EXECUTIVE SUMMARY

FINAL REPORT ARTI-21CR/611-20021-01
FLAT-TUBE HEAT EXHANGERS IN AIR-CONDITIONING AND REFRIGERATION APPLICATIONS – PHASE II

A study of flat-tube heat exchangers and their air-side thermal-hydraulic performance under dry-, wet-, and frosted-surface conditions is reported. This multi-pronged research project includes fundamental and applied work. The six chapters and eight appendices present findings that can be generally classified into the following areas, with the following contributions:

- Analysis, modeling and interpretation of air-side thermal-hydraulic data for flat-tube heat exchangers under wet- and frosted-surface conditions.
  - We provide a new solution, and mathematical proofs, for conduction in a two-dimensional slab on a one-dimensional fin. The solution is simplified to model-frosted fin performance for flat-tube heat exchangers.
  - We provide an analytically rigorous development of a new data-interpretation scheme, based on an intuitive extension of a *UA*-LMTD approach. The development includes a critical assessment and comparison to extant methods.
- Studies of the effects of fin design parameters on the performance of plain, wavy, strip, and louvered fins for flat-tube heat exchangers.
  - Analysis and experiments from the literature are used and extended to assess fin design parameters and make design recommendations for plain, wavy, strip and louvered fins.
  - New flow visualization is reported to elucidate the role of boundary layer effects on flow through louvered fins, providing guidance toward optimal fin design.
  - New convective data are obtained using naphthalene sublimation to explore the high-Reynolds-number behavior of offset-strip fin, flat-tube heat exchangers.
- Studies of the retention and drainage of water from the air-side surface of flat-tube heat exchangers with plain, wavy, strip, and louvered fins.
  - A new dynamic dip test method is validated and used to obtain drainage data from plain, wavy, strip, and louvered-fin heat exchangers. An analytical model of drainage successfully predicts the magnitude and trends in these transient data.
  - Wind-tunnel experiments are used to quantify the *in situ* retention of condensate on these heat exchangers over a range of operating condition. Ancillary experiments are conducted to examine off-cycle retention.
- Characterization of the thermal-hydraulic performance of plain, wavy, strip, and louvered-fin, flat-tube heat exchangers under dry-, wet-, and frosted-surface conditions.
  - Extensive experiments are conducted to quantify the frictional and heat-transfer behavior of plain-, wavy-, strip-, and louvered-fin heat exchangers. Data for each heat exchanger are correlated, and the physical mechanisms affecting performance are discussed.
  - Wet-surface performance is characterized in terms of *multipliers*, developed for the Darcy friction factor, f, and the Colburn j-factor for each heat exchanger.
  - Frosted-surface behavior is characterized in terms of frost distribution, accumulation, pressure drop, and thermal resistance.
  - The performance of flat-tube heat exchangers is compared to that of round-tube heat exchangers using a Second-Law-based analysis.
  - We provide a new correlation that covers a broader parameter space more accurately than any existing louvered-fin performance prediction.