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Project Summary

Miscibility, Solubility, and Viscosity Measurements for R-236ea with Potential Lubricants

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Miscibility, solubility, and viscosity data are needed to determine the suitability of refrigerant/lubricant combinations for use in refrigeration systems. Miscibility data have been obtained for R-236ea and three potential lubricants. The lubricants are a mineral oil, alkylbenzene, and polyol ester, each with a nominal viscosity of 68 cSt. The miscibility tests were performed in a test facility consisting of a series of miniature test cells in a constant temperature bath. The bath temperature was precisely controlled over a temperature range of -50 to 90°C (-58 to 194°F). The test cells are constructed to allow for complete visibility of the refrigerant/lubricant mixtures under all test conditions. Critical solution temperatures obtained from the miscibility data are presented for each refrigerant/lubricant combination.

In addition to miscibility data, both solubility and viscosity data were obtained for R-236ea and the most promising lubricant. These data were obtained for a refrigerant concentration range of 0 to 40 wt % refrigerant over a temperature range of 40 to 120°C. This range of conditions represents the area of interest necessary for the proper design of compressors. For comparison purposes, data were also taken for the existing U.S. Navy shipboard chiller refrigerant and lubricant concentration, namely R-114 and a naphthenic oil.

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This report was developed by the National Risk Management Research Laboratory's Air Pollution Prevention and Control Division, 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 development of acceptable alternative refrigerants requires the identification of compatible lubricants so that refrigeration systems will operate properly. The first requirement of a compatible lubricant is that it be miscible with the refrigerant over the operating temperatures of the system. Refrigeration systems require a miscible refrigerant/lubricant mixture for compressor lubrication, for maximum heat transfer performance in the evaporator, and for proper lubricant return to the compressor.

To satisfy these needs, miscibility data were taken in this study. Obtaining miscibility data requires that one visually observe and record the physical conditions of a refrigerant/lubricant mixture at a specific temperature. The procedure is repeated for desired ranges of temperatures and refrigerant concentrations. Visual inspection of the mixture allows for determination of whether the mixture showed signs of cloudiness, floc or precipitate formation, and the formation of a second liquid phase.

In addition to miscibility data, designers also require accurate and extensive data on the solubility, density, and viscosity of

alternative refrigerant and lubricant mixtures. To support the design of equipment using R-236ea, data on the viscosity, density, and solubility of lubricant/refrigerant mixtures at various pressures and temperatures were also taken in this study.

Scope

The scope consisted of a study of miscibility of various refrigerant/lubricant concentrations and then a study of solubility and viscosity for the lubricants which demonstrated miscibility with R-236ea. Initial miscibility tests were performed on R-236ea/lubricant mixtures for refrigerant concentrations of 25 and 50% by weight. Additional tests were performed for refrigerant concentrations of 75 and 95% if the initial tests showed complete miscibility (that is, miscible over the entire test temperature range).

In addition, solubility and viscosity tests were conducted on R-236ea/ISO68 pentaerythritol ester mixed-acid mixtures and R-114/ISO68 naphthenic mineral oil mixtures, with the latter used for comparison purposes.

Miscibility of R-236ea and Lubricant Mixtures

Miscibility Test Facility

The test facility includes test cells capable of withstanding the high pressures and the extreme temperatures encountered in the study of refrigerant/lubricant mixtures. The facility was designed for the purpose of determining the miscibility characteristics of refrigerant/lubricant mixtures over the temperature range of -50 to 90°C (-58 to 194°F) and for pressures up to 3.5 MPa (500 psia). The test cells are immersed in one of two constant temperature baths and have glass viewports so that the miscibility characteristics of the mixture can be observed and recorded.

These tests were performed by keeping the refrigerant/lubricant mixture visible at all times, by controlling temperatures to ±1°C (±1.8°F), and by agitating the test cells to ensure uniform mixture. Each refrigerant/ lubricant combination was tested for miscibility in 10°C (18°F) increments over the test temperature range of -40 to +90°C (-40 to +194°F).

When a refrigerant/lubricant mixture is miscible, it appears as one homogeneous transparent solution. However, when a refrigerant/lubricant mixture is immiscible, there is either cloudiness (evidence of particles dispersed throughout the mixture) or two liquid phases present in the cell. The presence of two liquid phases was the only form of immiscibility encountered in this study.

Miscibility Results

Results of the measurements of R-236ea in each lubricant are presented in Tables 1-3. For every refrigerant/ lubricant combination investigated, the data set consists of the concentration, temperature, and visual characteristics of the contents of the cell. The tables summarize the data for each lubricant and R-236ea pair. Additional data were taken at 75 and 95% refrigerant for the pentaerythritol ester mixed-acid (ISO68) lubricant since the 25 and 50% mixtures showed complete miscibility.

Based on observation of these tables, the naphthenic mineral oil and the alkylbenzene lubricant would be unsuitable as lubricants in refrigerants and air-conditioning equipment operating with R-236ea because of the lack of miscibility. In contrast, the pentaerythritol ester mixed-acid (ISO68) is completely miscible at all temperatures and is recommended for use with R-236ea.

Solubility, Density, and Viscosity of Refrigerant Lubricant Mixtures

Solubility and Viscosity Test Facility

The test facility utilized in this study can be used for measuring the solubility, viscosity, density, and miscibility of lubricant/ refrigerant mixtures. The test facility consists of a pressure vessel for preparing the refrigerant/lubricant concentrations, a commercially available viscometer, and windows for observation of the contents. The viscosity measurement range is from 1 to 200 cP, but this range may be easily extended. Precise and convenient charging of mixtures with refrigerant compositions ranging from 0 to 100% was provided. Operating temperature and pressure ranges for the test facility are 20°C (70°F) to 150°C (300°F), and 0 to 3.5 MPa (0 to 500 psia), respectively.

Table 1. *Summary of Miscibility Data for R-236EA and the Naphthenic Mineral Oil (ISO68)*

Mass Fraction Refrigerant	*Observations*
0.25	*immiscible from -40 to 90°C*
0.48	*immiscible from -40 to 90°C*

Table 2. *Summary of Miscibility Data for R-236EA and the Alkylbenzene Lubricant (ISO68)*

Mass Fraction Refrigerant	*Observations*
0.22	*miscible from 50 to 90° C immiscible from -40 to 50°C*
0.48	*immiscible from -40 to 90°C*

Table 3. *Summary of Miscibility Data for R-236EA and the Pentaerythritol Ester Mixed-Acid Lubricant (ISO68)*

Mass Fraction Refrigerant	*Observations*
0.21	*miscible throughout temperature range -40 to 90°C*
0.44	*miscible throughout temperature range -40 to 90°C*
0.77	*miscible throughout temperature range -40 to 90°C*
0.95	*miscible throughout temperature range -40 to 90°C*

Solubility and Viscosity Results

Data were collected for R-236ea/ISO68 pentaerythritol ester mixed-acid and R-114/ISO68 naphthenic mineral oil mixtures. These tests provide solubility, density, and viscosity information for temperatures as high as 100°C (212°F) and for pressures up to 1.4 MPa (200 psia). The results are presented as solubility, viscosity, and density charts, as well as in graphical form. The solubility graphs show pressure as a function of temperature, while the viscosity and density graphs show liquid viscosity and liquid density as functions of refrigerant concentration, respectively. Also provided are empirical correlating equations (applicable only over the range of data collected) that allow convenient interpolation of the data.

Conclusions

Miscibility data for the R-236ea in each of the three test lubricants have been collected for refrigerant concentrations of 25 and 50%. The raw data were presented and the results were summarized. Additionally, data for the pentaerythritol ester mixed-acid (ISO68) lubricant were taken at 75 and 95% (by weight) refrigerant. The pentaerythritol ester mixed-acid (ISO68) lubricant was found to be completely miscible over the temperature and concentration ranges tested.

These tests provide solubility, density, and viscosity information for temperatures as high as 100°C (212°F) and for refrigerant mass fractions from 0 to 50%, subject to a maximum pressure limitation of 1.4 MPa (200 psia). The results are presented as solubility, viscosity, and density charts and graphs that give pressure, liquid viscosity, and liquid density as functions of temperature and refrigerant concentration. Empirical correlating equations (applicable only over the range of data collected) that allow convenient interpolation of the data are also presented.

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The complete report, entitled "Miscibility, Solubility, and Viscosity Measurements for R-236ea with Potential Lubricants," (Order No. PB96-183884; Cost: $21.50, subject to change) will be available only from:
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The EPA Project Officer can be contacted at:
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