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Project Summary

The Performance of Chlorine-Free Binary Zeotropic Refrigerant Mixtures in a Heat Pump

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This study uses a simulation model and an experimental heat pump apparatus with counterflow heat exchangers to show that two hydrofluorocarbon (HFC) refrigerant mixtures, HFC-32/-152a and HFC-32/-134a, may be considered replacements for hydrochlorofluorocarbon (HCFC)-22 if the appropriate mixture compositions are chosen. Data indicate that multiple tradeoffs exist in mixture performance for different compressor speeds and mixture compositions.

If the results for the HFC-32/-152a mixture are compared at the same compressor speed and capacity at which the HCFC-22 results were obtained, the improvements over HCFC-22 range from 14% for the high-temperature cooling mode to 2% for the low-temperature heating mode. The global warming potential of the tested mixture is about 25% of the value of HCFC-22. However, this zeotropic mixture is flammable in the whole composition range.

The test results for the HFC-32/-134a mixture, for mixtures containing more than 35 mass percent of HFC-32, show similar performance to the HFC-32/-152a mixture. Since HFC-134a is not flammable, the HFC-32/-134a mixture exists in a certain range as a nonflammable mixture. The test results for both mixtures show no problems with respect to extreme pressures or temperatures in the tested composition range.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The growing concern about the environmental compatibility of currently used refrigerants requires development and use of new refrigerants and refrigerating methods. The incompatibility of chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) refrigerants with the Earth's ozone layer and their influence on the greenhouse effect make it desirable to investigate ozone-safe refrigerants with low greenhouse warming potentials (GWPs) that operate efficiently in refrigeration systems. This study investigated such ozone-safe refrigerants as zeotropic mixtures for heat pump applications.

The refrigerants considered in this study are chemical derivatives of methane and ethane. With the requirement that the ozone depletion potential (ODP) of the considered substances has to be zero, it follows that they cannot contain any chlorine or bromine (chlorine and bromine are considered the main catalytic substances destroying the ozone layer). With this in mind, the following substances were selected to find a suitable working fluid for heat pump applications: hydrofluorocarbon (HFC)-23, -32, -125, -134a, -143a, and -152a.

In order to evaluate their performance, the refrigerants were compared to HCFC-22 which is the commonly used refrigerant in heat pumps in the United States.

In the theoretical part of the report, a suitable refrigerant mixture for the possible replacement of HCFC-22 was determined by applying a simulation program for the different substances and their mixtures under certain operating conditions. The results of this computer study were compared and analyzed with respect to the performance data.

The experimental part of this research project consisted of tests with the theoretically best performing refrigerant mixtures, the binary zeotropic mixtures HFC-32/-134a and HFC-32/-152a. These tests were conducted in a Mini-Breadboard Heat Pump (MBHP).

Theoretical Study

The results of the computer study show that there are two binary mixtures of HFCs that indicate a better performance than the currently used HCFC-22: HFC-32/-152a and HFC-32/-134a. Although the pure components of these mixtures show either lower coefficients of performance (COPs) and higher volumetric capacities or higher COPs and lower capacities, wide ranges of mixture compositions perform better in COP and show a higher volumetric capacity.

The HFC-32/-152a mixture is flammable since both pure substances are flammable. Both of these two refrigerants appear to have low toxicities. The mixture also has the lowest GWP of all considered mixtures. Operating temperatures and pressures are within acceptable limits.

The calculations for HFC-32/-134a show a smaller performance improvement than for HCFC-32/-152a but still a significant increase compared to HCFC-22. Both of these refrigerants are in the class of low toxicity, and only HFC-32 is flammable. If flammability tests show that a nonflammable refrigerant mixture exists within the composition range of performance improvement, this mixture would clearly be the substance of choice with respect to safety considerations. The GWP of HFC-32/-134a is higher than that of HFC-32/-152a. However, it still is significantly lower than that of HCFC-22. Again, the operating temperatures and pressures do not appear to pose any problems.

Given the results of the computer study, tests were conducted with these two refrigerant mixtures within certain composition ranges. The ranges of the tested mixtures were determined largely by the desire to find a mixture that achieves at least the same volumetric capacity and the same COP as HCFC-22. This should be the case for all operating conditions. At the same time, excessive amounts of HFC-32 should not be used in order to provide for acceptable discharge pressures even under extreme operating conditions. Tests were run for both refrigerant mixtures in a range between 15 and 40 mass-percent HFC-32. For all these compositions, the pressures are expected to be well within acceptable ranges.

Experimental Study

Tests over a wide range of mixture compositions using an experimental HFC heat pump apparatus with counterflow heat exchangers show that refrigerant mixtures HFC-32/-152a and HFC-32/-134a may be considered replacements for HCFC-22 if the appropriate mixture compositions are chosen. Data indicate that multiple tradeoffs exist in mixture performance for different system compressor speeds and mixture compositions.

If results for HFC-32 and -152a are compared at the same compressor speed and capacity at which the HCFC-22 results were obtained, the predicted improvements in COP are very close to the measured COPs. These improvements over HCFC-22 range from 14% for the high-temperature cooling mode to 2% for the low temperature heating mode. Operating pressures and temperatures of this mixture are well within acceptable limits. The GWP of the tested mixture is about 25% of the value ofHCFC-22. However, this zeotropic mixture is flammable in the whole composition range.

The other mixture, HFC-32/-134a, is not predicted to perform as well as the HFC-32/-152a mixture. However, the test results indicate that, for mixtures containing more than 35 mass percent of HFC-32, the performance is very similar to that of the HFC-32/-152a mixture. In the heating mode, slightly higher COPs were obtained, and in the cooling mode slightly lower COPs were measured (compared to the HFC-32/-152a mixture at the same HFC-32 mass fractions). The performance improvement over that of HCFC-22 at the compressor speed and capacity equivalent to the HCFC-22 tests ranges from 5% in the high-temperature heating mode to 2% in the low temperature heating mode. Since HFC-134a is not flammable, the HFC-32/-134a mixture exists in a certain range as a nonflammable mixture. Flammability tests will be conducted to determine this range. The test results for the HFC-32/-134a mixture show no problems with respect to extreme pressures or temperatures in the tested composition range.

The achieved COP increases for both mixtures offer enough potential that even cross-flow heat exchange systems (as currently used in household heat pumps) should benefit from the use of these mixtures.

The test results of the mixtures were compared with those of HCFC-22 at the same heating/cooling capacity. The test results for the different refrigerants were achieved with the same test apparatus, meaning that there is no optimization with respect to system pressure drops, compressor efficiency, and other operating factors.

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The complete report, entitled "The Performance of Chlorine-Free Binary Zeotropic Refrigerant Mixtures in a Heat Pump," (Order No. PB92-149814/AS; Cost: $19.00, subject to change) will be available only from:
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