SECY-98-154

June 30, 1998

FOR: The Commissioners

FROM: L. Joseph Callan /s/
Executive Director for Operations

SUBJECT: RESULTS OF THE REVISED (NUREG-1465) SOURCE TERM REBASELINING FOR OPERATING REACTORS

PURPOSE:

To provide the Commission with the results and findings of an evaluation of the impact of implementing the revised source term described in NUREG-1465, "Accident Source Terms for Light-Water Nuclear Power Plants," for operating reactors.

BACKGROUND:

The Commission's reactor site criteria, 10 CFR Part 100, requires that a fission product release into containment be postulated and that offsite radiological consequences be evaluated against the guideline dose values given in Part 100. Other Commission regulations, in 10 CFR Part 50, GDC 19, address regulatory requirements on the accident radiological doses for the control room. The evaluation of the release of fission products into containment (called "source term") is used for judging the acceptability of both the plant site and the effectiveness of engineered safety features. The original source term, which was based on releases from a severely damaged core, was published in 1962 by the U.S. Atomic Energy Commission in Technical Information Document (TID) 14844, "Calculation of Distance Factors for Power and Test Reactors." Since that time there have been significant advances in our understanding of the timing, magnitude and chemical forms of the fission product release from severe reactor accidents. NUREG-1465, "Accident Source Terms for Light-Water Nuclear Power Plants," was published in February 1995, and reflects that extensive research and experience culminating in the development of a new or revised source term. The development of the revised source term was originally intended for initial application to advanced reactors though it was recognized that current reactors may want to utilize the revised source term in licensing actions. The impetus for operating reactors to adopt the revised source term is that through its more realistic characterization of the source term, plants may modify existing restrictive plant features, (e.g., component actuation times, leakage control systems).

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The staff proposed, in SECY-96-242, "Use of the NUREG-1465 Source Term at Operating Reactors," dated November 25, 1996, an approach to allow use of the revised source term for operating plants. As part of its approach the staff indicated its plans to undertake a comprehensive assessment, referred to as rebaselining, of two plants to further evaluate issues attendant with applying the revised source term to operating plants. The staff also indicated its plans to undertake the review of five pilot plant submittals that address a wide range of revised source term applications.

In an SRM dated February 12, 1997, the Commission approved the staff's plan outlined in SECY-96-242 and directed the staff to commence rulemaking upon completion of the source term rebaselining and concurrent with the pilot plant evaluations. The Commission further stipulated that implementation of the NUREG-1465 source term at operating reactors should include the revised Part 20 dose methodology (total effective dose equivalent or TEDE criterion) and should include consideration of the dose over the worst two hour interval after the accident. In a memorandum to the Commission dated September 9, 1997, the staff provided the status of its plans to implement the revised source term at operating reactors and outlined a schedule of November 30, 1998, for completion of rebaselining analyses and the preparation of a rulemaking plan. Subsequently, the staff shifted its assignment of responsibilities on rebaselining to expedite the completion of those tasks to June 1998. In addition, a joint RES/NRR management committee was formed to meet regularly to oversee progress on rebaselining activities.

DISCUSSION:

The objective of the rebaselining effort was to develop a better understanding of the impacts of implementing the revised source term (NUREG-1465) at operating reactors. The major areas examined were:

i) effect on calculation of individual offsite and control room dose

ii) effect on calculation of dose for equipment qualification

iii) effect of potential plant modifications, including assessment of changes to plant risk

It has been recognized since the development of the revised source term that changes in the prescription of the source term from that originally described in TID-14844 would influence the major areas of dose analysis and could prompt plant, technical specification and procedure modifications. The most significant changes in the source term are the treatment of the fission product release as a time dependent process and the release of radioiodine primarily as an aerosol. In the revised source term the fission product release is assumed to occur over roughly two hours as opposed to the TID source term which assumed the release of the entire source term occurs instantaneously at time zero. In addition, in the revised source term, 95% of the radioiodine is assumed to be released as an aerosol, CsI, with the remaining 5% as a combination of inorganic and organic vapors. This is in contrast to the original TID source term which prescribed the opposite ratio, 95% of the iodine as vapor and 5% as aerosol. Therefore, plant systems

originally provided to mitigate an instantaneous source term by very rapid actuation would not be required to perform under such stringent requirements with the revised source term. Likewise, systems needed to remove iodine vapors are less important under conditions where iodine is an aerosol. As part of rebaselining these issues and a number of other more subtle differences between the source terms, as well as the impact of improved modeling of fission product processes, were explored to position the staff for review of pilot plants and rulemaking.

At the outset it was planned to study the impacts in depth for two plants, Grand Gulf and Surry, a BWR and PWR respectively. These plants were chosen to represent broad classes of reactors; they also represented plants which had been studied under NUREG-1150 and for which the risk profile had been carefully examined. In addition, in the early planning of this activity these plants' participation in providing detailed site data and information was important to the completion of a thorough examination. Shortly after initiation of the rebaselining project, the set of analyses was expanded to include calculations for the Zion plant, which is representative of a large class of PWR dry containment reactors. Rebaselining was the vehicle for assessment of the likely dominant issues associated with implementation of the revised source term as revealed by analysis of representative plants and as such provides the technical bases for development of regulatory guide criteria.

In the formulation of the rebaselining initiative the activities were divided into four phases which allowed for progression of analyses and insights to be factored into ongoing assessments. Phase I addressed DBA dose calculations using both the TID and NUREG-1465 source terms to evaluate the impact of the revised source term on individual dose. Analyses addressed a range of design basis accidents including a loss of coolant accident, fuel handling, main steam line break and rod drop accidents. Calculations were performed to determine the accident dose at the exclusion area boundary (EAB), low population zone (LPZ) boundary and for the control room. The approach taken in Phase I was to perform calculations as they were conducted as part of the staff's licensing review documented in the safety evaluation report.

In Phase II, similar calculations were performed as in Phase I, but, in this phase, calculations were performed using the approach and methodologies adopted by the licensees in their analyses, as described in the Final Safety Analysis Report (FSAR). Since the licensees often utilize different assumptions and techniques, these calculations were undertaken to examine the impact of the new source term under conditions representative of licensee analyses. In Phase II, the staff also performed equipment qualification dose calculations to assess the impact of the revised source term. In both Phases I and II, in addition to evaluating the impact of the revised source term versus the TID source term, the rebaselining analyses also addressed use of the revised dose acceptance criterion of 25 rem TEDE and use of the worst 2 hour interval for dose analysis.

In Phase III, the staff undertook a number of diverse analyses to investigate, in detail, technical issues associated with implementation of the revised source term. In conjunction with the development of the revised source term, the staff also reevaluated the modeling of fission product removal mechanisms associated with containment sprays and suppression pools. As a result of a previous effort, new models for fission product removal were developed, with the intent of quantifying uncertainty as well as representing current understanding. In Phase III, DBA dose calculations were repeated for the revised source term using the existing Standard Review Plan (SRP) treatment of the removal mechanisms and with the updated models. Also, equipment qualification dose calculations were repeated with both Regulatory Guide 1.89 and updated models. In addition to the DBA dose calculations, analyses were also performed using the MELCOR code, an integrated severe accident code which is used to calculate both thermal hydraulic and fission product behavior in the reactor and containment. MELCOR was used to perform a best estimate assessment of offsite doses to provide insights into the margins still inherent in the revised source term methodology. Because of MELCOR's capabilities, it was also used to investigate the consistency and margins between the treatment of thermal hydraulic conditions in the DBA dose calculations and those calculated for a postulated core damage accident with recovery of emergency core cooling systems (ECCS). Another technical issue examined under Phase III was the revaporization of iodine from the sump or suppression pool. It is known that radiolysis in acidic water pools can cause revaporization of dissolved iodine. Inherent to the relatively low vapor concentrations of iodine prescribed in NUREG-1465 is the assumption that sump/suppression pool pH is controlled at a value of 7 or greater to effectively inhibit the revaporization of dissolved iodine. Many PWRs already control pH of the post accident water inventory in containment. Analysis was performed to examine the extent to which pH control would be needed for BWRs.

In Phase IV the staff focussed on assessment of potential plant changes that may be proposed in conjunction with implementation of the revised source term. Dose calculations were performed with specific changes proposed in the pilot plants applications. These plant modification applications were submitted in conjunction with submittal of the generic industry proposal, EPRI Technical Report TR-105909, "Generic Framework for Application of Revised Accident Source Term to Operating Plants," November 1995. In Phase IV, the staff also factored in an evaluation of the risk impacts of potential plant modifications. A study of such risk impacts was conducted for the NUREG-1150 plants considering the risk impacts from relaxation of requirements related to design containment leak rate, containment spray operation, reactor building drawdown, subatmospheric containment operation and filtration systems.

A more detailed discussion of the rebaselining analyses, which involved a large number of calculations and assessments is provided in the attachment along with a more detailed description of the results. A summary of the general results is provided below.

RESULTS:

The overall impact of implementing the revised source term in the majority of cases is to produce lower calculated doses, ranging from a slight reduction up to an order of magnitude decrease, for an individual, whether for the EAB, LPZ or control room. In addition, in assessing the impact of implementing the revised source term and comparing new calculated doses against earlier (and occasionally much older) analyses, it was confirmed that changes in the calculated dose may also occur for reasons not directly related to the source term itself. For example, in older calculations, the dose to an individual was calculated using dose conversion factors taken from International Commission on Radiation Protection (ICRP) Publication 2. Current analyses including those implementing the revised source term would use updated dose conversion factors taken from EPA Federal Guidance Reports (FGR) 11 and 12. The use of updated dose conversion factors alone will produce reductions in the dose by up to 40%. The extent of further reduction in calculated doses is also influenced by several factors, two of which are connected to differences between the TID and revised source term. As noted previously, the revised source term treats the release of fission products as a time dependent release, thus reduction of doses will be strongly influenced by safety

features which are timing sensitive. In the case of Surry, a subatmospheric design, all containment leakage ceases after one hour, thus with the revised source term (released over 1.8 hrs) only a fraction of the source term is available for leakage (approximately 1/4 of the eventual release). Similarly, if dose mitigation is provided by a standby gas treatment system (e.g., Grand Gulf) which filters all releases after several minutes, then the dose release during the period of unfiltered release is relatively inconsequential using the revised source term. In the area of chemical form of radionuclides, cited previously, in the case of Zion, the TID dose calculation is heavily influenced by the assumption of a large release of iodine as organic vapor. Treatment of iodine primarily as an aerosol in the revised source term resulted in a substantial reduction of the dose. Lastly, comparing calculated doses from different analyses (SER and FSAR) which utilize different assumptions occasionally produces observed changes in doses which are driven by modeling assumptions which are plant specific.

Another finding from the rebaselining activity was that the time dependent release of the new source term, coupled with plant characteristics, can result in a substantial shift in the 2 hour interval associated with the maximum dose. In Grand Gulf LOCA dose analyses, the worst two hour interval for the TEDE dose of 6.8 rem began at 2.2 hrs. By comparison the calculated dose for the first two hours was 2.0 rem.

An evaluation of the equipment qualification dose using the TID and NUREG-1465 source terms revealed that the containment atmosphere dose using the revised source term was similar since most of the dose is from noble gases, for which the two source terms are identical. With respect to doses for equipment exposed to containment sump water, the revised source term again produces similar results. However, the revised source term produces somewhat higher doses later in time (after approximately 1 week in the case of the Surry analysis) due to a much higher inventory of cesium. These results confirm the overall trend of an assessment previously performed, (Memorandum to the Commission dated February 23, 1993, from J.M. Taylor, "Impact of New Source Term on Safety Related Equipment"). The significance of any higher dose in the containment sump will be considered in the pilot plant reviews.

In Phase III, analyses were also performed with the MELCOR code both to evaluate the extent of margins maintained with the revised source term calculations and to evaluate related thermal hydraulic issues. The MELCOR analyses indicated that the DBA dose calculations still have substantial margin (a factor of 2 or greater) even though the dose may be well below the earlier TID analysis. This margin often stems from the integral coupling of dose analysis and thermal hydraulic analysis in the MELCOR calculations. In the DBA dose analysis, a constant containment leak rate, associated with leakage at the peak containment pressure, is assumed for the 24 hours after the accident, whereas the MELCOR analysis varied leakage in accordance with the predicted containment pressure transient. Additionally, best estimate treatment of fission product removal in MELCOR yields a further reduction in doses against the updated DBA models.

In Phase IV, an evaluation of potential plant changes was undertaken with the objective of assessing the impact on the DBA dose calculation and the impacts on plant risk. The general conclusion from these studies was that indeed many of the types of changes proposed could be made and the DBA dose would remain within acceptance limits, though the plant specific changes will need to be reviewed. Furthermore, analysis indicated that since most of the systems being contemplated for modification are not involved in risk significant sequences their modification is not likely to have any substantial offsite risk impact, using a measure such as large early release frequency, as established in Regulatory Guide 1.174.

Having concluded the rebaselining initiative, the staff did not identify any issues that would prevent implementation of the revised source term at operating reactors. Further, the rebaselining activities have provided a technical basis to support rulemaking and changes to associated regulatory guides. The staff is therefore proceeding in accordance with Commission direction, in the SRM dated February 12, 1997, to commence rulemaking. A rulemaking plan is being submitted to the Commission by a separate paper. The staff is also proceeding with the evaluation of implementation of the revised source term for the pilot plant applications.

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Attachment: As stated