Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381

OCT 07 1994

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Gentlemen:

In the Matter of the Application of	)	Docket Nos. 50-390
Tennessee Valley Authority	)	50-391

WATTS BAR NUCLEAR PLANT (WBN) UNITS 1 AND 2 - SEVERE ACCIDENT MITIGATION DESIGN ALTERNATIVES (SAMDA) - RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION (RAI) - (TAC NOS. M77222 AND M77223)

This letter provides TVA's response to NRC's request for additional information dated September 20, 1994 (this letter superseded NRC's letter dated September 2, 1994), and NRC's additional requests dated September 27, 1994, concerning TVA's SAMDA analysis.

Enclosure 1 provides TVA's responses to the NRC's requests. These responses also include the results of discussions from the meeting held between TVA and NRC on September 29, 1994, in Rockville, Maryland. Enclosure 2 provides Revision 1 to the Executive Summary and an update to the Section 4 tables for "Calculation of Averted Offsite Dose - Enhancement Case" in TVA's report entitled "Watts Bar Nuclear Plant Unit 1 Value Impact Analysis of Potential Plant Enhancements," issued to the NRC on June 30, 1994. As agreed in the September 29, 1994 meeting, an update to the text in Chapter 4 has not been provided.

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If you should have any questions, contact John Vorees at (615)-365-8819.

Sincerely,

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50-390 TVA WATTS BAR 1

SEVERE ACCIDENT MITIGATION DESIGN ALTERNATIVE
RESPONSE TO NRC'S REQUEST FOR ADDITIONAL I
INFORMATION.

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WATTS BAR NUCLEAR PLANT (WBN) UNITS 1 AND 2
SEVERE ACCIDENT MITIGATION DESIGN ALTERNATIVE
RESPONSE TO NRC'S REQUEST FOR ADDITIONAL INFORMATION (RAI)

NRC REQUEST 1

The decision regarding which alternatives will be implemented at WBN appears to have been based on a strict interpretation of the $1000/person-rem criterion, without explicit consideration of uncertainties in core damage frequency estimates, containment performance, and offsite consequence modelling. Since several of the design alternatives were ruled out on this basis, even though they are close to being cost effective, a more detailed assessment of uncertainties in the risk reduction estimates is needed in order to justify not implementing additional design alternatives, particularly those that are within a factor of 10 of being cost beneficial. In this regard, provide an assessment of the maximum possible risk reduction for each candidate design improvement (Table 5, page ES-21), considering the following:

a. the increase in risk if the upper bound (e.g., 95th percentile) value for the WBN CDF is used,

b. the increase in the containment failure probability and risk associated with the most limiting MAAP sensitivity calculations recommended by EPRI, and

c. the impact of uncertainties in consequence assessment on the risk reduction estimates for the candidate SAMDAs. Consider both the uncertainties and sensitivities assessed in NUREG-1150 Sequoyah evaluation and those inherent in the Level 3 scaling described in Appendix C to the Value Impact Analysis.

TVA'S RESPONSE

The value impact analysis was performed using best estimate (mean) values for calculations. Estimates of risk reduction were performed in a manner which maximized the risk reduction calculated in order to bound individual uncertainties. The analysis of severe accidents involves the consideration of a wide variety of factors, many of which have uncertainties associated with them. The analyses performed in this value impact assessment utilize best estimate (mean) values for the computation of baseline risk and averted risk. A summary of some of the key sources of uncertainty are as follows:

Core Damage Assessment Uncertainties

- Initiating Event Frequencies
- Component Failure Rates
- Component Unavailabilities
- Human Error Rates

Containment Performance Assessment Uncertainties

- Severe Accident Phenomena
- Component/System Performance in Severe Accidents
- Containment Response

Consequence Assessment Uncertainties

- Meteorology
- Demographics
- Transport Phenomena

As discussed in Revision 1 of the Executive Summary in Enclosure 2 of this letter, the NUREG-1150 analysis of Sequoyah Nuclear Plant (SQN) Unit 1, a sister plant to WBN, was reviewed in order to assess the overall magnitude of uncertainties in the integrated result. As shown in Table 7 of the revised Executive Summary, the results provided in NUREG/CR-4551, Volume 3, for SQN indicate that the overall uncertainties (as expressed as a ratio from the 5th to 95th percentile values) range from a factor of 10 to over 2500. The core damage frequency (CDF) uncertainty band is the smallest and the early fatality uncertainties are the largest. The uncertainty analysis provided in the original WBN Individual Plant Examination (IPE) confirms that the WBN CDF uncertainty is consistent with, actually less than, the NUREG/CR-4551 results.

The value impact assessment utilizes the 50-mile population dose. In this case, the overall uncertainty band is approximately a factor of 50. However, as discussed above, the qualification of the dose reduction associated with the value impact assessment utilizes mean values. The differences between the mean value and the upper bound values (i.e., 95th percentile) are much smaller. Table 8 of the Executive Summary, Revision 1, provides a summary of the same NUREG/CR-4551 data expressed as a ratio with the mean value. This table shows that, for the figures of merit considered in this analysis, the potential uncertainty in results is slightly less than a factor of 4. Even the upper bound early fatality risk, which had the largest uncertainty band, is less than a factor of 5 from the mean value.

Therefore, the maximum uncertainty in the risk reduction computation utilized in the value impact analysis is judged to be less than a factor of 4. Thus, an upper bound of the cost benefit ratio is $4,000 per person-rem.

No credit was taken in the original submittal for implementation of the risk reducing enhancements which were found to be cost beneficial. As described in the revised Executive Summary, with credit for the enhancements incorporated, the minimum cost benefit ratio is greater than $7,500 per person-rem. Based on these results, consideration of uncertainties is found to have no impact on the conclusions of the value impact analysis.

NRC REQUEST 2

For each design alternative, provide a breakdown of the risk reduction (person-rem) in terms of the contribution from: early containment failure, containment bypass failure, late containment failure, and any other key release modes.

TVA'S RESPONSE

The risk reductions calculated in the original value impact assessment included a conservatism which was due to a few low frequency plant damage states (PDSs) that were conservatively deleted from each of the enhancement cases. The base case (8.0E-5/yr CDF and 200 person-rem total dose) included these PDSs, however, each of the sensitivity cases computed in the spreadsheets conservatively assumed them to be zero frequency. This resulted in the over-estimation of the benefit for the enhancements including the reactor coolant pump (RCP) seal improvements and the fifth diesel.

The risk reduction breakdown for each design alternative is obtained by reviewing the relationships of the Accident Progression Bins (APBs) and the associated containment response characteristics. The APBs are defined in NUREG-1150 and discussed in the SAMDA Methodology as follows:

CONTAINMENT RESPONSE CHARACTERISTIC	APB
Early Containment Failure with Vessel Breach During Core Degradation	1
Early Containment Failure at Vessel Breach (ALPHA Mode)	2
Early Containment Failure at Vessel Breach (RCS pressure > 200 psi)	3
Early Containment Failure at Vessel Breach (RCS pressure < 200 psi)	4
Late Containment Failure with Vessel Breach	5
Very Late Containment Failure (Basemat melt-through)	6
Containment Bypass	7
No Containment Failure	8
Early Containment Failure During Core Degradation (No Vessel Breach)	9
No Containment Failure (No Vessel Breach)	10

By grouping the appropriate APBs, specific containment response characteristics can be evaluated. The following table provides the relationship between the APBs and the containment response characteristics.

CONTAINMENT RESPONSE CHARACTERISTIC GROUP	APB
Early Containment Failure	
Vessel Breach	1,2,3,4
No Vessel Breach	9
Late Containment Failure	5
Basemat Melt-Through	6
Containment Bypass	7
No Containment Failure	
Vessel Breach	8
No Vessel Breach	10

For each alternative, tables in Section 4 are provided for the enhancement cases which present the calculation of averted offsite dose. Each table provides the APB classification number, base case APB frequency (events/yr), revised APB frequency (events/yr), base case population dose rate (person-rem/yr), revised population dose rate (person-rem/yr), base case population dose (person-rem), revised population dose (person-rem), and averted population dose (person-rem). In order to determine the risk reduction (person-rem) for a specific enhancement case, first locate column 6 of the "Calculation of Averted Offsite Doses," which provides the base case population dose (person-rem) for each APB. Secondly, locate column 7 which provides the Revised Population Dose (person-rem) for each APB. Next, combine the appropriate APBs for the Containment Response Characteristic Group of interest. Finally, the risk reduction (person-rem) can be determined by comparing the population dose for each Containment Failure Characterization Group.

NRC REQUEST 3

Discuss whether a purely procedural option would be viable in place of the "Install Reactor Depressurization System" option, and if not, why not.

TVA'S RESPONSE

A procedural option for depressurizing the reactor coolant system (RCS) was considered. However, thermal hydraulic analyses found that the existing pressurizer power-operated-relief-valves (PORVs) and head vents did not have sufficient capacity to depressurize the RCS.

Modular Accident Analysis Program (MAAP) 3.0B calculations were made to assess the impact of opening one or two pressurizer PORVs in loss of feedwater type sequences at WBN. In these calculations, the PORVs were opened when the peak core temperature reached 1200°F, and one train of low pressure injection (LPI) and the four cold leg accumulators were assumed available.

Opening the PORVs causes a rapid reduction in pressure until the accumulator setpoint of 600 psi is reached. Subsequent depressurization is very slow since steaming of the injected water tends to reduce or temporarily halt further accumulator discharge. When core relocation is subsequently predicted to occur, rapid steaming in the lower plenum repressurizes the RCS. This stops only when the lower head is dried out, assuming that vessel failure does not take place earlier. When dryout occurs, the system depressurized again until the accumulator pressure is reached, at which point depressurization is again essentially halted. In no case was the LPI shutoff head reached. It is worth noting that rapid repressurization was observed in the Three Mile Island (TMI) accident following core relocation.

These calculations found that there are several effects of opening the PORVs. While the RCS pressure is reduced, the combined effect of accumulator discharge and debris water interactions in the lower plenum make it difficult to reach a pressure sufficiently low to prevent debris dispersal from the reactor cavity. Moveover, depressurization is calculated to prevent induced rupture of one of the hot legs, which is predicted to occur in cases where the PORVs are not opened due to efficient transfer of heat from the core to the hot legs via natural circulation. Rupture of the hot legs would create a rather large opening, which should be sufficient to eliminate direct containment heating (DCH) concerns. More important, it appears likely that induced rupture will allow LPI to initiate, which could prevent vessel failure altogether. This has been noted in NUREG-1150 and many IPEs.

We conclude that there is no compelling reason to change emergency procedures at WBN to open the PORVs when only LPI is available. Opening the PORVs can moderate the pressure in the RCS and thus post-failure containment loads, but is unlikely to reduce pressure enough to either allow LPI to discharge or prevent high pressure melt ejection (HPME). If the PORVs remain closed, both the calculations reported here, as well as substantial body of other work indicates that induced failure to the hot leg or surge line will likely occur. This would prevent debris dispersal and would probably prevent containment failure.

Flow through the pressurizer PORVs is computed in MAAP 3.0B by applying standard critical flow models to an "effective" flow area. The effective flow area is computed from supplied values for the nominal steam flow rate and the PORV setpoint pressure at which it is assumed that this flow rate is measured. This procedure is used rather than supplying the area directly to eliminate any confusion or error associated with discharge coefficients. Benchmarking to Electric Power Research Institute (EPRI) PORV test results indicates that this technique will calculate flow rates with a worst-case error of

25 percent. For sequences involving RCS depressurization, this overstates the error since the cases with the worst errors involved highly subcooled water. More times than not, MAAP predicts a slightly higher flow rate than measured, with an average error of ±5 percent, EPRI TR-100741, MAAP, Thermal-Hydraulic Qualification Studies.

For the WBN IPE calculations, the PORV nominal flow rate in the MAAP input deck was specified to be 210,000 lbm/hr and the setpoint pressure is given as 2350 psia. Upon review, it has been found that the Final Safety Analysis Report (FSAR) provides both these values, but it is stated there that the design flow rate of 210,000 lbm/hr actually corresponds to a pressure of 2265 psia. The fact that MAAP will associate 210,000 lbm/hr with the setpoint pressure will result in a slight under-calculation of the effective flow area. This error is judged to be negligible; in fact, if anything it will approximately cancel the slight MAAP bias toward over-predicting flow.

NRC REQUEST 4

None of the Category 5 enhancements are procedural in nature. Please justify that there are no procedural enhancements (e.g., accident management strategies) that can improve containment performance 8.

TVA'S RESPONSE

This question addresses a common perspective with NRC Requests 8 and 9 on whether implementation of severe accident management strategies is cost/beneficial. The principal aim is (1) mitigation of the accident once core damage has begun and (2) protection of fission product barriers external to the vessel as these barriers become important.

The philosophy used in the development of candidate modifications for value impact analysis was as follows:

Review other industry SAMDA analyses for changes that might be beneficial to the risk profile for WBN.

Use the recently updated WBN IPE for guidance in changes to improve risk.

Examine the use of procedural fixes with an emphasis on front end improvements to risk (i.e., prevention or arrest in-vessel) where appropriate.

Our reviews and selections did not identify specific procedural enhancements for severe accident management strategies. Accident management following core damage lends itself to treatment similar to the Functional Restoration Guidelines used in Westinghouse emergency procedures. In this context, broad guidelines appear most appropriate for accident management. Depending on the multiple failures that have occurred, a variety of end states may be encountered. Specific equipment availability may not be assured and recovery must be addressed by assessing system availability and functionality. The Severe Accident Mitigation Guideline (SAMG) program is the industry effort at defining this type of guidance.

The Westinghouse Owners Group has recently completed (June 1994) an initial issue of a SAMG product to its member utilities. This effort extends the Emergency Response/Functional Restoration Guidelines to events which have progressed to a core damage state through the use of additional guidelines. It contains both Control Room and Technical Support Center guidance for decision making.

WBN is following the Westinghouse development program but does not believe that the effort has fully matured. A cost/benefit analysis for the WBN Value Impact Study is, therefore, not appropriate. WBN continues to follow and participate in Owners Group and Industry initiatives in the area of SAMG separate from the Value Impact Analysis program.

NRC REQUEST 5

Please explain why the options identified as V-2 and V-3 yield identical risk reductions.

TVA'S RESPONSE

Options V.2 and V.3 evaluated the installation of a reactor cavity flooding system and the installation of a filtered containment venting system, respectively. The purpose of the reactor cavity flooding system design alternative is to flood the reactor cavity region to provide mitigating effects on corium-concrete interactions and DCH. The purpose of the filtered containment venting design alternative is to provide the capability to vent the containment through an external filter to mitigate challenges to containment from long-term over-pressure and hydrogen burns.

Both enhancements were conservatively assigned maximum credit for precluding non-bypass containment failures. These two enhancements take maximum credit for risk reduction by assuming each of these enhancements precludes containment failures except bypass. Therefore, the evaluations for both enhancements are bounding and yield identical risk reductions.

NRC REQUEST 6

TVA considered two options to enhance the containment spray system -- installation of an independent train of containment spray with injection capacity only, and addition of an independent train of containment spray with recirculation and heat removal. Another option suggested in NUREG/CR-5589 (page 29) is to use the fire water spray pump as a backup means for spray injection into the containment. Please explain why this option was not considered as a design alternative.

<u>TVA'S RESPONSE</u>

WBN has four high pressure fire pumps (~150 psig discharge pressure). The plant design provides a connection between the fire system and the auxiliary feedwater system for makeup to the steam generators. Use of the fire water pumps for containment spray would require a plant modification. The benefit of such a modification would be limited for the following reasons:

- The sequences with containment spray unavailable primarily involve loss of key support systems such as electric power (i.e., station blackout) and cooling systems (i.e., ERCW).
- In the loss of AC-power sequences, the sprays would not inject.
- In the loss of cooling sequences, the sprays would inject but fail on recirculation.
- The electric powered fire pumps would only operate in non-blackout conditions.
- In the loss of cooling sequence, the additional injection capability would be of little value without containment heat removal.

Nevertheless, a bounding assessment was made of the potential maximum benefit which could be derived from such a modification. Based on the rebaselined results, approximately 9 percent of the CDF involves late containment overpressure failures (See Figure 3 of revised Executive Summary). This is equivalent to 5.2 x 10^{-6}/year or 40 percent of the late containment failures (based on Table 4 of the revised Executive Summary late failures constitute approximately 23 percent of the CDF, 9 percent is approximately 40 percent of 23 percent). Based on the overall contribution of late containment failures to total population dose of 38 person-rem (APB 5 contributes 18 percent of the total 211 person-rem dose of the plant). Assuming this modification could eliminate late containment failures, a bounding estimate of the maximum possible benefit is 15.2 person-rem (40 percent of 38 person-rem). Therefore, the maximum cost which could be justified to meet this benefit is $15,200 to $58,000, based on mean ($1,000 per person-rem) and upper bound estimates ($1,000 per person-rem * 3.8 upper bound to mean ratio), respectively. This justifiable cost range is much less than the cost of the modification.

NRC REQUEST 7

Combining two or more design alternatives can potentially offer a lower greater cost benefit ratio (CBR) than the CBR for the individual design alternatives. In this regard, please evaluate and identify combinations of design alternatives that could provide increased risk reduction potential, and provide a value impact assessment for the more promising combinations.

TVA'S RESPONSE

Based on the rebaselined results described in the revised Executive Summary, most of the enhancements have sufficiently high value impact ratios that evaluating them in combination could not yield a cost beneficial result. Therefore, enhancements with value impact ratios of $50,000 or less were evaluated in combinations.

Based on Table 10 of the revised Executive Summary, the following enhancements had value impact ratios of less than $50,000:

- Install Improved RCP Seals
- Provide DC Load Shed Analysis and Procedure
- Provide Portable Battery Charger
- Modify Charging Pump Cooling from CCS to ERCW
- Install Accumulators for Turbine-Driven AFW level control valves and steam generator PORVs.
- Install AC Independent Coolant Injection System.

Combinations of these enhancements were evaluated. Either no improvement was identified over the benefits of the individual enhancements or the costs associated with the combined enhancements were significantly greater than $211,000. Therefore, the combinations are also considered not cost beneficial.

NRC REQUEST 8

The Westinghouse Owners Group has recently completed its development of Severe Accident Management Guidelines (SAMG). These guidelines identify a set of accident management strategies that can be implemented by utility staff during an accident to either prevent or mitigate the consequences of severe accidents. Since the focus of the SAMG is on the use of existing plant equipment, and the risk reduction typically ascribed to accident management is on the order of a factor of 10, the cost benefit ratio for implementing the SAMG would appear favorable. In this regard, please provide a value impact assessment for implementing the SAMG at WBN. This assessment should consider both:

a. implementation of the entire guideline document, and

b. implementation of individual strategies in the document that have not already been assessed in the TVA value impact study.

TVA'S RESPONSE

This request has a common perspective to NRC's Request 4; therefore, see TVA's response to NRC's Request 4.

NRC REQUEST 9

Enhancement V.2 Reactor Cavity Flooding. Flooding the cavity before the corium is on the floor could create the possibility of severe explosions by the interaction of the hot molten mass falling into the pool of water. Introduction of a measured amount of water after the corium is on the floor would provide the same benefits and avoid the possibility of an explosion. Should, an enhancement be considered to suggest severe accident management practices which would avoid water-corium interactions?

TVA'S RESPONSE

This request has a common perspective to NRC's Request 4; therefore, see TVA's response to NRC's Request 4.

NRC REQUEST 10

Please explain the apparent inconsistency in the Value Impact Analysis between the CDF value for Sequoyah used in Table 1, page ES-4, of 1.7E-4 (mean value) and the value used in Table C-4, page C-7 of 5.58E-5 (mean value). This difference can have implications for the consequence scaling assessment.

TVA'S RESPONSE

The CDF value of 1.7E-4 used in Table 1 on page ES-4 of the Executive Summary is the CDF estimate for SQN based upon the results of the SQN IPE, September 1992. This CDF value was presented for comparison purposes to show the relationship of the WBN CDF results to other Ice Condenser Containment IPEs. The CDF value of 5.58E-5 used on page C-7, Table C-4, is the CDF estimate for SQN based upon the NUREG-1150 results and was used to ratio the NUREG-1150 results to WBN as discussed in the SAMDA Methodology submittal.

NRC REQUEST 11

Enhancement V.1 considered improving hydrogen control capabilities by providing additional hydrogen igniters throughout containment and an additional power source independent of existing AC and DC power systems. It would appear that similar benefits could be derived from a more modest design improvement that would utilize existing hardware. In this regard, provide an assessment of the costs associated with the following variations on this design enhancement (along with the risk reduction associated with each variation, if significantly different than that provided in the Value Impact Analyses for this design change).

a. use a subset of the existing igniters in conjunction with the new power source (e.g., connect one train of the existing igniters to the independent power system). As part of this assessment, include consideration of a new, non-safety grade portable generator dedicated for this purpose and pre-staged to facilitate connection during a station blackout.

b. use a subset of the existing igniters in conjunction with existing station batteries,

c. use a subset of the existing igniters in conjunction with existing AC- and DC-independent onsite power sources such as the security system diesel, small portable generators that may exist on site for maintenance purposes, or safe shutdown facility diesels.

TVA'S RESPONSE

The enhancements already implemented as a result of the value impact assessment have significantly reduced the potential for loss of AC-power to the igniters. Therefore, these enhancements will have less benefit than computed in the limiting case V.1 in the submittal.

A question has been raised as to the effectiveness of providing redundant power sources to the igniters in the WBN containment with or without also providing such a source for the air return fans (ARF). Air return fans play an important role in homogenizing ice condenser containment conditions and preventing high, localized hydrogen concentrations. By contrast to large, dry containments, ice condenser plants have a relatively small flow area available for gas to flow from the upper containment region back to the dead-end region or the lower-containment volume surrounding the reactor coolant system. Thus the predicted natural circulation flow rates between regions when the fans are not operating are relatively small. When fans are operating, there is general agreement (see for example the discussion associated with NUREG-1150 APET question 31) that the containment will be relatively well-mixed.

Several MAAP 3.0B calculations were performed for the WBN IPE to assess the effects from hydrogen detonations under various situations. These generally showed that maximum hydrogen concentrations develop in the ice condenser. This is expected, since the steam which dilutes (and may inert) the incoming gas mixture is nearly completely condensed by the ice, leaving just air and hydrogen. If ARF were not operating, calculated hydrogen concentrations in the ice condenser depend on sequence definition and whether or not igniters were available and effective in the lower-containment region which supplies the ice condenser. If igniters were not available in the lower containment or were rendered ineffective by high steam concentrations, peak hydrogen concentrations ranged from 25-45 percent, although the time intervals at which such high values were achieved were relatively short. If igniters were operating and effective in the lower-containment, given their number and placement generally low concentrations were predicted. Hydrogen concentrations were found to be highest when release rates from the RCS were large.

Station blackout calculations similar to those discussed above were performed by Sandia with the CONTAIN code, NUREG/CR-5586, Mitigation of Direct Containment Heating and Hydrogen Combustion Events in Ice Condenser Plants. Similar results were obtained as summarized in this paragraph from the report.

> The situation is more complex when dedicated power is supplied for the existing igniter systems. When the igniters in the lower containment are effective, burns initiating there and propagating into the ice condenser (which lacks igniters) were generally effective in preventing dangerous hydrogen concentrations from developing in the ice condenser. When steam inerting defeated the igniters in the lower containment, combustion in the ice condenser would not initiate until flammable concentrations were achieved in the upper plenum, which does contain igniters. By this time, detonable concentrations had sometimes been reached in the ice condenser. Dedicated power supplies for the ARF (both trains) resulted in significant benefits, both by reducing the likelihood that lower-containment igniters would be defeated by steam inerting, and also by reducing the differences in hydrogen concentrations between the ice condenser and the upper plenum in those scenarios for which the fans could not prevent inerting of the lower containment.

Sandia noted that the occurrence of a detonation in the ice condenser might not result in containment failure, considering the reflections of the shock waves which would occur at the ice basket surfaces and other structures, and the energy absorbing effect of deformation in these structures.

Finally, the Sandia report assessed the relative benefit of various mitigative measures on total plant risk using the methodology developed as part of the NUREG-1150 study. When analyzing SQN (which differs in its containment response from WBN essentially only in having a lower failure pressure), it was concluded that the most effective means for lowering risk was increasing the failure pressure to be representative of WBN. Providing for depressurization of the RCS and back-up power to either the igniters alone (Sandia's Case 3) or to both igniters and ARF (Case 2) was found to provide the next most significant benefit; i.e., a 37 percent and 31 percent reduction in risk, respectively.

In view of the deterministic results summarized above, the relatively small added benefit of providing power to the ARF is noteworthy. This may reflect the fact that detonations in the ice condenser were not considered a particularly large contributor to risk in NUREG-1150, despite the high hydrogen concentrations assumed to develop there. The median impulse due to detonations in the ice condenser was estimated to be 10.4 kilopascal/second (kPa-sec) in NUREG-1150, but the assigned failure criterion was 21.6 kPa-sec. These results are considered to be highly uncertain. NUREG/CR-5586 did not calculate detonation-induced loadings on the containment.

For completeness, it may be worth noting that Brookhaven National Laboratory recently listed several systems which could be added to ice condenser plants to mitigate severe accidents, NUREG/CR-5589, Assessment of Ice Condenser Containment Performance Issues. Among these, providing dedicated power to the igniters or ARF was mentioned. However, no assessment of the relative effectiveness of these measures or the expected reduction in risk was performed.

Based upon the above discussions, TVA does not believe that any conclusive evidence exits to support that the use of the H_2 ignitors without the ARFs would successfully mitigate potentially catastrophic hydrogen detonations.

With respect to operation of the igniters from the station batteries, the majority of the remaining loss of offsite power risk is due to long-term (i.e., battery depletion) type station blackout events. Therefore, the value of station battery powered igniters would be very limited.

In summary, operation of the igniters without ARF is questionable. Nevertheless, TVA has computed the maximum benefit which could be achieved by eliminating hydrogen related failures of the containment. As described in the response to NRC Question 21, the maximum population dose associated with hydrogen burns is 18.8 person-rem. However, based on a sensitivity analysis performed using the integrated spreadsheet model, late containment failures (including hydrogen and overpressure failures) which occur following a loss of offsite power only contribute 12.3 person-rem. Therefore, the maximum cost which could be justified to meet this benefit is $12,300 to $46,700 based on mean ($1,000 per person-rem) and upper bound estimates ($1,000 per person-rem * 3.8 upper bound to mean ratio), respectively. This justifiable cost range is much less than the cost of any plant modification and procedures which could provide alternate power to the ignitors.

NRC REQUEST 12

Some recurring costs appear not to have been discounted. What would costs be if recurring costs were discounted at 7 percent to the present?

TVA'S RESPONSE

Only two of the enhancements evaluated in the original value impact assessment included recurring costs which were not discounted. These enhancements were:

- II.2 - Complete Fifth Emergency Diesel Generator
- III.6 - Provide Portable Battery Charger

In both cases the recurring costs involved maintenance of the new equipment. The revised cost totals are summarized below and accounted for in the revised Executive Summary:

ENHANCEMENT	ONE-TIME COSTS	RECURRING COSTS*	TOTAL COST
II.2 - Complete Fifth Emergency Diesel Generator	$378,000	$53,300	$431,300
III.6 - Provide Portable Battery Charger	$93,800	$13,300	$107,100

* - Discounted at 7 percent per year.

NRC REQUEST 13

In Enhancement II.2, cost data need to be recalculated to show true costs. For II.2, the true cost should be the added cost of having 5th diesel general available at the earlier date vs. the later date. Other enhancements should be checked for similar problem.

TVA'S RESPONSE

There has been no commitment by TVA to make the fifth diesel generator available. Therefore, the cost of this enhancement is considered to include the costs of making the diesel available. The title and description of this enhancement has been modified in the revised Executive Summary to reflect this.

Nevertheless, for the purposes of evaluation, a hypothetical case was investigated involving an "acceleration" of the fifth diesel generator by first refueling cycle. In such a case, the true cost of the enhancement would be the added cost of making the diesel available at an earlier date (i.e., the time value of the money).

Assuming a total initial, one-time cost of $378,000 and a 7 percent discount rate, the added cost of accelerating the availability of the diesel would be

$$\text{Cost} = \$378{,}000\ ((1.07)^{1.5} - 1) = \$40{,}377$$

The small added cost due to the maintenance required during the first cycle is conservatively ignored.

The benefit associated with this "enhancement" would be an additional 1.5 years of operation at the lower risk value. Based on Table 10 of the revised Executive Summary, over 40 years, the fifth diesel generator averted 4.9 person-rem. This equates to an annual dose rate of 0.12 person-rem per year. Therefore, for the 1.5 years of advance use, the fifth diesel generator could avert 0.18 person-rem (1.5 x 0.12). This equates to a value impact ratio of $224,317 per person-rem ($40,377/0.18). Therefore, even on this basis, the fifth diesel generator is not cost beneficial.

All other enhancements were reviewed and this question does not apply.

As a point of clarification, the resulting risk reduction estimate reflects the elimination of the conservatism described in the response to NRC Question 2 which was present in the original submittal. The elimination of this conservatism accounts for both the elimination of the bypass contributors and the reduced benefit computed.

NRC REQUEST 14

If other values (reflecting uncertainty) than mean point estimate for person-rem yr. are used (say 90th percentile value), are cost benefit ratios significantly different?

TVA'S RESPONSE

As discussed in the response to NRC Question 1, the uncertainties which exist in severe accident analyses would not have a significant impact on the conclusions of the value impact assessment.

NRC REQUEST 15

Based on information provided in Section 3.2.1 of the Value Impact Analysis, it does not appear that averted onsite costs (AOSC) have been considered in determining the cost benefit ratio for any of the design alternatives. It is NRC's current policy that in the consideration of cost-benefit related to design alternatives, averted onsite costs should be accounted for in the cost benefit equation as reductions in the costs associated with the proposed design alternative. (Typical costs include the cost of replacement power, plant cleanup, and decontamination, as well as other costs). In this regard, please provide a reassessment of the potential design improvements considering AOSC where appropriate. In addition to providing the resulting cost benefit ratios, please include your estimates for each of the factors or attributes contributing to the ratio result (e.g., $ value of person-rem averted, implementation costs, AOSC, etc.) such that the NRC would be able to calculate the "Net Benefit" of the proposed design alternative. As part of this response, please identify the preventive and mitigative benefits of each design alternative separately, and provide an accounting of the impact of the design alternative on the frequency of each accident class and release class.

TVA'S RESPONSE

TVA does not agree that averted onsite cost (AOSC) should be considered in value impact analyses. Furthermore, previous licensee SAMDA analyses have not considered AOSC. This is primarily due to the fact that the previous SAMDA analyses have been focused on design alternatives which have involved mitigation of severe accidents. The scope of the WBN value impact analysis included both prevention and mitigation. These prevention alternatives have been lumped under the SAMDA umbrella.

For the purposes of resolving this question, TVA has prepared AOSC based on the recent NRC staff's regulatory analysis for the shutdown and low power rulemaking. Based on SECY 94-176, core damage events are considered to have an AOSC of $\$2.96 \times 10^8$. For a 40-year plant life and a 7 percent discount rate, this translates to a present value based on the following equation from the SECY:

$$AOSC_{PV} = \frac{\$2.96E8*((1+0.07)^{40} - 1)}{0.07*(1+0.07)^{40}} = \$3.95E9/\text{event}$$

The AOSC associated with an enhancement is the product of the change in the CDF and the present value of the AOSC. When AOSC is considered, there are several calculational methods which can be used. The following summarizes four different ways to compute the value impact:

METHOD 1 - DOLLARS PER AVERTED PERSON-REM

$$V1 = \frac{\text{COST OF ENHANCEMENT}}{\text{AVERTED DOSE}}$$

This is the method used in the original value impact assessment and the revised Executive Summary.

METHOD 2 - DOLLARS PER AVERTED PERSON-REM WITH AOSC

$$V1 = \frac{\text{COST OF ENHANCEMENT - AOSC}}{\text{AVERTED DOSE}}$$

The AOSC is based on the change in CDF and some assumed cost of cleanup and replacement power. The industry has maintained that this is an incorrect and meaningless computation since it relies on negative "benefits" in the numerator.

METHOD 3 - NET BENEFIT BASIS ($)

NET BENEFIT = (AVERTED DOSE * $1000 + ASOC) - COST OF ENHANCEMENT

This method computes the net benefit based on a sum of the costs (positive and negative).

METHOD 4 - BENEFIT TO COST RATIO (UNITLESS)

$$\text{BENEFIT/COST} = \frac{\text{(AVERTED DOSE * \$1000) + AOSC}}{\text{COST OF ENHANCEMENT}}$$

This method correctly places the AOSC in the numerator as a potential cost and is the mathematically correct approach to consideration of AOSC in a ratio.

The attached tables provide a summary of the value impact results for the quantitatively evaluated enhancements using each of these four methods. Data provided includes the person-rem averted, the dollar per person-rem used ($1,000 or an upper bound of $4,000), the change in CDF computed, the implementation cost, and the AOSC computed. Based on these results, it is concluded that consideration of AOSC would not have an impact of the overall conclusion of the value impact analysis.

SUMMARY OF AVERTED ONSITE COST/VALUE IMPACT INPUTS

ITEM	ENHANCEMENT	COST	DOSE AVERTED	DELTACDF	AOSC
I-2.	INSTALL CONTAINMENT SPRAY THROTTLE VALVES	$200,000	1.10	3.50E-06	$13,811.65
I-3.	REDESIGN TO DELAY CONTAINMENT SPRAY ACTUATION	$406,470	1.10	3.50E-06	$13,811.65
I-4.	INSTALL AUTOMATIC HIGH PRESSURE RECIRCULATION	$2,100,000	1.10	3.50E-06	$13,811.65
II-2.	COMPLETE 5TH EMERGENCY DIESEL GENERATOR	$431,300	4.86	1.10E-06	$4,340.80
II-3.	PROCEDURE CHANGE AND 5TH DIESEL GENERATOR (INCLUDED IN ITEM II-2)	N/A	N/A	N/A	N/A
III-2.	INSTALL IMPROVED RCP SEALS	$162,800	8.47	6.90E-06	$27,228.68
III-3.	INSTALL INDEPENDENT RCP SEAL COOL SYSTEM	$3,500,000	9.54	7.70E-06	$30,385.63
III-4.	INSTALL ACCUMULATORS FOR TURBINE DRIVEN AFW PUMP FLOW	$324,600	22.26	9.10E-06	$35,910.29
	CONTROL VALVES AND S/G PORVs				
III-5.	PROVIDE DC LOAD SHED ANALYSIS AND PROCEDURE	$113,200	13.84	2.70E-06	$10,654.70
III-6.	PROVIDE PORTABLE BATTERY CHARGER	$107,100	13.84	2.70E-06	$10,654.70
III-7.	INSTALL AC INDEPENDENT COOLANT INJECTION SYSTEM	$3,500,000	89.67	5.21E-05	$205,398.97
IV-1.	INSTALL IMPROVED RCP SEALS	$162,800	8.47	6.90E-06	$27,228.68
IV-2.	INSTALL INDEPENDENT RCP SEAL COOLING SYSTEM (W/O NEW DG)	$2,400,000	10.71	9.30E-06	$36,699.53
IV-3.	MODIFY CHARGING PUMP COOLING FROM CCS TO ERCW	$295,200	18.67	1.26E-05	$49,721.94
V-1.	INSTALL DELIBERATE IGNITION SYSTEM	$6,100,000	18.84	0.00E+00	$0.00
V-2.	INSTALL REACTOR CAVITY FLOODING SYSTEM	$8,750,000	89.67	0.00E+00	$0.00
V-3.	INSTALL FILTERED CONTAINMENT VENTING SYSTEM	$20,000,000	89.67	0.00E+00	$0.00
V-4.	INSTALL CORE RETENTION DEVICE	$44,500,000	61.47	0.00E+00	$0.00
V-5.	INSTALL CONTAINMENT INERTING SYSTEM	$10,900,000	18.84	0.00E+00	$0.00
V-6.	INSTALL ADDITIONAL CONTAINMENT BYPASS INSTRUMENTATION	$2,300,000	0.86	1.00E-07	$394.62
V-7.	INSTALL REACTOR DEPRESSURIZATION SYSTEM	$4,600,000	19.48	0.00E+00	$0.00
V-8.	INSTALL INDEPENDENT CONTAINMENT SPRAY SYSTEM	$5,800,000	61.47	0.00E+00	$0.00
V-9.	INSTALL AC INDEPENDENT AIR RETURN FAN POWER SUPPLIES	$1,000,000	18.84	0.00E+00	$0.00
VI-1.	INSTALL MG SET TRIP BREAKERS IN CONTROL ROOM (ATWS)	$142,500	2.76	4.20E-06	$16,573.98
VI-2.	IMPROVE PROCEDURES TO PROVIDE TEMPORARY HVAC DURING LOSS OF ROOM COOLING	$25,200	0.39	5.00E-07	$1,973.09

SUMMARY OF VALUE IMPACT CALCULATIONS USING AOSC

				$1,000 PER PERSON REM		$4,000 PER PERSON REM	
		METHOD 1	METHOD 2	METHOD 3	METHOD 4	METHOD 3	METHOD 4
ITEM	ENHANCEMENT	VIbase ($/prem)	VIaosc ($/prem)	NET COSTaosc ($)	B/C RATIO	NET COSTaosc	B/C RATIO
I-2.	INSTALL CONTAINMENT SPRAY THROTTLE VALVES	$181,818	$169,262	($185,088)	0.07	($181,788)	0.09
I-3.	REDESIGN TO DELAY CONTAINMENT SPRAY ACTUATION	$369,518	$356,962	($391,558)	0.04	($388,258)	0.04
I-4.	INSTALL AUTOMATIC HIGH PRESSURE RECIRCULATION	$1,909,090	$1,896,535	($2,085,088)	0.01	($2,081,788)	0.01
II-2.	COMPLETE 5TH EMERGENCY DIESEL GENERATOR	$88,745	$87,852	($422,099)	0.02	($407,519)	0.06
II-3.	PROCEDURE CHANGE AND 5TH DIESEL GENERATOR (INCLUDED IN ITEM II-2)	N/A	N/A	N/A	N/A	N/A	N/A
III-2.	INSTALL IMPROVED RCP SEALS	$19,221	$16,006	($127,101)	0.22	($101,691)	0.38
III-3.	INSTALL INDEPENDENT RCP SEAL COOL SYSTEM	$366,876	$363,691	($3,460,074)	0.01	($3,431,454)	0.02
III-4.	INSTALL ACCUMULATORS FOR TURBINE DRIVEN AFW PUMP FLOW	$14,582	$12,969	($266,430)	0.18	($199,650)	0.38
	CONTROL VALVES AND S/G PORVs						
III-5.	PROVIDE DC LOAD SHED ANALYSIS AND PROCEDURE	$8,179	$7,409	($88,705)	0.22	($47,185)	0.58
III-6.	PROVIDE PORTABLE BATTERY CHARGER	$7,738	$6,969	($82,605)	0.23	($41,085)	0.62
III-7.	INSTALL AC INDEPENDENT COOLANT INJECTION SYSTEM	$39,032	$36,741	($3,204,931)	0.08	($2,935,921)	0.16
IV-1.	INSTALL IMPROVED RCP SEALS	$19,221	$16,006	($127,101)	0.22	($101,691)	0.38
IV-2.	INSTALL INDEPENDENT RCP SEAL COOLING SYSTEM (W/O NEW DG)	$224,089	$220,663	($2,352,590)	0.02	($2,320,460)	0.03
IV-3.	MODIFY CHARGING PUMP COOLING FROM CCS TO ERCW	$15,811	$13,148	($226,808)	0.23	($170,798)	0.42
V-1.	INSTALL DELIBERATE IGNITION SYSTEM	$323,779	$323,779	($6,081,160)	0.00	($6,024,640)	0.01
V-2.	INSTALL REACTOR CAVITY FLOODING SYSTEM	$97,579	$97,580	($8,660,330)	0.01	($8,391,320)	0.04
V-3.	INSTALL FILTERED CONTAINMENT VENTING SYSTEM	$223,038	$223,040	($19,910,330)	0.00	($19,641,320)	0.02
V-4.	INSTALL CORE RETENTION DEVICE	$723,989	$723,930	($44,438,530)	0.00	($44,254,120)	0.01
V-5.	INSTALL CONTAINMENT INERTING SYSTEM	$578,556	$578,556	($10,881,160)	0.00	($10,824,640)	0.01
V-6.	INSTALL ADDITIONAL CONTAINMENT BYPASS INSTRUMENTATION	$2,674,419	$2,673,960	($2,298,745)	0.00	($2,296,165)	0.00
V-7.	INSTALL REACTOR DEPRESSURIZATION SYSTEM	$236,140	$236,140	($4,580,520)	0.00	($4,522,080)	0.02
V-8.	INSTALL INDEPENDENT CONTAINMENT SPRAY SYSTEM	$93,354	$94,355	($5,738,530)	0.01	($5,554,120)	0.04
V-9.	INSTALL AC INDEPENDENT AIR RETURN FAN POWER SUPPLIES	$53,079	$53,079	($981,160)	0.02	($924,640)	0.08
VI-1.	INSTALL MG SET TRIP BREAKERS IN CONTROL ROOM (ATWS)	$51,630	$45,625	($123,166)	0.14	($114,886)	0.19
VI-2.	IMPROVE PROCEDURES TO PROVIDE TEMPORARY HVAC DURING LOSS OF ROOM COOLING	$64,615	$59,556	($22,837)	0.09	($21,667)	0.14

NRC REQUEST 16

In a 9/19/94 teleconference, TVA indicated that they will revise the value impact analysis to take credit for the two design alternatives that they have already committed to implement (design alternatives I.1 and II.1). Describe and justify the credit that will be taken for these design alternatives in terms of reducing the baseline core damage frequency and risk for WBN. Include a discussion of the related human error probabilities and the bases for these values (such as estimated time available for operator actions in representative sequences, and the instrumentation on which the operators are to make their decisions).

TVA'S RESPONSE

The revised Executive Summary report provides a description of enhancements which have been credited in the rebaselined value impact assessment. Tables 1, 2, and 3 of the revised Executive Summary report provide a description of the functional impact of the enhancement, the approach used in crediting the enhancement in the PRA, and the bases for the credit taken.

NRC REQUEST 17

As described in Section 2.3 of the Value Impact Analysis, both the frequency of large early releases and the early fatality risk is dominated by SGTR events. However, none of the design alternatives considered by TVA appear to be directed at reducing the frequency or consequences of SGTR events. Such design alternatives could include improved instrumentation for responding to SGTR events (N-16 monitors), improved depressurization capabilities or procedures to terminate releases in unisolatable SGTR events, or additional systems to scrub fission product releases or to route these releases back to containment. In view of the importance of SGTR to total risk for WBN, please justify the adequacy of the alternatives considered with respect to this risk contributor. Include an assessment of the feasibility of the above design alternatives in your response, and a cost benefit analysis for any improvements judged feasible.

TVA'S RESPONSE

Steam generator tube rupture (SGTR) events were considered in developing the initial list of enhancements. However, due to the nature of the dominant SGTR core damage sequences, none were identified.

The specific sequences which dominate SGTR core damage risk involve the failure of human actions. The human error probabilities for these actions were quantified using the same methods used for other actions in the IPE. The actions involved are well trained, have adequate instrumentation, and involve relatively long periods of time. The overall human error rates for these sequences are low (< 1E-4), but they constitute the dominant failure causes for SGTR events at WBN.

As part of the effort to identify enhancements, the human reliability analysis for these scenarios were reviewed and no significant plant specific weaknesses were identified. Therefore, no enhancements specific to SGTR were evaluated.

NRC REQUEST 18

Based on information provided in Section 4.5.7, it appears that the benefits of the reactor depressurization system could be limited to reducing the threat of DCH and induced failure of the steam generator tubes and RCS piping. Please explain why enhanced reactor system depressurization would not offer additional benefits of reducing source terms for unisolated SGTR events by eliminating the driving head.

TVA'S RESPONSE

As discussed in the response to NRC Question 17, the dominant contributors to SGTR core damage risk at WBN involved human errors. The provision of a reactor depressurization system would not be of significant benefit in these sequences due to the dependence of operator actions in such scenarios. That is, the same operators which made errors leading to core damage would be the ones expected to use the enhanced depressurization system.

NRC REQUEST 19

Provide the total frequency of all core damage events that involve reactor coolant pump seal LOCA (as either sequence initiators or consequential events), and a breakdown of this frequency in terms of initiating events and support system failures that contribute to seal failure. Discuss which contributors are eliminated or reduced by each of the RCP seal-related design alternatives.

TVA'S RESPONSE

The frequencies of the core damage events that involve RCP seal loss-of-coolant-accidents (LOCAs) are as follows.

DESCRIPTION	CDF PERCENTAGE
Random Mechanical Failure of RCP Seals	17
RCP Seal Failure Due to Loss of Support	16
Total	33

The random mechanical failure of RCP seals is represented primarily by the initiating event SLOCAN which is a non-isolatable small LOCA (initiating event frequency of 5.83E-03) and accounts for approximately 17 percent of the CDF. The percentage of core damage events in which RCP seal failures are due to a loss of support system for the RCP seals is approximately 16 percent. Other core damage sequences have RCP seal failures occur but the RCP seal failure did not contribute directly to core damage. For example, a station blackout sequence in which auxiliary feedwater (AFW) is initially failed, RCP seal failure is assumed to occur due to loss of support systems to provide cooling. However, the resultant core damage sequence occurs whether RCP seal failure occurred or not. This type of sequence is not included in the above results.

The following enhancements were evaluated for the reduction and/or elimination of seal cooling failures:

III.2, IV.1	Install Improved RCP Seals
III.3, IV.2	Install Independent RCP Seal Cooling
IV.3	Modify Centrifugal Charging Pump Cooling from CCS to essential raw coolant water (ERCW)

The results of the evaluation for these enhancements found none were cost beneficial.

NRC REQUEST 20

Provide a more detailed discussion and cost breakdown for the independent RCP seal cooling system evaluated as design alternative IV.2. Discuss the feasibility of using an existing hydro test pump for seal injection, and provide a cost benefit analysis for this alternative.

TVA'S RESPONSE

The independent RCP cooling system evaluated as enhancement IV.2 is essentially identical to that evaluated under enhancement III.2. The evaluated system was composed of a high pressure pump capable of injecting between 32 and 52 gallon per minute (gpm) of water into the RCP seal injection lines at approximately 2500 psi. Appropriate tie-ins to the existing piping and power system were included. The piping tie in would require fluid system isolation from the safety-related piping and analysis/installation to ensure the seismic integrity of the existing piping. A permanent connection both to the seal injection piping and source of seal injection water was assumed in lieu of a manual spool piece or hose type connection due to the limited time available to initiate the system (less than 60 minutes if RCPs are shut down and seal injection and thermal barrier cooling are not available). A specific source of water or location for the pump skid was not identified, however, no additional costs were assumed based on these issues. Power was assumed to be available from the AC-power system, a new independent source of power was not included in the evaluation.

A cost estimate which SQN had developed in evaluating the replacement of the positive displacement charging pump with a centrifugal charging pump was used as a bounding estimate with appropriate reductions to address issues which were not applicable for WBN (such as decontamination and disposal of contaminated equipment). This was considered reasonable since some of the SQN costs which would not be required for WBN (SQN piping resizing/reroute for capacity and flow path issues) would be offset by WBN specific costs (additional piping to a water source, location specific issues related to limited space in the immediate area of the charging pumps and seal injection piping). Additionally, while some SQN control equipment could still be used (or at a minimum existing local/remote control locations used), WBN would require new equipment and locations. When considering that the cost estimated for this enhancement is reduced from the SQN estimate by approximately 33 percent, the estimate of $2.4M is considered reasonable. Any uncertainties in the cost estimate would clearly be bounded by the fact that the cost benefit is a factor of 220 greater than the $1000 criteria when using the rebaselined cost benefit results.

While it is possible to utilize an existing hydro test pump as an alternate to an independent, permanently installed system, several other considerations make this enhancement either questionable in its ability to actually prevent a seal failure and questionable in cost benefit. As indicated above, the amount of time available to initiate alternate seal injection is less than 1 hour.

The following discussion applies for the AC-power available scenario. To connect the hydro test pump would require dedicating an operator to connecting the water supply, pump discharge, and powering up the system. Due to the size of the pump skid (approximately a 6 feet by 8 feet skid) to ensure the action could occur would require dedicating a hydro test pump to the location. Unless a permanent plant modification was made, the suction connection would need to be made to a vent/drain connection in either the containment spray or safety injection system, between the RWST and the first normally closed valve, and the discharge connection would need to be made to a vent in the seal injection line. Both of these connections would require, at a minimum, the removal of a pipe cap. A screw on connection would then be made and the valves in the vent/drain lines would have to be opened. The most difficult task would be locating a power source. For different scenarios, different busses would have power. This could result in the operator losing critical time locating and connecting to a source with power. The only way to ensure power is available would be to install additional power connections to the safety-related shutdown boards in the immediate vicinity of the hydro pump staging area. This would increase costs. Procedures, training, and essentially immediate dedication of an operator from the crew available to respond to the event would be required. TVA does not consider it reasonable to assume that the action would be successful when the time constraints are considered and appropriate human error rates are assumed. The time to diagnose the event and determine that this action is required would take a significant amount of the available time.

Based upon the rebaselined value impact results, the maximum benefit which could be achieved from this enhancement is less than 11 person-rem assuming operator success (see enhancement IV.2). Considering the time constraints, this enhancement would require plant modifications to have a reasonable opportunity for success. When plant modifications, the cost of a dedicated hydro pump and procedure/training costs are combined, the cost of this enhancement would clearly exceed the $15,700 to $60,000 available to be considered cost beneficial.

For the station blackout case, a portable diesel generator would also be required. Due to the lack of portability of both the existing hydro pump and a portable diesel to power it (approximately 60 KW required), they would both have to be dedicated and staged to support the enhancement. Again the operator would be required to immediately be dispatched to start the diesel, connect the pump suction/discharge, and begin the alternate seal injection. This action is judged to be at least as difficult as the one for AC-power available with a lower possibility of success due to diesel generator reliability. Based upon the rebaselined value impact results, the maximum benefit which could be achieved from this enhancement is less than 25 person-rem assuming operator success. When the cost of the diesel generator is combined with the hydro pump cost, plant modification cost, and procedure change costs, it can be seen that this enhancement would not fall within the cost benefit criteria of $25,000 to $95,000.

NRC REQUEST 21

Please describe how importance analyses were used to derive risk reduction estimates for the three design alternatives related to improved hydrogen control (V.1, V.5, and V.9). The reported risk reduction worth of hydrogen burns for early containment failures (0.99635) appears to be inconsistent with the 3 percent contribution of hydrogen burn to early failure reported in Table 3 of the Executive Summary.

TVA'S RESPONSE

Enhancements V.1, V.5 and V.9 utilized the same bounding computation of the potential risk reduction associated with hydrogen control measures. The 3 percent value cited in Table 3 of the original Executive Summary referred to both HPME and hydrogen related failures which occurred at the time of vessel breach. The structure and analysis of the WBN containment event tree did not allow the segregation of this event into hydrogen and non-hydrogen HPME loads because of the integrated manner in which postulated pressure loadings were computed and evaluated. The risk reduction worth values for containment failures attributable to hydrogen were used to compute the potential averted doses.

The risk reduction benefit from the rebaselined results is computed from the following data:

- Risk reduction worth of hydrogen burns to Release Category Group I 0.99644
- Rebaselined dose contribution from APB 3 and 4 (19.48 + 0.56) 20.04

- Risk reduction worth of hydrogen burns to Release Category Group III 0.505
- Rebaselined dose contribution from APB 5 37.92

Therefore, the combined dose reduction value is

$$(1-0.99644) * 20.04 + (1-0.505) * 37.92 = 18.8 \text{ person-rem}$$

The original submittal had erroneously (and conservatively) used 0.536 instead of 1 - 0.536 in the computation of the risk reduction for APB 5. This conservatively represented the potential averted dose.

NRC REQUEST 22

Design alternatives V.3 (filtered vent) and V.4 (core retention device) would not generally be effective in eliminating the risk associated with containment failures at vessel breach. However, the risk reduction estimates reported in Sections 4.5.3.4 and 4.5.4.4 appear to take full credit for eliminating this component of risk. Please provide an estimate of risk reduction for each of these design alternatives assuming no credit for eliminating containment failure at vessel breach.

TVA'S RESPONSE

The original submittal conservatively estimated the risk reduction which could be achieved for all enhancements. Enhancements V.3 and V.4 also conservatively estimated risk reduction. The rebaselined value impact analysis shows benefit ratios of approximately $223,038 and $723,989 per person-rem for these enhancements. Reducing the benefit will only increase the ratio. No additional analyses have been performed due to the high benefit ratios.

NRC'S REQUEST 23

The existing hydrogen igniters would need to be powered from an AC independent power system in order to derive the risk reduction benefit estimated for design alternative V.9 (adding AC independent air return power supplies). Clarify whether this design alternative includes connecting both the ARF and the existing hydrogen igniters to the new power supply.

TVA'S RESPONSE

Consistent with the philosophy stated previously, the assessment of the risk reduction potential for this enhancement was biased in a conservative manner to maximize the calculated risk reduction. In this case, the risk reduction assessment provided a bounding estimate by effectively crediting the prevention of the hydrogen-related containment failures while the cost did not include the additional incremental cost of providing an AC independent supply to the hydrogen igniters.

NRC REQUEST 24

Steam Generator Tube Ruptures (SGTRs): Table 3 on page ES-6 indicates that SGTRs contribute 76 percent to large early releases. The staff in SECY 93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor Designs," required applicants for design certification to assess design features to mitigate the amount of containment bypass leakage that could result from SGTRs. Provide an assessment of the following design features that could mitigate the releases associated with SGTRs:

a. a highly reliable (closed loop) steam generator shell-side heat removal system that relies on natural circulation and stored water sources

b. a system which returns some of the discharge from the steam generator relief valve back to the primary containment

c. an increased pressure capability on the steam generator shell side with a corresponding increase in the safety valve setpoints

TVA'S RESPONSE

Based upon a scoping study of potential SGTR risk reductions, the maximum benefit which could be achieved would be approximately 86.5 person-rem. The first enhancement is not considered feasible for the ice condenser design. Even if it were, the costs would be several orders of magnitude greater than $86,500. The second option would also entail significant modifications, and the cost of such a system would be at least an order of magnitude more than $86,500. The last option, increasing steam generator shell side pressure capability and increasing steam generator safety valve setpoints, has the potential to jeopardize WBN's ability to mitigate design basis events. The current analysis requires the AFW pumps be able to deliver flow to steam generators at a pressure of approximately 1256 psi (setpoint plus 3 percent accumulation and 3 percent drift). Increasing the setpoints of the steam generator safety valves would require additional pump capability to ensure margin above the design basis exists. This would require either new AFW pumps or costly rebuilds. WBN's AFW pumps were recently rebuilt to ensure margin existed. The cost to rebuild again would be at least an order of magnitude greater than $86,500. A detailed analysis of these enhancements has not been performed for the above reasons.

NRC REQUEST 25

Section 4.5.1 discusses installation of an additional active deliberate hydrogen ignition system. Provide an assessment for addition of passive means for controlling hydrogen production, such as passive hydrogen recombiners or passive hydrogen igniters. (Ref.: Electric Power Research Institute, "Qualification of Passive Autocatalytic Recombiners for Combustible Gas Control in ALWR Containments," April 8, 1993.)

TVA'S RESPONSE

The rebaselined results show that Enhancement V.1 (deliberate H_2 ignition system) has a maximum risk reduction of approximately 18.8 person-rem (see enhancement V.1). Implementing a passive means for controlling H_2 production would result in no greater benefit. The cost to implement a new and untried passive means for controlling H_2 production would be at least an order of magnitude greater than $18,800. For this reason a detailed analysis has not been performed.

NRC REQUEST 26

Section 4.5.2 discusses installation of an active reactor cavity flooding system with substantial costs. More modest enhancements could be envisioned.

a. Provide an assessment of the potential for reactor cavity flooding using water from dead-ended volumes, the condensed blowdown of the reactor coolant system, or secondary system by drilling pathways in the reactor vessel support structure to allow drainage from the steam generator compartments, refueling canal, sumps, etc., to the reactor cavity. Provide as assessment for allowing drainage of water from melted ice into the reactor cavity. The equilibrium water levels within the reactor cavity from the RCS condensate and melted ice should be assessed to determine if they could potentially prevent reactor vessel melt-through (external vessel cooling) or just provide cooling for core debris in the reactor cavity.

b. Discuss the potential for reactor cavity flooding through overflow of cavity compartments with systems such as diesel driven fire pumps.

TVA'S RESPONSE

The enhancement of diverting emergency sump inventory to the reactor cavity is not considered feasible/cost beneficial for the following reasons.

The current accident analyses required that WBN seal the crane wall to 13.2 feet, install additional curbing, cap drains which routed potential sump water outside the crane wall, and install drains from some dead-ended volumes to ensure sufficient water inventory was available for emergency core cooling to support design basis event scenarios. Modifications to divert some of this inventory to the reactor cavity would require significant reanalysis, and would create a challenge to WBN's ability to mitigate design basis accidents.

The reactor cavity as currently configured will begin to flood when the contents of the refueling water storage tank (RWST) and approximately 25 percent of the ice is melted. For approximately 40 percent of CDF sequences the RWST has been injected. A total of greater than 600,000 gallons of inventory is available between RWST and ice melt. The reactor cavity will begin to flood when approximately 400,000 gallons are available.

The WBN fire pumps are electric motor-driven. The benefit of a reactor cavity flooding system (enhancement V.2) is conservatively estimated to be less than 90 person-rem. The enhancement to add diesel driven pumps to specifically flood the reactor cavity would have limited benefit due to the fact that for approximately 40 percent of the CDF sequences the RWST has been injected. In these sequences additional water to flood the cavity would not be of benefit. The cost to add a diesel driven system to flood the reactor cavity would be significantly greater than $90,000.

For these reasons, a detailed analysis was not performed of these potential enhancements.

NRC REQUEST 27

Section 4.5.4 discusses installation of a core retention device; however, it is unclear whether the device is designed to protect the containment liner from core dispersion under high pressure sequences or protect the liner beneath the reactor cavity in low pressure sequences. Provide a separate discussion of the system aspects for these two different scenarios.

TVA'S RESPONSE

The enhancement to install a core retention device was previously evaluated as enhancement V.4. A core catcher device located below the core was the option which was evaluated and determined not to be cost beneficial. This device was to address high pressure melt scenarios. The risk reduction estimates conservatively assumed that both high and low pressure risks were addressed by the device. To design and install a system to address low pressure melt scenarios is expected to be at least as costly as the one evaluated to address high pressure scenarios. Since the cost benefit and conclusions are not expected to change, a detailed evaluation was not performed.

NRC REQUEST 28

Provide an assessment of any new innovative methods of protecting the containment liner from core debris, such as Core-Melt Source Reduction System. (Ref.: Forsberg, C.W., Beahm, E.C., and Parker, G.W., 1993, "Core-Melt Source Reduction System to Terminate LWR Core-Melt Accidents," ASME/JSME Nuclear Engineering Conference - Volume 1.)

TVA'S RESPONSE

TVA has reviewed the research paper referenced in the NRC question and does not believe that the technology is currently at a point where meaningful cost estimates or system performance characteristics can be developed/assumed. The maximum risk reduction which could be achieved is less than 61.5 person-rem (enhancement V.4). The cost to develop, test, and implement a system such as that discussed in the referenced paper is judged to be significantly greater than $61,500. Additionally, as discussed in the referenced paper there still are significant uncertainties on whether the system will work. For these reasons a detailed analysis was not performed.

NRC REQUEST 29

Appendix B, p. B-4 discusses use of the diesel fire systems for injection to the containment sprays or the steam generators. Where is this system evaluated in the value-impact assessment? Provide a thorough discussion of the necessary procedures for accomplishing this and cost estimates for spool pieces, etc. It doesn't appear as though this system was considered in enhancement V.2, Reactor Cavity Flooding System, V.8, Independent Containment Spray Systems, or its benefits for providing hydrogen mixing.

TVA'S RESPONSE

As discussed in the response to NRC Question 6, WBN has four high pressure fire pumps (~ 150 psig discharge pressure). The plant design provides a connection between the fire system and the AFW system for makeup to the steam generators during external floods which are above plant grade. This connection was not credited in the IPE nor in the value impact assessment due to the small contribution from loss of feedwater events and the time required to make connections. Timeline analyses found that the fire connection would only support very long-term events (i.e., where alternate steam generator makeup would not be required for several hours). Thus events with loss of AFW early would not be recovered with this capability. In long-term events, such as a long-term station blackout, the fire connection could be effective. However, the only significant contributor to this class of sequences is station blackout. In these sequences, the restoration of feedwater with fire water would be of limited benefit due to the loss of RCS inventory through RCP seal leakage. That is, even if feedwater was supplied by the fire water system, core damage would not be avoided due to loss of RCS inventory. A bounding estimate of the benefit was made assuming that the sequences with an emergency diesel generator (EDG) available were recovered. This bounding estimate found the maximum averted dose to be less than 10 person-rem. Other design changes to provide a diesel fire pump or reduce the time required to align the system could be envisioned, but similar computations of bounding risk found less than 20 person-rem could be avoided. This type of risk reduction would not support the large cost of physical plant modifications.

As discussed in the response to NRC Question 6, the use of the fire water pumps for containment spray would require a plant modification. The benefit of such a modification would be limited for the following reasons:

- The sequences with containment spray unavailable primarily involve loss of key support system such as electric power (i.e., station blackout) and cooling system (i.e., ERCW).
- In the loss of AC-power sequences, the sprays would not inject.
- In the loss of cooling sequences, the sprays would inject, but fail on recirculation.
- The electric powered fire pumps would only operate in nonblackout conditions.
- In the loss of cooling sequence, the additional injection capability would be of little value without containment heat removal.

Nevertheless, a bounding assessment was made of the potential maximum benefit which could be derived from such a modification. Based on the rebaselined results, approximately 9 percent of the CDF involves late containment overpressure failures (see Figure 3 of revised Executive Summary). This is equivalent to 5.2×10^{-6}/year or 40 percent of the late containment failures (based on Table 4 of the revised Executive Summary, late failure constitute approximately 23 percent of the CDF, 9 percent is approximately 40 percent of 23 percent). Based on the overall contribution of late containment failures to total population dose of 38 person-rem, APB 5 contributes 18 percent of the total 211 person-rem dose of the plant. Assuming this modification could eliminate the late containment failures, a bounding estimate of the maximum possible benefit is 15.2 person-rem (40 percent of 38 person-rem). Therefore the maximum cost which could be justified to meet this benefit is $15,200 to $58,000 base on mean ($1,000 per person-rem) and upper-bound estimates ($1,000 per person-rem *3.8 upper-bound to mean ratio), respectively, This justifiable cost range is much less than the cost of the modification.

ENCLOSURE 2

WATTS BAR NUCLEAR PLANT UNIT 1

SEVERE ACCIDENT MITIGATION DESIGN ALTERNATIVE

EXECUTIVE SUMMARY, REVISION 1
CHAPTER 4 TABLES FOR
AVERTED OFFSITE DOSE ENHANCEMENT CASE

OCTOBER 7, 1994