

July 9, 1999

FOR: The Commissioners

FROM: William D. Travers /s/  
Executive Director for Operations

SUBJECT: ASSESSMENT OF THE IMPACT OF APPENDIX R FIRE PROTECTION EXEMPTIONS ON FIRE RISK

## PURPOSE:

In a Staff Requirements Memorandum (SRM) on [SECY 98-058](#), dated June 30, 1998, the staff was directed to "closely examine plants whose individual plant examinations for external events (IPEEEs) show fire protection vulnerabilities to gain a thorough understanding of the particular risk contributors. In evaluating those facilities, consideration is to be given to the cumulative effects of exemptions to current regulations to ensure that an adequate level of fire protection is maintained. The staff is directed to report to the Commission the results of lessons learned from the IPEEE efforts." In addition, in another SRM dated April 1, 1999, the staff was directed as follows: "when assessing the effect of exemptions to Appendix R, the staff needs to consider the cumulative effect of exemptions at a particular plant." The purpose of this paper is to summarize the results of a limited scope analysis investigating the potential core damage frequency (CDF) impact of exemptions to Appendix R.

## BACKGROUND:

[Appendix R to 10 CFR Part 50](#) applies only to plants operating before January 1, 1979. When it promulgated Appendix R, the Commission recognized that there would be plant conditions and configurations where strict compliance with the prescriptive fire protection features specified in Appendix R would not significantly enhance the level of fire safety already provided by the licensee. Therefore, in cases where a fire hazard analysis could adequately demonstrate that alternative fire protection features provided an equivalent level of fire safety to that required by Appendix R and satisfied the underlying purpose of Appendix R, the licensee could apply for an exemption from the prescriptive requirements of Appendix R. Thus, the exemption process provided a means of allowing flexibility to meet the performance objectives of Appendix R through alternative means.

For plants that began operation after January 1, 1979, guidance for the plants' fire protection programs is provided in Branch Technical Position (BTP) CMEB 9.5-1. For these newer plants, the staff approved "deviations" from the guidance during the licensing process. Since Appendix R requirements are included in BTP CMEB 9.5-1, this paper uses the term "exemptions" to refer to both BTP CMEB 9.5-1 deviations as well as Appendix R exemptions.

The staff has granted and continues to grant exemptions on the basis that the alternative fire protection strategies proposed provide an adequate level of fire safety and satisfy the underlying purpose of the regulation. However, this does not ensure that the fire risk associated with the alternative strategies is equal to that associated with a compliance-based strategy. Indeed, exemptions may represent relaxations in requirements (e.g., the lack of an automatic fire suppression system in an area where such a system is prescribed by the regulation). Thus, it is possible that the granting of exemptions could result in some increase in fire risk.

The Office of Nuclear Reactor Regulation's FIREDAT database contains information on NRC-approved exemptions; a recent summary is provided in NUREG-1521 (Draft). NUREG-1521 shows that almost 90 percent of the non-schedular exemptions (i.e., exemptions not associated with the schedule-related requirements of Appendix R) are associated with the requirements for fire protection of safe shutdown capability (see Appendix R, Sections III.G and III.L); a substantial fraction of these are associated with the requirements for protection of redundant trains of post-fire safe shutdown systems (see Section III.G.2). It should be noted that there is considerable variability in the scope of some of the exemptions. For example, some exemptions cover multiple fire areas while others cover specific elements in a single area.

## DISCUSSION:

The original Quad Cities IPEEE submittal identified fire protection vulnerabilities. Quad Cities also has over 30 exemptions to Appendix R, and the question has been raised as to whether or not the exemptions contributed significantly to the plant's fire risk. Commonwealth Edison has since notified the staff that they are revising the Quad Cities IPEEE, and on the basis of the re-analysis, they stated that the Appendix R exemptions have a negligible contribution to the plant's fire risk. However, the staff has not yet received the revised IPEEE and is currently unable to confirm this conclusion.

To provide additional information to the Commission, the staff, with contractor support, performed a limited scope study looking at the CDF impact of Appendix R exemptions at nine plants representing a total of 13 units. The plants were selected on the basis that the fire-induced CDFs reported in the plants' IPEEE fire analyses are high compared to other IPEEE submittals. The plants included in this study are Calvert Cliffs Unit 1, Dresden Units 2 and 3, Farley Units 1 and 2, Kewaunee, Palisades, Robinson Unit 2, St. Lucie Units 1 and 2, Summer, and Turkey Point Units 3 and 4. The total number of exemptions examined in this study is 169, and the number of exemptions per plant varied from 2 to 54. The question addressed is: On the basis of what we know now regarding plant-specific fire risk, do any exemptions (or sets of exemptions) have the potential to significantly affect CDF?

Based largely on available documentation for the IPEEE submittals, the results of this limited scope study indicate that out of the 169 exemptions for the nine plants, most have a small or very small impact on CDF. Only five of the exemptions are potentially risk significant <sup>(1)</sup> (three at Dresden Units 2 and 3 and two at Farley Units 1 and 2). Of the remaining 164 exemptions, 143 have a small or very small impact on fire risk, and 21 have an indeterminate risk impact. Additional discussion on the approach, results and conclusions of this study is included in an attachment to this paper.

There are, of course, uncertainties in these results stemming from the use of the IPEEEs (which were aimed at licensees identifying vulnerabilities and

gaining an appreciation of severe accident behavior at their plants, and not necessarily at accurate CDF estimates); from the information contained in the available documentation (many of the submittals contain insufficient information to allow definitive assessments of CDF impact); from the variability in quality of the IPEEEs from plant to plant; and from weaknesses in the IPEEEs themselves (there are gaps in the current state of the art of fire risk assessments which limit their ability to confidently deal with a number of key fire safety issues). Even with these limitations, the IPEEEs provide the best information readily available to address questions about the potential risk significance of Appendix R exemptions.

#### CONCLUSIONS:

The results of this study show that a simple count of the number of exemptions at a given plant provides little or no direct insight into the potential risk significance of exemptions at that plant. Similarly, a comparison of the number of exemptions between plants does not provide a reliable indication of the relative risk significance of exemptions at each plant.

With respect to the impact of individual exemptions, the results of this study have shown that a large majority (about 85 percent) of the Appendix R exemptions that were examined had a small or very small impact on plant CDF.

The two overall conclusions of the study discussed above should be considered robust. However, given the nature of this limited scope study, the plant-specific results discussed below for potentially risk-significant and indeterminate exemptions should be considered preliminary pending more detailed evaluation.

Five exemptions at two plants (Dresden and Farley) were found to be potentially risk significant. The risk significance of 21 exemptions could not be determined because the IPEEE lacked sufficient detail to assess their risk significance.

With respect to the cumulative effect of exemptions, this study found that the cumulative risk impact at three of the nine plants could be potentially significant. For two of these plants (Farley and Dresden), this result was based on the cumulative impact of individual exemptions, each of which was determined to be potentially risk significant. The third plant (Robinson) had exemptions that were considered, on an individual basis, to have a small impact on several fire areas; however, taken together, the CDF contributions for the impacted areas may be potentially significant. Four other plants in this study had a small or very small cumulative effect. The cumulative effect for the two remaining plants could not be determined with any degree of confidence because of the nature of the indeterminate individual exemptions for those plants.

As a follow-up to this limited scoping study, the staff will undertake the following actions:

- Commonwealth Edison has informed the staff that it will revise and resubmit the Quad Cities and Dresden IPEEEs. The staff will therefore review the risk significance of the Dresden and Quad Cities exemptions when the revised IPEEEs are submitted to the staff.
- Pursue the potentially risk significant exemptions at Farley and Robinson to assess the significance of the potentially risk-significant exemptions identified in this study. This will involve interactions with the licensee to confirm data used and judgments made in the study. If the exemptions are found to be sufficiently risk significant to justify a plant-specific backfit, the staff will pursue with the licensee improvements to the plant's fire protection program to reduce the risk.
- Continue to perform research to close gaps in the current state of the art in fire risk analysis methods and tools, including tools to provide a better understanding of the risk from main control room (MCR) fires. (Additional discussion on the risk significance of MCR fires is included in the attachment to this paper.)
- Collect additional information to assess the risk significance of a number of non-MCR exemptions whose impact is currently indeterminate.
- Include the identification and assessment of potentially risk-significant exemptions for plants not included in this study as part of the scope of the IPEEE follow-up program. The insights learned from this scoping study will be used to screen the exemptions, so that all exemptions will not have to be reviewed.

These activities will be prioritized and carried out consistent with available NRC resources.

In addition, the staff intends to encourage licensees to make future exemption requests risk-informed. That is, licensees will be encouraged to use the guidelines of Regulatory Guide 1.174 to develop their exemption requests. The exemption request should discuss whether or not the exemption affects a fire area or plant equipment that is a dominant fire risk contributor for the plant. If such an area or equipment is affected by the exemption, the request should provide an adequate basis, using Regulatory Guide 1.174, as to why the exemption is justified. Any procedure or hardware changes that were made subsequent to the IPEEE submittal that affect the exemption request should also be discussed. If licensees choose not to provide a risk-informed submittal, the staff may request additional information or may choose to independently assess the exemption's risk. This approach is consistent with the staff's recommendation in SECY-98-300.

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## Assessment of the Impact of Appendix R Fire Protection Exemptions on Fire Risk

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- Approach
- Results
- Limitations

### Approach

This study is based on the review of non-schedular exemptions that have been granted at nine nuclear plants representing a total of 13 units. The plants were selected on the basis that the fire-induced core damage frequencies (CDFs) reported in the plants' Individual Plant Examination of External Events (IPEEE) fire analyses are high compared to other IPEEE submittals. The plants included in this study are Calvert Cliffs Unit 1, Dresden Units 2 and 3, Farley Units 1 and 2, Kewaunee, Palisades, Robinson Unit 2, St. Lucie Units 1 and 2, Summer, and Turkey Point Units 3 and 4.<sup>(2)</sup> The total number of exemptions examined in this study is 169, and the number of exemptions per plant varied from 2 to 54.

One additional plant, Quad Cities, also reported a high fire-induced CDF estimate. However, the licensee is currently revising its IPEEE fire analysis. Because this revised analysis has not yet been submitted to the staff, Quad Cities has not been included in this study. Commonwealth Edison is also in the process of revising the IPEEE fire analysis for Dresden. Changes to the IPEEE might also result in changes to the plant-specific results for Dresden that are presented in this paper.

This study is based primarily on a review of each of the exemptions for the nine plants and on risk insights gained through an examination of the corresponding IPEEE fire analysis. The study has attempted to address both the quantitative and qualitative risk implications of the exemptions. The quantitative implications relate to the quantification of fire risk as represented by the fire-induced CDF. This was determined by assessing the potential reduction in CDF that might have resulted if the licensee had adopted a compliance-based strategy (i.e., met the prescriptive requirements of Appendix R) rather than selecting an alternative method to meet the underlying purpose of Appendix R. Qualitative risk implications relate to the impact that exemptions may have had on fire protection defense in depth (i.e., on the elements of fire prevention, fire detection and suppression, and protection of plant safe shutdown equipment).

The fire areas or zones impacted by a given exemption were compared to those cited in the IPEEE. If the impacted area or zone was reported to have an insignificant CDF contribution in the IPEEE, and if the fire protection-related phenomena or features cited in the exemption appear to have been considered in the IPEEE analysis, then the exemption itself was generally found to have a very small risk impact. On the other hand, if the impacted area was identified in the IPEEE as a significant CDF contributor, or the phenomena or features cited in the exemption were not included in the IPEEE fire analysis, the exemption was examined in greater detail to determine whether or not it could have an impact on the quantification of CDF. If such an impact was determined to exist, then attempts were made to estimate the potential magnitude of the risk reduction that might be realized if a compliance-based strategy had been implemented rather than seeking an exemption. In a number of cases, the attempts were unsuccessful because of: (a) a lack of sufficient detailed information in the IPEEE submittal, or (b) weaknesses in the current fire risk assessment state of the art (especially with respect to the assessment of main control room fires). For these cases, the associated exemptions were classified as having an indeterminate impact.

In ranking the direct CDF impact of specific exemptions, four risk-impact categories were identified: potentially significant risk impact, small risk impact, very small risk impact, and indeterminate.<sup>(3)</sup> A potentially significant exemption is defined as one that may have led to a CDF increase equal to or greater than  $1 \times 10^5$ /reactor-year. An exemption with a small risk impact is defined as one that potentially resulted in an increase in CDF between  $1 \times 10^{-6}$ /ry and  $1 \times 10^{-5}$ /ry. (Note that if a quantitative CDF estimate could not be made but it could be concluded with a reasonable level of confidence that the exemption was not potentially significant, then the exemption was generally ranked as having a small risk impact.) Those exemptions found to have had a CDF impact of less than  $1 \times 10^{-6}$ /ry were classified as having a very small risk impact. (In some cases a qualitative judgment was employed in making this assessment.) An indeterminate exemption is one that may or may not have a significant risk impact, but for which a CDF increase could not be established with any degree of confidence.

An assessment of the cumulative effect of exemptions on fire risk was done for each plant. In addition to considering each exemption individually, an attempt was made to assess the cumulative effect of all the exemptions for a particular plant. However, for some cases in which plants had indeterminate exemptions, the cumulative effect of exemptions could not be determined with any degree of confidence.

### Results

The nature, number, and significance of the exemptions granted varied significantly from plant to plant. The results of this study show that a simple count of the number of exemptions at a given plant provides little or no direct insight into the potential risk significance of exemptions at that plant. Similarly, a comparison of the number of exemptions between plants does not provide a reliable indication of the relative risk significance of exemptions at each plant. In large part this can be attributed to plant-to-plant differences in the scope of the exemptions themselves. In some cases, several individual exemptions for a given plant covered very specific features in a single fire area. In other cases, a single exemption impacted as many as 22 separate fire areas in the plant.

With respect to the impact of individual exemptions, the results of this study have shown that a large majority (143) of the 169 Appendix R exemptions

that were examined had a small or very small impact on plant CDF.<sup>(4)</sup> Five exemptions were found to be potentially risk significant. That is, had these exemptions not been granted, and the plant had not selected an alternative method to achieve compliance with NRC fire protection requirements, the estimated fire CDF in some or all of the impacted areas could have been reduced on the order of  $1 \times 10^5$ /ry. The risk significance of the remaining 21 exemptions could not be determined. Table 1 provides a tabulation of the categorization of all 169 exemptions for the nine plants in this study.

**Table 1:** Number of exemptions in each risk impact category.

			Indeterminate		Small Risk Impact	Very Small Risk Impact
	Total # of Exemptions	Potentially Significant	Relating to General Issues	Lack of MCR Fixed Suppression		
Calvert Cliffs 1	5	-	-	-	1	4
Dresden 2&3	11	3	2	1	3	2
Farley 1&2	54	2	2	-	3	47
Kewaunee	3	-	-	1	-	2
Palisades	5	-	-	1	-	4
Robinson	13	-	1	1	5	6
St. Lucie 1&2	40	-	4	2	2	32
Summer	2	-	-	-	-	2
Turkey Point 3&4 <sup>1</sup>	36	-	4	2	-	30
All 9 Plants	169	5	13	8	14	129

<sup>1</sup> The Turkey Point exemptions considered here are those that were in effect at the time of the IPEEE fire analysis. Since then several significant fire protection related plant improvements have been made, and a new set of exemptions has been granted. A number of the original exemptions considered in this study have been superseded by this new set of exemptions, and certain of the plant improvements would impact the assessment made in this study.

The five potentially risk-significant exemptions impacted two of the nine plants, Farley and Dresden. Both of the potentially significant exemptions at Farley related to lack of fixed automatic fire suppression and lack of one-hour fire barriers. The areas impacted are cable penetration/cable vault areas which were identified in the licensee's IPEEE as being significant contributors to fire CDF. Assuming that fire suppression and fire barriers had been installed, the IPEEE estimates of the CDF contribution for each fire area would likely have been reduced substantially.

Each of the three potentially significant exemptions at Dresden related to a lack of fixed automatic suppression, and two cited a lack of fixed detection as well. Each of the three impacted one or more areas identified in the IPEEE as significant or dominant contributors to fire CDF. Again, assuming that fire suppression had been installed in the impacted areas, the IPEEE estimates of the area CDF contribution would likely have been reduced significantly.

The impact of 21 out of 169 exemptions could not be determined from the information used in this study. For 13 of these 21, the IPEEE lacked sufficient detail to assess their risk significance. The remaining eight related to the lack of fixed suppression in the main control room (MCR). These were ranked as indeterminate because of the inherent uncertainty in current MCR fire risk evaluations (i.e., the assessment of the additional benefit that might be realized by installation of fixed automatic suppression). The fire risk research program is currently developing the tools to provide a better understanding of the risk from MCR fires.

With respect to the cumulative effect of exemptions, this study found that the cumulative risk impact at three of the nine plants could be potentially significant. For two plants (Farley and Dresden), this result was based on the cumulative impact of individual exemptions that were determined to be potentially risk significant. The third plant, Robinson, had exemptions that were considered to have a small impact on several fire areas; however, taken together, the CDF contributions for the impacted areas may be potentially significant. Four other plants in this study had a small or very small cumulative effect. The cumulative effect for the two remaining plants could not be determined with any degree of confidence because of the nature of the indeterminate individual exemptions for those plants.

Appendix R exemptions may impact the nature or source of the dominant plant fire CDF scenarios and the extent to which fire risk mitigation is dependent on various aspects of fire protection defense in depth. Several common areas of impact were identified; they include the following:

- *Manual versus Fixed Automatic Suppression:* The single most common "class" of exemption in this study involved the lack of fixed fire suppression systems (e.g., fire sprinkler systems) in fire areas containing redundant trains of safe shutdown equipment. With no fixed fire suppression in place, the impacted plants are more dependent on automatic fire detection and manual fire fighting. All of the potentially risk-significant exemptions

identified in this study included a lack of fixed fire suppression. (Note that the lack of fixed fire suppression by itself does not necessarily imply a large CDF impact because many risk-insignificant exemptions also involved the lack of automatic fire suppression.)

- *Lack of Separation and Absent Fire Barriers*: Several exemptions were related to cases in which fire barriers are required by Appendix R but not installed. In these cases, there is a shift from passive protection of one train of safe shutdown equipment as a means of ensuring plant safety to active methods, including fire prevention, minimizing fire hazards, prompt intervention, and alternative shutdown or manual recovery. When these cases are encountered in conjunction with a lack of fire suppression, the exemption is generally found to be potentially risk significant.
- *Reliance on Manual Recovery Actions To Overcome Damage to Redundant Trains*: Many of the exemptions were granted in part on the basis that procedures would be established to take manual actions to regain control of components and systems. In these cases there is a clear shift away from passive/active protection of one safe shutdown path and towards manual recovery of lost systems and equipment through operator actions. This also implies a heightened reliance on administrative controls (for the associated plant procedures) and on personnel performance and training. Depending on the number, complexity, and time required for the manual actions, this type of exemption could be risk significant.

In general, exemptions that applied to the following circumstances were found to have only a small or very small risk impact:

- Exemptions related to combustibles in areas having greater than 20 feet of physical separation of redundant trains, if the overall fire sources are minimal and/or the area has at least partial fire detection and suppression.
- Exemptions related to the lack of fixed automatic fire suppression and one train of equipment (usually cables) protected by a one-hour fire rated barrier, if the overall fire sources are minimal, fire detection is present, and manual fire fighting equipment and personnel are available.
- Exemptions related to barriers lacking specific fire rating, for example, major structural members (walls, ceilings, floors) and various openings in these members that are not protected by fire-rated closure devices, if there is evidence of a substantial fire barrier.
- Exemptions for lack of fixed emergency lighting if portable lighting is available.

## Limitations

One of the most significant limitations of this study is reliance on the IPEEE fire submittals as the primary basis for developing risk insights. This study utilized the IPEEEs in a manner that goes beyond the original intent of the IPEEE process. The objectives of the IPEEE were for licensees to identify potential plant vulnerabilities and gain an appreciation of severe accident behavior at each plant. In the case of fire, most licensees have applied simplified methods of analysis. Further, with very few exceptions, the NRC's IPEEE review process has considered only the IPEEE submittal itself with no attempt to validate the accuracy of the licensees' detailed findings or CDF estimates. Also, any improvements or changes that licensees have made since the performance of each IPEEE were not included in this study. The only exceptions are changes that were identified in the IPEEE submittal itself and that were credited in the IPEEE fire analysis. For many of the exemptions that were found to have very small risk impact, the findings were based entirely on low CDF values (less than  $10^6$ /reactor-year) for the impacted fire areas as reported in the IPEEE.

Another limitation concerns the limited detail available in the information that was used in this study. The initial assessments were completed based on (1) abstracts from the FIRE DAT database<sup>(5)</sup> of the rationale used by the staff to grant the exemption and (2) insights gleaned from the corresponding IPEEE submittal. (It should be noted that most licensees did not explicitly address exemptions in their IPEEE submittals.) Following the initial assessment, those exemptions identified as potentially risk significant or risk indeterminate were re-examined in greater detail (i.e., using the NRC staff safety evaluation for the corresponding exemptions). In two cases (Farley and Turkey Point), additional information, based on discussions with cognizant NRC staff, was factored into the assessment. No site visits or follow-up discussions with plant personnel were undertaken.

In order to characterize the risk impact of the exemptions with a high level of confidence, details of the fire area impacted by the exemption may be needed. In cases where the IPEEE submittals did not provide this level of detail, or the quantitative tools did not exist, judgment was used to assess the risk significance of the exemptions. This judgment was based upon knowledge and insights gained from performing and reviewing other fire risk studies, including the IPEEE submittals, a broad understanding of current fire PRA-related literature, and experience in the performance and interpretation of fire safety experiments.

Even with the above limitations, the IPEEEs provide the best information readily available to address questions about the potential risk significance Appendix R exemptions. The overall conclusions of the study (i.e., only a small fraction of the Appendix R exemptions have a potentially significant impact on plant risk; there is no direct correlation between the number of exemptions and the risk significance of exemptions at a plant) should be considered robust. However, given these limitations, the plant-specific results for potentially risk-significant and indeterminate exemptions should be considered preliminary pending more detailed evaluation.

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1. As discussed in the attachment, a "potentially risk significant" exemption is one which may have led to a CDF increase equal to or greater than  $1 \times 10^{-5}$  per reactor year.

2. This study generally relies upon the fire-induced CDFs reported in the IPEEEs. In the cases of Summer and Turkey Point, total fire CDFs were not reported in the submittal. For these cases, the staff developed estimates of the total fire CDF by summing the sequence frequencies for the dominant contributors provided in the submittals.

3. This classification of risk significance was selected to correspond to the categories for CDF acceptance guidelines in Regulatory Guide 1.174, " An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis."
4. Additional detailed information is provided in a June 1999 letter report from Sandia National Laboratories (SNL), "An Assessment of the Impact of Appendix R Fire Protection Exemptions on Fire Risk."
5. The Office of Nuclear Reactor Regulation's FIREDAT database contains information on NRC-approved exemptions; a recent summary is provided in NUREG-1521 (Draft).