Page	1
------	---

MEMORANDUM TO:	Gary M. Holahan, Director
	Division of Systems Safety and Analysis
	Office of Nuclear Reactor Regulation

- FROM: Farouk Eltawila, Acting Director Division of Systems Analysis and Regulatory Effectiveness Office of Nuclear Regulatory Research
- SUBJECT: EFFECT OF FISSION PRODUCT INVENTORY AVAILABLE FOR RELEASE ON SPENT FUEL POOL ACCIDENT CONSEQUENCES

As part of its effort to develop generic, risk-informed requirements for decommissioning, NRR requested (Reference 1) that RES evaluate the offsite radiological consequences of beyond-design-basis spent fuel pool accidents. In response to that user need, RES completed an in-house analysis (References 2 and 3) using the MACCS code (Reference 4). The focus of that work was estimation of consequences at one year after final reactor shutdown. Recently, NRR requested (References 5 and 6) that RES evaluate the consequences using fission product inventories at 30 and 90 days and one, two, five, and ten years after shutdown to provide additional insight into the effect of reductions in radionuclide inventory available for release. After discussion with RES, NRR requested that consequence estimates be made for two evacuation cases, late evacuation with evacuation beginning 1.4 hours after the release begins and early evacuation with evacuation beginning three hours before the release begins.

Because of radioactive decay, spent fuel pool accidents occurring long after fuel offload will progress more slowly and have smaller fission product releases and, as a result, will have smaller consequences. Radioactive decay affects accident progression and fission product release in three ways. The first effect is that the lower decay heat results in longer times (a) for the hottest assemblies to heat up to the temperatures required to drive off fission products and (b) for the heatup to propagate to assemblies with lower decay heat. This prolonged heat-up and propagation provides more time to prevent, recover, and mitigate the accident. It also provides more time to evacuate and take other protective measures. The second effect is that the lower decay heat results in fewer assemblies heating up to the temperatures required to drive off fission products. The third effect is that, for those assemblies that heat up, there is a lower fission product inventory in each assembly available for release.

As noted above, NRR requested that RES investigate the third effect, that is, the lower fission product inventory in each assembly available for release. RES performed these consequence calculations using the release fractions in Table 1. The release fractions in the second row of Table 1 are from NUREG-1465, *Accident Source Terms for Light-Water Nuclear Power Plants* (Reference 7). For this application, RES used the complete NUREG-1465 source term including the ex-vessel and late in-vessel phase releases. The release fractions in the first row of Table 1 (i.e., the upper bound case), other than those for ruthenium and fuel fines, also are from NUREG-1465. However, in this case, the ruthenium release fraction is that for a volatile

Direct

Deset

" 7 . . .

fission product. This is considered to be bounding for a couple of reasons. First, rubbling of the spent fuel after heat-up to about 2500K is expected to limit the ruthenium release. Second, following the Chernobyl accident, ruthenium in the environment was found to be in the metallic form (Reference 8). Metallic ruthenium has a much lower dose conversion factor, that is, rem per Curie inhaled, than oxidic ruthenium which is conservatively assumed in the MACCS code. Also, the fuel fines release fraction used in the upper bound case is that from the Chernobyl accident (Reference 8). This is considered to be bounding, because the Chernobyl accident AH ANCE involved more extreme conditions (i.e., two explosions followed by a prolonged graphite fire) $\mathcal{V}_{\mathcal{L}}$ than a spent fuel pool accident.

accident (involved r than a sp	Referen nore extr ent fuel p	ce 8). Tl reme cor bool acci	his is cons nditions (i. dent.	sidered to b e., two exp	e bounding losions follo	, because wed by a	the Chei prolonge	rnobyl acc d graphite	ident IVA fire) ^{교표} 상태	
		Т	able 1 Fi	ssion Proc	luct Releas	e Fractio	ns	<u></u>	\	NATION C
Source Term	Release Fractions							510,5.		
	noble gases	iodine	cesium	tellurium	strontium	barium	ruthe- nium	lantha- num	cerium	· ·
upper bound	1	.75	.75	.31	.12	.12	.75	.035	.035	-
NUREG- 1465	1	.75	.75	.31	.12	.12	.005	.0052	.00055	

Table 1 Fission Product Release Fractions

The results of the RES calculations for the population within 100 miles (consistent with the distance used in earlier RES analysis for NRR on spent fuel pool accidents) are given in Tables 2 and 3 for the upper bound and NUREG-1465 release fractions, respectively. These results are shown graphically in Figures 1 through 3. However, these results do not consider the additional time available to prevent, recover, and mitigate the accident and the additional time available to evacuate and take other protective measures. They also do not consider the reduced number of assemblies releasing fission products. Therefore, we believe that these results significantly overestimate the magnitude of the consequences and may not accurately portray the decline in consequences as a function of time. An integrated analysis of heatup, propagation, and release, together with explicit consideration of prevention, recovery, and mitigation and a systematic consideration of emergency response, is needed to address these deficiencies. Also, the ruthenium and fuel fines release fractions are uncertain. Because ruthenium and fuel fines releases are very important to the consequences, additional data are needed.

In Reference 5 and in subsequent discussions, NRR also requested RES estimates of the societal doses for the population within 50 miles and the cancer fatalities for the population within 1000 miles. The societal doses for the population within 50 miles are given in the last column in Tables 2 and 3. However, this memorandum does not report the cancer fatalities for the population within 1000 miles, because of the high degree of uncertainty in the atmospheric transport model at these large distances.



In Reference 5 and in subsequent discussions, NRR also requested RES estimates of the societal doses for the population within 50 miles and the cancer fatalities for the population within 1000 miles. The societal doses for the population within 50 miles are given in the last column in Tables 2 and 3. However, this memorandum does not report the cancer fatalities for the population within 1000 miles, because of the high degree of uncertainty in the atmospheric transport model at these large distances.

Table 2 Results based on Upper Bound Source Te	rm
--	----

Case	Decay Time	Mean Consequences			
			(Surry populati	on, 95% evacuat	ion)
			Within 100 mile	S	Within 50 miles
		Early	Societal Dose	Cancer	Societal Dose
2		Fatalities	(rem)	Fatalities	(rem)
79a	30 days	192	2.62x10 ⁷	21100	2.37x10 ⁷
79b	90 days	162	2.49x10 ⁷	20000	2.25x10 ⁷
79c	1 year	76.9	2.15x10 ⁷	17400	1.93x10 ⁷
79d	2 years	19.2	1.90x10 ⁷	15400	1.69x10 ⁷
79e	5 years	1.34	1.66x10 ⁷	12600	1.45x10 ⁷
79f	10 years	.360	1.53x10 ⁷	11400	1.34x10 ⁷
80aª	30 days	6.65	1.60x10 ⁷	15400	1.35x10 ⁷
80b ^a	90 days	3.95	1.52x10 ⁷	14300	1.29x10 ⁷
80c ^a	1 year	.951	1.34x10 ⁷	11500	1.12x10 ⁷
80d ^a	2 years	.149	1.20x10 ⁷	9480	9.93x10 ⁶
80e ^a	5 years	.0162	1.07x10 ⁷	7620	8.69x10 ⁶
80f ^a	10 years	.00601	1.00x10 ⁷	6490	8.13x10 ⁶

^aBased on early evacuation.

Table 3 Results based on NUREG-1465 Source Term

Case	Decay Time	Mean Consequences (Surry population, 95% evacuation)				
			Within 100 Mile	is	Within 50 Miles	
		Early	Societal Dose	Cancer	Societal Dose	
		Fatalities	(rem)	Fatalities	(rem)	
77a	30 days	2.21	7.15x10 ⁶	4540	5.58x10 ⁶	
77b	90 days	1.37	6.99x10 ⁶	4420	5.43x10 ⁶	
77c	1 year	.736	6.81x10 ⁶	4190	5.28x10 ⁶	
77d	2 years	.481	6.65x10 ⁶	4020	5.12x10 ⁶	
77e	5 years	.192	6.47x10 ⁶	3800	4.90x10 ⁶	
77f	10 years	.0778	6.26x10 ⁶	3620	4.72x10 ⁶	
78a ^a	30 days	.0720	5.69x10 ⁶	3240	4.12x10 ⁶	
78b ^a	90 days	.0461	5.58x10 ⁶	3150	4.02x10 ⁶	
78c ^a	1 year	.0301	5.48x10 ⁶	3020	3.95x10 ⁶	
78d ^a	2 years	.0208	5.40x10 ⁶	2930	3.87x10 ⁶	
78e ^a	5 years	.00882	5.33x10 ⁶	2820	3.77x10 ⁶	
78f ^a	10 years	.00400	5.24x10 ⁶	2730	3.69x10 ⁶	

^aBased on early evacuation.

Mean Consequences within 100 Miles (Surry population, 95% evacuation)





Mean Consequences within 100 Miles (Surry population, 95% evacuation)





Page 7

References: 1. Memorandum from G. Holahan to T. King dated March 26, 1999

2. Memorandum from A. Thadani to S. Collins dated November 12, 1999

3. Memorandum from F. Eltawila to G. Holahan dated August 25, 2000

4. Code Manual for MACCS2, NUREG/CR-6613, May 1998

5. Memorandum from R. Barrett to J. Flack dated August 25, 2000

6. Memorandum from S. Collins to A. Thadani dated September 11, 2000

7. Accident Source Terms for Light-Water Nuclear Power Plants, NUREG-1465,

8. Chernobyl Ten Years On, Radiological and Health Impact, An Appraisal by

Radiation Protection and Public Health, November 1995

February 1995 the NEA Committee on Page 8

cc: T. Collins

R. Barrett

J. Hannon

J. Wermiel

G. Hubbard

References: 1. Memorandum from G. Holahan to T. King dated March 26, 1999

- 2. Memorandum from A. Thadani to S. Collins dated November 12, 1999
- 3. Memorandum from F. Eltawila to G. Holahan dated August 25, 2000
- 4. Code Manual for MACCS2, NUREG/CR-6613, May 1998
- 5. Memorandum from R. Barrett to J. Flack dated August 25, 2000
- 6. Memorandum from S. Collins to A. Thadani dated September 11, 2000
- 7. Accident Source Terms for Light-Water Nuclear Power Plants, NUREG-1465,
- 8. Chernobyl Ten Years On, Radiological and Health Impact, An Appraisal by
- Radiation Protection and Public Health, November 1995

cc: T. Collins

R. Barrett

J. Hannon

J. Wermiel

G. Hubbard

Distribution: SMSAB R/F DSARE R/F JSchaperow R/F CTinkler MFederline AThadani

G:\SMSAB\SECYS\Schaperow\30daysto10yearsrev2.wpd

OAR in ADAMS?	Y	Publicly Available?	N
(Y or N)		(Y or N)	

February 1995

the NEA Committee on

To receive a copy of this document, indicate in the box: "C" = Copy without attachment/enclosure "E" = Copy with attachment/enclosure "N" = No copy

OFFICE	SMSAB	AC:SMSAB	D:DRAA	AD:DSARE
NAME	JSchaperow:mt	JFlack	TKing	FEltawila
DATE	/ /00	/ /00	/ /00	/ /00

Template= RES-006 Accession Number RES File Code _____

ŧ

Ŧ