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Effect of Loop Diameter, Height and Insulation on a High Temperature CO2 Based Natural Circulation Loop

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Abstract : Natural circulation loops (NCLs) are buoyancy driven flow systems without any moving components. NCLs have vast applications in geothermal, solar and nuclear power industry where reliability and safety are of foremost concern. Due to certain favorable thermophysical properties, especially near supercritical regions, carbon dioxide can be considered as an ideal loop fluid in many applications. In the present work, a high temperature NCL that uses supercritical carbon dioxide as loop fluid is analysed. The effects of relevant design and operating variables on loop performance are studied. The system operating under steady state is modelled taking into account the axial conduction through loop fluid and loop wall, and heat transfer with surroundings. The heat source is considered to be a heater with controlled heat flux and heat sink is modelled as an end heat exchanger with water as the external cold fluid. The governing equations for mass, momentum and energy conservation are normalized and are solved numerically using finite volume method. Results are obtained for a loop pressure of 90 bar with the power input varying from 0.5 kW to 6.0 kW. The numerical results are validated against the experimental results reported in the literature in terms of the modified Grashof number (Gr_m) and Reynolds number (Re). Based on the results, buoyancy and friction dominated regions are identified for a given loop. Parametric analysis has been done to show the effect of loop diameter, loop height, ambient temperature and insulation. The results show that for the high temperature loop, heat loss to surroundings affects the loop performance significantly. Hence this conjugate heat transfer between the loop and surroundings has to be considered in the analysis of high temperature NCLs.

Keywords : conjugate heat transfer, heat loss, natural circulation loop, supercritical carbon dioxide
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