Conference reviews

Advances in non-azeotropic mixed refrigerants, ASHRAE Symposia and EPRI Workshop, June 1985, Honolulu, USA

Various benefits of refrigerant mixtures have been recognized for more than a century, yet their application remains limited. Using the rate of publication as a measure, interest in non-azeotropic mixtures has dramatically increased in recent years. Several efforts have been undertaken, within the last decade, to develop analytical models. Moreover, a number of researchers have begun to measure and develop techniques to predict essential thermodynamic and thermophysical data. Premature efforts to commercialize specific mixtures have been attempted without success, leading some people to question whether non-azeotropic mixtures are a solution looking for a problem. The majority view remains more optimistic.

The term 'non-azeotropic mixed refrigerants' refers to fluids consisting of multiple components of different volatilities that change composition as they evaporate (boil) or condense. The description non-azeotropic is derived from the Greek words *zeo* (to boil) and *tropos* (to change), preceded by two cancelling negation prefixes, the Latin antecedent, *a*, and the English, non. The double negative results from the chronological acceptance of azeotropic mixtures (refrigerant compositions that act as single components) prior to attention to non-azeotropes. Purists sometimes revert to zeotropic as a synonym to non-azeotropic. Not surprisingly, some researchers have adopted acronyms (e.g. NARBs for non-azeotropic refrigerant blends).

Experts agree that non-azeotropic mixtures offer unique characteristics as refrigerants. These features have been investigated in the hope of achieving improvements in efficiency, capacity, and by composition management capacity modulation in heat pump and refrigeration systems. Additional benefits investigated include system optimization, when desired refrigerant properties fall between discrete choices afforded by single-component and azeotropic refrigerants, and split-temperature evaporator or condenser functions (e.g. refrigerator freezer or space-water heating applications).

An update on research and development of non-azeotropic mixture refrigerants was included in the two symposia. These sessions, comprising eight papers, were co-sponsored by ASHRAE Technical Committees 3.1, Refrigerants and Brines; 7.6, Unitary Air Conditioners and Heat Pumps; and 9.4, Applied Heat Pump and Heat Recovery Systems. The papers included:

The ABCs of NARBs (non-azeotropic refrigerant blends) by T. Atwood.
The characteristics of fluid mixtures and their utilization in vapour compression refrigeration systems by U. W. Schulz.
Two refrigerant mixtures and the hard sphere fluid by G. Morrison and M. McLinden.
Prediction of refrigerant ternary mixture properties using the Redlich-Kwong-Soave equation of state by E. G. Wright.
Heat transfer of non-azeotropic mixtures in a falling film evaporator by T. Berntsson, K. M. Berntsson and H. Panholzer.
Condensing coefficients when using refrigerant mixtures by W. F. Stoecker and E. Kornota.
Simulation of a heat pump operating with a non-azeotropic mixture by P. A. Domanski and D. A. Didion.
Theoretical and experimental investigations of advantageous refrigerant mixture applications by H. Kruse, M. Kuever, U. Quast, M. Schroeder and B. Upmeier.

A workshop on research and development of non-azeotropic mixture refrigerants for heat pumps, conducted after the ASHRAE meeting, was organized and sponsored by the Electric Power Research Institute (EPRI) with the cooperation of the Hawaiian Electric Company and the National Bureau of Standards. The intent of this workshop was to:

1. assess the status and potential of non-azeotropic mixture refrigerants;
2. identify research and development needs associated with such refrigerants and the equipment in which they would be used; and
3. encourage international cooperation and coordination in the conduct of such research.

Participation in the workshop was by invitation extended to the authors of the symposia papers, internationally recognized researchers in non-azeotropic mixtures, representatives of both refrigerant producers and heat pump manufacturers, utility representatives, and others selected from research organizations.

The following specific research and development topics were proposed for the near term:

1. completion and validation of current efforts to develop equations of state for binary and ternary mixtures;
2. integration of these equations of state into simulation models to enable development studies;
3. theoretical cycle analyses, including hybrid absorption compression cycles, to identify opportunities;
4. screening of non-azeotropic mixture candidate fluids suitable for vapour-compression cycles;
5. collection of property data as needed for the above; sensitivity analyses based on these data to determine precision requirements for future data collection;
6. laboratory tests of new concepts and fluids as they emerge (considerable attention has already focused on R22/R114, R12/R114, and R13B1/152a mixtures; R23/R12 and R23/R22 are possible candidates warranting evaluation for increased capacity for low

evaporator temperature applications; and
7. impact study identifying likely applications and quantifying the increase in performance as well as the return to the manufacturer and consumer.

Several conclusions were derived from the workshop discussions:

1. Non-azeotropic mixture refrigerants are not ready for widespread commercialization. Demonstration of their practical utility will require at least several more years.
2. Research, both basic and applied, is needed to identify and establish the viability of specific non-azeotropic mixtures and associated cycle modifications. This research must develop the necessary data, design tools and thermodynamic impact of selected cycles for specific applications.
3. Because of opportunities to exploit the advantages of gliding temperature evaporation and/or condensation (e.g. a Lorentz rather than a Carnot cycle), non-azeotropic mixture refrigerants may initially be found more attractive in heat pumps and refrigeration systems requiring high temperature glide. Such systems may include heat pump water heaters, community heat pump systems, industrial heat pumps and multi-stage refrigeration systems.
4. Although nearly 100 years have passed since the use of refrigerant mixtures was first proposed, the full potential of non-azeotropic mixtures in refrigeration systems is still relatively unexplored. Opportunities for identification and development of appropriate mixtures and associated cycles exist, and more intensive research and development are needed, and believed justified, to evaluate their ultimate potential.
5. To date, test results with mixtures have shown only modest improvements over single-component refrigerants. It is felt that this has been due to inadequate design changes to the hardware systems to fully capitalize on mixture attributes.
6. Commercialization of mixtures introduces a number of complexities in all stages of industry practice from equipment design to field services presenting additional cost elements beyond those directly attributable to the refrigerants themselves.

This workshop provided a useful forum for examination of non-azeotropic mixture refrigerant status. Moreover, this meeting afforded international leaders in this field an opportunity to meet and establish a basis for further communication and cooperation.

The eight ASHRAE Symposia papers, resulting discussion, and a summary of the EPRI Workshop are available in a bound volume entitled 'Advances in Nonazeotropic Mixture Refrigerants for Heat Pumps' (TDB-54) from ASHRAE, 1791 Tullie Circle NE, Atlanta, GA 30329, USA. The cost is US$15 for ASHRAE members and US$30 for others.

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Recent advances in refrigerated storage and transport, Meeting of Section D of the IIR, 17–21 November 1985, Orlando, USA*

Gustav Lorentzen, IIR President of the General Conference, was a speaker at the opening plenary session which was chaired by Bob Pedersen, President of the International Frozen Food Association. Other IIR dignitaries who also spoke were Per Oskar Persson, Head of Second D, Andre Gac, Director of the IIR and Fred Kohloss, President-elect of ASHRAE. Two hundred and ten delegates from 23 countries attended the meeting and listened to 41 papers, as well as participating in technical tours of Citrus World and the Publix processing facility and distribution centre in Lakeland.

A pragmatic account of the design and operation of the world's first air-supported refrigerated warehouse was presented by R. Hampson of Maritime Terminal. The use of winter ice to supplement food refrigeration and a system, employing a pressure vessel containing carbon dioxide at its triple point, designed to reduce peak electricity demand were also presented.

Two papers, presented by R. D. Heap of the Shipowners' Refrigerated Cargo Research Association, Cambridge, dealt with temperature distribution in ISO containers. Under operating conditions some product temperatures were often found to be warmer than the warmest air temperature (air returning to the evaporator), while the effect of age on polyurethane insulation was found to increase heat leakage by 3 5% per annum.

Two authors (Grinzato and Panozzo) from the Instituto per la Tecnica del Freddo in Padua, Italy, presented some measurements designed to test insulated vehicles by infra-red thermography when seeking certification of insulated vehicles under the ATP agreement ('Agreement on the International Carriage of Perishable Foodstuffs and on the Special Equipment to be

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