ESTIMATING THE RADIOACTIVE WASTE VOLUME OF THE CONCRETE GROUND PLATE AT THE TRIGA VIENNA

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ABSTRACT

In support of the future decommissioning of the TRIGA reactor Vienna an inventory of expected radioactive structural materials turned up several holes in the locally available data. The following work attempts to close one of the two major ones with a mix of simulations and measurements of similar material because the real structures are not directly accessible. The concrete floor below the reactor pool is calculated by an extension of the MCNP reactor model, which is validated by flux measurements at the reactor pool bottom. This results in an additional 0.63 m³ radioactive and 2.2 m³ restricted release heavy concrete waste to 4.3 and 8.6 m³ from the biological shield

Introduction

In 2016 Atominstitut was approached by a group from Institute of Nuclear and Physical Engineering, Slovak University of Technology, for a collaboration to test their decommissioning costing codes CERREX and eOMEGA_RR by using the 250 kW TRIGA reactor in Vienna as a pilot project. The results this collaboration were presented at the RRFM 2017 [1]. For the Viennese side the project revealed several holes in the locally available data and documentation for the structural materials but also that those fortunately were not critical at least as far as costing the decommissioning was concerned. As the sensitivity analysis by the above codes showed the cost increase for an order of magnitude more radioactive inventory only about 1%.

Still it was decided to try to fill the two major gaps found in the documentation: the radioactive inventory of the concrete below the reactor pool and the graphite in the reactor reflector. This paper will focus on the first part by expanding the model used on the biological shield to the sides of the reactor to the bottom. Obviously the structure is currently not directly accessible and simulations with measurements taken on similar material have to be used fill the void, often together with outright best guesses. The assumptions in this case being that the concrete directly below the core is the same barite concrete used in the radial biological shield (see figure 1 for the sampling position) and that the steel reinforcements can be ignored as there are no plans available for where and in which density it was used.

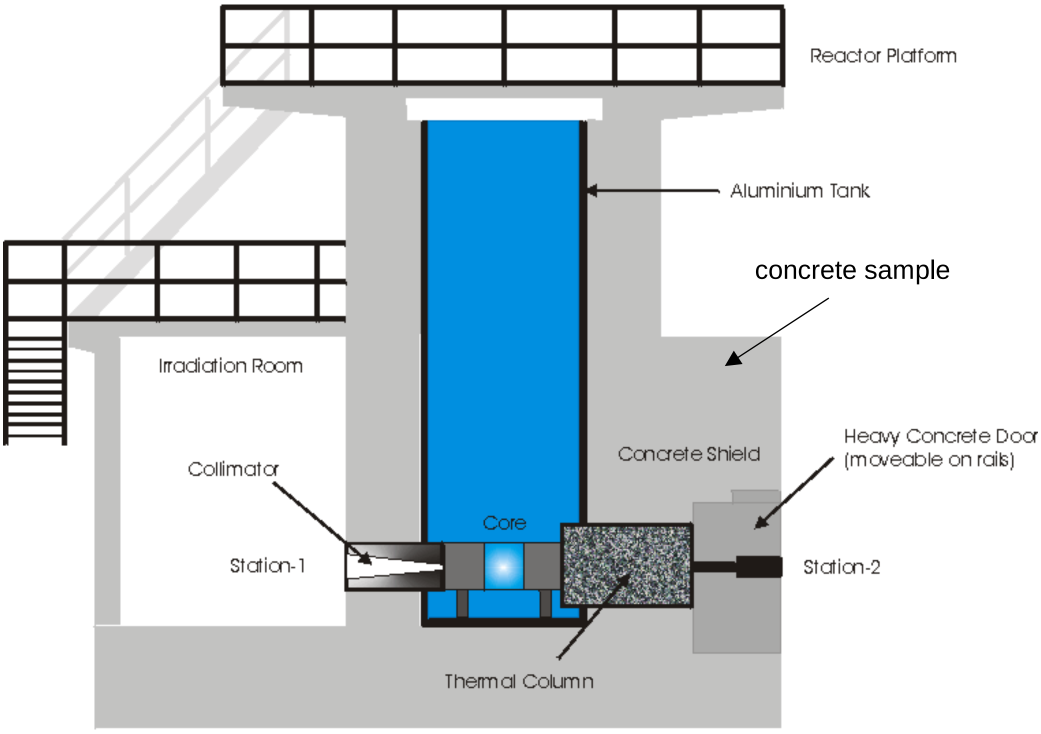

Figure 1: vertical view of the reactor with concrete sample position

Concept and Geometry

A model to estimate the radioactive waste volume for the radial biological shield according to Austrian radioprotection law was developed by Stefan Merz et .al. [2] based on calculating the neutron flux density in the shield. The starting point are tightly spaced neutron flux measurements on tank wall and in the beam lines and together with the diffusion length of neutrons in concrete and the composition of the concrete, it allows the calculation of the radioactive isotope vector in the shield.

		limits according to Austrian law		rel. contribution	
isotope	x_i [cm^{-2}]	free release [Bq/g]	conditional release [Bq/g]	free	conditional
H-3	2.094E-06	1000	1000	0.06%	2.10%
Co-60	4.556E-08	0.1	4	13.19%	11.44%
Ba-133	1.221E-06	1	30	35.35%	40.88%
Cs-134	1.497E-08	0.2	6	2.17%	2.51%
Eu-152	3.283E-07	0.2	8	47.51%	41.21%
Eu-154	1.175E-08	0.2	7	1.70%	1.69%

Table 1: relative activity and contribution to the legal limit for the major isotopes two years after reactor shutdown

Table 1 above shows the relative activity and importance in terms of the legal limit for the major contributing nuclides after 47 years of operation and two years of cooldown. The corresponding neutron flux limit at full reactor power are given as 2.895E+05 1/cm²s for free release and 1.006E+07 1/cm²s for conditional release respectively. Any concrete exposed to higher flux must be treated as radioactive waste.

Because the reactor is in the way of making flux measurements at tank floor, this cannot directly be applied to the concrete below the tank. To get around that the neutron flux below the core is simulated with MCNP5 1.40 [3] with the JEFF3.1 cross section library and calibrated with a single gold foil activation measurement below the centre of the core through the central irradiation tube.

Generally the standard MCNP model for the reactor at the Atominstitut includes the major features in the reactor pool up to the pool wall radially and to the upper/lower limit of the thermal column vertically. Figure 2 gives a horizontal cross section of the model with the reactor configuration of late 2007/early 2008 as illustration. For more details please see the thesis of R. Khan [4]. Because a criticality calculation is not efficient for the flux at the periphery of the model, a surface source was generated below the lower grid plate covering the entire reactor tank. With it the derived model could be reduced to a transport problem below the core, which removed the reactor itself from consideration.

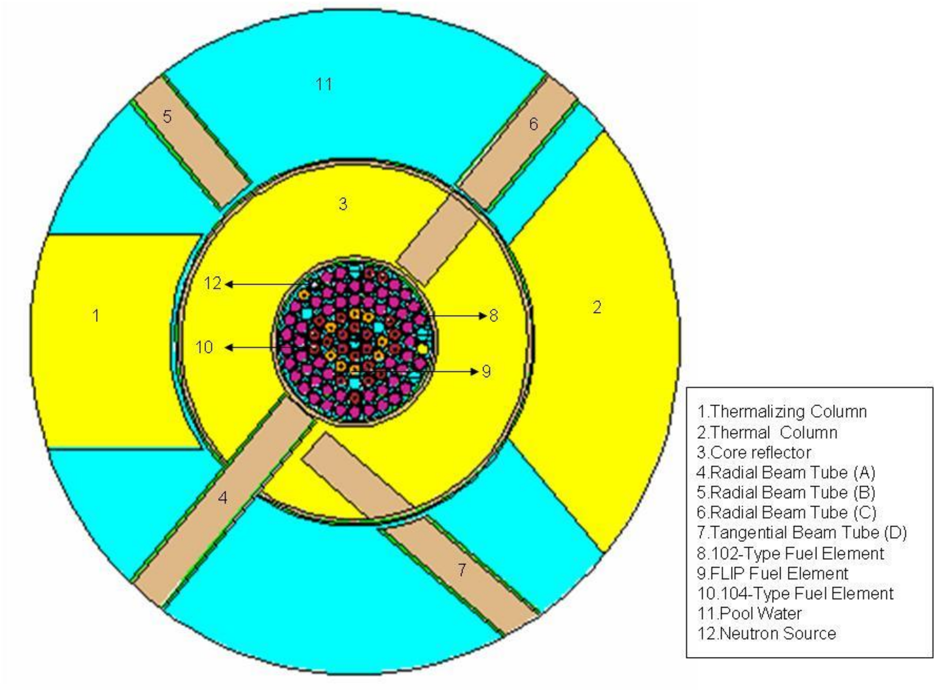

Figure 2: Horizontal cross section of the TRIGA Mark II core in Vienna 2008

The modelled geometry below the core is shown together with result of the type f4 mesh tally in figure 3 on the next page. The bottom of the lower grid plate and the surface source is 36 cm below reactor median plane and is followed by a 63 cm layer of water up to the 7 mm thick Al tank wall. Sandwiched between the Al tank and the 5 mm thick steel tank are 8 cm of gravel and finally the concrete below everything else. The calibration gold foil is placed 81 cm below the reactor centre and 18 cm above the bottom of the tank.

Results

As mentioned above to calibrate the neutron flux in the MCNP model several gold foils were irradiated at full reactor power for 30 minutes at different depths below the core. The lowest was used for calibration for simplicity's sake because the neutron spectrum there should be closest to a purely thermal one. For that position a neutron flux of 5.19E+09 1/cm²s was calculated from the activity measurement, which divided through simulated value at the same position gives the normalisation factor for the MCNP model.

	Measurement		MCNP	
Au mass [g]	Activity [kBq]	rel. error	F4 tally	rel. error
0.2922	14.4	1.9%	1.01E-08	5%

Table 2: measured and simulated values for the calibration position

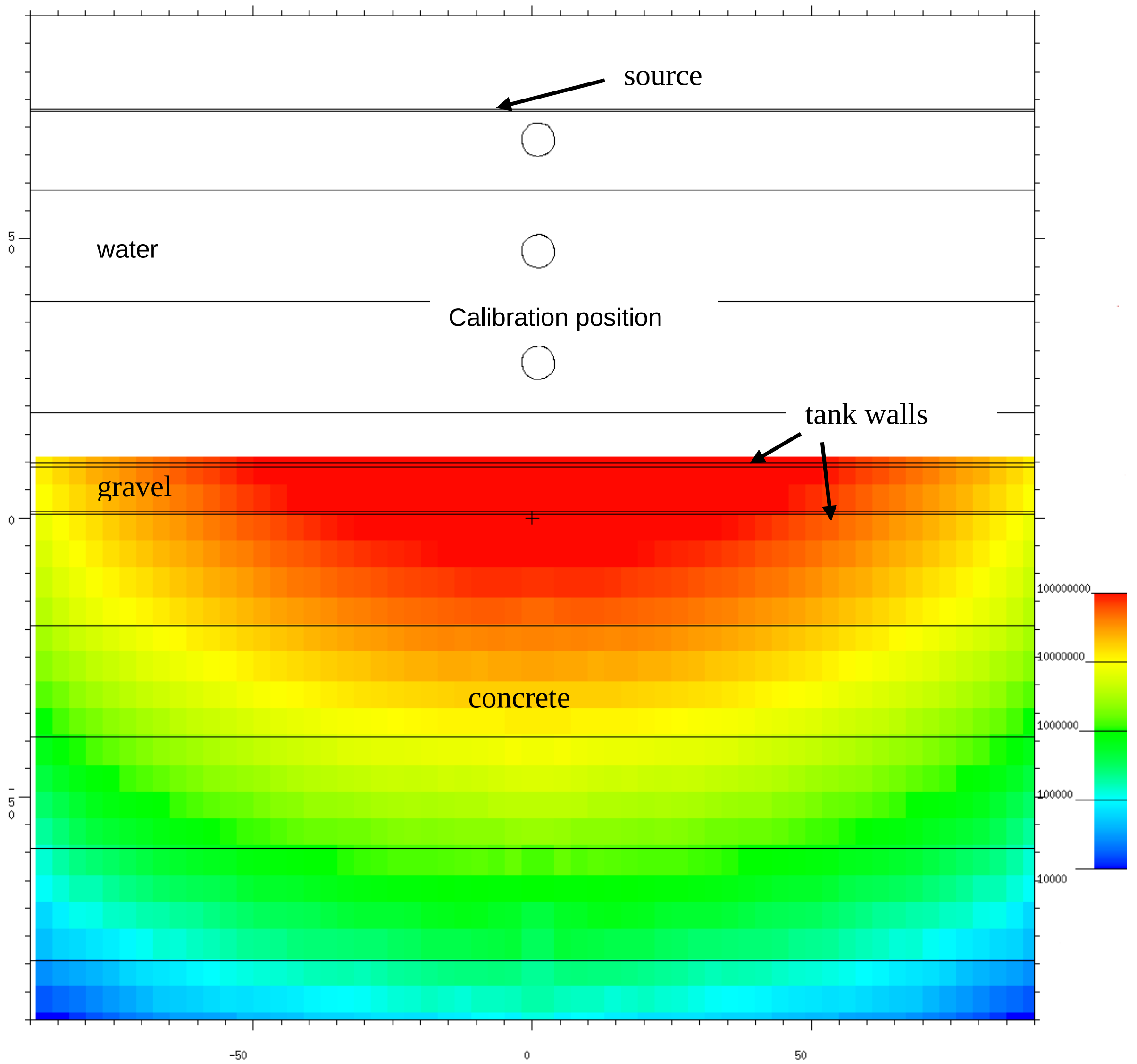

Figure 3: neutron flux below at the reactor tank bottom

The resulting mesh tally plot in figure 3 above shows of course the expected flux density shape but also a bit over 50 % higher penetration depth than expected at the radial tank wall. Some of that is expected due to the stronger 1/r flux dependence in the radial direction but rerunning the model for the radial shield would allow for direct comparison. Because the absolute waste volumes for such a low power reactor are so small as shown in the table 3 below, this is not a significant handicap for the decommissioning.

	Volume [m³]		
Waste category	Biological shield	Below tank	total
Radioactive waste	4.30	0.63	5.03
Restricted release	8.56	2.20	10.76

Table 3: Waste volume per legal category and source

References

1. K. Kristofova et al., “ADVANCED DECOMMISSIONING COSTING CALCULATION TOOLS FOR PILOT VIENNA TRIGA MARK-II RESEARCH REACTOR”, RRFM 2017
2. S. Merz et al.: „ Neutron flux measurements at the TRIGA reactor in Vienna for the prediction of the activation of the biological shield “, Applied Radiation and Isotopes November 2011
3. J. F. Briesmeister, Ed. “MCNP – A General Monte Carlo N-Particle Transport Code, Version 5”, Manual, April 2003
4. R. Khan: “Neutronics Analysis of the TRIGA Mark II Reactor Core and its Experimental Facilities”, Thesis TU Wien, Vienna March 2010