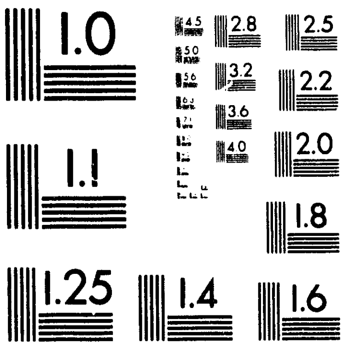
1.0
4.5
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2.8
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1.25
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Conf-931160--9

Radiological Consequences of Radioactivity Release From Spallation Targets

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Introduction

A preconceptual design for an Accelerator Production of Tritium (APT) facility is currently under development by several national laboratories in conjunction with industry. The design consists of an accelerator that bombards a spallation target with high energy protons. Neutrons are produced in the spallation target and are absorbed in a blanket material to produce tritium. Two spallation targets are currently under investigation: (1) a tungsten neutron source target and (2) a lead neutron source target. In the tungsten target the neutrons are captured in helium-3, which is circulated through the system, thus producing tritium. The lead target is surrounded with a lithium-aluminum blanket and the tritium is produced in the lithium-6.

The investigation of possible radiological impacts on the public is being performed as a part of the safety evaluations of the preconceptual design. These studies include the estimation of releases of radioactive materials from the two spallation targets and the possible impacts on the public.

Release Mechanisms Considered

Scoping calculations have been performed on both targets to estimate the potential release of radionuclides during severe accident conditions. A thermochemical equilibrium model, which uses the ideal solution approximation, was used to calculate the total vapor pressure for each element of interest. The chemical compounds and reactions considered were limited to interactions of the various spallation products with steam, hydrogen, and oxygen with very few exceptions.

Given a range of thermal and chemical environments of the target under severe accident conditions, the model was used to calculate the fractions of the various radionuclides that could be vaporized from the target. However, this treatment neglects mass transport limitations within the target and would be excessively conservative for the tungsten target. Therefore, the release from the tungsten target is limited to the greater of diffusion rates within the tungsten rods or the amount of tungsten ablated by oxidation.

A similar analysis was performed for the lead target; however, difficulties in defining the geometry of the lead during the accident due to the low melting point of lead complicates the analysis substantially. For this reason, diffusion limits were not calculated for the lead target.

Potential Radiological Effects

Applying the above approach for determining release fractions in conjunction with bounding accident conditions, the highest calculated release fractions from the tungsten target were for tungsten itself, tellurium, cesium, iodine, and noble gases, assuming a steam-hydrogen environment. For more strongly oxidizing conditions, molybdenum, rhenium, and osmium would join the group having the highest release fractions. For the lead target, the highest calculated release fractions were for mercury, iodine, cesium, and noble gases, with osmium and rhenium releases being enhanced for sufficiently oxidizing conditions. However, most of the radioactivity released from the target (in terms of Curies) is accounted for by isotopes of tungsten for the tungsten target and by isotopes of mercury for the lead target. For this reason, the radiological effects of tungsten and mercury were further investigated.

The International Commission on Radiological Protection has published annual limits on intake (ALIs) and although these are for routine exposures, these can yield insights into the effect of exposure to radionuclides during accident conditions. Another indicator of radiological effect is dose conversion factors. Comparison of dose conversion factors and ALIs for tungsten and mercury with those for iodine and xenon show that, per unit activity released, the potential doses are no greater for tungsten and mercury than for radionuclides that could be a primary constituent of an accident source term from existing tritium production facilities. In addition, since smaller amounts of radioactivity are likely to be released from an APT facility, the radiological impact of a severe accident may be less.

To support this assessment, consequence calculations were performed for bounding severe accident scenarios for both target systems. Conservative values for the confinement decontamination factor were applied to the release fractions from the target. No credit was taken for retention in the piping systems. A 5 volume percent per day leak rate from the confinement was assumed and doses were calculated for a 24-hour exposure to a 24 hour plume. Within a few hundred meters of the facility, the 24-hour Effective Dose Equivalent was on the order of 10 rem.

Acknowledgements

This work was performed at Sandia National Laboratories which is operated for the U. S. Department of Energy under contract DE-AC04-76DP00789.

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