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November 20, 1990
ST-HL-AE-3636
File No. G25

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

South Texas Project Electric Generating Station
Units 1 & 2
Docket Nos. STN 50-498, STN 50-499
Responses to NRC Request for Additional Information on
Fire Risk Analysis in the Probabilistic Safety Assessment (PSA)
<u>South Texas Project Electric Generating Station (STPEGS)</u>

Reference: (1) Letter from the NRC dated October 15, 1990 (ST-AE-HL-92585).

In the Reference letter, the NRC requested additional information regarding the assessment of the fire hazard contribution to the STPEGS PSA results. These questions resulted from a meeting with the NRC and its contractor, Sandia National Laboratory (SNL), held in Rockville, Maryland, on September 19 and 20, 1990. HL&P's written responses to these questions are provided as an attachment to this letter.

HL&P's responses to these questions were discussed in meetings with the NRC and SNL at the STP plant site on October 24 and 25, 1990.

If you should have any questions on this matter, or the attachment, please contact Mr. A. W. Harrison at (512) 972-7298 or myself at (512) 972-8530.

M. A. McBurnett

M. A. McBurnett
Manager,
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SDP/

Attachment: (1) Responses to NRC Questions on the STPEGS PSA Fire Risk Analysis.

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ATTACHMENT 1
RESPONSES TO NRC QUESTIONS ON THE STP
PSA FIRE RISK ANALYSIS

ADDITIONAL REVIEW QUESTION 1

1. The licensee is requested to discuss the relevance of the Rancho Seco annunciator control panel fire on the STPEGS PSA. (SNL will provide information on the fire to the licensee.)

Response: The referenced fire at Rancho Seco occurred in an annunciator control panel located in an auxiliary equipment room outside the main control room. This fire and two possibly related fires at Calvert Cliffs Unit 2 and Beaver Valley Unit 2 seem to have been caused by overheating of carbon resistors or other components on annunciator input circuit cards and were compounded by excessively high trip current ratings for the circuit breakers that protect these cards. The Calvert Cliffs and Beaver Valley fires also occurred in panels outside the main control room, and they were much smaller than the Rancho Seco fire. All three fires occurred in panels manufactured by Electro Devices, Inc. The South Texas plant does not contain any panels from this manufacturer.

Attachment 1.1 presents a sensitivity study that was performed to investigate the impact on the severity curve presented in STP PSA Figure 9.4-1 from adding the Rancho Seco fire to the panel fire event database. Two considerations indicate that the results from this sensitivity study may be quite conservative and inappropriate for use in a realistic fire analysis.

(1) By including only the Rancho Seco fire, the sensitivity study modifies the fire event database to inappropriately bias the population toward a higher conditional frequency of larger panel fires. The two smaller fires at Calvert Cliffs and Beaver Valley have not been included in this analysis, nor have any other panel fires that may have occurred since the PLG database was last updated in 1987. Since at least 8 of the 13 panel fires in the database are quite small, addition of a single larger fire without updating the database to include the full experience from all panel fires may significantly bias the results displayed by the panel fire severity curve.

(2) The Rancho Seco, Calvert Cliffs, and Beaver Valley fires may not be directly relevant to the analysis for South Texas. There is some evidence that these fires were all related to a design deficiency that may be unique to panels manufactured by Electro Devices, Inc. This assertion is supported by the fact that no similar fires have been reported in annunciator control panels from other manufacturers. It is not possible to completely dismiss these panel fires as irrelevant to South Texas

without more information about the fire causes and propagation modes, and more detailed information about the South Texas panel designs. However, evaluations performed by South Texas engineering personnel have concluded that these fires are isolated to a specific manufacturer's design and that no South Texas panel modifications are necessary in light of these events.

Figure 1-1 duplicates the panel fire severity curve from Figure 9.4-1 in the STP PSA final report and shows the results from the sensitivity study presented in Attachment 1.1. As noted in the study, the overall impact from including the Rancho Seco fire is quite small, increasing the combined geometry and severity factor for control room fire Scenario 6 by approximately 5%. When considered in the context of the database biases introduced by including only the Rancho Seco fire, this conclusion confirms that the original severity curve in Figure 9.4-1 quite reasonably represents the available data and may, in fact, be somewhat conservative.

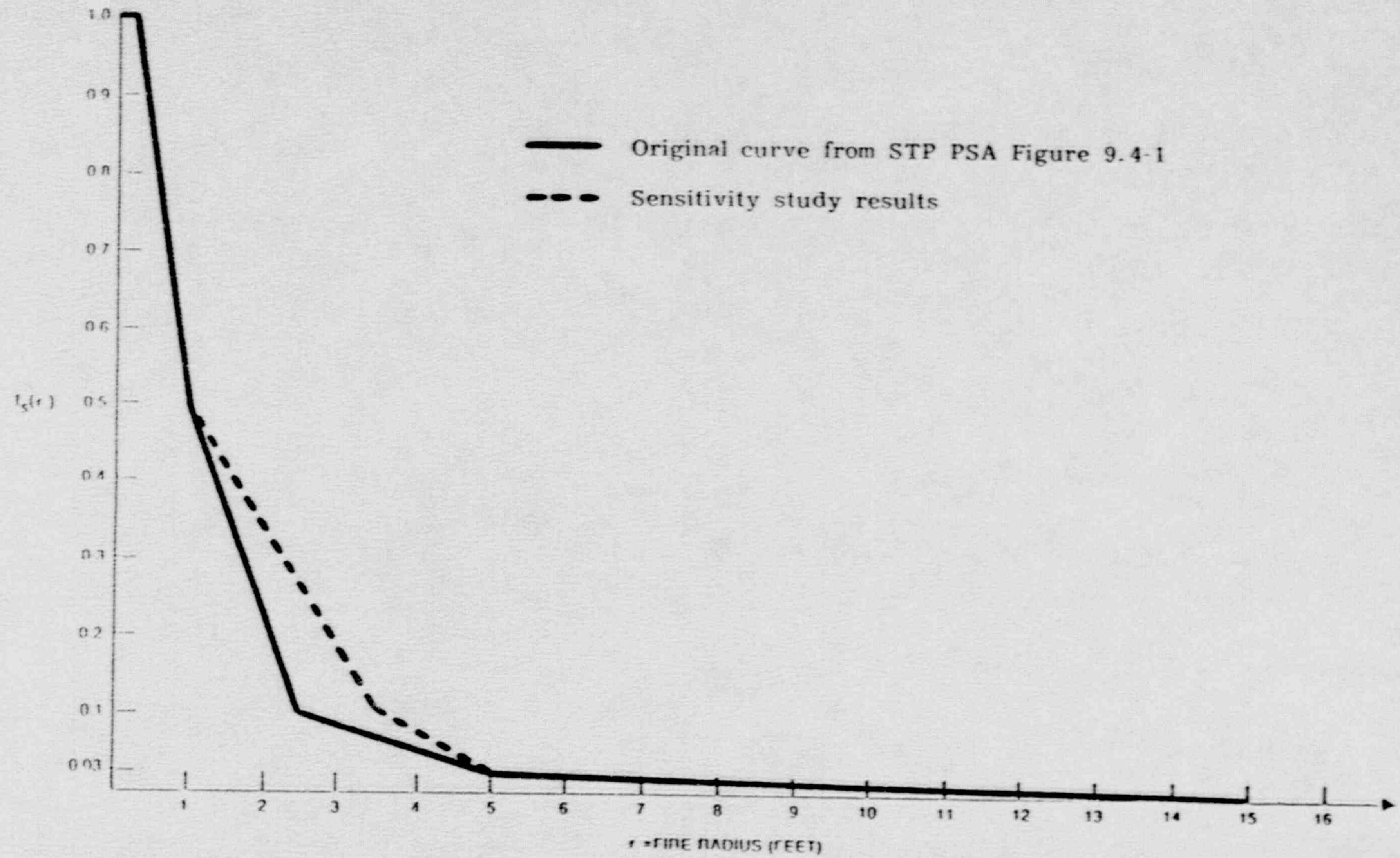

Figure 1-1. Comparison of Panel Fire Severity Factors from Original STP PSA Analysis and Rancho Seco Fire Sensitivity Study

ATTACHMENT 1.1

Rancho Seco Panel Fire Sensitivity Study

Zone: Main Control Room (Sensitivity Analysis Incorporating Rancho Seco Panel Fire)

Contents: Electrical Panels
Cable

Scenarios: Panel fire

Relevant Data:

Previous Analysis:

See Ref. 1. Figure 9.4-1 presents an assumed complementary cumulative distribution function for the damage radius associated with panel fires in the control room. This figure can be represented with the equations provided in Figure 9.4-1:

$$f_s = \begin{cases} 1 & 0.0 \leq r \leq 0.25 \text{ ft} \\ 1.167 - 0.667 \cdot r & 0.25 \leq r \leq 1.0 \text{ ft} \\ 0.767 - 0.267 \cdot r & 1.0 \leq r \leq 2.5 \text{ ft} \\ 0.017 - 0.03 \cdot r & 2.5 \leq r \leq 5.0 \text{ ft} \\ 0.045 - 0.003 \cdot r & 5.0 \leq r \leq 15.0 \text{ ft} \end{cases} \qquad (1)$$

Table 9.4-2, reproduced below in Table 1, applies this function towards the analysis of a single scenario (Scenario 6). (All units are in feet.)

Table 1 – Control Room Fire Scenario 6, Values for Δ_{ai} and f_{si}

Slice	Range	Radius	Area	f_s	$f_s \cdot$Area
1	3–4	3.5	2.5	0.072	0.180
2	4–5	4.5	5.5	0.044	0.242
3	5–6	5.5	7	0.0285	0.200
4	6–7	6.5	11	0.0255	0.281
5	7–8	7.5	11.5	0.0225	0.259
6	8–9	8.5	15	0.0195	0.293
7,8,9	9–12	10.5	52.5	0.0135	0.709
10	12–13	12.5	16.5	0.0075	0.124
11	13–14	13.5	15.5	0.0045	0.0698
12	14–15	14.5	14.5	0.0015	0.0218
				Total	2.38

$$f_{g3} = \frac{1}{1350} \cdot 2.38 = 1.76 \cdot 10^{-3}$$

Data from PLG Data Base [2]:

A review of panel fires incorporated in the PLG fire data base is discussed in Ref. 3. The review identifies 13 fires that are relevant, and provides damage radius estimates for 8 of the 13. (Information is too sketchy to provide estimates for the remaining 5.)

Table 11 of Ref. 3 is reproduced below in Table 2. It can be seen that none of the 8 fires is believed to have been very large. This is somewhat conservatively represented in Figure 9.4-1, which states that 50% of all panel fires have a damage radius of 1 ft or less, and 90% of all panel fires have a damage radius of 2.5 ft or less.

Table 2 – Electrical Panel/Relay Fires in PLG Fire Event Database [2]

ID	Location	Radius (ft)[1]	Radius (ft)[2]
156	CSR	0.25 ft	0.25 ft
166	Aux Bldg	0.50 ft	1.00 ft
169	Aux Bldg	< 0.10 ft	
188	Ctrl Bldg		
225	Ctrl Room	1.00 ft	
271	Other Bldg		
295		< 0.10 ft	
318	Other Bldg		
331	Ctrl Bldg		
336	Comp Room		
384	Rx Bldg	< 0.10 ft	
397	Ctrl Room	< 0.10 ft	
398	Ctrl Room	< 0.10 ft	

Notes:

1) Damage radius, estimated as part of the review in Ref. 3.
2) Damage radius, estimated in Ref. 4.

New Data (Not Included in Ref. 2):

Ref. 5 refers to 3 fires involving annunciator panels that occurred in early 1988:

Beaver Valley Unit 2 (January 28, 1988)
Calvert Cliffs Unit 2(February 1, 1988)
Rancho Seco (February 8, 1988)

All 3 involved panels produced by the same manufacturer.

According to Ref. 6, all 3 fires were extinguished within 10 minutes. It does not appear that any of the affected panels were in the main control rooms. In all cases, the annunciator system was disabled for a number of hours. Damage seems to have been more limited in the first 2 fires. In the Rancho Seco fire, 112 out of 192 circuit cards were damaged by heat, and 3 printed circuit boards were destroyed.

Conversations with an engineer at Rancho Seco indicates that the panel involved was 6–8 ft high, 4 ft wide, and 1 ft deep [7]. The damaged cards were distributed fairly uniformly throughout the panel. No thermal damage was observed outside of the panel, although there were smoke traces on the panel exterior. The panel is ventilated by louvers.

Sensitivity Analysis:

For the purposes of a sensitivity analysis, it is of interest to see how the results of Ref. 1 change if a single fire, comparable in severity to the Rancho Seco fire, is added to the data base.

Assume that 1 out of 9 fires has a damage radius of 3.5 ft[1]. Further assume that this fire can be represented by shifting a single point on the original curve for Figure 9.4–1: the point corresponding to $r = 2.5$ ft and $f_s = 0.10$ (roughly). Points lower on the curve need not be changed since most of the fires are still small, and points higher on the curve need not be changed since these correspond to very large fires that spread beyond the confines of the cabinet/panel.

The resulting modified fire severity curve is then:

$$f_s = \begin{cases} 1 & 0.0 \le r \le 0.25 \text{ ft} \\ 1.167 - 0.667 \cdot r & 0.25 \le r \le 1.0 \text{ ft} \\ 0.656 - 0.156 \cdot r & 1.0 \le r \le 3.5 \text{ ft} \\ 0.297 - 0.053 \cdot r & 3.5 \le r \le 5.0 \text{ ft} \\ 0.045 - 0.003 \cdot r & 5.0 \le r \le 15.0 \text{ ft} \end{cases} \tag{2}$$

The modified area and severity fractions are then as given in Table 3. Examination of Table 3 shows that the change in the reduction factor (i.e., the geometry–severity fraction f_{gs}) is very small, as only the first two slices (with the smallest corresponding panel areas) are affected. Larger changes in the reduction factor can be obtained only if it is shown that a larger fraction of panel fires can cause significant damage outside of the originating panel.

Conclusion:

The result of this sensitivity analysis is that incorporation of an event comparable to the Rancho Seco annunciator fire has a very small impact on the risk computed in Ref. 1 for a given scenario. Similar arguments can be made to show that the risk impact is small for all control room fire scenarios. Note that the impact of this event is expected to be even weaker when less conservative assumptions regarding the damage radius for that fire and the damage radii for the 5 neglected fires in Table 2 are made, and when the PLG fire event data base is properly updated to incorporate all panel fires that have occurred since the data base was last updated.

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[1]Note that this is conservative in three ways: a) it corresponds to a damage area of 38 ft^2, somewhat greater than the entire panel area, b) it neglects the fact that roughly 60% of the panel, rather than 100%, was damaged in the Rancho Seco fire, and c) it neglects the reasonable likelihood that the 5 events in Table 2 for which damage radii are not estimated actually were small.

Table 3 – Control Room Fire Scenario 6,
Sensitivity Analysis Values for Δ_{ai} and f_{si}

Slice	Range	Radius	Area	f_s	f_s•Area
1	3–4	3.5	2.5	0.11	0.275
2	4–5	4.5	5.5	0.059	0.266
3	5–6	5.5	7	0.0285	0.200
4	6–7	6.5	11	0.0255	0.281
5	7–8	7.5	11.5	0.0225	0.259
6	8–9	8.5	15	0.0195	0.293
7,8,9	9–12	10.5	52.5	0.0135	0.709
10	12–13	12.5	16.5	0.0075	0.124
11	13–14	13.5	15.5	0.0045	0.0698
12	14–15	14.5	14.5	0.0015	0.0218
				Total	2.50

$$f_{gs} = \frac{1}{1350} \cdot 2.50 = 1.85 \cdot 10^{-3}$$

References:

1) Pickard, Lowe and Garrick, Inc., "South Texas Project Probabilistic Safety Assessment," Draft Report Section 9, prepared for Houston Lighting and Power Company, 1989.
2) PLG Inc., "Database for Probabilistic Risk Assessment of Light Water Nuclear Power Plants," PLG-0500, Volume 8, Fire Data, Revision 0, September 1990.
3) N. Siu, "Damage Fractions and Related Issues in Fire Risk Analysis: Discussion and Applications to South Texas," prepared for PLG, Inc., September 1990.
4) K.N. Fleming, W.T. Houghton, and F.P. Scaletta, "A Methodology for Risk Assessment of Major Fires and Its Application to an HTGR Plant," GA-A15402, GA Technologies, Inc., 1979.
5) S. Newberry, Chief, Instrumentation and Control Systems Branch, Division of Engineering and Systems Technology, USNRC, Memorandum to W. Lanning, Chief, Events Assessment Branch, Division of Engineering and Systems Technology, USNRC, December 20, 1988.
6) Viewgraphs on Annunciator Cabinet Fires, 1988. (Included in same package as Ref. 4, transmitted from R. Murphy to N. Siu, October 4, 1990.)
7) Telephone conversation with J. Delezinski, Sacramento Municipal Utility District, October 5, 1990.

ATTACHMENT 1
RESPONSES TO NRC QUESTIONS ON THE STP
PSA FIRE RISK ANALYSIS

ADDITIONAL REVIEW QUESTION 2

2. The licensee is requested to assess the contribution to core damage frequency from fires originating in the control room cabinets which were previously screened from the analysis.

Response: The STP PSA control room fire analysis examined the core damage contribution from panel fires that could disable one or more of the components included in the plant event tree models. Other control room fires in panels that do not contain any equipment modeled in the PSA were screened from explicit evaluation. Concerns have been raised about possible human errors that may lead to core damage if the operators are forced to abandon the control room during any of these fires. The following observations conclude that these fire scenarios are not significant contributors to the frequency of core damage.

Frequency of Control Room Abandonment

The Surry PRA (Ref. 1) analyzes large control room fires that can lead to control room abandonment. The analysis focuses on fires in Benchboard 1-1. It is assumed that 10% of all fires involving this benchboard lead to control room abandonment. The Limerick PRA (Ref. 2) assumes that 1/40 (i.e., 2.5%) of control room cabinet fires propagate beyond the walls of the cabinet and that abandonment follows. The Diablo Canyon PRA (Ref. 3) assumes that 95% of all fires will be extinguished before evacuation is required.

None of the 13 panel fires in the PLG fire event database (Ref. 4, listed in Appendix C of Ref. 5) are described as having generated much smoke. This is probably because most, if not all, were small fires with a damage radius of less than 1 foot. It may also be due to a possible lack of sensitivity towards smoke issues on the part of the reporters. The recent Vandellos turbine building fire in Spain did generate a large amount of smoke that entered the control room. However, reports of that event do not indicate that the control room was abandoned.

On the basis of the information cited above, it seems that the assumption used in the Diablo Canyon analysis (i.e., that 5% of all control room fires will require abandonment) is reasonable for scoping studies. It is suspected that even this 5% value may be conservative, but this cannot be proven without more detailed modeling and/or more extensive fire event data.

The total frequency of control room fires used in the STP PSA is approximately 4.9E-03 fire per year. If 5% of these fires require abandonment, the estimated frequency of fire-induced control room abandonment is approximately 2.45E-04 event per year.

Background for Quantifying Operator Error Rates

Current state-of-the-art human reliability analyses do not generally address severe, unspecified errors of commission that may lead to core damage. Analyses are typically performed in the context of directed mission activities. The operators must complete a specific desired action in response to a defined set of equipment failures or procedural instructions. Failure to complete the action results in a known plant condition as defined by the PRA event sequence logic model. If combinations of automatic equipment responses and directed operator actions bring the plant to a stable shutdown condition, the analysis is considered complete, and the PRA concludes that no core damage will occur.

To establish the proper context for addressing the issue of control room abandonment, it should be noted that current PRAs do not quantify the core damage frequency that may result from operator errors of commission while they remain in the control room. Although a large number of relatively routine actions must be performed to maintain the plant in a stable shutdown condition, none of these actions are typically modeled or quantified as potential core damage contributors. This approach is reasonable. In these "success paths" through the PRA event model, the plant has been placed in a stable condition of core subcriticality, decay heat removal, and coolant inventory control. The operators must continue to monitor the running systems and provide relatively routine manual control functions such as adjusting cooldown rates, aligning makeup water supplies, controlling pressure, etc. If the operators make an error during a specific activity, there is generally a large amount of time available for the error to be discovered and corrected. If the error damages a specific piece of equipment, redundant alternatives are usually available to provide the same function.

It is generally agreed among PRA analysts that these conditions represent a "negligibly small" contribution to the frequency of core damage. However, it is extremely difficult, and beyond the state of the art in current human reliability analysis methods, to estimate how small this contribution might be. The entire nuclear power industry has accumulated experience from a very large number of reactor trips and other forced plant shutdowns. No event has led to core damage without a preceding series of equipment failures. In other words, there is no evidence that plant operators have ever been involved in a series of errors of commission that was so severe as to result in core damage. (The Chernobyl accident may refute this claim, but the pre-accident testing conditions at Chernobyl are certainly not typical of stable plant response.) This evidence supports the assertion that the "fatal" control room operator error rate must be less than approximately 1.0E-04 error per shutdown.

Recent U.S. nuclear power plant operating experience shows a typical forced shutdown rate of approximately 5 events per reactor year. Modern PRA results typically display individual core damage event sequences with frequencies in the range of 1.0E-08 per year or lower. Quantitative screening cutoff values are typically set at least two orders of magnitude below the displayed frequencies. These results infer that the assigned error rates for severe errors of commission must be much less than 1.0E-08 error per shutdown. Otherwise, the PRA results would display core damage sequences that contain no other failures except the initiating event and the unspecified "fatal" error.

The preceding discussion is not presented as justification for a specific human error rate for these unspecified errors of commission. It simply provides a "semi-quantitative" context for error rates that may be inferred from published PRA results. Modeling and quantification of these errors is, in fact, beyond the state of the art in current PRA methods and is an interesting topic for fundamental human reliability research. Omission of these errors from PRA models does not reduce the credibility of the quantitative results, and it does not detract from the ultimate goal of developing plant-specific insights for risk reduction and risk management. The methods, models, and data necessary to address these errors are essentially a generic issue related to the ultimate limits of human reliability, which apply equally to all plants, regardless of their specific designs, personnel, training, and procedures.

Conditional Frequency of Core Damage After Control Room Abandonment

The South Texas operators have three major tasks to accomplish when they abandon the control room.

(1) Trip the reactor if it has not already been shut down. This can be accomplished from the control room as the operators are leaving or from a number of remote locations throughout the plant.

(2) Transfer control to the auxiliary shutdown panels. This is accomplished at the transfer switch panels located in each essential switchgear room and at the auxiliary shutdown panels.

(3) Monitor and control operation of the systems required to maintain stable hot shutdown conditions. These actions are essentially the same as those performed from the main control room, using the controls at the auxiliary shutdown panels and local equipment control stations.

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RESPONSES TO NRC QUESTIONS ON THE STP
PSA FIRE RISK ANALYSIS

The STP PSA fire analysis results quantify the impact from control room panel fires that disable equipment required to maintain stable hot shutdown conditions. Therefore, the remaining fires that require control room abandonment have the full complement of mitigation systems available. Operator errors that lead to core damage under these conditions are analogous to the unspecified control room errors of commission discussed above.

All licensed operators at South Texas receive training on controlling the plant from the auxiliary shutdown panels. The plant emergency operating procedures contain instructions for all required actions after the decision is made to abandon the control room. The ability to transfer control to the auxiliary shutdown panels and subsequently maintain stable hot shutdown conditions was demonstrated during the plant startup testing program. However, it seems reasonable to expect that the operator error rate may be higher under these less familiar conditions of controlling plant operation from the auxiliary shutdown panels, compared with error rates in the main control room.

The preceding calculation indicates that the frequency of control room abandonment from all control room fires is approximately 2.45E-04 event per year. Table 7.6-1 in the STP PSA final report shows that the total frequency of plant trips from all causes other than fires is approximately 4.5 events per year. Since the total core damage frequency is approximately 1.7E-04 event per year, it is apparent that nearly all of these plant trips culminate in the desired condition of stable plant shutdown.

As noted above, control room errors of commission are judged to be negligibly small contributors to the frequency of core damage. It is not possible to provide reasonable absolute estimates for either of these error rates. However, it is possible to infer how much higher the error rate from the auxiliary shutdown panels would have to be, if these errors were to have the same core damage impact as the control room errors. The ratio of these error rates is given by the following equation.

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Error Rate Ratio = (Frequency of non-fire events)/
                   (Frequency of control room abandonment)
                 = (4.5)/(2.45E-04)
                 = 1.84E+04
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Therefore, in order for the fire-induced control room abandonment scenarios to have the same (negligibly small) contribution to core damage as the control room error scenarios, the operator error rate for controlling the plant from the auxiliary shutdown panels must be approximately 18,000 times higher than the control room error rate. This seems quite unlikely, based on the available procedures, training, and equipment to control the plant.

As a final comment, it should also be noted that the operators are not expected to remain outside the control room for an extended period of time. The available panel fire experience data indicate that the majority of control room fires are expected to be quite small and quickly extinguished. The operators may have to abandon the control room for a small fraction of these fires because of concerns about remaining in a smoky environment or the inconvenience of operating in supplied breathing apparatus. When the fire is extinguished and the room is ventilated, the operators may reoccupy the control room and resume their more familiar operating stations. Thus, it is expected that most of the activities performed from the auxiliary shutdown panels will involve monitoring and maintenance of essentially steady-state heat removal and inventory control functions with only minor adjustments to flows, levels, pressures, etc. More active changes in plant status, such as preparation for cooldown to cold shutdown, will be delayed until the control room is habitable.

References

1. "External Event Risk Analyses: Surry Power Station", NUREG/CR-4550, Volume 3, Revision 1, Part 3, prepared for the U.S. Nuclear Regulatory Commission by Sandia National Laboratories, September 1989.

2. NUS Corp., "Severe Accident Risk Assessment: Limerick Generating Station", prepared for Philadelphia Electric Co., Report No. 4161, April 1983.

3. Pacific Gas and Electric Co., "Final Report of the Diablo Canyon Long Term Seismic Program", Chapter 6, Probabilistic Risk Analysis, July 1988; PLG, Inc., "Diablo Canyon Probabilistic Risk Assessment", PLG-0637, Appendix F.3, Diablo Canyon Fire Risk Assessment, draft report, August 1988.

4. PLG, Inc., "Database for Probabilistic Risk Assessment of Light Water Nuclear Power Plants", PLG-0500, Volume 8, Fire Data, Revision 0, September 1990.

5. N.O. Siu, "Damage Fractions and Related Issues in Fire Risk Analysis: Discussion and Applications to South Texas", prepared for PLG, Inc., September 1990.

ADDITIONAL REVIEW QUESTION 3

3. The licensee is requested to assess the contribution to core damage frequency from fires in the turbine building which could fail offsite power.

Response: A conservative estimate for the frequency of turbine building fires that may cause a nonrecoverable loss of offsite power shows that these fires are insignificant compared with the frequency of unrecovered offsite power failures from other causes that are explicitly included in the STP PSA results.

3.1. Description of Turbine Building Fire Scenarios

The relevant components and cables that affect the availability of offsite power for the essential switchgear buses are listed below.

(1) 13.8 kV power cables from the Unit Auxiliary Transformer to the 13.8 kV switchgear buses.

(2) 13.8 kV power cables from the Standby Transformer to the 13.8 kV switchgear buses.

(3) 125 V DC normal control power cables to the 13.8 kV switchgear buses.

(4) 125 V DC alternate control power cables to the 13.8 kV switchgear buses.

(5) 13.8 kV switchgear buses F, G, and H.

3.1.1. Fires That May Damage the 13.8 kV AC Power Cables

The power supplies from the Unit Auxiliary Transformer are routed in a non-segregated bus duct that enters the northwest corner of the Turbine Building at Elevation 29'-0" and then enters the west side of the 13.8 kV Switchgear Room. The power supplies from the Standby Transformer are routed in underground conduits that enter the northeast corner of the Turbine Building and then enter each supply cabinet in the 13.8 kV Switchgear Room through the floor. Loss of offsite power to any of the 13.8 kV buses requires failure of power from both the Unit Auxiliary Transformer and the Standby

Transformer. Except for fires in the 13.8 kV Switchgear Room, no credible Turbine Building fires could be identified that would damage both of these supplies.

3.1.2. Fires That May Damage the 125 V DC Control Power Cables

Open circuits in both 125 V DC control power supplies will not affect the availability of offsite power to the 13.8 kV switchgear unless one of the 13.8 kV AC power supplies is also interrupted. It is quite unlikely that short circuits in these control power cables could cause spurious operation of the 13.8 kV circuit breakers. Each 13.8 kV circuit breaker is equipped with a mechanical ratchet to charge the breaker operating springs and mechanical pushbutton releases that allow the operators to locally trip or close the circuit breaker if no control power is available. However, it is conservatively assumed for this screening analysis that any Turbine Building fire that damages both sets of control power cables will cause a loss of all offsite power supplies to the 13.8 kV buses.

Normal 125 V DC control power for operation of the 13.8 kV circuit breakers is supplied from a battery bus located at Elevation 29'-0" in the Turbine Building. Two sets of cables are routed from this battery bus to separate distribution panels in the 13.8 kV Switchgear Room. One distribution panel supplies control power for operation of the circuit breakers at 13.8 kV buses F and H, and the second panel supplies control power for 13.8 kV buses G and J. One set of control power cables is routed in cable trays, and the second set is run in conduit. The exact routing of these cables was not fully verified in the field. However, it is assumed for this analysis that both sets of cables are routed in a relatively direct path from the battery bus to the 13.8 kV Switchgear Room and that the cable trays and conduit are reasonably close to each other throughout most of this span.

Alternate 125 V DC control power for operation of the 13.8 kV circuit breakers is supplied from a battery bus located at Elevation 10'-0" in the Electrical Auxiliary Building. The cables from this bus are routed in conduit along the eastern wall of the Turbine Building at Elevation 29'-0". Until the cables enter the 13.8 kV Switchgear Room, the separation distance between the first two sets of cables (from the Turbine Building battery bus) and the third set of cables (from the Electrical Auxiliary Building battery bus) is at least 20 feet.

Due to the large separation distance between these cables and the fact that two sets of cables are run in conduit, only an extremely large fire could be expected to cause damage to both control power supplies. Very large Turbine Building fires have occurred in nuclear power plants outside the United States (e.g., at the Muehleberg plant in Switzerland, the Maanshan plant in Taiwan, and the Vandellos plant in Spain). All of these fires had their origins at the main turbine generator. The available data do not indicate that any fires of comparable magnitude have occurred at nuclear power plants in the United States.

Examination of the equipment layout in the South Texas Turbine Building shows that fires located on the turbine floor at Elevation 79'-0" are unlikely to damage equipment at Elevation 29'-0" unless burning oil from these fires reaches the lower floors. The burning oil from a large turbine fire is most likely to fall into the condenser hotwell area. The farthest cable of interest is routed in conduit more than 100 feet away along the eastern wall of the Turbine Building. Therefore, the postulated oil pool fire at Elevation 29'-0" must be extremely large to damage this cable. It appears unlikely that any of the turbine fires experienced to date (including those in foreign nuclear power plants) caused thermal damage this far away from the fire source. (The Muehleberg fire did cause smoke damage throughout much of the Turbine Building, creating a long-term cleanup problem, but thermal damage was confined to the immediate vicinity of the fire.) However, further investigation regarding the exact damage radii for the Muehleberg, Maanshan, and Vandellos fires is required before the possibility of huge turbine oil fires can be summarily rejected as being of completely negligible frequency. Therefore, this screening analysis examines the likelihood that an extremely large Turbine Building fire damages all three sets of DC control power cables and causes an assumed loss of power at the 13.8 kV switchgear.

3.1.3. Fires That May Damage the 13.8 kV Switchgear

A large fire in the 13.8 kV Switchgear Room may damage the three 13.8 kV buses (i.e., buses F, G, and H) that supply normal offsite power to the essential AC power buses located in the Electrical Auxiliary Building. The following data summarize the geometry of this room.

Floor: 137 ft. long x 48 ft. wide = 6576 sq. ft. (Ref. 1)
Floor Elevation: 31 ft. (Ref. 1)
Ceiling Height: ~24 ft. (next zone at Elevation 55'-0")
Cabinet Separation (different divisions): >8 ft. (Ref. 1)
Cable Tray Width: 2 ft. (Ref. 2,3)
Typical Cable Run Length: 137 ft. (Ref. 2,3)

3.2. <u>Availability of Emergency Offsite Power</u>

None of the fires described in Section 3.1 will cause a complete loss of offsite power to all three essential AC power divisions. An additional offsite power supply is available from an independent 138 kV transmission circuit (the Blessing line) that connects to the Emergency Transformer in the South Texas Project switchyard. The 13.8 kV power supply cables from this transformer are routed in underground conduits directly from the switchyard to the Emergency Bus (i.e., 13.8 kV bus L) located in the Electrical Auxiliary Building. Therefore, this emergency offsite power supply cannot be damaged by any fires that occur in the Turbine Building.

If the normal 13.8 kV power supplies from the Unit Auxiliary Transformer and the Standby Transformer are deenergized, the operators can reenergize at least one of the essential buses from the main control room by simply closing the emergency offsite power supply breaker to the selected bus. Control power for operation of the emergency supply breakers is provided from the 125 V DC battery bus at Elevation 10'-0" in the Electrical Auxiliary Building. The emergency offsite power circuit has sufficient capacity to supply all loads from at least one essential AC power division. If the operators shed selected loads, more than one essential division may be reenergized from this supply.

3.3. Screening Analysis for Turbine Building Fire Frequencies

Table 3-1 lists 23 fires included in a Turbine Building fire frequency analysis documented in Reference 4. (The data are obtained from Reference 5.) The 23 events break down as follows.

Type	Fuel	Severity(1)	Events
Pump	Oil	Small	52, 341, 355, 378
Pump	Unknown	Unknown	283
Turbine-Generator	Oil, H-2	Small	69, 152, 199, 267, 345, 375, 377
Turbine-Generator	Oil, H-2	Moderate	107, 153, 299, 337, 376
Oil Line	Oil	Large(2)	255
Cable	Insulation	Small	240, 264
Other	See Notes	See Notes	87(3), 189(4), 366(5)

Notes:

(1) Based on narratives; "small" fires lead to minor, localized damage; "moderate" fires lead to widespread damage on burning component and have some potential to damage other components; "large" fires have strong potential to damage other components.

(2) Assumed, based on type of fire (ruptured oil line) and presence of offsite fire department.

(3) Small transient-fueled fire.

(4) Auxiliary boiler fire; no specifics on size or damage caused.

(5) Large outdoor transformer; caused damage to metal siding of Turbine Building; started fires within the building.

Although one event listed in Reference 4 (Event 20) is actually not a Turbine Building fire, the computed fire frequencies from that reference are conservatively used for this analysis. The mean Turbine Building fire frequency from Reference 4 is 0.047 fire per year during plant power operation.

3.3.1. Large Turbine Building Fires

Of the 23 Turbine Building fires listed in Table 3-1, 13 involved the main turbine-generator (including Event 255, which appears to be related). Thus, the fraction of Turbine Building fires in this category is approximately:

F(tg) = F(Turbine-generator fire | Fire in Turbine Building)

= 13/23

= 0.57

Large turbine-generator fires have occurred in at least three foreign nuclear power plants (e.g., at Muehleberg, Maanshan, and Vandellos). A review of the available data indicates that no comparably-sized fires seem to have occurred at nuclear power plants in the United States, although Event 255 appears to have been a relatively large fire.

Due to the intervening floor at Elevation 55'-0", fires on the turbine deck at Elevation 79'-0" are very unlikely to cause damage to the 125 V DC cables at Elevation 29'-0". The experience data indicate that hydrogen fires away from the main generator are unlikely. Extremely large hydrogen fires, away from the main generator, that are capable of damaging equipment more than 100 feet away from the fire source are even less likely. However, it seems possible that burning oil from a large turbine oil fire could flow from the upper floor areas to Elevation 29'-0" in the vicinity of the main condenser hotwell. The available descriptions for the foreign turbine-generator fires do not indicate the extent of damage from burning oil.

For the purpose of this screening calculation, it is conservatively assumed that Event 255 from Table 3-1 represents a fire that is large enough to damage both sets of cables from the Turbine Building battery bus and the cables from the Electrical Auxiliary Building battery bus in the conduit along the eastern wall of the Turbine Building. Using this extremely conservative assumption, the conditional frequency of large Turbine Building fires is approximately

F(tbl) = F(Large turbine-generator fire | Fire in Turbine Building)

˜ 1/23

= 0.043

No additional plant-specific fire severity or geometry reduction factors are applied to further reduce this frequency. Therefore, a conservative screening estimate for the frequency of large turbine-generator fires that may produce enough burning oil to damage all the control power cables at Elevation 29'-0" is:

f(tbl) = f(Fire in Turbine Building)*F(tbl)

= (0.047)*(0.043)

= 2.04E-03 fire per year

3.3.2. 13.8 kV Switchgear Room Fires

Reference 6 presents Auxiliary Building switchgear room fire frequencies that range from 1.28E-03 per year to 1.33E-03 per year. The zones involved (Z004, Z042, and Z052) have less floor area than the Turbine Building 13.8 kV Switchgear Room, and they house lower voltage switchgear. However, each Auxiliary Building switchgear room contains more circuit breakers (approximately 200 480V and 4160V breakers, versus approximately 60 13.8 kV circuit breakers for the Turbine Building switchgear room).

None of the 23 Turbine Building fires listed in Table 3-1 appear to have occurred within a switchgear room. A Bayesian estimate for the fraction of Turbine Building fires occurring within a switchgear room, based on a uniform prior distribution and 0 events in 23 trials, is

F(swg) = F(Fire in switchgear room | Fire in Turbine Building)

˜ 4.0E-02

It is noted that when this value is combined with the mean Turbine Building fire frequency from Reference 4 (0.047 fire per year), the estimated switchgear room fire frequency is 1.88E-03 fire per year, which is slightly higher than the values given in Reference 6 for Auxiliary Building switchgear room fire frequencies.

The different divisions of switchgear cabinets in the 13.8 kV Switchgear Room are widely separated. Thus, it will take quite a large fire to damage all three buses of concern (i.e., buses F, G, and H). As in the analysis for Zone Z004 discussed in Reference 7, it is assumed that 10% of all fires in the switchgear room lead to damage of all switchgear. (In the case of Auxiliary Building switchgear room fires, the actual experience data indicate that this assumption appears to be very conservative.)

F(swl) = F(Switchgear room fire damages all buses | Fire in Turbine Building)

= F(Fire in switchgear room damages all buses | Fire in switchgear room)*

F(Fire in switchgear room | Fire in Turbine Building)

= (0.10)*(0.04)

= 4.0E-03

Therefore, the frequency of a nonrecoverable loss of offsite power caused by a large fire in the 13.8 kV Switchgear Room is

f(swl) = f(Fire in Turbine Building)*F(swl)

= (0.047)*(4.0E-03)

= 1.88E-04 fire per year

3.4. Comparison with Equivalent Impact from Other Internal Events

A very conservative estimate for the total frequency of Turbine Building fires that may disable the normal offsite power supplies to the essential buses is given by the sum of the frequencies for large turbine-generator fires and large fires in the 13.8 kV Switchgear Room. It is assumed for this screening analysis that these fire-caused power failures are not recoverable during the time windows defined for the STP PSA electric power recovery models.

$$
\begin{aligned}
f(LOSP,fire) &= f(tbl) + f(swl) \\
&= (2.04E-03) + (1.88E-04) \\
&= 2.23E-03 \text{ event per year}
\end{aligned}
$$

A quantitative screening evaluation was performed for these Turbine Building fires in the same manner as described for all other fire scenarios documented in the STP PSA final report.

3.4.1. First Level of Scenario Screening Evaluation

Table 7.6-1 from the STP PSA final report indicates that the loss of offsite power frequency used for this study is 1.29E-01 events per site calendar year. A nominal plant availability factor of 70% was applied to yield an initiating event frequency of 9.03E-02 loss of offsite power events per year during plant power operation.

A plant-specific offsite power recovery analysis for the South Texas Project site is documented in Section 15.6.3.1 of the STP PSA final report. All electric power recovery models applied in the final study results use a conservatively bounding available time window of 1 hour to restore power. (This time window is the most limiting time obtained from the combination of steam generator dryout, reactor coolant pump seal failure, and battery depletion described in Section 15.6.4 of the STP PSA final report.) Figure 15.6-1 shows that the mean conditional frequency for failure to recover offsite power within 1 hour at South Texas is approximately 0.45. (i.e., It is estimated that approximately 55% of the offsite power failures will be restored within 1 hour).

The frequency for unrecovered losses of offsite power that is used in the STP PSA final results is the product of these two values.

f(LOSP,int) = (9.03E-02 LOSP event per year)*

(0.45 failure to recover power within 1 hour)

= 4.06E-02 event per year

Thus, the frequency of unrecovered offsite power failures caused by Turbine Building fires (2.23E-03 event per year) is approximately 5.5% of the event frequency from other causes that are explicitly quantified in the STP PSA final results. This comparison fails to meet the first level of quantitative screening criteria used for other fire scenarios in the study (i.e., that the fire-induced event frequency is less than approximately 1% of the equivalent event frequency from "internal" causes).

3.4.2. Second Level of Scenario Screening Evaluation

The second level of fire event scenario screening examines the dominant additional system failures that must occur before these Turbine Building fires can cause core damage. These failures include combinations of the emergency diesel generators, essential cooling water trains, essential chilled water and Electrical Auxiliary Building HVAC trains, component cooling water trains, the turbine-driven auxiliary feedwater pump, the positive displacement charging pump, and the Technical Support Center diesel generator. The resulting equipment failure scenarios include credit for recovery of emergency diesel generator failures according to the models described in Section 15.6.3.2 of the STP PSA final report. The screening evaluation does not account for the relative timing of diesel generator failures, and the assigned recovery time window is 1 hour.

It is noted in Section 3.2 above that the emergency offsite power supply from the 138 kV Blessing line would be available to reenergize at least one of the essential buses during any Turbine Building fire event. The electric power recovery analyses documented in the STP PSA final report do not model this line as a fully independent power supply for offsite power failure events that are caused by external transmission grid or switchyard disturbances. However, the second level of quantitative screening for these Turbine Building fire scenarios conservatively models the emergency power supply from the Blessing line as a possible source of offsite power for one of the essential AC power divisions. A nominal unavailability of 0.10 is used for this power supply. It is believed that this estimate is a conservative upper bound for the actual unavailability of emergency offsite power, considering the combined effects from transmission line hardware failures, maintenance, and operator failures to close the emergency power supply circuit breaker within the available 1-hour time window.

Table 3-2 summarizes the dominant additional failures that must occur to cause core damage after loss of normal 13.8 kV power, and it provides estimates for the conditional frequency of each core damage scenario. These scenarios and the corresponding frequency estimates are derived from the event trees and the systems analyses documented in the STP PSA final report.

The results from the second level of scenario screening indicate that the total core damage frequency from all dominant event sequences initiated by a Turbine Building fire-induced loss of offsite power is approximately 3.0E-07 event per year. This is less than two-tenths of one percent (actually, 0.0017) of the total core damage frequency from all other events documented in the STP PSA final report (i.e., 1.7E-04 event per year).

3.5. Conclusions

The screening evaluations summarized in Section 3.4 indicate that Turbine Building fires that cause a loss of offsite power are inconsequential contributors to the frequency of core damage at STP. Several very conservative assumptions have been combined in these evaluations. The most important of these conservatisms are summarized below.

(1) It is assumed that failure of both 125 V DC control power supplies will cause a nonrecoverable loss of offsite power to the 13.8 kV switchgear. Open circuits in these control power cables will not cause circuit breakers to trip, and short circuits are quite unlikely to cause spurious circuit

breaker operations. No credit has been taken for possible operator actions to mechanically open and close the bus transfer circuit breakers in the 13.8 kV Switchgear Room after damage to the DC control power cables from a fire outside this room.

(2) Although three large turbine-generator fires have occurred at foreign nuclear power plants, the available data do not indicate that any comparably-sized fires have occurred at nuclear power plants in the United States. One event in the database appears to have involved the burning of a quantity of turbine hydraulic oil. This fire is used as direct evidence for the conditional frequency of turbine-generator fires that may produce large quantities of burning oil.

(3) It is assumed that a large turbine-generator fire will produce a sufficient amount of burning oil in a pool at Turbine Building Elevation 29 -0" to damage all three sets of 125 V DC control power cables. This damage includes the two Turbine Building battery supplies that are routed through Elevation 29'-0" (one in cable trays and one in conduit) and the Electrical Auxiliary Building battery supply that is routed in conduit along the eastern wall of the Turbine Building, more than 100 feet from the most likely location of a burning oil pool. No additional fire severity or geometry factors are applied to reduce the conditional frequency of damage to the Electrical Auxiliary Building battery cables.

(4) It is assumed that the emergency offsite power supply from the Blessing line can be used to reenergize one essential AC power division. A conservative value of 0.10 is assigned for the unavailability of this power supply, including operator failures to close the emergency supply breakers from the control room within 1 hour after the initial loss of normal 13.8 kV power.

(5) It is assumed that 10% of all fires that occur in the 13.8 kV Switchgear Room will be large enough to damage all three 13.8 kV buses F, G, and H.

It is believed that more detailed analyses of the initiating fire event frequency, the conditional frequency for loss of 13.8 kV power during a Turbine Building fire, and the conditional frequency of core damage after the loss of normal 13.8 kV power would show that these fires contribute substantially less to the total frequency of core damage than estimated from these conservative screening evaluations. Therefore, it is concluded that these Turbine Building fires are insignificant compared with the frequency of core damage from other causes of unrecovered losses of offsite power that are explicitly quantified in the STP PSA final results.

3.6. References

1. General Arrangement, Turbine Generator Building, Plan El. 29'-0", Area-A, Drawing 6G-01-9-M-0007, Revision 6.

2. Electrical, Turbine Generator Building Conduit Plan, Ground Floor El. 29'-0", Drawing 6-E-50-9-E-2230, Revision 9.

3. Electrical, Turbine Generator Building Conduit Plan, Ground Floor El. 29'-0", Drawing 6-E-50-9-E-2231, Revision 9.

4. Pickard, Lowe, and Garrick, Inc., "Analysis of Fire Frequency During Shutdown", prepared for Public Service Company of New Hampshire, PLG-0602, January 1988.

5. PLG, Inc., "Database for Probabilistic Risk Assessment of Light Water Nuclear Power Plants", PLG-0500, Volume 8, Fire Data, Revision 0, September 1990.

6. Pickard, Lowe, and Garrick, Inc., "South Texas Project Probabilistic Safety Assessment", Section 8, Table 8.5-2, prepared for Houston Lighting and Power Company, 1989.

7. N.O. Siu, "Damage Fractions and Related Issues in Fire Risk Analysis: Discussion and Applications to South Texas", prepared for PLG, Inc., September 1990.

Table 3-1. Turbine Building Fires (References 4 and 5)

Event	Description
52	Feedwater pump; oil-soaked insulation; hot pipe; portable extinguishers (30 minutes); small losses.
69	High pressure turbine; oil-soaked insulation; hot pipe.
87	Ping pong balls; smoking; sprinklers (15 minutes); small losses.
107	Turbine oil purifier system; leaking oil; heater; portable extinguishers (30 minutes); cables above fire charred; moderate losses.
152	Turbine generator; leaking hydrogen; spontaneous combustion; automatic CO2 (<5 minutes); small losses.
153	Turbine generator; leaking hydrogen; spontaneous combustion; manual CO2 (45 minutes); moderate losses.
189	Auxiliary boiler.
199	Turbine generator; hydrogen in bearings; spontaneous combustion; fire brigade, hose stream, manual CO2 (35 minutes); minor water damage to electronics.
240	Cable tray fire; smoldering.
255	Ruptured hydraulic oil line; offsite fire department.
264	Cable tray fire; welding/cutting.
267	Generator pilot exciter unit.
283	Condensate booster pump.
299	Turbine generator; hydrogen leaked into exciter; fire brigade.
337	Turbine generator; hydrogen leak, explosion; automatic CO2 (14 minutes).
341	Feedwater pump; oil-soaked insulation; fire brigade; minor fire.
345	Turbine generator; insulation.
355	Feedwater pump; overheated bearing; fire brigade (15 minutes); localized damage.
366	Auxiliary transformer; spread to turbine building after damaging metal siding; automatic deluge, fire brigade (15 minutes).
375	Turbine generator; leaking hydrogen; (30 seconds).
376	Turbine generator; leaking oil (immediately followed Event 375); fire brigade (30 minutes).
377	Generator brush assembly; automatic CO2 (35 minutes).
378	Feedwater pump; fire brigade (15 minutes); localized damage.

NOTE: "Small loss" fires led to losses of less than $5,000; "moderate loss" fires led to losses between $5,000 and $50,000.

Table 3-2. Level 2 Screening: Evaluation of Dominant Additional Failures to Cause Core Damage from Turbine Building Fires that Disable All Normal 13.8 kV Power

Fire Event Frequency: 2.23E-03/yr

Additional Failures to Cause Core Damage:

1. DG A, DG B, DG C, Blessing, DG Recovery, (AFW D or PDP)
2. DG A, DG B, ECW C, Blessing, DG Recovery, (AFW D or PDP)
3. DG A, ECW B, DG C, Blessing, DG Recovery, (AFW D or PDP)
4. ECW A, DG B, DG C, Blessing, DG Recovery, (AFW D or PDP)
5. DG A, ECW B, ECW C, Blessing, DG Recovery, (AFW D or PDP)
6. ECW A, DG B, ECW C, Blessing, DG Recovery, (AFW D or PDP)
7. ECW A, ECW B, DG C, Blessing, DG Recovery, (AFW D or PDP)
8. ECW A, ECW B, ECW C, (AFW D or PDP)
9. DG A, DG B, ECH C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
10. DG A, DG B, Fan C, Blessing, DG Recovery, (AFW D or PDP)
11. DG A, ECH B, DG C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
12. DG A, Fan B, DG C, Blessing, DG Recovery, (AFW D or PDP)
13. ECH A, DG B, DG C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
14. Fan A, DG B, DG C, Blessing, DG Recovery, (AFW D or PDP)
15. DG A, ECH B, ECH C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
16. DG A, ECH B, Fan C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
17. DG A, Fan B, ECH C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
18. DG A, Fan B, Fan C, Blessing, DG Recovery, (AFW D or PDP)
19. ECH A, DG B, ECH C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
20. ECH A, DG B, Fan C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
21. Fan A, DG B, ECH C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
22. Fan A, DG B, Fan C, Blessing, DG Recovery, (AFW D or PDP)
23. ECH A, ECH B, DG C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
24. ECH A, Fan B, DG C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
25. Fan A, ECH B, DG C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
26. Fan A, Fan B, DG C, Blessing, DG Recovery, (AFW D or PDP)
27. ECH A, ECH B, ECH C, Smoke Purge, (AFW D or PDP)
28. ECH A, ECH B, Fan C, Smoke Purge, (AFW D or PDP)
29. ECH A, Fan B, ECH C, Smoke Purge, (AFW D or PDP)
30. Fan A, ECH B, ECH C, Smoke Purge, (AFW D or PDP)
31. ECH A, Fan B, Fan C, Smoke Purge, (AFW D or PDP)
32. Fan A, ECH B, Fan C, Smoke Purge, (AFW D or PDP)
33. Fan A, Fan B, ECH C, Smoke Purge, (AFW D or PDP)
34. Fan A, Fan B, Fan C, (AFW D or PDP)

Table 3-2. (Page 2 of 7) Level 2 Screening: Evaluation of Dominant Additional Failures to Cause Core Damage from Turbine Building Fires that Disable All Normal 13.8 kV Power

35. DG A, ECW B, ECH C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
36. DG A, ECW B, Fan C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
37. DG A, ECH B, ECW C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
38. DG A, Fan B, ECW C, Blessing, DG Recovery, (AFW D or PDP)
39. ECW A, DG B, ECH C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
40. ECW A, DG B, Fan C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
41. ECH A, DG B, ECW C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
42. Fan A, DG B, ECW C, Blessing, DG Recovery, (AFW D or PDP)
43. ECW A, ECH B, DG C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
44. ECW A, Fan B, DG C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
45. ECH A, ECW B, DG C, Blessing, DG Recovery, Smoke Purge, (AFW D or PDP)
46. Fan A, ECW B, DG C, Blessing, DG Recovery, (AFW D or PDP)
47. ECW A, ECW B, ECH C, Smoke Purge, (AFW D or PDP)
48. ECW A, ECW B, Fan C, (AFW D or PDP)
49. ECW A, ECH B, ECW C, Smoke Purge, (AFW D or PDP)
50. ECW A, Fan B, ECW C, (AFW D or PDP)
51. ECH A, ECW B, ECW C, Smoke Purge, (AFW D or PDP)
52. Fan A, ECW B, ECW C, (AFW D or PDP)
53. ECW A, ECH B, ECH C, Smoke Purge, (AFW D or PDP)
54. ECW A, ECH B, Fan C, Smoke Purge, (AFW D or PDP)
55. ECW A, Fan B, ECH C, Smoke Purge, (AFW D or PDP)
56. ECW A, Fan B, Fan C, (AFW D or PDP)
57. ECH A, ECW B, ECH C, Smoke Purge, (AFW D or PDP)
58. ECH A, ECW B, Fan C, Smoke Purge, (AFW D or PDP)
59. Fan A, ECW B, ECH C, Smoke Purge, (AFW D or PDP)
60. Fan A, ECW B, Fan C, (AFW D or PDP)
61. ECH A, ECH B, ECW C, Smoke Purge, (AFW D or PDP)
62. ECH A, Fan B, ECW C, Smoke Purge, (AFW D or PDP)
63. Fan A, ECH B, ECW C, Smoke Purge, (AFW D or PDP)
64. Fan A, Fan B, ECW C, (AFW D or PDP)
65. DG A, DG B, CCW C, Blessing, DG Recovery, PDP
66. DG A, CCW B, DG C, Blessing, DG Recovery, PDP
67. CCW A, DG B, DG C, Blessing, DG Recovery, PDP
68. DG A, CCW B, CCW C, Blessing, DG Recovery, PDP
69. CCW A, DG B, CCW C, Blessing, DG Recovery, PDP
70. CCW A, CCW B, DG C, Blessing, DG Recovery, PDP
71. CCW A, CCW B, CCW C, PDP
72. DG A, ECW B, CCW C, Blessing, DG Recovery, PDP
73. DG A, CCW B, ECW C, Blessing, DG Recovery, PDP

Table 3-2. (Page 3 of 7) Level 2 Screening: Evaluation of Dominant Additional Failures to Cause Core Damage from Turbine Building Fires that Disable All Normal 13.8 kV Power

74. ECW A, DG B, CCW C, Blessing, DG Recovery, PDP
75. CCW A, DG B, ECW C, Blessing, DG Recovery, PDP
76. ECW A, CCW B, DG C, Blessing, DG Recovery, PDP
77. CCW A, ECW B, DG C, Blessing, DG Recovery, PDP
78. ECW A, ECW B, CCW C, PDP
79. ECW A, CCW B, ECW C, PDP
80. CCW A, ECW B, ECW C, PDP
81. ECW A, CCW B, CCW C, PDP
82. CCW A, ECW B, CCW C, PDP
83. CCW A, CCW B, ECW C, PDP

Approximate Conditional Core Damage Frequency:

1. G3*(0.10)*(0.273)*(AFR' + PDJ)
   3.375E-05
2. G2*WCO*(0.10)*(0.273)*(AFR' + PDJ)
   1.356E-06
3. G2*WBE*(0.10)*(0.273)*(AFR' + PDJ)
   1.781E-05
4. G2*WAB*(0.10)*(0.273)*(AFR' + PDJ)
   7.464E-07
5. G1*W23*(0.10)*(0.348)*(AFR' + PDJ)
   1.752E-06
6. G1*W25*(0.10)*(0.348)*(AFR' + PDJ)
   1.609E-07
7. G1*W22*(0.10)*(0.348)*(AFR' + PDJ)
   8.549E-07
8. W32*(AFR' + PDJ)
   1.083E-05
9. G2*CLG*(0.10)*(0.273)*OS03*(AFR' + PDJ)
   3.289E-07
10. G2*FCM*(0.10)*(0.273)*(AFR' + PDJ)
    6.322E-06
11. G2*CLO*(0.10)*(0.273)*OS03*(AFR' + PDJ)
    1.822E-07
12. G2*FBG*(0.10)*(0.273)*(AFR' + PDJ)
    2.720E-07
13. G2*CLK*(0.10)*(0.273)*OS03*(AFR' + PDJ)
    1.822E-07
14. G2*FAB*(0.10)*(0.273)*(AFR' + PDJ)
    2.720E-07
15. G1*CLX*(0.10)*(0.348)*OS03*(AFR' + PDJ)
    7.545E-09
16. G1*CLO*FCM*(0.10)*(0.348)*OS03*(AFR' + PDJ)
    6.510E-08
17. G1*FBG*CLG*(0.10)*(0.348)*OS03*(AFR' + PDJ)
    5.056E-09

Table 3-2. (Page 4 of 7) Level 2 Screening: Evaluation of Dominant Additional Failures to Cause Core Damage from Turbine Building Fires that Disable All Normal 13.8 kV Power

18. G1*F25*(0.10)*(0.348)*(AFR' + PDJ)
1.178E-07
19. G1*CLW*(0.10)*(0.348)*OS03*(AFR' + PDJ)
2.103E-08
20. G1*CLK*FCM*(0.10)*(0.348)*OS03*(AFR' + PDJ)
6.510E-08
21. G1*FAB*CLG*(0.10)*(0.348)*OS03*(AFR' + PDJ)
5.056E-09
22. G1*F25*(0.10)*(0.348)*(AFR' + PDJ)
1.178E-07
23. G1*CLQ*(0.10)*(0.348)*OS03*(AFR' + PDJ)
2.924E-08
24. G1*CLK*FBG*(0.10)*(0.348)*OS03*(AFR' + PDJ)
2.801E-09
25. G1*FAB*CLO*(0.10)*(0.348)*OS03*(AFR' + PDJ)
2.801E-09
26. G1*F23*(0.10)*(0.348)*(AFR' + PDJ)
2.620E-08
27. CLP*OS03*(AFR' + PDJ)
2.545E-07
28. CLQ*FCM*OS03*(AFR' + PDJ)
3.203E-07
29. CLW*FBG*OS03*(AFR' + PDJ)
9.911E-09
30. CLX*FAB*OS03*(AFR' + PDJ)
3.556E-09
31. F25*CLK*OS03*(AFR' + PDJ)
3.720E-08
32. F25*CLO*OS03*(AFR' + PDJ)
3.720E-08
33. F23*CLG*OS03*(AFR' + PDJ)
1.493E-08
34. F33*(AFR' + PDJ)
8.239E-07
35. G1*WBE*CLG*(0.10)*(0.348)*OS03*(AFR' + PDJ)
3.311E-07
36. G1*WBE*FCM*(0.10)*(0.348)*(AFR' + PDJ)
6.364E-06
37. G1*CLO*WCO*(0.10)*(0.348)*OS03*(AFR' + PDJ)
1.397E-08
38. G1*FBG*WCO*(0.10)*(0.348)*(AFR' + PDJ)
2.085E-08
39. G1*WAB*CLG*(0.10)*(0.348)*OS03*(AFR' + PDJ)
1.388E-08
40. G1*WAB*FCM*(0.10)*(0.348)*(AFR' + PDJ)
2.667E-07
41. G1*CLK*WCO*(0.10)*(0.348)*OS03*(AFR' + PDJ)
1.397E-08

Table 3-2. (Page 5 of 7) Level 2 Screening: Evaluation of Dominant Additional Failures to Cause Core Damage from Turbine Building Fires that Disable All Normal 13.8 kV Power

42. G1*FAB*WCO*(0.10)*(0.348)*(AFR' + PDJ)
2.085E-08
43. G1*WAB*CLO*(0.10)*(0.348)*OS03*(AFR' + PDJ)
7.686E-09
44. G1*WAB*FBG*(0.10)*(0.348)*(AFR' + PDJ)
1.147E-08
45. G1*CLK*WBE*(0.10)*(0.348)*OS03*(AFR' + PDJ)
1.834E-07
46. G1*FAB*WBE*(0.10)*(0.348)*(AFR' + PDJ)
2.738E-07
47. W22*CLG*OS03*(AFR' + PDJ)
4.872E-07
48. W22*FCM*(AFR' + PDJ)
9.366E-06
49. W25*CLO*OS03*(AFR' + PDJ)
5.078E-08
50. W25*FBG*(AFR' + PDJ)
7.581E-08
51. W23*CLK*OS03*(AFR' + PDJ)
5.531E-07
52. W23*FAB*(AFR' + PDJ)
8.257E-07
53. WAB*CLX*OS03*(AFR' + PDJ)
9.759E-09
54. WAB*CLO*FCM*OS03*(AFR' + PDJ)
8.420E-08
55. WAB*FBG*CLG*OS03*(AFR' + PDJ)
6.539E-09
56. WAB*F25*(AFR' + PDJ)
1.524E-07
57. WBE*CLW*OS03*(AFR' + PDJ)
6.490E-07
58. WBE*CLK*FCM*OS03*(AFR' + PDJ)
2.009E-06
59. WBE*FAB*CLG*OS03*(AFR' + PDJ)
1.560E-07
60. WBE*F25*(AFR' + PDJ)
3.636E-06
61. WCO*CLQ*OS03*(AFR' + PDJ)
6.872E-08
62. WCO*CLK*FBG*OS03*(AFR' + PDJ)
6.583E-09
63. WCO*FAB*CLO*OS03*(AFR' + PDJ)
6.583E-09
64. WCO*F23*(AFR' + PDJ)
6.159E-08

Table 3-2. (Page 6 of 7) Level 2 Screening: Evaluation of Dominant Additional Failures to Cause Core Damage from Turbine Building Fires that Disable All Normal 13.8 kV Power

65. G2*KCO*(0.10)*(0.273)*PDJ
5.525E-07
66. G2*KBE*(0.10)*(0.273)*PDJ
1.096E-05
67. G2*KAB*(0.10)*(0.273)*PDJ
4.253E-07
68. G1*K23*(0.10)*(0.348)*PDJ
5.244E-07
69. G1*K25*(0.10)*(0.348)*PDJ
5.049E-08
70. G1*K22*(0.10)*(0.348)*PDJ
4.015E-07
71. K32*PDJ
2.801E-06
72. G1*WBE*KCO*(0.10)*(0.348)*PDJ
5.562E-07
73. G1*KBE*WCO*(0.10)*(0.348)*PDJ
8.407E-07
74. G1*WAB*KCO*(0.10)*(0.348)*PDJ
2.331E-08
75. G1*KAB*WCO*(0.10)*(0.348)*PDJ
3.261E-08
76. G1*WAB*KBE*(0.10)*(0.348)*PDJ
4.626E-07
77. G1*KAB*WBE*(0.10)*(0.348)*PDJ
4.281E-07
78. W22*KCO*PDJ
8.186E-07
79. W25*KBE*PDJ
3.056E-06
80. W23*KAB*PDJ
1.291E-06
81. WAB*K23*PDJ
6.782E-07
82. WBE*K25*PDJ
1.558E-06
83. WCO*K22*PDJ
9.437E-07

Approximate Total Core Damage Frequency: 2.87E-07/yr

Table 3-2. (Page 7 of 7) Level 2 Screening: Evaluation of Dominant Additional Failures to Cause Core Damage from Turbine Building Fires that Disable All Normal 13.8 kV Power

Split Fraction*	Description	Value
G1	Diesel Generator A (B) (C) Failure	1.178E-01
G2	Diesel Generators A and B (A and C) (B and C) Failure	1.887E-02
G3	Diesel Generators A, B, and C Failure	4.524E-03
WAB	ECW Train A Failure	5.302E-03
WBE	ECW Train B Failure	1.265E-01
WCO	ECW Train C Failure	9.636E-03
W22	ECW Trains A and B Failure	7.632E-04
W25	ECW Trains A and C Failure	1.436E-04
W23	ECW Trains B and C Failure	1.564E-03
W32	ECW Trains A, B, and C Failure	3.962E-05
CLK	ECH Train A Failure	2.609E-02
CLO	ECH Train B Failure	2.609E-02
CLG	ECH Train C Failure	4.710E-02
CLQ	ECH Trains A and B Failure	5.262E-04
CLW	ECH Trains A and C Failure	3.785E-04
CLX	ECH Trains B and C Failure	1.358E-04
CLP	ECH Trains A, B, and C Failure	1.878E-05
FAB	EAB HVAC Fan Train A Failure	1.932E-03
FBG	EAB HVAC Fan Train B Failure	1.932E-03
FCM	EAB HVAC Fan Train C Failure	4.491E-02
F23	EAB HVAC Fan Trains A and B Failure	2.339E-05
F25	EAB HVAC Fan Trains A and C (B and C) Failure	1.052E-04
F33	EAB HVAC Fan Trains A, B, and C Failure	3.015E-06
KAB	CCW Train A Failure	4.236E-03
KBE	CCW Train B Failure	1.092E-01
KCO	CCW Train C Failure	5.503E-03
K22	CCW Trains A and B Failure	5.025E-04
K25	CCW Trains A and C Failure	6.319E-05
K23	CCW Trains B and C Failure	6.563E-04
K32	CCW Trains A, B, and C Failure	1.437E-05
AFR'	AFW Train D Failure (After Turbine Recovery)	7.836E-02
PDJ	PDP Failure (Including TSC Diesel)	1.949E-01
OS03	Operator Failure to Start Smoke Purge	4.960E-02

*NOTE: System failure split fractions are documented in STP PSA Appendix F. Operator action split fractions are documented in STP PSA Table 15.4-53. Diesel generator recovery factors are from STP PSA Table 15.6-2 with offsite power not recoverable. Total unavailability of emergency offsite power from the Blessing line is assumed to be 0.10 for this analysis.