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Thermohydraulic and safety analysis on China advanced research reactor under station blackout accident

Wenxi Tian [a], Suizheng Qiu [a,*], Guanghui Su [a], Dounan Jia [a], Xingmin Liu [b], Jianwei Zhang [b]

[a] Department of Nuclear Energy Engineering, Xi'an Jiaotong University, 710049, Xi'an, PR China
[b] China Institute on Atomic Energy, 100024, Beijing, PR China

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Abstract

A thermohydraulic and safety analysis code-TSACC has been developed using Fortran90 language to evaluate the transient thermohydraulic behavior of the China advanced research reactor (CARR) under station blackout accident (SBA). For the development of TSACC, a series of corresponding mathematical and physical models were applied. Point reactor neutron kinetics model was adopted for solving the reactor power. All possible flow and heat transfer conditions under station blackout accident were considered and the optional correlations were supplied. The usual finite difference method was abandoned and the integral technique was adopted to evaluate the temperature field of the plate type fuel elements. A new simple and convenient equation was proposed for the resolution of the transient behaviors of the main pump instead of the complicated four-quadrant model. Gear method and Adams method were adopted alternately for a better solution to the stiff differential equations describing the dynamic behavior of the CARR. The computational result of TSACC showed the adequacy of the safety margin of CARR under SBA. For the purpose of Verification and Validation (V&V), the simulated results of TSACC were compared with those of RELAP5/MOD3 and a good agreement was obtained. The adoption of modular programming techniques enables TASCC to be applied to other reactors by easily modifying the corresponding function modules.

1. Introduction

The CARR being built at the China Institute of Atomic Energy (CIAE) in Beijing China, is a tank-in-pool, inversed neutron-trap-type, multi-purpose research reactor. Slightly pressurized light water is used as the primary coolant and moderator, heavy water as the reflector. The systematic diagram of the CARR is shown in Fig. 1. The reactor body is immersed in a pool of 16 m in depth and the core is located 12 m below the pool water surface. The core is about 0.85 m in height and 0.45 m in diameter.

The operation modes of CARR are various and complicated. Under normal full power working condition, the coolant is pumped to flow through the cold leg, the flow guiding tank, then downward through reactor core, the decay tank, the hot leg, the heat exchanger and finally recirculates to the main pump. Under the emergency core cooling (ECC) condition, the pool water is forced into the main cold pipe, then flows downward through the core and returns to the pool from the filter fixed on the top the decay box. During the cold shutdown phase, the natural circulation valve (NCV) fixed on the top the guiding tank is open. The pool water enters the decay box from the filter, up flows through the active core, the guiding tank, and returns to the pool through the NCV. The residual power is removed by natural circulation (NC) of the pool water.

The objective of this present study is to analyze the thermohydraulic behaviors of CARR under SBA case. For this purpose, an analysis code has been developed using Fortran90 language. At the same time, the computational results by TSACC were compared with those of the RELAP5/MOD3 for the purpose of V&V.

* Corresponding author.
E-mail addresses: wxtian@mailst.xjtu.edu.cn (W. Tian), szqiu@mail.xjtu.edu.cn (S. Qiu).

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Nomenclature

C_p	specific heat, J/(kg K)
D_e	equivalent diameter, m
f	friction factor, dimensionless
g	gravity acceleration, m/s^2
Gr	Grashof number, dimensionless
h	heat transfer coefficient (W/m^2 K)
H_p	pump head, m
I	inertia of the rotor, kg m^2
K	thermal conductivity, (W/m K)
Nu	Nusselt number, dimensionless
Pr	Prandtl number, dimensionless
q	heat flux, W/m^2
R	heat conduction resistance (K m^2/W)
Re	Reynolds number, dimensionless
T	temperature, K
ΔT	temperature difference, K
V	velocity m/s
W	mass flow rate, Kg/s

Greek symbols

ε	roughness, m
β	expansion coefficient
ρ	density, Kg/m^3
ω	rotation speed, rps
η	pump running efficiency

Superscript/Subscript

b	main fluid flow
c	clad
ci	inside surface of the clad
co	outside surface of the clad
f	coolant
o	normal working condition
s	saturated
u	fuel
w	wall

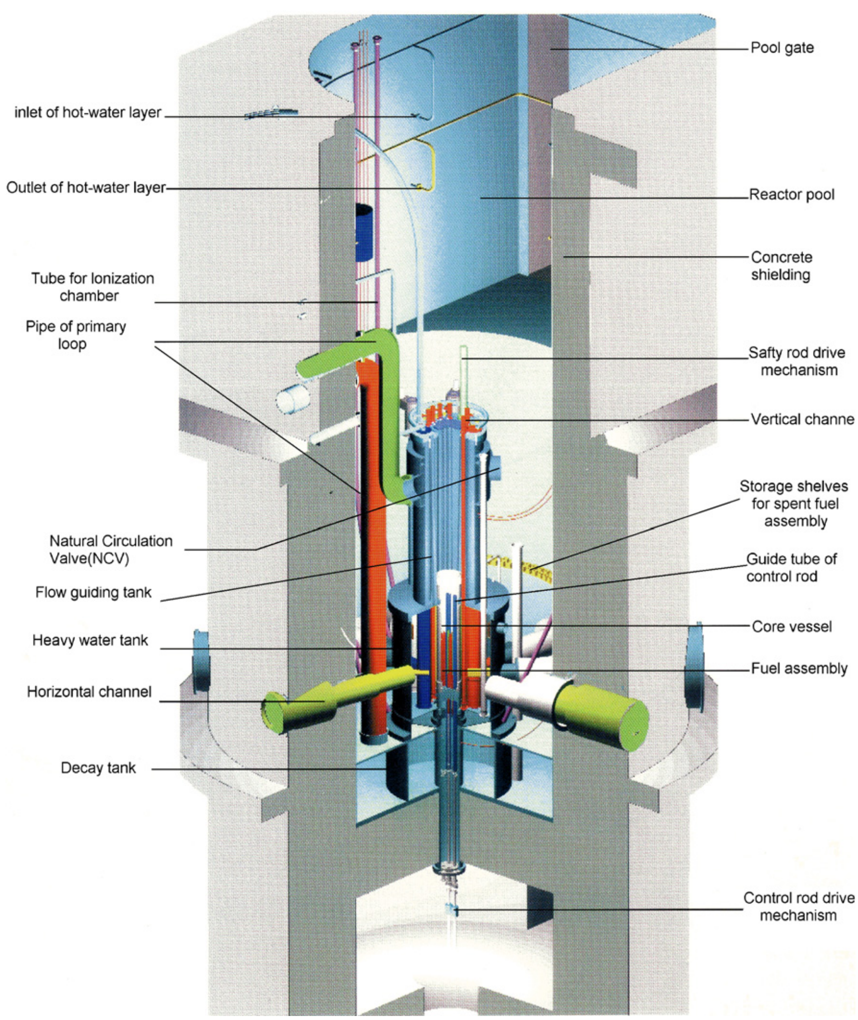

Fig. 1. Schematic diagram of the CARR.