UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

November 7, 2000

MEMORANDUM TO: Samuel J. Collins, Director
Office of Nuclear Reactor Regulation

FROM: Ashok C. Thadani, Director
Office of Nuclear Regulatory Research

SUBJECT: RESPONSE TO USER NEED REQUEST FOR TECHNICAL STUDY OF SPENT FUEL POOL ACCIDENT RISK AT DECOMMISSIONING PLANTS

This memorandum documents and summarizes RES activities performed in support of a technical study of spent fuel pool accident risk at decommissioning plants. This memorandum also responds to NRR's user need request of September 11, 2000, (Reference 1) for additional RES support on this technical study.

As part of the agency's effort to develop generic, risk-informed requirements for decommissioning, RES has, and is currently supporting, NRR's generic technical study on the risk associated with spent fuel pool accidents at decommissioning plants. This study includes certain key elements including evaluations of the frequency of beyond-design-basis seismic events, thermal hydraulics, accident progression, and offsite radiological consequences. RES has supported NRR by performing detailed technical analyses in all of these areas as described below.

With regard to seismic events, NRR has requested that RES perform an independent review of the seismic part of the generic study, as well as the input from the Nuclear Energy Institute on the seismic checklist (Reference 2). RES provided comments on both the study, and on the input from the Nuclear Energy Institute (Reference 3). As part of this effort, RES also provided a review and evaluation of the seismic risk for plants using both Lawrence Livermore National Laboratory and Electric Power Research Institute hazard curves. In addition, RES made specific recommendations on practical measures to mitigate the effects of seismic vulnerability that would be adopted by the decommissioning plants. The most recent NRR user need letter (Reference 1) requests additional RES effort in this area. Specifically, this letter requests an evaluation of the conservatism and uncertainty in the treatment of seismic issues. It also requests an assessment of the most likely spent fuel pool failure modes and locations and the expected level of offsite collateral damage. As noted in the user need letter, RES has completed the evaluation of the conservatism and uncertainty, which was used to support an August 23, 2000, meeting with the Nuclear Energy Institute. RES also has completed the assessment of failure modes and locations and of offsite collateral damage (Reference 4).

With regard to thermal hydraulics and accident progression, NRR previously estimated the critical decay time using the COBRA-SFS and SHARP codes. (Critical decay time refers to the time required to ensure that natural circulation of air will keep the fuel temperatures below a specified value after a complete loss of pool coolant.) The models utilized by NRR are uniquely designed for spent fuel analysis but they rely on simplified thermal-hydraulic assumptions.

II-13

These assumptions include a constant pressure and temperature control volume above the fuel racks. To assess the validity of the thermal-hydraulic modeling assumptions used in these spent fuel heatup codes, NRR requested (Reference 5), and RES performed (References 6 and 7) integral three-dimensional calculations of the fuel heatup and natural circulation flows in the fuel pool and surrounding building after an instantaneous drain-down of the pool. RES utilized the FLUENT computational fluid dynamics (CFD) code for this purpose. The predictions focus primarily on the natural circulation flows and do not include specific models for radiation and clad oxidation energy. The three-dimensional predictions indicate significant pressure and temperature variations above and below the fuel racks. In addition, the complex flow fields predicted by FLUENT indicate that flow entrainment blocks a significant portion of the downcomer from receiving cooling flows. In another region, cooling flow to the downcomer is enhanced by the momentum of a cold plume of air. These flow phenomena, among others, can have an impact on the critical decay time. The flowfield boundary conditions in the fuel heatup models used by NRR do not account for these flow phenomena. The FLUENT predictions include critical decay time estimates at 2 fuel burnups and sensitivity studies on the major thermal-hydraulic parameters. The fuel temperatures are most sensitive to fuel burnup and ventilation rate in this study. These CFD predictions provide a data base for use in understanding the natural circulation flow behavior and its sensitivities. In addition, these results are useful for assessing the significance of the thermal-hydraulic boundary conditions applied in other spent fuel models. Similar to other code prediction, however, the assumptions and limitations (including validation) of the model must be considered when using these results. Assumptions and limitations are outlined in the Final Report (NUREG 1726).

With regard to accident progression, NRR requested a reexamination of the temperature criteria used in conjunction with the thermal hydraulic analysis to assess (a) the decay time needed to provide sufficient time to carry out an ad hoc evacuation prior to significant fission product release and (b) the critical decay time. RES has completed this reexamination (Reference 8) which concluded that appropriate temperature criteria can be prescribed, but some conservatism is unavoidable due to the lack of prototypic experimental data. This reexamination also concluded that it is essential that the analysis of spent fuel pool accidents account for all the important heat generation and heat loss mechanisms, and recommended that this be done in an integrated analysis and consistently performed for individual sequences. RES provided the results of this reexamination to your staff and subsequently presented the results to the ACRS on October 18, 2000.

With regard to consequences, NRR requested evaluations of the offsite radiological consequences of spent fuel pool accidents occurring up to one year after final reactor shutdown, and analyses of other related issues (References 9 and 10). RES has performed the requested evaluations (References 11 through 16). The objective of these evaluations was to assess the effect of one year of decay on offsite consequences to understand decommissioning risk in the staff's generic study. As such, these evaluations included consideration of the reduction in consequences associated with the reduced fission product inventory available for release and the reduced decay heat providing additional time for early evacuation. Related issues examined were the importance of cesium and ruthenium releases, the number of assemblies releasing fission products, the release fractions for each class of fission products, the plume heat content, and the plume spreading. RES concluded that the main uncertainty in these evaluations stemmed from the release fraction of ruthenium, which has a high dose per curie inhaled for its assumed chemical form of ruthenium oxide. The focus of these evaluations was for accidents occurring at one year after final shutdown.

Recently, NRR requested additional consequence evaluations using fission product inventories at 30 and 90 days and one, two, five, and ten years after final shutdown (Reference 17). The objective of these evaluations was to provide additional insight into the effect of reductions in inventory available for release on decommissioning risk. RES performed these evaluations at the requested decay times for both early and late evacuation cases. Because of the uncertainty in the ruthenium and fuel fines release fractions, two sets of evaluations were performed. The release fractions used for the first set were from the revised (NUREG-1465) source term. The release fractions used for the second set, other than those for ruthenium and fuel fines, also were from the revised source term. For this case, the ruthenium release fraction is that for a volatile fission product, and the fuel fines release fraction is that for the Chernobyl accident. RES provided the results of these evaluations to your staff and subsequently presented the results to the ACRS on October 18, 2000.

In addition to specific evaluations of seismic, thermal hydraulics, accident progression, and radiological consequence issues, RES performed an overall review of a draft version of the technical study of spent fuel pool accidents and provided comments (References 18 and 19). The most recent NRR user need letter (Reference 1) requests that RES review and comment on the final version of the technical study as well as provide technical support at upcoming ACRS and other public meetings. RES plans to perform this review and participate in the public meetings.

References:

1. User Need Request for Technical Study of Spent Fuel Pool Accident Request at Decommissioning Plants, memorandum from S. Collins to A. Thadani, September 11, 2000
2. Request of Review of Draft Technical Study of Spent Fuel Pool Accidents for Decommissioning Plants, memorandum from G. Holahan to J. Craig, August 18, 1999
3. Review of Draft Technical Study of Spent Fuel Pool Accidents for Decommissioning Plants, memorandum from J. Craig to G. Holahan, November 19, 1999
4. Response to Questions Concerning Spent Fuel Pool Seismic-Induced Failure Modes and Locations and the Expected Level of Collateral Damage, Robert P. Kennedy, September 2000
5. Technical Support for Spent Fuel Pool Heatup Analysis, memorandum from G. Holahan to T. King, April 16, 1999
6. Completion of 3D CFD Analysis for Spent Fuel Pool and Containment, memorandum from F. Eltawila to J. Wermiel, February 4, 2000
7. Final Report: Predictions of Spent Fuel Heatup after a Complete Loss of Spent Fuel Pool Coolant, memorandum form F. Eltawila to G. Holahan, June 29, 2000
8. Risk-Informed Requirements for Decommissioning, memorandum from F. Eltawila to G. Holahan, September 27, 2000
9. Technical Support for Spent Fuel Pool Zirconium Fire Consequence Analysis, memorandum from G. Holahan to T. King, March 26, 1999
10. Support for Spent Fuel Pool Accident Risk Assessment for Decommisioning Plants, memorandum from J. Hannon to F. Eltawila, December 3, 1999
11. Technical Support for Spent Fuel Pool Zirconium Fire Consequence Analysis, memorandum from C. Rossi to G. Holahan, May 25, 1999

12. Spent Fuel Pool Risk Assessment, memorandum from A. Thadani to S. Collins, November 12, 1999
13. Opportunities to Reduce Uncertainty in consequence Assessment for Spent Fuel Pool Accidents, memorandum from F. Eltawila to J. Hannon, December 10, 1999
14. Issues Related to Spent Fuel Pool Accident Analysis, memorandum from F. Eltawila to J. Hannon, January 19, 2000
15. Effect of Fission Product Inventory and Air Ingression on Spent Fuel Pool Accident Consequences, memorandum from F. Eltawila to J. Hannon and R. Barrett, March 29, 2000
16. Risk-Informed Requirements for Decommissioning, memorandum from F. Eltawila to G. Holahan, August 25, 2000
17. Consequence Calculations for Decommissioning Probabilistic Risk Assessment, memorandum from R. Barrett to J. Flack, August 25, 2000
18. Request of Review of Draft Technical Study of Spent Fuel Pool Accidents for Decommissioning Plants, memorandum from G. Holahan to T. King, August 3, 1999
19. Review of Draft Technical Study of Spent Fuel Pool Accidents for Decommissioning Plants, memorandum from T. King to G. Holahan, November 23, 1999

cc: B. Sheron, NRR
J. Strosnider, NRR
G. Holahan, RR
T. Collins, NRR
J. Hannon, NRR
R. Barrett, NRR
J. Wermiel, NRR
G. Hubbard, NRR

<u>Distribution:</u> DSARE Action Number: 2000-85
SDuraiswamy
CTinkler
CKasputys
ASummerour
JSchaperow R/F
CGrimes
CBoyd
SMSAB R/F

C:\MYFILES\Checkout\rev4.wpd

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

*See previous concurrence
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	C	SMSAB	E	AC:SMSAB	E	AD:DSARE	E
NAME	JSchaperow:mb		SArndt		JFlack		FEltawila	
DATE	10/23/00*		--/-- /00		10/26/00*		10/30/00*	
OFFICE	RES	E	RES	E	RES		RES	
NAME	MMayfield		TKing		MVFederline		ACThadani	
DATE	10/12/00*		10/12/00*		--/--/00		11/17/00*	

Template= RES-006 **Accession Number** ML003767398 **RES File Code** ______

12. Spent Fuel Pool Risk Assessment, memorandum from A. Thadani to S. Collins, November 12, 1999
13. Opportunities to Reduce Uncertainty in consequence Assessment for Spent Fuel Pool Accidents, memorandum from F. Eltawila to J. Hannon, December 10, 1999
14. Issues Related to Spent Fuel Pool Accident Analysis, memorandum from F. Eltawila to J. Hannon, January 19, 2000
15. Effect of Fission Product Inventory and Air Ingression on Spent Fuel Pool Accident Consequences, memorandum from F. Eltawila to J. Hannon and R. Barrett, March 29, 2000
16. Risk-Informed Requirements for Decommissioning, memorandum from F. Eltawila to G. Holahan, August 25, 2000
17. Consequence Calculations for Decommissioning Probabilistic Risk Assessment, memorandum from R. Barrett to J. Flack, August 25, 2000
18. Request of Review of Draft Technical Study of Spent Fuel Pool Accidents for Decommissioning Plants, memorandum from G. Holahan to T. King, August 3, 1999
19. Review of Draft Technical Study of Spent Fuel Pool Accidents for Decommissioning Plants, memorandum from T. King to G. Holahan, November 23, 1999

cc: B. Sheron, NRR
J. Strosnider, NRR
G. Holahan, RR
T. Collins, NRR
J. Hannon, NRR
R. Barrett, NRR
J. Wermiel, NRR
G. Hubbard, NRR

Distribution: DSARE Action Number: 2000-85
SDuraiswamy
CTinkler
CKasputys
ASummerour
JSchaperow R/F
CGrimes
CBoyd
SMSAB R/F

G:\SMSAB\SECYS\Schaperow\rev4.wpd

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

*See previous concurrence

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	C	SMSAB	E	AC:SMSAB	E	AD:DSARE	E
NAME	JSchaperow:mb		SArndt		JFlack		FEltawila	
DATE	10/23/00*		--/-- /00		10/26/00*		10/30/00	

OFFICE	RES	E	RES	E	RES		RES	
NAME	MMayfield		TKing		MVFederline		ACThadani	
DATE	10/12/00*		10/12/00*		/ /00		11/7/00	

Template= RES-006 Accession Number ______ RES File Code ______

14. Issues Related to Spent Fuel Pool Accident Analysis, memorandum from F. Eltawila to J. Hannon, January 19, 2000
15. Effect of Fission Product Inventory and Air Ingression on Spent Fuel Pool Accident Consequences, memorandum from F. Eltawila to J. Hannon and R. Barrett, March 29, 2000
16. Risk-Informed Requirements for Decommissioning, memorandum from F. Eltawila to G. Holahan, August 25, 2000
17. Consequence Calculations for Decommissioning Probabilistic Risk Assessment, memorandum from R. Barrett to J. Flack, August 25, 2000
18. Request of Review of Draft Technical Study of Spent Fuel Pool Accidents for Decommissioning Plants, memorandum from G. Holahan to T. King, August 3, 1999
19. Review of Draft Technical Study of Spent Fuel Pool Accidents for Decommissioning Plants, memorandum from T. King to G. Holahan, November 23, 1999

cc: B. Sheron, NRR
J. Strosnider, NRR
G. Holahan, RR
T. Collins, NRR
J. Hannon, NRR
R. Barrett, NRR
J. Wermiel, NRR
G. Hubbard, NRR

Distribution: DSARE Action Number: 2000-85
SDuraiswamy
CTinkler
CKasputys
ASummerour
JSchaperow R/F
CGrimes
CBoyd
SMSAB R/F

G:\SMSAB\SECYS\Schaperow\rev4.wpd

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

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 JHS	C	SMSAB		AC:SMSAB		AD:DSARE	
NAME	JSchaperow:mb		SArndt		JFlack		FEltawila	
DATE	10/23/00		/ /00		10/26/00		/ /00	

OFFICE	RES		RES		RES		RES	
NAME	MMayfield		TKing		MVFederline		ACThadani	
DATE	/ /00		/ /00		/ /00		/ /00	

Template= RES-006 Accession Number ________ RES File Code ________

16. Risk-Informed Requirements for Decommissioning, memorandum from F. Eltawila to G. Holahan, August 25, 2000
17. Consequence Calculations for Decommissioning Probabilistic Risk Assessment, memorandum from R. Barrett to J. Flack, August 25, 2000
18. Request of Review of Draft Technical Study of Spent Fuel Pool Accidents for Decommissioning Plants, memorandum from G. Holahan to T. King, August 3, 1999
19. Review of Draft Technical Study of Spent Fuel Pool Accidents for Decommissioning Plants, memorandum from T. King to G. Holahan, November 23, 1999

cc: BSheron, NRR
JStrosnider, NRR
GHolahan, RR
TCollins, NRR
JHannon, NRR
RBarrett, NRR
JWermiel, NRR
GHubbard, NRR

Distribution: DSARE Action Number: 2000-85
Duraiswamy
CTinkler
Kasputys
Summerour
JSchaperow R/F
Grimes
CBoyd
SMSAB R/F

G:\SMSAB\SECYS\Schaperow\rev4.wpd

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

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	C	SMSAB	E	AC:SMSAB	E	AD:DSARE	
NAME	JSchaperow:mb		SArndt		JFlack		FEltawila	
DATE	10/2/00		10/11/00		10/11/00		/ /00	
OFFICE	RES		RES	E	RES		RES	
NAME	MMayfield		TKing		MVFederline		ACThadani	
DATE	10/ /00		10/12/00		/ /00		/ /00	

Template= RES-006 Accession Number ______ RES File Code ______