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Project Summary

Two-Phase Flow of Two HFC Refrigerant Mixtures Through Short-Tube Orifices

W. Vance Payne and Dennis L. O'Neal

An experimental investigation was performed to develop an acceptable flow model for short-tube orifice expansion devices used in heat pumps. The refrigerants investigated were two hydrofluorocarbon (HFC) mixtures considered hydrochlorofluorocarbon (HCFC)-22 replacements: HFC-32/HFC-125/HFC-134a (23/25/52% on a mass percentage basis) and HFC-32/HFC-125 (50/50%). Tests for both refrigerants were performed to generate data at varying operating conditions with 12 short tubes. The tests included both single- and two-phase flow conditions at the inlet of the short tube with different oil concentrations. Experimental data were presented as a function of major operating parameters and short-tube diameter. Based on test results and analysis, a mass flow model was developed. The test results for both refrigerants showed that the mass flow rate was strongly dependent on upstream conditions, but slightly dependent on downstream conditions. The mass flow rate was extremely sensitive to changes in short-tube diameter. The presence of oil below a concentration of approximately 2% would appear to affect the mass flow rate only slightly (less than 5%). It was found that the semi-empirical flow model estimates were in good agreement with laboratory results for both single- and two-phase flow entering the short tubes.

This Project Summary was developed by EPA's 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).

Overview

The need for new refrigerants was established when scientists first realized the ozone depleting effects of chlorine-containing refrigerants. The chlorine in these refrigerants is capable of reaching the upper atmosphere where one chlorine atom can destroy more than 100,000 ozone atoms. Section 608 of the Clean Air Act Amendments of 1990 (CAAA) prohibits the venting of ozone depleting refrigerants as of July 1, 1992. In addition, the CAAA also require the Environmental Protection Agency to develop regulations limiting the emissions of ozone depleting refrigerants. Efforts are currently underway to find replacement refrigerants before the complete phaseout of most of these refrigerants in January 1996.

Much of the effort to replace chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) refrigerants has centered on development of refrigerant mixtures that could replace HCFC-22 used in domestic heat pumps and air conditioners. An important component in these systems is the expansion device. Because of their low cost, short-tube orifices have been chosen by several manufacturers as expansion devices in their systems instead of the more expensive thermal expansion devices. Designing a system with an orifice requires knowledge of the flow characteristics of short-tube orifices. Recent work on orifices has focused on

CFC-12 and HCFC-22. In addition, unpublished data exist on HFC-134a and the effect of lubricants on flow characteristics.

To develop an acceptable flow model, an experimental investigation was performed. The refrigerants investigated were two HFC mixtures considered HCFC-22 replacements: HFC-32/HFC-125/HFC-134a (23/25/52% on a mass percentage basis) and HFC-32/HFC-125 (50/50%). Tests for both refrigerants were performed to generate data at varying operating conditions with 12 short tubes. The tests included both single- and two-phase flow conditions at the inlet of the short tube with different oil concentrations. Experimental data were presented as a function of major operating parameters and short-tube diameter. Based on test results and analysis, a mass flow model was developed.

Short-tube orifices 0.5-1.0 in. (12.7-25.4 mm) long with diameters of 0.0431-0.0763 in. (1.09-1.94 mm) were tested for the two refrigerant mixtures at selected testing conditions found in heat pump or air-conditioner applications. The general trends observed in both refrigerants were consistent with the previous results for HCFC-22. At the same condensing temperature conditions, the mass flow rate of the ternary mixture varied by approximately ±5% (compared to HCFC-22) while the binary refrigerant flow rate averaged 15% higher than that for HCFC-22 due to its higher operating pressures. The maximum percent difference occurred at high levels of subcooling and high qualities (i.e., a high mass percentage of the refrigerant is in vapor form). Generally, flow trends of both refrigerants were also quite similar to each other even though mass flow rate for the binary mixture was approximately 6-15% higher than that for the ternary mixture. The test results for both refrigerants showed that the mass flow rate was strongly dependent on upstream conditions, but slightly dependent on downstream conditions.

The major factor affecting the flow rate was upstream conditions. For both subcooled liquid and two-phase flow entering a short tube, the mass flow rate was directly proportional to upstream pressure. The increase in mass flow rate with upstream pressure was accelerated for high levels of upstream subcooling. The refrigerant flow rate increased in a polynomial fashion with increases in upstream subcooling. The mass flow rate continued dropping inside the saturation region as the quality increased.

The mass flow rate was extremely sensitive to changes in short-tube diameter. The binary mixture showed more effects of short-tube diameter on flow rate than the ternary mixture. While the ternary refrigerant mass flow rate in the subcooling region varied approximately with the square of the orifice diameter, the binary refrigerant mass flow rate tended to vary more closely with diameter raised to the 2.6 power. The effects of diameter varied as a function of upstream subcooling and quality.

The effects of oil contamination on the flow through short tubes were studied by comparing test results for oil contaminated refrigerants with pure refrigerants. The presence of oil below a concentration of approximately 2% would appear to affect the mass flow rate only slightly (less than 5%). For both refrigerants at high levels of subcooling [beyond 10°F (5.6°C)], the addition of oil varied flow rate from the pure case by ±5%. As subcooling decreased, the decrease in mass flow rate (compared to the pure case) followed a linear trend.

To predict the mass flow rate, the semi-empirical models for both single- and two-phase flow at the inlet of the short tubes were developed by empirically correcting the modified orifice equation as a function of normalized forms of operating conditions. Due to the limited range of oil concentrations tested, new coefficients were calculated for each oil concentration tested. It was found that the semi-empirical flow model estimates were in good agreement with laboratory results for both single- and two-phase flow entering the short tubes.

The tests for the effects of oil concentration were performed over a limited range of test conditions and short-tube diameters with one lubricant: RL 32S POE. The polyol ester lubricant was of a single viscosity, 32 centistokes. Oils of higher viscosity could produce different results from that seen here. Also, the miscibility of the oil and refrigerant was not factored into model development. Although this oil was reported to be miscible with the refrigerants under the test conditions, other oils may not show this same behavior. Further study would be required to characterize the effects of oil concentration with short-tube geometry and test conditions.

It was noted earlier that the limitations on the application of the semi-empirical flow model were imposed by the range of the experimental data. Therefore, a more comprehensive semi-empirical model may need to be developed to obtain wider applicability.

W. Vance Payne and Dennis L. O'Neal are with Texas A & M University, College Station, TX 77843.
***Robert V. Hendriks** is the EPA Project Officer (see below).*
The complete report, entitled "Two-Phase Flow of Two HFC Refrigerant Mixtures Through Short-Tube Orifices," (Order No. PB98-142 045; Cost: $36, subject to change) will be available only from
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at
Air Pollution Prevention and Control Division
National Risk Management Research Laboratory
U.S. Environmental Protection Agency

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Center for Environmental Research Information
Cincinnati, OH 45268

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