UNITED STATES NUCLEAR REGULATORY COMMISSION

POLICY ISSUE
(Information)

May 20, 1994 SECY-94-134

FOR: The Commissioners

FROM: James M. Taylor
Executive Director for Operations

SUBJECT: STATUS OF IPE AND IPEEE INSIGHTS PROGRAMS

PURPOSE:

To inform the Commission of the status of the Individual Plant Examination (IPE) and IPE External Events (IPEEE) Insights Programs. In addition, to respond to a Staff Requirements Memorandum dated May 24, 1993 in which the Commission requested a paper outlining the major achievements obtained from the IPE and IPEEE programs. These achievements will also include any insights or conclusions the staff is able to reach on the broad perspective of benchmarking the public risk associated with the operation of existing nuclear power plants with the Commission's Safety Goals policy.

SUMMARY:

The IPE database, which captures core damage frequency and containment performance information from the IPE submittals using Dbase IV, currently has data from 52 IPEs and is being used to support the IPE Insights program. Preliminary insights, based on examination of the unreviewed results of the industry's estimate of core damage frequencies (CDFs) and early containment failure, indicate that the average of reported CDFs for the U.S. industry population of plants is below the subsidiary CDF safety goal of 1E-4 and would meet the prompt fatality quantitative health objective. The staff notes that these reported CDF estimates only include the contribution from internal events (including internal flooding) at full power and do not include the contribution from external events or from other modes of operation (such as low power shutdown). The staff is currently examining the IPE results for various classes of plants to identify any item of potential generic safety significance relative to plant design, operational or maintenance features.

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In regards to the IPEEEs, similar efforts are planned. Preliminary work relative to a database has started; however, since 50% of the IPEEE submittals are not expected until 1995, the derivation of insights will not start until 1996. The staff plans to continue providing updates of progress to the Commission regarding the IPE and IPEEE efforts.

BACKGROUND:

In SECY-90-105, "Staff Plans for Capture, Retrieval and Use of Plant-Specific Data from Individual Plant Examinations" dated March 20, 1990, the staff provided the Commission the status of plans for retrieval and use of plant-specific data from IPEs. The staff, with the assistance of Brookhaven National Laboratory, and based on initial reviews of IPEs, identified information that would provide valuable insights, and therefore, should be extracted and entered into a database.

In SECY-93-308, "Status of Implementation Plan for Closure of Severe Accident Issues, Status of the Individual Plant Examinations and Status of Severe Accident Research" dated November 15, 1993, the staff provided the status of the IPE Insights program. One objective, as stated in this SECY, "is to identify insights gained from reviewing the IPE submittals." The IPE database is the major source of information for identifying insights regarding plant behavior. These insights, as stated in this SECY, "will help identify potential weaknesses [and strengths] associated with groups or classes of plants, and provide a framework from which the strength of the regulations can ultimately be evaluated." These insights are being captured on an individual plant basis in the SERs of the IPE reviews and will be presented (for all plants) on a generic basis in an overall summary report. The status of this report and preliminary insights are discussed in this paper.

DISCUSSION:

The staff has initiated two major IPE and IPEEE follow-up programs to identify patterns and extract insights from the IPE and IPEEE submittals to support regulatory efforts. The IPE follow-up program is in progress and discussed in detail below.

The IPE database was developed by RES and Brookhaven National Laboratory to store information about plant design, core damage frequency and containment performance in a structured and formal manner. It is designed so that the user can extract information and can make detailed inquiries regarding these characteristics across a defined class of plants. Specifically, information from the IPEs regarding general plant design, core damage frequency results (e.g., frequencies, accident sequences, contributors), system dependencies, core damage prevention strategies, containment failure modes, plant damage states, release categories, and source terms is entered in to the database using Dbase IV.

The IPE database allows the user to compare the CDF and containment performance of boiling water reactors (BWRs) and pressurized water reactors (PWRs) as a function of their design features, based on information that is in the IPE submittals. Therefore, particular differences between plant IPE reported results that are driven by differences in redundancy and/or diversity in safety systems, or different success paths for core cooling, can be identified. Similarly, if one plant is an outlier by virtue of lacking a design feature common to other plants or due to an adverse functional system interaction, this type of difference will also be available. At the present time, information from 52 IPEs have been entered into the IPE database, with the remaining to be complete in early 1995. A user's manual on the database is scheduled to be issued this year.

The IPE Insights program is providing a global examination of the IPE results using the IPE database, the staff review of the IPEs and the IPE submittals. The emphasis of the program is to search for any potential generic significance arising from plant features (e.g., system design, plant operation) for different classes of plants. In addition, the staff is quantitatively assessing the impact of the proposed plant changes and modifications (identified by the licensees from their IPE program) on CDF and containment performance. The IPE insights program will, therefore, document the significant safety insights relative to the core damage frequency and containment performance results of the different reactor and containment types and plant designs. Specifically, the program will perform the following:

- Assess the significance of core damage and containment performance results (e.g., frequency, accident sequences, dominant contributors, containment failure, source terms) relative to the operational, maintenance and design characteristics of the various reactor and containment types for generic insights. Methods, data, boundary conditions, and assumptions used in the IPEs will be considered in understanding the differences and similarities observed for the various classes of plants.

- Assess the significant plant improvements identified by the licensees as a result of their IPE efforts and estimate their relative impact on the CDF and containment performance.

The results of the IPE Insights program is scheduled to be completed by mid 1995 in a NUREG report (a copy will be provided to the Commission prior to issuance).

IPE Insights Program Preliminary Results

The following patterns in the IPE results, although preliminary, are intended to illustrate the potential uses of the IPE submittals and database and the type of information that can be gained from the IPEs to support regulatory efforts. It should be noted that the staff is currently exploring the reasons for the variabilities and similarities seen in the results. For example, the underlying causes for those plants with CDFs above 1E-4 are being examined to determine if they are due to particular plant design features or analytical assumptions; the dominant accident sequences are being investigated for similarities and differences; etc. Similarly, in regards to those plants with low CDFs, comparable questions are also of interest and are being explored by the staff.

The first set of patterns in the reported results provide CDF (Level 1 probabilistic risk assessment (PRA)) insights from 62 IPEs. The second set of examples provide early containment failure and bypass frequency (Level 2 PRA) insights for the same IPEs.

The total plant CDF results for internal events (including internal flooding) for 62 IPEs are shown in Figure 1. The results are presented in terms of the mean and the median with the high and low reported CDFs. (It should be noted that licensees were not requested to perform an uncertainty analysis of their CDF. Therefore, the mean CDFs, as discussed below for the various plant groupings and as indicated in the subsequent figures, are the average values based on the reported plant CDFs. The median values represent the midpoint in the range of reported plant CDFs; i.e., 50% of the reported CDFs fall above this median value and 50% below.)

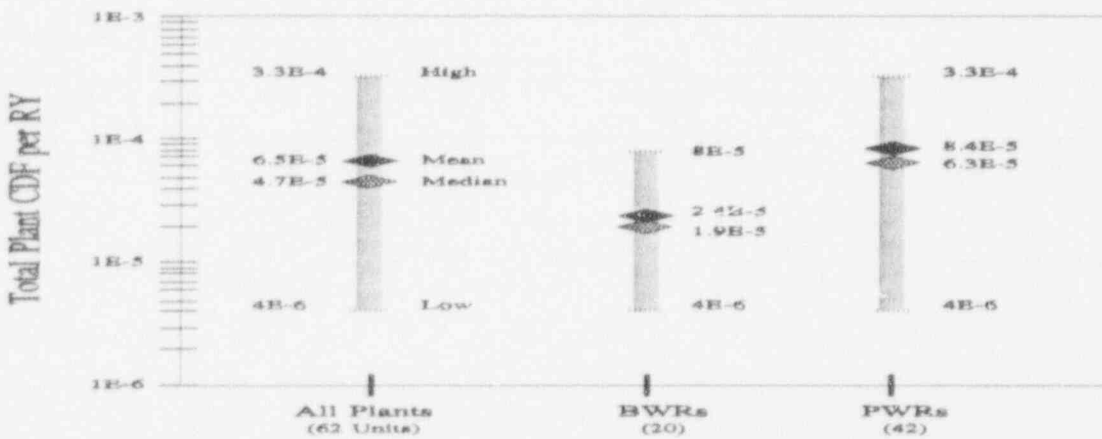

Figure 1. Preliminary CDF Estimates of BWRs and PWRs.

As indicated in Figure 1, the mean CDF (that is, the average value of the reported CDFs from the IPEs) for the 62 plants is 6.5E-5 per reactor year (ry) with a CDF of 2.4E-5 per ry for 20 BWRs and 8.4E-5 per ry for 42 PWRs. Figure 1 includes an estimate of the industry average of the likelihood of core damage (and most have not yet been reviewed by the staff). As can be seen, both the mean and median values fall below the subsidiary CDF safety goal of 1E-4 for the industry and for both BWRs and PWRs. The highest reported value, however, is slightly greater than 1E-4, which is caused by the PWR CDF contribution. The average CDF is somewhat lower for BWRs confirming the similar insights from NUREG-1150 and WASH-1400.

These CDFs are further categorized on the basis of plant design and containment types to better understand the driving contributors. The individual CDFs (including their mean, high and low values) for the different BWR containment types are shown in Figure 2. As indicated, the mean BWR CDF, the mean CDFs for each BWR containment type and the high BWR CDFs fall below the subsidiary CDF safety goal of 1E-4. In addition, an order of magnitude difference exists between the low and high values for the BWRs and between the low and high values for Mark I and II BWRs; however, only a factor of two variation is seen for the Mark III BWRs.

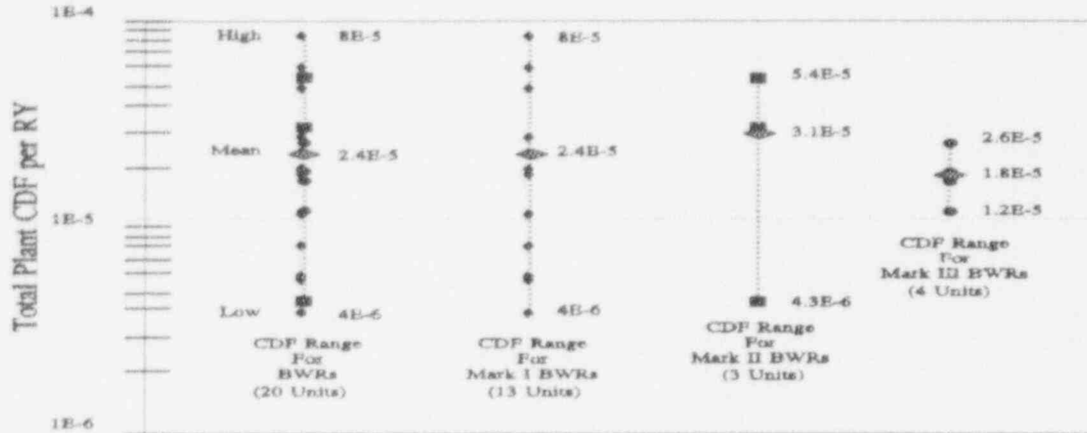

Figure 2. Individual CDFs for BWRs by Containment Type.

The CDFs for BWRs are fairly evenly distributed from a low value of 4E-6 per ry to a high value of 8E-5 per ry. As indicated, there does not appear to be a "cluster" or "group" of BWRs with similar CDFs, nor does a single BWR appear to be an outlier. In examining the CDFs for the different containment types, the same can be seen for the Mark I and III BWRs. This situation, however, does not appear to be the same for Mark II BWRs. For these BWRs, one plant has a CDF approximately an order of magnitude lower than the other two. The identification of the cause for this difference is one example of the type of insights being pursued by the staff as part of this program.

The individual CDFs (including their mean, high and low values) for the different PWR vendor types (i.e., Westinghouse, Babcock and Wilcox (B&W), and Combustion Engineering (CE)) are shown in Figure 3. As indicated, the mean PWR CDF and the mean CDF for CE and B&W PWRs fall below the subsidiary CDF safety goal of 1E-4. The mean CDF for Westinghouse PWRs is equal to 1E-4 and the high Westinghouse CDF is above 1E-4. In addition, two orders of magnitude difference exists between the high and low values because of the Westinghouse PWRs.

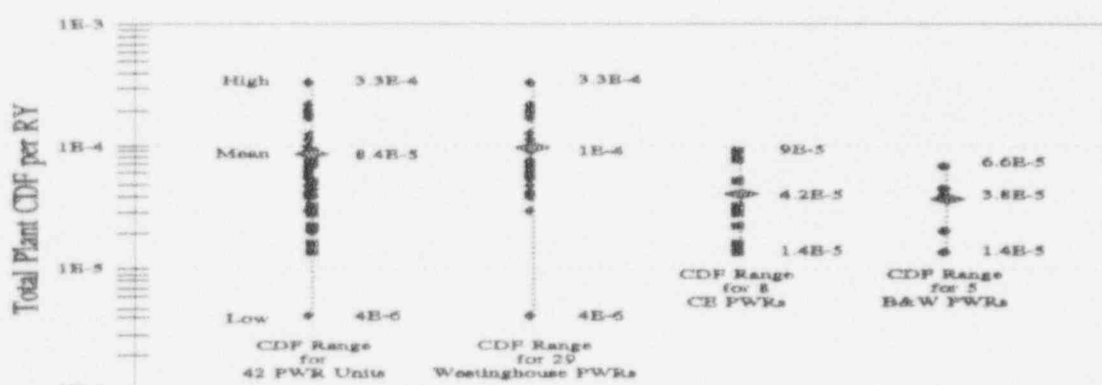

Figure 3. Individual CDFs for PWRs by NSSS Vendor.

In examining the individual CDFs, it appears that the CDFs are fairly evenly distributed for the PWRs except for one Westinghouse plant. The CDFs for the CE and B&W PWRs range from a low value of 1.4E-5 per ry to a high value of 9E-5 per ry and 1.4E-5 per ry to 6.6E-5 per ry, respectively. There does not appear to be a "cluster" or "group" of CE or B&W PWRs with similar CDFs nor does a single CE or B&W PWR appear to be an outlier. This situation, however, does not appear to be the same for Westinghouse PWRs.

For Westinghouse PWRs, one plant has a CDF over an order of magnitude lower than the mean CDF and two orders of magnitude lower than the high value of the Westinghouse PWRs. This IPE plant, Zion, is currently under review by the staff. One factor causing this difference is the licensee's definition of core damage that allows for different success criteria than normally seen for other plants of similar design. The bases for this assumption are being reviewed by the staff. This example illustrates the difference that can be seen in results when different analytical assumptions are used.

The underlying reasons for the differences and similarities, whether design or operational or maintenance driven, or due to analysis assumptions, data or methods are being explored as part of the insights program. These causes will indicate any potential generic significance regarding classes of plants relative to plant design, operational or maintenance characteristics.

The second set of preliminary insights involve containment early failure and bypass frequency (CEFF) that is one of the key measures for containment performance. Containment early failure or bypass are two types of failures that could result in a large release of radioactive material to the environment. The timing of containment failure is very important in terms of radiological consequences. If the containment remains intact for a longer time, the operator will have time for protective actions to prevent radioactive material from being released to the environment (as part of accident management strategies). Therefore, the containment early failure or bypass frequency is a key measure for containment performance.

The early containment failure or bypass frequencies can also provide a perspective on the degree to which the existing nuclear power plants compare with the safety goals. As discussed in SECY-93-138, "Recommendations on Large Release Definition," dated May 19, 1993, a frequency of early release or bypass of 1E-5 per ry or less results in a risk to an individual less than that of the Safety Goal prompt fatality quantitative health objective (QHO). (The prompt fatality QHO is the more constraining of the two quantitative health objectives.)

The information about the containment early failure or bypass frequencies was extracted from the summary section of each IPE submittal without elaborate analysis for its assumptions or boundary conditions; that is, without independently confirming the licensees' calculations or rebaselining them using a common methodology or containment failure definition. (These frequencies do not include the frequencies associated with "small" failure or release as they do not tend to dominate risk.) The term "large" and "small" are defined by the licensees and vary from plant to plant. Therefore, unlike the CDF results, the information is much more subject to interpretation of the licensees own definition of certain key parameters. These parameters include plant damage states, timing of containment failure, and magnitude (i.e., "small" and "large") of source terms. This lack of uniformity in defining these key parameters has made meaningful comparisons between plants in terms of containment performance difficult.

In addition, it should be noted that the CEFF is not the conditional containment failure probability (CCFP), but the product of the CDF and CCFP. However, due to the lack of consistency of the information in the IPEs, the CEFF was used. Normalization of these various parameters is being pursued by the staff as part of the IPE Database and Insights programs (e.g., comparisons of the CCFPs are being pursued by the staff). Until then, the following information should be considered as quite preliminary and only as an example to illustrate the potential utilization of the IPE database and the IPE submittals.

The CEFFs for 62 IPEs are shown in Figure 4. The results are presented in terms of the mean and the median with the high and low reported CEFFs. As indicated, the mean CEFF for the 62 plants is 4.5E-6 per ry with a mean CEFF of 3.8E-6 per ry for 20 BWRs and 4.9E-6 per ry for 42 PWRs. These mean CEFFs are below the 1E-5 per ry release frequency which can serve as a conservative surrogate for the prompt fatality QHO. It is noted that the CEFF for the 62 plants results in a broad range, which varies from a high value of 2.2E-5 per ry to a low value of 3E-8 per ry. Further categorization should help the staff understand the reason for this variation.

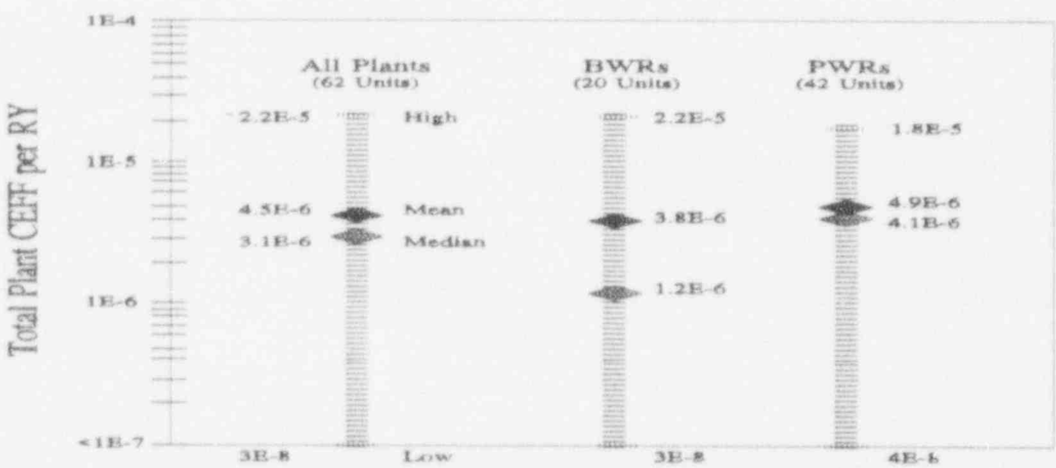

Figure 4. Preliminary CEFF Estimates of BWRs and PWRs.

In Figure 5, the individual CEFFs for the different BWR containment types are shown and range from a high value of 2.2E-5 per ry to a low value of 3.8E-8 per ry with a mean value of 3.8E-6. The difference between the high and low CEFFs is three orders of magnitude and at least an order magnitude for each containment type. The mean CEFF for each containment type falls below 1E-5 with Mark I BWRs having the largest contribution.

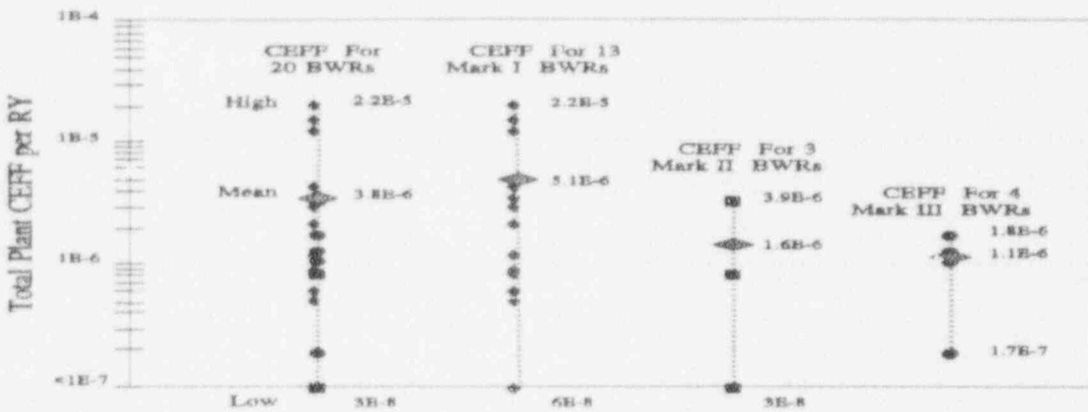

Figure 5. Individual CEFFs for BWRs by Containment Type.

In examining each BWR containment type, there appears to be "outliers" for each type. One Mark I BWR appears to have a CEFF two orders of magnitude lower than the "group" of CEFFs and three plants with CEFFs almost an order of magnitude higher. One Mark II BWR appears to have a CEFF two orders of magnitude higher. For the Mark III BWRs, one plant appears to have a CEFF an order of magnitude lower. This plant is the same Mark III BWR whose CDF is also an order of magnitude lower. This difference could be more of a result of the lower CDF than design features related to containment performance. These causes are being explored by the staff.

The individual CEFFs for the different PWR vendor types (i.e., Westinghouse, B&W, and CE) and containment types are shown in Figure 6. As indicated, the CEFFs range from a high value of 1.8E-5 per ry to a low value of 4E-8 per ry with a mean value of 4.9E-6. In examining the PWR groups, the mean CEFF for each falls below 1E-5. The sub-atmospheric plants have the largest mean with a value of 8.6E-6.

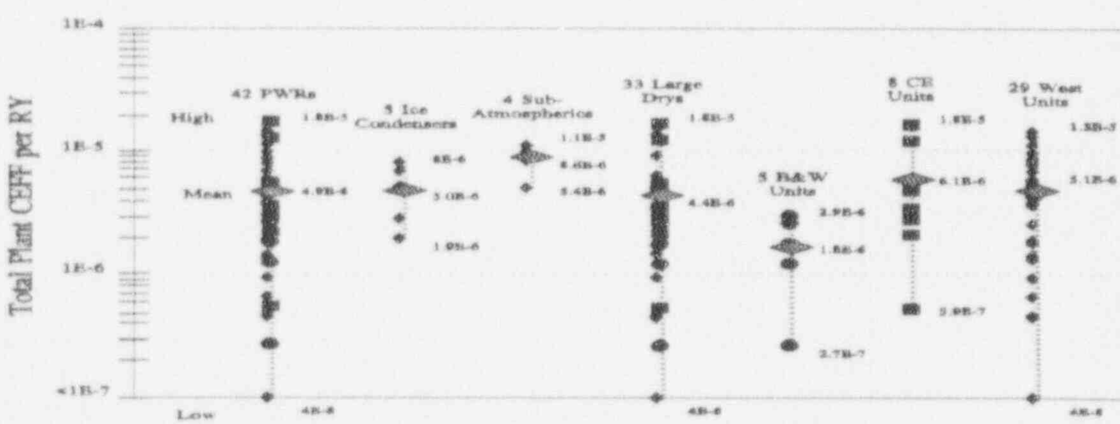

Figure 6. Individual CEFFs for PWRs by NSSS Vendor and Containment Type.

In examining the PWR groups and individual CEFFs, there appears to be plants at the low range outside of the "group." For CE and B&W plants, an order of magnitude difference is seen while two orders of magnitude is seen for the Westinghouse and large dry PWRs.

CONCLUSIONS:

The differences seen in the various classes of plants and their causes are being explored as part of the Insights program. As indicated before, the differences may be due to plant (e.g., containment) design features, or due to analytical assumptions, or due to the plant-specific analytical definitions. For example, even for similar plants (e.g., McGuire and Catawba that are both 4-loop Westinghouse plants), differences in the support system to front line system dependencies can result in different results. Although cooling of the reactor coolant pump (RCP) is by component cooling water (CCW) at both these plants, cooling of the emergency core cooling system (ECCS) components is by the service water system (SWS) at McGuire; therefore, loss of CCW will not result in loss of RCP seal cooling at McGuire. At Catawba, the CCW, which is cooled by the SWS, cools the RCP seals and the ECCS pumps; therefore, loss of CCW or loss of SWS results in loss of RCP cooling and loss of ECCS pumps. It is estimated that this difference, in addition to other differences between units, leads to approximately a factor of three difference in the CDF contribution from loss of CCW/SWS events.

Although there are many plant to plant differences and different assumptions and analytical techniques used, the results of the IPEs have identified similar dominant core damage sequences as did previous risk assessments. For example, although the CDF has decreased for loss of offsite power (LOSP) sequences because of plant changes, LOSP continues to be an important contributor to core damage since it is one of the few events with the potential to commonly affect many of the systems required for core damage prevention. In addition, not all plants have taken credit in their IPEs for changes resulting from the Station Blackout rule. The staff is exploring the impact of such issues (e.g., station blackout, RCP seal LOCA) as part of the Insights program. Small loss of coolant accidents (LOCAs) continue to be important contributors at most plants, especially transient initiated RCP seal LOCAs at PWRs. Events initiated by internal flooding have also been found to be important at several plants.

The overall reported results in regard to CDFs among nuclear power plants do indicate that BWRs typically have CDFs lower than for PWRs. Among PWRs, Westinghouse plants tend to have the higher CDFs (than CE and B&W plants). Results from analyses of operational events (from 1988 through 1992) in the Accident Sequence Precursor (ASP) program follow these patterns. Analysis and comparisons of IPE results to ASP results are being explored by the staff as part of the ASP Insights Program (refer to SECY-94-076, dated March 22, 1994, "Status Report on Accident Sequence Precursor Program and Related Initiatives").

Analytical assumptions also lead to different results. In NUREG-1150, analysis of the Grand Gulf Nuclear Station (GGNS), it was assumed that the SWS pumps would not fail on loss of heating, ventilating and air conditioning

(HVAC); however, in the GGNS IPE, due to more detailed calculations by the licensee, it was assumed that the loss of HVAC resulted in loss of the SWS pumps. This assumption was a major contributor to the order of magnitude increase in the CDF between the two analyses of the same plant.

Similar type observations can also be seen in regards to containment performance. Some failure modes are common to all plants (e.g., liner meltthrough for Mark I Containments) and contributions change among plants of similar containment design. The relative contribution of liner meltthrough to risk is dependent on the assumptions used in the analysis and, of course, specific design features. (For example, more recent research information indicates that liner meltthrough results in a relatively lower contribution to early containment failure when water is available in the drywell (NUREG/CR-5423, The Probability of Liner Failure in a Mark-I Containments) while NUREG-1150 assumed a high probability of liner meltthrough for both a wet and dry cavity. This research will be available to licensees for consideration in their accident management program and any future IPE updates.)

The different plant characteristics also have a major impact on CEFF. Such characteristics as reactor thermal power, containment free volume, sump volume, drywell floor area, pedestal radius, distance form pedestal wall to line and height of vent lines above drywell floor determine whether liner meltthrough is an issue. At Millstone 1 and Fitzpatrick, for example, liner meltthrough dominates the early release (34% and 54%, respectively). The staff is examining the IPEs to determine whether these relatively high contributions are because NUREG-1150 type assumptions were used instead of the more recent research. At Monticello, however, liner meltthrough was assigned a zero probability due to the plant's large in-pedestal sumps that resulted in insufficient amounts of debris to contact the drywell liner.

The overall results in regard to CEFFs, however, do not indicate that BWRs generally have lower CEFFs, but that CEFFs for BWRs and PWRs are not vastly different (less than a factor of 1.5 difference can be seen between the mean values, Figure 4). Although the mean CDF for the BWRs is almost a factor of 4 lower than the mean CDF for the PWRs (see Figure 1), the CCFPs tend to be higher for BWRs due to their smaller containments. The CEFF reflect the combination of both CDF and CCFP.

Over the next months, the staff will continue to explore the causes for the differences and similarities in the IPE results observed for various classes of plants to determine any generic insights. Details regarding plant features, analytical assumptions and techniques are being considered as part of this examination to better understand the generic implication of plant features. In addition insights are also being explored relative to the proposed "plant improvements" that have been identified by licensees as a result of their IPE efforts.

Most of the IPE submittals reviewed to date have not identified major plant vulnerabilities. Licensees, however, have identified plant modifications or enhancements that have either been implemented or planned to be implemented to reduce the likelihood of core damage events or to mitigate the consequences of such events. Typical of the improvements that many licensees have implemented are the following:

- Implement system or unit cross-ties in both electrical and water systems to provide additional redundancy or diversity.
- Improve internal flood protection such as water tight doors and procedure enhancements to respond to floods.
- Utilize fire water systems to provide alternate cooling or makeup water sources (as part of their accident management). Examples include cooling of charging pumps and emergency diesel generators, makeup source for auxiliary feedwater systems in PWRs and for alternate injection through the residual heat removal system in BWRs.
- Utilize fire water systems to provide alternate drywell spray capabilities in BWRs (e.g., liner meltthrough benefit).
- Improve or implement new procedures for recovery actions, load shedding, refilling water storage tanks or to minimize operator errors in existing actions.
- Improve the ability to mitigate the effects of loss of room cooling.
- Enhance or revise operator training.

These improvements (i.e., plant modifications and enhancements) are being assessed as part of the Insights program to determine their generic importance relative to CDF and containment performance. The staff will continue to provide the Commission insights gained during its IPE reviews and from the IPE Insights program as part of the semi-annual status paper on severe accident implementation. In addition, it is apparent that licensee's state of knowledge regarding severe accident behavior relative to the design and operation of their nuclear facility has improved from the IPE process. The majority of the licensees intend to maintain and update their IPE.

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