RECENT ADVANCES IN RADIATION TRANSPORT SIMULATION CAPABILITIES AT POINT LEPREAU GENERATING STATION

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The use of the SCALE 4.3 [1] and the ITS 3.0 [2] codes by Atlantic Nuclear Services Ltd (ANSL), for the Point Lepreau Generating Station (PLGS), offers an efficient and accurate means to solve radiation transport problems in many diverse areas, including health physics, plant operation and accident analysis. Two recent studies (currently in progress), demonstrate the usefulness of these two code suites for solving highly complex problems involving (a) channel decay heat following shut-down and (b) hydrogen radiolysis in containment, following a loss-of-coolant accident (LOCA). This paper summarizes the application of the SCALE 4.3 and ITS 3.0 codes in modelling and simulation in these studies.

The objective of the decay heat study was to determine the distribution of heat in the fuel channel and its surroundings, after a reactor shutdown. Following a reactor shut-down, the primary source of in-core heating is from energy deposition by gamma-rays and beta particles, originating from decaying nuclides (composed of fission products etc) in the fuel. Historically, it has been assumed that the spatial distribution of energy deposition in the reactor core is the same after shutdown as during typical reactor operating conditions. This is a poor assumption, however, as during normal reactor operation, the primary mechanism of energy deposition in-core is the kinetic energy lost by fission fragments in the fuel (approximately 80% of fission energy is released via the kinetic energy of fission fragments). It is reasonable to conclude, therefore, that the spatial distribution of energy deposition in-core *should* be markedly different before and after shutdown. The solution to this question requires that two problems be addressed individually - the energy spectrum of radiation (for gamma-rays and beta particles) emitted from a typical fuel bundle, as a function of time, must be determined and the spatial distribution of energy deposition within the core must be simulated, via Monte Carlo techniques. As will be discussed subsequently, the SCALE and ITS codes were used to address the former and latter problems, respectively.

The purpose of the study of hydrogen radiolysis occurring in containment, following a LOCA was to determine the production rate of hydrogen gas in the sump water in the reactor building. After a LOCA, for a worst-case scenario, it is assumed that the mechanical integrity of a given fraction of fuel bundles will be compromised. In terms of hydrogen radiolysis, the worst-case scenario is that all of the radionuclide inventory released from the fuel, into containment, ends up being dispersed throughout the sump water. To determine the amount of hydrogen liberated from the sump water via radiolysis, the energy deposited in the water by gamma-ray and beta-emitting nuclides must be determined via Monte Carlo simulation. Similar to the study of decay heat, a solution to the hydrogen radiolysis problem required a means of generating the gamma-ray/beta particle source term and a radiation transport code to simulate energy deposition in the sump water. The SCALE and ITS codes were again utilized to address these problems.

The SCALE 4.3 code is an integrated, modular code system for performing <u>S</u>tandardized <u>C</u>omputer <u>A</u>nalyses for <u>L</u>icensing <u>E</u>valuation. In our studies, the ORIGEN-S [3] module of SCALE was employed to calculate "source terms" for 37 element CANDU fuel bundles, using CANDU specific data libraries, developed by AECL/WRL [4]. In this context, source terms refers to both nuclide inventories and the corresponding gamma-ray and beta-particle energy spectra (both differential and integral, with respect to time). In the study of decay heat, ORIGEN-S was used to compute the decay inventory of radioactive nuclides in the fuel following shutdown, and the resulting gamma-ray and beta particle spectra (both integral and differential w.r.t. time). The calculation of beta spectra was made possible by the use of a new SCALE code module (to be released in the next version of the SCALE code), appropriately named BETA-S [5], obtained from AECL/WRL. In the hydrogen radiolysis study, the ORIGEN-S code was first used to generate the nuclide inventory in the fuel at the time of LOCA. Fractional release data (supplied by PLGS), for all the nuclides in the fuel inventory, were then applied to determine the radionuclide inventory released from the ruptured fuel bundles into containment. ORIGEN-S was subsequently used to calculate the time-dependent radionuclide inventory that was released into containment. Gamma-ray and beta energy spectra (integral and differential w.r.t. time) were also generated via ORIGEN-S. In both the decay heat and hydrogen radiolysis studies, the gamma-ray and beta particle energy spectra generated by ORIGEN-S/BETA-S were used as source terms for the Monte Carlo radiation transport analysis, performed with the ITS code.

The <u>I</u>ntegrated <u>T</u>iger <u>S</u>eries (ITS v3.0) code suite is a powerful and user-friendly software package which permits state-of-the-art Monte Carlo solution of linear time-independent coupled electron/photon radiation transport problems in multi-dimensions and multi-materials. The three-dimensional version of the ITS code, called ACCEPT, was used to perform beta particle and gamma-ray transport simulations, for the purpose of determining energy deposition. For the decay heat study, the distribution of energy deposition from betas and gammas emitted by the fuel was simulated, using a realistic three-dimensional reactor fuel channel lattice. The ACCEPT code was modified to provide spatial source sampling (for both betas and gamma-rays) from all 37 elements of the fuel bundle. This permitted very accurate simulation of the spatial distribution of energy deposition in the reactor core. In the study of hydrogen radiolysis, the reactor building was modelled as a simple cylindrical concrete structure, filled to an appropriate level with a D_2O/H_2O/radionuclide mixture. The ITS/ACCEPT code was used to determine the fraction of source energy deposited in the sump water mixture, by the gamma-ray and beta-emitting nuclides, which were assumed to be uniformly dispersed throughout the sump water.

In summary, the SCALE (v4.3) and ITS (v3.0) codes have proven to be very useful analytical computational tools in our work and for use in the nuclear industry, in general. These codes suites have been benchmarked and validated extensively in many diverse nuclear applications. Many man years have gone into their development to provide not only reliable and useful computational tools, but also a relatively "user friendly" environment. These codes run on a variety of computing platforms, ranging from PCS to UNIX engineering workstations. Together, or individually, the SCALE and ITS codes have provided PLGS and ANSL with a cost-effective, accurate means of obtaining solutions to many complex problems of current interest to CANDU operations.

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