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Domestic Refrigerator Using Alkane Series As A Reserve Refrigerant - Performance Study & Analysis

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Abstract: Domestic refrigerator designed to work with R-134a was used as associate investigation unit to assess the prospect of exploitation mixed refrigerants. The recital of the refrigerator exploitation mixed refrigerant was investigated and compared with the performance of refrigerator once R-134a was used as refrigerant. The results of condenser temperature and evaporator temperature on COP, refrigerant result were calculated. The energy consumption of the refrigerator throughout experiment with mixed refrigerant and R-134a was measured. The result shows the permanent running and cycling results showed that R134a with a charge of a hundred g or mixed refrigerant with charge of 80 mg or extra satisfy the required deep freezer air temperature of −18 °C. All-time low electricity consumption was achieved victimization mixed refrigerant with heat level is a smaller quantity than -18°C. This mixture achieved higher volumetric cooling capacity and lower freezer air temperature compared to R134a. Experimental results of the domestic refrigerator exploitation mixed refrigerant were scrutiny with those using R134a. During a final output may be a forceful modification whereas employing a mixed refrigerant compared with R134a. Typically this can be often an indication of higher performance of mixed refrigerant as refrigerants. Once the results acquire throughout this experiment, it had been show a positive clue of using mixed refrigerant as refrigerants in domestic refrigerator. The thermodynamic properties of refrigerants are obtained using REFPROP 9 software that contains details of refrigerants. Different combinations of the refrigerants along with their COPs are obtained by the REFPROP 9. It consumes time in obtaining the correct combination of refrigerants as lot of menu options have to be chosen in the REFPROP 9. In order to make the process of finding out the correct mixed refrigerants with less manual intervention, RBF is trained and tested with the patterns of mixed refrigerants. The RBF / BPA mixed refrigerant analysis software has been developed by using MATLAB 11a.

Keywords : Chlorofluorocarbons, propane, Butane, R134a, Mixed refrigerant, Isobutane, COP, ANN, Back propagation algorithm, Radial basis function.

Introduction

Refrigerators are extensively used to store foods which deteriorate at ambient temperatures; spoilage from bacterial growth and other processes is much slower at low temperatures. Normal coolness was disseminated and used in both commercial and domicile application in the middle-1800s to refrigerate food. The proposal that

cold could be produced by the forced evaporation of a impulsive liquid under reduced pressure had been previously pursued by Willam Cullen in the eighteenth century. A domestic refrigerator is a cooling appliance comprising a thermally insulated screened-off area and a heat pump - element or perfunctory means - to transfer heat from it to the external atmosphere cooling the contents to a temperature below ambient. An apparatus described as a "refrigerator" maintains a temperature a slight degrees above the freezing point of water; a similar device which maintain a temperature below the freezing point of water is called a "freezer." The refrigerator is a fairly modern invention among kitchen appliance[15]. It replaced the icebox, which had been a common domestic appliance for almost a century and a half earlier.

Chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs) have many suitable properties, for example, non flammability, low toxicity and material compatibility that have led to their common widespread use by both consumers and industries around the world, especially as refrigerants in air conditioning and refrigerating systems[1and 10]. Results from many researches show that this ozone layer is being depleted. The general consensus for the cause of this event is that free chlorine radicals remove ozone from the atmosphere, and later, chlorine atoms continue to convert more ozone to oxygen[13]. The presence of chlorine in the stratosphere is the result of the migration of chlorine containing chemicals. The chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs) are a large class of chemicals that behave in this manner[2 and 14].

Hydrocarbon for the most part propane, butane and isobutene are proposed as an environment benign refrigerant[3]. Hydrocarbons are free from ozone depletion potential and have negligible global warming potential. Akash and Said[2] conducted an experiment study on the use of isobutene as refrigerant in domestic refrigerator. The performance was comparable with those of CFC-12 and HCFC-22 was used as refrigerant[7].

Marketable fridge and freezer units, which go by many other names, were in use for almost 40 years prior to the common home models[6]. They used noxious gas systems, which occasionally leaked, making them unsafe for home use. Practical household refrigerators were introduced in 1915 and gained wider acceptance in the United States in the 1930s as prices fell and non-toxic, non-flammable synthetic refrigerants such as Freon or R-12 were introduced. It is notable that while 60% of households in the US owned a refrigerator by the 1930s, it was not until 40 years later, in the 1970s, that the refrigerator achieved a similar level of penetration in the UK.

Refrigerant selection involves balancing conflicting requirements such as: ability to transfer heat, chemical stability, and compatibility with compressor lubricants, flammability, and toxicity. Akash and Said[2] studied the performance of mixed refrigerant from local market (30%propane, 55% n-butane and 15% isobutene by mass) as an alternative refrigerant for CFC-12 in domestic refrigerator with masses of 50g, 80g and 100g[8]. The result showed that a mass charge of 80g gave the best performance. Scientist and researcher are searching the environment benign refrigerant for the domestic refrigerator and freezer. Finally we decide to choose the mixed refrigerant as an alternate source of HFC-134.

ANN – Artificial Neural Network

ANN is an abstract simulation of a real nervous system that contains a collection of neuron units communicating with each other via axon connections. Such a model bears a strong resemblance to axons and dendrites in a nervous system. Due to this self-organizing and adaptive nature, the model offers potentially a new parallel processing paradigm. This model could be more robust and user friendly than the traditional approaches. ANN can be viewed as computing elements, simulating the structure and function of the biological neural network[4]. These networks are expected to solve the problems in a manner which is different from conventional mapping. Neural networks are used to mimic the operational details of the human brain in a computer.

Neural networks are made of artificial neurons which are actually simplified versions of the natural neurons that occur in the human brain[5]. It is hoped that it would be possible to replicate some of the desirable features of the human brain by constructing networks that consist of a large number of neurons[16]. A neural architecture comprises massively parallel adaptive elements with interconnection networks which are structured hierarchically. Artificial neural networks are computing elements which are based on the structure and function of the biological neurons. These networks have nodes or neurons, which are described by difference or differential equations. The nodes are interconnected layer wise or intra-connected among themselves. Each node in the successive layer receives the inner product of synaptic weights with the outputs of the nodes in the previous layer. The inner product is called the activation value. The activation value is passed through a non-

linear function. When the vectors are binary or bipolar, hardlimiting non-linearity is used. When the vectors are analog a squashed function is used. Some of the squashed functions are sigmoid (0 to 1), tanh (-1 to +1), Gaussian, logarithmic and exponential[17]. A network with two states of a neuron 0 or 1 and -1 or 1 is called discrete and the same with a continuous output is called analog. In a discrete network at a particular time the state of every neuron is updated, the network is said to be synchronous. If thestate of only one neuron is updated, the network is said to be asynchronous. A network is feed forward, if there is no closed chain of dependence among neural states. The same network is feed backward, if there is such a closed chain.

When the output of the network depends upon the current input the network is static. If the output of the network depends upon past inputs or outputs, the network is dynamic. If the interconnection among neurons changes with time, the network is adaptive. The synaptic weight updation of the networks can be carried out by supervised methods or by unsupervised methods or by fixed weight association networks methods. In the case of the supervised methods, inputs and outputs are used in the unsupervised methods, only the inputs are used and in the fixed weight association networks methods, inputs and outputs are stored weights.

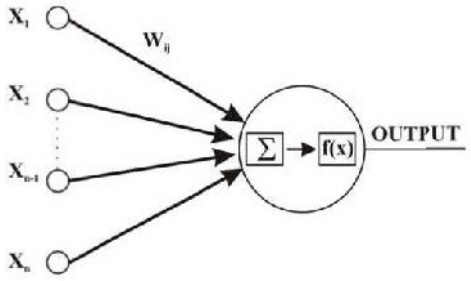

Fig. 1 Neuron – Operation

Some of the supervised learning algorithms are the perceptrons, decision based neural networks, adaptive linear element (ADALINE) (Fig.1), multilayer perceptrons, temporal dynamic models and hidden Markov analysis. The various unsupervised learning algorithms are neo-cognition, self-organizing feature map, competitive learning, and adaptive resonance theory. The fixed weight networks are Hamming net, Hopfield net and the combinatorial optimization. The total pattern recognition system constitutes instantiation space, feature extraction, training the network, and the testing the network. Inan *et al*.[9] has made the concept of ANN widely known through their publications.

Experimental Setup And Test Procedure

This section provides a description of the facilities developed for conducting experimental work on a domestic refrigerator. The technique of charging and evacuation of the system is also discussed here. Experimental data collection was carried out in the research laboratory of our institution. The experimental setup of the test unit is shown in the Fig. 1.

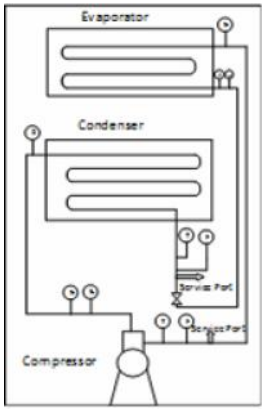

Fig. 2 Schematic diagram of the investigation unit

Experimental Methodology

The experimental setup of the household refrigerator used in the experiment is shown in Fig 2. The domestic refrigerator consists of an evaporator, wire mesh air-cooled condenser and hermetically sealed reciprocating compressor. The 165 liters domestic refrigerator of tropical class originally designed to work with HFC134a was taken for this study. The refrigerator was instrumented with one pressure gauge at the inlet of the compressor for measuring the suction pressure, one temperature sensor mounted at inside the refrigerator (freezer) compartment. As per the refrigerator manufactures recommendation quantity of charge requirement for HFC134a was 100 g. In the experiment, refrigerant charge is 10% higher due to the presence of instruments and connecting lines etc. To optimize the mixed refrigerant charge, the refrigerator is charged with 80g. The refrigerator was charged with 110 g of HFC134a and the base line performance was studied. After completing the base line test with HFC134a, the refrigerant was recovered from the system and charged with 80g of mixed refrigerant and the performance was studied. The refrigerant charge requirement with hydrocarbons is very small due to their higher latent heat of vaporization. During the experimentation the atmospheric is maintained at 28 ± 2^{o}C. The experimental procedures were repeated and take the reading from the various modes of different loading conditions. Specially, we conduct the investigation is purely based on the vegetable and chicken in 0.5 and 1 kg load factor. Service port is installed at the inlet of expansion valve and compressor for charging and recovering the refrigerant is shown in Figure. Digital Temperature Indicator was used to measure the inside freezer temperature for this research.

Test Procedure

The system was evacuated with the help of vacuum pump to remove the moisture and charged with the help of charging system. The temperature inside the chamber was maintained at 25°C and 28°C. When the temperature and humidity inside the chamber was at steady state, the experiments were started. The experiment has been conducted on the domestic refrigerator at no load and load conditions.

Normalization of the Patterns

The patterns are normalized so that the values of the features are in the range of 0 to 1 and the computational complexity is reduced[11]. The normalization of the patterns is done as per equation (1).

$$xi = xi / xmax \qquad (1)$$

where, xi is the value of a feature, and xmax is the maximum value of the feature.

Selection of Patterns for Training

The numbers of classes (Range of COPs), which are based on the classification range of the outputs, are decided. If only one output is considered the range of classification is simple. If more than one output is considered a combination criterion has to be considered. The total number of patterns is decided for each class. Out of these patterns, the number of patterns to be used for training the network is decided. The remaining patterns are used for testing the classification performance of the network. The patterns selected for training the network should be, such that they represent the entire population of the data.

Back Propagation Algorithm

The BPA uses the steepest-descent method to reach a global minimum. Flow-chart of the BPA is given in Figure 2. The number of layers and number of nodes in the hidden layers are decided. The connections between nodes are initialized with random weights. A pattern from the training set is presented in the input layer of the network and the error at the output layer is calculated. The error is propagated backwards towards the input layer and the weights are updated. This procedure is repeated for all the training patterns. At the end of each iteration, test patterns are presented to ANN and the classification performance of ANN is evaluated. Further training of ANN is continued till the desired classification performance is reached.

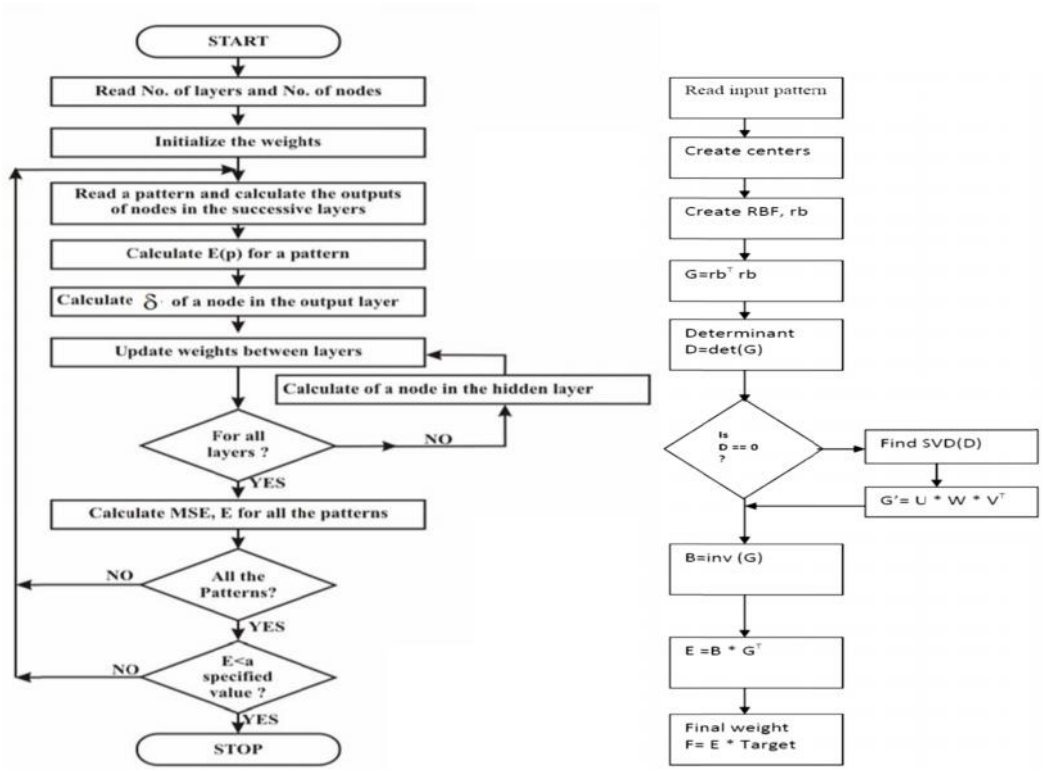

Fig. 3 Flow Chart of BPA & RBF

Results And Discussions

From this section the comparison of the performance parameter of the refrigerants and energy consumption by the refrigerator was discussed this investigation deals with mixed refrigerant (hydrocarbon mixtures of propane, butane and isobutane) in order to assess their feasibility for replacing HFC-134a in refrigeration systems by comparing their relevant parameters[12].

The refrigerating effect is the main purposes of the refrigeration system. The liquid refrigerant at low pressure side enters the evaporator. As the liquid refrigerant passes through the evaporator coil, it continually absorbs heat through the coil walls, from the medium being cooled. During this, the refrigerant continues to boil and evaporate. Finally the entire refrigerants have evaporated and only vapor refrigerant remains in the evaporator coil.

The liquid refrigerant still colder than the medium being cooled, therefore the vapor refrigerants continue to absorb heat. The experiment was performed on the domestic refrigerator purchased from the market, the components of the refrigerator was not changed or modified. This indicates the possibility of using mixed refrigerant as an alternative of HFC-134a in the existing refrigerator system. Freezer temperature was measured at the different time interval and also observed the lowest temperature level.

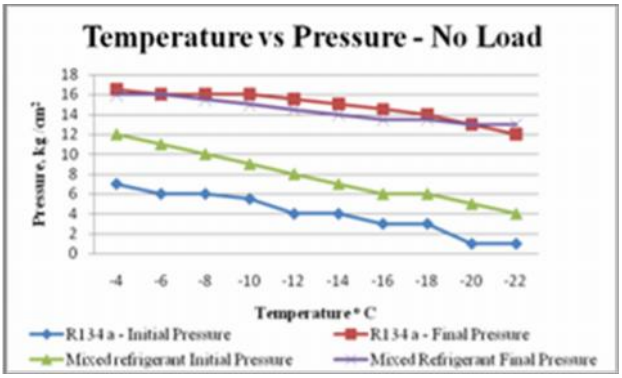

Fig. 4 Observed value for R134a & Mixed Refrigerant – No Load (Temp. vs Pressure)

Fig 4 shows the observed values for R134a and mixed refrigerant at no load condition. For this observation, base refrigerant reach -22°C in a low pressure value. But, mixed refrigerant will take maximum pressure of 12kg/cm^2 to reach -22°C. Based on the above graph, we observe mixed refrigerant was shows a best cooling effect.

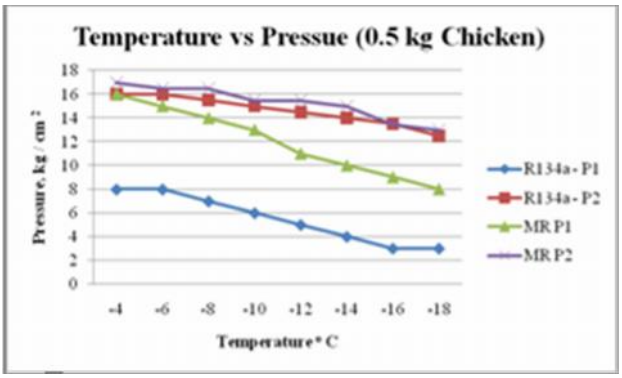

Fig. 5 Observed value for R134a & Mixed Refrigerant – 0.5kg Chicken (Temp. vs Pressure)

Fig 5 shows the observed values for R134a and mixed refrigerant at 0.5kg chicken condition. For this observation, base refrigerant reach -18°C in a low pressure value. But, mixed refrigerant and R134a will take maximum pressure of 13kg/cm^2 to reach -18°C. Based on the above graph, we observe both mixed refrigerant and R134a pressure values are shown.

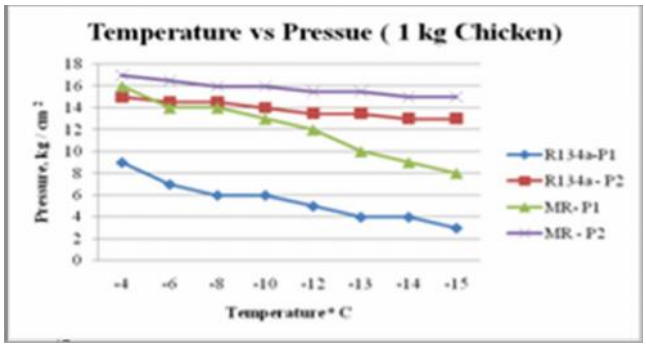

Fig. 6 Observed value for R134a & Mixed Refrigerant – 1kg Chicken (Temp. vs Pressure)

Fig 6 shows the observed values for R134a and mixed refrigerant at 1 kg chicken load condition. For this observation, base refrigerant reach -15°C in a low pressure value. But, mixed refrigerant final pressure was maximum value of 15kg/cm ^{2} and R134a will take maximum pressure of 13kg/cm^2 to reach -18°C. Based on the above graph, we observe both mixed refrigerant and R134a pressure values are shown at 1kg chicken.

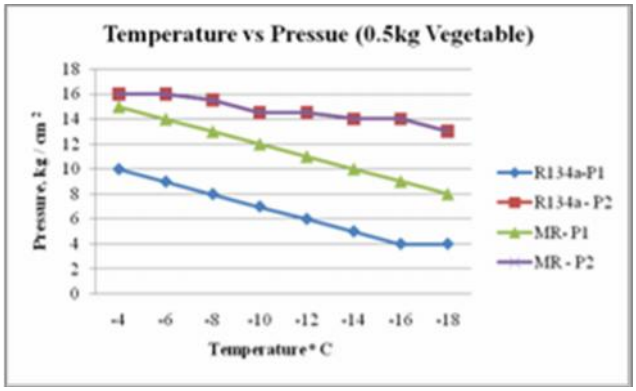

Fig. 7 Observed value for R134a & Mixed Refrigerant – 0.5 kg Vegetable (Temp. vs Pressure)

Fig 7 shows the observed values for R134a and mixed refrigerant at 0.5 kg vegetable load condition. For this observation, base refrigerant and mixed refrigerant reach -18°C in a same pressure value. Based on the above graph, we observe both mixed refrigerant and R134a pressure values are shown at 0.5kg vegetable.

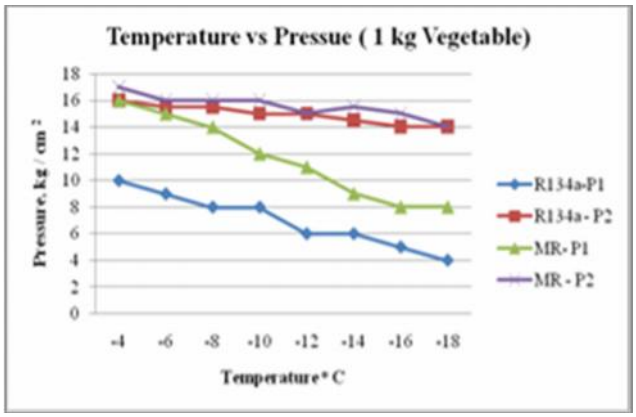

Fig. 8 Observed value for R134a & Mixed Refrigerant – 1 kg Vegetable (Temp. vs Pressure)

Fig 8 shows the observed values for R134a and mixed refrigerant at 1 kg vegetable load condition. For this observation, base refrigerant and mixed refrigerant reach -18°C in a same pressure value. Based on the above graph, we observe mixed refrigerant initial pressure value is maximum compared to base refrigerant.

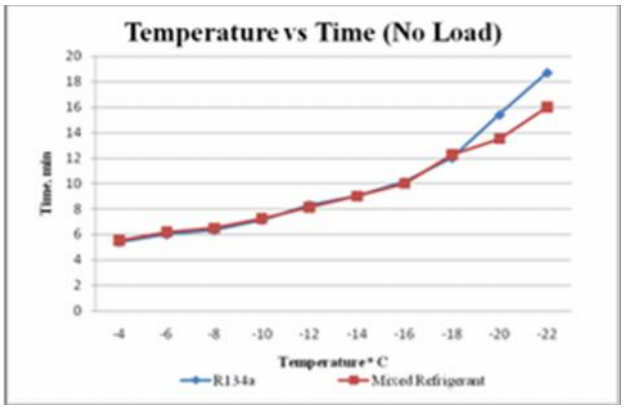

Fig. 9 Observed value for R134a & Mixed Refrigerant –No Load (Temp. vs Time)

Fig 9 shows the observed values for R134a and mixed refrigerant at no load condition. For this observation temperature level reach up to -18°C, R134a and mixed refrigerant take same time limit. But -20°C and -22°C, Mixed refrigerant gives better performance compare to sole (R134a) refrigerant.

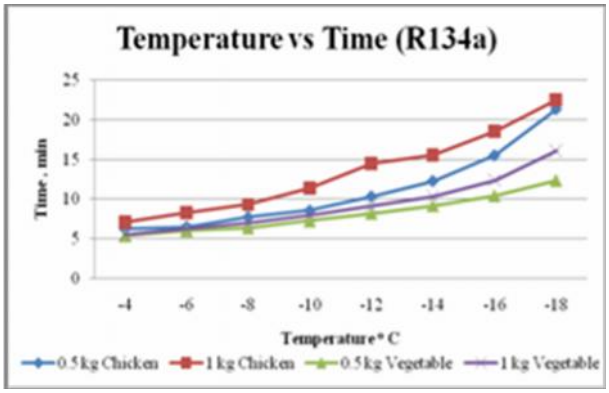

Fig. 10 Observed value for R134a – Load (Temp. vs Time)

Fig 10 shows the observed values for R134a at different load condition. i.e.,0.5kg,1 kg Chicken and 0.5kg, 1 kg vegetables. For this observation, 0.5kg vegetable reach -18°C in a short duration of 12 minute. But,

1 kg chicken will take maximum time of 23 minutes to reach -18°C. Based on the above graph, we observe vegetables are suddenly reaching the best cooling effect. When loading the chicken, lowest temperature was observed in maximum time.

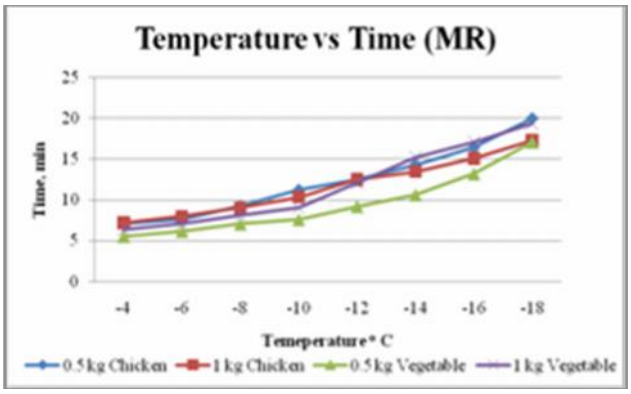

Fig. 11 Observed value for Mixed Refrigerant – Load (Temp. vs Time)

Fig 11 shows the observed values for mixed refrigerants at different load condition. i.e., 0.5kg, 1 kg Chicken and 0.5kg, 1 kg vegetables. For this observation, 0.5kg vegetable and 1kg chicken reach -18°C in a short duration of 17 minute. Based on the above graph, a smart observation was found in the loading of vegetables and chicken at the up and down the cooling effect.

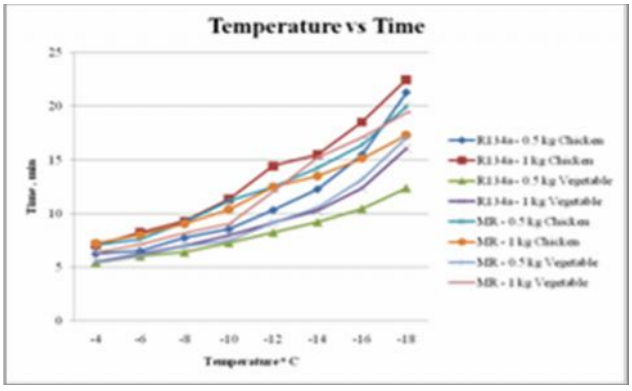

Fig. 12 Observed value for R134a & Mixed Refrigerant – Load (Temp. vs Time)

Fig 12 shows the observed values for R134a and mixed refrigerants at different load condition. i.e., 0.5kg, 1 kg Chicken and 0.5kg, 1 kg vegetables. For this observation, 0.5kg vegetable reach -18°C in a short duration of 12 minute for R134a.Using R134a, 1 kg chicken will take maximum time of 23 minutes to reach -18°C. At the same time the involvement of mixed refrigerant 1kg of chicken reaches -18°C in duration of 18minutes. Based on the above graph, we observe a drastic change of while using a mixed refrigerant compared with R134a.

The following table was shown the pattern used for testing the ANN with BPA/RBF

Table 1: Patterns used for testing the ANN with BPA / RBF

	Testing the ANN with BPA / RBF Inputs to BPA / RBF , Erol *et al.*, (2004)							Target
S.No.	**R32**	**R125**	**R290**	**R134a**	**R143a**	**R152a**	**R600a**	**COP**
1	0	15	0	4	81	0	0	2.181
2	0	25	0	15	60	0	0	2.185
3	0	40	10	50	0	0	0	2.158
4	0	60	15	25	0	0	0	2.113
5	10	30	0	0	60	0	0	2.178
6	35	5	0	60	0	0	0	2.239
7	0	0	20	80	0	0	0	2.159
8	0	0	0	70	0	0	30	2.223
9	0	0	0	40	0	60	0	2.243
1	0	80	0	0	20	0	0	2.144

The input data of the Table 1 is plotted in Fig.13.

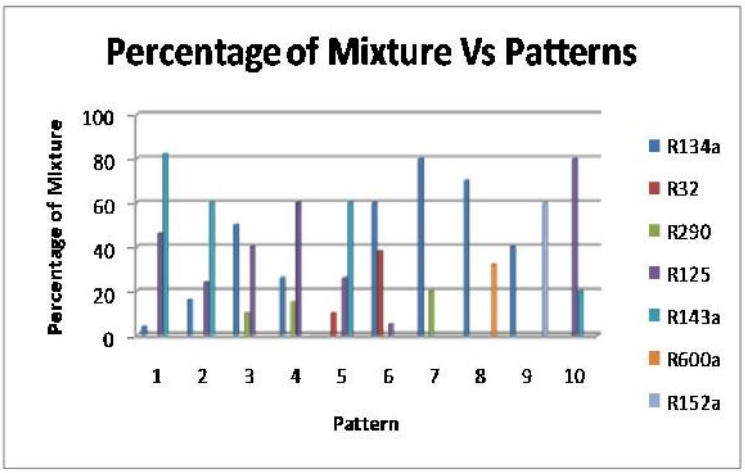

Fig. 13 Composition of Refrigerant Mixture

Training and testing of BPA

Table 1 presents test patterns using 7 combinations of pure refrigerants. Ten patterns are used for testing the BPA. To train the BPA , 50 patterns have been used. Fig.14(a) presents the convergence of MSE for increased iterations while training the 50 patterns with 3 nodes in the hidden layer of the network. The topology of the ANN is 7 X 3 X 1. Higher number of nodes in the hidden layer can also be preferred depending the rate of convergence of MSE. Fig. 14 (b) presents the number of test patterns presented in Table during the testing process by using the final trained weights. During the process of testing the ANN, only forward propagation of the BPA have been used. The plot shows the percentage of patterns for which COP has estimated correctly.

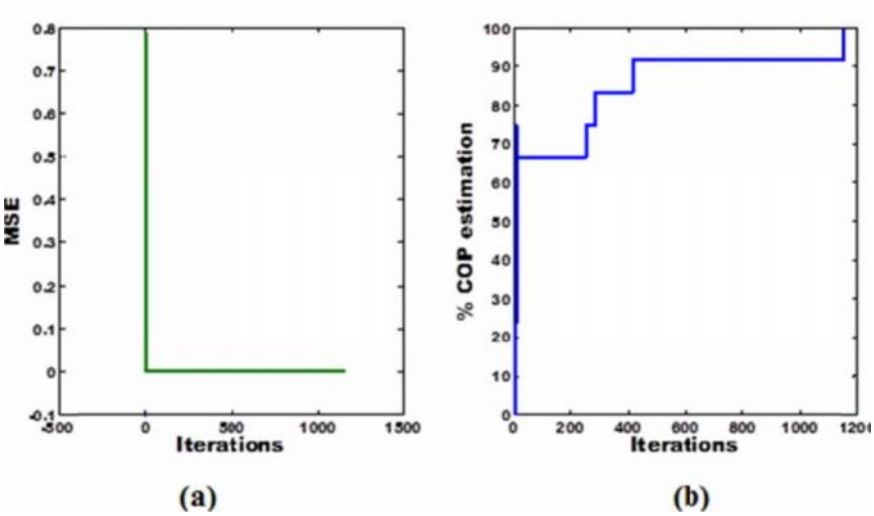

Fig.14 Testing of BPA

The COP is the ratio of the cooling capacity power to the compressor power.

Training and testing RBF

Table 1 is used for training the ANN with RBF. The performance of RBF is shown in Fig. 15. Red color marker shows the actual target COP. The blue color marker shows the RBF output during testing. The number of RBF centres used is 10.

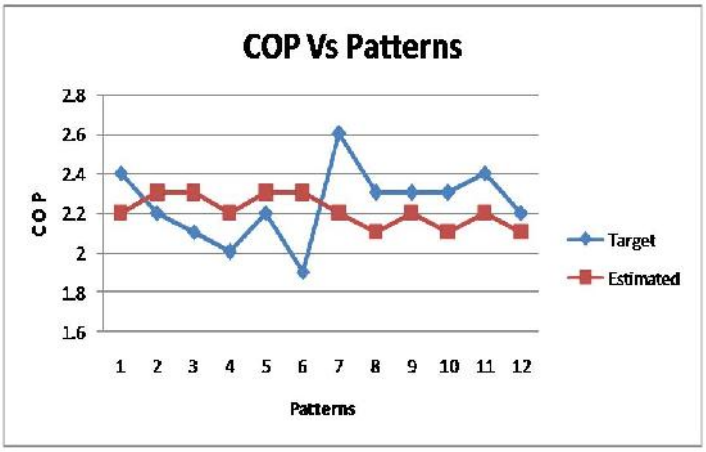

Fig.15 Performance of RBF

IV. Conclusion

This project invested an ozone friendly, energy efficient, user friendly, safe and cost-effective alternative refrigerant for HFC134a in domestic refrigeration systems. After the successful investigation on the performance of mixed refrigerants the following conclusions can be drawn based on the results obtained. This experimental investigation carried out to determine the performance of a domestic refrigerator when a propane/butane mixture is used as a possible replacement to the traditional refrigerant R134a. The domestic refrigerator was charged with 140g of R134a and 80g of mixed refrigerant. Based on the above graphs, we observe a drastic change while using a mixed refrigerant compared with R134a. This is an indication of better performance of mixed refrigerant as refrigerants. In this research various pressure values are observed and compared with the sole refrigerant (R134a) and mixed refrigerant (Propane - Butane Mixture). The subsequent conclusions can be elicited from our research, i.e., Each and every loading conditions of mixed refrigerant (Propane-Butane) yields higher performance of cooling effect while compared with R134a. Using the mixed refrigerant in domestic refrigerator, we were observed the freezer temperature lower than that of the R134a. A

smart observation was found in the loading of vegetables and chicken at the up and down the cooling effect, because chicken was taken more times to reach the lowest freezer temperature. And also this paper presents training and testing of ANN with BPA / RBF for finding out optimum mixed refrigerants to achieve very high COP. Data have been simulated to train and test the performance of ANN algorithms. The BPA requires some iteration for learning the data. However, RBF requires one iteration to learn all the training patterns. This is a major advantage of RBF over BPA is learning the data. Sometimes, BPA may not converge due to the property of data. However, RBF can produce a better result when compared to BPA in estimation of COP. The number computational complexity is more for BPA than that of RBF.

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