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**European Project for the development of HTR Technology -
Materials for the HTR**

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HTR-M – Activation analysis – (up to 500 days after irradiation)
of the Vessel steel Modified 9Cr 1 Mo for the LYRA irradiation

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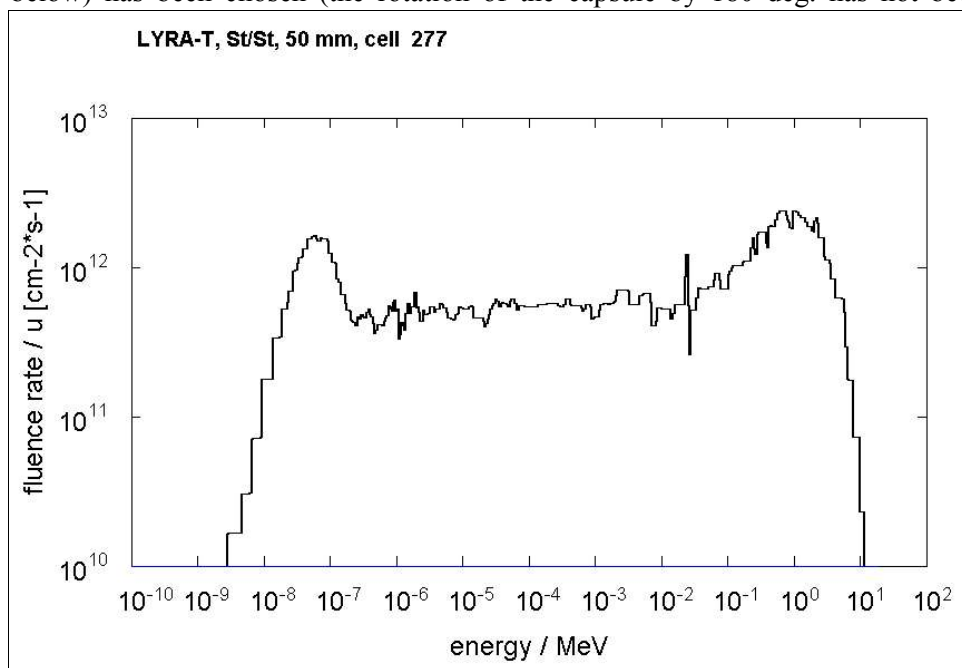
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LYRA-08 activity and dose rate calculations

Transports of irradiated radioactive material have to be accompanied by forms specifying the activities (and dose rates) of the most relevant nuclides. In order to provide these values the activities of the specimens irradiated in the LYRA-08 capsule have been calculated with the FISPACT-03 code and the eaf_gxs_172_fis_20030 library. A number of conservative assumptions have been made for these calculations. The neutron spectrum for the FISPACT calculation has been taken from the Monte Carlo radiation transport calculations performed for the LYRA-T nuclear analysis with the code MCNP-4B [1]. The chosen spectrum holds for the LYRA-capsule completely filled with steel specimens and a distance from the core wall of 50 mm. To be conservative the spectrum of the hottest specimen position (see figure below) has been chosen (the rotation of the capsule by 180 deg. has not been taken into



account).

The activities are calculated for an irradiation time of 20 days.

The calculated dose rates are simply the product of the calculated activity and the dose rate constant of a specific nuclide. That means that no kind of absorption (not in the specimen itself nor in air or any other shield material) is taken into account.

Remark:

The presented results are only meant to satisfy the requirements of the transport forms. They are not representative for any irradiated specimen in the LYRA-08 capsule (because of their conservative character) and they are also not representative for the activities that may be expected for the material of a HTR (because the spectra in the vessel wall and the spectrum used here are different and therefore the realized thermal and fast fluences may be different).

[1] W.E. Freudenreich, *LYRA-T Nuclear Analysis*, Report 910780/02.49980/I, NRG, Petten, October 2002.

Nuclide activities [Bq/kg] of irradiated material:

nuclide	20. d	1. d	10. d	25. d	50. d	100. d	150. d	200. d	250. d	400. d	500. d
V 52	3.45E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr 51	6.21E+11	6.05E+11	4.83E+11	3.32E+11	1.78E+11	5.08E+10	1.46E+10	4.17E+09	1.19E+09	2.80E+07	2.29E+06
Cr 55	2.02E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn 54	6.48E+09	6.47E+09	6.34E+09	6.13E+09	5.80E+09	5.19E+09	4.65E+09	4.16E+09	3.72E+09	2.67E+09	2.14E+09
Mn 56	1.72E+12	2.72E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe 55	4.15E+10	4.15E+10	4.12E+10	4.08E+10	4.01E+10	3.87E+10	3.74E+10	3.61E+10	3.49E+10	3.15E+10	2.93E+10
Fe 59	2.35E+10	2.31E+10	2.01E+10	1.59E+10	1.08E+10	4.95E+09	2.27E+09	1.04E+09	4.78E+08	4.63E+07	9.74E+06
Co 58	3.73E+08	3.74E+08	3.43E+08	2.97E+08	2.32E+08	1.42E+08	8.73E+07	5.35E+07	3.28E+07	7.57E+06	2.85E+06
Cu 64	2.39E+10	6.44E+09	4.90E+04	1.44E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu 66	5.05E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb 94m	3.11E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo 99	6.38E+10	4.95E+10	5.12E+09	1.16E+08	2.12E+05	7.08E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo101	1.57E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc 99m	5.61E+10	4.77E+10	4.96E+09	1.13E+08	2.06E+05	6.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc101	1.57E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb122	3.69E+10	2.85E+10	2.82E+09	5.97E+07	9.64E+04	2.52E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb124	3.33E+09	3.29E+09	2.97E+09	2.50E+09	1.87E+09	1.05E+09	5.93E+08	3.33E+08	1.88E+08	3.34E+07	1.06E+07
total	3.04E+12	8.16E+11	5.67E+11	3.98E+11	2.36E+11	1.01E+11	5.96E+10	4.59E+10	4.05E+10	3.43E+10	3.15E+10

Element activities [Bq/kg] of irradiated material:

element	20. d	1. d	10. d	25. d	50. d	100. d	150. d	200. d	250. d	400. d	500. d
V	3.46E+11	7.78E+04	7.63E+04	7.39E+04	7.02E+04	6.32E+04	5.69E+04	5.12E+04	4.61E+04	3.36E+04	2.73E+04
Cr	6.41E+11	6.05E+11	4.83E+11	3.32E+11	1.78E+11	5.08E+10	1.46E+10	4.17E+09	1.19E+09	2.80E+07	2.29E+06
Mn	1.73E+12	9.19E+09	6.34E+09	6.13E+09	5.80E+09	5.19E+09	4.65E+09	4.16E+09	3.72E+09	2.67E+09	2.14E+09
Fe	6.50E+10	6.46E+10	6.13E+10	5.67E+10	5.09E+10	4.37E+10	3.97E+10	3.72E+10	3.54E+10	3.15E+10	2.94E+10
Co	1.51E+09	5.49E+08	3.44E+08	2.97E+08	2.32E+08	1.43E+08	8.75E+07	5.37E+07	3.30E+07	7.74E+06	3.00E+06
Cu	2.89E+10	6.44E+09	4.90E+04	1.44E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb	3.14E+10	2.06E+08	1.17E+08	4.97E+07	1.84E+07	1.09E+07	1.01E+07	9.91E+06	9.78E+06	9.55E+06	9.44E+06
Mo	7.95E+10	4.95E+10	5.12E+09	1.16E+08	2.95E+05	8.28E+04	8.28E+04	8.27E+04	8.27E+04	8.27E+04	8.27E+04
Tc	7.19E+10	4.77E+10	4.96E+09	1.13E+08	2.17E+05	1.15E+04	1.15E+04	1.15E+04	1.15E+04	1.15E+04	1.15E+04
Sb	4.29E+10	3.18E+10	5.79E+09	2.56E+09	1.87E+09	1.05E+09	5.93E+08	3.34E+08	1.88E+08	3.34E+07	1.06E+07
total	3.04E+12	8.16E+11	5.67E+11	3.98E+11	2.36E+11	1.01E+11	5.96E+10	4.59E+10	4.05E+10	3.43E+10	3.15E+10