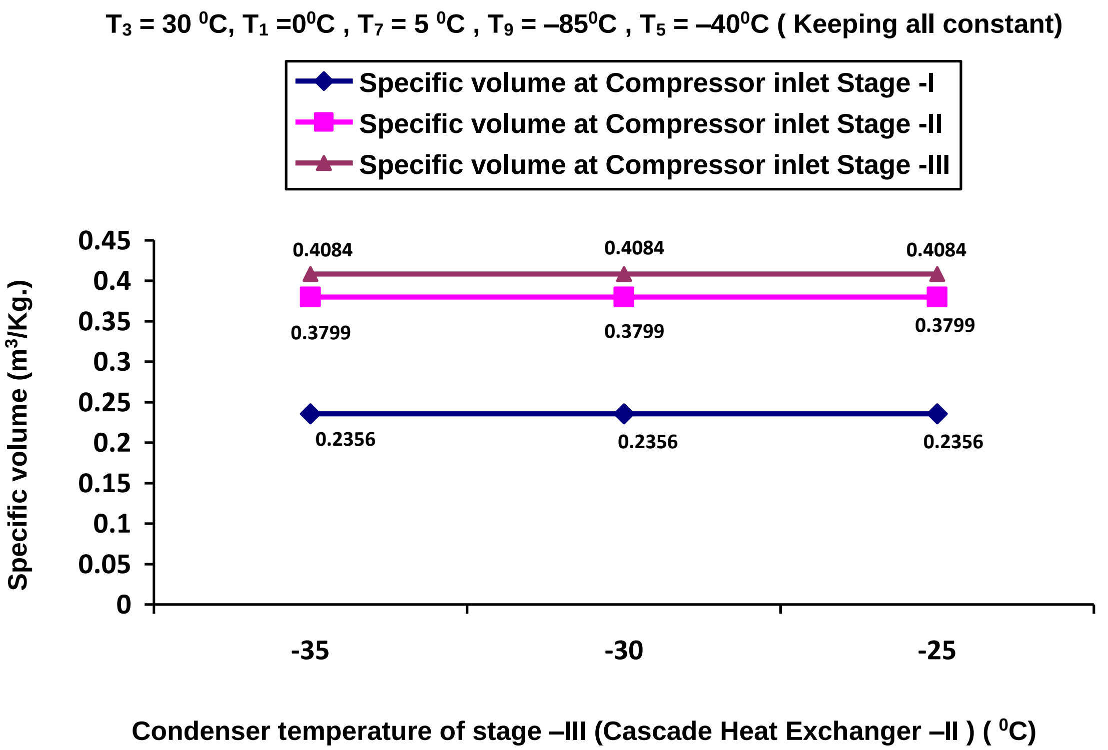


Fig. 4.5.4 : Effect of Condenser temperature of stage- III on specific volume at inlet of compressors

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_7 = 5 ^{0}C , T_9 = –85^{0}C , T_5 = –40^{0}C (Keeping all constant)

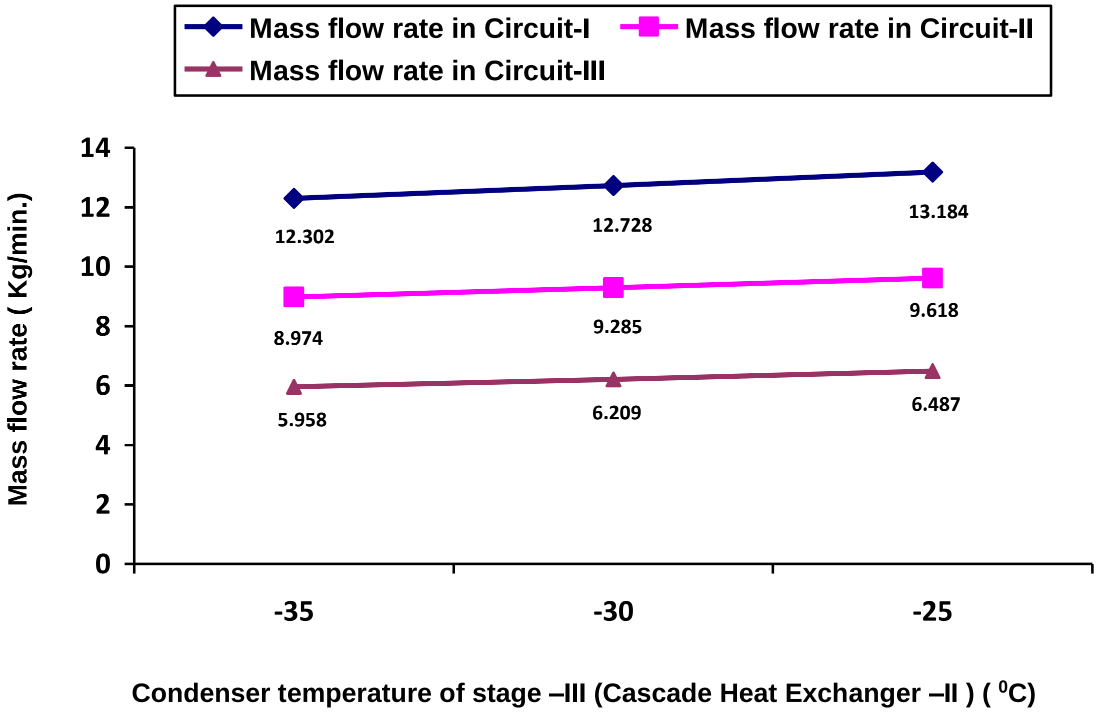


Fig. 4.5.5 : Effect of Condenser temperature of stage- III on mass flow rate through various stages

T_3 = 30 ^{0}C, T_1 =0^{0}C , T_7 = 5 ^{0}C , T_9 = –85^{0}C , T_5 = –40^{0}C (Keeping all constant)

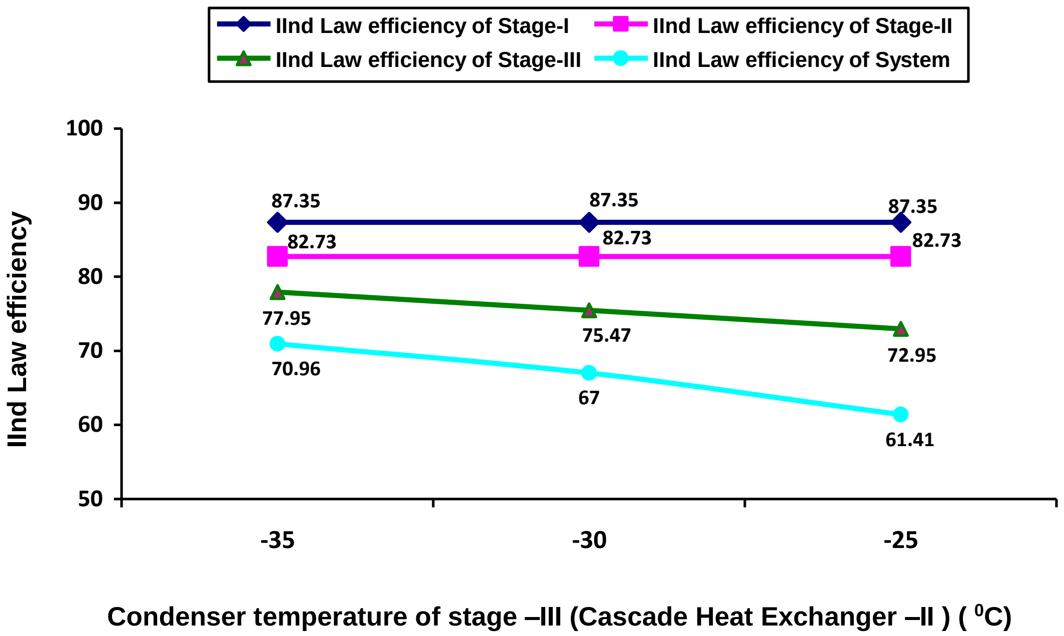


Fig. 4.5.6 : Effect of Condenser temperature of stage- III on IInd Law efficiency of Stage-I, II, III & system.

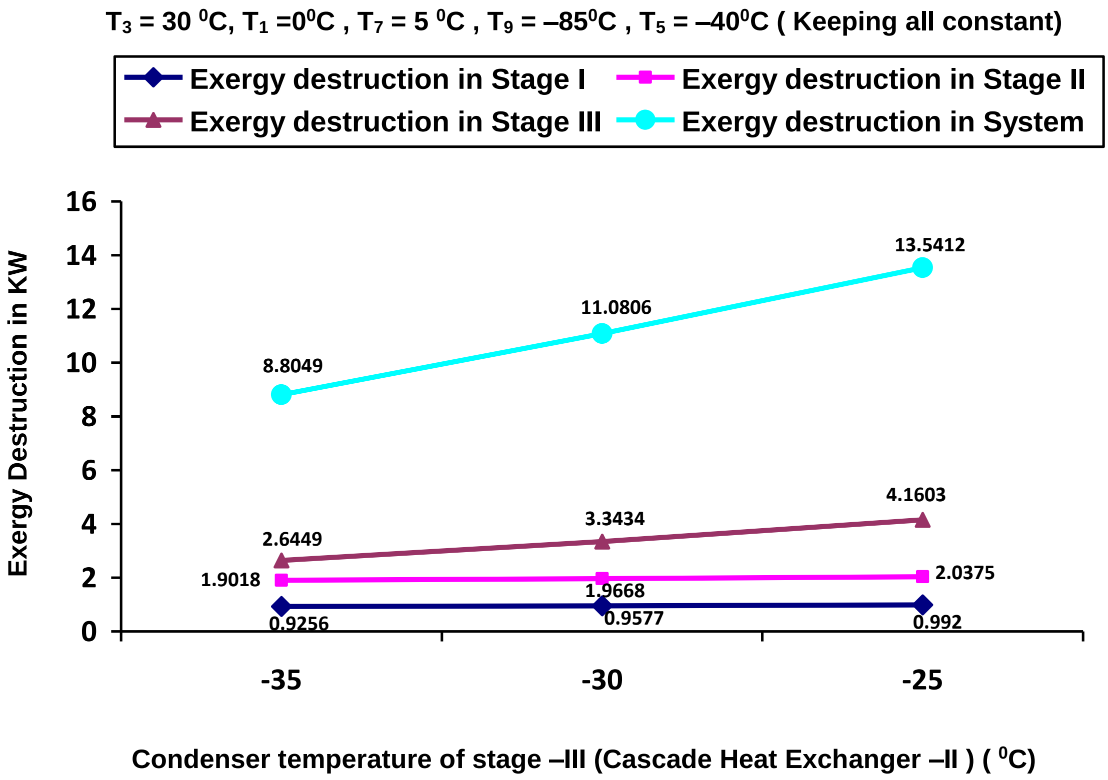


Fig. 4.5.7 : Effect of Condenser temperature of stage- III on Exergy destruction of Stage-I, II, III & System.

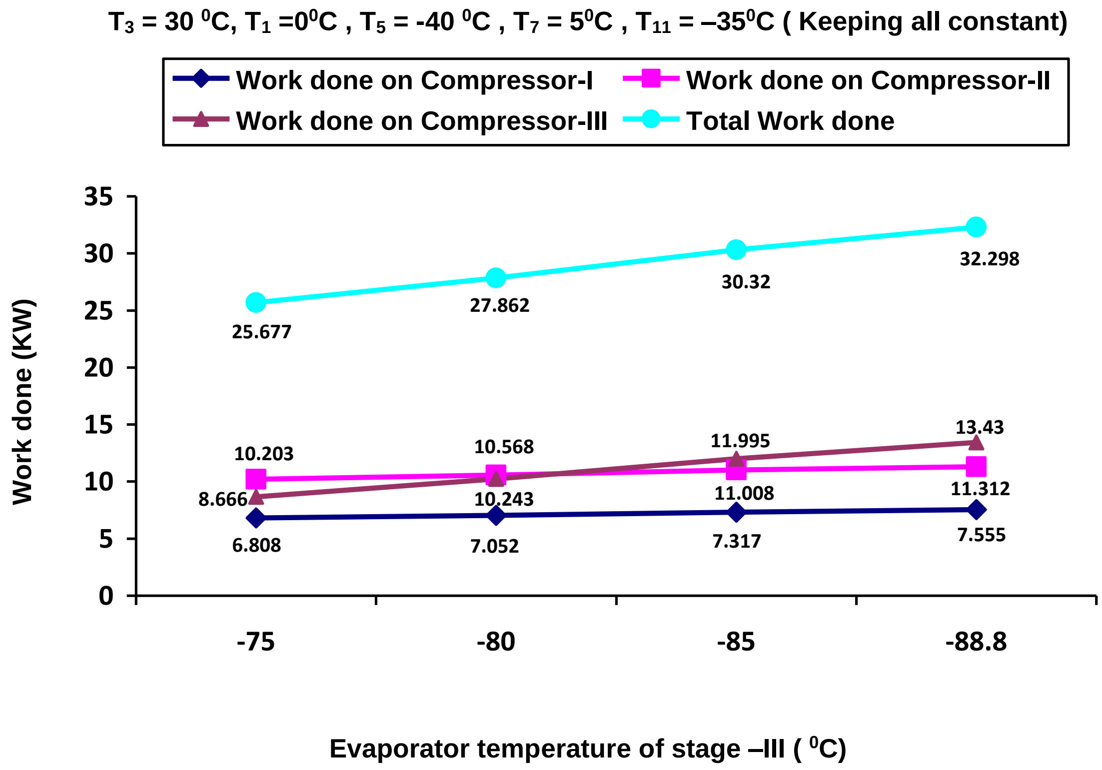


Fig. 4.6.1 : Effect of Evaporator temperature of stage- III on work done by various compressor

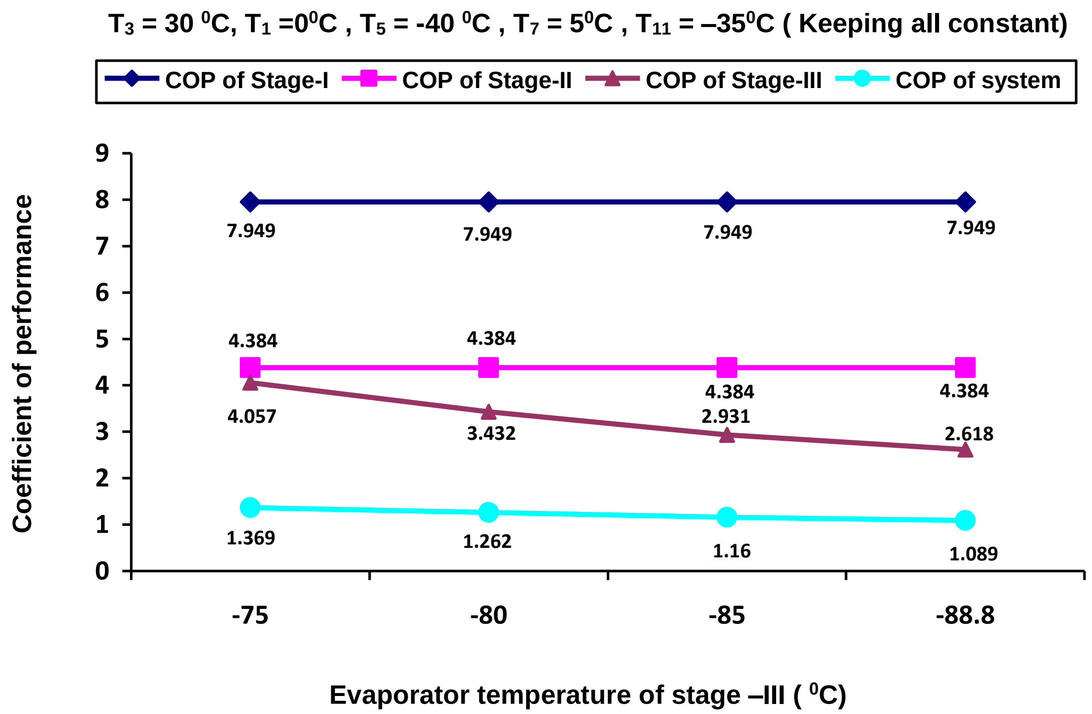


Fig. 4.6.2 : Effect of Evaporator temperature of stage- III on COP of stage-I, II , III & system

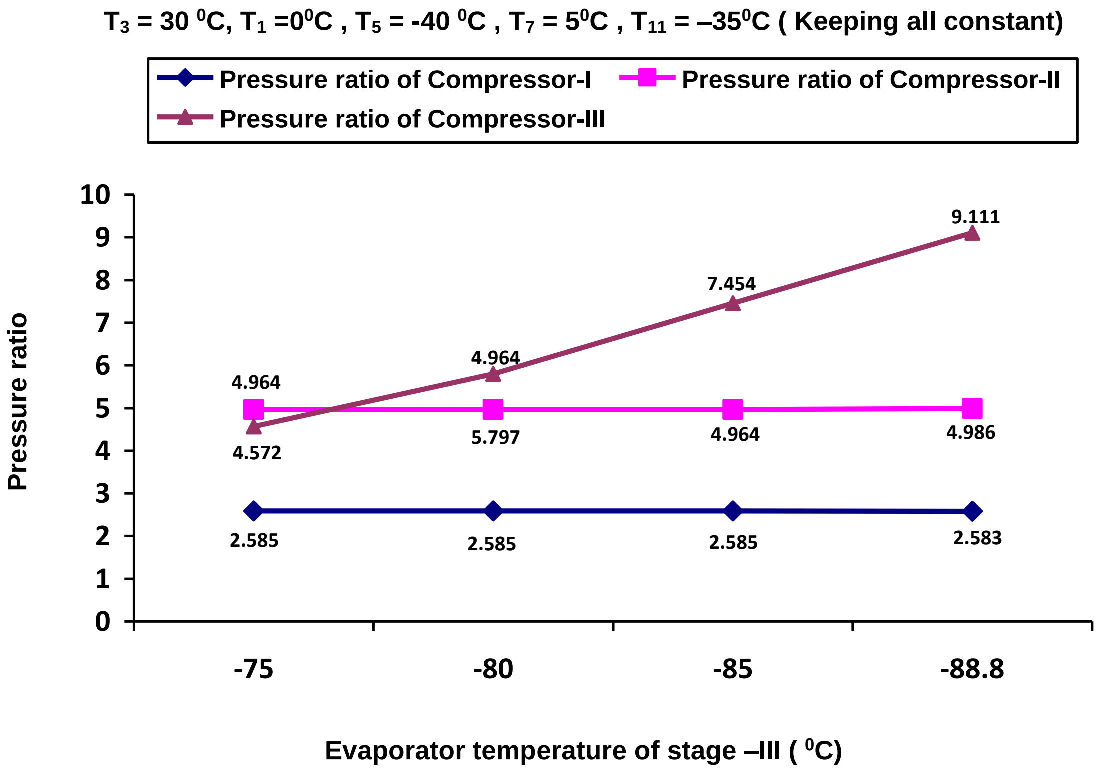


Fig. 4.6.3 : Effect of Evaporator temperature of stage- III on pressure ratio of stage-I, II & III

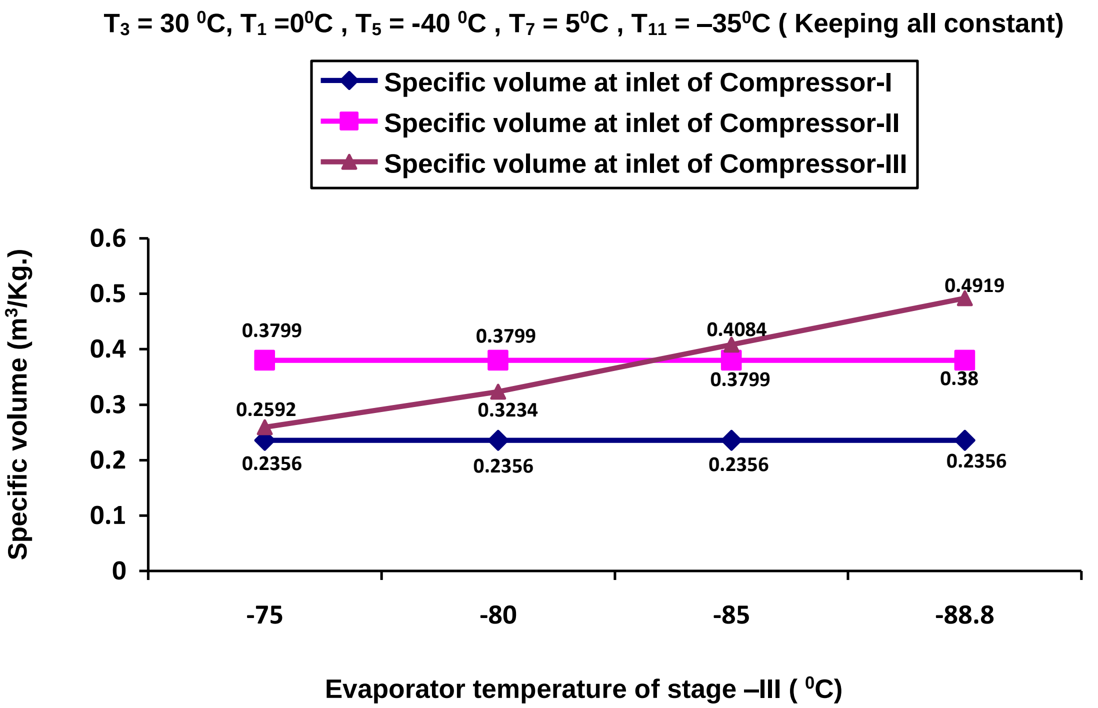


Fig. 4.6.4 : Effect of Evaporator temperature of stage- III on specific volume at compressor inlet of stage-I, II & III

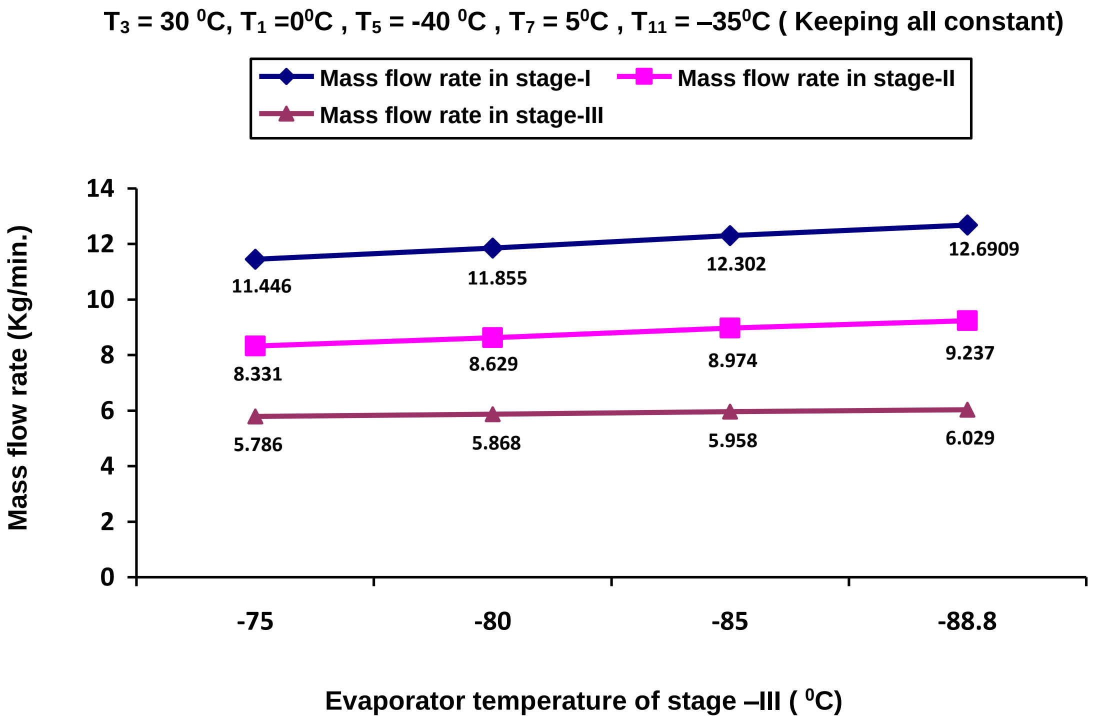


Fig. 4.6.5 : Effect of Evaporator temperature of stage- III on Mass flow rate in stage-I, II & III

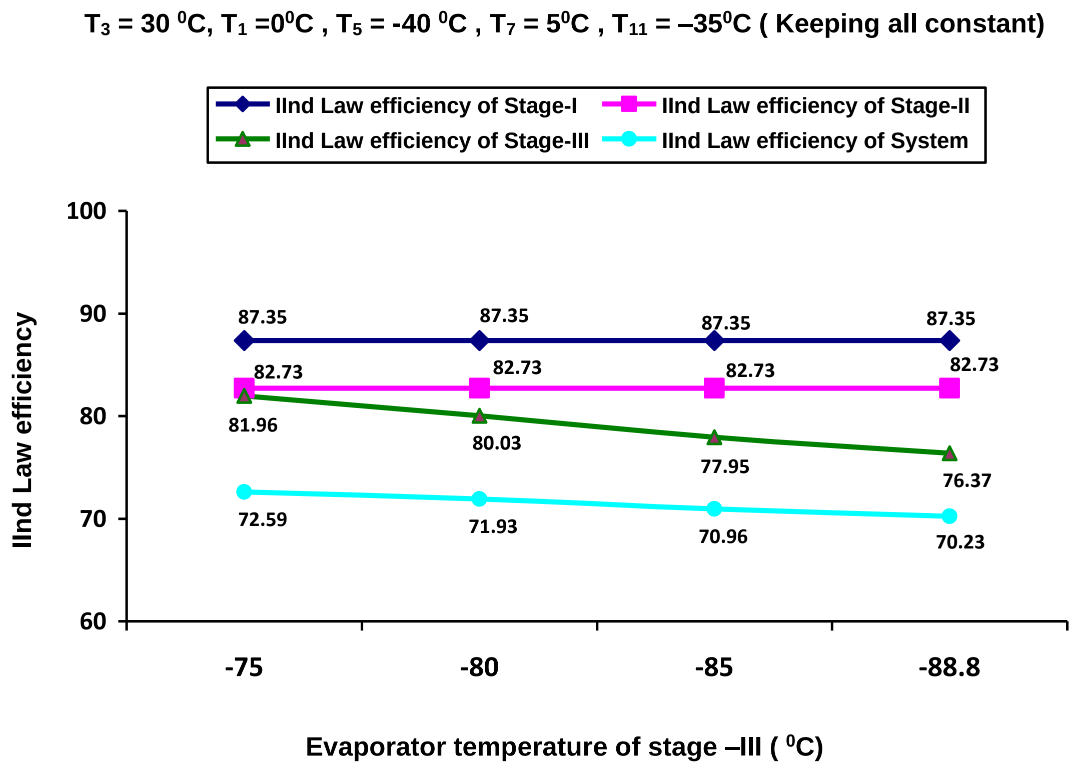


Fig. 4.6.6 : Effect of Evaporator temperature of stage- III on IInd Law efficiency of Stage-I, II, III & system.

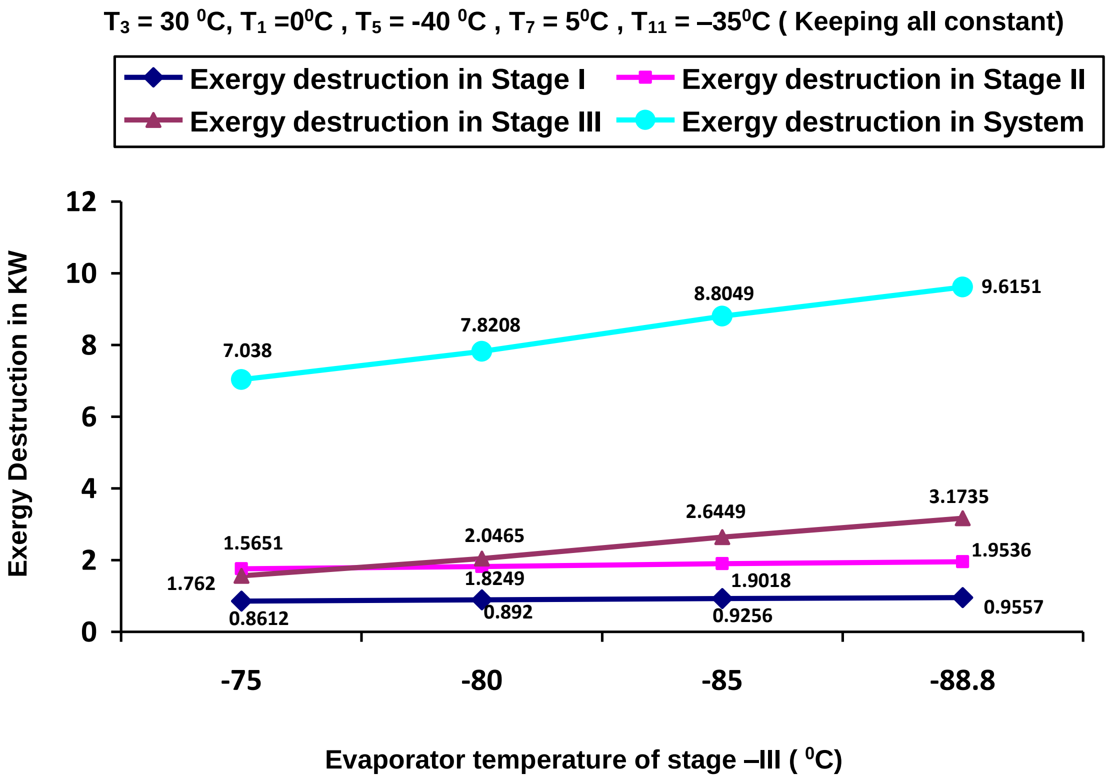


Fig. 4.6.7 : **Effect of Evaporator temperature of stage- III on Exergy destruction of Stage-I, II, III & System.**