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COMPUTER TECHNICS IN CORROSION PRODUCT ACTIVATION RESEARCH FOR SHUT-DOWN DOSE REDUCTION AT PAKS NPP

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Several codes and measuring technics have been elaborated for shut-down dose reduction research at Paks nuclear power plant /NPP/. Main principles and some results of these codes as well as comparison to measurements at Paks and at other NPP are given.

Introduction

The major radiation source in PWR reactors for personnel exposure during shut-down maintenance has been identified to be the activated corrosion products deposited on the primary system piping wall. These products give about 95-98% of doses received by personnel of power plants, therefore a program of corrosion product monitoring and control is justified by reduction of the radiation field and man-sievert exposure. An extensive program has been developed and carried out in Paks NPP to follow the behavior and movement of corrosion products. Based on the results of field studies, some important transport mechanisms have been hypothesized and mathematical models of corrosion product transport have been developed /Fig.1/.

Calculations using the models are capable of reproducing the observed data and confirm that the radiation fields can be controlled and reduced by operational practices.

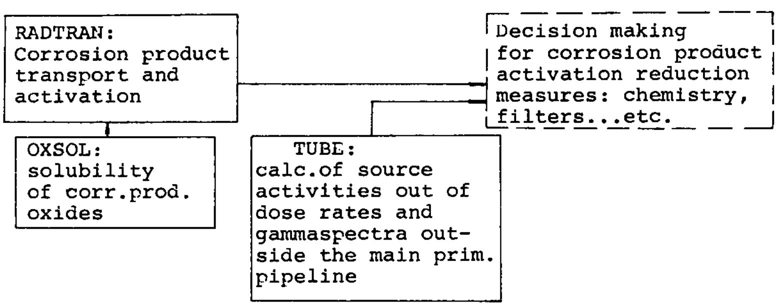

Fig.1. Corrosion product transport modelling code system and decision making process

Research was started several years earlier and resulted in more understanding of the physical processes and a code system /Fig.1/

RADTRAN code [1]

This code calculates the corrosion product amounts generated, deposited, on in- and out-core surfaces, and the corrosion product activity on these surfaces. It takes into account corrosion product particle deposition, corrosion product release due to differences in corrosion product /at present Fe_3O_4/ solubilities between the bulk of the coolant and surfaces, activity built-in into the growing oxide layer on out-core surfaces. Different chemistry /pH/ can be taken into account. It has been shown that in normal operation the primary coolant pH is the most important parameter affecting the out-core activity levels.

OXSOL code

Solubility of the most frequent metals as Fe, Cu, Co, Ni, Cr, Mn in the primary circuits and of their various oxides can be computed by this code, based on thermodynamic functions: Gibbs free energy, entropy and specific heat. A set of theoretical calculations were carried out with parameters relating to the working conditions of a NPP. The temperature dependence of the solubilities was given in the range 25-300 ^{o}C. The pH dependence was given by the theory; actual pH values can be correlated with a set of H_3BO_3, KOH and NH_4OH concentrations in the coolant.

The results are very sensitive to the accuracy of the basic thermodynamic functions. The computations were tested by the experimental solubility data for some oxides as Fe_3O_4, Fe_2O_3 and NiO. A comparison shows the agreement to be within one order of magnitude. For the other oxides the calculations may serve as predictions.

TUBE code

The activity of corrosion products deposited on the internal surfaces of the main circulation pipeline of the primary circuit can only be derived from out-of-the tube γ-ray spectra measurements. The detected γ-ray flux is in a rather complicated functional relation with the specific surface - or volume activities due to the various absorption and multiple scattering processes to be taken into account.

The TUBE code serves for the decomposition of the observed spectra into the activities of the most important isotopes inside the tube. To solve this problem, a semiempirical method is applied with simplified geometrical models fitted to the real measurement system. The main variables of the model are the geometry and structural materials in question, their γ-ray absorption and energy build up factors given in the literature for simplified geometries.

The code can discuss three cases for the tube: 1/ in an empty pipeline only the surface activity of the deposited corrosion products can act as the source for γ-rays, 2/ in a pipeline filled up with water an additional absorbing material appears, and 3/ in the general case the transported corrosion products serve for an additional volume source. In such a case only the function binding the volume activity with the surface activity can be determined.

Consistency checks for the TUBE code show that the results of computations are reliable within one order of magnitude.

Test calculations for the measured γ-ray spectrum at the Paks reactor resulted in surface actitivity values nearly by one order of magnitude higher than those from electrochemical sample-taking during shut-down, for the most important isotopes. The results support a sequence order of decreasing activity of $^{60}Co > {}^{54}Mn > {}^{110}Ag >$ other isotopes.

Preliminary calculations for a calibration of the measurement system directly to the inner surface activities show that a nearly linear function can serve as a good approximation.

Code verification

After the first and second refuelling shut-down of the first unit of Paks NPP in 1984 and 1985, after 0.912 and 1.68 effective full power years /eff. f.p. years/, extended surface activity measurements were done. Smear and electrochemical samples of the activated oxide layer were taken and dose rates and gamma-spectra were measured at not accessible places /E.g. internal surfaces of the main circulating pipeline.Fig. 2 gives the activity of different stainless steel corrosion product nuclides. Activity of non-stainless steel corrosion products was at least ten times smaller. Comparison of Paks measurements to RADTRAN code showed that RADTRAN results are closer to isothermical surfaces than to steam generator tubes. Measured Co-60 surface activities at Paks-1 are similar to other VVER-440 units and are much lower than at other nuclear power plants /Fig.3/.

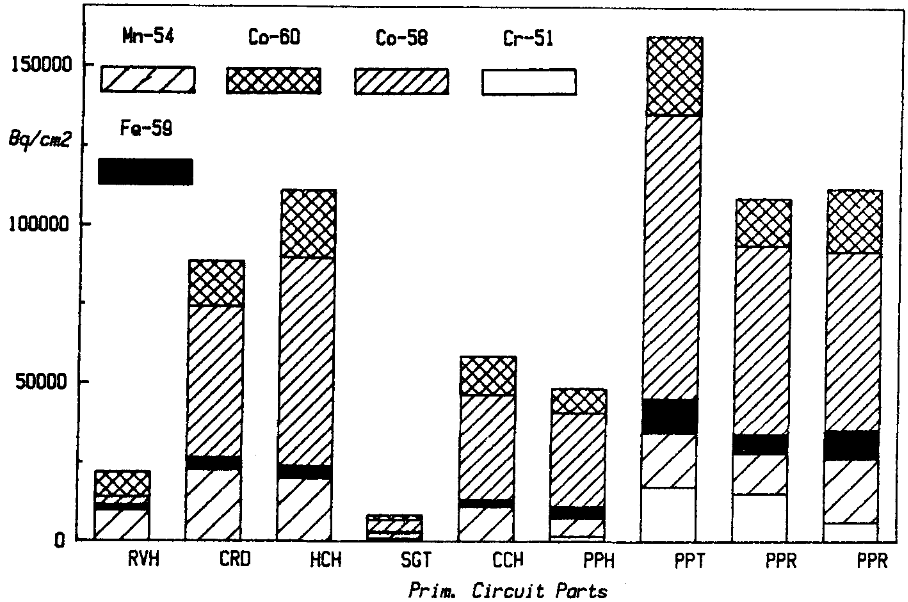

Fig.2. Surface activities at PAKS-1 after the second refuelling shut-down measured by electrochemical sampling, 1.68 eff.f.p.years

RVH-Reactor Vessel Head,
CRD-Control Rod Drives,
HCH-SG.Hot Channel Head,
SGT-Steam Generator Tubes,
CCH-SG. Cold Channel Head
PPH-Primary Pump House
PPT-Primary Pump Tubes
PPR-Primary Pump Wheel

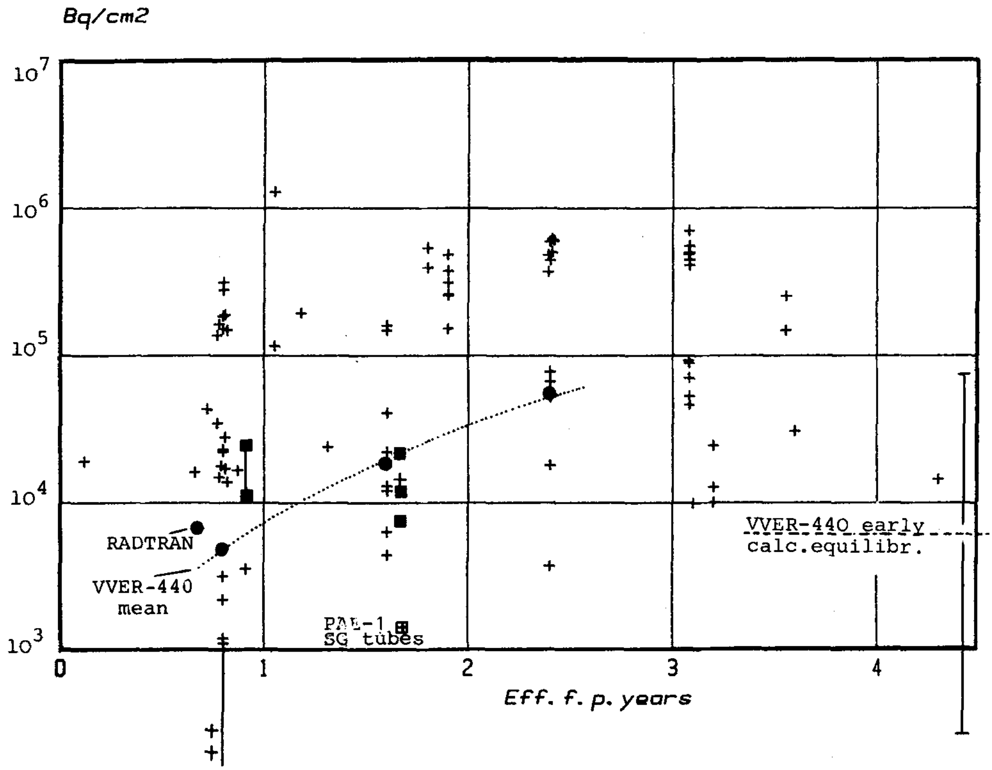

Fig.3. Co-60 activities of the primary circuit surfaces at different power plants including PAKS-1

+ different outcore surfaces of different plants
● out core mean of VVER-440 and RADTRAN Code
■ PAE-1 different out core isothermal surfaces
⊞ PAE-1 SG. Tubes

References

1. G.L. Horváth, M. Snellman, E.G. Rämö, Computer Simulation of Radioactivity Transport in PWR Systems, Water Chemistry II, BNES, Paper 34.