



ASHRAE WORK STATEMENT
FROM TECHNICAL COMMITTEE 8.5
LIQUID TO REFRIGERANT HEAT EXCHANGERS

TITLE

Experimental Determination of the Effect of Oil on Heat Transfer in Flooded Evaporators with Refrigerants HCFC-123, HFC-134a and HCFC-22

BACKGROUND

ASHRAE Research Project RP-392 has focused on modeling the heat transfer performance of finned and enhanced tubes as used in flooded evaporators. References 1 through 4 are ASHRAE publications resulting from this study. Because of the difficulty of modeling the convective component of low pressure refrigerant evaporation, initial emphasis was placed on comparison of theory with test data from R-11 chillers (1,2). Construction of an evaporation model requires knowledge of both the nucleate boiling and convective modes of heat transfer for a given geometry and fluid. References 3 and 4 cover the nucleate boiling research necessary to model heat transfer without regard for the influence of oil. This influence can be substantial for enhanced nucleation surfaces in pool boiling but may be considerably less in a finned tube bundle with a convective contribution. RP-392 is currently looking at the combination of boiling and convection for pure refrigerant by use of tests on a model flow bank simulating a portion of a flooded evaporator.

RP-392 does not cover the influence of oil as a parameter and, as such, will be mainly applicable to systems of low oil content or to tube geometry not sensitive to the presence of oil. Reference 5 contains data for R-12 and R-22 with oil boiling on a small cluster of finned tubes. References 6 through 8 give data for a variety of single tube geometries boiling with refrigerant and oil. None of these studies accurately simulate a flooded evaporator environment and none test alternate refrigerants with compatible oils. These references do, however, show that the presence of oil can have a major influence on the refrigerant side boiling coefficient. For example, Reference 5 shows about 30 percent increase in heat transfer coefficient due to the foaming action of a low percentage oil for finned tubes while Reference 7 shows an equivalent decrease in performance with an enhanced boiling surface, both at the same oil concentration. Reference 9 gives an in-depth study of one refrigerant and four oils in single tube pool boiling and extends the study with an idealized model of bubble growth in oil layers. This model leads to equations for use in predicting the pool boiling performance of smooth single tubes.

Data on the effect of oil on heat transfer for alternate refrigerants will be used for flooded evaporator design. Such evaporators are typically used in water-cooled liquid chiller systems. Such information will also be valuable in predicting performance of current systems if a changeover to alternate refrigerants is planned. A critical part of such a retrofit is oil selection and prediction of the effect of oil on system performance.

Evaporator heat transfer performance data from this study will appear in the Heat Transfer chapter of the ASHRAE Handbook of Fundamentals and in the Equipment Handbook chapter on evaporators.

JUSTIFICATION

The HVAC industry is facing a phase-out of CFC refrigerants such as R-11 and R-12. Heat transfer data with oil and refrigerants does not now exist for flooded evaporators so design and prediction of performance with alternate refrigerants and new oils is especially difficult.

Evaporator data with alternate refrigerants and oils will provide information to rate flooded evaporators and will provide component information for advanced liquid chilling systems.

The need for data on the influence of oil in flooded evaporators was made known in a forum held at the Denver meeting in 1980. It was judged one of the two most important topics discussed - the other being basic flow modeling as its now being done on RP-392.

OBJECTIVE

The objective of this research is to obtain average shellside boiling coefficients for refrigerants R-123, R-134a and R-22 with compatible oils on finned and enhanced tube surfaces as used in flooded evaporators. The influence of oil type, oil concentration, heat flux, and local vapor quality will be determined. Extension of the analytical modeling methods of RP-392 will be applied to permit prediction of performance for full size flooded evaporators.

SCOPE

This project is designed to study the influence of oil in flooded evaporators with a variety of refrigerants and tube surface geometries. Since one focus of the investigation is alternate refrigerants, it will be important to test with oils compatible with the new refrigerants. The variables of heat flux, mass flux, and vapor quality will cover typical HVAC industry application ranges of interest.

An initial phase of this study will be a literature search to acquaint the investigator with the history of oil-refrigerant boiling research and to clarify the difference between past experiments and actual flooded evaporator geometry as modeled on RP-392.

The research apparatus for this study should consist of the following:

1. Test section consisting of a simulated horizontal bank of 3/4" diameter staggered tubes. Investigator must show that the test section size will simulate effect of oil in a full size bundle. It is desirable that the test section have provision for changing individual tubes or bundle. The most central tube of selected horizontal rows must

have provision for determining the average shellside boiling heat transfer coefficient. The instrumented rows should include the bottom and top row and at least three others equally spaced between these two. The test section will have provision for the introduction and distribution of the refrigerant liquid-gas mixture below the lowest row of tubes. The walls of the test section must be so configured as to prevent bypass of excess amounts of refrigerant along the wall. Finned tubes of 26 fpi and two types of enhanced tubes such as Wolverine Turbo-B and Wieland GEWA-SE will be tested.

The challenge of determining the average shellside boiling coefficient of the selected tubes will require special attention. The investigator must illustrate in detail how the average shellside boiling coefficient of the instrumented tubes will be determined with an accuracy of ± 5 percent.

2. Refrigerant flow loop to provide a source of 35 to 40°F saturated liquid and gas to provide flow into the flooded evaporator test section. Flow of liquid must be sufficient to operate the test section at an evaporative heat loading of up to 2,000 BTU/hr. per linear foot of tubing used. The flow loop will have the capability of providing the inlet quality at values typical of a flooded evaporator operating at 40°F evaporating and 100°F condensing temperature.
3. The oil management system must permit operation with controlled oil concentration in the test section during heat transfer tests. Concentration of oil in the test section should be variable from zero to ten percent by weight and must be measured to an absolute accuracy of plus or minus 20 percent. The test section must have provision for refrigerant-oil sampling at the elevation of each of the instrumented tube rows.

Results for each tube type and each instrumented row will be plotted as a function of the appropriate variable, heat flux, mass flux, local quality, and oil concentration. Also, average bundle heat transfer coefficient will be plotted as a function of bundle heat flux and average oil concentration.

LEVEL OF EFFORT

The estimated total completion time for this project is 24 to 30 months. The level of effort is anticipated to be 12 man-months for a research assistant and 6 man-months for a Principal Investigator, plus secretarial and shop support. Additional funds will be needed for materials and computing time.

DELIVERABLES

- a. Progress and Financial Reports in quadruplicate shall be made to the Society through its Manager of Research at quarterly intervals.

- b. The Principal Investigator shall report in person to the TC at the annual and winter meetings, and answer such questions regarding the research as may arise.
- c. A Final Report shall be prepared and submitted to the Society by the end of the contract period covering complete details of all research carried out on the project. Unless otherwise specified, the final report shall be furnished in the following manner:
 - Six bound copies.
 - One unbound copy, printed on one side only, suitable for reproduction.
 - Two copies on 5 1/4" diskette(s); one in ASCII format and one in the word processing format used to produce the report.
- d. One or more Technical Paper(s) shall be prepared in a form suitable for presentation at a Society meeting. The Paper(s) shall conform to Section 5 of the Society's "Authors' Manual for Technical and Symposium Papers."
- e. A Technical Article suitable for publication in the *ASHRAE JOURNAL*, may be requested by the Society.
- f. A summary which delineates suggested changes to the *ASHRAE Handbook* that were suggested by this research.

All documents shall be prepared using dual units; e.g., rational inch-pound with equivalent SI units shown parenthetically. SI usage shall be in accordance with ASTM Standard E 380-79.

ADDITIONAL INFORMATION FOR BIDDERS

It is expected that those bidding for this project will have a capability for performing shellside evaporation studies of refrigerants. The project budget should not include funds to develop this capability.

Successful bidders will be required to make semi-annual reports to the Research Oversight Committee at both the Winter and Summer ASHRAE meeting.

Proposals

Proposals submitted to ASHRAE for this project should include the following minimum information:

1. Statements describing test facilities, equipment, capabilities, procedures, etc., to be used.

2. Statements indicating experience in conducting research associated with performing heat transfer measurements under conditions of condensation and evaporation.
3. Résumé of the Principal Investigator and others involved in the study.
4. Planned schedule and length of time for the project to be completed.
5. Budget information.

REFERENCES

1. R.L. Webb, K-D Choi and T.R. Apparao, "A Theoretical Model for Prediction of the Heat Load in Flooded Refrigerant Evaporators," ASHRAE Transactions, Vol. 95, Part 1, 1989.
2. R.L. Webb, T.R. Apparao and K-D Choi, "Prediction of the Heat Duty in Flooded Refrigerant Evaporators," ASHRAE Transactions, Vol. 95, Part 1, 1989.
3. R.L. Webb and C. Pais, "Nucleate Pool Boiling Data for Five Refrigerants on Three Tube Geometries," ASHRAE Transactions, Vol. 97, Part 1, 1991.
4. C. Pais and R.L. Webb, "Literature Survey of Pool Boiling on Enhanced Surfaces," ASHRAE Transactions, Vol. 97, Part 1, 1991.
5. P. Heimbach, "Boiling Coefficients of Refrigerant-Oil-Mixtures Outside a Finned-Tube Bundle," Bulletin of the International Institute of Refrigeration - Heat and Mass Transfer in Refrigeration Systems Used in Air conditioning, p. 117, Freudenstadt 1972.
6. S. Chongrungreong and H.J. Sauer, Jr., "Nucleate Boiling Performance of Refrigerants and Refrigerant Oil Mixtures," ASME Journal of Heat Transfer, Vol. 102, No. 4, pp. 701-704, 1980.
7. A.S. Wanniarachchi, P.J. Marto, and J.T. Reilly, "The Effect of Oil Contamination on the Performance of R-114 from a Porous-coated Surface," ASHRAE Transactions, Vol. 92, part 2B, 1986.
8. K.I. Bell, G.F. Hewitt and S.D. Morris, "Nucleate Pool Boiling of Refrigerant/Oil Mixtures," Experimental Heat Transfer, Vol. 1, No. 1, 1987.
9. D.L. Jackman and M.K. Jensen, "Nucleate Pool Boiling of Refrigerant/Oil Mixtures," ASME Paper 82-WA/HT-45, 1982.