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C3Or2B-06: Two-phase flow patterns for zeotropic mixtures of tetrafluoromethane/ethane in a horizontal smooth tube

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With the rapid development of life science and the increasing demand of clean energy, refrigeration technology in the temperature range from 80 to 230K is widely required. Mixed-refrigerant Joule-Thomson Refrigeration (MJTR) systems have distinct advantages in this temperature range: i.e., simple structure, low cost, convenient cooling power adjustability, and high reliability due to non-moving parts at low temperature parts. The working fluids of MJTR are typically zeotropic mixtures, which are generally mixed by several components. Tetrafluoromethane (R14) and ethane (R170) are essential components of mixed-refrigerants. Regarding to the real performance of MJTR systems, the exergy loss in heat exchanger is a crucial part for MJTR (always greater than 20%). Heat transfer and pressure drop for two-phase flow are closely related to corresponding flow patterns.

In this paper, an experimental investigation on adiabatic and condensation two-phase flow patterns for four R14/R170 mixtures in a horizontal smooth tube with inner diameter of 4 mm was presented. Experiments were carried out at mass fluxes from 100 to 350 kg m-2 s-1, saturation pressures from 1.5 to 2.5 MPa and heat fluxes from 7.8 to 38.4 kW m-2 over the entire range of vapor quality. Six flow patterns of wavy-stratified, slug, plug, transition, wavy-annular and smooth-annular flow were observed. The influences of concentration, mass flux, saturation pressure and heat flux on flow pattern transitions were analyzed and discussed. It was found that transitions between different flow patterns varies regularly with the temperature-glide of the zeotropic mixtures. In addition, the observed adiabatic flow patterns were compared with six well-known flow pattern maps, none of them can predict all the transition lines accurately. Finally, an improved transition equation of intermittent/annular flow was proposed.

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