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Second Law Analysis of Series and Parallel Flow Double Effect Vapor Absorption Chiller

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Abstract: *The motive of this study is an attempt to provide design engineers, appropriate information for developing sustainable machines. In the present article, a parametric study of double effect series flow and double effect parallel flow vapour absorption machines is carried out. Second law analysis has been performed and efforts have been made to reduce irreversibility in each component of the whole system, thereby reducing net exergy loss. It has benn observed that the exergetic efficiency first increases , reaches a maxima and then starts decreasing with increase in high pressure generator temperature. . It has also been observed that the exergetic efficiency is more in parallel flow as compared to the series flow for the same generator temperatures.*
Keywords: *Exergy, vapor absorption, irreversibility, double effect, parallel, series.*

Nomenclature

COP	coefficient of performance
ED	exergy destruction
h	enthalpy
m	mass flow
P	pressure
Q	heat transfer
s	specific entropy
T	temperature
W	work done
I	irreversibility

Greek letters

∑	sum
η	efficiency

Subscripts

o	dead state of the environment
a	absorber
c	condenser
e	evaporator
ex	exergetic
g	generator
p	pump

I. Introduction

Due to the relatively low COP associated with single effect technology, it is difficult for single effect machines to compete economically and thermally with vapor compression systems. Double effect technology with COP in the range 1.0 to 1.2 is much more competitive. There are different pairs of working fluids such as H_2O-NH_3, $LiNO_3$-NH_3 and LiBr-H_2O etc. LiBr-H_2O pair is used for air-conditioning applications whereas NH_3-H_2O combination finds usage in refrigeration applications since water is used as the absorbent in this case. Absorption refrigeration systems are heat operated due to which it can be driven either by low-grade energy such as solar energy, geothermal energy, waste heat from industries and so on. The eco-friendly aspect of vapour absorption refrigeration system overshadows their low coefficient of performance as compared to vapour compression refrigeration systems. In this article, double effect cycles with different flow configurations of the system like parallel and series flow have been proposed. It is found that the performance of the system improves in the parallel flow type as compared to the series flow.

II. Mathematical Analysis

The analysis was carried out for one ton of refrigeration.

The Exergetic equation is given by:

$$\sum(\mathbf{me})_i - \sum(\mathbf{me})_o \pm \sum \mathbf{Q}\left(\mathbf{1} - \frac{\mathbf{T_0}}{\mathbf{T}}\right) \pm \mathbf{W} - \mathbf{ED} = \mathbf{0}$$

The Exergetic efficiency is given by:

$$\eta_{ex} = \frac{Q_e \left|1 - \frac{T_0}{T_e}\right|}{Q_g\left(1 - \frac{T_0}{T_g}\right) + Wp}$$

The Irreversibility is given by:

$$I_{total} = T_o\left[\left(\frac{Q_a}{T_a} + \frac{Q_c}{T_c}\right) - \left(\frac{Q_e}{T_e} + \frac{Q_g}{T_g}\right)\right]$$

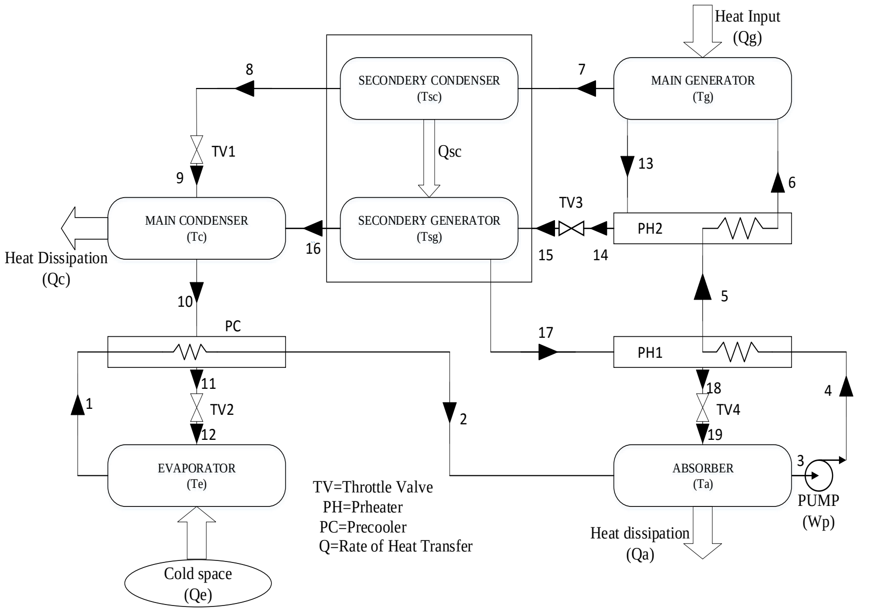

Fig. 1: Double Effect Series Flow Vapour Absorption Refrigeration System

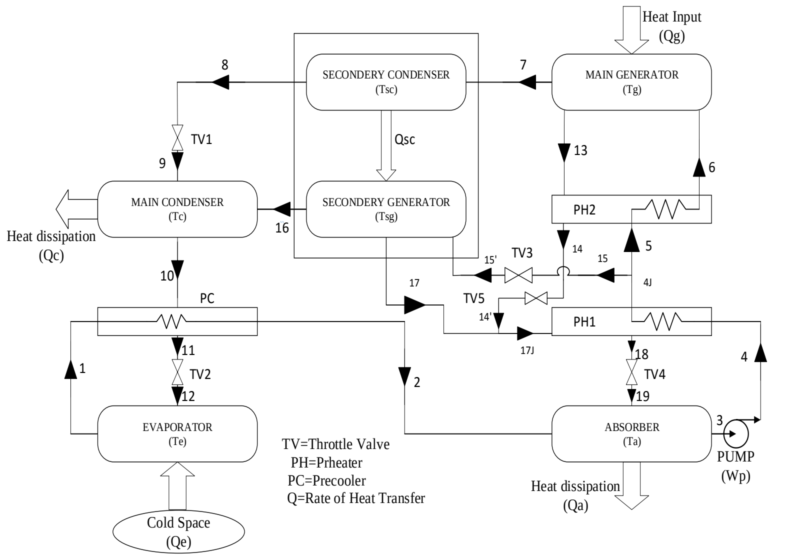

Fig. 2: Double Effect Parallel Flow Vapour Absorption Refrigeration System

III. Results

Non-Linear Equations for mass balance, energy balance and exergy loss have been solved using Programming in FORTRAN language. The equations have been solved using iterative methods. The results are presented in the following figures.

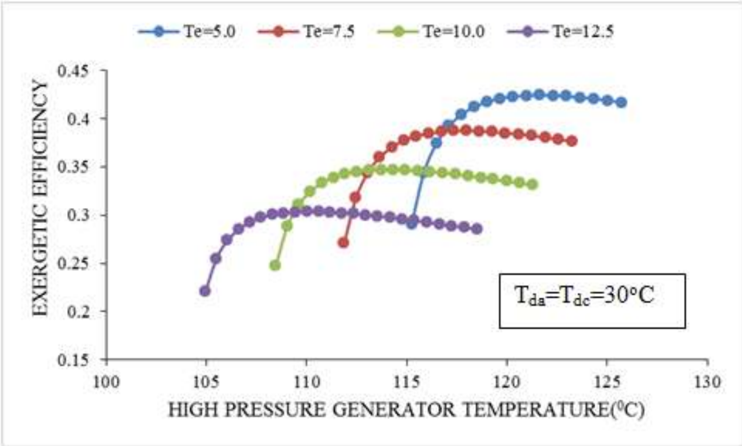

Fig. 3 Variations in exergetic efficiency of double effect series flow cycles with high pressure generator temperature at secondary condenser temperature 80 ^{0}C.

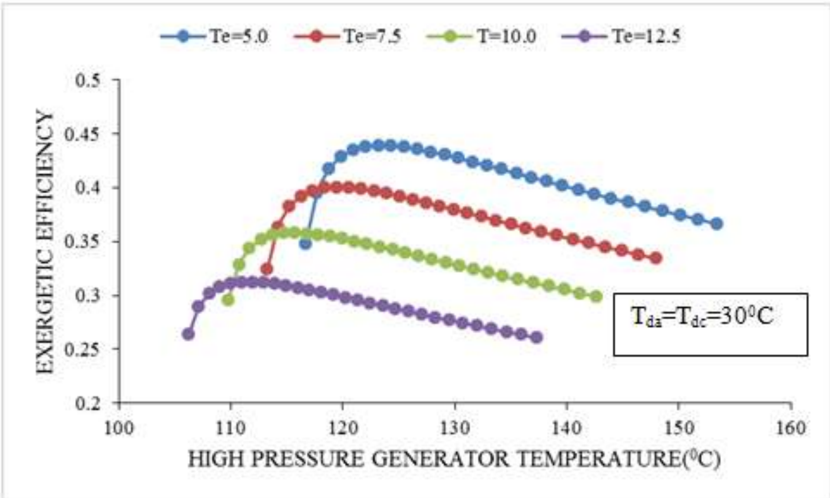

Fig. 4 Variations in exergetic efficiency of double effect parallel flow cycles with high pressure generator temperature at secondary condenser temperature 80 ^{0}C.

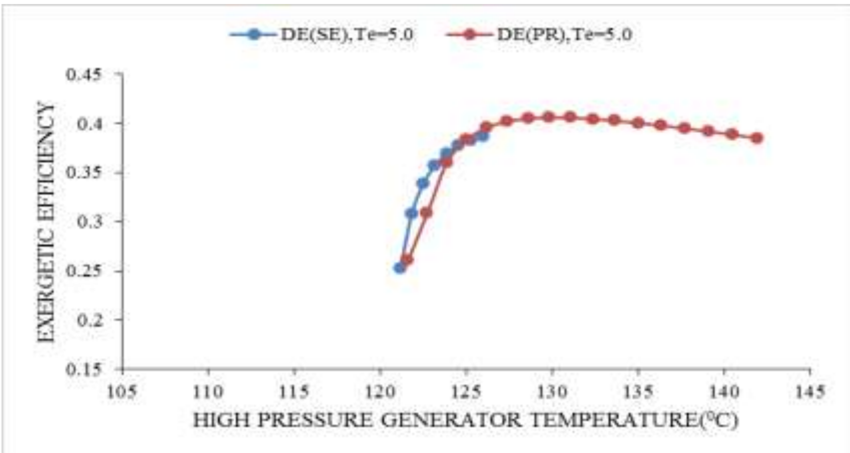

Fig 5 Variation in exergetic efficiency of double effect (series and parallel flow) cycle with high pressure generator temperature at T_e=5.0^{0}C and T_{da}= T_{dc}=35^{0}C

Figures 3 to 7 show the variation of exergetic efficiency with generator temperature. From the figures it is observed that exergetic efficiency is more in parallel configuration (around 0.3 to 0.44) as compared to series configuration (around 0.28 to 0.42) for the same parameters. At evaporator temperature of 5°C, the maximum exergetic efficiency is at the generator temperature of 135°C . At the evaporator temperature of 12.5°C, the maximum exergetic efficiency is at the generator temperature of 120°C.

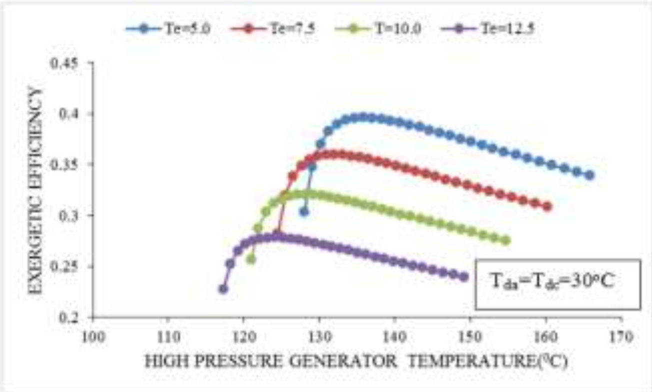

Fig. 6 Variations in exergetic efficiency of double effect parallel flow cycles with high pressure generator temperature at secondary condenser temperature 90 ^{0}C.

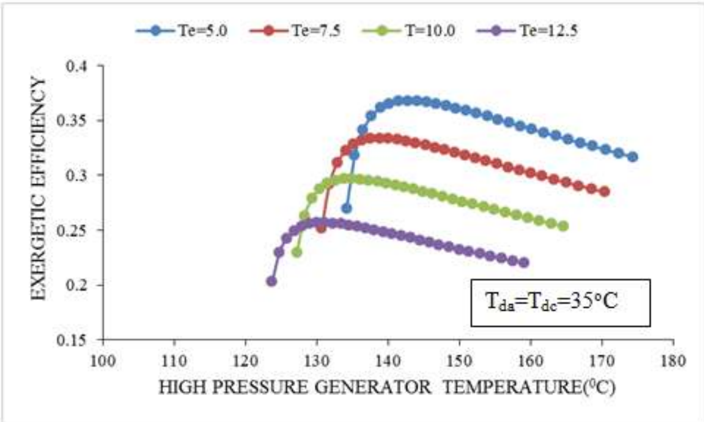

Fig. 7 Variations in exergetic efficiency of double effect parallel flow cycles with high pressure generator temperature at secondary condenser temperature 90 ^{0}C.

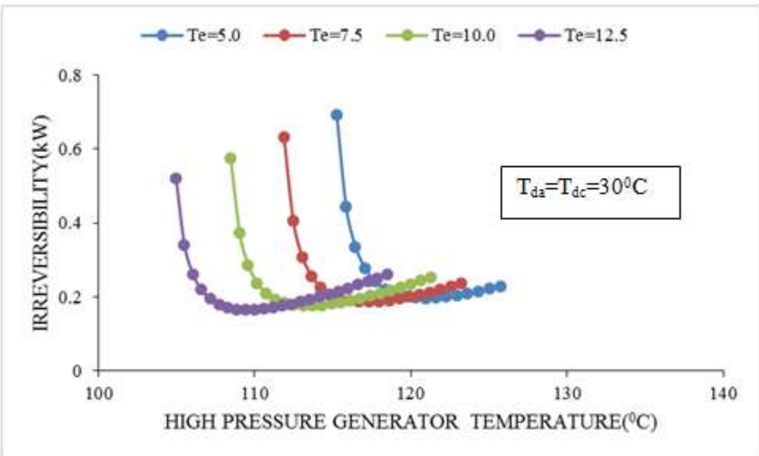

Fig. 8 Variations in irreversibility of double effect series flow cycles with high pressure generator temperature at secondary condenser temperature 80 ^{0}C.

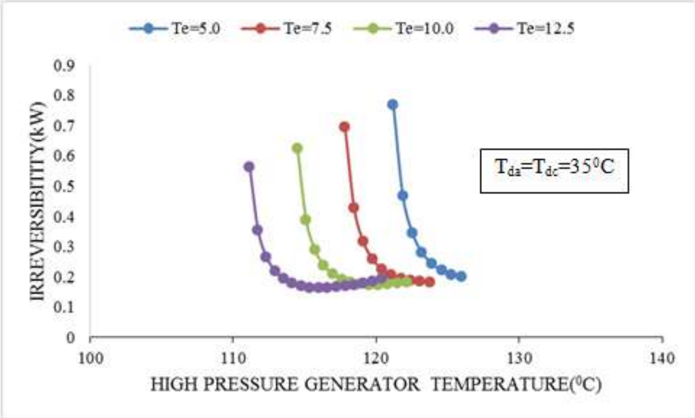

Fig. 9 Variations in irreversibility of double effect series flow cycles with high pressure generator temperature at secondary condenser temperature 80 ^{0}C.

Figures 8 to 15 show the variation of the irreversibility with generator temperature. From the figures it is observed that the irreversibility is lesser in case of parallel flow cycle (0.1 kW) as compared to series flow cycle (0.2 kW) for the same parameters. At evaporator temperature of 5 ^{o}C, the minimum value of irreversibility is at generator temperature of 132^{o}C. At evaporator temperature of 12.5^{o}C, the minimum value of irreversibility is at the generator temperature of 120^{o}C.

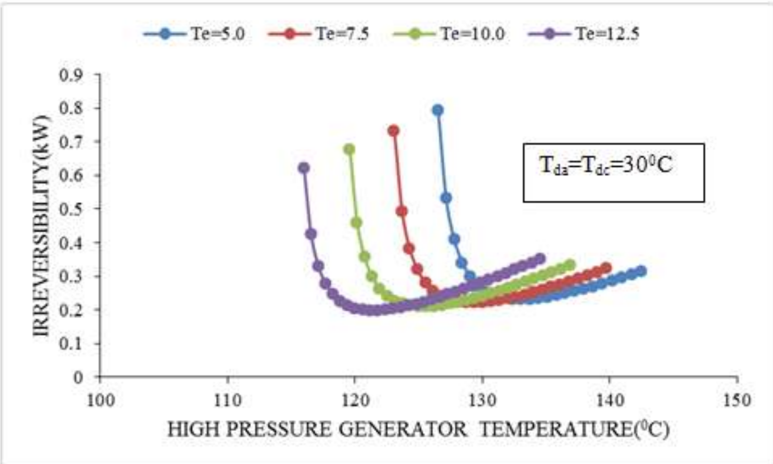

Fig. 10 Variations in irreversibility of double effect series flow cycles with high pressure generator temperature at secondary condenser temperature 90^{0}C.

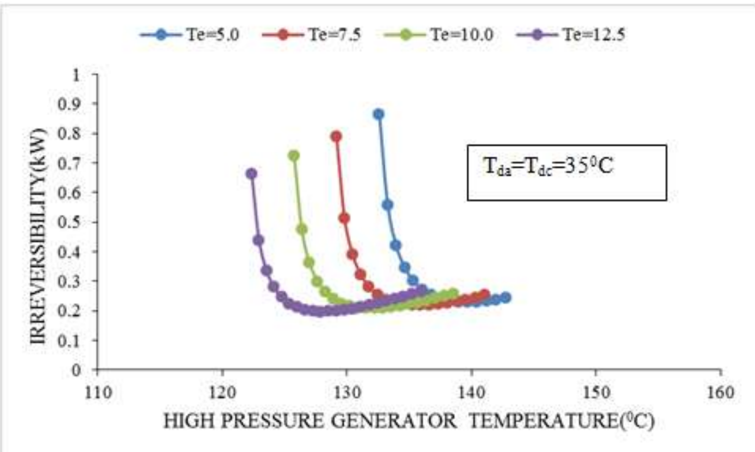

Fig. 11 Variations in irreversibility of double effect series flow cycles with high pressure generator temperature at secondary condenser temperature 90^{0}C.

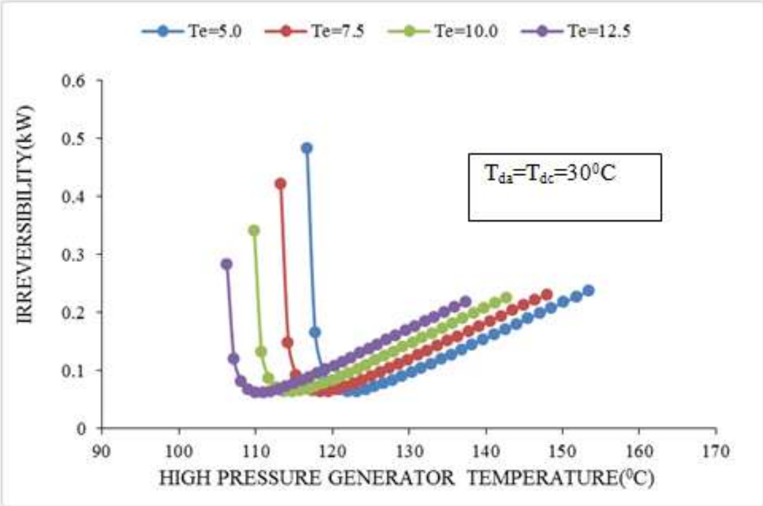

Fig. 12 Variations in irreversibility of double effect parallel flow cycles with high pressure generator temperature at secondary condenser temperature 80^0C.

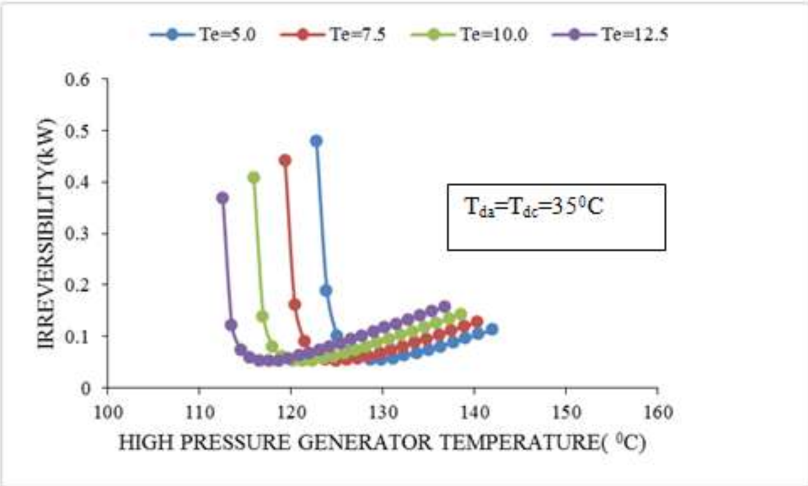

Fig. 13 Variations in irreversibility of double effect parallel flow cycles with high pressure generator temperature at secondary condenser temperature 80 ^{0}C.

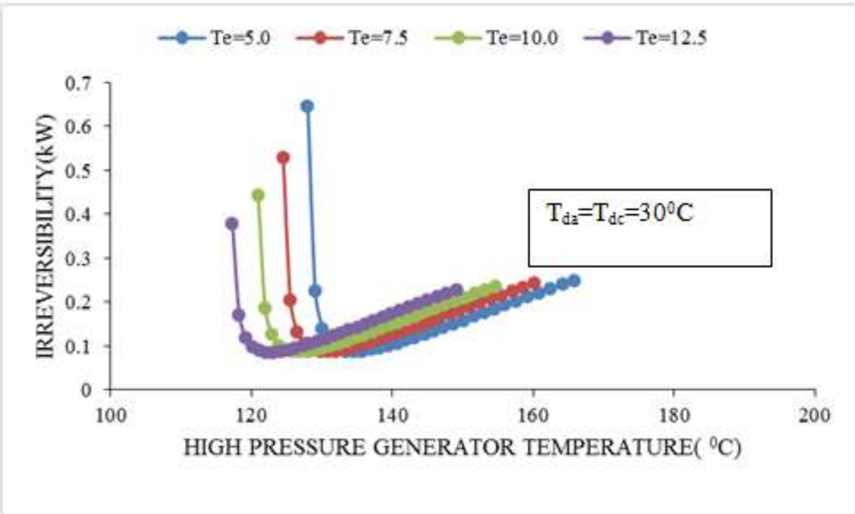

Fig. 14 Variations in irreversibility of double effect parallel flow cycles with high pressure generator temperature at secondary condenser temperature 90^0C.

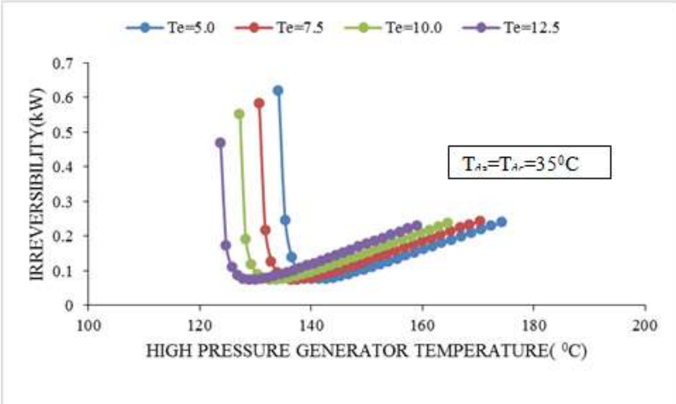

Fig. 15 Variations in irreversibility of double effect parallel flow cycles with high pressure generator temperature at secondary condenser temperature 90^0C.

IV. Conclusions

1. Exergetic efficiency of double effect series flow and double effect parallel flow vapour absorption cycle initially increases with an increase in generator temperature to which heat is supplied up to a certain limit and decreases thereafter. Exergetic efficiency is more in parallel flow configuration as compared to the series flow configuration for the same parameters.
2. Irreversibility first decreases in both cases, reaches a minimum and then increases. Irreversibility is less in parallel configuration as compared to the series one.

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