RESEARCH PAPER | Engineering | Volume : 3 | Issue : 3 | March 2013 | ISSN - 2249-555X

Optimum Choice of Refrigerant for Miniature Vapour Compression Refrigeration System

KEYWORDS: Miniature refrigerator, electronic cooling, R134a, COP.

M. M. Tayde	Pranav Datar	Pankaj kumar
Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala.	Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala.	Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala.

Dr. L. B. Bhuyar

Professor, Ram Meghe Institute of Technology and Research, Badnera, Amravati- 444041

ABSTRACT *Recently in most of the studies mesoscale vapour compression refrigerator is integrated in high power microelectronic packaging and it offers a new cooling solution. Thermodynamic efficiency of such system depends on its operating temperatures. However, important practical issues like system design, sizing, cost, safety, reliability etc. depends on the type of refrigerant selected for given application. Now a days, global warming and ozone layer depletion are the prior issues to be considered while selecting the refrigerant. This work presents a comparison between four refrigerants and finding out the most suitable one for miniature refrigerator. In this work it is found that NH3 gives the highest COP but because of its drawbacks like corrosive nature, fouling smell and highly toxic nature R134a is selected for the system.*

Nomenclature
Q Heat (W)
W Power input (W)
h Specific enthalpy (kJ/kg)
T Temperature (0C)
COP Coefficient of performance
RE Refrigerating effect

Greek Symbols
η efficiency

Subscripts
C compressor
c condenser
e evaporator

Introduction
In recent years the development of power electronic devices [1] has led to many thermal issues. Air cooling technology has been in use for cooling of electronic devices since many years. But now a days liquid cooling is also attracting increasing interest as it is more effective than air cooling so it becomes necessary to develop a new technique which will serve the purpose. From the study of various alternatives such as Heat pipe, Liquid immersion, Thermoelectric, VCR and Jet impingement [2], the vapour compression system is found to be most effective for dissipating heat[3,4,5].

For developing such a small size refrigerator it is necessary to select the type of refrigerant to be used before designing the system [6]. There is no general rule governing the selection of refrigerants. There are of course five basic criteria thermo physical properties, technical aspects, economic aspects, safety and environment factors.

Increasing concern about climate change has resulted in the developments of efficient and energy conserving refrigerants. New refrigerants are developed keeping in mind its effect on Ozone Depletion potentail (ODP) and Global Warming Potential (GWP) [7]. Considering the contribution to climate change it is important to select the refrigerant considering their performance merits and properties. Hence in this investigation a comparative study of four different refrigerants is done. Table-1 shows different properties and applications of refrigerants.

Table-1 Properties and applications of various refrigerants.

Sr. No.	Refrigerant	Boiling Point	Critical Temperature	Properties	Applications
1	Ammonia (NH_3)-R717	-33^{0}C	133^{0}C	Penetrating smell, Non-flammable but Explosive, efficient, Attacks copper, No ODP and GWP, Highly toxic.	Large industrial plants. Since it attacks copper, used in open type reciprocating or screw compressors and steel pipes
2	R12 (CCl_2F_2)	-30^{0}C	112^{0}C	Has little odour, Colourless, Non-flammable, stable and Noncorrosive, Has ODP and GWP	Small plants with reciprocating compressors, used in domestic and commercial refrigeration.
3	R22 ($CHClF_2$)	-40.8 ^{0}C	96^{0}C	Colourless, Non-flammable, Noncorrosive and stable, Has ODP and GWP	Packaged air conditioning unit where size and economy of equipment are important.
4	R134a (CH_2FCF_3)	-26^{0}C		Colourless, Non-flammable, Noncorrosive Nontoxic and stable, GWP-1300	Centrifugal and high speed screw compressor, widely used automobile A/C.

Effect of refrigerant type on COP

Volume : 3 | Issue : 3 | March 2013 | ISSN - 2249-555X

Fig. 1 Simple Vapour compression cycle.

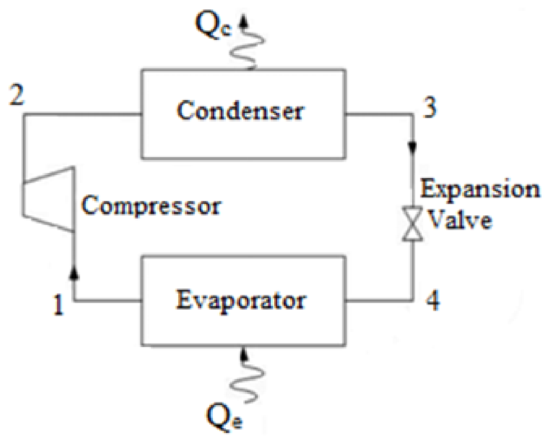

Fig. 1 shows a simple vapour compression cycle and component details. It consists of a compressor, condenser, expansion valve and evaporator. Evaporator absorbs the heat from the Integrated Circuit (IC) chip connected to it. Heat dissipated by chip is given by Qe and heat rejected by condenser is shown by Qc. WC is the power input given to the compressor in form of electric supply. Work is done on compressor while compressing the refrigerant in the process (1-2). Hence net work done during the cycle equals to compressor work i.e.

$$WC = (h2 - h3) \text{ kj/kg} \qquad (1)$$

Heat is rejected at the condenser end during process (2 - 3) i.e.

$$Qc = (h2 - h3) \text{ kj/kg} \qquad (2)$$

Refrigerating effect is the heat absorbed by the vaporizing refrigerant in the evaporator during process (4 - 1) i.e.

$$R.E. = Qe = (h1 - h4) \qquad (3)$$

The efficiency of refrigeration system is given by COP.

$$COP = Qe / WC = (h1 - h4) / (h2 - h1) \qquad (4)$$

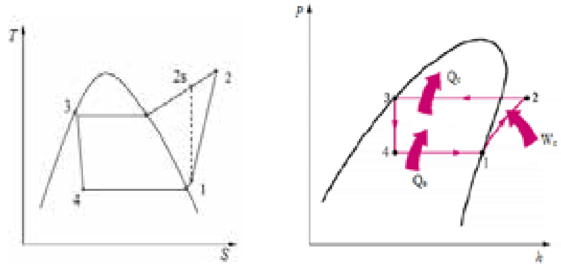

Fig. 2 P-h and T-S diagrams of Vapour compression cycle.

In ideal process compressor work is assumed as isentropic but in actual practice it is not so. The actual work is more than the isentropic work as shown in the Fig by line (1-2). So a term isentropic efficiency come into account and given by,

$$\eta C = \frac{(h2s - h1)}{(h2 - h1)} \qquad (5)$$

Table-2 summarizes our calculated results using software named COOLPACK [8] and shows the effect of Te and ηC on COP of four refrigerants (NH3, R12, R22, and R134a).

$$COP = \frac{Te}{(Tc - Te)} \qquad (6)$$

From equation (6) it is clear that as the difference between Tc and Te decreases the value of COP increases. Same trend can be observed in the Table-2. It is clear from Table-2 that for same values of Te, Tc and ηC, NH3 yields highest value of COP followed by R12, R134a and R22. Apart from this NH3 possesses very large latent heat hfg=1225.039 kj/kg then R22 possesses hfg=196.958 kj/kg after that R134a possesses hfg = 190.87 kj/kg and at last R12 possesses hfg= 146.363 kj/kg, at 100C.

Table-2 Effect of refrigerants on COP.

Tc (^{0}C)	Tc (^{0}C)	ηC	COP			
			NH3	R12	R22	R134a
-10	50	0.85	2.88	2.85	2.78	2.76
-10	50	0.75	2.54	2.52	2.45	2.44
-10	50	0.6	2.03	2.01	1.96	1.95
-5	50	0.85	3.27	3.24	3.15	3.15
-5	50	0.75	2.88	2.86	2.78	2.78
-5	50	0.60	2.31	2.29	2.22	2.22
0	50	0.85	3.74	3.71	3.60	3.62
0	50	0.75	3.30	3.28	3.18	3.20
0	50	0.60	2.64	2.62	2.54	2.56
5	50	0.85	4.31	4.29	4.16	4.20
5	50	0.75	3.81	3.79	3.67	3.71
5	50	0.60	3.04	3.03	2.94	2.96
10	50	0.85	5.03	5.02	4.86	4.93
10	50	0.75	4.44	4.43	4.28	4.35
10	50	0.60	3.55	3.54	3.43	3.48
15	50	0.85	5.96	5.95	5.75	5.86
15	50	0.75	5.26	5.25	5.08	5.17
15	50	0.60	4.21	4.20	4.06	4.14

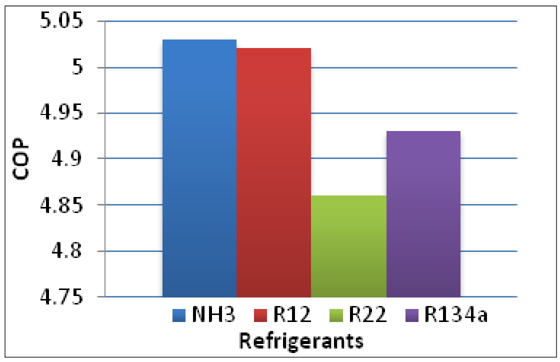

Fig. 3 COP of different refrigerants for (Tc - Te) = 400C and ηC = 0.85

Conclusion

A comparison of refrigerants NH3, R12, R22 and R134a reveals that NH3 gives the maximum value of COP. But NH3 cannot be used because of its drawbacks such as fouling smell and toxic nature. It is non-flammable but explosive. Next refrigerant is R12 hiving highest COP after NH_3. R12 is basically stable and non-flammable but it causes serious damage to ozone layer. Hence R12 cannot be used. After that R22 also have same drawbacks as that of R12. It also causes harmful effects to ozone layer.

Now last refrigerant is R134a which is most widely used because of its certain advantages over the others like non-toxic, non-flammable, high COP and also harmless for Ozone layer. Also existing compressors are designed for R134a. Hence, it can be said that R134a is the most suitable refrigerant for miniature refrigerator.

Future Scope: - Experimentally investigate the developed miniature refrigerator using the above mentioned refrigerants.

Volume : 3 | Issue : 3 | March 2013 | ISSN - 2249-555X

REFERENCE [1] R.R. Schmidt, B.D Notohardjono (2002). 'High end server low temperature cooling.' IBM J. RES & DEV vol 46 no. 6 | [2] Ioan Sauciue, Ravi Prasher, Je Young Chang, Hakan Erturk, Gregory Chrysler, Chia-Pin Chiu, Ravi Mahajan (2005). 'Thermal performance and key challenges for future CPU cooling technologies.' ASME InterPACK'05. | [3] Phelan, P.E., Chiriac, V., & Lee, T.Y., (2003), 'Performance Comparison of Mesoscale Refrigeration Technologies for Electronics Packaging," Paper No. InterPack2003-35 140. | [4] Heydari, A., (2002), 'Miniature Vapor Compression Refrigeration Systems for Active Cooling of High Performance Computers,' Proceedings of ITHERM | 2002, Inter Society Conference on Thermal Phenomena | [5] Phelan, P.E., Chiriac, V., & Lee, T., (2002), 'Current and Future Miniature Refrigeration Cooling Technologies for | High Power Microelectronics,' IEEE Transactions on Components and Packaging Technologies, Vol. 25, 356-365 | [6] Patrick E. Phelan, Jason Swanson, Florea Chiriac and Victor Chiriac (2004), 'Designing A Mesoscale Vapor-Compression Refrigerator for Cooling High-Power Microelectronics', Inter Society Conference on Thermal Phenomena, 218-223. | [7] A.Baskaran, P.Koshy Mathews (2012). 'A Performance Comparison of Vapour Compression refrigeration system using eco friendly refrigerants of low global warming potential', International Journal of Scientific and Research Publications, Volume 2, Issue 9, 1-8. | [8] 'COOLPACK', Technical University of Denmark, Department of Mechanical Engineering, Lyngby, Denmark, 2004, vol.46. | [9] ASHRAE, 'American society of Heating Refrigeration and Air-conditioning Engineers', Handbook fundamentals, 1997.