3.6 Consequences and Risks Associated With SFP Accidents

This section provides an assessment of the consequences and risks associated with SFP accidents. Estimated consequences of SFP accidents are presented in Section 3.6.1. Results are provided for both early evacuation and late evacuation cases to address the impact of protective measures on consequences, and for two different source terms to show the impact of source term uncertainties on results. In Section 3.6.2, the severe accident consequences for either the early or late evacuation cases are assigned to each of the major types of SFP accidents, as appropriate, and then combined with the respective event frequencies to provide a scoping estimate of SFP risks. The risks of SFP accidents are contrasted with and shown to be equivalent to or less than those for reactor accidents and to meet the Commission's Safety Goals. The impact of changes in EP regulations on these risk measures is discussed later in Section 4.

3.6.1 Consequences of SFP Accidents

Earlier analyses in NUREG/CR-4982 and NUREG/CR-6451 included a limited evaluation of offsite consequences for a severe SFP accident occurring up to 90 days after the last discharge of spent fuel into the SFP. These analyses showed that the consequences of a SFP accident could be comparable to those for a severe reactor accident. As part of its effort to develop generic, risk-informed requirements for decommissioning, the staff performed a further evaluation of the offsite radiological consequences of beyond-design-basis spent fuel pool accidents. An initial set of calculations was performed to extend the earlier analyses to SFP accidents occurring one year after plant shutdown, and to supplement the earlier analyses with additional sensitivity studies, including varying evacuation assumptions as well as other modeling assumptions. The results of these calculations were documented in the Draft Final Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants, February 2000, and are reproduced as Appendix 4 in the present report.

Subsequently, the ACRS raised issues with the source term and plume modeling associated with spent fuel pool accidents. In particular, the ACRS believed that the ruthenium and fuel fines releases and plume spreading were too low. To address these issues, the staff performed additional sensitivity studies, as documented in Appendix 4A in the present report.

To provide insight into the impact on results of shorter or longer decay times than one year, additional consequence calculations were performed using fission product inventories at 30 and 90 days and two, five, and ten years after final shutdown. The results of these latest consequence calculations were used as the basis for assessing the risk from SFP accidents. These results are summarized in Tables 3.6-1 and 3.6-2 for several key consequence measures, and are described in more detail in Appendix 4B.

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Table 3.6-1 Consequences (Per Event) of a SFP Accident Based on High Ruthenium Source Term

Time after Shutdown	Mean Consequences For High Ruthenium Source Term (Surry population, 95% evacuation)				
	Early Fatalities	Societal Dose (p-rem within 50 miles)	Latent Cancer Fatalities (within 100 miles)	Individual Risk of Early Fatality (within 1mile)	Individual Risk of Latent Cancer Fatality (within 10 miles)
Late Evacuation					
30 days	192	2.37E7	21100	4.43E-2	8.24E-2
90 days	162	2.25E7	20000	4.19E-2	8.20E-2
1 year	76.9	1.93E7	17400	3.46E-2	8.49E-2
2 years	19.2	1.69E7	15400	2.57E-2	8.42E-2
5 years	1.34	1.45E7	12600	8.96E-3	7.08E-2
10 years	0.360	1.34E7	11400	4.68E-3	6.39E-2
Early Evacuation					
30 days	6.65	1.35E7	15400	2.01E-3	4.79E-3
90 days	3.95	1.29E7	14300	1.87E-3	4.77E-3
1 year	0.951	1.12E7	11500	1.50E-3	4.33E-3
2 years	0.149	9.93E6	9480	1.12E-3	3.70E-3
5 years	0.0162	8.69E6	7620	3.99E-4	2.93E-3
10 years	0.00601	8.13E6	6490	2.05E-4	2.64E-3

Table 3.6-2 Consequences (Per Event) of a SFP Accident Based on Low Ruthenium Source Term

Time after Shutdown	Mean Consequences For Low Ruthenium Source Term (Surry population, 95% evacuation)				
	Early Fatalities	Societal Dose (p-rem within 50 miles)	Latent Cancer Fatalities (within 100 miles)	Individual Risk of Early Fatality (within 1mile)	Individual Risk of Latent Cancer Fatality (within 10 miles)
Late Evacuation					
30 days	2.21	5.58E6	4540	1.27E-2	1.88E-2
90 days	1.37	5.43E6	4420	9.86E-3	1.82E-2
1 year	0.736	5.28E6	4190	7.13E-3	1.68E-2
2 years	0.481	5.12E6	4020	5.64E-3	1.58E-2
5 years	0.192	4.90E6	3800	3.18E-3	1.43E-2
10 years	0.0778	4.72E6	3620	1.63E-3	1.29E-2
Early Evacuation					
30 days	0.072	4.12E6	3240	8.36E-4	9.92E-4
90 days	0.0461	4.02E6	3150	6.83E-4	9.62E-4
1 year	0.0301	3.95E6	3020	5.44E-4	9.09E-4
2 years	0.0208	3.87E6	2930	4.41E-4	8.71E-4
5 years	0.00882	3.77E6	2820	2.54E-4	8.14E-4
10 years	0.00400	3.69E6	2730	1.47E-4	7.70E-4

The consequences in Table 3.6-1 are based on the upper bound source term described in Appendix 4B. With the exception of ruthenium and fuel fines, the release fractions are from NUREG-1465, *Accident Source Terms for Light-Water Nuclear Power Plants,* (Reference 1) and include the ex-vessel and late in-vessel phase releases. The ruthenium release fraction is assumed to be equivalent to that for a volatile fission product consistent with an ACRS comment, and the ruthenium is assumed to be in an oxidic rather than metallic form. The source term is considered to be bounding for several reasons. First, rubbling of the spent fuel after heat-up to about 2500K is expected to limit the potential for ruthenium release to a value less than that for volatile fission products. Second, following the Chernobyl accident, ruthenium in the environment was found to be in the metallic form (Reference 2). Metallic ruthenium (Ru-106) has about a factor of 50 lower dose conversion factor (rem per Curie inhaled) than oxidic ruthenium assumed in the MACCS calculations. Finally, the fuel fines release fraction is that from the Chernobyl accident (Reference 3). This is considered to be bounding because the Chernobyl accident involved more extreme conditions (i.e., two explosions followed by a prolonged graphite fire) than a spent fuel pool accident. In subsequent discussions, this source term is referred to as the high ruthenium source term.

The consequences obtained using the NUREG-1465 source term (which treats ruthenium as a less volatile fission product) in conjunction with SFP fission product inventories are provided in Table 3.6-2 for comparison. Although the NUREG-1465 source term was developed to represent fission product releases in a severe reactor accident, this source term could be considered to provide a more central estimate of the releases in a SFP accident. In subsequent discussions, this source term is referred to as the low ruthenium source term.

The consequence calculations for both the high and low ruthenium source terms assume that all of the fuel discharged in the final core off-load plus the previous 9 refueling outages participates in the SFP fire. These assemblies are equivalent to about 3.5 reactor cores. Approximately 85% of all the ruthenium in the pool is in the last core off-loaded since the ruthenium-106 half-life is about one year. For cesium-137, with a 30 year half-life, the inventory decays very slowly and is abundant in all of the batches considered. The staff assumed that the number of fuel assemblies participating in the SFP fire remains constant with time, and did not consider the potential that fewer assemblies might be involved in a SFP fire in later years due to substantially lower decay heat in the older assemblies. This assumption therefore adds some conservatism to the calculation of long-terms effects associated with cesium, but is not important with regard to the effects of runtenium.

The results for early fatality and societal dose (person-rem) consequences for a SFP accident are shown graphically in Figures 3.6-1 and 3.6-2. Because latent cancer fatalities are directly proportional to societal dose through a dose-to-cancer risk conversion factor, results for latent cancer fatalities are not displayed separately in the main report.

Figure 3.6-1 Early Fatality Consequences for Spent Fuel Pool Source Terms **(Insert Here)**

Figure 3.6-2 Societal Dose (Person-Rem) Consequences for Spent Fuel Pool Source Terms **(Insert Here)**

Consequence estimates are also included on Figures 3.6-1 and 3.6-2 for the two operating

reactors for which risk results for both internal and seismic events are available in NUREG-1150 and supporting NUREG/CR-4551 reports, i.e., the Surry and Peach Bottom plants. The values shown are for the reactor accident source terms that produced the greatest number of early fatalities (Figure 3.6-1) or the greatest societal dose and latent cancer fatalities (Figure 3.6-2). Results are displayed separately for internally- and seismically-initiated accidents, and indicate that for these plants, reactor accident consequences for seismically-initiated events are substantially higher than those for internally-initiated events.

On the basis of the consequence calculations described in Appendices 4 through 4B, the staff concludes the following regarding SFP accident consequences:

- The short- and long-term consequences of SFP accidents are generally comparable to those for severe reactor accidents, and remain so for as long as a SFP fire is possible.

- The short-term consequences (i.e., early fatalities) decrease by about a factor of three when the fission product inventory decreases from that for 30 days to that for one year after final shutdown. An additional factor of 10 reduction is realized by the 3rd to 10th year following shutdown depending on whether the source term is assumed to contain a high or low fraction of ruthenium

- The short-term consequences for the high ruthenium source term are driven by the large ruthenium release fraction, and decrease substantially during the first 5 years following shutdown given its one year half-life. After about 5 years, the consequences are dominated by cesium which decays at a slower rate (30 year half-life). In contrast, the consequences for the low ruthenium source term are driven primarily by cesium and exhibit a more gradual and constant decrease throughout the entire period.

- Within the first year following shutdown, the short-term consequences for the high ruthenium source term are about a factor of 100 higher than for the low ruthenium source term for either early or late evacuation. The effect of the source term diminishes with time and results in less than a factor of five difference after 5 years.

- Early evacuation, where it can be effectively implemented (via either formal or ad hoc emergency planning), reduces the short-term consequences by about one to two orders of magnitude relative to late evacuation[1] for the entire period considered, and is a more important determinant of early fatalities than source term in later years.

- Long-term consequences (i.e., societal dose and latent cancer fatalities) are strongly impacted by the quantity of fission long-lived fission products released, and impacted to a lesser extent by evacuation timing. Long term consequences are only marginally

[1] Early evacuation refers to situations in which evacuation is initiated and completed prior to the SFP release. Situations in which the evacuation is not completed prior to release are referred to as late evacuation.

affected by additional fission product decay time, and decrease by only about a factor of two by the 10th year following shutdown.

- Increasing the ruthenium release fraction from that for a non-volatile (2E-5) to that for a volatile (0.75) results in a large increase in both short-term and long-term consequences for scenarios without early evacuation. This is attributed to the high dose per curie for ruthenium assigned in the MACCS code based on an assumption that the ruthenium is released in an oxide form. Increases in short-term consequences from ruthenium would be largely offset by early evacuation, where evacuation can be effectively implemented.

- Although several of the parameters varied in the staff's analyses (Appendix 4A) can significantly impact the results, these analyses do not change the conclusion that the consequences of a SFP accident are generally comparable to those of reactor accidents

In Section 3.6.2 which follows, the consequence results presented in Tables 3.6-1 and 3.6-2 are assigned to each SFP event based on accident considerations (such as time available for evacuation in each sequence), and then combined with the respective event frequencies to provide a scoping estimate of SFP risks.

3.6.2 Risk Modeling for SFP Accidents

The quantitative assessment of risk involves combining the estimated frequencies of severe accident sequences with their corresponding offsite consequences. In this section, severe accident consequences are assigned to each of the major types of events that lead to uncovery of the spent fuel, and then combined with the respective event frequencies to provide a scoping estimate of risk.

The SFP accidents discussed in Section 3 can be broadly classified as either boil down or rapid drain down sequences. Rapid drain down sequences are further divided into seismically- and non-seismically-initiated events. In assigning consequences to each of these events, the staff considered whether protective measures to evacuate the population around the site could be effectively implemented prior to fission product release. This included consideration of the effectiveness of offsite notification, the delay between event initiation and fission product release (dependent on time after shutdown), the time required to initiate and complete an evacuation, and the impact that a relaxation in current EP requirements might have on these factors. As a result of this assessment, consequences were assigned based on either the early evacuation case or late evacuation case.

A brief description of the frequency and consequence modeling is provided below for each class of SFP accident. The resulting risk estimates for each sequence (in terms of early fatalities and societal dose per year) are presented in Figures 3.6-3 through 3.6-6 and discussed in Section 3.6.3.

<u>Boil Down Sequences</u>

Boil down sequences (including loss of inventory events) and their associated frequencies are listed in Table 3.6-3. These sequences involve heatup of the pool to boiling followed by gradual

reduction in pool level until the spent fuel is eventually uncovered. This process would take over 100 hours at 60 days, and substantially longer at later times as shown in Table 3.3. The long delay provides sufficient time for licensee staff to effectively intervene in the large majority of these events, and results in very low frequencies of fuel uncovery. For those events that proceed to fuel uncovery, fuel heatup will continue until either steady-state conditions are achieved or cladding oxidation occurs. All boil down sequences that uncover spent fuel were assumed to result in a SFP fire. Loss of inventory events are classified as boil down events since the time to uncover the fuel will be in excess of 24 hours (as described in Section 4.5.4.1 of Appendix 2a) and will provide ample time for licensee to take corrective measures.

Table 3.6-3 Frequency of Boil Down Events (greater than 60 days after shutdown)

Initiating Event	Frequency (per year)
Loss of off-site power -- severe weather	1.1E-7
Loss of off-site power -- plant centered and grid related events	2.9E-8
Internal fire	2.3E-8
Loss of pool cooling	1.4E-8
Loss of coolant inventory	3.0E-9
Total	1.8E-7

The failure paths leading to a zirconium fire involve failure to acquire off-site resources to provide pool inventory makeup, despite the large amount of time available for recovery in the boil down event. For sequences involving loss of off-site power due to severe weather, the weather is assumed to drain regional resources or limit their access to the facility. The staff assumes that if it is difficult for off-site resources to reach the facility or regional resources are engaged in other efforts, then it would also be unlikely that the population in the area would be effectively notified and/or evacuated under these conditions. For sequences other than loss of offsite power due to severe weather, the dominant reason that recovery is not provided in the failure paths is that there was a general breakdown in the overall facility organization. The failure to acquire off-site resources implies there is also a failure to contact regional authorities and declare a general emergency when the SFP level drops below the proceduralized limit in these sequences. Accordingly, the consequences for boil down sequences are based on results for the late evacuation case (reported in the first portion of Tables 3.5-1 and -2). This same assumption is applied for cases with and without EP relaxations, and for all times after shutdown. The net effect is that EP, as well as relaxations in EP, do not impact the risk associated with those boil down sequences that proceed to spent fuel uncovery.

Rapid Drain Down Due to Seismic Events

Given the robust structural design of SFPs, it is expected that a seismic event with peak spectral acceleration several times larger than the safe shutdown earthquake (SSE) would be required to produce catastrophic failure of the structure. The estimated frequency of events of this magnitude differs greatly among experts and is driven by modeling uncertainties. The estimated frequency of seismic events sufficiently large to result in structural failure of the SFP is provided in Table 3.6-4 based on the use of LLNL and EPRI seismic hazard estimates.

Both the LLNL and EPRI hazard estimates were developed as best estimates and are

considered reasonable by the NRC. Furthermore, because both sets of curves are based upon data extrapolation and expert opinion for the magnitudes of interest, there is no technical basis for excluding consideration of either set.

Using the LLNL hazard curves, a return frequency equivalent to the Pool Performance Guideline (1E-5 per year) for a 1.2g peak spectral acceleration (PSA) earthquake bounds all but four sites (one CEUS and three western sites). The frequency for the remaining sites falls in the range of less than 7E-8 per year to 9E-6 per year. The majority (45 sites) have hazard estimates (for a 1.2 PSA earthquake) near 1E-6 per year and 20 sites fall below 6E-7 per year. The mean value for the population of plants is approximately 2E-6 per year.

If EPRI hazard estimates are used, only one site has an estimate that exceeds 1E-6 per year (excluding western sites). Ten sites are near 5E-7 per year, and the remaining 49 sites analyzed by EPRI have estimates less than 3E-7 per year, with half of these sites (25 sites) estimated at less than 7E-8 per year. The mean value for the population of plants is approximately 2E-7 per year.

In characterizing the risk of seismically-induced SFP accidents for the population of sites, the staff has displayed results based on both the LLNL and EPRI hazard estimates, and has used an accident frequency corresponding to the mean value for the respective distributions, i.e., a frequency of 2E-6 per year to reflect the use of LLNL hazard estimates and a frequency of 2E-7 per year to reflect use of the EPRI hazard estimates. Use of the mean value facilitates comparisons with the Commission's Safety Goals and QHOs. About 70 percent of the sites are bounded using the mean value.

Table 3.6-4 Frequency of Rapid Drain Down Due to Seismic Events

Source of Hazard Estimate	Frequency (per year)
LLNL	2E-6
EPRI	2E-7

A discussion of likely SFP failure modes and locations is provided in Appendix _, and indicates that drainage of the pool would be fairly rapid and a small but uncertain amount of water is likely to remain in the pool, with post-seismic failure water depths ranging from essentially zero depth to about 4 feet of depth depending upon the critical failure mode. For purposes of consequence assessment, all seismically-initiated sequences were assumed to result in a rapid drain down followed by a SFP fire, regardless of the SFP failure mode and location.

The SFP risk estimates are strongly dependent on the assumptions regarding the effectiveness of emergency evacuation in seismic events, since these events dominate the SFP fire frequency. In NUREG-1150, evacuation in seismic events was treated either of two ways depending on the peak ground acceleration (PGA) of the earthquake:

- for low PGA earthquakes, the population was assumed to evacuate; however, the evacuation was assumed to start later and proceed more slowly than evacuation for internally-initiated events. A delay time of 1.5 times the normal delay time and an evacuation speed of 0.5 times the normal evacuation speed were assumed for this case.

- for high PGA earthquakes, it was assumed that there would be no effective evacuation and that many structures would be uninhabitable. The population in the emergency response zone was modeled as being outdoors for the first 24 hours, and then relocating at 24 hours.

Since the SFP fire frequency is driven by seismic events with PSA several times larger than the SSE, the assumption that there would be no effective evacuation was adopted in developing the baseline estimate of the risk. This is consistent with the expert opinion provided in Appendix _ regarding the expected level of collateral damage within the Emergency Planning Zone given a seismic event large enough to fail the SFP. Specifically, for ground motion levels that correspond to SFP failure in the Central and Eastern U.S., it is expected that electrical power would be lost and more than half of the bridges (including those housing communication systems and emergency response equipment) would be unsafe even for temporary use within at least 10 miles of the plant. This assumption is also consistent with previous Commission rulings on San Onofre and Diablo Canyon in which the Commission found that for those risk-dominant earthquakes that cause very severe damage to both the plant and the offsite area, emergency response would have marginal benefit because of its impairment by offsite damage.

The consequences for seismic sequences are therefore based on results for the late evacuation cases in Tables 3.6-1 and -2. This same assumption is applied for cases with and without EP relaxations, and for all times after shutdown. The net effect is that EP, as well as relaxations in EP, do not impact the risk associated with seismic events that result in SFP failure. A sensitivity case was also performed to explore the impact on risk if the seismic event only partially degrades the emergency response, as discussed in Section 4.2.1.

Rapid Drain Down Due to Non-Seismic Events

Non-seismically-initiated events leading to rapid drain down are listed in Table 3.6-5. These events are dominated by cask drop accidents, with the next highest contributor nearly two orders of magnitude lower.

Table 3.6-5 Frequency of Rapid Drain Down Due to Non-Seismic Events

Initiating Event	Frequency (per year)
Cask drop	2.0E-7
Aircraft impact	2.9E-9
Tornado missile	<1.0E-9
Total	2.0E-7

Cask drop accidents that lead to catastrophic failure of the SFP include accidents in which the load is dropped either on the pool floor, or on or near the pool wall. Load drops on the pool floor are more likely to result in complete drain down of the pool, and creation of an air flow path through the fuel assemblies. Load drops on the pool wall would likely result in residual water in the pool which would obstruct air flow. For purposes of consequence assessment, all cask drop accidents leading to fuel uncovery were assumed to result in a rapid drain down followed by a SFP fire.

Given the limiting pool failure mode and location, fuel heatup would be close to adiabatic. **(Refer to appropriate place in J. Staudenmeier section)** For adiabatic conditions and 60MWd/ton burnup, the time of fission product release would range from about 5 to 8 hours for accidents initiated one year following shutdown to about one day or more for accidents initiated five years after shutdown or later. At 60 days after shutdown, fission product release could begin as early as __ **hours (Joe).** The actual time depends on reactor type, fuel burnup, fuel rack structure, and other plant-specific parameters, as discussed in Appendix 1.

The fuel handlers would be immediately aware of a cask drop accident. It is expected that with procedures that detail the SFP water level at which a general emergency is to be declared, the proper offsite authorities would be promptly informed. For the case in which current EP requirements are retained, it was assumed that cask drop accidents occurring one or more years following shutdown would afford sufficient time to implement protective measures before fission products are released (5 to 8 hours as discussed in Appendix 1). This is consistent with the evacuation time estimates in the NUREG-1150 study for Surry, which assumed a 1.5 hour delay time and a 4 mile per hour evacuation speed. As such, the consequences within the first several months following shutdown are based on late evacuation, and the consequences at one year and beyond are based on early evacuation.

Relaxations in EP requirements are expected to result in additional delays in initiation and implementation of protective measures relative to the case in which current EP requirements are retained. If EP requirements were relaxed, as many as 10 to 15 hours may be required at some sites to implement an equivalent evacuation **(Supplement this statement based on info from Barss or FEMA)**. Based on adiabatic heatup rates for the reference pool, the minimum time to fission product release following a load drop that catastrophically fails the pool is about 10 hours for PWR pools and 15 hours for BWR pools two years following shutdown. These release times increase to 23 and 33 hours for PWR and BWR pools five years following shutdown. Thus, implementation of emergency measures on an ad hoc basis could provide equivalent protection two years following shutdown or later, and fully equivalent protection at five years following shutdown. For the case in which current EP requirements are relaxed, the consequences within the first two years following shutdown are based on late evacuation, and the consequences at five years and beyond are based on early evacuation results reported in Tables 3.6-1 and -2.

3.6.3 Risk Results

The frequency and consequences for each SFP accident were combined to provide a scoping estimate of the risk of SFP accidents. The frequency of each event was based on the estimated value at one year following shutdown as described above, and was assumed to remain constant over time. In reality, the frequency would vary with time, and could be higher or lower than the one-year estimate, as a result of plant configuration changes described in Section 3.1 (e.g., replacement of pool cooling and makeup systems with skid-mounted systems) and reductions in decay heat levels which would impact human reliability estimates. However, as described in Section 3.4.7, these impacts are not expected to be significant for decay times greater than 60 days.

Figures 3.6-3 through 3.6-6 show the total early fatality and societal dose as a function of time

after final shutdown (upper curve), as well as the contribution from each major SFP accident. Companion curves are provided based on both the LLNL and the EPRI seismic hazard studies since both studies are considered equally valid. The SFP risk results depicted in these figures are based on the high ruthenium source term and a fuel burnup of 60 GWd/MTU.. Also shown are the corresponding mean risk measures for two operating plants, Surry and Peach Bottom[2], for which risk results for both internal and seismic events are available in NUREG-1150.

Figure 3.6-3 Early Fatality Risk, By Contributor -- LLNL Seismic **(Insert here)**

Figure 3.6-4 Early Fatality Risk, By Contributor -- EPRI Seismic **(Insert here)**

Figure 3.6-5 Societal (person-rem) Risk, By Contributor -- LLNL Seismic **(Insert here)**

Figure 3.6-6 Societal (person-rem) Risk, By Contributor -- EPRI Seismic **(Insert here)**

The staff concludes the following based on consideration of the risk results for the high ruthenium source term:

- For the first one to two years following shutdown, the early fatality risk for a SFP fire is comparable to that for a severe accident in an operating reactor (based on the two operating reactors considered). 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.
- Early fatality and societal risks are clearly dominated by seismic events when seismic hazard frequency is based on the LLNL study. Cask drop and boil down sequences become important contributors when seismic hazard frequency is based on the EPRI study. As a result, even though the seismic event frequency based on the EPRI study is an order of magnitude lower than the LLNL study, only a factor of three reduction in total risk is realized with the use of the EPRI hazard study since the non-seismic sequences will become important to the total.

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[2] The LLNL seismic risk results reported in NUREG-1150 are based on a 1989 version of the LLNL hazard curves. An update of these curves performed in 1993 resulted in a factor of 10 reduction in the LLNL mean hazard for Peach Bottom and a smaller reduction for Surry. To provide a more meaningful comparison, the LLNL seismic risk results for Peach Bottom reported in NUREG-1150 have been reduced by a factor of 10. The results for Surry and the EPRI seismic risk results are not affected by this adjustment.

- 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. As discussed previously, changes to EP requirements only affect the risk from cask drop accidents in the time period between 1 and 5 years since: (1) prior to one year (e.g., 30 days and 90 days), the time available before fission product release in the postulated event is insufficient to initiate and complete protective actions even with full EP, and (2) at 5 years and beyond, ample time is available to initiate and implement protective actions before fission product release even on an ad hoc basis.

- The above observations are valid regardless of whether seismic event frequencies are based on the LLNL or the EPRI seismic hazard study.

The prior figures and observations are based on the high ruthenium source term. Figures 3.6-7 and 3.6-8 show the differences in early fatality and societal risk if the fission product releases for the SFP fire are based on the low ruthenium source term.

Figure 3.6-7 Effect of Fission Product Decay Time on Early Fatality Risk **(Insert Here)**

Figure 3.6-8 Effect of Fission Product Decay Time on Societal (Person-Rem) Risk **(Insert Here)**

The staff concludes the following regarding the low ruthenium source term:

- 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 one to two 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 two years following shutdown. (In making these comparisons it is important to compare the SFP risks based on a particular seismic hazard study, e.g., EPRI, with reactor accident risks based on the same hazard study.)

- 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 that drive long term doses.

- As with the high ruthenium source term, 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.

- The above observations are valid regardless of whether seismic event frequencies are based on the LLNL or the EPRI seismic hazard study.

Figures 3.6-9 and 3.6-10 show the risk measures relevant to the Commissions's Safety Goal Policy statement, specifically, the individual risk of early fatality (to an individual within 1 mile of the site) and the individual risk of latent cancer fatality (to an individual within 10 miles of the site). The upper curves are based on the LLNL seismic hazard curves and the high ruthenium source term, and the lower curves are based on the EPRI hazard curves and the low ruthenium source term. As such, these results may be viewed as representing a range of credible risk results, given the conservative assumption that all SFP accidents result in a fire.

Figure 3.6-9 Individual Early Fatality Risk Within 1 Mile **(Insert Here)**

Figure 3.6-10 Individual Latent Cancer Fatality Risk Within 10 Miles **(Insert Here)**

The individual early fatality risk for a SFP accident is 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 the upper end of this range (corresponding to use of the LLNL seismic hazards and the 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 the lower end of the range (corresponding to use of the EPRI seismic hazards and the low ruthenium source term) the risks are about an order of magnitude lower than those for reactor accidents, and about two 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).

Similarly, the individual latent cancer fatality risk for a SFP accident is 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 the upper end of this range (corresponding to use of the LLNL seismic hazards and the 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 the lower end of the range (corresponding to use of the EPRI seismic hazards and the low ruthenium source term) the risks are slightly lower than those for reactor accidents, and about two decades lower than the Safety Goal. The individual latent cancer fatality risk for a SFP are 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.