CHAPTER 8

CONCLUSIONS

8.1 SUMMARY

This study brings to focus the possibility of using the warm water from the upper surface of the ocean for vaporization and condensing the vapour with cold water, obtainable in the ocean depths, for a low energy desalination system. The feasibility of desalination by low pressure vaporization of sea water at temperatures between 26°C and 32°C is demonstrated in two different experimental facilities by “Spray Flash Evaporation” method. The plant operated at vacuum pressures between 10 mm of Hg and 18 mm of Hg (abs). The selected temperatures are corresponding to the warm temperatures of the ocean surface in the tropics.

A parametric study conducted and the result gives a valuable output for developing technology for desalination. Temperature of the water droplet, pressure in the vaporizer, resident time of the injected water (i.e., droplet) inside the vaporizer and the size of droplet are identified as parameters influencing vaporization at low pressures by spray flashing method. The evaporation time for a vacuum level between 10 mm of Hg and 18 mm of Hg (abs) is found out for different droplet size and is proportional to the square of the diameter of the droplet and increases with the feed temperature due to larger temperature difference between the feed temperature and the final temperature at which vaporization ceases.
The rate of vaporization found out based on Energy balance at the droplet surface shows that, rate of vaporization increases as the temperature of feed water and decreases in the pressure of the vaporizer increases the rate of vaporization. A vapour diffusion model is also developed, which takes into account the reduction of droplet temperature during the evaporation process, when the saline water was injected as fine droplets in a low-pressure vaporizer. The values obtained from the two models are almost identical. The predictions from the model were verified by a large number of experiments in two different experimental facilities (low flow and high flow facility).

First set of experiments conducted in low flow facility (nominal flow rate of 1000 kg/hr). Typical time required for evaporation of the droplets was found to be few hundred milliseconds and this was less than the residence time of the spray provided for in the vaporizer. Changes in the height of water injection in the vaporizer did not significantly influence the yield of fresh water. The resident times in excess of vaporization times are obtained in the experimental facility for the three values of injection heights used. Hence the resident time provided appears to be adequate. Small values of water injection pressures of about 0.5 bar (gauge) were found to be adequate when a swirl injector, used for garden sprays, was employed. The yield of fresh water increases as the temperature of feed water increases and in the pressure of the vaporizer decreases as predicted by theory and it was upto 3.6 %. A correlation is proposed for the coefficient of vaporization rate ($K_v$), which is independent of time for three vaporizer pressures.

Second set of experiments conducted in a flash evaporator [1000 mm height x 1200 mm diameter] for the same pressure and temperature conditions for high flow rate (nominal flow rate of 5400 kg/hr. per jet), where the saline water is injected into the evaporator through a pair of high flow swirl injector. The influence of the different thermal, hydrodynamic and
geometric parameters on the evaporator performances was investigated. The distance between injection planes of impinging water jets is varied between 100 mm and 400 mm and thereby the droplet sizes and the distributions of injected feed water are modified to study the impact on rate of vaporization. Higher fresh water yield is seen when the distance between the injectors is 200 mm. Also the influence of vaporizer volume on the rate of vaporization by varying the vaporizer diameter is studied. The vaporizer volume is indirectly a function of the residence time. The volume of vaporizer has large influence on the rate of vaporization, higher yield is seen when the volume of the vaporizer was 1200mm. The result shows that the 20 % more in diameter of vaporizer is required to achieve the theoretical expected yield. It is also seen that the purity of the fresh water is slightly affected when the diameter of the vaporizer is reduced.

The dispersions in the yield due to the uncertainties in the measurements are found to be less than 15% for both the experimental facilities. Higher accuracy in the flow rate of feed water, temperature of feed water and pressure in the vaporizer will be useful to reduce the dispersion in the experimental results. Experiments conducted using the artificially prepared seawater adequately demonstrate the technical feasibility of the process for the application of desalination. The fresh water standards meet the requirement of Indian standard specifications of potable water. Since process to be demonstrated is towards application for desalination, measurements at steady state which is reached in a vary short time is adequate and meet the objectives.

8.2 SUGGESTIONS FOR FURTHER WORK:

This facility with improved instrumentation could continue as a research tool for generating additional data for developing desalination technology. However the theoretical model and the experimental results indicate high potential for further investigation and development of the
technology for desalination application. The facility can be incorporated with sophisticated instrumentation system and used for continuing the vaporization studies such as the evaporation time for different droplet size and other related parameters, which affect the rate of vaporization, can be studied.

The high flow facility can be modified and used for continuing the vaporization studies with different injector configurations with high flow nozzles and the number of injectors can be optimized for a bigger vaporizer to develop commercial desalination plants. Further, the design and construction of the vaporizer assembly could be optimized to minimize the energy requirement for the operation of the vacuum pumping system used for maintaining vacuum. Also further research can be conducted to investigate the effects of non-condensable gases on the operation of the proposed desalinator. The use of cold brine (instead of steam) for operation of the ejector system will lead to a highly energy efficient desalination system, so researches can be proceeded in the direction of optimal design of water jet ejector for low temperature desalination system. The successful completion of the above proposed work will give valuable input for establishing pilot scale offshore and onshore desalination plant to study the techno-economic viabilities.

This system could be integrated with the OTEC system with common warm ocean water system, cold deep ocean water system and support services or alternately integrated thermodynamically with the OTEC, where favorable bathymetry is available and fresh water and power for community needs around that area could be met. This system can be implemented without affecting the operations at Power Station, by utilizing waste heat from power plants condenser, there by marine ecosystem can be preserved. The cold water pumped used in the condenser can be subsequently used for air conditioning as the return temperature of this water is around
17°C. The cold water being pumped from the lower levels of the sea is rich in minerals and plankton and when discharged on sea surface becomes a potential breeding area for fish and other marine life; researches can be preceded in these directions to utilize the maximum benefit from the available resources.