ABSTRACT

This thesis primarily focuses on thermodynamic performance evaluation of single and double effect VARS configurations with relatively a newer working fluid pair. Water–lithium chloride (H_2O–LiCl) is considered and energy and exergy analyses are conducted to depict the complete system performance characteristics of the H_2O–LiCl operated single and double effect VARS configurations. Further, the energetic and exergetic performances of the H_2O–LiCl based single and double effect VARS configurations are compared with their water–lithium bromide (H_2O–LiBr) counterparts' under identical operating conditions. The following methodologies are adopted in accomplishing the research works of this thesis.

➢ Development of thermodynamic model for performance simulation of single effect VARS configuration.

➢ Conduction of thermodynamic performance analysis of H_2O–LiCl operated single effect VARS on the basis of both first (energy) and second law (exergy) of thermodynamics with operating temperatures estimated though inverse analysis.

➢ Comparison of energetic and exergetic performance between H_2O–LiCl and H_2O–LiBr operated single effect VARSs under identical operating conditions.

➢ Development of thermodynamic models for performance simulation of double effect series, parallel and reverse parallel VARS configurations.

➢ Model validation and conduction of energy and exergy based parametric analyses of double effect VARS configurations using H_2O–LiCl at four various cases of fixed condenser (also equal absorber) and evaporator temperatures.

➢ Comparison of energetic and exergetic performance between double effect H_2O–LiCl and double effect H_2O–LiBr VARS configurations under identical operating conditions.

➢ Carrying multi-objective optimization of H_2O–LiCl and H_2O-LiBr operated double effect series and parallel flow VARS configurations using an evolutionary based optimization algorithm.

First, a single effect VARS is considered for modeling and performance simulation with H_2O–LiCl as working solution pair. Since, the VARS components' temperatures are the key regarding maximum solution concentration and particularly with H_2O–LiCl, the crystallization risk is high; therefore, the operating temperatures of

the H_2O–LiCl operated single effect VARS are estimated first using an inverse technique. This inverse method uses a differential evolution (DE) based optimization algorithm to estimate the unknown VARS components' temperatures against a known weak solution concentration of just below 50% at generator exit. Thus, the weak solution concentration is the objective function which is minimized in this optimization problem for estimating the VARS generator, condenser, evaporator and absorber temperatures. Total 34 combinational temperatures are obtained and for each of these combinations the VARS energetic and exergetic performance results are presented. Parametric analysis is performed to show performance variation with component temperatures. A performance comparison between the H_2O–LiCl and H_2O–LiBr operated single effect VARS is also provided under identical conditions. Results indicate that coefficient of performance (COP) of the single effect VARS increases with evaporator temperature while its exergy efficiency decreases and the total system irreversibility increases. COP is also more at lower condenser and absorber temperature, however the exergy efficiency becomes less and total system irreversibility increases. This contradiction actually arises due to the water temperatures at entry and exit of the condenser, evaporator and absorber which are considered to vary with component temperatures in this research study. However magnitude wise the exergy efficiency is more and total system irreversibility is less when variable water temperatures are considered instead of fixed. It was found that performance variation of the single effect VARS with generator temperature solely depends upon selection of condenser and absorber temperatures. While comparing the performances of the single effect VARS with H_2O–LiCl and H_2O–LiBr, it is found that H_2O–LiCl performs better in the single effect VARS than H_2O–LiBr under identical condition of operating temperatures. COP and exergy efficiency are higher while the total system irreversibility is less in the H_2O–LiCl operated VARS compared to those of the H_2O–LiBr operated system. The total system irreversibility is also found less with H_2O–LiCl under identical operating conditions.

Next, the series, parallel and reverse parallel configurations of double effect VARS configurations are thermodynamically modeled to provide performance comparison among the three systems with H_2O–LiCl as working fluid under identical operating conditions. Model validation was done by comparing separately some specific property values of H_2O–LiCl solution with previously published experimental

results and the system model for H_2O–LiBr based double effect series configuration. This is followed by parametric analysis that is carried out to investigate the effect of component temperatures and distribution ratio on COP of the double effect VARS configurations. Results show that the maximum solution concentration, which is limited to 0.5 in H_2O–LiCl based VARS, is mainly controlled by the system operating temperatures. In case of the parallel and reverse parallel systems, maximum solution concentration also depends upon the distribution ratio. It is also found that there exists an optimal combination of high pressure generator (HPG) and low pressure generator (LPG) temperature at which the COP of a particular double effect H_2O–LiCl VARS is maximized. This optimal combination however varies with temperatures in the other components (absorber, condenser and evaporator). A performance comparison between double effect H_2O–LiCl and H_2O–LiBr systems under identical conditions shows better performance in case of the double effect H_2O–LiCl VARS configurations. It is recommended that due to its low maximum concentration limit (0.5 against 0.65 of H_2O–LiBr VARS), double effect H_2O–LiCl VARS configurations would be more appropriate and efficient compared to the H_2O–LiBr systems, particularly at low LPG and HPG temperature applications.

Subsequently, in this thesis, the exergy analysis is carried out to evaluate and compare the thermodynamic performances of the H_2O–LiCl operated double effect series, parallel and reverse parallel flow VARS configurations under identical operating conditions. A comparison between double effect H_2O–LiCl and H_2O–LiBr systems is also provided to compare their exergetic performances under identical conditions. It is found that the exergy based results conform well with the energy based results of the H_2O–LiCl operated series, parallel and reverse parallel double effect VARS configurations. The optimal operating conditions, identified through energy analysis with respect to maximum COPs are almost identical with the ones corresponding to maximum exergy efficiencies and minimum total system irreversibility. Further, the exergy based performance comparison between the double effect H_2O–LiCl and H_2O–LiBr systems confirm superior performances of the H_2O–LiCl systems not only with higher COP but also with higher exergy efficiency and comparatively lower total system irreversibility.

The thesis further presents multi-objective optimization of the series and parallel flow type double effect VARS configurations using H_2O–LiCl and H_2O–LiBr as solution pairs in the two systems. An evolutionary based Genetic Algorithm is used to find the

optimal solutions and the Pareto-optimal fronts. The optimization is done considering COP, exergy efficiency and the total system irreversibility rate as objective functions. The low and high pressure generator temperatures are taken as decision variables in the series configuration while for the parallel system; additionally the distribution ratio is also taken as a decision parameter. The optimization is done for four different cases of fixed evaporator, absorber and condenser temperatures. For each case, the optimal decision parameter values are determined for both the H_2O–LiCl and H_2O–LiBr operated double effect series and parallel configurations. The optimized coefficients of performance are found to be slightly lower for H_2O–LiCl. Contrary to this, the optimal exergy efficiencies are relatively more and the total system irreversibility is found less for H_2O–LiCl. Further, the optimal performances of the double effect H_2O–LiCl systems have been obtained comparatively at lower generator temperatures than those of the H_2O–LiBr systems.

Thus, the details regarding the energetic and exergetic performances of H_2O–LiCl operated single and double effect VARS configurations have been evaluated and presented in this thesis. Specifically, for the double effect systems, first the optimal operating conditions are identified through a detailed parametric analysis and later, refinement in the optimal results is done through an optimization study for the double effect series and parallel VARS configurations with both H_2O–LiCl and H_2O–LiBr as solution pairs.