CHAPTER 7
Overall Conclusions & Recommendations
For Future Work

7.1 Overall Conclusions

Present work involves energy and exergy analysis of different refrigeration and heat pump systems. The study was carried out with a view to analyze different refrigeration systems including heat pumps for their efficient operation and ways to minimize exergy destruction. Various systems analyzed in the present thesis are:-

1. Vapor Absorption System
2. Vapor Compression System
3. Vapor Compression-Absorption System
4. Vapor Compression Cascade System

and the conclusions drawn from the present thesis are as below:-

7.1.1 Vapor Absorption System

A simple vapor absorption system was designed and fabricated to analyze the performance of the system. The system is tested with heat input from an electric heating element of 1500 watts capacity for a pressure of 10.7 bars and the following conclusions are made:-
1. The COP is found to be 0.599 and this is because of higher generator temperature. A more efficient thermal system should have higher COP and lower total entropy generation.

2. The COP can be increased further by using a heat exchanger between the absorber and generator as well as between the condenser and pressure reducing valve.

3. The COP can also be increased by using double effect VAR system, other attempts have been made to improve the performance of the present experimental system.

The thermodynamic analysis of 496 TR absorption system using LiBr-H2O as working fluid has been presented. The irreversibility rate in generator is found to be the highest while it is found to be the lowest in the condenser and absorber. It is found that the irreversibility rate in the generator is more because of increase rate of heat transfer in the generator, also the exergy losses are more in generator because of heat of mixing in the solution, which is not present in pure refrigerant/fluids.

Results show that as expected the COP of the system increases minutely as the generator temperature is increased but the exergy efficiency of the system drops with the increase in generator temperature. It is also found that the COP of the system increases with increase in evaporator temperature and this largely depends on the enthalpy difference between the chilled water at inlet and outlet of evaporator. However, it is reverse in case of exergy efficiency.

The results with respect to exergy losses in each component and exergy efficiency are very important for the optimization of absorption system. These results
are helpful for designers to bring changes in the actual system for optimum performance and less wastage of energy.

7.1.2 Vapor Compression System

In this experimental study, a window air conditioning system based on compression refrigeration system is modified for experimental analysis. The vapor compression system is made of a compressor, a capillary tube (expansion device), a condenser and an evaporator. Its cooling capacity is 24K BTU. Based on the experiment testing following conclusions are drawn:

Exergy losses are affected by the quantity of refrigerant charged but on analysis it is found that the losses in all the conditions are maximum in the compressor. This is attributed to the frictional losses and losses due to wire drawing effect during suction and delivery of the refrigerant. Hence a more efficient compressor is required.

1. It is observed that the total exergy destruction is comparable when the system is 75% and 100% charged and it is least when the system is 25% charged because the evaporator temperature is very close to the reference temperature.

2. The average coefficient of performance is highest when the system is 50% charged and this is because of higher refrigerating effect and reduced compressor work.

3. The exergy destruction in each component in ascending order with respect to percentage of refrigerant charged is as under:

   Refrigerant Charged (25%): Condenser, Expansion Valve, Evaporator and Compressor
Refrigerant Charged (50%): Condenser, Evaporator, Expansion Valve, and Compressor

Refrigerant Charged (75%): Evaporator, Expansion Valve, Condenser and Compressor

Refrigerant Charged (100%): Condenser, Evaporator, Expansion Valve, and Compressor

4. The exergy efficiency of the system varies from 3.5% to 45.9%. This is due to variation of refrigerant (evaporator) temperature.

5. The average value of system exergy efficiency is more when the system is 100% charged. These values show that the overall exergy performance is better when the system is fully charged but the compressor work is the highest in this case and the COP is also less as compared to other situations. When the actual requirements are less the system should be operated with variable refrigerant flow so as to achieve optimum balance between the exergy efficiency and energy saving.

7.1.3 Vapor Compression-Absorption System

The experimental and theoretical investigations of a modified hybrid vapor compression/absorption heat pump system using ammonia-water as the working fluid have been presented and the following conclusions are made:

1. The irreversibility rate (exergy loss) in the low pressure compressor is found to be the highest while it is found to be the lowest in the case of expansion valve. It is also found that the irreversibility rate of the low and high pressure compressors as well
as of the solution pump increase as the ambient air temperature increases. On the other hand, the irreversibility rates of the solution heat exchangers, desuperheater, and the absorber is found to be decreasing function of the ambient air temperature while its found to be reverse in the case of intercooler.

2. The effects of ambient air temperature is found to be more pronounced for the desorber while it is found to be reverse in the case of solution heat pump. The irreversibility rates in some components are found to be decreasing function of ambient air temperature, which may be due to various reasons, such as the composition of the refrigerant mixture and chemical reactions. The performance of the present hybrid heat pump system is found to be much less than that of a conventional heat pump system. To obtain satisfactory results, further modifications with improved design of certain components in the present system are required.

7.1.4 Vapor Compression Cascade System

The exergetic investigation of a sea water source cascade heat pump system using different working fluid has been presented. Based on the second law analysis, the following conclusions are made:

1. The irreversibility rates in the heat exchanger and expansion devices are found to be decreasing function of the ambient air temperature, while it is found to be increasing function for the compressors and the pumps.

2. The effect of ambient air temperature on rate of irreversibility is found to be more pronounced for the evaporator, while it is found to be less pronounced in the case of the expansion devices.
3. The rate of irreversibility (exergy loss) in the evaporator is found to be the highest while it is found to be reverse in the case of expansion valves. For other components, the rates of irreversibility are found to be somewhere between these two extreme cases, mentioned above.

4. The rate of irreversibility for the low pressure compressor (LP) is found to be higher than that of the high pressure compressor (HP). Similarly, the rate of irreversibility for the sea water pump is found to be more than that of the circulating water pump. Again, the overall irreversibility rate for the first heat pump is found to be higher than that of the second heat pump.

5. Since, the rate of irreversibility decreases with the increment of the reference temperature and hence, the overall irreversibility in all the heat exchangers and the expansion devices decreases with increasing the ambient temperature.

6. The rates of irreversibility due to friction and heating of the working fluid and/or the cooling fluid in the compression and pumping devices increases with the increment in the reference temperature. This causes the higher loss of the useful energy in these devices. As a result, the rates of irreversibility in the pump and compressor increase as the ambient air temperature is increased.
7.2 Recommendations for Future Work

1. Fabrication and performance evaluation of modified VAR system using exergoeconomic evaluation of the systems and other thermal energy conversion systems.

2. Modification of VAR system using biogas, solar energy with the use of conversion devices as solar collector and solar PV to make it a zero energy system and to study this system using exergy and exergieconomic analysis for both heating and cooling applications.