Attachment 7

PSAT Calculation 04011H.05

"Additional Radionuclide Data"

CALCULATION TITLE PAGE

CALCULATION NUMBER: PSAT 04011H.05

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"Additional Radionuclide Data"

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REASON FOR REVISION:	Nonconformance Rpt
0 - Initial Issue	N/A
1 - Changed first paragraph of Methodology discussion Expanded Assumption 1 and changed Assumption 2 to delete Reference 1 Changed Reference 1 and expanded title of Reference 8	N/A
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3	
4	

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Purpose

The purpose of this calculation is to present additional data regarding the dose conversion factors (DCFs) for Kr-90, Cs-134, and Cs-137, to develop a treatment for Te-132 based on its ability to decay to I-132 in elemental form, and to develop a treatment for radionuclides other than noble gas, radioiodine, radiocesium, and Te-132; i.e., the "Other".

Methodology

Reference 1 identifies one radioactive decay chain that has the potential to significantly affect doses for core damage accidents; i.e., the formation of I-132 by the decay of Te-132. Even this effect is described as being small for cases where the vessel remains intact and the release of Te-132 from the fuel is limited (such as the DBA case being considered here). Nevertheless, it is worthwhile to consider what that impact could be.

The basis for the majority of the DCFs in Reference 2 is Reference 3. The whole body and skin DCFs given in Reference 3 for Kr-90, Cs-134, Cs-137 (and its important, short-lived decay daughter Ba-137m), and Te-132 are zero (in fact, Kr-90 is not included at all). The thyroid DCF for Te-132 is a small, non-zero value which does not reflect its decay daughter (I-132). The class of radionuclides defined above as "Other" is a concept introduced by Reference 4 (and not explicitly treated in the revised DBA source term of Reference 5) which must be treated specially in any case.

Each one of these cases is discussed separately below, with whole body DCFs being based on

Reference 6 and skin DCFs being based on beta energies from Reference 7 and the expression for skin DCF, given beta energy, from Reference 8. Reference 8 is also used as the basis for the whole body DCF for the "Other".

Assumptions

Assumption 1: Te-132 is treated as I-132 with the half-life of Te-132.

Justification: The half-life of Te-132 is more than thirty times greater than that of I-132, and I-132 has a half-life of only 2.3 hours. Therefore, it is a conservative, but not unreasonable, to assume that I-132 appears immediately upon decay of Te-132. This can be accommodated by simply adding the DCFs for I-132 to those for Te-132. Based on Reference 3 this effectively means using I-132 DCFs.

I-132 has a thyroid DCF (from Reference 3) that is 0.6% that of I-131. Although the core activity of I-132 is greater than that of I-131 by 45% (Item 1 of Reference 2), the half-life of I-131 is 83 times greater than that of I-132. Therefore, the thyroid dose potential of I-132 (the product of core inventory, half-life, and DCF) is only 0.01% that of I-131. This means that if released as equal fractions of core inventory, the thyroid dose from I-132 will be negligible compared to that from I-131. A similar comparison can be made for whole body dose; in this case the dose potential of I-132 is 11% that of I-131. Whole body dose, however, is generally dominated by noble gas anyway.

Consider the thyroid dose potential of Te-132 which, based on References 2 and 3, is 0.001% that of I-131. Consider, too, that Te-132 has a release fraction for BWRs only 17% that of I-131 (see Reference 5). It is very clear that Te-132, as Te-132, has virtually no potential to influence the dose results. However, if Te-132 is deposited or trapped on particulate filters and is then released as I-132, the thyroid and whole body dose potentials become that of Te-132 for core inventory and half-life, but of I-132 for DCFs; i.e., 0.3% that of I-131 for thyroid dose and 360% that of I-131 for whole body dose. Moreover, while the release fraction of Te-132 is 17% that of I-131, only 5% of the I-131 release from the core is gaseous. Therefore, the potential exists for the Te-132 to produce 3.4 times as much gaseous I-132 (as a fraction of core inventory) as there exists gaseous I-131, or for that matter, gaseous I-132 released directly from the core.

Given the above discussion, it is clear that Te-132, as Te-132, has no potential to influence the dose results. However, there is a potential for gaseous I-132 released from the decay of trapped Te-132 to contribute significantly (relative to other iodine contribution) to the whole body dose. Therefore, Te-132 should be given I-

132 DCFs.

Assumption 2: The "Other" can be conservatively treated as described in Reference 4.

Justification: Reference 4 suggests that "other" radionuclides (not including noble gas and radioiodine) be assumed to be released to the containment at the level of one percent of the core inventory. This release is comparable, or quite conservative, with respect to the release magnitude of "other" radionuclides in Reference 5 with the exception of tellurium (Te-132 in particular) and cesium (Cs-134 and Cs-137 in particular). But since the Te-132, Cs-134, and Cs-137 are being explicitly treated separately, the "Other" can be treated as described in Reference 4 to verify that its contribution to the whole body dose is small.

References

Reference 1: Williams, D. C. and Murata, K. K., "Phenomenological Uncertainties in the Suspended Radionuclide Concentrations in Containment During Severe LWR Accidents", ANS Topical Meeting on Fission Product Behavior and Source Term Research, Snowbird, Utah, July 15-19, 1984

Reference 2: PSAT 04000U.03, "Design Data Base for Application of the Revised DBA Source Term to the TVA Browns Ferry Nuclear Power Plant", Revision 0

Reference 3: TACT5 Data File MLWRICRP.30 from "User's Guide for the TACT5 Computer Code", NUREG/CR-5106, June 1988

Reference 4: DiNunno, J. J., et al., "Calculation of Distance Factors for Power and Test Reactor Sites", TID-14844, March 1962

Reference 5: Soffer, L., et al., "Accident Source Terms for Light-Water Nuclear Power Plants", NUREG-1465, February 1995

Reference 6: Chanin, D. I., et al., "MELCOR Accident Consequence Code System (MACCS) User's Guide", NUREG/CR-4691, Volume 1, February 1990

Reference 7: The Chemical Rubber Co., Handbook of Chemistry and Physics, 51st Edition, Cleveland, Ohio, 1970

Reference 8: NRC Regulatory Guide 1.3, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors", Revision 2, June 1974

Calculation

Kr-90

Kr-90 has a half-life of 33 seconds (Reference 7). Given the fact that the gap release does not even begin in Reference 1 until 30 seconds and that the release is at a rate of only 0.0028 %/second during the first 1800 seconds, the percent released over four half-lives would be less than 0.3 percent of the core inventory. Since Kr-90 is not further distinguished by either its abundance (Reference 2) or by its energy of disintegration (Reference 7), it is appropriate that it be dropped from further consideration.

Cs-134

External exposure DCF in Reference 6 of:

6.97E-14 Sv-m^3/Bq-sec x 3.7E12 Rem-Bq/Sv-Ci = 0.258 Rem-m^3/Ci-sec

Beta energy from Reference 7 = 0.28(0.089)+0.01(0.410)+0.71(0.662) = 0.5 Mev

DCF = 0.23 x beta energy (by Reference 8) = 0.23 x 0.5 = 0.115 Rem-m^3/Ci-sec

Cs-137

External exposure DCF in Reference 6 of:

2.53E-14 Sv-m^3/Bq-sec (which includes impact of Ba-137m) x 3.7E12 Rem-Bq/Sv-Ci = 0.093 Rem-m^3/Ci-sec

Beta energy from Reference 7 = 0.94(0.511)+0.04(1.176) = 0.55 Mev

DCF = 0.23 x beta energy (by Reference 8) = 0.23 x 0.55 = 0.127 Rem-m^3/Ci-sec

Note that according to Reference 7, Ba-137m is not a beta emitter

Te-132

By Assumption 1, use I-132 DCFs already in Reference 3 to represent Te-132.

Other

The core inventory of "Other" is taken from Reference 4 based on an initial gamma source

strength of 3.72E16 Mev/sec-Mw, an average gamma energy of 0.7 Mev/dis, 3.7E10 dis/Ci-sec, and the Reference 2 power level of 3458 Mw; i.e.,

Ci inventory = 3458 x 3.72E16 / (0.7 x 3.7E10) = 4.967E9 Ci

The effective half-life over the first two hours is given in Reference 4 (Table IV) as 2.72 hours. This represents a decay constant of 7.05E-5/second. Beyond two hours the 2.72 hour half-life overstates decay, but the particulate is largely removed by this point in time.

The expression for the whole body DCF from Reference 8 is:

WB DCF = 0.24 x average energy = 0.24 x 0.7 Mev = 0.168 Rem-m^3/Ci-sec

Results and Conclusions

1. Kr-90: Can be neglected altogether.

2. Cs-134: WB DCF = 0.258 Rem-m^3/Ci-sec

   Skin DCF = 0.115 Rem-m^3/Ci-sec

3. Cs-137: WB DCF = 0.093 Rem-m^3/Ci-sec

   Skin DCF = 0.127 Rem-m^3/Ci-sec

4. Te-132: Same as I-132 except for half-life

5. Other: 4.967E9 Ci in core at shutdown

   Decay Constant = 7.05E-5/second

   WB DCF = 0.168 Rem-m^3/Ci-sec

The "Other" is intended to show only that the dose contribution from radionuclides other than those explicitly considered (i.e., noble gas, radioiodine, radiocesium, and Te-132) is small.