# MODELING OF FLOW AND HEAT TRANSFER FOR FLUIDS AT SUPERCRITICAL CONDITIONS

By

Tara Gallaway

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Examining Committee:

Michael Z. Podowski, Thesis Adviser
Steven P. Antal, Member
Kenneth Jansen, Member
Bimal Malaviya, Member
Donald Drew, Member

Rensselaer Polytechnic Institute
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# ABSTRACT

The Supercritical Water Reactor (SCWR) has been proposed as one of the six Generation IV reactor design concepts under consideration. The key feature of the SCWR is that water at supercritical pressures is used as the reactor coolant. At supercritical pressures, the working fluid does not undergo phase change as it is heated, but rather the fluid properties experience dramatic variations throughout what is known as the pseudo-critical region. Highly nonuniform temperature and fluid property distributions are expected in the reactor core, which will have a significant impact on turbulence and heat transfer as well as stability limits for future SCWRs. The goal of this work is to understand and predict the effects of these fluid property variations on turbulence and heat transfer throughout the reactor core and to predict the potential onset of dynamic instabilities.

$CO_2$ at supercritical conditions is included in the current study due in some part to its use as a viable simulant fluid in place of water for experimental studies. The use of $CO_2$ at supercritical conditions as a reactor coolant has also gained popularity in recent years. Spline-type property models have been developed for both water and $CO_2$ at supercritical pressures in order to include the property variations into a numerical solver. Turbulence and heat transfer models for fluids at supercritical conditions have been developed and implemented into the NPHASE-CMFD computer code. The results of predictions using the proposed models have been compared to experimental data from the Korea Atomic Energy Research Institute (KAERI) for various heat transfer regimes. While no model is without some deficiency, the Chien Low-Reynolds $k - \epsilon$ model performs best at predicting the experimental data.

A stability model has been developed and is presented in this dissertation as well. This model utilizes three different solution methods and tests the effects of inlet temperature, mass flow rate, local loss coefficients, radial property variations, heat flux distribution, and thermal storage in the fuel rods. This model has been benchmarked using a rigorous analytic solution and has been compared to other

studies addressing stability concerns for the SCWR. The conclusions drawn from the parametric study using the new stability model have been used to comment on the proposed SCWR design. It has been found that at normal operating conditions and with an inlet loss coefficient of 10, the SCWR falls well within the stability limits predicted by the developed code.