TITLE:	Identification and Experimental Database for Binary and Multicomponent Mixtures with Potential for Increasing Overall Cycle Efficiency
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ABSTRACT

OBJECTIVE

One of the methods that has been considered for an improvement of power plant efficiency, is to use a binary mixture as the working fluid in a thermodynamic cycle. The "Kalina cycle" has been suggested as a replacement for the Rankine cycle, and has been shown to provide a significant increase in cycle efficiency. Most work on the Kalina cycle however, has assumed the use of an ammonia - water binary fluid. The objective of the present investigation, is to explore the use of alternative mixtures in place of ammonia-water and to develop a database for boiling heat transfer coefficients that can be used in heat exchanger design. Of particular interest are mixture systems that might be suitable for low temperature heat recovery from waste gases.

Specific tasks for this investigation are:

(1) Review existing databases for binary and ternary mixture boiling data and identify mixture systems as potential working fluids in a Kalina cycle.

(2) Experimentally obtain boiling heat transfer coefficients for those binary and ternary mix-

tures identified as having good potential as being suitable working fluids in a Kalina cycle for both plain and enhanced boiling surfaces.

(3) Develop a conceptual design of a heat exchanger for removing heat from shell-side waste gas to a binary or ternary tube-side mixture.

ACCOMPLISHMENTS TO DATE

An experimental facility, used previously in the development of a multicomponent mixture boiling database, was refurbished and a new plain surface boiling tube was installed. To insure that results with the new boiling surface were consistent with data previously obtained in the facility, the new boiling surface was with a used to produce pool boiling heat transfer coefficients for methanol-water mixtures. (The data was found to be in agreement with previous work.) A series of ethylene-glycol mixtures were then boiled in the facility, and heat transfer coefficients were obtained as functions of mixture composition. Ethylene glycol - water mixtures were selected based on a review of binary and multicomponent mixture systems. The review focussed on vapor-liquid equilibrium data, and was performed with the objective of identifying binary and ternary mixture systems with wide-boiling ranges and saturation temperatures in the range of 200 to 300 ^{o}C. Mixtures were eliminated from consideration if they were especially toxic or flammable. The ethylene glycol - water system was selected for the initial phase of this investigation because of its wide boiling range, and availability.

Initial work has used a plain surface boiling tube. A GEWA Turbo-B tube, which has structured surface to enhance evaporation was obtained and used to constuct a test section. This test section, scheduled for completion in early June, will be used to generate heat transfer coefficients for mixtures from an enhanced boiling surface.

SIGNIFICANCE TO FOSSIL ENERGY PROGRAMS

Successful development of an alternative to the ammonia-water Kalina cycle will provide new possibilities for improving the cycle efficiency of a fossil fired unit. Identification of a binary mixture, with a wide boiling range that can be adjusted to various temperature heat sources may allow its use not only as the working fluid in the primary cycle, but also in bottoming cycles where regenerative heat exchangers must often operate with relatively small temperature differences between fluid streams. The enhanced boiling surface provides verification and data to design systems that operate with very low wall superheats for evaporation.

Identification of an appropriate third component that can be added to the binary cycle offers the possibility of controlling the local boiling temperature in a heat exchanger and increasing the efficiency by maintaining a temperature difference sufficient to continue boiling in the working fluid as the gas side (heat source) temperature decreases. This feature may provide increases in efficiency beyond those realized by the basic binary Kalina cycle.

PLANS FOR COMING YEAR

Between the present writing and end of 2000, the experimental program will develop heat transfer coefficients for a ternary mixture system (where ethylene glycol and water will be two of the components), and at least one other binary mixture system. Results from these tests will be used to (a) develop a conceptual design for a heat exchanger for extracting waste heat from a flue gas stream by a binary (or ternary) mixture, and (b) access the increase in cycle efficiency that can be obtained by use of the "new" mixture in a Kalina cycle relative to a Rankine cycle.

ARTICLES, PRESENTATIONS, and STUDENT SUPPORT

Journal articles based on the present investigation will be written later in the year as more results are produced. Articles related to this work are:

Journal Articles

Bajorek, S. M., and Lloyd, J. R., "New Model for Nucleate Pool Boiling in Binary and Ternary Mixtures," (in preparation for ASME J. Heat Transfer).

Conference Presentations

Bajorek, S.M., Yeh, H.C., McNamee, K., and Hochreiter, L.E., " Two-Phase, Three-Dimensional Thermal-Hydraulic Analysis of a Waste Heat Boiler", Proc. 34th National Heat Transfer Conf., Pittsburgh PA, August 20-23, 2000.

The PI is also the organizer and chairperson for the Session 27 "Advances in Static and Dynamic Energy Systems " at the 34th National Heat Transfer Conference.

Students Supported Under This Grant

Jay Schnelle, undergraduate (now M.S. graduate) student in Mechanical Engineering
Aaron Burger, undergraduate student in Mechanical Engineering