ENERGY EFFICIENCY OF HFC-134A VERSUS HFC-152A

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ABSTRACT

In response to regulatory actions arising from the Montreal Protocol and the National Appliance Energy Conservation Act, appliance manufacturers and government researchers are investigating the energy efficiency of replacement refrigerants for CFC-12 in refrigerator-freezers. In an effort to evaluate the tradeoff between efficiency and safety of two alternative refrigerants, HFC-152a (flammable), and HFC-134a (nonflammable), energy consumption tests were performed by six refrigerator-freezer manufacturers as part of a joint project. The results showed no statistically significant difference between the efficiencies of HFC-134a and HFC-152a. Thus, HFC-134a is a more acceptable substitute for CFC-12 in refrigerator-freezers than HFC-152a assuming safety is the main difference between the two alternatives. However, other issues, such as global warming potential and ozone depletion potential influence the selection of replacement refrigerants and could outweigh the effects of the reduced safety of HFC-152a and other flammable refrigerants, such as hydrocarbons.

INTRODUCTION

The need to assess the energy efficiency of HFC-134a vs. HFC-152a in refrigerator-freezers became apparent in 1991 when conflicting assessments for the two refrigerants were being circulated. At a meeting for its Significant New Alternatives Program, the Environmental Protection Agency (EPA) produced a comparison showing that HFC-152a was 8 percent more efficient than HFC-134a (EPA 1991). However, this energy difference was based on an earlier project conducted by the Appliance Research Consortium (ARC) which used available calorimeter data on R-12 compressors that had not been optimized for use with either HFC-134a or HFC-152a. A conflicting study by Sanvordenker at Tecumseh Products Company (a compressor manufacturer) concluded that HFC-152a had no energy efficiency advantage over HFC-134a (Sanvordenker 1991). Sanvordenker discussed in his paper that results relative to the energy savings attributed to HFC-152a may be associated with errors in the thermodynamic data of the refrigerant. Specifically, Sanvordenker notes that the boiling point of HFC-152a as listed in the American Society of Heating Refrigeration and Air-conditioning Engineers handbook is low by 1°C based on recent measurements by researchers in Germany. This error results in a 0.6 PSIA differential in the saturation pressure at -10°F, producing as much as a 4 percent variance in system capacity and a 2 percent variance in the Energy Efficiency Ratio (EER). These assertions were supported by data from DuPont and the National Institute of Standards and Technology.

In a third study conducted at Oak Ridge National Laboratory, HFC-152a and HFC-134a were tested in refrigerators equipped with compressors sized to reflect changes in the volumetric capacity of each refrigerant (Vineyard 1991). In addition to the compressor change, different oils were selected based on recommendations from compressor manufacturers concerning life test results and equivalent viscosity values at operating conditions. A capillary tube manifold was also installed on the refrigerator-freezer to enable small changes in refrigerant flow. The results from that study showed that HFC-152a was approximately 2 to 3% more efficient than HFC-134a when the results were normalized for compressor EER.

Since the flammability of HFC-152a compared to HFC-134a makes it a safety issue that must be addressed due to litigation concerns, it is desirable to objectively compare the relative energy performance of the two refrigerants in household refrigerator-freezers in order to determine if the rewards outweigh the risks. In an effort to resolve the energy efficiency issue, the ARC initiated a project to conduct energy consumption tests for HFC-152a and HFC-134a at appliance manufacturers test facilities.

METHODOLOGY

The ARC, founded in 1989, performs research to identify replacement chemicals that are environmentally acceptable, cost-effective, and energy-efficient for CFC-11 in foam insulation and CFC-12 in refrigeration systems. ARC was organized by eight residential refrigerator-freezer manufacturers under the auspices of the Association of Home Appliance Manufacturers. Member companies at the time this research was conducted were Admiral (Maytag Corporation), Amana Refrigeration, Frigidaire Company, GE Appliances, Sanyo E&E Corporation, Sub-Zero Freezer, W. C. Wood Company Ltd., and Whirlpool Corporation. The U.S. Department of Energy and the EPA serve as liaison members. Supplier companies also contribute to research projects where appropriate.

In February 1992, ARC representatives from industry and government agreed to perform a research project that would evaluate the relative energy performance of HFC-134a as compared to HFC-152a. The project was to be as general as possible to allow each manufacturer to conduct tests according to their normal protocol and still maintain the experimental validity.

Test Method

Using a refrigerator-freezer design chosen by each test lab, energy consumption tests were performed in accordance with ANSI/AHAM Standard HRF-1-1988 "Household Refrigerators/Household Freezers" (AHAM 1988). Compressors were provided by Americold Compressor Company to yield an equivalent capacity as the CFC-12 compressor that they replaced. Each refrigerant was tested until the proper capillary tube size and refrigerant charge was determined. Following completion of the testing, each company submitted its data on a standard reporting form for averaging.

Test Units

In order to be able to make a reasonable comparison of the results with a statistically significant sample, it was determined that 18 to 21 cubic-foot top-mount automatic defrost refrigerator-freezers would be the preferred test units. However, other sizes and types of refrigerator-freezers could be tested in addition to the preferred units to assess if certain factors affected the relative difference in energy consumption between the two refrigerants.

Compressors

Calorimeter results from the compressor manufacturer indicated that a compressor designed to use HFC-134a would yield capacities that were 10–15 percent higher when retested with HFC-152a at the same rating conditions (-10° F evaporator and 130° F condenser). Accordingly, refrigerant-specific compressors were assembled for use by each test participant. Identical compressor shells and motors were used for both the HFC-152a and the HFC-134a compressors. However, the displacements were adjusted to produce equivalent capacities for each refrigerants.

Refrigerants

The refrigerant HFC-134a was taken from present supplies that each manufacturer had in its inventory. It was assumed that all samples were relatively close in purity so that the results of the study would not be affected. Since DuPont is the only supplier of HFC-152a, all samples used in the project were provided by them.

Lubricants

The type of lubricants used in comparing the two refrigerants was decided by each test facility. The only stipulation was that all lubricants were to have the same viscosity at 100° C. Alkylbenzene oils were chosen for all the tests with HFC-152a and ester lubricants were selected for HFC-134a. While each manufacturer and research lab may have had a different supplier of oil with special additives specific to that supplier, the assumption was that the additives were to reduce wear and would have no impact on the short term energy consumption test results.

Dessicants

It was initially recommended that all participants use XH-9 desiccant in their filter/dryers since it is compatible with both refrigerants tested. However, an XH-7 desiccant was considered to be an acceptable alternative in HFC-134a/ester oil systems for this research effort.

RESULTS

Prior to analyzing the data from the six participants, there was some question as to whether or not actual test results should be mathematically adjusted, or normalized, to account for differences between the two refrigerants. Following a discussion among members of the ARC refrigerant technical advisory committee, the decision was to make no adjustments to the data. Following are the comments against normalizing the results:

1. The compressors used in this testing are representative of a population of compressors available in a production situation.

2. The difference between average HFC-134a and average HFC-152a energy measurements as determined by the six project participants represents the statistical performance difference of the test variation between refrigerants to be expected.

3. The compressors supplied for the testing were of equivalent technology level and the displacement altered to give equivalent capacity. The accuracy of the displacement is evidenced by the nearly equal percentage run times of the tested refrigerator-freezers.

4. The EERs of the compressors are resultant from the effect of the different properties of the two refrigerants. The effect of HFC-152a on compressor efficiency is an integral part of the total product energy consumption and cannot be neglected. To normalize this data would eliminate this effect, and a direct comparison would not be obtained.

Energy Consumption

The data in Table 1 show that the energy consumption ranged from 682.6 to 944.6 kwh/yr for HFC-134a and from 668.0 to 966.6 kwh/yr for HFC-152a, indicating that the investigation covered a wide range of efficiency levels. The relative energy consumptions of HFC-134a to HFC-152a are also shown in Table 1. Overall, there is no evidence of a difference in the energy efficiencies of HFC-134a and HFC-152a. The average of all the efficiency ratios is 0.994 with a 95% confidence interval of 0.978 to 1.010. Since the confidence interval contains the point 1.000, there is not a statistically significant difference between the two energy efficiencies in the data.

Run Time

Run time is an indication of proper sizing of the compressor for a given refrigerator-freezer cabinet. Since run times affect energy performance, it was desirable to analyze the run times for each refrigerant to determine if improper compressor sizing affected the results. Looking at the ratios of run time for the two refrigerants in Table 1 shows similar results as those for the efficiency ratios. There is no clear evidence to indicate a difference between the two refrigerants tested. The average of all ratios is 1.007, and a 95 percent confidence interval is 0.984 to 1.030. Once again, since this confidence interval contains the point 1.000,

TABLE 1: DATA LISTING

lab	KWH/yr.			% run time			capillary length (in)	
	134a	152a	134a/ 152a	134a	152a	134a/ 152a	134a	152a
A	743.0	770.0	0.9649	55.6	56.7	0.981	120.0	156.0
B	935.9	949.0	0.9862	54.4	54.5	0.998	110.8	110.8
B	921.3	931.3	0.9865	53.0	54.1	0.980	110.8	110.8
B	935.9	926.4	1.0100	54.6	54.4	1.004	110.8	110.8
B	944.6	928.2	1.0180	55.0	55.7	0.987	110.8	110.8
C	922.3	950.8	0.9700	*	*	*	125.5	125.5
C	942.1	966.6	0.9750	*	*	*	125.5	125.5
D	864.9	856.5	1.0100	*	*	*	*	*
D	848.1	897.0	0.9455	*	*	*	*	*
E	682.6	668.0	1.0220	48.0	47.0	1.021	84.0	204.0
E	711.8	697.2	1.0210	51.0	49.0	1.041	84.0	204.0
E	697.2	671.6	1.0380	51.0	48.0	1.062	84.0	204.0
F	764.3	788.8	0.9689	47.0	49.0	0.959	194.0	242.0
F	768.3	771.6	0.9957	52.0	50.0	1.040	194.0	242.0

* indicates missing data

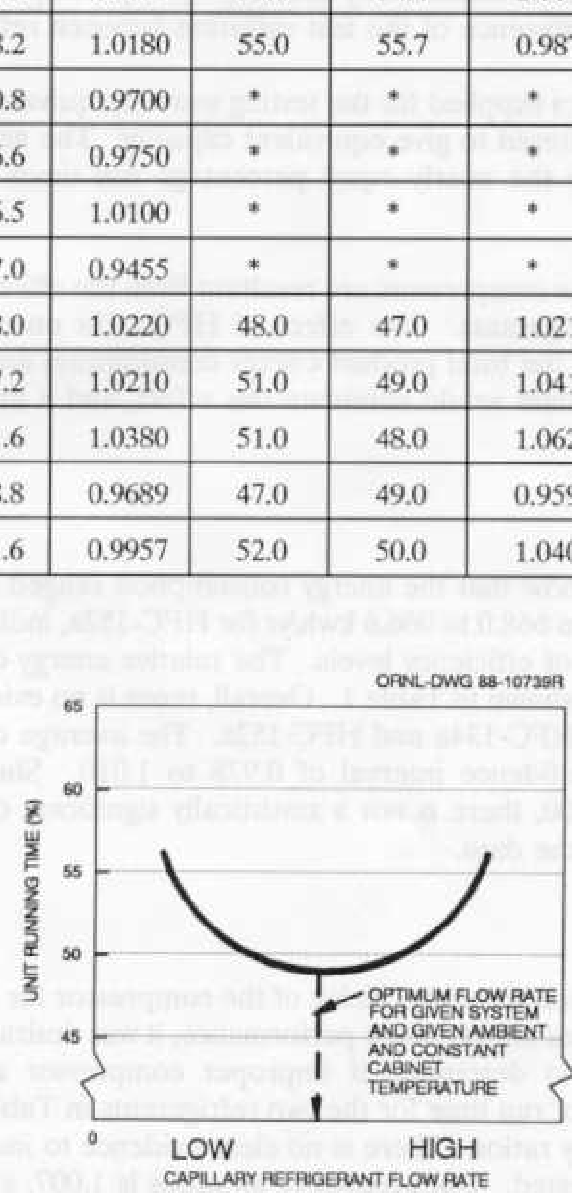

Fig. 1. Effect of capillary tube on run time

there is not a statistically significant difference between the run times of HFC-134a and HFC-152a. Thus, run time differences do not adversely affect the energy consumption results of either refrigerant.

Capillary Length

In addition to compressor size, the run time is also affected by the length of the capillary tube. As shown in Figure 1, the capillary tube can make a sizable difference in run time of the unit. Using a different refrigerant in a system with a preexisting capillary tube can cause the capillary tube to be undersized or oversized as a result of changes in the refrigerant properties that affect the amount of refrigerant flow that is necessary. By using a refrigerant whose density is different, the mass flow rate will be changed, which would affect the capacity of the unit. Shown in Table 1 are the capillary tube lengths that were used in the test series. Tests were performed with both equal and unequal lengths for the two refrigerants. There were only small or no differences in energy consumption associated with equal versus unequal capillary lengths. The two groups had nearly the same average and both had efficiency ratios above and below 1.000.

CONCLUSIONS

The statistical analysis of the data from this project concludes that the data produced from this testing give no evidence of a significant difference in efficiency between HFC-134a and HFC-152a in a refrigerator-freezer. In addition, the energy consumption for HFC-134a or HFC-152a does not appear to be affected when the capillary length is maintained the same for both refrigerants or adjusted to yield optimum results.

REFERENCES

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