XA9951825

THERMAL-HYDRAULIC ANALYSIS OF VVER-440 SPENT-FUEL STORAGE SYSTEMS

Z. HÓZER, Gy. GYENES
KFKI Atomic Energy Research Institute,
Budapest,
Hungary

In the framework of a contract between the IAEA and the KFKI Atomic Energy Research Institute, numerical models have been developed for the simulation of thermal-hydraulic behaviour of CASTOR type spent fuel store constructed in Dukovany NPP and MVDS type spent fuel store operated in Paks NPP with VVER-440 fuel. The model is based on the use of US code COBRA-SFS, which is well validated for spent fuel storage systems with Western type PWR and BWR fuel.

The COBRA-SFS code [1] performs thermal-hydraulic analysis of spent-fuel storage and transportation systems. It predicts flow and temperature distributions in spent fuel storage systems and fuel assemblies, under forced and natural convection heat transfer conditions. The code has detailed models of the basic processes taking place in dry storage facilities: it calculates the convective, conductive and radiative heat transfer regimes and determines the view factors for radiative heat transfer as well.

Two separate models were developed for CASTOR and MVDS store systems. However the fuel assembly simulation is common for the two cases, as both stores are used for the storage of VVER-440 fuel (Fig. 1). The hexagonal fuel assembly of VVER-440 reactor is simulated by fluid sub channels and fuel rods. The flow area of the assembly was divided into 37 channels. The radiative heat transfer exchange factors are defined within assemblies. The model describes the shroud of the fuel assembly as well.

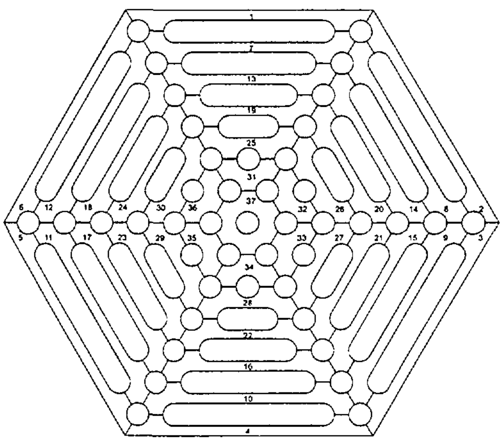

FIG. 1. Fuel assembly simulation

The CASTOR 440/84 spent-fuel storage cask consists of a rigged cast-iron body for structural integrity. The fuel basket is composed of hexagonal tubes made of borated steel 'atabor' in honeycombed arrangement. The casks are closed with two lids. The fuel assemblies are stored in helium gas environment. From modelling point of view the vertical arrangement the cask can be represented by one-sixth section of symmetry. The model developed for Dukovany CASTOR spent fuel storage system has been tested against the a real container measurements carried out at Dukovany NPP. On the basis of these assessment results, calculations were carried out for the design case and for the planned lifetime of the spent fuel storage system.

The CASTOR system was designed to store assemblies with maximum 250 W/assembly power. Total design power of the CASTOR is 21 kW with 84 fuel assemblies. In the present test this design power was set to each fuel assemblies of the model. The external temperature of the air were set to 40°C. The calculation provided detailed information on the temperature distribution of the system (Fig. 2).

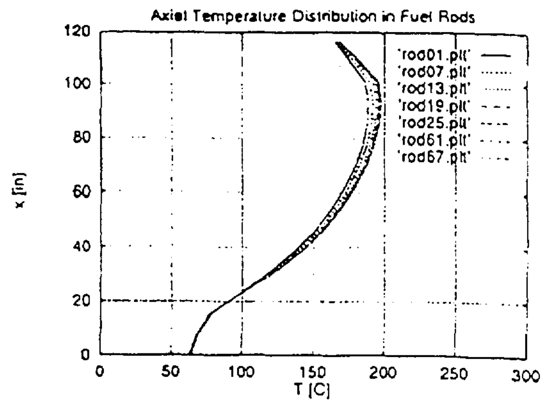

FIG. 2. Temperature distribution

In the MVDS (Modular Vault Dry Storage) the fuel assemblies are stored vertically in steel tubes. Each tube stores a single assembly. A passive self regulating cooling system induces buoyancy driven ambient air flow across the exterior of tubes and provides heat-removal from the store. In the model only a part of the whole vault module is described: six storage tubes were selected. The tubes are surrounded by concrete wall. The air flow is set to flow in on the left hand side at low elevations and to flow out on the right hand side at the top of the system.

In order to show the behaviour of the system under different boundary conditions sensitivity calculations were carried out, which included summer and winter conditions and also the effect of partial blockage. The results of calculations showed that the peak clad temperature follows the external temperature variation. In partial blockage cases the decay heat is driven away with increased outlet temperature.

The most important output of COBRA-SFS calculations can be the prediction of the maximum cladding temperature. To demonstrate the capability of the present model to solve such problems a series of calculations was performed for fuel assemblies with 3.6% enrichment for 50 years. The fuel had 40 GW·d/tU burnup and after 3 year wet storage was transported to the vault (Fig. 3).

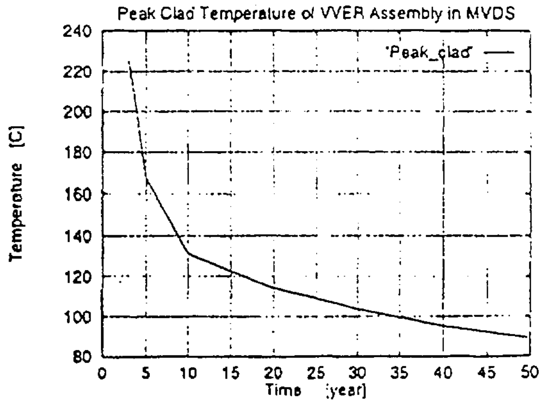

FIG. 3. Cladding temperature

The main results of this project are the CASTOR and the MVDS VVER-440 working models, which are available for the potential users through IAEA. The models have been tested and the results are reasonable. The models were constructed in such a way, that the new users could solve the typical spent fuel store thermal problems with small changes in the boundary and operational conditions.

REFERENCE

[1] MICHENER, T.E., RECTOR, D.R., CUTA, J.M., DODGE, R.E., ENDERLIN, C.W., COBRA-SFS: A Thermal-Hydraulic Analysis Code for Spent Fuel Storage And Transportation Casks, September 1995, PNL-10782 (1995).