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EXPERIMENTAL RESEARCHES ON DOMESTIC REFRIGERATORS USING HFC-134a AS REFRIGERANT

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ABSTRACT

This paper describes in detail the experimental findings on using HFC-134a instead of CFC-12 as refrigerant on the unmodified refrigerator. Results and comparisons are given in the areas of storage temperature, pull down, energy consumption, starting and safety characteristics, etc. In addition, an infrared thermovision was used to record the distribution and changing trend of the condenser temperature while using the two different refrigerants. After over 300 days of continuous operation, all properties seemed stable and normal. Experimental results show that the HFC-134a refrigerator satisfied all chinese national standards. However, the HFC-134a refrigerator consumed about 4% more electricity than the CFC-12 refrigerator. Concerning this problem, we conducted more experiments using an HFC-134a refrigerator under different frequencies (46 Hz, 50 Hz, and 55 Hz) to study its performances including energy consumption, pull down.

INTRODUCTION

It is generally acknowledged that HFC-134a has great potential as an alternative to CFC-12. However, the problem of energy consumption is puzzling. Among internationally published results, some say that HFC-134a energy consumption is 8-12% higher than CFC-12 [1]; some say it's 7.8% higher [2]; still others say it may not be higher at all [3]. In order to understand the situation first hand, we conducted various experiments on the unmodified refrigerator. Then experiments using different electrical frequencies were also conducted to study actual energy consumption, pull down, running time as well as to explore the effectiveness of various energy saving steps. This paper gives the results of these experiments.

EXPERIMENTAL APPARATUS

Experiments were conducted using the refrigerator. After careful cleaning of the compressor, an ester-based low lubricant oil was added to it. To meet the needs of the experiments, thermal couples were installed in the evaporator and capillary tube before the foaming process.

Tests were done separately at Snow Flake Electrical Group Corporation's laboratory and at Tsinghua University Thermal Engineering Department's refrigerator thermal performances experimental apparatus [4]. Both sets of equipment met the national precision standards.

The optimum charge of CFC-12 usable on the refrigerator is 146g. Under room temperature (25°C), outlet temperature of the evaporator is 21-23°C. Before modifying the refrigerator, tests done with HFC-134a used different amounts of 120g, 140g and 160g. The first two charges yielded temperature of higher than 23°C at the evaporator outlet. Only the last charge gave temperature in the 21-23°C range, close to the CFC-12 measurements. Therefore, a charge of 160g for HFC-134a was decided upon before modification of the refrigerator.

Various statistics on CFC-12 are available in the Snow Flake company's factory test report. Since this is fairly representative of the CFC-12 refrigerators manufactured, no tests were repeated on CFC-12 during this experiment.

TEST RESULTS OF THERMAL PERFORMANCE FOR THE UNMODIFIED REFRIGERATOR

Separate tests were done to gather data on storage temperature, pull down, energy consumption, starting characteristics, condenser surface temperature distribution and electrical insulating properties. All experiments were strictly conducted to meet national standards.

1. Storage temperature

Table 1 shows the comparison of storage temperature between HFC-134a and CFC-12. It can be seen that even without modification, using HFC-134a met the national standard. In ambient temperature of 18°C, results using HFC-134a were even better, than using CFC-12. But the opposite occurred in ambient temperature of 38°C.

Table 1 Storage temperature

Ambient temperature	Standard	CFC-12	HFC-134a (unmodified)
18°C	Freezer ≤ -18°C	-21.4 °C	-20.0°C
	Fresh Food 0≤ t1,t2,t3 ≤12 tm ≤ 7°C	t1=3.8 °C t2=3.75°C t3=3.05°C tm=3.53°C	3.1 °C 3.0 °C 2.05°C 2.72°C
38°C	Freezer ≤ -18°C	-19.5 °C	-19.7°C
	Fresh Food 0≤ t1,t2,t3 ≤12 tm ≤ 7°C	t1=6.1 °C t2=5.85°C t3=4.25°C tm=5.4 °C	7.3 °C 6.75°C 5.25°C 6.43°C

2. Pull down

Table 2 shows the comparison of pull down during 3 hours of continuous operation in ambient temperature of 32°C. It can be seen from Table 2 that pull down of HFC-134a was slightly slower than that of CFC-12. This was due to the lower temperature and higher specific volume of HFC-134a at the entrance of the suction tube, when the compressor displacement was constant, the volumetric capacity was smaller than that of CFC-12.

Table 2 Pull down

Item	Sandard	CFC-12	HFC-134a(unmodified)
Freezer	≤ -18·C	-29·C	-24.1·C
Fresh Food	0≤ t1,t2,t3 ≤12 tm ≤ 7·C	t1= 2.3 ·C t2= 1.6 ·C t3=-0.4 ·C tm= 0.17·C	7.1 ·C 5.8 ·C 4.1 ·C 5.67·C

3. Energy consumption

This area is of great interest to researchers. Table 3 shows our experimental results. From the table, it can be seen that after over 300 days of continuous operation has given stability, the HFC-134a refrigerator used 4% more energy than the CFC-12 refrigerator. This number is smaller than some of the other reported data. Thus, our results suggest that using HFC-134a as an alternative to CFC-12 doesn't increase energy consumption significantly and that if appropriate steps were taken, it is entirely possible that HFC-134a's performance can match that of CFC-12.

Table 3 Energy consumption

Item	CFC-12	HFC-134a(unmodified)
Energy consumption (KWh/day)	1.25	1.30

4. Safety characteristics

Table 4 shows the safety characteristics such as leakage current, insulating resistance, and grounding installation which all meet the national standards.

Table 4 Safety characteristics

Standard	HFC-134a(unmodified)
leakage current < 1.5mA	0.077 mA
insulating resistance > 2.5MΩ	18.7 MΩ
grounding installation < 0.1Ω	0.05 Ω

To sum up, using HFC-134a as refrigerant and an ester-based oil on the unmodified refrigerator, thermal performance still met the national standards. However, pull down was a little slower, and energy consumption was higher.

CONDENSER SURFACE TEMPERATURE DISTRIBUTION

An infrared thermovision was used to record the condenser surface temperature distribution during the entire starting process. Figure 1 shows the temperature distribution and changing process for using both CFC-12 and HFC-134a. There were 36 surface sections between the entrance and exit of the condenser. Fixing time zero at when condenser was started, different symbols on the graph designate different instances during the starting process.

From the figure it can be seen that

(1) the surface temperature distributions on the main condenser were very different between one that used CFC-12 and one that used HFC-134a;

(2) because of the special structure of the condenser on the refrigerator, the subcool of both CFC-12 and HFC-134a were very apparent;

(3) CFC-12 showed significant temperature drop toward the rear sections of the main condenser whereas HFC-134a showed significant temperature drop toward the beginning;

(4) at the early stages of compressor operation, the temperature of HFC-134a was higher than that of CFC-12 at the entrance section of the main condenser, but at the middle and later stages of compressor operation, including the instance when it was stopped, HFC-134a's temperature was lower than that of CFC-12; It showed HFC-134a's temperature near the entrance section to be about 2-3°C lower than CFC-12;

(5) the heat transfer surface area of the main condenser seemed slightly too large, for both HFC-134a and CFC-12, and especially for HFC-134a, the last half of the main condenser provided almost no cooling effects; therefore the refrigerator to be used for actual experiments will need to have its main condenser surface area adjusted.

EFFECTS OF ELECTRICAL FREQUENCY ON THE THERMAL PROPERTIES OF HFC-134a REFRIGERATORS

As mentioned above, using HFC-134a on an unmodified refrigerator caused energy consumption to increase, pull down to decrease and volumetric capacity to decrease. Thus, in order to match CFC-12's volumetric capacity, the compressor's displacement needed to increase. During our studies, rather than frequently taking apart and reassembling or changing compressors, we operated the existing compressor under different power frequencies to observe the effects on the refrigerator. Tests were conducted on Tsinghua University's refrigerator performance apparatus using an adjustable power generator to supply the compressor motor with three different frequencies of 46Hz, 50Hz and 53Hz. Because the compressor may have had trouble starting in the 46Hz and 53Hz cases, 50Hz was used to start all runs. Immediately after starting,the frequency was changed to either 46Hz or 53Hz. The maximum frequency was set at 53Hz to avoid damage to the motor with higher frequencies.

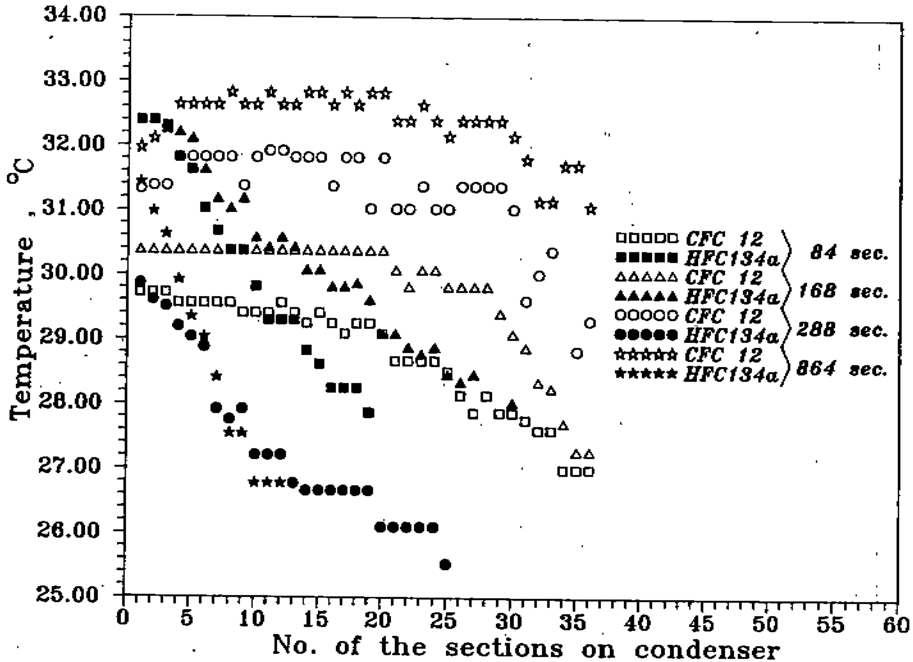

Fig. Temperature profile on surface of condenser

Table 5 Effect of different frequency on performance of refrigerator

f (Hz)	Energy consumption (KWh/day)	Running time,%	Power , (W) (Compressor off)		Energy consumption for pull down (KWh)	
			Continuously Running mold	On/Off mode	Freezer 32→18°C	Fresh Food 32→7°C
46	1.416	0.509	92-93	93-94	0.170	0.425
50	1.330	0.506	93-94	95-96	0.166	0.420
53	1.303	0.496	94-95	98-99	0.150	0.435

Table 5 shows the comparison of energy consumption, running time and power parameter for different frequencies.From Table 5, we can observe that:

(1) With a higher frequency, because of faster rotation speed, the compressor's starting power and instantaneous power under normal operation both increased. Obviously this is not good for trying to decrease energy consumption.

(2) However, a higher frequency also correspondingly increased compressor displacement and volumetric capacity, and both the fresh food and freezer compartment temperatures decreased more rapidly, especially the freezer compartment temperature. Running time decrease correspondingly as well which is good for lowering energy consumption.

(3) Therefore, summarizing the above two aspects, under certain conditions, increasing frequency and compressor displacement by appropriate amounts can decrease energy consumption. For example when frequency was 46Hz, energy consumption was 1.416, for 50Hz it was 1.330 and for 53Hz it was 1.303. Increasing frequency from 50Hz to 53Hz (+6%) decreased energy consumption by 2%. However, this does not imply that the higher the frequency the better, or the higher the compressor displacement the better. There exists an optimum compressor displacement.

(4) With respect to using HFC-134a under these three frequencies, the pull down of the fresh food compartment was slower than with CFC-12. The freezer pull down was even slower. This not only showed that the volumetric capacity was still too low but also reflected some problems in the matching of heat transfer surface area between the fresh food and freezing compartments.

CONCLUSION

Through the above described experiment, we can conclude that:

1. Using HFC-134a as refrigerant in the unmodified refrigerator still enabled various refrigerator characteristics to meet the national standards such as low exhaust temperature and high pressure ratio. Even though the starting power was high, under starting conditions of 187V, all three starts met requirements. After more than 300 days of continuous operation, everything was normal, and no unusual behavior was observed.

2. Without modification of the refrigerator, HFC-134a's energy consumption was lightly higher than CFC-12; volumetric capacity was slightly smaller, and pull down was slightly slower.

3. Increasing compressor displacement by an appropriate amount can decrease energy consumption.

4. In order to lower energy consumption while using HFC-134a as refrigerant, changes must be made to the compressor, condenser, evaporator, capillary tube, etc. Therefore, further study of component matching is also very important.

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REFERANCE

1. "Technical Progress on Protecting the Ozone Layer-Refrigeration, Air Condition and Heat Pumps Technical Options Report ", UNEP. June 30, 1989.

2. Vineyard, E.A., Sand, J.R. and Miller, W.A., "Refrigerator-Freezer Energy Testing with Alternative Refrigerants", ASHRAE Transactions, 1989, Vol.95, part 2.

3. Behrens, N., Dekleva, T.W., Hartley, J.G., Murphy, F.T. and Powell, R.L., "The R-134a Energy Efficiency Problem. Fact or Fiction ", ASHRAE-Purdue CFC Conference, Purdue, July 17, 1990.

4. M.S. Zhu, L.Z. Han, Z.Z. Lin, L. Li, Y.D. Fu,. "Experimental Research for Refrigerator's Thermal Performance with Thransient Substitute R500 for R12", ASIA-PACIFIC Conference on CFC Issue and Greenhouse Effect, Singapore, May 15-17, 1991.