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DOSE CALCULATION FOR ACCIDENT SITUATIONS AT TRIGA RESEARCH REACTOR USING LEU FUEL TYPE★

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Abstract. The 14MW TRIGA R.R. is a unique design of TRIGA conception. The core was fully converted in May 2006 to use LEU fuel instead of the HEU fuel type. The core contains 29 fuel assemblies, 8 control rods and beryllium reflector, associated instrumentation and controls. The U-235 enrichment for TRIGA – HEU fuel is 93.15 wt % and for TRIGA – LEU is 40.00 wt %. The differences between the two fuel types, as shown by the calculations, will results in a higher core inventory especially for heavy elements (*i.e.*, actinides and transuranium elements), but modifications for noble gases, halogens and other volatile fission products are not so important. Dose calculations for an hypothetical accident scenario was considered and dose and radiological consequence calculations were performed. The results of the calculations and a discussion related to the differences between the consequences in the two cases are also presented.

Key words: nuclear accident, nuclear fuel, exposure, radiation dose.

1. INTRODUCTION

Back in 1978 the United States of America and, later on, the International Atomic Energy Agency, recommended an international program related to the decrease of uranium enrichment in research reactors by converting the nuclear fuel containing highly enriched uranium into a fuel with low uranium enrichment.

Romania joined this program in 1980 and dynamically supported political, scientific, technical and economic actions which led to the conversion of the TRIGA 14MW reactor at the Institute for Nuclear Research in Pitesti. This fact validates the continuity of Romania's Government policy for non-proliferation as well as its active back-up of international cooperation.

The conversion of the research reactor in Pitesti was made possible by attaining certain important research stages in the framework of the Research Agreement for Reactor Conversion, concluded with the US Department o Energy and Argon National Laboratories. Thus the scientific support was ensured and around 65% of the fuel needed for conversion start-up has been delivered from the US, between 1992–1994.

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The continuation of conversion was made possible within the program for technical cooperation with the International Atomic Energy Agency: Program ROM/4/024 provided the support for technical and scientific efforts and the delivery of low enriched uranium nuclear fuel for the completion of conversion. This type of fuel was manufactured by the CERCA Co. in France, based on a tripartite supply contract, jointly signed by IAEA – CERCA – Romania.

Latest time when HEU fuel was used was 10 May 2006. First power rise for fully converted core operation, containing only LEU was 24 May 2006.

Reactivity coefficients of temperature over the normal operating range and for anticipated operational occurrences for TRIGA-LEU core are smaller than HEU coefficients but the inherent safe characteristics of the TRIGA design are maintained. Fuel and moderator temperatures, coolant flow rates, pressure drop and temperatures are the same as in the original design for HEU. The new LEU fuel has the same geometry and construction as HEU fuel. The new LEU core performances are comparable with the initial HEU performances, in terms of utilization of experimental and irradiation facilities.

2. ACCIDENT SCENARIO

We considered two accident scenarios: a design severe accident scenario and a hypothetical severe accident scenario. The design severe accident scenario is 25-pins fuel bundle failure in air. The core has operated discontinuously for a total of 1780 MWd. The affected fraction of the core is 4.00% for HEU core and 3.45% for LEU core. Fraction of available fission products released to the pool are100% for noble gases and halogens. Condition of ventilation system is normal with an exhaust rate from stack of 24,360 m^3/h. The release height is 60 m. For hypothetical severe accident scenario we considered that a large part of the reactor hall roof or a heavy object escaped from the crane hook is dropped over the 14-MW TRIGA-SSR core, resulting in mechanical damage of the core. It is assumed, also, that no core melting is occurring, but only fuel-cladding rupture being involved for several 25-pins fuel bundles. The core has operated discontinuously for a total of 1780 MWd. The affected fraction of the core is 40%. Fraction of available fission products released to the pool are100% for noble gases and halogens. Condition of ventilation system is normal with an exhaust rate from stack of 24,360 m^3/h. The release height is 60 m.

3. RESULTS

The core inventory was calculated using ORIGEN computer code which is part of modular code system SCALE [3].

Comparative results for HEU and LEU fuel bundle inventory for krypton and iodine isotopes are presented in Figs. 1 and 2.

The air concentration and ground deposition for both fuel types and both accident scenario was calculated. The estimated mean individual 1-day radiation doses are presented in Figs. 3 and 4.

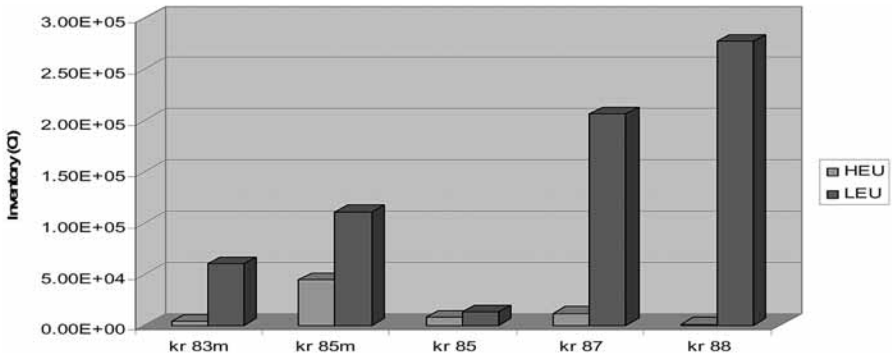

Fig. 1 – Comparative results for HEU and LEU inventory for krypton.

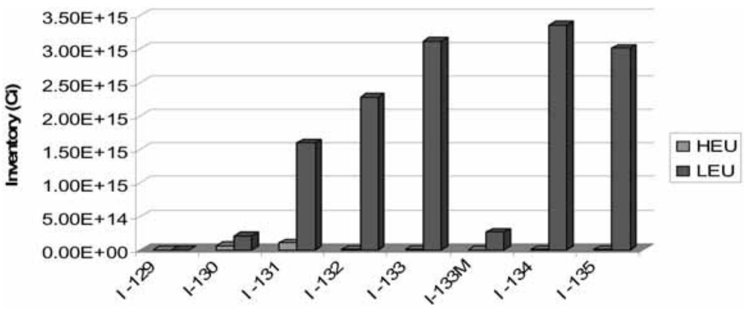

Fig. 2 – Comparative results for HEU and LEU inventory for iodine.

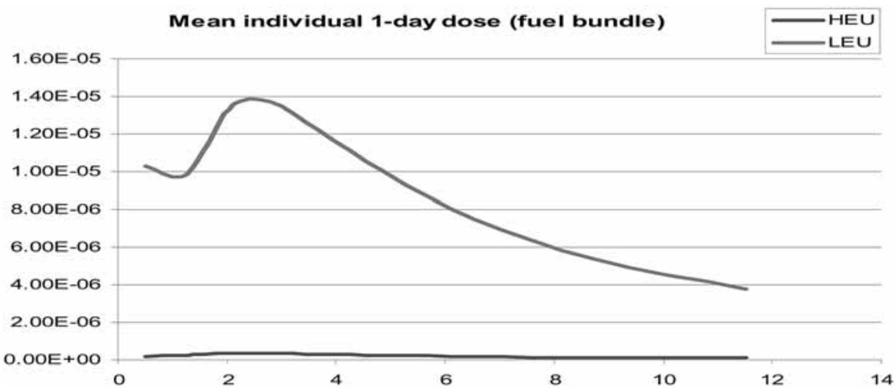

Fig. 3 – Comparative results for HEU and LEU fuel for mean individual 1-day dose for 25-pins fuel bundle failure in air.

The relative contribution of pathways to total dose per organ for one day individual dose is shown in Fig. 5.

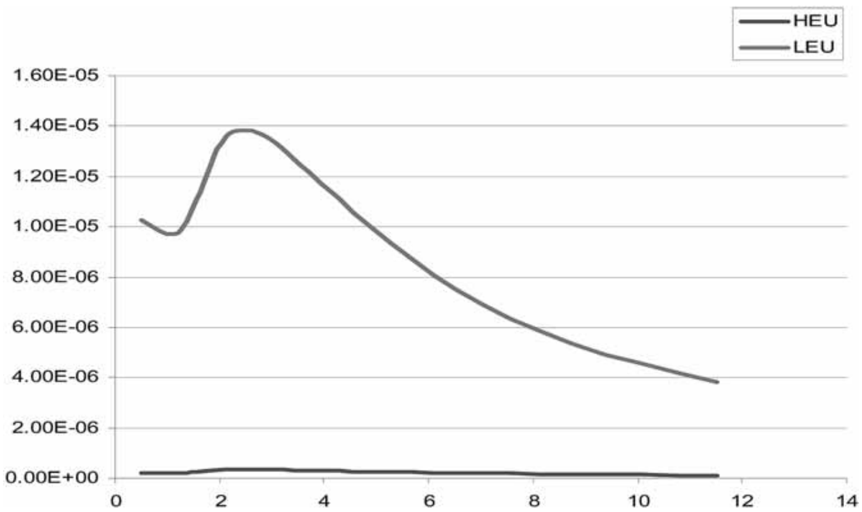

Fig. 4 – Comparative results for HEU and LEU fuel for mean individual 1 -day dose for partial damage of the core.

	Fuel bundle						40% of core					
	Dose (Sv)	Cloud	Ground	Inhalation	Ingestion	Resuspension	Dose (Sv)	Cloud	Ground	Inhalation	Ingestion	Resuspension
B.MARROW	4.45E-07	14	85	1	0	0	5.70E-07	33	66	1	0	0
B.SURFACE	4.89E-07	17	81	1	0	0	7.13E-07	43	56	1	0	0
BREAST	4.62E-07	17	83	1	0	0	6.35E-07	39	60	1	0	0
LUNG	4.78E-07	14	83	2	0	0	6.25E-07	34	64	2	0	0
STOMACH	4.27E-07	15	83	2	0	0	5.57E-07	34	64	2	0	0
COLON	4.05E-07	14	84	1	0	0	5.24E-07	34	65	1	0	0
LIVER	4.20E-07	15	84	1	0	0	5.49E-07	35	65	1	0	0
PANCREAS	3.88E-07	15	84	1	0	0	5.01E-07	34	65	1	0	0
THYROID	1.60E-05	0	3	97	0	0	1.61E-05	2	3	96	0	0
GONADS	4.29E-07	14	85	1	0	0	5.53E-07	33	66	1	0	0
REMAINDER	4.79E-07	15	82	3	0	0	6.30E-07	35	62	2	0	0
EFFECTIVE	1.23E-06	6	31	63	0	0	1.38E-06	16	28	57	0	0

Fig. 5 – The relative contribution of pathways to total dose per organ for one day individual dose for both accident scenarios.

4. CONCLUSIONS

The results have demonstrated that, even in the event of severe accidents, releases are likely to be small and doses to workers, public and environment are not likely to be significant.

Both accident scenarios considered only mechanical damage of the fuel, this is why only noble gases and halogens are available for release, this is why the differences are not so big. In the case of a partial or full core melting, depending on accident conditions and progression, temperature could rise to extremely high values, so other fission products (some of them with important impact on health effects) will become available for release, and the differences between the two types of fuel will increase.

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