NRR

TENERA
Risk Management Services

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Mr. Thomas L. King
U.S. Nuclear Regulatory Commission
5650 Nicholson Lane
Rockville, MD 20852

Dear Tom:

This letter is to provide additional information for NRC consideration on several ALWR source term matters which came up at our August meeting. We appreciate the frank exchange of information thus far and believe that this process which the NRC and ALWR Program are going through for source term update will lead to safer designs and a more stable regulatory environment.

Attached is a note from Dick Hobbins which emphasizes the meeting comments regarding the need to consider experimental evidence in three areas: (1) in-vessel releases, (2) ex-vessel releases, and (3) timing of pin failures following a LOCA. Some of the experimental evidence is described in our February, 1991 report. Additional data is included in the note.

An additional comment which effects ex-vessel release is the need to address debris coolability. For NUREG 1150 the accident sequences are unterminated. We do not expect this to be the case for the ALWR.

Please feel free to call with questions or requests for additional information.

Very truly yours,

Dave Leaver

David E. Leaver

cc: Ted Marston, EPRI
Dick Hobbins, EG&G
Dave Modeen, NUMARC

for T. Kenyon

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1340 Saratoga Sunnyvale Road, Suite 206, San Jose, California 95129 (408) 446-4242 Telecopy (408) 252-8542

COMMENTS ON MEETING WITH NRC ON DEVELOPMENT OF SIMPLIFIED SOURCE TERM

R. R. Hobbins

I am pleased to see the NRC working on changes to TID-14844 to reflect new source term knowledge and the open exchange of information that occurred in the meeting is commendable. All the information presented by Brookhaven National Laboratory (BNL) and NRC was based solely on calculational results with large systems codes. I hope that in addition to this information the NRC will consider experimental evidence (in some cases more recent than the calculational results) in their deliberations on simplified source terms. My comments fall into three areas: (a) in-vessel releases, (b) ex-vessel releases, and (c) timing of fuel pin failures following a large break LOCA.

Simplified source terms for in-vessel release (including revaporization) into containment proposed by ARSAP [1] and BNL [2] are compared in Table 1. The ARSAP-proposed releases are at low pressure because automatic depressurization systems assure low system pressure in passive ALWRs during accidents leading to extensive core damage. The BNL-proposed values at low pressure are generally higher - up to a factor of about three - than the ARSAP values. The BNL values at high pressure are in better agreement with the ARSAP values. The ARSAP values in Table 1 include RCS retentions for iodine of 0.5 (PWR) and 0.6 (BWR), and for all other fission products of 0.6 (PWR) and 0.7 (BWR) based on : (a) the extremely low likelihood of a core damage accident initiated by large, close-to-vessel pipe breaks; (b) the strong likelihood of a detectable leak allowing plant shutdown before the occurrence of a large rupture in primary system piping; (c) experimental evidence indicating 70% or higher aerosol retention in vapor pathway piping systems; and (d) analytical results and NUREG-1150 expert judgement.

In the area of ex-vessel releases due to molten core-concrete interaction (MCCI), the BNL-proposed values for Sr-Ba and La-Ce are approximately two orders of magnitude larger than the ARSAP-proposed values, as is shown in Table 2. The BNL values are apparently based on STCP calculations and results from NUREG-1150 that predate more recent experimental results from the ACE program. The ACE MCCI tests have utilized a variety of compositions of concrete and corium doped with fission product simulants. Great attention has been paid to the introduction of fission product simulants of appropriate chemical form within the proper phase of the corium (oxide or metal). Careful measurements have been made of the effluent, including the amount of fission products released and the characteristics of the aerosols. The ACE MCCI test matrix presented in Table 3 indicates the wide variety of concrete and corium compositions investigated. Some of the important characteristics of tests conducted to date, such as maximum melt temperature, ablation depth, aerosol collection

time, and aerosol mass are given in Table 4. Characteristics of the aerosol collected are provided in Table 5 and fractional releases of fission products and uranium are given in Table 6. The status of documentation of the ACE MCCI data is given in Table 7 and indicates that data reports are currently available from three tests. NRC is a member of the ACE consortium and it is recommended that the results of these tests be factored into the development of ex-vessel source terms due to MCCI.

MCCI experiments are also being carried out at Sandia under NRC support. These experiments have concentrated on measuring the ablation of concrete, heat transfer and temperatures, and the production of gases and aerosols. I understand that there may be one experiment (SURC-2) in which fission product materials were introduced into the corium and their releases measured during MCCI, but I have not seen the results.

The fuel pin failure times presented at the meeting by NRC based on calculations performed at INEL (see Table 8) struck me as very short. I checked with the people at INEL doing the calculations and reviewed some experimental results from LOCA testing at INEL. I found that the calculations were being performed under extremely conservative and physically unrealistic boundary conditions (per NRC requirements). For example, high power peaking factors (up to 2.6) were being applied to high burnup fuel (up to 55 GWd/t). For peaking factors less than 2 and burnups less than 20 GWd/t no fuel pin failures are calculated within 60 seconds of the start of a LOCA. In the LP-FP-1 test, the first fuel pin failure occurred 325 seconds after initiation of the LOCA. I recommend that NRC consider calculations of fuel pin failure at more reasonable boundary conditions to provide more realistic estimates.

References

1. D. E. Leaver, et al., "Passive ALWR Source Term," DOE/ID-10321, February 1991.

2. H. P. Nourbakhsh, "Estimate of Radionuclide Release Characteristics into Containment under Severe Accident Conditions." Presentation to USNRC, August 27, 1991.

Table 1. Comparison of in-vessel release (including revaporization) to containment

	PWR			BWR		
	ARSAP	BNL		ARSAP	BNL	
		Hi P.	Low P.		Hi P.	Low P.
NG	1.0	1.0	1.0	1.0	1.0	1.0
I	0.55	0.35	0.77	0.50	0.60	0.77
Cs	0.48	0.32	0.76	0.41	0.55	0.76
Te	0.11	0.22	0.50	0.09	0.12	0.16
Sr,Ba	0.004	0.003	0.01	0.003	0.003	0.01
Ru	0.004	0.003	0.01	0.003	0.003	0.01
La,Ce	0.00004	0.00005	0.00015	0.00003	0.00005	0.00015

Table 2. Ex-vessel MCCI releases

	ARSAP	BNL			
		Limestone Concrete		Basaltic Concrete	
		PWR	BWR	PWR	BWR
Sr,Ba	0.002	0.40	0.70	0.15	0.30
La,Ce	0.001	0.05	0.10	0.05	0.10

TABLE 3. **ACE MCCI/Fission Product Release Tests**

Test Conditions

Corium composition will be determined from specific Code Cases:

- Oxides from in-vessel: UO_2, ZrO_2, Fe_2O_3, Cr_2O_3, NiO
- Oxides from early ex-vessel ablation: CaO, SiO_2
- Metals: Zr OR Zry, Fe, Cr, Ni, Ru-steel alloy
- Fission products: La_2O_3, BaO, SrO, CeO_2,

Test No.	Concrete Type (1)	Net Heat Generation W/kg UO_2	Corium Mixture	Initial Zr Oxidation, %	Absorber Material
L5	L/S	350	BWR	100	
L2	S	350	PWR	70	
L1	L/S	350	PWR	70	
L6	S	350	PWR	30	Ag, In
L4	S	250	BWR	30	B_4C
L7	L/S	250	BWR	30	B_4C
L3	L/S	350 (2)	PWR	30	Ag, In
L8	L/L	350	PWR	70	Ag, In

Note: (1) concrete type: L/S = limestone/common sand concrete plus rebar
S = siliceous concrete plus rebar
L/L = limestone/limestone concrete plus rebar
(2) consider reduced power operation after Zr is fully oxidized to represent longer-term corium-concrete interaction

TABLE 4. AEROSOL MASS IN ACE MCCI TESTS

Test	L5	L2	L1	L6	L4
Aerosol Mass, g	153	455	1213	6546	4760
Collection Time, min	121	10	7	95	180
Ablation Depth, cm	10.2	3.8	4.0	8.8	12.7
Aerosol Mass/Depth, g/cm	15	120	303	748	375
Concrete Mass, kg	61	23	24	72	97
Aerosol Mass/ Concrete Mass	0.0025	0.020	0.050	0.091	0.049
Maximum Melt Temperature, K	2200	2400	2625	2425	2300
Concrete Type	LCS	Sil	LCS	Sil	Serp/Sil
Metal, kg	0	14	14	34[a]	32

a 23 kg of Zr

TABLE 5. AEROSOL CHARACTERISTICS

Test	L5	L2	L1	L6	L4
Total Mass (G)	158	455	1213	6546	4760
Mass on Final Filters (G)	92	212	663	4582	2733
Collection Time (Min)	121	10	7	85	180
Peak Concentration (G/M^3)	30	400	835	4400	1444
Respirable Mass (%)	92	83	68	80	81
Particle Size AMMD (Micron)	0.6-1	1.6	2-4	1.1	-----
Major Constituents	KCl NaCl	SiO_2	SiO_2	SiO_2	SiO_2 MgO
Maximum Melt Temperature (K)	2200	2400	2625	2425	2300
Concrete Type	LCS	Sil	LCS	Sil	Serp/Sil

TABLE 6. MAXIMUM AEROSOL RELEASES FROM ACE MCCI TESTS

Element	L5	L2	L1	L6	L4
Ba	2.4×10^{-4}	2.9×10^{-5}	7.6×10^{-4}	1.7×10^{-3}	3.3×10^{-3}
Ce	9.8×10^{-5}	3.5×10^{-5}	1.5×10^{-4}	5.1×10^{-4}	1.0×10^{-4}
La	3.4×10^{-4}	1.5×10^{-5}	1.2×10^{-4}	6.2×10^{-4}	8.4×10^{-5}
Mo	-----	5.1×10^{-3}	5.3×10^{-4}	7.0×10^{-3}	1.3×10^{-3}
Sr	9.6×10^{-5}	1.8×10^{-5}	9.8×10^{-4}	2.2×10^{-3}	3.5×10^{-3}
Te	-----	1.4×10^{-1}	5.6×10^{-2}	6.3×10^{-1}	5.9×10^{-1}
U	8.0×10^{-5}	1.6×10^{-5}	1.1×10^{-4}	1.9×10^{-4}	5.8×10^{-5}

Ce and La are Maximums for Tests L2, L1, L6 and L4

TABLE 7

ACE MCCI TEST DATA REPORTS

ACE MCCI Test	Report No.	Report Completed	Estimated Date of Report Completion
L5 (August 1, 1988)	ACE-TR-C7	November 1988	
L2 (February 16, 1989)	ACE-TR-C10 Vol. I-T-H Vol. II-Aerosol	 April 1989 November 1989	
L1 (April 25, 1989)	ACE-TR-C14 Vol. I-T-H Vol. II-Aerosol	 January 1990 March 1990	
L6 (Benchmark) (May 22, 1990)	Vol. I-T-H Vol. II-Aerosol		August 1991 November 1991
L4 (October 26, 1990)	Vol. I-T-H Vol. II-Aerosol		October 1991 January 1992
L7 (Benchmark) (February 21, 1991)	Vol. I-T-H Vol. II-Aerosol		November 1991 February 1992
L8 (Benchmark) (June 10, 1991)	Vol. I-T-H Vol. II-Aerosol		December 1991 April 1992

TABLE 8.

Preliminary Results

(time in seconds until initial pin failure)

	Babcock & Wilcox		Westinghouse	
	LOCA Starts	High Pressure[a]	LOCA Starts	High Pressure[a]
RELAP5 - 100%	13.0	10.5	24.6	18.9
- 90% flow	13.6	11.1	26.8	21.1
- 75%	14.6	12.1	27.0	21.3
- 50%	20.3	17.8	43.0	37.3
Leak—Before—Break[b]	>6.5 minutes		20 min[c]	
TRAC - 100%	N/C	N/C	34.9	29.1

Notes: a - From time of containment high pressure alarm and instrument delay of two seconds

b - Six inch line break

c - Estimated minimum time until pin failure