

CRITICALITY ACCIDENT CODE

IDENTIFICATION SHEETS

CHATEAU

GENERAL INFORMATIONS (1)

Designation of the code	CHATEAU	
Summary (General purpose)	Models the transient criticality of UO ₂ fuel rods array in an open cylindrical shipping cask, so that the water is able to expand (thermal dilatation of water, void effect of vapor bubbles). The transient criticality arise from water penetration in a dry cask when criticality is reached for a given water height in the cask and the water continues to rise. The fuel rods array is divided with axial meshes and radial regions. The energy deposited in each axial mesh and radial region is calculated based on the power profile (assuming fundamental neutronic mode), coupled with the central power calculated with the point kinetic equation. In each axial mesh and radial region, there is a representative fuel rod cell (fuel + clad + water layer). Heat transfer between the fuel, the clad and the water is calculated by heat conduction equation within a radial meshing and accounting for nucleate boiling.	
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Status of code	First version released (date and reference number)	CHATEAU (1984).
	Current version released (date and reference number)	CHATEAU V2 (2000).
	Current development	
	Language program / Modularity	Fortran 90.
	Operating system (windows, linux, unix,...)	Windows.

	Software requirements (fortran compiler,...)	Fortran 90 compiler.
	Portability (PC / Workstation/Supercomputer))	PC. Workstation.
	Availability / web site (executable, source files, data files, ...)	
	Typical running time (for one calculation)	10 s → 10 min.
Comments		

GENERAL INFORMATIONS (2)

User Interface	Input data file for a CHATEAU run is built manually.
<p>Calculated Standard Outputs / and Units</p> <p>Time step output : power, energy, pressure, temperature, ...</p> <p>Main characteristics : first peak power, total energy release, maximum pressure, temperature, time of boiling,...</p>	<p>Peak fuel and clad temperature at a position (axial mesh and radial region) given by user in input data file.</p> <p>Time, central volumetric power, total power, central volumetric energy released, total energy released.</p> <p>Fuel temperature, clad temperature, water temperature at a position (axial mesh and radial region) given by user in input data file.</p> <p>Reactivity inserted, reactivity feedback (doppler, water thermal dilatation, void effect of vapor bubbles), total reactivity of the system, mean void rate, void rate at a position (axial mesh and radial region) given by user in input data file.</p> <p>First volumetric and total peak power, secondary volumetric and total peak powers.</p>
Graphic editor	
<p>Quality Assurance (data and code package)</p>	<p>Description of code modeling (report). Code production (report). Comparison with two reactor SPERT 3 E experiments and RB0 accident (report).</p>
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Comments	

GENERAL DESCRIPTION

(3)

Fissile Materials	Physical Forms				
	Solution <small>(nitrate, fluorure, sulfate,...)</small>	Powder <small>(dry, wetted,...)</small>	Metal <small>(dry, wetted,...)</small>	Fuel rods	...
Uranium <small>(isotopic content %)</small>				UO ₂ oxide. U metal. Any enrichment.	
Plutonium <small>(isotopic content %)</small>					
Mixed Plutonium / Uranium <small>(isotopic content %)</small>					
Geometry description <small>Cylindrical, spherical,... Space Dimension (1D, 2D,...), Meshing / Region, Finite Element Method, ...</small>				<p>Axial meshing and radial regions for power profile.</p> <p>In each axial mesh and radial region, there is a representative fuel rod cell (fuel + clad + water layer).</p> <p>There is a radial meshing in the representative fuel rod cell (fuel + clad + water layer) to solve the heat conduction equation.</p>	
Comments					

DESCRIPTION OF MODELS USED

Neutronic Power / Kinetics	Point kinetic equation, transport or diffusion theory	Point kinetic equation.
Reactivity and Reactivity feedback	Transport or diffusion theory, mathematical formulas, input or calculated data (reactivity insertion, temperature coefficients : Doppler, dilatation,...)	<p>Reactivity is inserted by polynomial formula with coefficients and water filling rate given by user in input data file.</p> <p>Reactivity can be inserted by “reactivity against water height” data given by user in input data file.</p> <p>Temperature feedback coefficients for doppler, thermal water dilatation and void effect of vapor bubbles are given by user in input data file.</p>
Thermal – hydraulics Hydrodynamics	Thermal (heat conduction, convection, boiling...) / Meshing and region	<p>Axial meshing and radial regions for power profile.</p> <p>Heat conduction equation is solved for a representative fuel cell (fuel + clad + water layer) in each axial mesh and radial region.</p> <p>There is a radial meshing in the fuel, clad and water layer to solve the heat conduction equation.</p> <p>Heat transfer between clad and water is natural convection.</p> <p>The nucleate boiling is taken into account with ROHSENOW correlation for heat transfer between clad and water.</p>
	Multi-phase flow	The vapor bubble velocity with ZUBER correlation is taken into account for calculating the void rate.
	Fluid motion / Meshing and region	
	Pressure modeling	

Radiolysis (for solutions)	Radiolytic formation and migration models	
Data libraries : External or/and Internal (constants, calculated / tabulated, experimental, bibliography, ...) ...	Neutronics – kinetics (cross sections libraries, k_{∞} , neutron lifetime, delayed neutrons)	Neutron lifetime and delayed neutron constants are given by user in input data file.
	Thermal and hydrodynamics (heat capacity, conductivity,...)	Heat capacity, density, conductivity, heat transfer coefficients are calculated by internal formula.
	Radiolysis (yield, threshold formation, velocity,...)	

VALIDATION BASE OF THE CODE

Summary of the main assumptions in the code	The power is calculated with point kinetic equation and a power profile assuming fundamental neutronic mode. The reactivity feedback takes into account the water expansion (thermal dilatation of water, void effect of water vapor bubbles), doppler effect.	
Limitations to the use of the code	Uranium oxide, uranium metal. Heat transfer between clad and water is natural convection. There is no heat transfer between axial meshes and radial regions.	
Experimental benchmarks (reactor : fissile media, geometry, reactivity insertion, duration,...)	Reactor SPERT 3 E (USA) experiments n°18 and n°42 (1969) with UO ₂ (4.7% en ²³⁵ U) fuel rods moderated by water.	
Past Accidents (simulations)	RB0 (VINCA Institute, YUGOSLAVIA 1958) with natural U metal fuel rods moderated by heavy water.	
Codes comparison	Validation of the modeling with standard codes (neutronics, thermal,...)	
	Accidents code	Comparison with "SARTEMP" a similar code of "UK/AEA".
Domain of validation and level of confidence		

References

(reports, communications, publications,...)

- C. BONHOMME
"CODE CHATEAU"
CEA/IPSN/DERS/SRSC n°84.35 (1984)
- C. BONHOMME , F. BARBRY
"Estimation des phénomènes régissant une hypothétique surcriticalité accidentelle survenant lors de la manipulation ou du transport d'éléments combustibles irradiés REP"
CEA/IPSN/DERS/SRSC n°85.68 (1987)
- P. HAGUE , D. J. MATHER , P.M. SHAW
F. BARBRY, C. BONHOMME
"Theoretical studies of the transient criticality of irradiated fuel elements in a transport flask"
Proceedings of the ISCS'87
- P. GIROUD
"Accident de criticité en milieu hétérogène – Guide d'utilisation et mise en production du code CHATEAU version 2"
CEA/IPSN/DPEA/SRSC n°00.11 (2000)
- P. GIROUD
"Comparaison du code CHATEAU aux résultats des essais réalisés sur le réacteur SPERT 3 E et aux données de l'accident de criticité de 1958 sur le réacteur RB-0 de l'Institut VINCA (YOUUGOSLAVIE)"
CEA/IPSN/DPEA/SRSC n°01.07 (2001)