UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D.C. 20555-0001

November 17, 2000

MEMORANDUM TO: ACRS Members
ACRS Staff

FROM: Medhat El-Zeftawy
Senior Staff Engineer, ACRS

SUBJECT: CERTIFIED MINUTES OF THE ACRS SUBCOMMITTEE MEETING ON REACTOR FUELS, OCTOBER 18, 2000

The proposed minutes of the subject meeting issued November 9, 2000, have been certified as the official record of the proceedings for that meeting.

Attachment:
Certified Minutes-Subcommittee Meeting on
Reactor Fuels, October 18, 2000

cc: J. Larkins, ACRS
J. Lyons, ACRS

MEMORANDUM TO: Medhat El-Zeftawy, Senior Staff Engineer
ACRS

FROM: Thomas Kress, Acting Chairman
Reactor Fuels Subcommittee

SUBJECT: CERTIFICATION OF THE MINUTES OF THE ACRS SUBCOMMITTEE MEETING ON REACTOR FUELS, OCTOBER 18, 2000- ROCKVILLE, MARYLAND

I certify that, to the best of my knowledge and belief, that the Minutes of the subject meeting issued on November 9, 2000, are accurate record of the proceedings for that meeting.

T. S. Kress

Thomas Kress, Acting Chairman

Nov. 16, 2000

Date

Issued: November 9, 2000
CERTIFIED BY: T. S. Kress - November 16, 2000

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
REACTOR FUELS SUBCOMMITTEE MINUTES
OCTOBER 18, 2000
ROCKVILLE, MARYLAND

The Advisory Committee on Reactor Safeguards (ACRS) Subcommittee on Reactor Fuels held a meeting on October 18, 2000 in Room T-2B1, 11545 Rockville Pike, Rockville, Maryland, with representatives of the NRC staff, Nuclear Energy Institute, and the Institute for Resource and Security Studies. The purpose of this meeting was to discuss the NRC staff's effort regarding the revised technical study of Spent Fuel Pool (SFP) accident risk at decommissioning nuclear power plants. The Subcommittee also heard presentations by the Nuclear Energy Institute (NEI) and Institute for Resource and Security Studies (IRSS) representatives on this matter. Dr. Medhat El-Zeftawy was the cognizant ACRS staff engineer for this meeting. The meeting was convened at 8:30 a.m. on October 18, 2000, and adjourned at 3:30 p.m.

ATTENDEES

ACRS

T. Kress, Acting Chairman
D. Powers, Member
A. Cronenberg, Fellow
R. Seale, Member
M. El-Zeftawy, Staff

NRC

G. Bagchi, NRR
E. Throm, NRR
G. Hubbard, NRR
D. Diec, NRR
D. Jackson, NRR
D. Wrona, NRR
D. Barss, NRR
C. Gratton, NRR
A. Murphy, RES
J. Strosnider, NRR
I. Schoenfeld, EDO
F. Gillespie, NRR
J. Mitchel, RES
F. Kantor, NRR
G. Tracy, NRR
R. Laufer, NRR
S. Uttal, OGC
G. Kelly, NRR
T. Collins, NRR
G. Parry, NRR
W. Huffman, NRR
P. Ray, NRR
J. Schaperow, RES
N. Chokshi, RES
S. Pullani, RES
S. La Vie, NRR
R. Palla, NRR
J. Flack, RES
S. Arndt, RES
K. Gibson, NRR
J. Beall, OCM/EM

INDUSTRY AND OTHERS

N. Goldstein, FEMA
S. Edwards, CP&L
R. Kunita, CP&L
L. Hendericks, NEI
R. Kennedy, Struct. Mech. (Consultant)
E. Wills, CP&L
A. Nelson, NEI
E. Wieser, BPI

G. Thompson, IRSS K. Green, ISL, Inc.

Dr. Gordon Thompson, IRSS, requested to make oral statement regarding this matter. A list of attendees is available in the ACRS Office and will be made available upon request.

OPENING REMARKS BY THE SUBCOMMITTEE CHAIRMAN

Dr. Thomas Kress, Acting Subcommittee Chairman, convened the meeting at 8:30 a.m. and stated that the purpose of this meeting is to discuss the NRC's staff effort regarding the revised technical study of SFP accident risk at decommissioning plants. The Subcommittee will also hear the views of NEI and IRSS representatives on this issue. Dr. Kress stated that in a Staff Requirements Memorandum dated December 21, 1999, the Commission requested the ACRS to perform a technical review of the validity and risk objectives of the draft technical study prepared by the NRC staff regarding the SFP risk assessment. During the 471th meeting of the ACRS (April 5-7, 2000), the Committee reviewed the draft technical study and issued its report to the Commission. The Committee in its report expressed its concern regarding the study and recommended the following:

- The integrated rulemaking on decommissioning should be put on hold until the staff provides the technical justification for the proposed acceptance criterion for fuel uncovery frequency. In particular, the staff needs to incorporate the effects of enhanced release of Ruthenium under air-oxidation conditions,
- The technical basis underlying the Zirconium-air interactions and the criteria for ignition needs to be strengthened. In particular, the potential impact of Zirconium-hydrides in high burnup fuel and the susceptibility of the clad to breakaway oxidation need to be addressed,
- Uncertainties in the risk assessment need to be quantified and made part of the decision-making process.

NRC STAFF PRESENTATION

Mr. Timothy Collins, NRR, stated that the staff previously prepared a draft technical study (dated February 2000) to address the SFP accident risk at decommissioning plants. In this draft study, the staff estimated that after one year following permanent shutdown, the generic frequency of events leading to Zirconium fires to be less than $3x10^{-6}$ per year for a plant that implements the design and operational characteristics assumed in the risk assessment performed by the staff. This frequency was estimated based on the assumption that the industry decommissioning commitments (IDCs) plus additional staff assumptions would be implemented. The staff recognized that this estimate could be much higher for a plant that does not implement these operational characteristics. The staff noted in the draft study that the most significant contributor to the SFP risk issue is a seismic event which exceeds the design basis earthquake. However, the staff indicated that the overall frequency of this event is within the developed SFP performance guideline for large radionuclide releases (related to Zirconium fire) of $1x10^{-5}$ per year.

On October 12, 2000, the staff completed its revision of the technical study. The revised technical study indicated that the risk at SFPs is not markedly lower than that for operating reactors especially in the earliest years after shutdown. Even though the likelihood of a Zirconium fire is very low, the consequences in terms of both the integrated dose to the public and the early fatalities can be comparable to a large early release frequency (LERF) from an operating plant during a potential severe core damage accident. The revised study indicates that the analysis of early fatality risk shows that the range of the SFP risk estimates, which address seismic, source term, and thermal hydraulic uncertainties, overlap with the range of operating reactor risk estimates during the first few years after shutdown. The analysis of latent cancer fatality risk shows that the range of possible SFP risk continues to overlap with the range of operating reactor risk until the time when ad hoc accident management recovery actions can be credited to suppress the SFP risks. The staff stated that the effects of a significant ruthenium and fuel fines release , as suggested by the ACRS, was notable, but not so important as to result in consequences for individual risk or prompt fatalities that are larger than those associated with a reactor accident large early release. Thus, the staff concluded that the original spent pool performance guideline (PPG) of $1x10^{-5}$ per year is deemed appropriate. Using either the Lawrence Livermore National Laboratory (LLNL) or the Electric Power Research Institute (EPRI) seismic hazard curve, the staff concluded that the risk is well below the Safety Goal Quantitative Health Objectives (QHO) for both the individual risk of early fatality and the individual risk of latent cancer fatality. However, the risks are not dramatically reduced relative to operating reactor risks as estimated in NUREG-1150.

Mr. Charles Tinkler, Office of Nuclear Regulatory Research, briefed the Subcommittee regarding the air-ingression and temperature criteria for analysis of SFP accidents. The staff has reevaluated appropriateness of temperature criteria considering Zr reaction kinetics, hydriding, fuel damage testing, fission product release data, and materials interactions. The staff concluded that for assessing the onset of fission product release under transient conditions, to establish the critical decay time for determining availability of 10 hours to evacuate, it is acceptable to use a temperature of 900 °C if fuel and cladding oxidation occurs in air. If steam kinetics dominate the transient heat-up case, as it would in many boildown and drain down scenarios, then a suitable temperature criterion would be around 1200 °C.. For establishing long term equilibrium conditions for fuel pool integrity during SFP accidents which preclude significant fission product release it is necessary to limit temperatures to values of 600 °C to 800 °C. Mr. Tinkler indicated that if the critical decay time is sufficiently long (more than 5 years) that Ruthenium inventories have substantially decayed, then it would be appropriate to consider the use of a higher temperature of 800 °C. Mr. Tinkler added that the degradation of fuel during SFP accidents is an area of uncertainty since most research on severe fuel degradation has focused on reactor accidents in steam environments.

Mr. Jason Schaperow, Office of Nuclear Regulatory Research, briefed the Subcommittee regarding the Consequence Assessment for SFP accidents. Mr. Schaperow stated that it was initially thought that at one year after final shutdown, the radiological consequences from a SFP accident might be negligible. If consequences were negligible, requirements for emergency planning and insurance could be eliminated. Therefore, RES performed offsite radiological consequence calculations with MACCS (for 30 days, 90 days, and 1 year after final shutdown) to quantify the consequences. The issues examined were reduced inventory (at 1 year), early vs. late evacuation (at 1 year), importance of Cesium, importance of Ruthenium, number of assemblies releasing fission products, fission product release fractions, plume heat content, plume spreading, decay times beyond 1 year, and reassessment of source term. The results of large number (about 300) of MACCS calculations were used to understand decommissioning risk in staff's generic study. The effect of reduced inventory is that early fatalities was reduced by a factor of 2 from 30 days to 1 year. The cancer fatalities and societal dose was unaffected. The effect of early evacuation is that early fatalities was reduced by up to a factor of 100, and the cancer fatalities and societal dose were unaffected.

Mr. Schaperow also discussed the effects of number of fuel assemblies releasing fission products. The original staff's calculations assumed entire SFP inventory of Millstone 1 was involved in heatup and release (3.5 cores). The revised calculations , depending on reductions in decay heat from radioactive decay, assumed less fuel may be involved in heatup. The staff performed MACCS calculations for two cases: entire SFP inventory (3.5 cores), and inventory in final core offload. Mr. Schaperow stated that the calculations showed that smaller consequence reduction for case with large ruthenium release because most ruthenium is in final core offload due to its one year half-life.

Other issues such as the effect of plume heat content was analyzed by the staff. The potential for plume heat content to be higher than that of a reactor accident was considered. The staff performed sensitivity calculations using different plume heat contents. The base case was plume heat content from NUREG-1150 (3.7 MW). The staff estimated plume heat content to be about 256 MW for complete oxidation of one core in 30 minutes. A more detailed estimate of plume heat content (about 43 MW) was performed by Sandia National Laboratory . As part of international cooperative effort on consequence assessment codes, experts provided updated values for the dispersion parameters σ_y and σ_z. Experts provided distributions instead of point estimates.

Mr. Schaperow stated that the revised technical study included atmospheric and consequence determination. Instead of relying on a LERF surrogate, the results can be directly compared with the prompt and latent fatality Safety Goals. Based on the sensitivity study, the staff adopted a revised source term with a ruthenium release fraction of 0.75 and an actinide release fraction of 0.035.

Dr. Robert Palla, NRR, briefed the Subcommittee regarding the risk analysis results and conclusion. He stated that for the first 1 to 2 years, the early fatality risk for a SFP fire is comparable to that for a severe accident in an operating reactor. At 5 years following shutdown, the early fatality risk for SFP accidents is approximately two orders of magnitude lower than for a reactor accident. Societal risk for a SFP fire is also comparable to that for a severe accident in an operating reactor, and does not exhibit a substantial reduction with time due to the slow decay of somefission products. Changes to emergency preparedness requirements affect only the cask drop accident, and do not substantially impact either the total risk or the margin between SFP risk and operating reactor risk due to the low frequency of cask drop accidents.

Dr. Palla stated that the revised technical study used a less conservative method that made use of a typical high confidence of low probability of failure (HCLPF) for a plant. The staff combined the HCLPF with both the LLNL and EPRI seismic hazard curves to estimate the seismic risk. Both the individual early fatality risk and the individual latent cancer fatality risk are about 1 to 2 orders of magnitude lower than the Commission's Safety Goal, depending on assumptions regarding the SFP accident source term and seismic hazard:

- At upper end (LLNL seismic hazard estimates and high ruthenium source term) the risks are somewhat lower than the corresponding risks for reactor accidents, and about a decade lower than the Safety Goal.

- At lower end (EPRI seismic hazard estimates and low ruthenium source term) the risks are lower than those for reactor accidents, and about 2 decades lower than the Safety Goal.

The staff stated that a lower zirconium ignition temperature would shorten the time to a release, but this was found not to be significant in early years because of the already short times available. Partial drain down scenarios result in restricted air flow which can be important to insurance considerations. The staff summarized its findings as follows:

- The risk at decommissioning plant SFPs is low, but within the range of operating reactor risk for at least the first few years after shutdown

- Relaxation of offsite emergency planning a few months after shutdown results in a small change in risk and is consistent with staff guidelines for small changes in risk

- Insurance requirements could be considered as a function of time available for implementation of accident management measures, but are not recommended in the first five years

- As long as spent fuel is present in the SFP, some level of safeguards and security is necessary

- Research regarding source term generation in an air environment is recommended.

NEI PRESENTATION

Ms. Lynnette Hendricks briefed the Subcommittee regarding industry views on risk informing decommissioning regulations. She stated that the industry envision the use of risk insights to adapt deterministic rules for operating plants to decommissioning plants. The Commission principles on risk informing must be adapted to address different types of consequences, lower probability, and different type of system (e.g., passive, robust, slowly evolving sequences).

Ms. Hendricks noted that best estimates should be used, and consequences should not be based on phenomena that have not been validated through NRC's severe accident program. She added that more efforts should be devoted to probability side of risk equation, and if probability of SFP fire is acceptably low there are diminishing returns on efforts to refine consequences.

Industry characterizes huge seismic events that are background risk factors for operating plants to dominate risk profile for decommissioning plants. In addition, seismic risk should be treated in the same manner for decommissioning plants as for operating plants.

In conclusion, Ms. Hendricks stated the following:

- Bounding estimate of seismic risk should not be used to justify retention of operating plants requirements intended for a much broader scope of initiating events,

- Overly conservative treatment of seismic risk leads to conclusion that operating plant requirements should be retained,

- Opportunities to apply practical risk insights are lost if operating plant requirements are retained,

- Speculative phenomena should not be used to determine consequences.

IRSS PRESENTATION

Dr. Gordon Thompson, IRSS, stated that the potential for pool fires could be almost completely eliminated by storing spent fuel using a combination of low-density pool storage and dry storage. The potential for a runaway exothermic reaction of cladding in a high-density spent fuel pool, following water loss, has been known since the late 1970's. Dr. Thompson indicated that the potential for a pool fire can exist at any high-density pool but may be especially significant for pools at operating plants due to the presence of recently discharged fuel with a high decay heat and the potential for a reactor accident to initiate a pool accident. Dr. Thompson stated the following:

- Pool fires have not been studied to the same extent as reactor accidents (e.g., NUREG-1150, IPEs)

- There are major gaps in knowledge about the probability of pool fires, their phenomenology, and their consequences.

- Pool fires deserve attention because they could contaminate large areas of land with comparatively long-lived radioisotopes (Cesium-137), leading to significant health and economic impacts.

- Pools generally have a low inventory of short-lived radioisotopes, and as a result pool fires would generally have a comparatively low potential for causing early fatality.

Dr. Thompson cited the NRC Safety Goals , " Societal risks to life and health from nuclear power plant operation should be comparable to or less than the risks of generating electricity by viable competing technologies and should not be a significant addition to other societal risks". Dr. Thompson stated that the NRC staff's analysis has not addressed land contamination, which is the most important indicator of pool risk, and accordingly the analysis does not provide a credible basis for decisionmaking.

In conclusion, Dr. Thompson provided the following steps:

- The NRC should declare a moratorium on any decisions or licensing actions that could increase the risk of a radioactive release from any spent fuel pool, pending the completion of new studies on pool accident risk.

- The NRC should perform studies and supporting experiments, to at least the depth of NUREG-1150, on the probability of pool fires, their phenomenology, and their consequences (for operating plants, this work should address interactions between reactor accidents and pool fires)

- Licensees should be required to extend IPEs and IPEEEs to address pool fires.

Subcommittee Discussion and Follow-up

- The Subcommittee members indicated that regulatory decisions related to SFP should not be based solely on individual risk of prompt fatalities and the individual cancer risk. Societal risk (total death), injuries, and land contamination may become more important consequences than individual prompt and latent fatalities. The revised technical study provided adequate basis for decisions on EP requirements at decommissioning plants.

- The NRC staff, NEI and IRSS representatives will brief the Full Committee on November 2, 2000 regarding this issue.

Background material provided to the Subcommittee

On October 12, 2000, the NRC staff provided the Subcommittee with a copy of the revised Technical Study.

Presentation Slides and Handouts Provided during the Subcommittee Meeting

The presentation slides and handouts used during the meeting are available in the ACRS Office files or as attachments to the meeting transcripts.

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NOTE: ACRS Subcommittee meeting agenda and transcripts are available for downloading or reviewing on the Internet at http://www.nrc.gov/ACRSACNW.

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON REACTOR FUELS

OCTOBER 18, 2000
Today's Date

ATTENDEES - PLEASE SIGN BELOW

PLEASE PRINT

NAME	AFFILIATION
NANCY GOLDSTEIN	FEMA
Robert Kennedy	Struct. Mech. Consult.
STEVEN Edwards	Carolina Power & Light
EDWARD WILLS	CAROLINA POWER & LIGHT
ROBERT KUNITA	CAROLINA POWER & LIGHT
Alan Nelson	NEI
Lynnette Hendricks	NEI
Eric Wiesler	BPI
Kathy Halvey Gibson	NRR ✓
GORDON THOMPSON	IRSS
Glenn Tracy	NRR ✓
JIM BEALL	OCM/EM ✓
Rich Lanfer	NRR ✓
Kim Green	ISL, Inc.

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON REACTOR FUELS

OCTOBER 18, 2000
Today's Date

NRC STAFF SIGN IN FOR ACRS MEETING

PLEASE PRINT

NAME	BADGE #	NRC ORGANIZATION
~~GOLDSTEIN~~		
Goutam Bagchi	B8626	DE/NRR
Susan Uttal		OGC
Edward D Throm	B7179	NRR/DSSA/SPSB
Glenn Kelly		NRR/DSSA/SPSB
George Hubbard	B 6279	NRR/DSSA/SPLB
Tim Collins	A-7568	NRR/DSSA
David Diec		NRR
Gareth Parry	B8060	NRR/DSSA
Diane Jackson	B-8592	NRR/DSSA
Bill Huffman	B-8097	NRR/DLPM
DAVID WRONA	B-8701	NRR/DLPM
Phillip Ray	B 6977	NRR/DLPM
Dan Barss	A-6041	NRR/DLPM
J. Schaperow	B-7363	RES
C. Grattan	B6180	NRR
N. Chokshi	B6495	RES
A. Murphy	B8400	RES
S. PULLANI	B-8414	RES
J. Staudenmeier	B-7661	NRR
S. LANE	B 8172	NRR

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON REACTOR FUELS

OCTOBER 18, 2000
Today's Date

NRC STAFF SIGN IN FOR ACRS MEETING

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NAME	BADGE #	NRC ORGANIZATION
Isabelle Schoenfeld	B6983	EDO
ROBERT PALLA	B-6891	NRR
Frank Gillespie	A6876	NRR
JOHN FLACK	B-6114	RES
Jocelyn Mitchell	B6685	RES
STEVEN ARNDT	B-8396	RES
F KANTOR	B6350	NRR

NRR STAFF PRESENTATION TO THE ACRS

SUBJECT: Risk Analysis Results and Conclusions

DATE: October 18, 2000

PRESENTER: Robert L. Palla

TITLE/ORG: Sr. Reactor Engineer
Probabilistic Safety Assessment Branch
Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation

TELEPHONE: 415-1095

Risk Characterization

- Risk for each accident estimated based on frequency of fuel uncovery and SFP consequence estimates
- Fuel uncovery assumed to result in SFP fire (large release)
- Consequences assigned based on either early or late evacuation cases, depending on factors affecting EP
  - effectiveness of offsite notification
  - fission product release times relative to evacuation times
- Evacuation modeled as follows:

Event	Full EP	Relaxed EP
Seismic	Late	Late
Cask Drop	Early (for t > 4-5 h)	Early (for t > 10 h)
Boildown	Late	Late

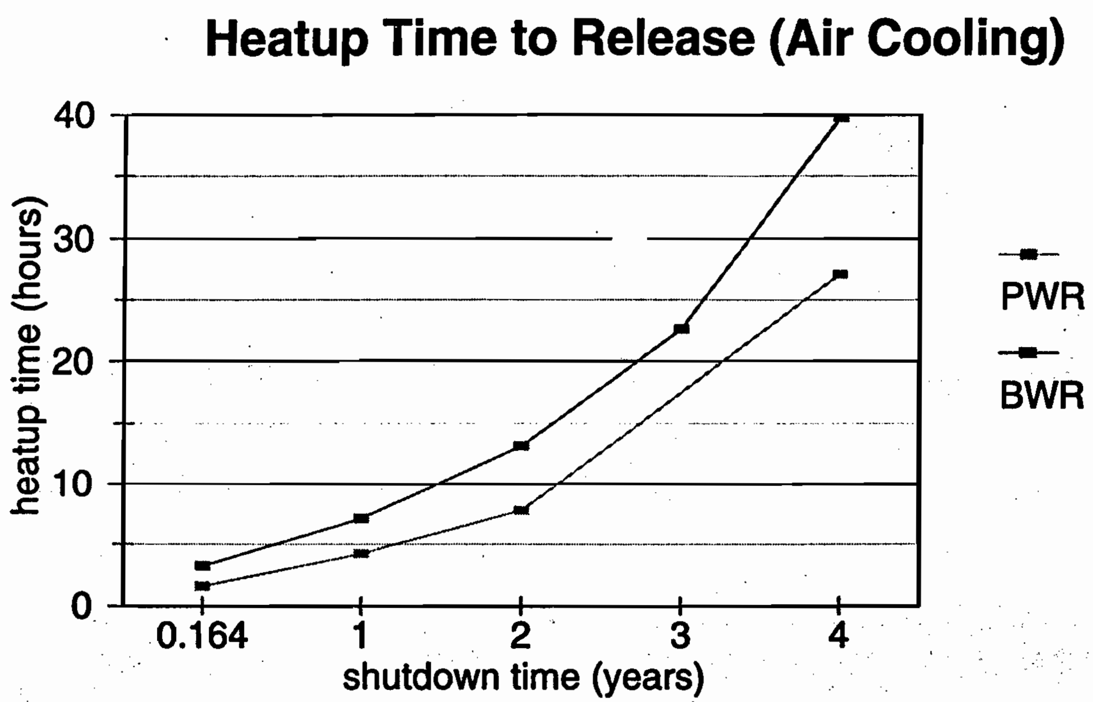


Figure 2.1 Heatup time from 30 °C to 900 °C

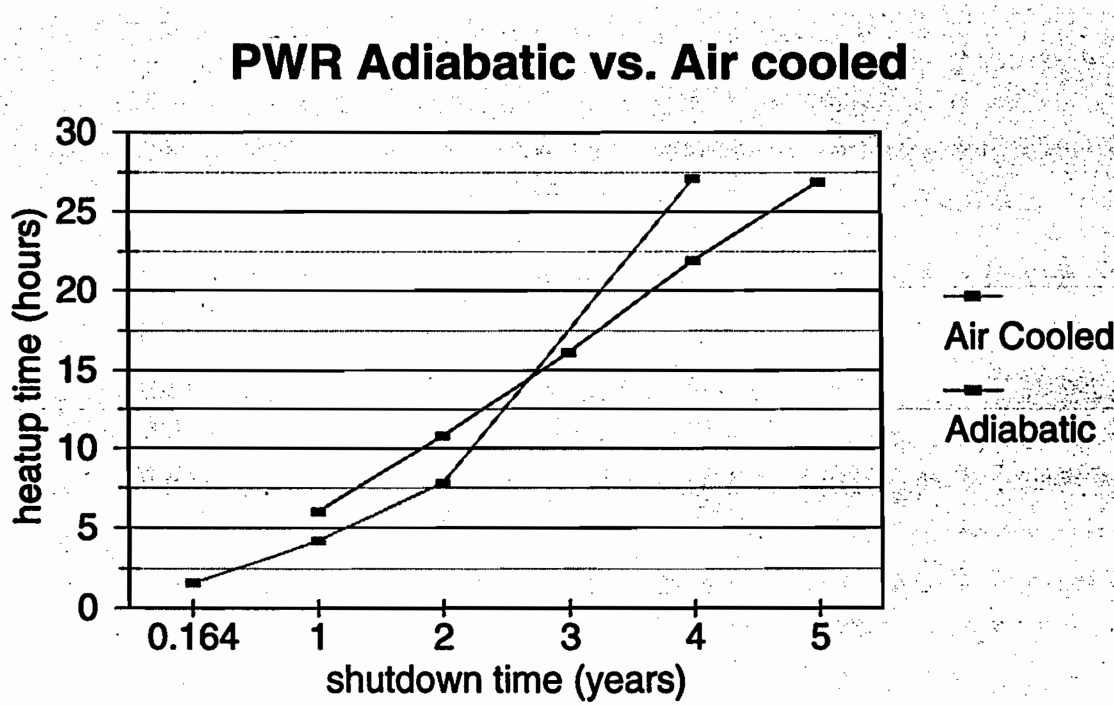


Figure 2.2 PWR heatup times for air cooling and adiabatic heatup.

Rationale for Evacuation Modeling

- **Seismic**
  - for ground motion corresponding to SFP failure, there would be extensive collateral damage within the emergency planning zone (electric power, structures, roads, bridges)
  - radiological pre-planning would have marginal impact because of impairment by offsite damage

- **Cask Drop**
  - unambiguous indication of event; intact infrastructure for emergency response
  - Full EP: evacuation credited when > 4-5 hours delay time (1 year after shutdown and beyond)
  - Relaxed EP: evacuation credited when > 10 hours delay time (5 years after shutdown and beyond)

- **Boildown**
  - failure paths involve failure to acquire offsite resources to provide SFP makeup
  - failure to contact offsite authorities or implement effective response also expected for the same reasons

Sensitivity of Early Fatality Risk to Emergency Planning -- Cask Drop Event

(Conditional upon: High Ruthenium Source Term)

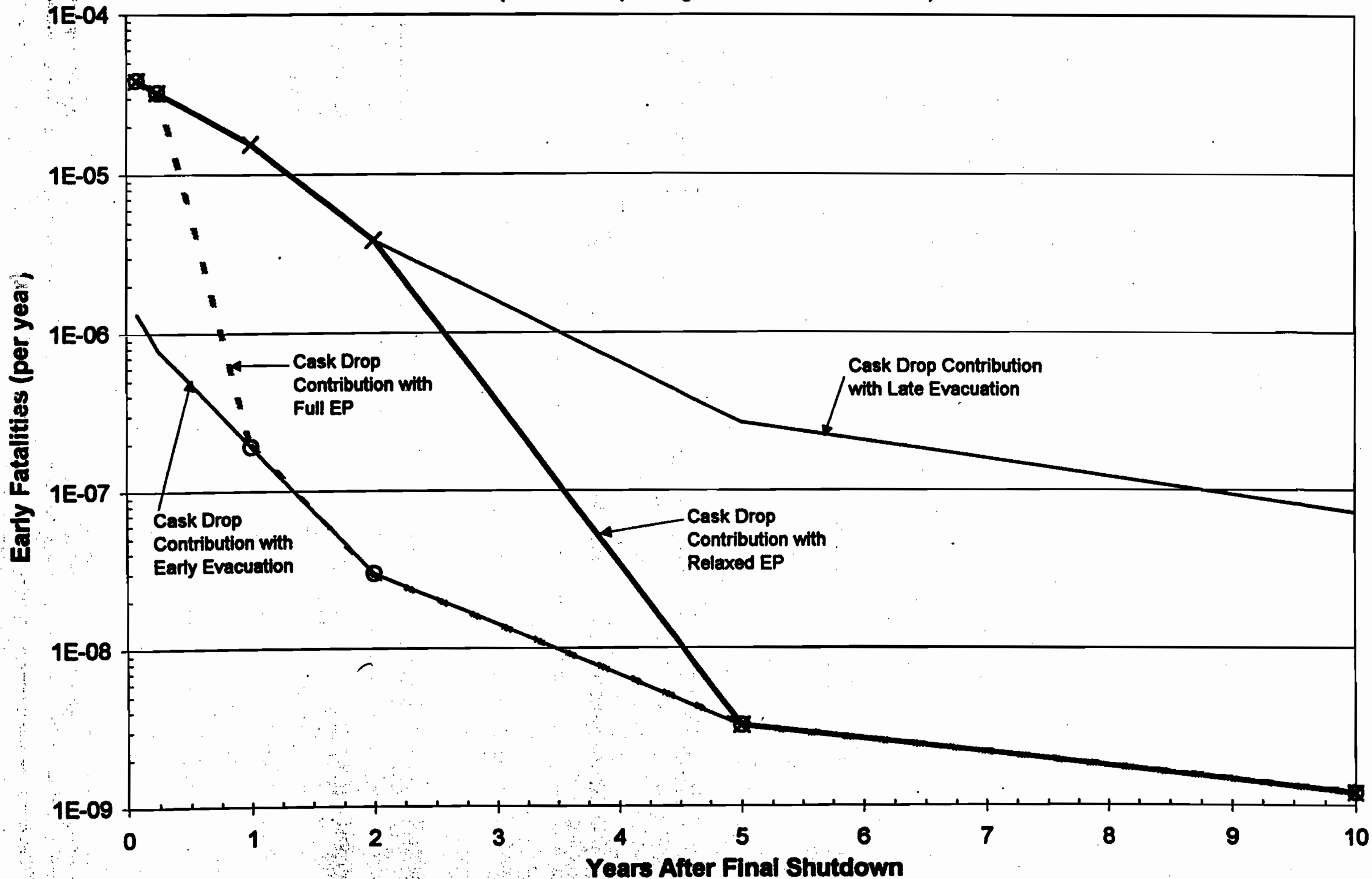
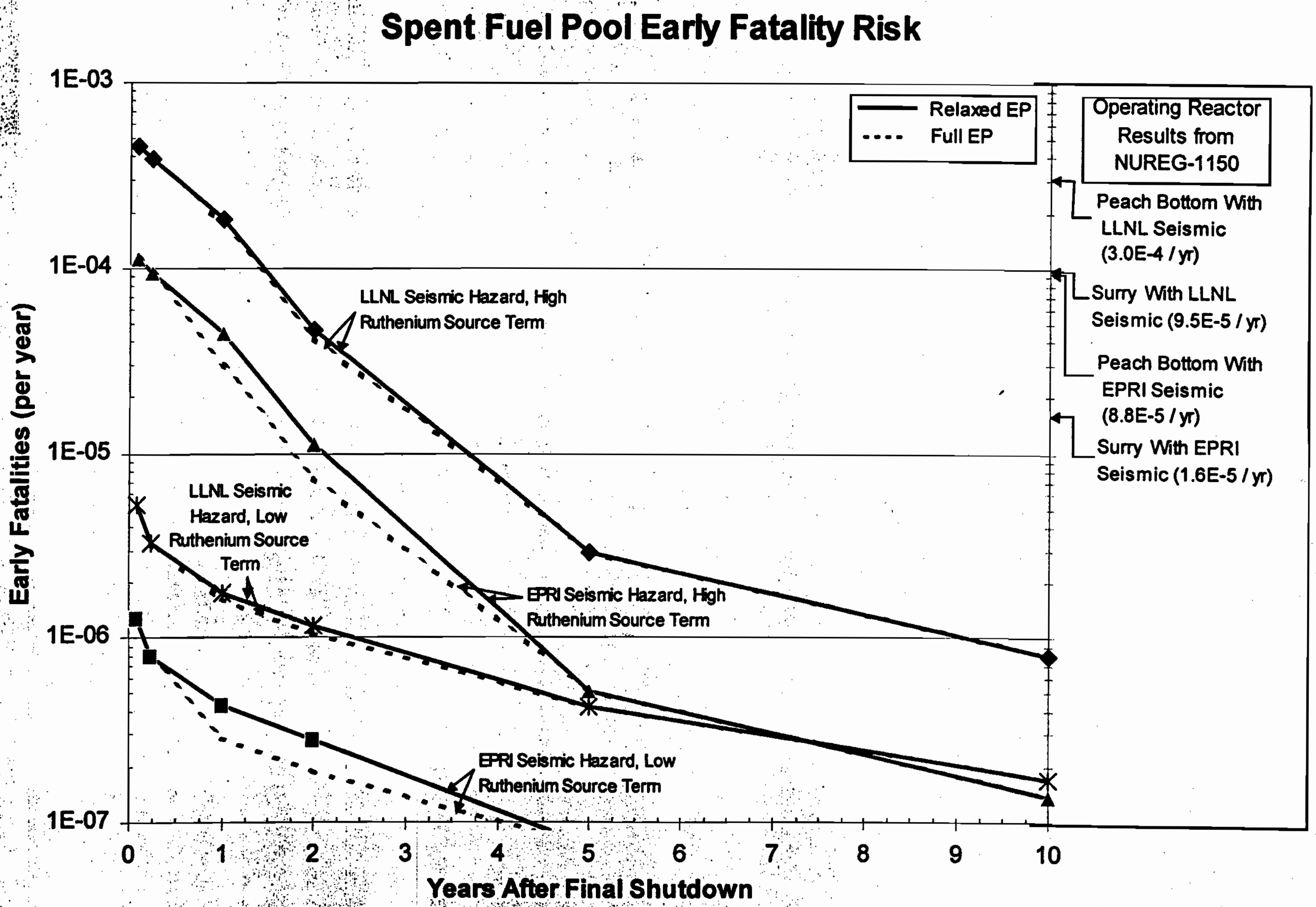


Figure 3.7-5



Spent Fuel Pool Early Fatality Risk
1E-03
1E-04
1E-05
1E-06
1E-07
Early Fatalities (per year)
0
1
2
3
4
5
6
7
8
9
10
Years After Final Shutdown
Relaxed EP
Full EP
Operating Reactor Results from NUREG-1150
Peach Bottom With LLNL Seismic (3.0E-4 / yr)
Surry With LLNL Seismic (9.5E-5 / yr)
Peach Bottom With EPRI Seismic (8.8E-5 / yr)
Surry With EPRI Seismic (1.6E-5 / yr)
LLNL Seismic Hazard, High Ruthenium Source Term
LLNL Seismic Hazard, Low Ruthenium Source Term
EPRI Seismic Hazard, High Ruthenium Source Term
EPRI Seismic Hazard, Low Ruthenium Source Term

Figure 3.7-3

Spent Fuel Pool Societal (Person-rem) Risk

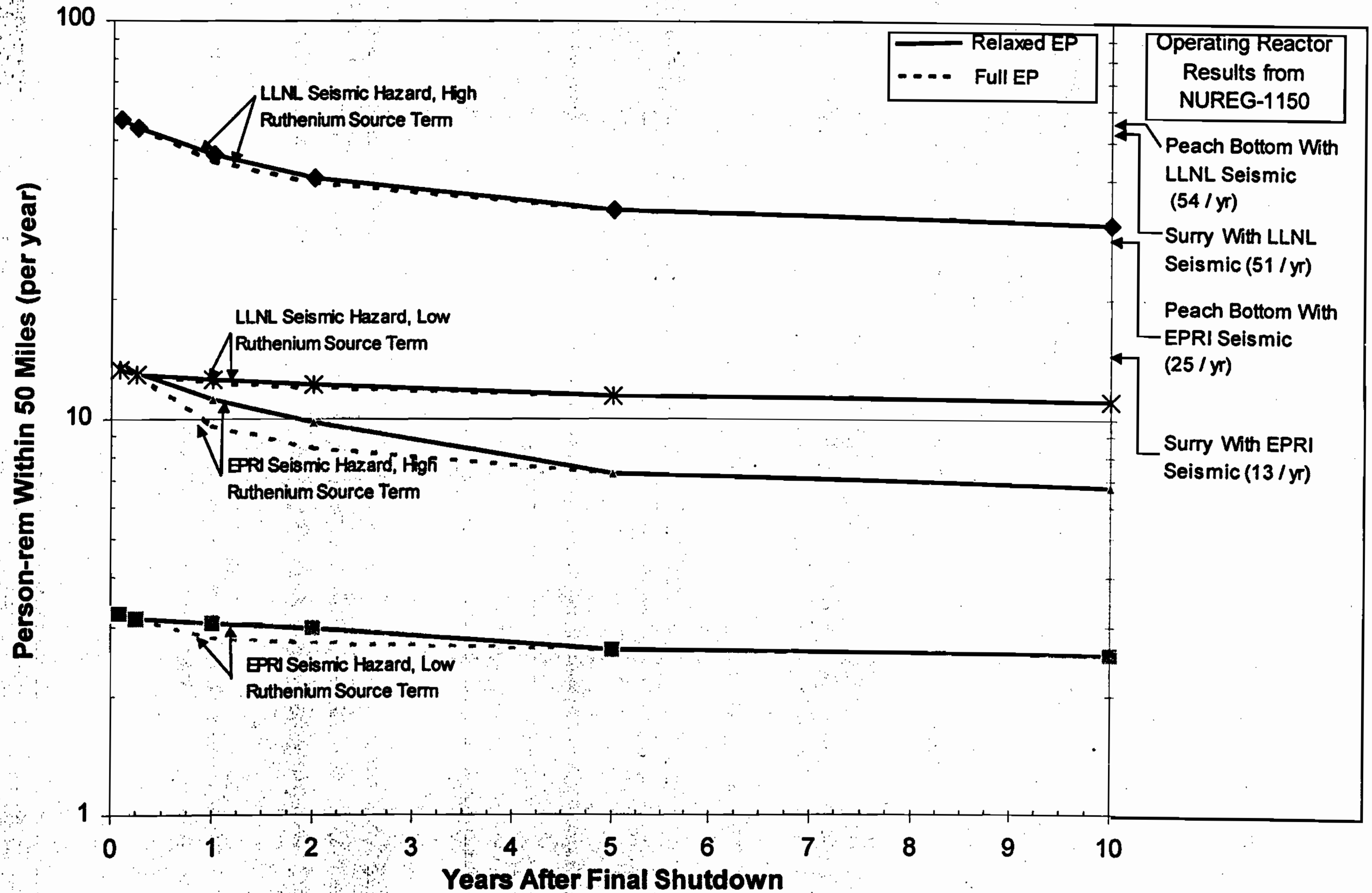


Figure 3.7-4

Risk Conclusions

- For the first 1 to 2 years, the early fatality risk for a SFP fire is low, but comparable to that for a severe accident in an operating reactor. At 5 years following shutdown, the early fatality risk for SFP accidents is approximately two orders of magnitude lower than for a reactor accident

- Societal risk for a SFP fire is also comparable to that for a severe accident in an operating reactor, but does not exhibit a substantial reduction with time due to the slower decay of fission products and the interdiction modeling assumptions that drive long term doses

- Changes to EP requirements affect only the cask drop accident, and do not substantially impact either the total risk or the margin between SFP risk and operating reactor risk due to the low frequency of cask drop accidents

Risk Conclusions (continued)

- Use of the low ruthenium source term reduces early fatality risk by about a factor of 100 (relative to the high ruthenium source term) within the first 1 to 2 years, and by about a factor of 10 at 5 years and beyond
- With the low ruthenium source term, the early fatality risk for SFP accidents is about an order of magnitude lower than the corresponding values for a reactor accident shortly following shutdown, and about two orders of magnitude lower at 2 years following shutdown
- With the low ruthenium source term, the societal risk for SFP accidents is also about an order of magnitude lower than the corresponding values for a reactor accident shortly following shutdown, but does not exhibit a substantial reduction with time due to the slower decay of fission products and the interdiction modeling assumptions
- The above observations are valid regardless of whether seismic event frequencies are based on the LLNL or the EPRI seismic hazard study.

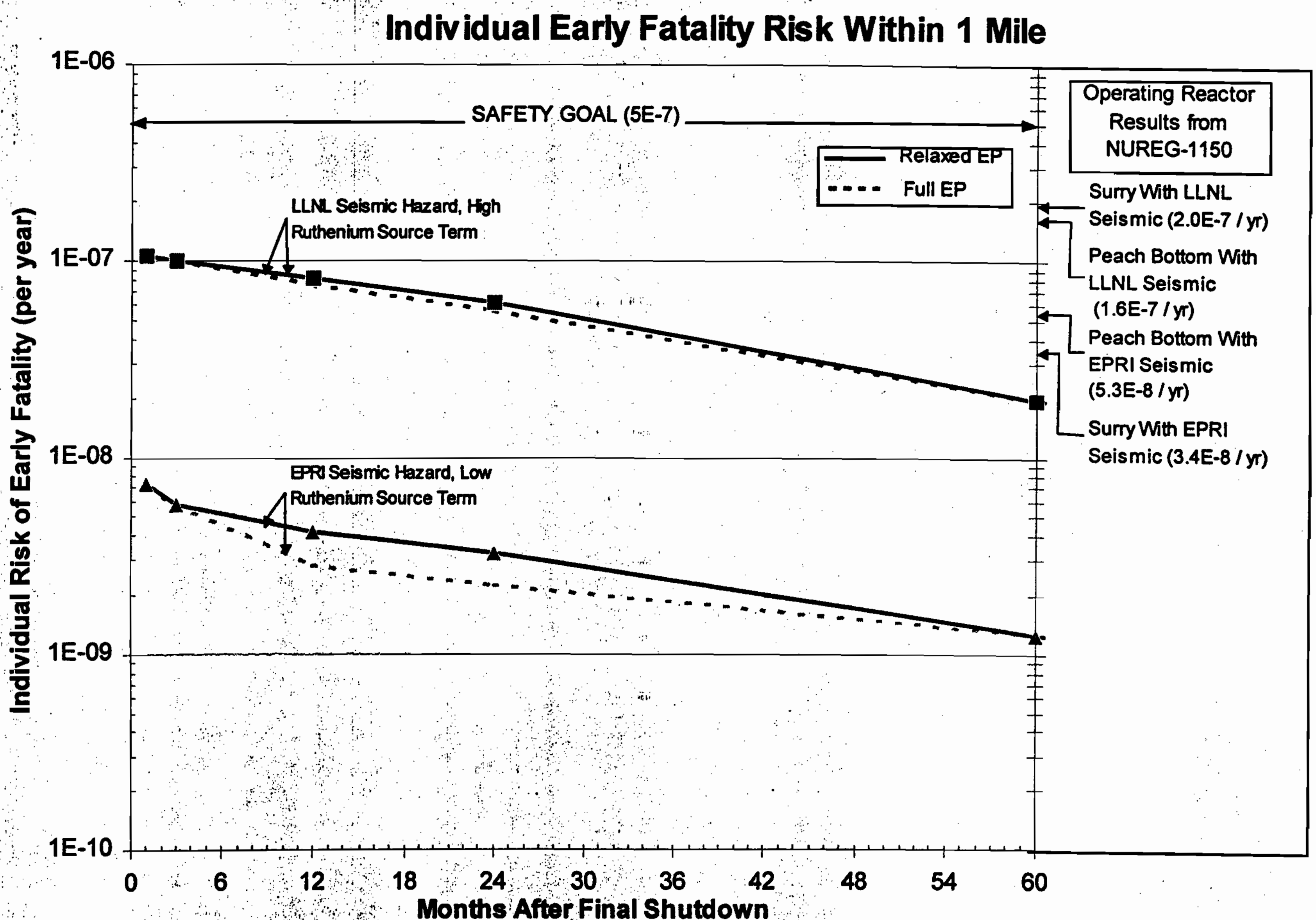
Comparisons to the Safety Goals

- Both the Individual Early Fatality Risk and the Individual Latent Cancer Fatality Risk for a SFP accident are about one to two orders of magnitude lower than the Commission's Safety Goal, depending on assumptions regarding the SFP accident source term and seismic hazard
  - At upper end (LLNL seismic hazard estimates and high ruthenium source term) the risks are somewhat lower than the corresponding risks for reactor accidents, and about a decade lower than the Safety Goal
  - At lower end (EPRI seismic hazard estimates and low ruthenium source term) the risks are lower than those for reactor accidents, and about 2 decades lower than the Safety Goal

- The Individual Early Fatality Risk for a SFP accident decreases with time, and is about a factor of 5 lower at 5 years following shutdown (relative to the value at 30 days)

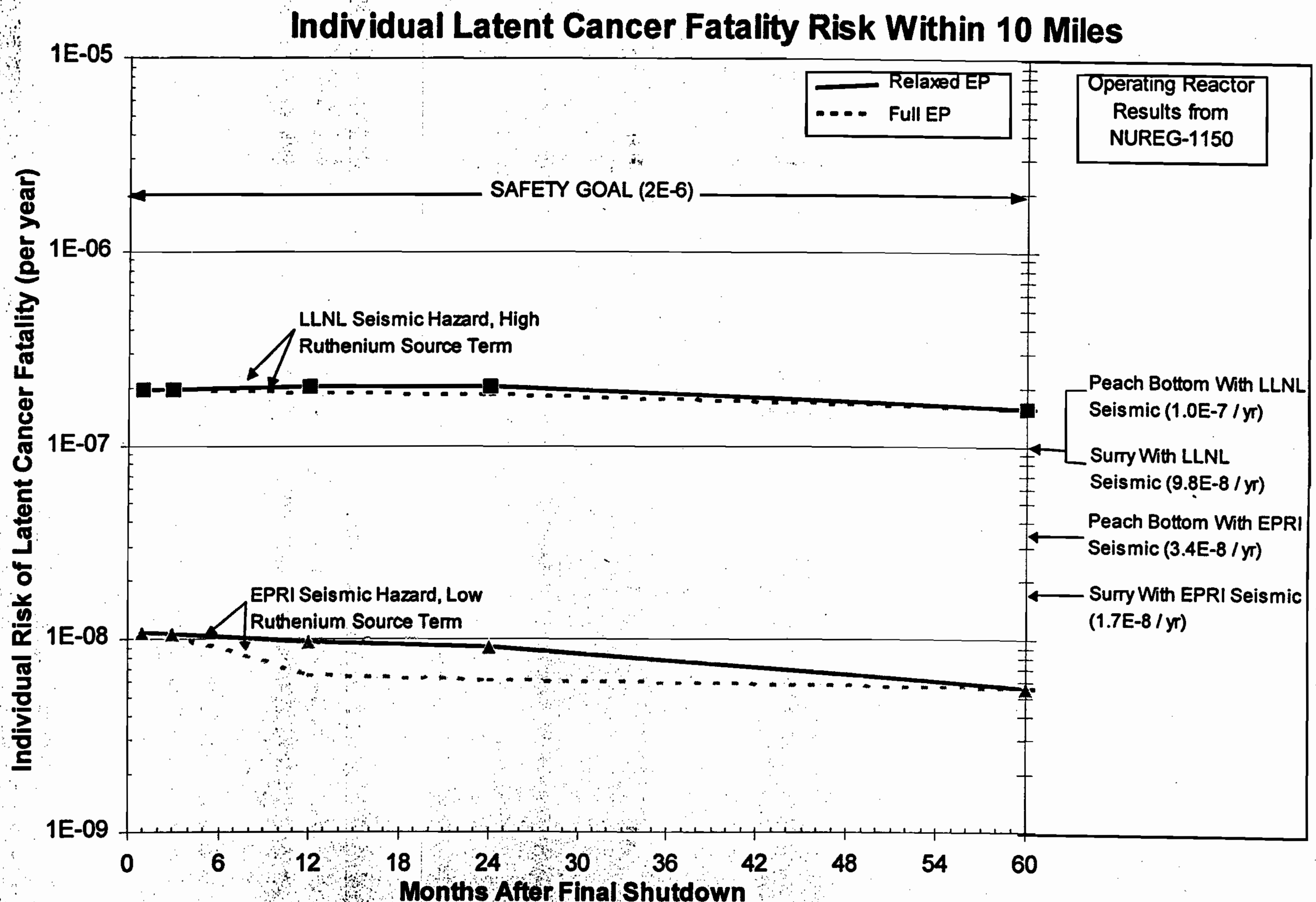
- The Individual Latent Cancer Fatality Risk is not substantially reduced with time due to the slower decay of fission products and the interdiction modeling assumptions that drive long term doses

- Changes to EP requirements, as modeled, do not substantially impact the margin between SFP risk and the Safety Goals due to the low frequency of events for which EP would be effective



Individual Early Fatality Risk Within 1 Mile
Individual Risk of Early Fatality (per year)
1E-06
1E-07
1E-08
1E-09
1E-10
SAFETY GOAL (5E-7)
Relaxed EP
Full EP
LLNL Seismic Hazard, High Ruthenium Source Term
EPRI Seismic Hazard, Low Ruthenium Source Term
Operating Reactor Results from NUREG-1150
Surry With LLNL Seismic (2.0E-7 / yr)
Peach Bottom With LLNL Seismic (1.6E-7 / yr)
Peach Bottom With EPRI Seismic (5.3E-8 / yr)
Surry With EPRI Seismic (3.4E-8 / yr)
0
6
12
18
24
30
36
42
48
54
60
Months After Final Shutdown

Figure 3.7-7



Individual Latent Cancer Fatality Risk Within 10 Miles
1E-05
1E-06
1E-07
1E-08
1E-09
Individual Risk of Latent Cancer Fatality (per year)
Relaxed EP
Full EP
Operating Reactor Results from NUREG-1150
SAFETY GOAL (2E-6)
LLNL Seismic Hazard, High Ruthenium Source Term
EPRI Seismic Hazard, Low Ruthenium Source Term
Peach Bottom With LLNL Seismic (1.0E-7 / yr)
Surry With LLNL Seismic (9.8E-8 / yr)
Peach Bottom With EPRI Seismic (3.4E-8 / yr)
Surry With EPRI Seismic (1.7E-8 / yr)
0
6
12
18
24
30
36
42
48
54
60
Months After Final Shutdown

Figure 3.7-8

Comparison to RG 1.174 Principles
1. Small Increases in Risk

- A SFP facility that conforms with IDCs and SDAs would meet the QHOs by one to two orders of magnitude shortly after shutdown, and with greater margins at later times

- Risk increases associated with EP relaxations are small, even under optimistic assumptions regarding the value of EP in seismic events, and the QHOs continue to be met with margin

- Continued conformance with IDCs and SDAs provides reasonable assurance that the SFP risk and risk increases associated with regulatory changes would remain small

Table 4 - Comparison of Risk Increase with RG 1.174 Guideline (at one year)

Risk Measure	Risk Increase Due to EP Relaxation (per year)		RG 1.174 Guideline Risk Increase (per year)
	Baseline [1]	Seismic Sensitivity [2]	
Early Fatalities	$1.5x10^{-5}$	$1.6x10^{-4}$	$2.5x10^{-4}$
Population Dose	1.6	17.6	11
Individual Early Fatality Risk	$6.6x10^{-9}$	$7.3x10^{-8}$	$8.7x10^{-8}$
Individual Latent Cancer Fatality Risk	$1.6x10^{-8}$	$1.8x10^{-7}$	$6.9x10^{-8}$

1 - Assumes no effective evacuation in seismic events, regardless of pre-planning
2 - Assumes maximum effectiveness of emergency planning (i.e., early evacuation) when EP requirements are maintained, and minimum effectiveness (i.e., late evacuation) when EP requirements are relaxed

Comparison to RG 1.174 Principles
2. Defense-in-Depth

- Remaining EP requirements, together with the substantial amount of time available for emergency response will provide a sufficient level of defense-in-depth for SFP accidents

- In the large seismic events that dominate SFP risk, current EP would be of marginal value due to extensive collateral damage offsite. Accordingly, relaxations in EP requirements are not expected to substantially alter the outcome from such a large seismic event

- In those sequences in which current EP would be effective, such as cask drop accidents, a comparable level of protection should continue to be provided though remaining requirements for on-site EP and the capability to implement offsite protective actions on an ad hoc basis.

Comparison to RG 1.174 Principles
3. Safety Margins

- A SFP facility that conforms with IDCs and SDAs would meet the QHOs by one to two orders of magnitude shortly after shutdown, and with greater margins at later times

- A SFP facility maintained at or below the recommended PPG would continue to meet the QHOs for even the most severe source term.

- The estimated risk increases associated with the EP relaxations are well below the values developed from the RG 1.174 LERF criteria (by about a factor of 10)

- Even under optimistic assumptions regarding the value of EP in seismic events, the change in risk associated with EP relaxations is relatively small
  - increases in early fatalities and individual early fatality risk remain below the maximum allowable for each risk measure
  - population dose and individual latent cancer fatality risk are about a factor of two higher than the allowable value inferred from RG 1.174, however, the increase in individual latent cancer risk represents less than 10 percent of the QHO

Comparison to RG 1.174 Principles
4. Monitoring Program

- The following monitoring should continue following decommissioning in order to assure SFP risk remains low:
  - Performance and reliability monitoring of the SFP systems, heat removal, AC power and inventory should be carried out similar to the provisions of the maintenance rule (10 CFR 50.65)
  - The current monitoring programs identified in licensee's responses to Generic Letter 96-04 with respect to monitoring of the Boraflex absorber material should be maintained by decommissioning plants until all fuel is removed from the SFP (SDA #7)
  - Heavy load activities and load paths should be monitored and controlled by the licensee (IDC # 1)
  - Licensees should continue to provide a level of onsite capabilities to assure prompt notification of offsite authorities, characterization of potential releases, development of protective action recommendations and communication with the public. These capabilities should be monitored by holding periodic onsite exercises and drills
- Continued compliance with the maintenance rule, the IDCs, and the SDAs, together with remaining requirements related to onsite EP provides a reasonable level of monitoring of SFP safety

Pool Performance Guideline (PPG)

- PPG provides threshold for controlling risk from decommissioning plant SFP
- PPG of 1E-5/y proposed in February 2000 report was reassessed in view of SFP source term issues
- Based on further evaluation, PPG of 1E-5/y is appropriate -- by maintaining fuel uncovery frequency less than PPG:
  - zirconium fires remain unlikely
  - risk will continue to meet Commission's Safety Goals
  - small increases in risk may be permitted
- Plants that conform with Industry Decommissioning Commitments (IDCs) and Staff Decommissioning Assumptions (SDAs) will have SFP accident frequencies consistent with reference plant analysis and meet PPG (with exception of high seismic sites)
- Plants that do not meet IDCs and SDAs (including high seismic sites) would need to demonstrate compliance with PPG on plant-specific basis

Comparison of Spent Fuel Pool Accident Risk One Year After Shutdown with Quantitative Health Objectives (QHOs)

Case	QHO for Individual Risk of Prompt Fatality					QHO for Societal Risk of Latent Cancer Fatality				
	Ind. Early Fatality Risk (per event)	PPG (events per year)	Prob of Early Fatality (per year)	QHO (per year)	% of QHO	Ind. Latent C. Fatality Risk (per event)	PPG (events per year)	Prob of Latent C. Fatality (per year)	QHO (per year)	% of QHO
Low Ruthenium Source Term, Early Evacuation	5.44E-4	1E-5	5.44E-9	5E-7	1	9.09E-4	1E-5	9.09E-9	2E-6	<1
Low Ruthenium Source Term, Late Evacuation	7.13E-3	1E-5	7.13E-8	5E-7	14	1.68E-2	1E-5	1.68E-7	2E-6	8
High Ruthenium Source Term, Early Evacuation	1.50E-3	1E-5	1.50E-8	5E-7	3	4.33E-3	1E-5	4.33E-8	2E-6	2
High Ruthenium Source Term, Late Evacuation	3.46E-2	1E-5	3.46E-7	5E-7	69	8.49E-2	1E-5	8.49E-7	2E-6	42
Worst Source Term in App. 4A, Late Evacuation	3.66E-2	1E-5	3.66E-7	5E-7	73	5.16E-2	1E-5	5.16E-7	2E-6	26

Consequence Assessment for Spent Fuel Pool Accidents

Presentation to the Advisory Committee on Reactor Safeguards

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October 18, 2000

Overview

As a result of radioactive decay:

- lower inventory available for release from spent fuel.
- lower decay heat, providing time for early evacuation.

It was initially thought that at one year after final shutdown the radiological consequences from a spent fuel pool accident might be negligible.

If consequences were negligible, requirements for emergency planning and insurance could be eliminated.

Therefore, performed offsite radiological consequence calculations with MACCS to quantify the consequences.

Overview (cont.)

Issues examined

- reduced inventory (at 1 year)
- early vs. late evacuation (at 1 year)
- importance of cesium
- importance of ruthenium
- number of assemblies releasing fission products
- fission product release fractions
- plume heat content
- plume spreading
- decay times beyond 1 year
- reassessment of source term

Results of large number of MACCS calculations were used to understand decommissioning risk in staff's generic study.

Consequence Assessment

Original objective: evaluate effect of one year of decay on offsite consequences

- **reduced inventory available for release**
- **reduced decay heat (i.e., early vs. late evacuation)**

Summary of approach

Update of spent fuel pool accident study in NUREG/CR-4982 (GSI-82)

Used the MACCS consequence code with fission product inventories for 30 days, 90 days, and 1 year after final shutdown

Source Term	Release Fractions								
	noble gases	iodine	cesium	tellurium	strontium	barium	ruthenium	lanthanum	cerium
NUREG/CR-4982	1	1	1	.02	.002	.002	$2x10^{-5}$	$1x10^{-6}$	$1x10^{-6}$

Representative Results

Decay Time Prior to Accident	Mean Consequences for Surry Population Density (0-100 miles)		
	Early Fatalities	Societal Dose (rem)	Cancer Fatalities
30 days	1.75	4.77×10^6	2,460
1 year	1.01	4.54×10^6	2,320
1 year[a]	.0048	4.18×10^6	1,990

[a]Based on early evacuation.

Conclusions

Effect of reduced inventory

- **Early fatalities reduced by about a factor of 2 from 30 days to 1 year.**
- **Cancer fatalities and societal dose unaffected.**

Effect of reduced decay heat (early evacuation)

- **Early fatalities reduced by up to a factor of 100.**
- **Cancer fatalities and societal dose unaffected.**

Effect of Cesium

As a follow-up, evaluated the impact of cesium to better understand why consequence reduction from a year of decay not greater.

Cesium release fraction: 1.0
Cesium half-lives: Cs-134, 2 years; Cs-136, 13 days; Cs-137, 30 years

Decay Time Prior to Accident	Mean Consequences for Surry Population Density (0-100 miles)		
	Early Fatalities	Societal Dose (rem)	Cancer Fatalities
1 year	1.01	4.54×10^6	2,320
1 year (without cesium)	0.00	1.46×10^5	42

Effect of Ruthenium

Small-scale Canadian tests with an air environment showed significant ruthenium release following cladding oxidation.

MACCS calculations show that release of all ruthenium increases early fatalities by a factor of 20 to 100, because the assumed form (oxide) has a large dose per Ci inhaled due to its long clearance time from the lung.

Mitigating factors for ruthenium releases in spent fuel pool accidents

- **rubbling of the fuel limits air ingression**
- **1 year half-life of ruthenium**

PHEBUS test planned to examine effect of air ingression on a larger scale in an integral facility

Effect of Ruthenium (cont.)

Decay Time Prior to Accident	Mean Consequences for Surry Population Density (0-100 miles)		
	Early Fatalities	Societal Dose (rem)	Cancer Fatalities
1 year	1.01	4.54×10^6	2,320
1 year (100% ruthenium release)	95.3	9.53×10^6	9,150
1 year (100% ruthenium release)[a]	.13	6.75×10^6	6,300

[a]Based on early evacuation.

Conclusion: Ruthenium release can increases consequences, but can be offset by early evacuation.

Effect of Number of Fuel Assemblies Releasing Fission Products

- **Original calculations assumed entire spent fuel pool inventory of Millstone 1 was involved in heatup and release (3.5 cores).**

- **Depending on reductions in decay heat from radioactive decay, less fuel may be involved in heatup.**

- **Performed MACCS calculations for two cases: (a) entire spent fuel pool inventory (3.5 cores) and (b) inventory in final core offload.**

Effect of Number of Fuel Assemblies Releasing Fission Products (cont.)

Ruthenium Release Fraction	# of cores	Mean Consequences for Surry Population Density (0-100 miles)		
		Early Fatalities	Societal Dose (rem)	Cancer Fatalities
$2x10^{-5}$	3.5	1.01	$4.54x10^6$	2,320
$2x10^{-5}$	1	.014	$3.23x10^6$	1,530
1	3.5	95.3	$9.53x10^6$	9,150
1	1	50.5	$7.25x10^6$	7,360

Number of cores reduced for cases with and without large ruthenium release

Smaller consequence reduction for case with large ruthenium release because most ruthenium is in final core offload due to its one year half-life

Other Issues

Results with and without large ruthenium releases presented to ACRS in April 2000.

ACRS comments

Fission product release fractions from spent fuel pool accident study in NUREG/CR-4982 not supported

Plume-related parameters

- **Plume heat content**
- **Plume spreading**

Sensitivity calculations were performed to follow-up on ACRS comments.

Effect of Release Fractions

Case	Release Fraction							Mean Consequences (0-100 miles)		
	I,Cs	Ru	Te	Ba	Sr	Ce	La	Early Fatalities	Societal Dose (rem)	Cancer Fatalities
1	1	$2x10^{-5}$	.02	.002	.002	$1x10^{-6}$	$1x10^{-6}$	1.01	$4.54x10^{6}$	2,320
45	1	1	.02	.002	.002	$1x10^{-6}$	$1x10^{-6}$	92.2	$9.50x10^{6}$	9,150
45a	1	1	.02	.01	.01	.01	.01	103	$1.33x10^{7}$	11,700
45b	.75	.75	.02	.01	.01	.01	.01	54.9	$1.17x10^{7}$	10,300
46[a]	1	1	.02	.002	.002	$1x10^{-6}$	$1x10^{-6}$	1.32	$6.84x10^{6}$	6,430
46a[a]	1	1	.02	.01	.01	.01	.01	1.54	$8.89x10^{6}$	8,160
46b[a]	.75	.75	.02	.01	.01	.01	.01	.543	$7.94x10^{6}$	6,880
46c[a]	.75	.75	.75	.01	.01	.01	.01	.544	$7.94x10^{6}$	6,880
46d[a]	.75	.75	.75	.75	.01	.01	.01	.544	$7.94x10^{6}$	6,880
46e[a]	.75	.75	.75	.75	.75	.01	.01	.644	$1.01x10^{7}$	8,350

[a]Based on early evacuation.

Effect of Release Fractions (cont.)

Results

Increased fuel fines release fraction: increased consequences for cases with early and late evacuation.

Increased tellurium and barium release fractions: no change in consequences due to short half-lives.

Increased strontium release fraction: increased consequences.

Also evaluated the effect of evacuation percentage (99.5% vs. 95%).

Main difference involved early evacuation; factor-of-ten increase in early fatalities.

Effect of Plume Heat Content

Potential for plume heat content to be higher than that of a reactor accident —> staff performed sensitivity calculations using different plume heat contents

Base Case: plume heat content from NUREG-1150 (3.7 MW)

Staff estimated plume heat content to be about 256 MW for complete oxidation of one core in 30 minutes

SNL performed a more detailed estimate of plume heat content (about 43 MW)

Effect of Plume Heat Content (cont.)

Case	Release Fraction							Plume Heat Content (MW)	Mean Consequences (within 100 miles)		
	I,Cs	Ru	Te	Ba	Sr	Ce	La		Early Fatalities	Societal Dose (rem)	Cancer Fatalities
1	1	$2x10^{-5}$	.02	.002	.002	$1x10^{-6}$	$1x10^{-6}$	3.7	1.01	$4.54x10^{6}$	2,320
45	1	1	.02	.002	.002	$1x10^{-6}$	$1x10^{-6}$	3.7	92.2	$9.50x10^{6}$	9,150
47	1	1	.02	.002	.002	$1x10^{-6}$	$1x10^{-6}$	83.0	57.3	$9.24x10^{6}$	9,280
49	1	1	.02	.002	.002	$1x10^{-6}$	$1x10^{-6}$	256.0	18.3	$8.24x10^{6}$	8,380
46[a]	1	1	.02	.002	.002	$1x10^{-6}$	$1x10^{-6}$	3.7	1.32	$6.84x10^{6}$	6,430
48[a]	1	1	.02	.002	.002	$1x10^{-6}$	$1x10^{-6}$	83.0	.00509	$7.28x10^{6}$	7,060
50[a]	1	1	.02	.002	.002	$1x10^{-6}$	$1x10^{-6}$	256.0	.00357	$6.96x10^{6}$	6,650

[a]Based on early evacuation.

Increasing plume heat content mainly affects early fatalities.

Effect of Plume Spreading

MACCS uses a Gaussian plume model with the amount of spreading determined by the model parameters σ_y and σ_z.

As part of international cooperative effort on consequence assessment codes, experts provided updated values for σ_y and σ_z.

Experts provided distributions for σ_y and σ_z, instead of point estimates.

SNL performed MACCS calculations using values for σ_y and σ_z selected by sampling from the distributions; a total of 300 MACCS calculations were run.

Results: Factor of 1.1 to 15 decrease in prompt fatalities. Up to a 60% increase in cancer fatalities and population dose. (Expect similar effects for reactor accidents.)

<u>**Decay Times Beyond One Year**</u>

Performed calculations at longer decay times (out to 10 years) with and without early evacuation.

As part of these calculations, reassessed the source terms used.

In these calculations, used release fractions from NUREG-1465 (both in-vessel and ex-vessel releases) instead of NUREG/CR-4982.

> **NUREG-1465 has received significant peer review and is representative of a low pressure core-melt accident**
>
> **Performed consequence calculations for two cases**
>
> - **NUREG-1465**
> - **NUREG-1465, with the ruthenium and fuel fines release fractions changed to .75 and .035, respectively**

Source Terms

Source Term	Release Fractions								
	noble gases	iodine	cesium	tellurium	strontium	barium	ruthenium	lanthanum	cerium
NUREG/CR-4982	1	1	1	.02	.002	.002	$2x10^{-5}$	$1x10^{-6}$	$1x10^{-6}$
NUREG-1465	1	.75	.75	.31	.12	.12	.005	.0052	.0055
NUREG-1465 (mod)	1	.75	.75	.31	.12	.12	.75[a]	.035[b]	.035[b]

[a]Ruthenium release fraction is that of a volatile fission product.
[b]Fuel fines release fraction is that of the Chernobyl accident (*Chernobyl Ten Years On, Radiological and Health Impact, An Appraisal by the NEA Committee on Radiation Protection and Public Health*, November 1995).

Results for Decay Times Beyond One Year (NUREG-1465)

Case	Decay Time	Mean Consequences (0-100 miles)		
		Early Fatalities	Societal Dose (rem)	Cancer Fatalities
77a	30 days	2.21	$7.15x10^6$	4540
77b	90 days	1.37	$6.99x10^6$	4420
77c	1 year	.736	$6.81x10^6$	4190
77d	2 years	.481	$6.65x10^6$	4020
77e	5 years	.192	$6.47x10^6$	3800
77f	10 years	.0778	$6.26x10^6$	3620
78a[a]	30 days	.0720	$5.69x10^6$	3240
78b[a]	90 days	.0461	$5.58x10^6$	3150
78c[a]	1 year	.0301	$5.48x10^6$	3020
78d[a]	2 years	.0208	$5.40x10^6$	2930
78e[a]	5 years	.00882	$5.33x10^6$	2820
78f[a]	10 years	.00400	$5.24x10^6$	2730

[a]Based on early evacuation.

Results for Decay Times Beyond One Year (NUREG-1465 modified)

Case	Decay Time	Mean Consequences (0-100 miles)		
		Early Fatalities	Societal Dose (rem)	Cancer Fatalities
79a	30 days	192	2.62×10^7	21100
79b	90 days	162	2.49×10^7	20000
79c	1 year	76.9	2.15×10^7	17400
79d	2 years	19.2	1.90×10^7	15400
79e	5 years	1.34	1.66×10^7	12600
79f	10 years	.360	1.53×10^7	11400
80a[a]	30 days	6.65	1.60×10^7	15400
80b[a]	90 days	3.95	1.52×10^7	14300
80c[a]	1 year	.951	1.34×10^7	11500
80d[a]	2 years	.149	1.20×10^7	9480
80e[a]	5 years	.0162	1.07×10^7	7620
80f[a]	10 years	.00601	1.00×10^7	6490

[a]Based on early evacuation.

Summary

Issues examined

- **reduced inventory (at 1 year)**
- **early vs. late evacuation (at 1 year)**
- **importance of cesium**
- **importance of ruthenium**
- **number of assemblies releasing fission products**
- **fission product release fractions**
- **plume heat content**
- **plume spreading**
- **decay times beyond 1 year**
- **reassessment of source term**

Results of large number of MACCS calculations were used to understand decommissioning risk in staff's generic study.

Presentation to the ACRS Reactor Fuels Subcommittee

Subcommittee Meeting

October 18, 2000

Charles G. Tinkler
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Air Ingression and Temperature Criteria For Analysis of Spent Fuel Pool Accidents

- Past evaluations of spent fuel pool accidents have used temperature criteria of 800–900 °C, identified as a temperature criterion for self-sustaining reaction of Zr cladding in air (autoignition/ignition).

- More appropriately, temperature criterion may be thought of as threshold for temperature escalation leading to significant fuel damage.

  - Criterion dependent on system conditions, physical configuration, heat generation and losses.

Air Ingression and Temperature Criteria For Analysis of Spent Fuel Pool Accidents (continued)

- Practically, the temperature criteria was used in draft generic study:

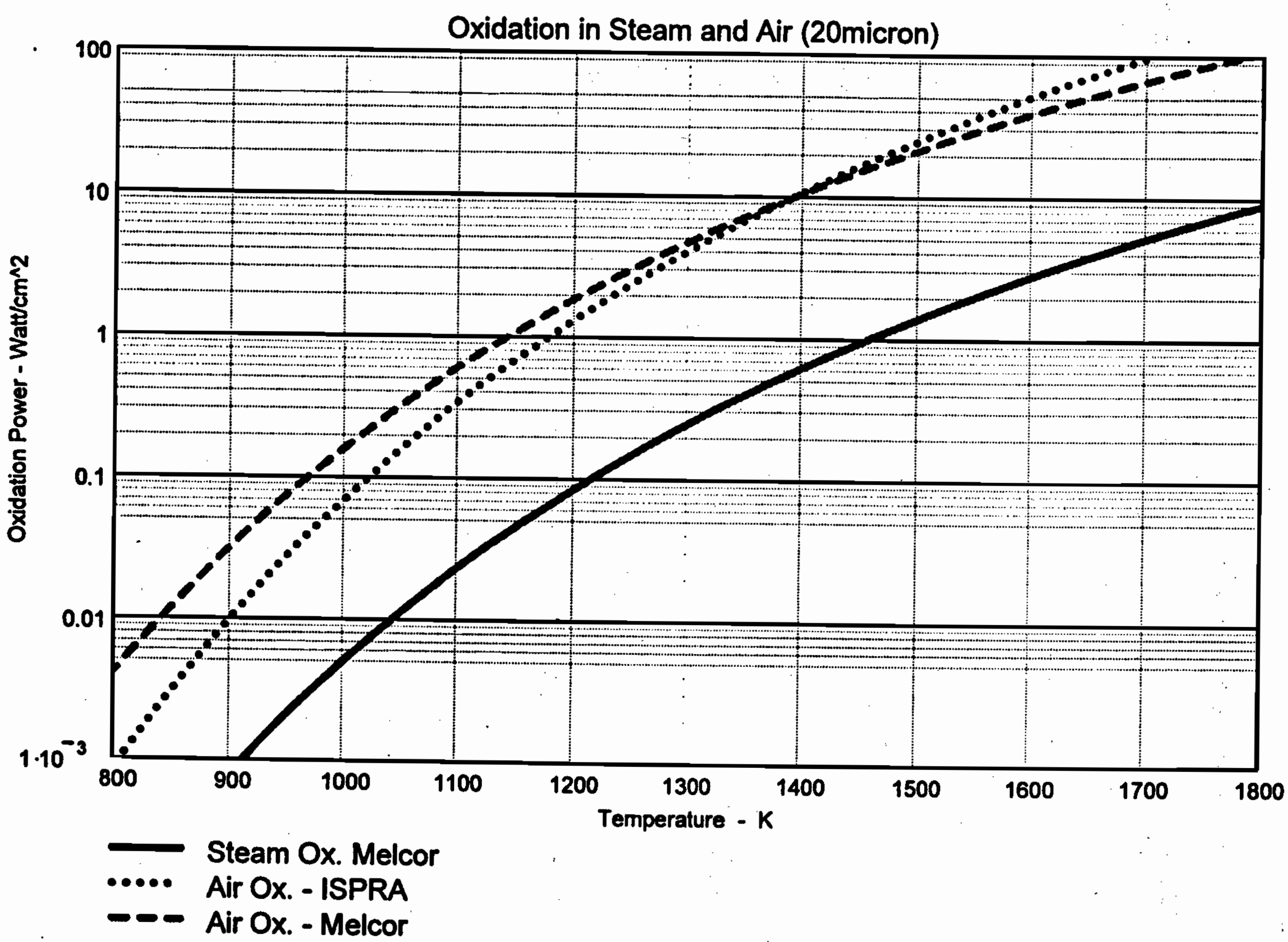
  1) Signal onset of significant fuel pool release for evaluating time for ad hoc evaluation.

  2) For determination of decay heat level and corresponding time ("critical decay time") at which equilibrium temperature could be maintained, precluding large release (~ 5 years).

- NRC has reevaluated appropriateness of temperature criteria considering:
  - Zr reaction kinetics
  - Hydriding/autoignition
  - Fuel damage testing
  - Fission product release data (ruthenium)
  - Materials interactions

Zr Oxidation Kinetics

- Review of steam and air oxidation data
  - CORA, QUENCH, PHEBUS, and CODEX data on temperature escalation.
  - Determination of temperatures for equivalent heat generation between air and steam.
- Temperature of 1200 °C, representative of temperature escalation in steam core damage tests corresponds to an equivalent heat generation in air at ~ 925 °C using ISPRA's best fit to CODEX data.
- Above approach produces a threshold for temperature escalation quite close to CODEX observation.


Oxidation in Steam and Air (20micron)
Oxidation Power - Watt/cm^2
100
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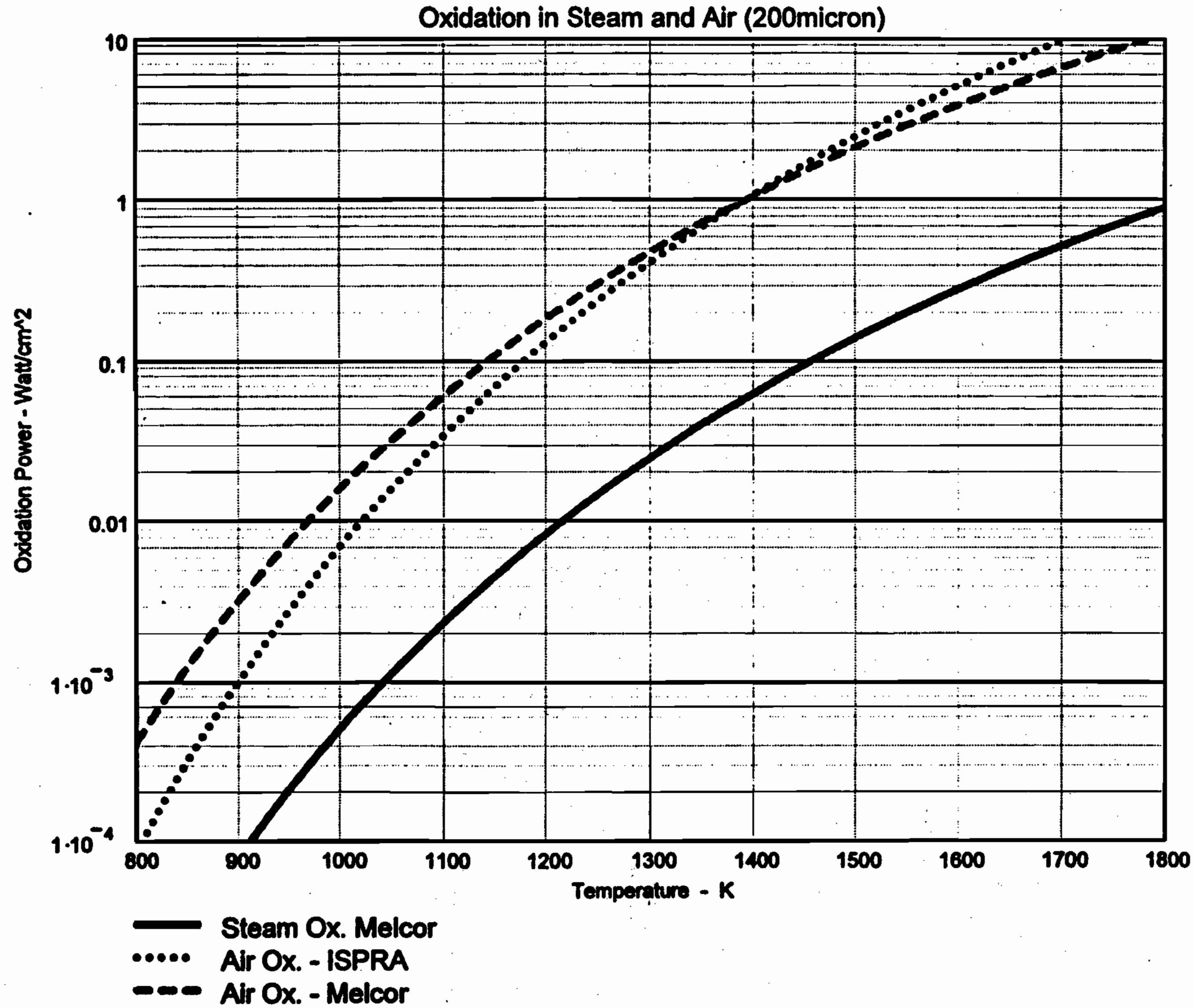
Temperature - K
Steam Ox. Melcor
Air Ox. - ISPRA
Air Ox. - Melcor


Oxidation in Steam and Air (200micron)
Oxidation Power - Watt/cm^2
10
1
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800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
Temperature - K
Steam Ox. Melcor
Air Ox. - ISPRA
Air Ox. - Melcor

Zr Oxidation Kinetics (continued)

- Autoignition of clean metal or hydride.
  - Normally oxidized but exposed on ballooning/burst small surface area.
  - Hydrides dissolution prior to reaching conditions for ignition.
- Breakaway oxidation.
  - Reported in isothermal tests (Leistikow, Evans).
  - Instability of nitride layer.
  - Deviation from parabolic rate kinetics.
  - Incubation time of 4–10 hours at 800 °C.
    - Not limiting for transient heatup but would be limiting for long-term equilibrium criterion.

Temperature Criteria and Fission Product Releases

- Fission product releases
  - Initial release of fission products upon cladding failure.
  - High-temperature release of volatiles
  - Release of Ru after oxidation of fuel. (Under what low temperature conditions might fuel oxidize leading to large ruthenium releases?)
  - To avoid rapid releases of Ru, in draindown scenarios temp should be maintained less than 600 °C

Summary

	Adequacy of 10 hrs for Evacuation	Precluding Large Release Fuel <5yrs	Precluding Large Release Fuel >5yrs
Dominant Air Environment	900 °C	600 °C	800 °C
Dominant Steam Environment	1200 °C	N/A	N/A

- Use of temperature criteria must be supported by analysis of all significant heat generation and loss mechanisms.

- Determination of an acceptable long term condition requires confirmation of equilibrium temperature condition.

- Integrated modeling of thermal hydraulics, cladding reactions and fuel heatup and fission product release would provide consistent consideration of conditions for sequence specific analysis. Would provide means for more realistic estimates.

Spent Fuel Pool Accident Risk Study

Timothy E. Collins
Deputy Director, DSSA

ACRS Fuels Subcommittee Meeting

October 18, 2000

Presentation Outline

- February report findings
- Summary of significant comments
- Approach to comment resolution
- Results of re-analysis
- Conclusions

February Report Conclusions

- Frequency of zirconium fire is low
- Consequences comparable to reactor accident large early release
- Seismic events dominate
- EP relaxation after one year is supportable
- Security needed as long as fuel in pool
- Insurance relaxation is more plant specific

Comments On February Draft

- Source term may be non conservative
- Seismic hazard estimates too conservative
- Zr ignition temperature may be too high
- Partial draindown needs more attention
- Results support EP relaxation at 60 days
- Recommendations not risk-informed

Approach To Comment Resolution

- Ruthenium and fuel fines added to source term for consequence analyses
- Risks assessed using EPRI and LLNL estimates
- Consequences calculated at earlier times

Approach To Comment Resolution (con't)

- "Small change" analysis per RG 1.174
- Evaluated sequences for likelihood of flow blockage
- Impact of lower temperature criterion examined

Results

- Consequences with ruthenium and fuel fines still comparable to reactor large early release
- Risk is low but in ball park of operating reactors for first years
- Use of EPRI hazard estimate reduces total risk by about a factor of 4

Results (con't)

- EP relaxation after 60 days is "small change" consistent with guidelines
- Obstructed air flow potential precludes generic decay time when "significant release is no longer possible"
- Temperature criterion effect not important due to already short times in first years

Conclusions

- Risk at decommissioning plants is low even in consideration of ruthenium source term
- Relaxation of EP after 60 days is consistent with "small change" in risk guidelines
- New criterion needed if insurance relaxation is to be considered
- Security required as long as fuel is in pool

Risk Informing Decommissioning Regulations

ACRS Subcommittee on Reactor Fuels

October 18, 2000

by

Lynnette Hendricks, NEI

Commission Directives 12/21/99 SRM

- Integrated, risk informed rulemaking addressing EP, FP, Security, Backfit and Operator Training
- Consider all realistic scenarios
- (Later Commission decisions on applicability of m maintenance rule, fitness for duty, station blackout, fire protection, etc. to D&D plants will benefit from risk insights)

Scope

- Use risk insights to adapt deterministic rules for operating plants to decommissioning plants
- Commission principles on risk informing must be adapted to address
  - Different type of consequences
  - Lower probability
  - Different type of system, e.g., passive, robust, slowly evolving sequences

NEI

Objective

- Best Inform Commission to make judgement calls (no magic formula)
  - Provide "apples to apples" type comparison to risk profile presented by operating plants
  - Examine defense in depth in context of simple, passive system where most sequences evolve over very long time frames

NEI

Risk treatment

- Best estimates should be used
- Consequences should not be based on phenomena that have not been validated through NRC's severe accident program
- More efforts should be devoted to probability side of risk equation.
- If probability of spent fuel fire is acceptably low there are diminishing returns on efforts to refine consequences

NEI

Seismic risk in spent fuel pool risk study

- Huge seismic events that are background risk factors for operating plants, dominate risk profile for decommissioning plants
- Seismic risk should be treated in the same manner for decommissioning plants as for operating plants

NEI

Treatment of seismic risk

- Disposition deterministically
  - Screen out using checklist, at 2-3SSE provides large margin
  - Most PRAs screen out at SSE by using seismic experts to establish seismic margins

NEI

Commission Policy on Treatment of Seismic Risk

- NUREG 1150:
  - Use of LLNL: rare but large events contribute significantly to risk
  - EPRI and LLNL approaches are fundamentally sound
  - Avoided including offsite consequences and risk from seismic in findings without context
  - Recommend context: reactor induced accident losses be compared to overall losses (report observes nuclear losses likely to be very small)

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Defense in Depth Considerations for spent fuel pool

- Draft risk report observes defense in depth provided by:
  - Robustness of Pool Structure
  - Simplicity of operation
  - Slow evolution of all but 2 sequences
- By comparison operating PRA's have 100's of sequences for internal events

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Conclusions

- Bounding estimate of seismic risk should not be used to justify retention of operating plant requirements intended for a much broader scope of initiating events
- Overly conservative treatment of seismic risk leads to conclusion that operating plant requirements should be retained

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Conclusions (cont.)

- Opportunities to apply practical risk insights are lost if operating plant requirements are retained
- Speculative phenomena should not be used to determine consequences

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