

IMPROVEMENTS IN THE DECAY HEAT MODEL IN THE THERMALHYDRAULIC CODE TRAC-BF1

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ABSTRACT

In the nuclear safety analysis, it is very important to be able to simulate the different transients that can occur in a nuclear power plant with a very high accuracy. The transient simulations involve both neutronic and thermalhydraulic calculations. One of the most used codes in nuclear industry is the TRAC-BF1 code, which has already been proved against different transients in many nuclear power plants.

Whether nuclear reactor system codes perform power calculations, the prompt power and the decay heat energy must be obtained. The first power value comes from the neutrons fission reactions while the second one comes from the decay of the fission products that appear inside the reactor core as it is burnt. The total decay heat is obtained solving the system of ODE equations which takes into account the generated heat by the decay of the fission products that appear in the reactor core. Equation 1 describes the system of equations where i represents the number of fissionable nuclides (from 1 to 4) and j the number of groups per nuclide (23 groups per nuclide).

$$\frac{dH_{ij}}{dt} = -\lambda_{ij}^H H_{ij} + E_{ij} \frac{P_i}{Q_i}$$

The implemented models in TRAC-BF1 code for the decay heat calculations are based on the 1971 ANS standard by default and the 1979 ANS standard selected by the user. With the entry into force of the 1994 ANS standard, and the later review 2005 ANS, the TRAC-BF1 models are completely obsolete, therefore a revision of the older models and the implementation of ANSI/ANS-5.1-2005 in the code are required.

The present paper describes a comparative study of decay heat models implemented in the different thermalhydraulic codes, the analytic resolution of the decay heat equation and its comparison with different numerical solution methods based on ODEs, and the influence of the short-term power histories in the total decay heat power calculation due to the high interest in the simulation of severe transients like Anticipated Transients without Scram (ATWS). Even though all the studied codes solve the decay heat equations using Runge-Kutta-Gill 4th order method, the analytical resolution was implemented based on the number of reactor operation histories k , number of fissionable nuclides j , and number of groups per fissile i .

$$P'_d(t, T) = \sum_{k=1}^{hist} \sum_{j=1}^{nfi} \sum_{i=1}^{23} \frac{e^{-\lambda_{ij}(t+T)}}{Q_j} \alpha_{ij} \frac{P_j(T_k)}{\lambda_{ij}} [e^{\lambda_{ij}T_k} - e^{\lambda_{ij}T_{k-1}}]$$

The results show that the decay heat model in TRAC-BF1 code needed to be revised and updated to the ANSI/ANS-5.1-2005 standard, the analytical solution provides the same results as the Runge-Kutta-Gill 4th order method in a more straightforward manner, and how the decay heat is affected by conditions that occur in an ATWS during the period of time in which there is power generation without control rod insertion and therefore they cannot be ignored in the nuclear safety analysis.