

**Thermodynamic Analysis of Multi Evaporator Vapour Compression  
Refrigeration System with Individual Compressor Using Mixed Refrigerant  
and Comparison with Pure Refrigerant**

*A Major Thesis Submitted in Partial Fulfilment of the requirements for the award  
of the degree of*

*MASTER OF TECHNOLOGY*

*In*

*THERMAL ENGINEERING*



*Submitted by*

**ABHISHEK VERMA**

**Roll No. 2K14/THE/02**

**Session 2014-16**

*Under the Guidance of*

**Dr. Akhilesh Arora &**

**Prof. P.K. Jain**

**DEPARTMENT OF MECHANICAL ENGINEERING**

**DELHI TECHNOLOGICAL UNIVERSITY**

**(FORMERLY DELHI COLLEGE OF ENGINEERING)**

## CANDIDATE'S DECLARATION

I hereby declare that the work which being presented in the major thesis entitled “**Thermodynamic Analysis of Multi Evaporator Vapour Compression Refrigeration System with Individual Compressor using Mixed Refrigerant and Comparison with Pure Refrigerant**” in the partial fulfilment for the award of the degree of Master of Technology in “THERMAL ENGINEERING” submitted to Delhi Technological University (Formerly Delhi College of Engineering), is an authentic record of my own work carried out under the supervision of Dr. Akhilesh Arora and Prof. P.K. Jain, Department of Mechanical Engineering, Delhi Technological University (Formerly Delhi College of Engineering). I have not submitted the matter of this dissertation for the award of any other Degree or Diploma or any other purpose what so ever. I confirm that I have read and understood ‘Plagiarism policy of DTU’. I have not committed plagiarism when completing the attached piece of work, similarity found after checking is 10% which is below the permitted limit of 20%.

ABHISHEK VERMA

Roll No. 2K14/THE/02

Place: Delhi

Date:

\*\*\*\*\*

## CERTIFICATE

This is to certify that the above statement made by ABHISHEK VERMA is true to the best of my knowledge and belief.

**Prof. P.K. Jain**

Associate Professor

Department of Mechanical Engineering

Delhi Technological University

(Formerly Delhi College of Engineering)

Delhi- 110042

**Dr. Akhilesh Arora**

Assistant Professor

Department of Mechanical Engineering

Delhi Technological University

(Formerly Delhi College of Engineering)

Delhi- 110042

## **ACKNOWLEDGMENT**

It is a great pleasure to have the opportunity to extend my heartiest felt gratitude to everybody who helped me throughout the project.

It is distinct pleasure to express my deep sense of gratitude and indebtedness to my learned supervisor Dr. AKHILESH ARORA, Assistant Professor and Prof. P.K. JAIN, Associate Professor, in Mechanical Department, Delhi Technological University (Formerly Delhi College of Engineering), for their invaluable guidance, encouragement and patient review. Their continues inspiration only has made me complete this dissertation.

I would also like to take this opportunity to present my sincere regards to Dr. R S MISHRA, Head of Department, Mechanical Department, Delhi Technological University (Formerly Delhi College of Engineering), for his kind support and encouragement.

I am thankful to my friends and classmates for their unconditional support and motivation for this dissertation.

ABHISHEK VERMA

Roll No. 2K14/THE/02

## **ABSTRACT**

Thermodynamic analysis is carried out which is based on the energy and exergy analysis of multi evaporator refrigeration system with individual compressor and multiple expansion devices using flash chamber at different temperatures of both evaporator and condenser for R12, R134a, R436a (0.52R290 / 0.48R600a) and R436b (0.56R290 / 0.44R600a). The properties of blend refrigerant (R290/R600a) are calculated using Refprop and a computational model is developed using engineering equation solver. The present work has been carried out for food freezing plant (fishes, fruits, vegetables) which works on multi evaporator vapour compression refrigeration system for evaporator-1 in the range of  $-30^{\circ}\text{C}$  to  $-15^{\circ}\text{C}$ , evaporator-2 in the range of  $-6^{\circ}\text{C}$  to  $10^{\circ}\text{C}$  and the condenser in the range of  $25^{\circ}\text{C}$  to  $44^{\circ}\text{C}$ . Performance parameters (total work input for the system, the coefficient of performance (COP), exergy destruction (ED) for whole system, exergy destruction ratio (EDR), exergetic efficiency) are calculated over these ranges of temperature and compared all these refrigerants.

After the performance evaluation of the system for different refrigerants, it is found that R436b (0.56R290 / 0.44R600a) has the highest COP and Exergetic Efficiency, it has also the least Total Work Input for the system and Exergy Destruction.

Now it is concluded that R436b is the best among all other refrigerants which are used for the system, and it has zero GWP. Thus it is recommended that it can be used for the replacement of R134a in the household refrigerator and food freezing plant.

## TABLE OF CONTENT

<b>Content</b>	<b>Page No.</b>
Candidate's Declaration	ii
Certificate	ii
Acknowledgement	iii
Abstract	iv
Table of Contents	v
Lists of Figures	vii
List of Tables	xi
Nomenclatures	xii
1. Introduction	1
1.1 Environmental Impacts	2
1.2 Ozone Layer Depletion	3
1.3 Global Warming Potential	3
1.4 Blending	3
1.5 Scope for Present Thesis	5
2. Literature Survey	6
2.1 Literature	6
2.2 Conclusions and Gap	9
2.3 Problem Formulation	10
3. Thermodynamic Analysis	11
3.1 System Description	11
3.2 Energy Analysis	13
3.3 Exergy Analysis	16
3.4 Input Parameters	19
4. Results and Discussion	20
4.1 Total work input for the compressor	21

4.2 Coefficient of Performance	29
4.3 Exergy Destruction for the system	37
4.4 Exergy Destruction Ratio	45
4.5 Exergetic Efficiency	53
5. Conclusion	61
6. Scope for Future Work	62
7. Reference	63

## LIST OF FIGURES

Fig. 1: A thermodynamic cycle involving heat transfer	1
Fig. 2: Comparison of evaporation and condensation of pure refrigerant (single component) and mixed refrigerant (blends)	4
Fig. 3: System Diagram of Multi-evaporator system with flash chamber, Individual compressors and multiple expansion valves	12
Fig. 4: p-h diagram of the multi evaporator refrigeration system for R12	14
Fig. 5: System diagram of evaporator-1	16
Fig. 6: System diagram of evaporator-2	16
Fig. 7: System diagram of compressor-1	16
Fig. 8: System diagram of compressor-2	17
Fig. 9: System diagram of condenser-1	17
Fig. 10: System diagram of expansion valve-1	17
Fig. 11: System diagram of expansion valve-2	18
Fig. 12: System diagram of flash tank	18
Fig. 13: Variation of total work input with Evaporator Temperature-1 using R134a	21
Fig. 14: Variation of total work input with Evaporator Temperature-1 using R12	22
Fig. 15: Variation of total work input with Evaporator Temperature-1 using R436a	22
Fig. 16: Variation of total work input with Evaporator Temperature-1 using R436b	23
Fig. 17: Comparison of Variation of total work input with Evaporator Temperature-1	23
Fig. 18: Variation of total work input with Evaporator Temperature-2 using R134a	24
Fig. 19: Variation of total work input with Evaporator Temperature-2 using R12	24
Fig. 20: Variation of total work input with Evaporator Temperature-2 using R436a	25
Fig. 21: Variation of total work input with Evaporator Temperature-2 using R436b	25
Fig. 22: Comparison of Variation of total work input with Evaporator Temperature-2	26
Fig. 23: Variation of total work input with Condenser Temperature using R134a	26

Fig. 24: Variation of total work input with Condenser Temperature using R12	27
Fig. 25: Variation of total work input with Condenser Temperature using R436a	27
Fig. 26: Variation of total work input with Condenser Temperature using R436b	28
Fig. 27: Comparison of Variation of total work input with Condenser Temperature	28
Fig. 28: Variation of COP with Evaporator-I Temperature using R134a	29
Fig. 29: Variation of COP with Evaporator-I Temperature using R12	30
Fig. 30: Variation of COP with Evaporator-I Temperature using R436a	30
Fig. 31: Variation of COP with Evaporator-I Temperature using R436b	31
Fig. 32: Comparison of Variation of COP with Evaporator-I Temperature	31
Fig. 33: Variation of COP with Evaporator Temperature-2 using R134a	32
Fig. 34: Variation of COP with Evaporator Temperature-2 using R12	32
Fig. 35: Variation of COP with Evaporator Temperature-2 using R436a	33
Fig. 36: Variation of COP with Evaporator Temperature-2 using R436b	33
Fig. 37: Comparison of Variation of COP with Evaporator Temperature-2	34
Fig. 38: Variation of COP with Condenser Temperature using R134a	34
Fig. 39: Variation of COP with Condenser Temperature using R12	35
Fig. 40: Variation of COP with Condenser Temperature using R436a	35
Fig. 41: Variation of COP with Condenser Temperature using R436b	36
Fig. 42: Comparison of Variation of COP with Condenser Temperature	36
Fig. 43: Variation of Exergy Destruction with Evaporator temperature-1 using R134a	37
Fig. 44: Variation of Exergy Destruction with evaporator temperature-1 using R12	38
Fig. 45: Variation of Exergy Destruction with evaporator temperature-1 using R436a	38
Fig. 46: Variation of Exergy Destruction with evaporator temperature-1 using R436b	39
Fig. 47: Comparison of Variation of Exergy Destruction with evaporator temperature-1	39
Fig. 48: Variation of Exergy Destruction with evaporator temperature-2 using R134a	40
Fig. 49: Variation of Exergy Destruction with evaporator temperature-2 using R12	40
Fig. 50: Variation of Exergy Destruction with evaporator temperature-2 using R436a	41



Fig. 51: Variation of Exergy Destruction with evaporator temperature-2 using R436b	41
Fig. 52: Comparison of Variation of Exergy Destruction with evaporator temperature-2	42
Fig. 53: Variation of Exergy Destruction with condenser temperature using R134a	42
Fig. 54: Variation of Exergy Destruction with condenser temperature using R12	43
Fig. 55: Variation of Exergy Destruction with condenser temperature using R436a	43
Fig. 56: Variation of Exergy Destruction with condenser temperature using R436b	44
Fig. 57: Comparison of Variation of Exergy Destruction with condenser temperature	44
Fig. 58: Variation of EDR with Evaporator Temperature-1 using R134a	45
Fig. 59: Variation of EDR with Evaporator Temperature-1 using R12	46
Fig. 60: Variation of EDR with Evaporator Temperature-1 using R436a	46
Fig. 61: Variation of EDR with Evaporator Temperature-1 using R436b	47
Fig. 62: Comparison of Variation of EDR with Evaporator Temperature-1	47
Fig. 63: Variation of EDR with Evaporator Temperature-2 using R134a	48
Fig. 64: Variation of EDR with Evaporator Temperature-2 using R12	48
Fig. 65: Variation of EDR with Evaporator Temperature-2 using R436a	49
Fig. 66: Variation of EDR with Evaporator Temperature-2 using R436b	49
Fig. 67: Comparison of Variation of EDR with Evaporator Temperature-2	50
Fig. 68: Variation of EDR with condenser temperature using R134a	50
Fig. 69: Variation of EDR with condenser temperature using R12	51
Fig. 70: Variation of EDR with condenser temperature using R436a	51
Fig. 71: Variation of EDR with condenser temperature using R436b	52
Fig. 72: Comparison of Variation of EDR with condenser temperature	52
Fig. 73: Variation of Exergetic Efficiency with Evaporator Temperature-1 using R134a	53
Fig. 74: Variation of Exergetic Efficiency with Evaporator Temperature-1 using R12	54
Fig. 75: Variation of Exergetic Efficiency with Evaporator Temperature-1 using R436a	54
Fig. 76: Variation of Exergetic Efficiency with Evaporator Temperature-1 using R436b	55
Fig. 77: Comparison of Variation of Exergetic Efficiency with Evaporator Temperature-1	55

Fig. 78: Variation of Exergetic Efficiency with Evaporator Temperature-2 using R134a	56
Fig. 79: Variation of Exergetic Efficiency with Evaporator Temperature-2 using R12	56
Fig. 80: Variation of Exergetic Efficiency with Evaporator Temperature-2 using R436a	57
Fig. 81: Variation of Exergetic Efficiency with Evaporator Temperature-2 using R436b	57
Fig. 82: Comparison of Variation of Exergetic Efficiency with Evaporator Temperature-2	58
Fig. 83: Variation of Exergetic Efficiency with Condenser Temperature using R134a	58
Fig. 84: Variation of Exergetic Efficiency with Condenser Temperature using R12	59
Fig. 85: Variation of Exergetic Efficiency with Condenser Temperature using R436a	59
Fig. 86: Variation of Exergetic Efficiency with Condenser Temperature using R436b	60
Fig. 87: Comparison of Variation of Exergetic Efficiency with Condenser Temperature	60

## **LIST OF TABLES**

Table 1: Properties of Refrigerants	9
Table 2: comparison of different proportion of blend of R290 and R600a	20

## NOMENCLATURE

COP	Coefficient of Performance (non-dimensional)
ED	Exergy Destruction (kW)
EDR	Exergy Destruction Ratio (non-dimensional)
Eta or $\eta$	Efficiency (non-dimensional)
h	Specific Enthalpy (kJ / kg)
m	Mass flow rate (kg / s)
P	Pressure (kPa)
Q	Refrigerant capacity (kW)
s	Specific Entropy (kJ / kg-K)
T	Temperature ( $^{\circ}$ C)
TR	Tonne of Refrigeration
W	Specific Work (kJ/kg)

### **Subscript/Superscript**

c1	Compressor-1
c2	Compressor-2
cond or c	Condenser
e1	Evaporator-1
e2	Evaporator-2
ex	Exergetic
flash	Flash tank
o	Dead state
r1	Refrigerated space at low temperature (evaporator-1)
r2	Refrigerated space at high temperature (evaporator-2)
t1	Expansion device-1
t2	Expansion device-2