ACKNOWLEDGMENT

I offer respectful obeisance unto the lotus feet of **Prof. Mani Sankar Dasgupta**, Head of Department, Mechanical Engineering, BITS Pilani and **Prof. Dileep Kumar Gupta**, Mechanical Engineering, IIITRAM, for all their valuable guidance, excellent direction, everlasting encouragement and inspiration given to me without which the present work would not have been possible. It was indeed my privilege to work under the supervision of both.

I am grateful to **Prof. Souvik Bhattacharyya,** Vice-Chancellor, BITS Pilani, **Prof. A. K. Sarkar,** Director, BITS Pilani, Pilani Campus for their support and blessings. I also express my sincere thanks to **Prof. Srinivas Krishnaswamy**, Dean, Academic - Graduate Studies and Research Division (AGSRD) and **Prof. Jitendra Panwar**, Associate Dean, AGSRD for their motivation, constant support and encouragement.

I am highly indebted to **Prof. Sharad Shrivastava,** DRC convener Department of Mechanical Engineering. Sincere thank is also due to my respected DAC members **Prof. Manoj Soni** and **Prof. P. Srinivasan**, Department of Mechanical Engineering, Pilani Campus for their valuable and fruitful discussions and suggestions, and for sparing their valuable time for departmental evaluation of this thesis. I would also like to acknowledge all faculty members as well as non-academic staff of Department of Mechanical Engineering for their support, encouragement and cooperation. I would like to thank **HEMAIR LTD.**, Hyderabad and **ASHOK KUMAR PVT. LTD.**, Pilani for assisting and fabricating experimental set up.

I would like to thank **IUSSTF, New Delhi** for providing the **BHAVAN Internship** and SERB, **Government of India** for providing the **Travel Grant** to attend International Conference. Sincere thanks to **Dr. Brian Fricke and Mr. Vishaldeep Sharma,** host at **Oak Ridge National Laboratory, USA**. I would also like to thank **Prof. Adriano Millazo** for inviting me for a discussion at **University of Florence, Italy**, which helped me in refining my thought process. Sincere thanks to **Dr. Nitin Karwa** for his extraordinarily support regarding fabrication of experimental setup as well as for guidance on experimentation.

Sincere thanks to all research scholars of Mechanical Engineering Department for their support. I would also like to thank my entire family that their constant love, affection and support that has empowered me to accomplish this work. Last but not the least, I pray and thank the ALMIGHTY for showering HIS divine blessings and giving me an inner strength and patience.

Nilesh Purohit
December 2018

I dedicate this thesis work to my grandfather,
Respected Late Professor Anand Krishna Purohit

ABSTRACT

The refrigeration sector consumes more than half of the total energy consumption in a building (supermarket) and contributes to green-house gases. Traditionally, such systems employ synthetic refrigerants from which typically, about 3 to 35% of the refrigerant charge leaks into the atmosphere per year depending on the make, age and usage of system. Leaked synthetic refrigerants are detrimental to environment as they are often greenhouse gases and/or contribute to ozone depletion. With increase in environmental consciousness in recent times, stricter regulations have been enacted globally to control ozone depletion and indirect and direct greenhouse gases emission from refrigerating plants. In such situation, adoption of natural or low-GWP refrigerants such as Carbon Dioxide (CO_2), Ammonia (R717), Propane (R290), R1234ze(E) etc. are expected to increase. This will significantly reduce the harmful effects of direct emissions. For reduction of indirect emission, the systems need to be inherently more efficient compared to the existing systems, which is the focus of research work worldwide at present.

Among the natural refrigerants, CO_2 is one of the preferred choices owing to its high specific heat, non-toxicity, non-flammability, eco friendliness and low cost. From the engineering perspective, CO_2 used as a refrigerant in vapour compression cycle has number of advantages such as lower compression ratio, high volumetric cooling capacity, compatibility with normal lubricants and common machine construction materials and well defined thermo-physical properties.

CO_2 has an old history as refrigerant, widely used before (1930s), however was abandoned later due to the invention of the synthetic refrigerants which were more effective at the then technological state. Meanwhile the world was getting conscious about ozone depletion effect from leaked refrigerants and later, regarding greenhouse effect caused by the synthetic

refrigerants. CO_2 being a constituent of biosphere and environmentally benign is clearly a preferred fluid. Use of CO_2 as a refrigerant was revived in the year 1993 by the work of Norwegian Professor Gustav Lorentzen, who successfully demonstrated working of a Automotive Air Conditioning (AAC) system based on CO_2. Thereafter, studies on CO_2 as refrigerant gained tremendous impetus and are being explored extensively for use in various applications.

With conventional vapor compression cycle design, the performance of CO_2 refrigeration system is economically advantageous only when operated in cold climate. Due to low critical temperature (31.3°C) and high critical pressure (73.8 bar), the performance of CO_2 refrigeration system deteriorates when operated in warm climatic conditions. Further, there are technical challenges of handling high pressure system. Owing to the high-pressure operation, physical issues such as selection of tubing material, safety, cost etc associated with a CO_2 system also poses challenge.

The work conducted in this thesis is broadly divided into three parts. Firstly, experimental investigation is carried out on a fully instrumented, laboratory setup of CO_2 trans-critical refrigeration system equipped with internal heat exchanger. Based on experimental data, analysis is carried out on energetic and exergetic perspectives, especially at high ambient up to 45°C.

Thereafter, theoretical models (physics based as well as an Artificial Neural Network) of CO_2 refrigeration system are developed, validated and implemented to perform parametric investigation and optimization based on two controllable parameters viz gas cooler pressure and cooling air flow velocity across the gas cooler (termed as gas cooler face velocity).

Lastly, application of CO_2 system in supermarket is focussed. Detailed thermodynamic models on booster, indirect/cascade and integrated configurations are developed. Various booster configurations are evaluated using thermodynamic modelling based on both energetic

and economic analysis. The performance of booster configurations is compared to that of indirect/cascade configurations. With regard to intergated system, multi-jet ejetcor configuartion is compared to cascaded booster configuration based on energy and environmental perspectives. Overall the work conducted in thesis is expected to contribute towards promotion of adoption of natural refrigerant, especially CO_2, in warmer part of the globe, like in India.

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