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Comparative Study of Improvements in Multiple Effect Vapor Absorption Systems using Loop Heat Pipes

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Abstract: The research work is based on the research done on the modification of vapor absorption refrigeration systems (VARS) by incorporating Loop Heat Pipes (LHP). A comparison of the performance enhancements of different effect systems namely single, double, half and triple effect systems is performed in this research work. The modification in the systems is brought in by replacing the condenser of the VARS systems by LHPs. It's shown through the simulations that intra cycle heat exchange increases with the change in design, materials of the LHP and operating temperatures. The COP $_I$ and COP $_{II}$ are maximum for triple effect system whereas the percentage increase in the performance is highest in double effect system 78% & 28%. Higher the generator temperature, higher is the heat utilization factor for the LHPs. The system becomes concise and flexible at the same time.

Keywords: Loop Heat Pipes, Vapor Absorption Refrigeration System, Half Effect, Double Effect, Triple Effect, Double Effect

I. INTRODUCTION

The performance parameters of different Vapor absorption systems have been studied. The systems have been modified by removal of condenser from the original system. The advantages in the new systems have been discussed earlier, this research work happens to be comparing all the aspects.

II. LITERATURE REVIEW

Fabian Korn et al. [2012] performed several vital experiments on heat pipes to establish it to be one of the most effective procedures to transport thermal energy from one point to another, mostly used for cooling[1]. R.Z. Wang et al.[2008]added heat pipes in adsorption water chiller or ice maker initials. His work showed that the adsorption refrigerators are very efficient [2]..R. Rajashree et al.[1990]went through a numerical analysis of an unsteady, viscous, laminar, incompressible, two dimensional heat and mass transfer, in the vapour gas region of gas loaded circular heat pipe [3]. M.M. Talbi et al. (2000) carried out an exergy analysis on a single-effect absorption refrigeration cycle with lithium-bromide±water as the working Fluid pair [4]. E. Kurem et al.(2001) analyzed the Absorption Heat Pump (AHP) and Absorption Heat Transformers (AHT) using ammonia-water and water-lithium bromide solutions. A fundamental AHP and AHT systems was described and explained the operating sequence [5]. S.A. Adewusi et al (2004). studied the performance of single-stage and two- stage ammonia–water absorption refrigeration systems (ARSs).They calculated entropy generation of each component and the total entropy generation of all the system components as well as COP of the ARSs [6] . S. Arivazhagan et al. (2006) investigated experimentally on the performance of a two-stage half effect vapour absorption cooling system .The prototype is designed for 1 kW cooling capacity using HFC based working fluids (R134a as refrigerant and DMAC as absorbent) [7] . Rabah Gomri et al. (2008) performed exergy analysis of double effect lithium bromide/water absorption refrigeration system. The system consisted of a second effect generator between the generator and condenser of the single effect absorption refrigeration system, including two solution heat exchangers between the absorber and the two generators [8]. S.C. Kaushika et al. (2009) presented the energy and exergy analysis of single effect and series flow double effect water–lithium bromide absorption systems. They developed a computational model for the parametric investigation of the systems [9]. Gulshan Sachdeva et al.(2014) performed an exergy analysis of VAR system using LiBr- H_2O as working fluid with the modified Gouy-Stodola approach [10]. Ankit Dwivedi et al. (2018) through computer simulations of the replacement of condensers from single, double, half &triple effect VARS, showed the improvements in the performance in COP $_I$ and COP $_{II}$ [11].

Based on the research work presented in the section, the comparison of the improvements in the performance parameters in all the different type of VARS based on the effect is due. This research article focuses on the comparative analysis. It will be described how the COPI and COPII vary for across the VAR systems with heat interaction and temperature in the LHP.

III. SYSTEMS DESCRIPTION

The following Fig.1 Shows the modification made by Ankit Dwivedi et. al. [42] in the simple single effect VARS operating between 373K & 273K . The system is able to reduce the waste of heat very effectively. Fig. Shows the changes made by Ankit Dwivedi et. al. [44] in Double effect VARS operating between 403K and 277K . The system operates without the presence of condenser. Also the heat exchange has improved with the use of LHP between low temperature generator and absorber. The LHP works on a very constant temperature, that reduces the exergy loss due to heat transfer through a large temperature difference.

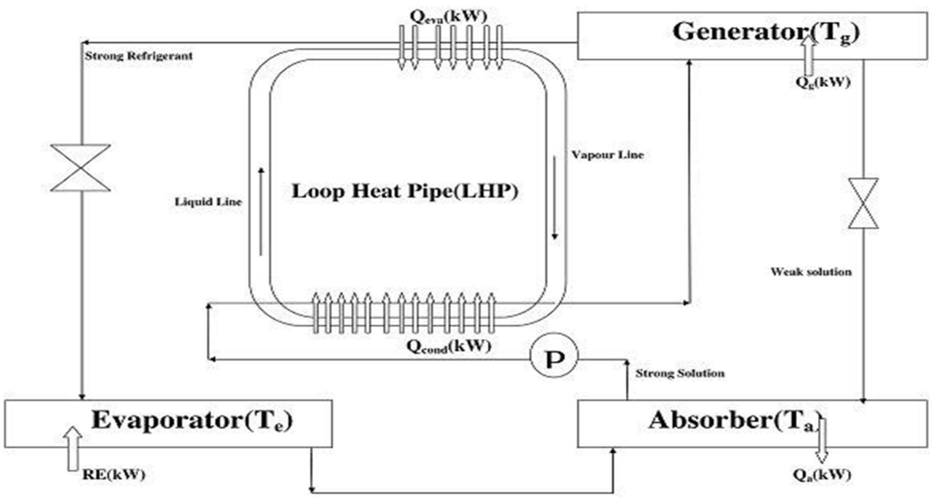

Fig.1: Modified VARS with a LHP [42].

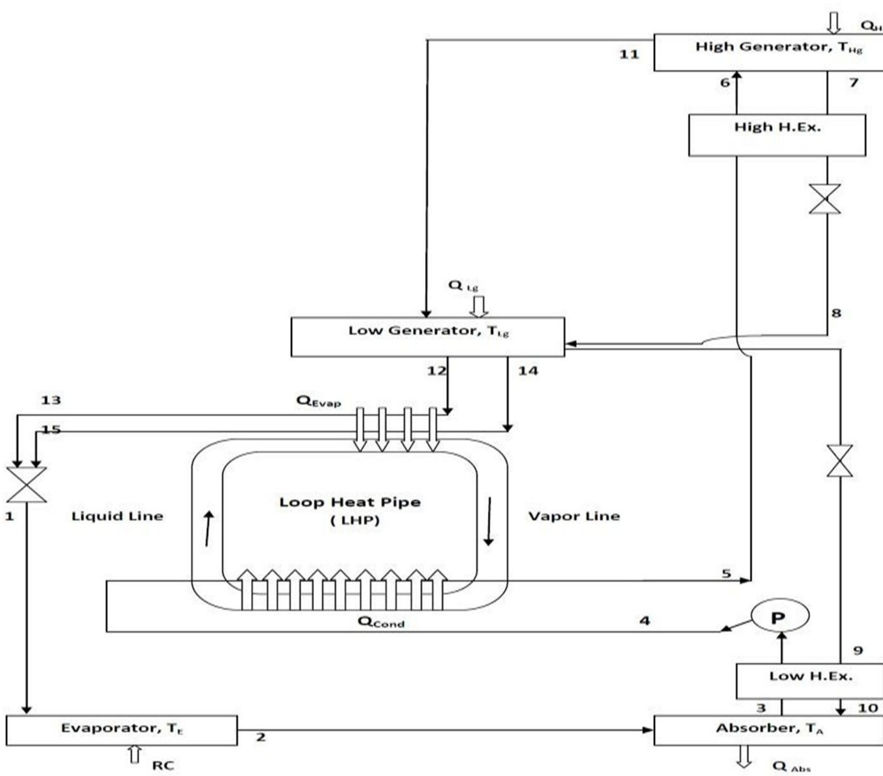

Fig.2: Modified Double Effect VARS with a LHP [44]

Fig. 2 is the schematic of the modifiation of Half effect VARS by installing the LHP arranging heat exchange between High Generator and High Absorber, for the similar reason of reducing heat input to the generator and making possible of effective utilization of heat from low temperature sources. The system operates between 363K & 278K.

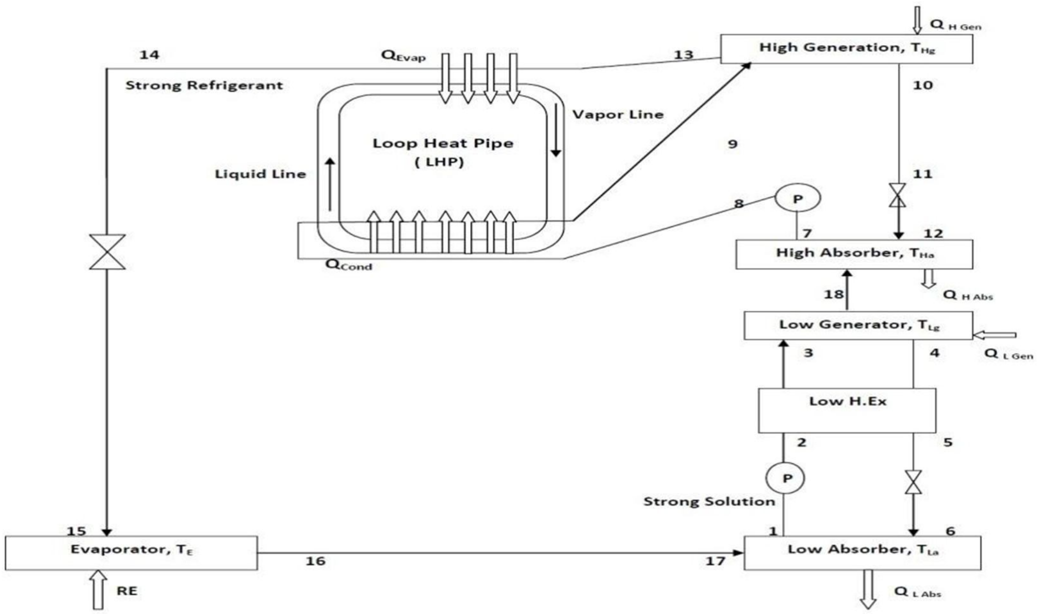

Fig.3: Modified Half Effect VARS with a LHP [43]

Triple effect system is modified by using 2 LHPs as can be seen in the Fig. 3 Mixture from the absorber is pumped directly through the LHPs. With the help of these LHPs, heat exchange at two levels is arranged. This system operates between 433K and 276 K.

These designed systems in Fig. 4 are obtained by removing condensers by LHPs. The design is flexible and intra-cycle heat exchange is achieved, heat loss to the environment is reduced, reducing the entropy generation.

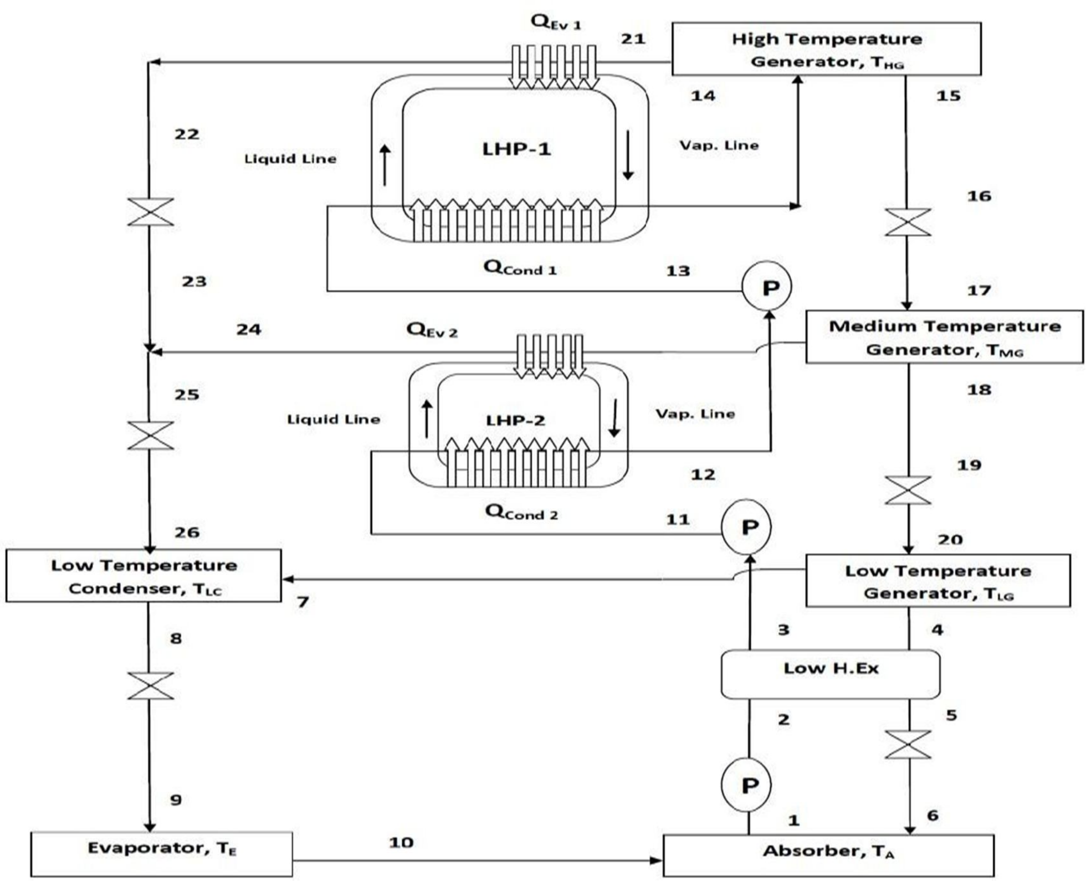

Fig.4: Modified Tripple Effect VARS with a LHP [45]

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The following tables contain the parameters used in the systems explained above in order to obtain the required simulations.

Table1: Terms Used in Simulation of Single Effect VARS [46].

Terms	**Abbreviations**
Refrigeration Effect in kW	RE (kW)
Heat rejected in absorber in kW	Q_a (kW)
Heat supplied in generator in kW	Q_g (kW)
Heat rejected in condenser of LHP in kW	Q_{cond} (kW)
Heat absorbed in evaporator of LHP in kW	Q_{eva} (kW)
Absorber Temperature in K	T_a,T_A (K)
Generator Temperature in K	T_g, T_G (K)
Condenser Temperature in K	T_c (K)
Evaporator Temperature in K	T_E,T_e (K)
Heat Rejected in Condenser in kW	Q_C (kW)
First Law Coefficient of Performance	COP_I
Second Law Coefficient of Performance	COP_{II}
Heat Leaked from the LHP in kW	Q_{Leak} (kW)
Percentage Improvement in First Law Coefficient of Performance	%$COP_{I\ imp}$
Percentage Improvement in Second Law Coefficient of Performance	%COP II imp
Improvement in First Law Coefficient of Performance	COP I imp
Improvement in Second Law Coefficient of Performance	COP II imp

Table2: Terms Used in Simulation of Double Effect VARS[44]

Terms	Abbreviations
Refrigeration Effect in kW	RE (kW)
Heat rejected in absorber in kW	Q_a (kW)
Heat supplied in generator in kW	Q_g (kW)
Heat rejected in condenser of LHP in kW	Q_{cond} (kW)
Heat absorbed in evaporator of LHP in kW	Q_{eva} (kW)
Absorber Temperature in °C	T_{La},T_{Ha} (°C)
Generator Temperature in °C	T_{Hg}, T_{LG} (°C)
LHP Condenser Temperature in °C	T_c (°C)
Evaporator Temperature in °C	T_E,T_e (°C)
Heat Rejected in Condenser in kW	Q_C (kW)
First Law Coefficient of Performance	COP_I
Second Law Coefficient of Performance	COP_{II}
Heat Leaked from the LHP in kW	Q_{Leak} (kW)
Percentage Improvement in First LawCoefficient of Performance	%$COP_{I\ imp}$
Percentage Improvement in Second LawCoefficient of Performance	%COP II imp
Improvement in First Law Coefficient ofPerformance	COP I imp
Improvement in Second Law Coefficient of Performance	COP II imp
Low Pressure Generator	LPG
High Pressure Generator	HPG

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Table3: Terms Used in Simulation of Half Effect VARS [43]

Terms	**Abbreviations**
Refrigeration Effect in kW	RE (kW)
Heat rejected in absorber in kW	Q_a (kW)
Heat supplied in generator in kW	Q_g (kW)
Heat rejected in condenser of LHP in kW	Q_{cond} (kW)
Heat absorbed in evaporator of LHP in kW	Q_{eva} (kW)
Absorber Temperature in °C	T_{La},T_{Ha} (°C)
Generator Temperature in °C	$T_{Hg,}$ T_{LG} (°C)
LHP Condenser Temperature in °C	T_c (°C)
Evaporator Temperature in °C	T_E,T_e (°C)
Heat Rejected in Condenser in kW	Q_C (kW)
First Law Coefficient of Performance	COP_I
Second Law Coefficient of Performance	COP_{II}
Heat Leaked from the LHP in kW	Q_{Leak} (kW)
Percentage Improvement in First Law Coefficient of Performance	$\%COP_{I\ imp}$
Percentage Improvement in Second Law Coefficient of Performance	%COP II imp
Improvement in First Law Coefficient of Performance	COP I imp
Improvement in Second Law Coefficient of Performance	COP II imp

Table4: Terms Used in Simulation of Triple Effect VARS [45]

Terms	Abbreviations
Refrigeration Effect in kW	RE (kW)
Heat rejected in absorber in kW	Q_a (kW)
Heat supplied in generator in kW	Q_g (kW)
Heat rejected in condenser of LHP in kW	Q_{cond} (kW)
Heat absorbed in evaporator of LHP in kW	Q_{eva} (kW)
Absorber Temperature in °C	T_{La},T_{Ha} (°C)
Generator Temperature in °C	$T_{Hg,}$ T_{LG},T_{MG} (°C)
LHP Condenser Temperature in °C	T_c (°C)
Evaporator Temperature in °C	T_E,T_e (°C)
Heat Rejected in Condenser in kW	Q_C (kW)
First Law Coefficient of Performance	COP_I
Second Law Coefficient of Performance	COP_{II}
Heat Leaked from the LHP in kW	Q_{Leak} (kW)
Percentage Improvement in First Law Coefficient of Performance	$\%COP_{I\ imp}$
Percentage Improvement in Second Law Coefficient of Performance	%COP II imp
Improvement in First Law Coefficient of Performance	COP I imp
Improvement in Second Law Coefficient of Performance	COP II imp
Low Temperature Generator, Condenser	LG,LC
Medium Temperature Generator, Condenser	MG, MC
High Temperature Generator, Condenser	HG, HC

IV. RESULTS AND DICSUSSIONS

Based on the simulations this section revolves abounds the results obtained. The COP_I, COP_{II} are analysed with variations in Q_{Cond} & T_C . The performance enhancements in the above detailed systems are compared.

A. *Comparison of Improvements in COP_I & COP_{II} with Varying Heat Input in Condenser of the Loop Heat Pipe (LHP)*

This section is based on the results obtained by varying the parameter Heat Exchange in the condenser of the LHP. It's the energy that moves from the condensing strong refrigerant in the evaporator of the LHP. The idea is to transfer this energy to the mixture out of the absorber, to reduce the heat loss, improving both the COPs. Fig shows the COPs of single effect.

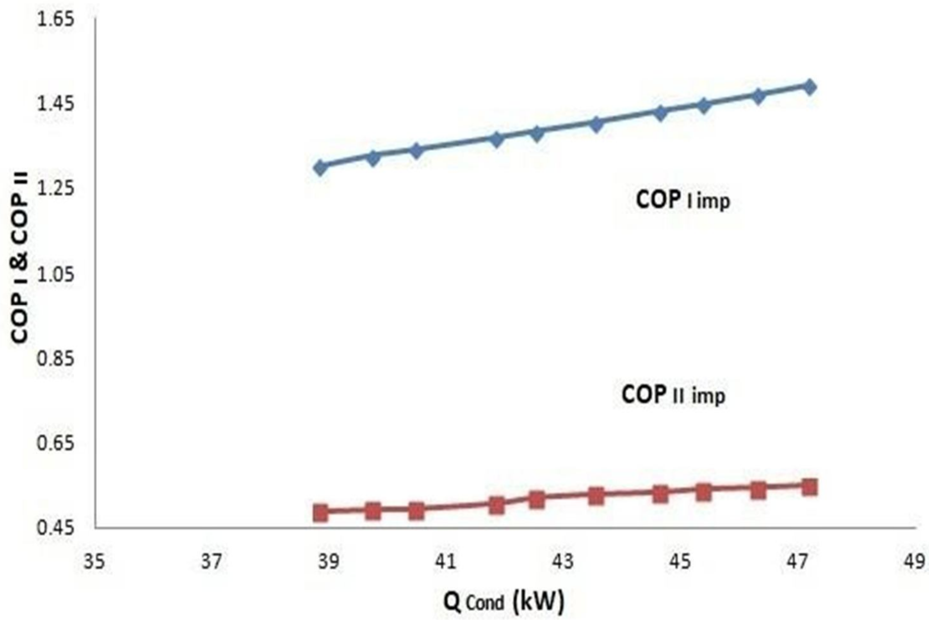

Fig.5: Single Effect

Fig is the plot of COPs with Q_{Cond} for the double effect system, whereas Fig is showing results for half effect system. The results of triple effect follows in fig .

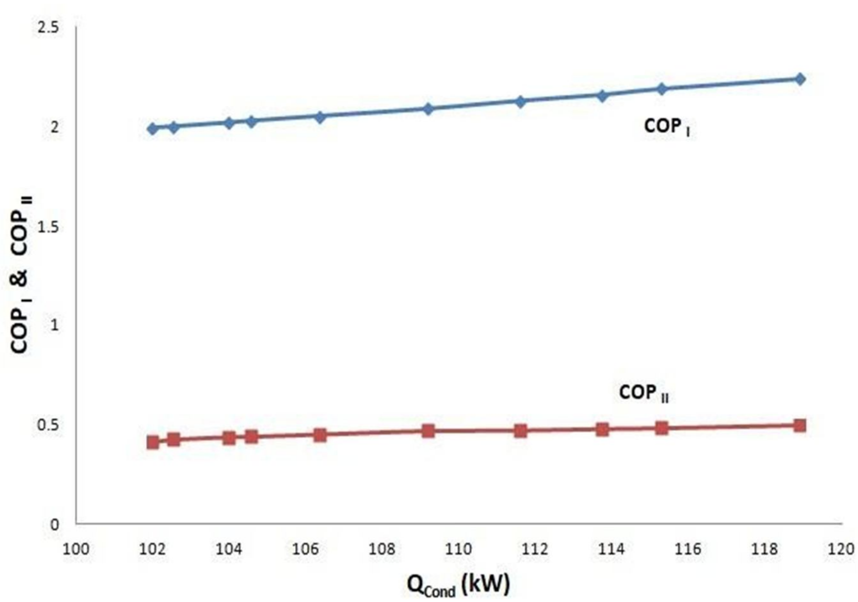

Fig.6: Double Effect

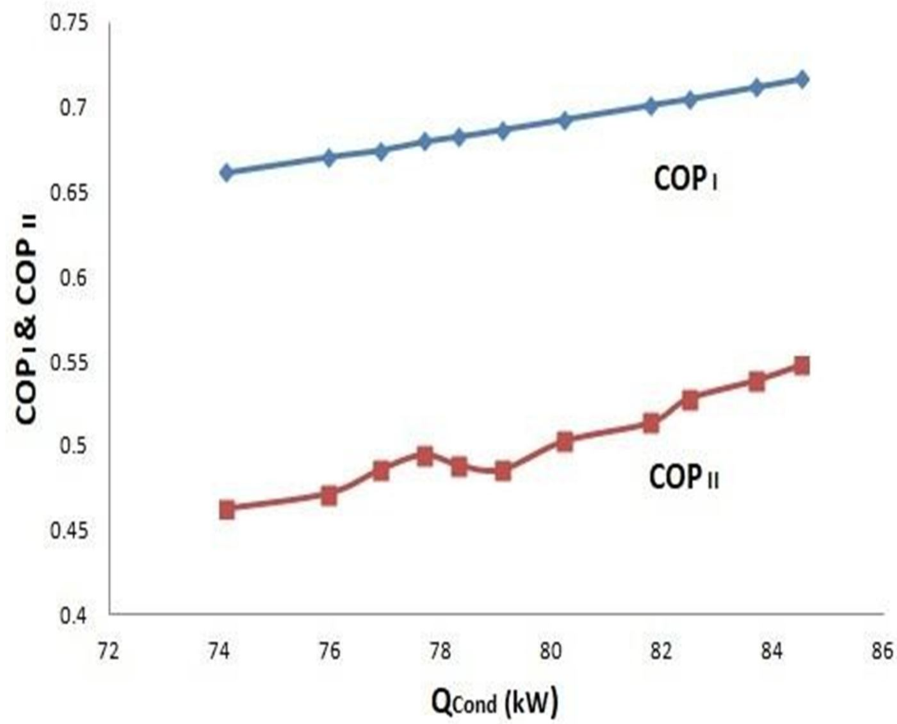

Fig.7: Half Effect

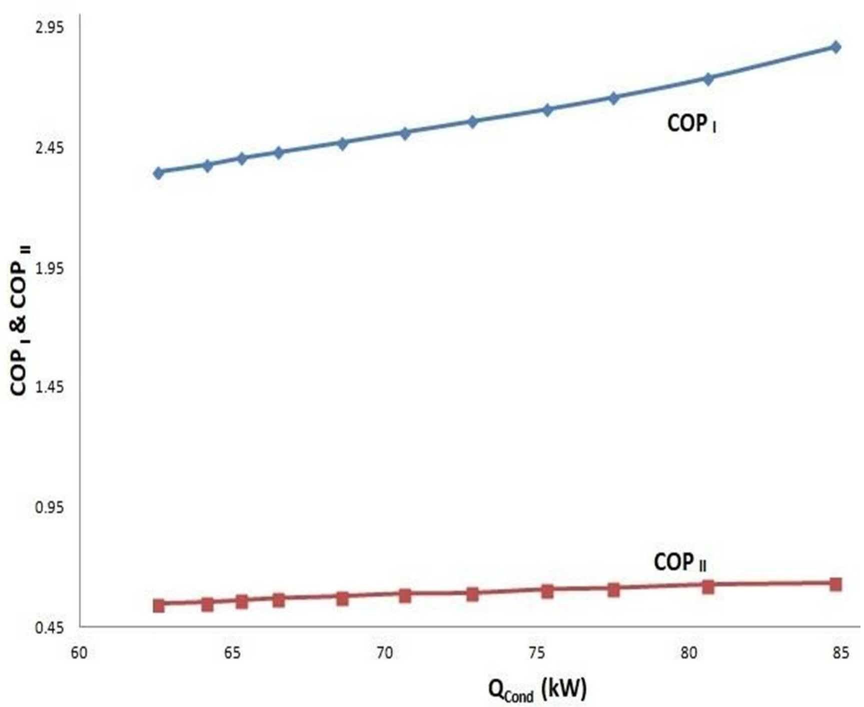

Fig.8: Triple Effect

It can be observed from the above figures that average COP_I & COP_{II} is for the improved single effect system are 1.4 & 0.51respectively. For the double effect system the figures of average COP_I & COP_{II} are 2.09 & 0.4571 respectively. The modified half effect system has average COP_I & COP_{II} as 0.69 and 0.502 respectively. The enhanced average COP_I & COP_{II} for Triple effect system is found to be 2.545 and0.588.

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B. Comparison of Percentage Improvements in COP_I & COP_{II} with Varying Heat Input in Condenser of the Loop Heat Pipe (LHP)

The above section explains the values of the COPs for the modified systems, while in this section it will be clear about the percentage enhancement of the COPs compared to that of the conventional systems with varying Q_{Cond}. Fig shows the average improvements in COP_I & COP_{II} for modified single effect system to be 68% and 23% respectively. Moreover Fig if showing the results for modified double effect system where average enhancement in COP_I & COP_{II} is 75.85% & 28.5 % respectively. Average increase in COP_I & COP_{II} is 64% & 27 % for the modified half effect system. The new triple effect system gets the improvement in COP_I & COP_{II} of about 61% and 25% as can be accessed from the Fig 9 to fig 12.

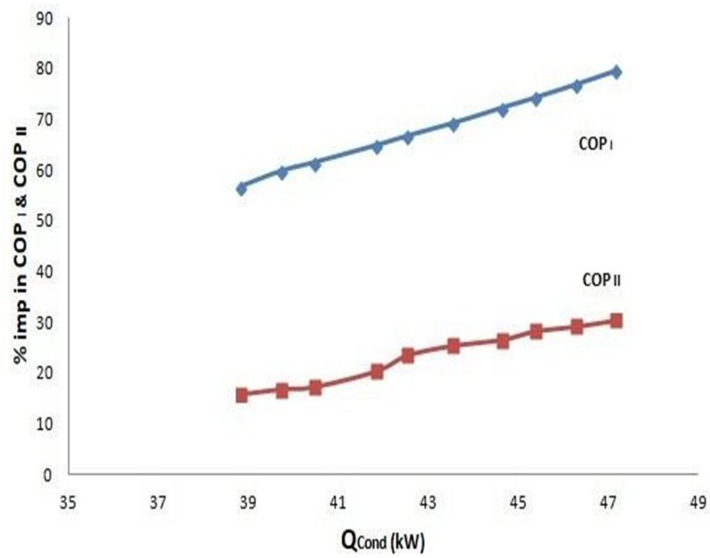

Fig.9: Single Effect

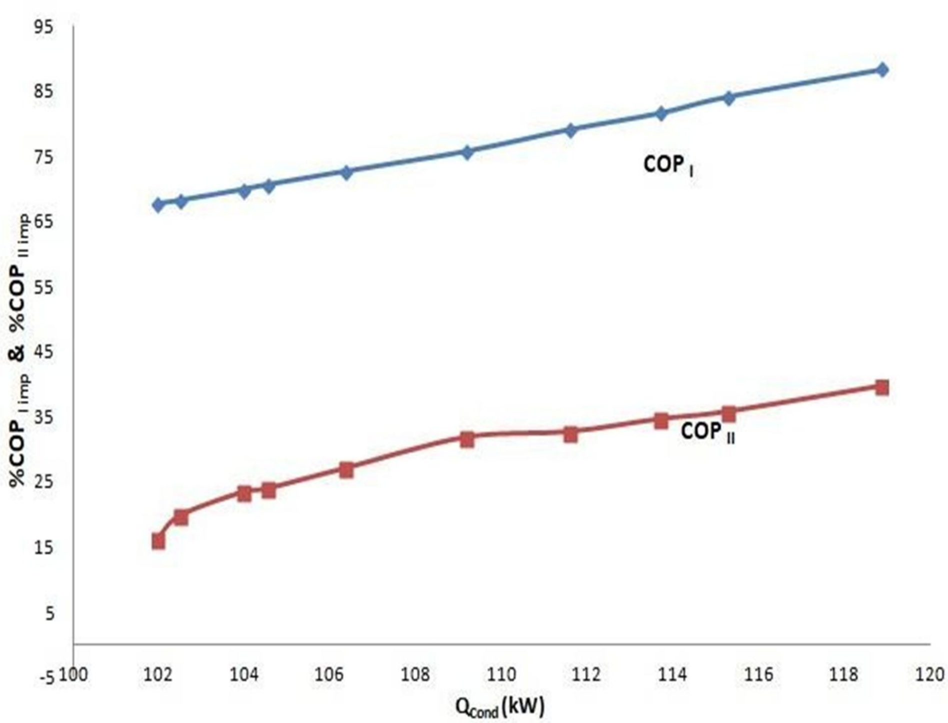

Fig.10 Double Effect

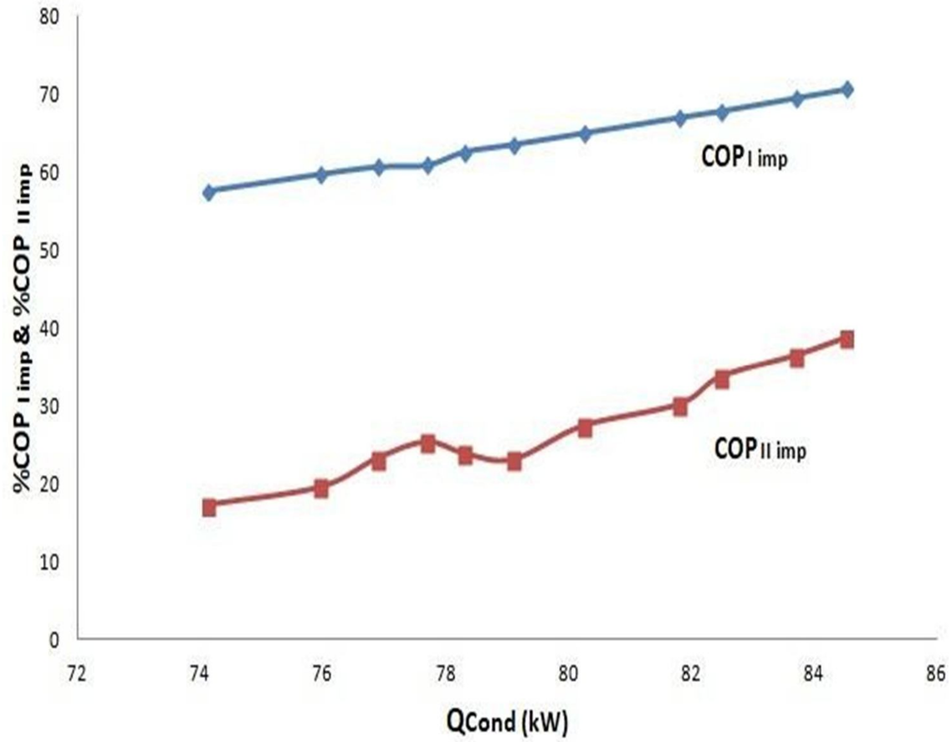

Fig.11: Half Effect

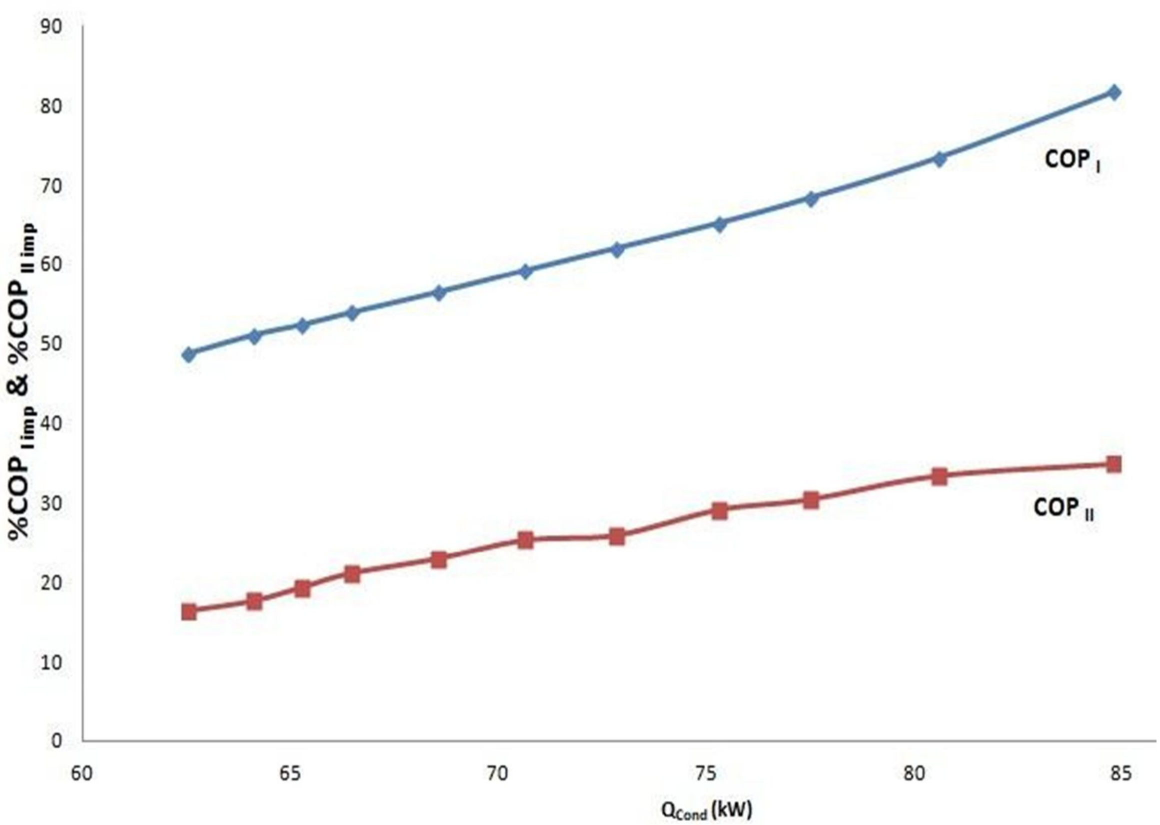

Fig.12: Triple Effect

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C. Comparison of Percentage Improvements in COP_I & COP_{II} with Varying Temperature in Condenser of the Loop Heat Pipe (LHP):

This section shows the results on performance parameters with varying T_C for the systems. The percentage increases in the figure from Fig 13 to Fig 15 for double, half and triple effect respectively.

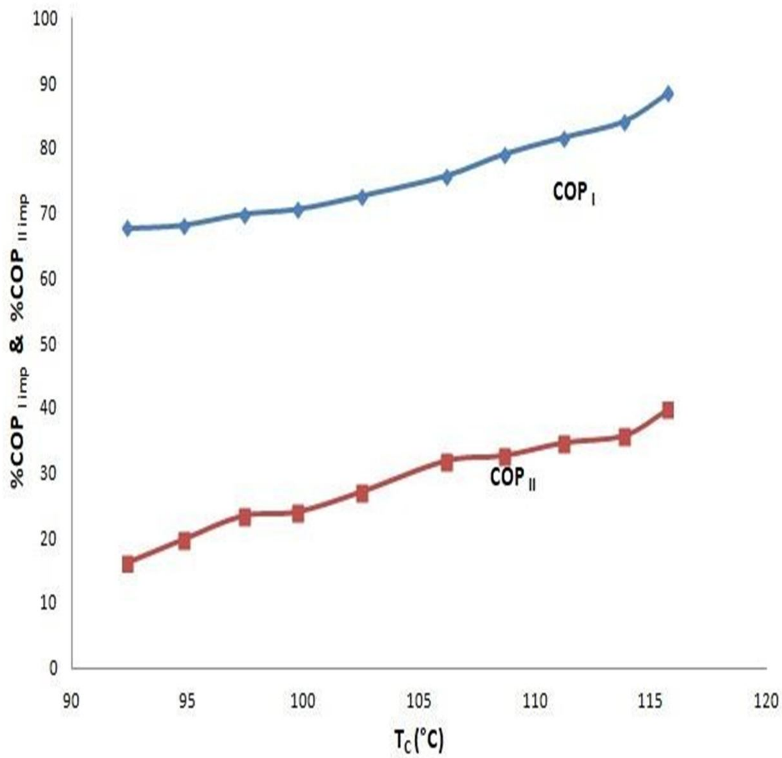

Fig.13: Double Effect

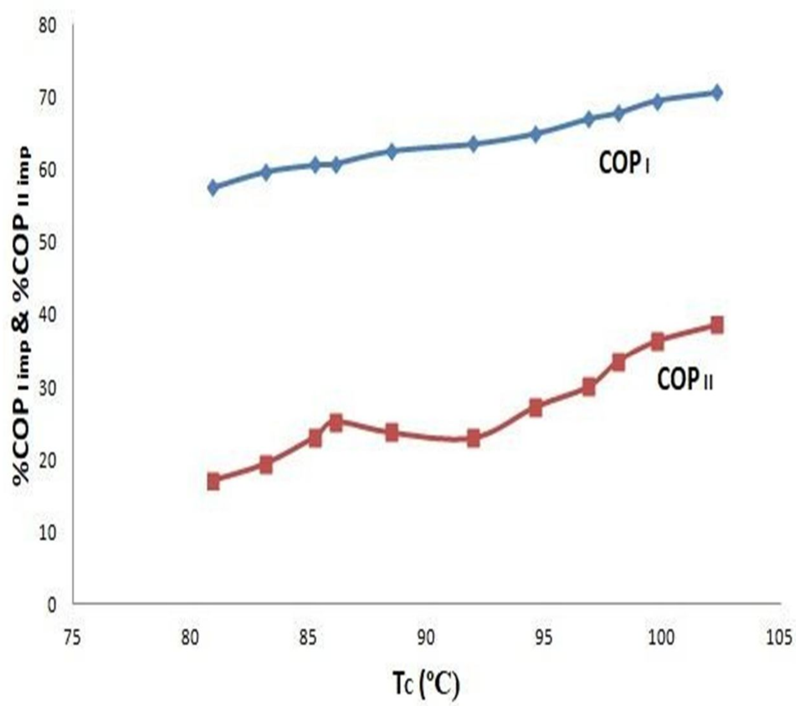

Fig.14: Half Effect

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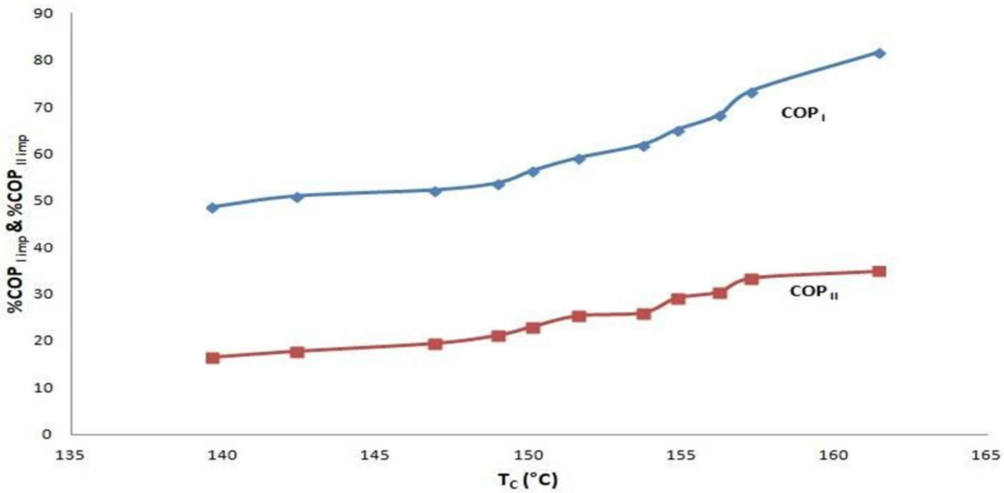

Fig.15: Triple Effect

D. Comparison of Percentage Improvements in COP_I & COP_{II} with Varying Generator Temperature:

The variation with the T_G can be seen from Fig 16 to Fig 18 for double, half and triple effect respectively.

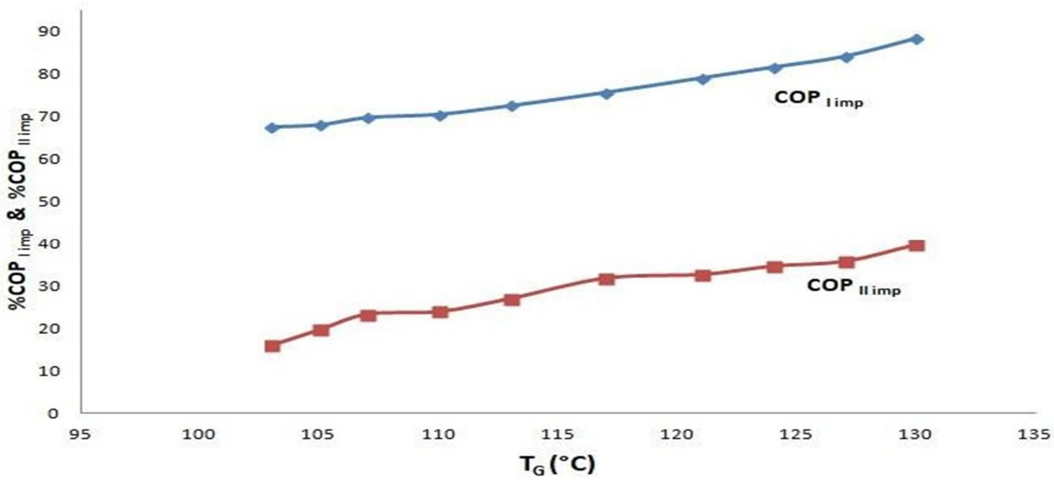

Fig.16: Double Effect

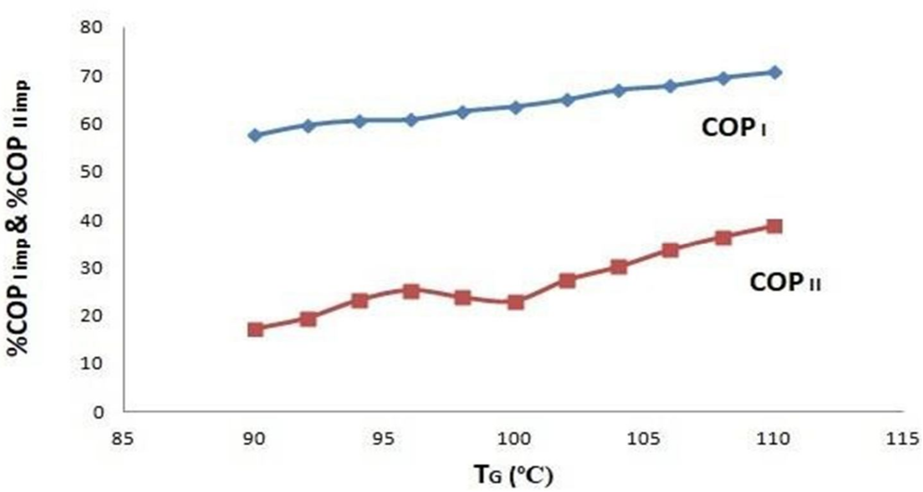

Fig.17: Half Effect

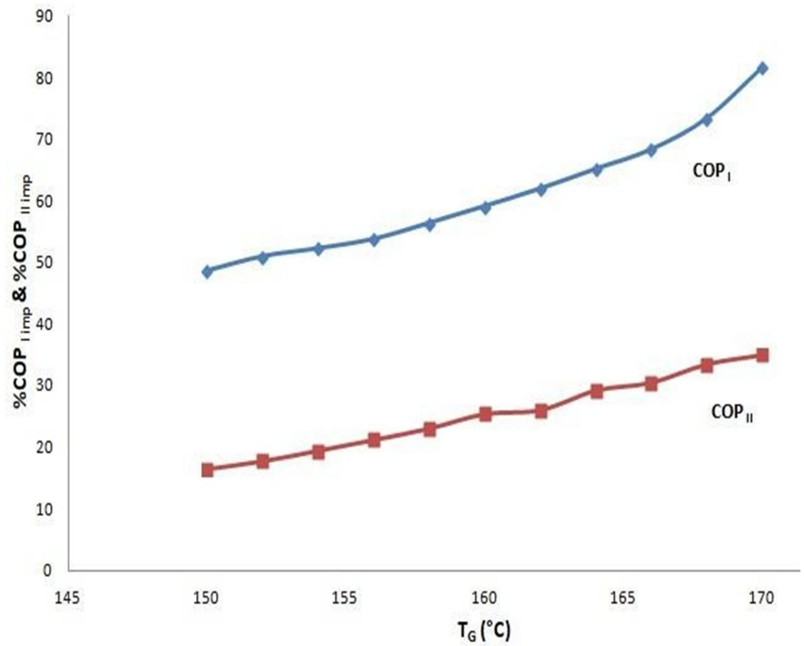

Fig.18: Triple Effect

V. CONCLUSIONS

Studies from the simulations have been presented in the previous sections. Following conclusions can be made from the results.

A. The intra cycle utilization of energy increases with the change in design, materials of the LHP and operating temperatures.
B. Maximum COP_I can be observed in Triple effect system whereas the maximum percentage increase is observed in double effect system as 78% from the initial value.
C. COP_{II} is highest for triple effect system while the increase is found to be highest for double effect system to be 28%.
D. The size of the system is gets reduced and the parts having exergy loss are eliminated along with the enhanced flexibility of the system.
E. For the systems the COP_{II} has a steeper rise over the range when compared to the COP_I for the range of heat exchange in the condenser of LHP.
F. With increase in T_G both COP_I and $COP_{II}$are increasing along with the T_C sharply.

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