40

From: Thomas Bergman _RES _DRE _DPR _RES
To: Christopher Grimes; Steven West; Stewart Magruder
Date: Wed, May 29, 2002 8:25 AM
Subject: Fwd: ADVANCED REACTOR

FYI, there is a fair amount of direct and (mostly) indirect discussion on the new framework "for future reactor licensing" (sigh...). Coherence is woven throughout although I didn't see it mentioned specifically in my initial skim. I assume you'll want to be involved in this.

Amy Cubbage will have the lead for us

CC: Amy Cubbage; James Lyons

Forwards same docs as TAB 057

(i.e., TAB 057.1 & TAB 057.1.1

O-15

TAB 058

NRR

From: James Lyons
To: Amy Cubbage; Leslie Fields; Thomas Bergman
Date: Tue, May 28, 2002 5:22 PM
Subject: Fwd: ADVANCED REACTOR

jul. 8

FYI

TAB 057

-RES -NRR release

From: Farouk Eltawila
To: Holahan, Gary; James Lyons; John Zwolinski
Date: Fri, May 24, 2002 8:18 AM
Subject: ADVANCED REACTOR

Jim:

Attached is a draft of the Paper we are preparing for the Commission to Address Key Policy Issues for non-LWRs. The paper is due to the Commission the end of June 2002. To facilitate your review, we will welcome the opportunity to review it with you and the NRR leadership. To help us meet the deadline, I would like to get your comments on this draft by June 7, 2002. After reviewing your comments, and incorporate your suggestions that we agree with, I recommend a meeting to discuss the remaining issues. The middle of the June 10 week will be appropriate so we can finalize the paper in time to allow for our respective executive teams' review and concurrence. I would like to get NRR concurrence on a final version of the paper by June 21, 2002.

I'm planning to discuss the technical basis for each of these issue at the ACRS meeting on June 6, 2002. Do you want to make part of the presentation?

I appreciate your help in meeting this tight schedule. Thanks.

P.S. Please treat this paper as pre-decisional not to be discussed outside the NRC

CC: Charles Ader; Flack, John; Mark Cunningham; Mayfield, Michael; Mel Fields; Newberry, Scott; Strosnider, Jack; Thomas King

TAB 057.1

release

DRAFT, 5/23
T. KING

(INFORMATION PAPER)

FOR: The Commissioners

FROM: William D. Travers
Executive Director for Operations

SUBJECT: PLAN FOR RESOLVING POLICY ISSUES RESULTING FROM TECHNICAL CONSIDERATIONS RELATED TO ADVANCED REACTOR LICENSING

PURPOSE:

To provide the Commission a status report on issues with potential policy implications resulting from technical considerations associated with advanced reactor licensing and the staff's plans for seeking Commission guidance and resolving these issues.

BACKGROUND:

The current regulations have been developed over the past 40 years and contain many provisions that are specific to light water reactor (LWR) designs and technology. These regulations have served as the underlying basis for licensing the current generation of plants as well as certifying three advanced LWRs. In the past, when NRC has reviewed non-LWR designs (e.g., Ft. St. Vrain, Clinch River Breeder Reactor) it was necessary for the staff to make determinations with respect to the applicability of the regulations to the designs and the need

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TAB 057.1.1

for exemptions and/or additional requirements to address the unique aspects of these designs. These determinations were done on a case-by-case basis and were implemented by exemptions and/or license conditions, where the current regulations did not apply.

Accordingly, it is possible to review and license future plants regardless of their technology, using a similar case-by-case approach; however, this is likely not the most efficient or effective approach. To facilitate licensing of new reactor designs, substantially different than current generations LWRs, the Commission has encouraged interactions between NRC and designers at the preapplication stage to identify early in the process key safety and licensing issues and a path to their resolution. This could then be used by the staff and the designers as guidance in the preparation and review of an actual application. Recently, with the renewed interest in future plant licensing, the staff has initiated activities at the pre-application stage on AP-1000 and the pebble bed modular reactor (PBMR) to identify key issues and an approach for their resolution. These pre-application activities have involved discussions on specific plant designs but have also identified topics of a generic nature. For example, in October 2001, the staff provided the Commission a status report (SECY-01-207) on legal and financial issues with policy implications resulting from the PBMR preapplication work, but which are also generic in nature. A final report on these issues is scheduled to be provided in August 2002 for Commission consideration. Likewise the staff has identified certain topics resulting from the technical review of the PBMR which may have generic implications for high temperature gas cooled reactors as well as other designs substantially different than current generation LWRs. In addition the staff has had interactions with NEI regarding the possible development of a generic (technology neutral) risk-informed, performance-based framework for future plant

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licensing. NEI recently submitted a white paper (letter dated May 7, 2002 to Chairman Meserve) on this topic for Commission consideration.

As a result of the above, the staff believes that it is appropriate that certain key policy issues be provided to the Commission for guidance as soon as possible so as to facilitate the reviews of future plants to determine to what extent, if any, one should establish generic, risk-informed, performance based requirements for future plant licensing. These policy issues are those associated with the technical aspects of future plant designs (particularly non-LWR designs) that may be key to the viability of those designs and will likely need to be addressed in establishing regulatory requirements for those designs, regardless of whether or not those requirements are established on a plant specific basis or generically, such as suggested by NEI. It is recognized that no decision has been made regarding the need for a generic licensing approach for future plants and that the number and type of future plant applications is uncertain (e.g., Exelon's recent decision to phase out the PBMR pre application activities); nevertheless, the establishment of guidance in key areas early in the process will benefit all stakeholders by improving the effectiveness, efficiency and stability of the review process. To provide the Commission with an early indication of the scope and nature of these issues, it was decided to provide an information paper at this time to be followed later with a policy paper for Commission action. This is consistent with the intent of the Commission's April 1, 2002, SRM which requested the staff engage the Commission early on policy issues associated with new reactor designs. The policy issues that have been identified to date are discussed below along with the staff's plans for seeking Commission guidance and resolving these issues.

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DISCUSSION:

Industry's approach to safety for future plants emphasizes prevention of radionuclide release and proposes to use probabilistic risk assessment (PRA) in the design process to a greater extent than current generation LWRs. Key to their safety case is the prevention of fuel damage. For example, on the PBMR it is claimed that the fuel (small ceramic coated fuel particles) can withstand very high temperatures without significant release of radionuclides. For advanced LWRs, prevention of core uncovery is the goal. In the case of PBMR, it is claimed that with such fuel performance, a conventional pressure retaining low leakage containment structure (such as is provided on current LWRs) is not necessary and that the emergency planning zones around the plant can be significantly smaller than for current generation LWRs. Fundamental to evaluating the above claims are the approach and criteria that lead to the selection of events to be considered in the design and for emergency planning purposes and the accident source terms used in the analysis. For example, the proposed method for PBMR uses probabilistic criteria to select events for consideration in conjunction with accident scenario specific source terms and dose limits to demonstrate the acceptability of the plant design. Although the technical foundation for this method has not been fully developed, reviewed or accepted, it nevertheless has reached a stage where the key issues associated with its application can be developed and discussed. This paper discusses the major technical issues with policy implications resulting from the above identified during the preapplication activities to date. These issues relate to the following five areas:

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- event selection and safety classification
- fuel performance and qualification
- source term
- containment vs. confinement
- emergency evacuation

Each of the above areas is discussed below with emphasis on the policy issues, the underlying considerations and staff plans for seeking Commission guidance and resolving the issues. However, related to each of these areas are two overarching policy issues, the resolution of which could impact decisions in each of these five areas. The first of these overarching policy issues is:

- How to implement the Commission's expectation (as expressed in the Commission's 1986 Advanced Reactor Policy Statement) that advanced reactors will provide enhanced margins of safety and/or utilize simplified, inherent, passive, or other innovative means to accomplish their safety functions. For example:
  - Should a higher level of safety be a criterion for new plant designs so as to help:
    - maintain a low cumulative risk to the public as more plants become operational?

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- compensate for uncertainties due to limited operating experience, especially for non-LWR designs?

- Should specific attributes of defense-in-depth be defined for future plants that address:
  - balance between accident prevention vs. mitigation?
  - multiple barriers to release of radioactive material?
  - treatment of uncertainties?
  - reliability, redundancy, diversity, independence of safety systems?
  - inherent/passive features?
  - RG 1.174 attributes?

It is recognized that in the Advanced Reactor Policy Statement, the Commission states that it expects, as a minimum, at least the same degree of protection of the public and the environment that is required for current generation LWRs and that advanced reactor designs will comply with the Commission's Safety Goal Policy statement. However, given the experience over the pat 15 years with LWRs and risk-informed regulation, does the Commission wish to revisit that policy? Likewise, given that experience, does the Commission wish to be more specific regarding defense-in-depth than the current policy as stated in the 1999 White Paper on Risk-Informed and Performance-Based Regulation? For example, should consideration of ACRS views on defense-in-depth, as stated in their May 19, 1999 letter to Chairman Jackson, be considered?

The second overarching issue is:

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- What should be the relationship of NRC safety requirements to international safety requirements? For example:

  - should NRC utilize international standards where possible?

  - should NRC engage in international activities to help develop guidance when needed?

This would be a way of bringing in international expertise to our regulatory decision-making, particularly in areas not currently a part of NRC's infrastructure or covered by NRC regulation.

The staff believes that it is necessary to address those overarching issues as part of considering the issues in the following five areas and plans to provide recommendations on these issues at the same time as recommendations are provided on the following.

Event Selection and Safety Classification

For the purposes of discussion, the approach proposed for the PBMR for the selection of events and event scenarios to be considered in the design and for emergency planning purposes (as well as for the remaining issues) is used as an example. The approach is very similar to that proposed in the late 1980s as part of a preapplication review of a modular high temperature gas-cooled reactor (MHTGR) sponsored by DOE. The approach establishes three frequency categories for events and event scenarios (along with existing dose criteria for public

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protection for each category) and then proposes to use a probabilistic risk assessment (with consideration of uncertainties) to determine which events (or event scenarios) fall within each category.

The three frequency categories for events are:

- Anticipated Operational Occurrences (AOO)
- Design Basis Events (DBE) and
- Emergency Planning Basis Events (EPBE)

For the PBMR, these three categories are defined as follows:

Anticipated Operational Occurrences

Anticipated Operational Occurrences are those conditions of normal operation which are expected to occur one or more times during the life of the plant (a plant can be up to 10 modules). Using a design lifetime of 40 years, a lower boundary for the AOO region of 2.5×10^{-2} per plant year was proposed. For this region, 10 CFR 50, Appendix I was proposed as the applicable acceptance criteria as it specifies the guidance on dose limits to assure that releases of radioactive material to unrestricted areas during normal reactor operations, including AOOs, are maintained As Low As Reasonable Achievable (ALARA).

Design Basis Events

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Design Basis Events encompass releases that are not expected to occur during the lifetime of one nuclear power plant. The frequency range covers events that are expected to occur during the lifetime of a population (several hundred) of nuclear power plants; and therefore a lower limit of 10^{-4} per plant year was proposed. For this region, 10 CFR 50.34(a)(1) was proposed as the quantitative dose guidance (25 rem TEDE) for accidental releases for siting a nuclear power plant to ensure that the surrounding population is adequately protected.

Emergency Planning Basis Events

Emergency Planning Basis Events are improbable events that are not expected to occur during the lifetime of several hundred nuclear power plants. This is to assure that the risk to the public from low probability events is acceptable, and that adequate emergency planning is developed to protect the public from undesirable exposure to radiation for improbable events. The frequency cutoff implicit in the acute fatality risk goal in NUREG-0880 was proposed as the lower frequency boundary of the EPBE region(i.e., 5×10^{-7} per plant year). The EPA Protective Action Guidelines (PAGs) were proposed as the dose guidelines for the EPBE region.

The systems, structures and components (SSCs) needed to ensure the dose criteria are met are then considered safety grade; however, only DBEs (and not AOOs or EPBEs) were to be considered in determining the safety classification of SSCs.

The above approach represents a departure from current practice in that heavy reliance is

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placed on the use of probabilistic analysis and criteria in the selection of events and event scenarios, thus relating PRA quality, completeness and treatment of uncertainties directly to the licensing basis.

The use of a probabilistic approach such as described above for event selection and safety classification raises the following policy issues:

- To what extent should a probabilistic approach be used to establish the licensing basis for new plant designs?

- What should be the criteria for event selection and safety classification?

To arrive at a recommendation on the above policy issues, the staff will consider the following:

- What are the implications of heavy reliance on probabilistic information to establish the licensing basis for new plant designs considering:
  - large uncertainties (i.e., limited experience base and data)?
  - PRA quality, completeness and documentation?
- What should be changed in our traditional method of event selection (e.g., considering operating experience, use of bounding events to envelop scenarios, etc.)?

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- Assuming probabilistic analysis is an acceptable approach, what criteria should be applied for the selection of events and event scenarios to be considered in the design and for emergency planning purposes considering

  - risk metrics?
  - treatment of uncertainties?
  - confidence level desired?
  - cost-benefit?

As stated earlier, the concept of using a probabilistic approach to define events or event scenarios to be considered in the design was proposed in the late 1980s for the MHTGR. The staff reviewed this approach (in conjunction with reviews of the MHTGR and three other designs - PIUS, PRISM and CANDU 3) and proposed in SECY-93-092 an approach that was deterministically based supplemented by PRA information. The Commission, in an SRM dated July 30, 1993, approved the staff recommendation. However, given the Commission's recent emphasis on and experience with risk-informed and performance-based regulation, the staff proposes to revisit this issue and whether or not modifications should be made.
The resolution of the above issues will also impact the resolution of the containment and emergency evacuation issues discussed below.

Fuel Performance and Qualification

Future plant designers are proposing fuels with higher burnups and greater fission product retention capabilities than current generation fuels. To achieve such performance requires

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higher enrichment, new cladding materials and, in the case of HTGRs, ceramic coated fuel particles.

For example, the PBMR fuel is claimed to be able to withstand high temperatures without releasing fission products. A design value of 1600° C has been chosen by the designers as the maximum allowable fuel temperature to ensure fission product retention for slow heatup events. Also, it is claimed that no significant amount of air or water will enter into the hot core.

Testing to qualify such fuels needs to be done; however, testing may be done overseas as well as in parallel with or subsequent to the COL application. For example, the initial fuel for the U.S. PBMR was to be manufactured in South Africa and shipped to the U.S. The initial COL application was to be supported by testing on fuel other than that from PBMR production fuel and was to be limited to design basis events. Since fuel performance is key to plant safety, the application should be supported by a fuel qualification program that establishes the performance of the fuel, how the quality of the fuel fabrication will be maintained over the life of the plant, and how the temperature or condition of the fuel will be reliably predicted over the life of the plant for normal and accident conditions.

Given the above, the staff considers the following to be policy issues:

- Should the applicant's fuel qualification test program be completed prior to granting a COL or can it be considered a condition of the license to be verified during or after plant construction?

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- Should the scope of the applicant's fuel qualification test program include beyond design basis events to establish margins and support PRA?

- What independent fuel testing should NRC perform?

- Under what conditions can fuel (or other key components) manufactured outside the U.S. be accepted for use in a U.S. plant?

- What licensing requirements and NRC oversight should be employed on the fuel fabrication process in the U.S. to ensure fuel quality over the life of the plant?

In assessing the policy issues the staff will consider the following:

- what scope of fuel qualification testing should be completed to support the application and when and how should the remainder be obtained?

- how should the analytical tools be validated to ensure reliable prediction of fuel temperature?

- how should experimental data for beyond design basis events be used in the licensing process?

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The above issues were not provided for Commission consideration in previous advanced reactor work.

Licensing Source Term

Current LWRs use site specific parameters (e.g., exclusion area boundary) and a predetermined source term to analyze the effectiveness of their containment and site suitability for licensing purposes. These source terms are described in documents TID-14844 and NUREG-1465 and are based upon the fission product releases that would occur if a core melt accident were to occur. On the other hand, future plants, particularly non-LWRs, propose not to use a predetermined source term for assessing the effectiveness of plant mitigation features or site suitability, but rather to use plant specific accident source terms corresponding to each of the AOOs and DBEs described in the event selection section above. Such an approach puts a burden on the applicant and staff to understand the fission product release characteristics and uncertainties associated with a variety of accident scenarios. Also, the LWR source terms represent a composite of a number of LWR core melt scenarios and thus bound a number of accident scenarios, thus reducing the dependence of the analysis on precisely understanding the fission product release characteristics of individual accident scenarios. However, it should also be mentioned that a limited number of scenario specific source terms are used in LWR licensing (e.g., reactivity insertion accidents).

The proposed plant/accident specific approach for source term raises the following policy issue:

- Under what conditions, if any, will the Commission accept the use of scenario specific source terms for licensing decisions regarding containment and site

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suitability?

In developing a recommendation on this issue the staff will assess:

- what was done on previous reviews of non-LWR designs, and
- how should uncertainties be taken into account?

The above issue has been addressed in previous staff work on advanced reactors. A recommendation was provided for Commission consideration in SECY-93-092 which recommended that scenario specific (mechanistic) source terms be allowed provided there was a sufficient understanding of fuel performance, fission product behavior and accident selection to bound uncertainties. The Commission, in a July 30, 1993, SRM, approved the staff recommendation. The current staff work is related to whether or not any modification in this approach is warranted.

It should be recognized that this issue is closely related to the event selection issue discussed above as well as to the issue of containment vs. confinement discussed below.

Containment vs. Confinement

The proposed PBMR design includes a concrete building structure that houses the reactor vessel, the power conversion unit (i.e., helium turbine and generator) and connecting piping. The reactor and power conversion unit are partially below grade in concrete silos, which in turn

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are enclosed in a reinforced concrete building. This building is filled with air during normal operation and maintained at a slightly negative pressure (with filtered exhaust) but is not a pressure retaining building (like LWR containments). Such a building is typically called a confinement building, and has been used on a licensed HTGR in the U.S. (Ft. St. Vrain) as well as on gas cooled reactors operated in other countries (e.g., Germany, U.K.) In the event of a leak of the helium coolant, the building is designed to vent excess helium to the atmosphere and, if electric power is still available, maintain negative pressure inside the building. In effect, the design modifies the traditional 3 leaktight barrier defense-in-depth approach to one that puts a greater reliance on the first barrier (fuel integrity).

Such a design raises the following policy issue:

- "Under what conditions, if any, can a plant be licensed without a pressure retaining containment building?"

To arrive at a recommendation on the above policy issue, the staff will consider the following:

- Plant performance (including uncertainties) during normal, design basis and beyond design basis events and the role of containment vs. confinement in meeting acceptance criteria, reducing risk and facilitating emergency actions and plant recovery

- the need for containment vs. confinement to achieve an appropriate balance in plant

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design and operation between accident prevention and mitigation in defense-in-depth, and

- the role of containment vs. confinement in maintaining public confidence.

It is recognized that plant performance under accident conditions is highly dependent upon fuel performance and that uncertainties in fuel performance and quality over the life of the plant need to be considered. Accordingly, the resolution of the issues discussed under fuel performance and qualification could impact the containment vs. confinement issue.

In assessing this issue, the staff will review earlier work on this topic (e.g., Ft. St. Vrain, SECY-88-203, SECY-93-092, NUREG-1338, "Draft Safety Evaluation on the MHTGR"), previous Commission guidance as well as the relationship of this issue to other technical aspects of future designs (e.g., RPV integrity, high temperature materials, etc.). As stated in SECY-93-092, the staff had proposed an approach for containment that focused on functional performance, rather than prescriptive design criteria. The Commission, in a July 30, 1993, SRM approved the staff proposal, with the addition of an air ingress event to the MHTGR proposed accidents to be considered. The current staff work will focus on whether or not the previous position should be modified.

Emergency Evacuation

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It has been proposed that the PBMR design has sufficient fission product retention capability that the emergency planing zone (EPZ) can be reduced from 10 miles (typical for LWRs) to the exclusion area boundary for the site (assumed to be 400 meters for analysis purposes). As discussed previously, the proposed licensing basis events for the PBMR include a set of emergency planning basis events which are to be used to test the fission product retention capability of the plant for emergency planning purposes. As defined by Exelon, these events are in the frequency range of 10^{-4}/plant-yr to 5×10^{-7}/plant-yr and are to be evaluated using mean values of frequency and consequences so that the dose to an individual at the exclusion area boundary is less than the EPA-PAGS. As stated previously, the foundation for this approach has not been fully developed, reviewed or accepted; however, the issues it raises are clear. In effect, the PBMR proposal would eliminate the need for offsite emergency notification and drills although there would be guidance kept onsite that could be used to facilitate ad hoc protective measures, if deemed necessary. The PBMR proposal seeks to establish a probabilistic cutoff (using the safety goal early fatality QHO) for events that need to be considered for emergency planning purposes. This differs from the basis used to establish the current 10 mile EPZ for LWRs in that the full range of accidents were considered and a 10 mile distance chosen as the point where early doses to the public rapidly diminish.

Accordingly, the policy issue is:

- Under what conditions, if any, would the Commission approve reducing the EPZ including a reduction to the site exclusion area boundary?

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To arrive at a recommendation on the policy issue, the staff will consider the following:

- Should there be minimum requirements for emergency evacuation as part of the defense-in-depth philosophy, regardless of plant design or projected risk and if so, what should they be?
- To what extent should probabilistic criteria be used to define the events to be considered for emergency planning and if so, what should they be?
- Are projected doses to individuals that are less than the EPA-PAGs sufficient to use as criteria to establish the EPZ?
- What demonstration of plant performance, if any, would be necessary to find such a proposal acceptable?

It is recognized that the resolution of this issue is related to the issues associated with event selection as well as predicted plant performance, including fuel performance and fuel quality over the life of the plant, projected fission product source terms for various accident scenarios, and how to account for uncertainties due to the lack of operating experience as compared to current LWRs.

Previously, in SECY-93-092, the staff had assessed the issue of emergency planning and did not recommend any generic policy or regulation changes. Rather, EP for each advanced design would be reviewed on a case-by-case basis. The Commission, in a July 30, 1993 SRM, stated that it was premature to reach a conclusion on emergency planning for advanced reactors, but requested the staff remain open to suggestions to simplify EP requirements for

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reactors with greater safety margins. Additionally, the staff was requested to submit to the Commission recommendations for proposed technical criteria and methods to use to justify simplification of existing EP requirements. The current staff work will be related to this request.

FUTURE WORK:

Although the above issues are broad and fundamental in nature, they have been considered in previous Commission work on advanced reactors, including HTGRs and other non-LWRs, as well as in other countries. Accordingly, as stated above, the staff will build upon this previous work as well as additional information that may be received in developing recommendations for Commission consideration. Specifically, the following will be considered:

- the Commission's policy and previous guidance on advanced reactors and on using risk information in regulatory programs

- the approach and rationale used in licensing Ft. St. Vrain for event selection, source term, containment and emergency evacuation.

- the preapplication reviews conducted in the late 1980s and early 1990's, on the DOE sponsored MHTGR and other advanced designs and the ALWR certification reviews.

- Previous ACRS views and recommendations on these issues.

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- Information to be submitted by Exelon in closeout of the PBMR preapplication activities (e.g., a report on containment).

- Work in other countries and international organizations (e.g., IAEA, NEA)

- Information provided in future interactions on the proposed NEI regulatory framework, GT-MHR or other future plant activities.

The staff plans to engage stakeholders on these issues prior to providing recommendations to the Commission. The staff plans to provide recommendations to the Commission in the Fall 2002.

COORDINATION:

The contents of this paper have been discussed with ACRS. In preparing the final paper for Commission consideration the staff plans to conduct discussions with other stakeholders as well as conduct additional discussions with ACRS.

William D. Travers
Executive Director
for Operations

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