Attachment 2

Plan for Preapplication Activities on the PBMR

INTRODUCTION

In a letter dated December 5, 2000, to William Travers, Exelon Generation Co. requested pre-application interactions with NRC directed toward assessing the viability of licensing a pebble bed modular reactor (PBMR) in the United States. The PBMR is a modular high-temperature gas-cooled reactor (HTGR), utilizing helium as the coolant and having online refueling capability, similar to HTGRs developed in Germany in the 1970s and 1980s. The current design is being developed in the Republic of South Africa (RSA) where a full-scale prototype PBMR module may be built and demonstrated. In addition to being a non-light water reactor, the design concept of the PBMR being developed in the RSA has other features which together are characteristic of (and unique to) modular high-temperature gas-cooled reactors. These characteristics make the PBMR approach to protecting public health and safety very different from reactor designs currently licensed in the United States. Chief among these features are:

- passive decay heat removal processes that are to be demonstrated under postulated accident conditions
- coated UO_2 fuel particles that are designed to contain the fission products and to be demonstrated at very high (accident) temperatures
- low power density (an order of magnitude below that for light water reactors (LWRs)) with large thermal capacity that are to be demonstrated to provide for slow transient behavior
- no conventional containment building
- a significantly reduced emergency planning zone (EPZ)
- multi-modular site concept with incremental power generation

Concurrently, DOE has informally inquired into the feasibility of the NRC staff conducting an independent assessment of HTGR technology and safety in order to assist in assessing their advanced reactors program. The proposed assessment (which would be conducted with DOE funding) would examine the design and the safety basis for HTGRs (including the PBMR) from a generic perspective. The assessment would include DOE support for the development of key analytical tools and NRC staff expertise in order for the NRC to conduct qualitative and quantitative safety assessments of HTGR reactors such as the PBMR. It is expected that most of the work for DOE would benefit the staff by developing the understanding, expertise and capabilities it would need to conduct a future licensing review of an HTGR, including the PBMR.

The Commission's Policy Statement on Advanced Reactors encourages early interactions on such advanced designs so as to facilitate the resolution of safety issues early in the design process. Additionally, many of the Commission's current reactor regulations are specific to LWRs and, as such, would not be applicable to the PBMR. Likewise, due to the different technology and approach to safety employed by the PBMR new requirements will be necessary in some areas. Accordingly, preapplication activities with DOE and Exelon are proposed to identify key safety and policy issues, propose a path to their resolution and establish a regulatory framework providing guidance on applicable requirements for the PBMR. It is proposed that these preapplication activities be structured to include: (1) a preliminary assessment of HTGR (including PBMR) technology and safety, and (2) a preliminary assessment of the regulatory framework and regulatory process for the PBMR. These preapplication activities would also help NRC to be prepared to review the PBMR in a timely fashion, if and when an actual application is received. The objectives of these activities would be as follows:

<u>HTGR Technology Assessment</u>:

- conduct early interactions with DOE on the NRC preliminary technology assessment scope and content to meet both NRC and DOE needs
- familiarize a nucleus of staff with the design and technology of HTGRs and their approaches to safety
- assess analytical tools and establish an independent staff capability to quantitatively assess the safety performance of HTGRs
- identify key generic technology issues with safety implications
- identify research needs to address these issues

PBMR Regulatory Framework and Process

- conduct early interactions with Exelon on its PBMR design and technology
- conduct early interactions with Exelon on its proposed licensing approach
- identify a resolution approach for key PBMR safety and technology issues
- evaluate the applicability of current regulatory criteria to the PBMR
- identify and solicit Commission guidance on PBMR policy issues
- support ongoing efforts to identify NRC infrastructure, research, and resource needs to support a PBMR licensing review, and reactor and fuel facility inspections.

HTGR technology issues and areas which are unique to the PBMR being developed in the RSA (and therefore not included in the scope of the DOE modular HTGR technology assessment scope) would be assessed directly through interactions with Exelon. These design-specific assessments will identify key issues with safety, technical and policy implications.

The outcomes of these technology assessment, regulatory framework and regulatory process assessment activities would be staff familiar with HTGRs, including the PBMR; identification of key safety and policy issues, and research needs; and preliminary guidance for the staff and potential applicants sufficient to establish the expectations for licensing. Documentation would include SECY papers to the Commission for information or for guidance on policy issues, letter reports to DOE and letters to Exelon providing feedback on technical and process issues (i.e., a preapplication safety evaluation report on the PBMR design itself would not be written).

PROPOSED PLAN

This paper describes a plan for preapplication activities, which involve technology, safety, regulatory framework and process assessment activities. These activities are directed toward HTGR technology transfer and preparing the agency for a possible application to license a HTGR, such as the PBMR, in the United States consistent with the above objectives. It is based upon experience in the past with preapplication reviews, including an earlier preapplication review of a DOE-sponsored modular HTGR, and would build upon that previous work. The plan describes preapplication activities that would be conducted over an approximately 18 month period and consists of technology assessment and transfer, and regulatory framework and process

assessment elements described below. The plan also describes conduct of interactions and documentation and office coordination, resources and schedule.

Technology Assessment and Transfer

- familiarization with the design, safety, fuel cycle, and research issues via:
  - interaction with foreign partners and domestic organizations, including Exelon, with HTGR design, safety or operating experience
  - interaction with the RSA regulatory organization
- identification of reactor and materials safety and policy issues
- technology assessment, infrastructure and contractor support
- development and implementation of staff training

Familiarization with Design, Safety, Fuel Cycle, and Research Issues

Initial staff technology assessment and transfer efforts will be directed toward becoming familiar with HTGR (including PBMR) design, technology, safety and fuel cycle issues and research needs. This will be accomplished first through discussions and interactions with Exelon and others with PBMR and HTGR experience. An initial meeting was held with Exelon on January 31, 2001, at NRC-HQ to discuss the PBMR design, safety issues, and proposed Exelon schedule and approach for preapplication interactions related to technology assessment. Additional follow-on meetings will be scheduled on an as-needed basis to discuss specific topics and issues. In parallel with interactions with Exelon, the staff will contact others with HTGR and, to the extent possible, PBMR-specific experience to obtain their insights and views on HTGR and PBMR-specific safety issues and technology. These contacts are discussed below and include international as well as domestic organizations.

The NRC has a number of agreements with foreign countries that provide a mechanism to cooperate on a wide variety of safety matters. Some of our foreign partners have HTGR experience and some also have currently operating HTGRs (which utilize Helium coolant and coated particle fuel designs). Specifically, Germany has had many years experience with small (~45 MWt) and large (~750 MWt) HTGRs of pebble bed (i.e., coated particle/fuel sphere) design. Although the German HTGRs are no longer operating, their experience is

relevant to the PBMR. Japan currently has an operating research HTGR (~30 MWt), although not of the pebble bed design. It does, however, utilize coated particle fuel and helium coolant and operates at high temperatures. China has recently begun initial startup of a small (~10 MWt) pebble bed research HTGR, from which experience should be obtained. In addition, they are developing a larger (200 MWt) modular pebble bed reactor design. The United Kingdom operates 14 advanced gas reactors (AGRs). Although they are different from HTGRs and the PBMR (e.g., the coolant is CO_2 and the fuel is not a coated particle design), they are graphite moderated and some experience may be relevant to HTGRs including the PBMR. Russia has had some HTGR development efforts in the past and is currently engaged in a joint effort with General Atomics (sponsored by DOE) to develop a modular HTGR (although not a pebble bed design) for plutonium (Pu) disposition. In addition, IAEA has some activities (in both the development and safety areas) looking at the design and safety of the PBMR. The NRC staff would also build upon and utilize their work in our activities. Finally, we would plan to discuss with the South African regulatory authorities their views on the PBMR design, safety issues, and research conducted (or to be conducted) to address the issues. In calendar year 2001, we would intend to arrange interactions with our international partners to discuss their experience with HTGRs and their views on safety issues.

Domestically, there remains some HTGR expertise, primarily at Los Alamos National Laboratory (LANL), Oak Ridge National Laboratory (ORNL) and General Atomics (GA). Preliminary discussions have been held with LANL and ORNL regarding the feasibility of drawing upon their expertise. Relevant experience at the other DOE labs will also be determined. Access to expertise at GA may be limited because GA is an NRC licensee and has indicated an interest in having preapplication interactions with NRC on their modular HTGR design. In addition, for the past several years the Massachusetts Institute of Technology has had an effort to design a modular pebble bed HTGR. Their experience will also be sought. Finally, previous NRC experience with earlier generation HTGRs (e.g., Ft. St. Vrain and the NRC review of a DOE- sponsored modular HTGR in the late 1980s and early 1990s) would be utilized to help identify safety and technology issues, research needs, and approaches to their resolution.

<u>Identification of Safety and Policy Issues</u>

HTGRs, such as the PBMR, involve characteristics that make their approach to protecting public health and safety very different from reactor designs currently licensed in the United States. For example, among the four basic layers of defense-in-depth for ensuring public health and safety against potential adverse consequences - prevention, protection, mitigation and emergency planning - modular HTGRs typically result in a shift in emphasis from mitigation features to highly reliable protection features. That is, HTGRs aim to achieve high reliability and protection through the use of fuel capable of withstanding high temperature, simple and passive decay heat removal and reactor shutdown processes as compared to high reliability through active standby engineered safety systems in LWR designs. Mitigation is provided through different concepts for fission product containment and through long response times of the reactor in the event of an accident. These and other differences between HTGRs and current generation LWRs are expected to lead to a number of safety, technology and policy issues. Issues such as high temperature materials performance; the qualification of accident analysis codes and methods; the qualification and performance of the coated particle/fuel spheres, the siting source terms, and the range of events that must be considered for design and siting purposes, are expected to be among the key safety, technology and policy issues that will need to be assessed.

Technology Assessment, Infrastructure and Contractor Support

Along with the identification of key technology, safety, and policy issues associated with HTGRs, including the PBMR, the staff will also identify the technology assessment and infrastructure needs to be ready to review an actual application. This will include needed in-house and contractor expertise, analytical tools, and the resources to obtain them. It is expected that the expertise needs will be in areas unique to HTGR technology and include:

- fuel design, fabrication and performance
- high-temperature materials performance
- helium turbine technology
- accident analysis
- HTGR risk analysis

A complete identification of infrastructure needs is, to some extent, dependent upon the identification and nature of the safety issues. However, in regard to analytical tools, it is important for the agency to have an independent capability to verify the plant response to accidents, particularly those related to loss of coolant, decay heat removal, and reactivity insertion. Such independent capability is valuable in providing a deeper understanding of plant behavior under a wide range of off-normal conditions, which can result in insights that contribute to the quality and thoroughness of the staff review and determine confidence in information provided by the applicant. Independent analyses have, in the past, led to the identification of significant advanced reactor safety issues that may otherwise have gone undetected (e.g., AP-600 fourth stage depressurization valve under-sizing). Currently, NRC does not maintain any analytical tools, data bases, or activities on HTGRs. The most recent efforts in this regard were approximately seven years ago when the agency had under way a preapplication review of a DOE-sponsored modular HTGR (MHTGR) design in accordance with the Commission's Advanced Reactor Policy Statement.

A draft preapplication safety evaluation on the MHTGR was issued in 1989 for comment (NUREG-1338); however, although a final NUREG was prepared in the early 1990s, it was never issued because DOE canceled the program. In developing NUREG-1338, the staff utilized contractor support and analytical tools from Oak Ridge National Laboratory (ORNL) and Brookhaven National Laboratory (BNL). Since that time, ORNL has remained active in the HTGR field and currently supports DOE-sponsored work on HTGRs for Pu disposition. Accordingly, there is expertise at ORNL (including analytical tools) that the agency could draw upon in the preapplication phase to assist the staff in the identification of issues and approaches for the preapplication review, as well as familiarizing the staff with the available analytical tools, their basis, and how to use them. In this regard, ORNL has available the GRSAC code (a three-dimensional thermal-hydraulic code with point kinetics reactor physics) that it is using in assisting DOE; this is an improved version of a code used in the staff's review of the DOE modular HTGR ten years ago. Other expertise and codes are also available and would be reviewed for applicability and possible use. Any needed improvements in the analytical tools will be identified and plans developed for their implementation.

<u>Staff Training</u>

One outcome of the technology assessment and transfer work would be the development of a small nucleus of staff familiar with HTGR technology and the unique attributes of the PBMR such that they can participate and facilitate an actual application review, if and when an actual application is received. This nucleus would include staff from RES, NRR, and NMSS.

To help achieve this outcome, development and implementation of a training program will also be included in the technology assessment and transfer work. The training program will consist of information on basic HTGR design, technology, safety features, operation, and experience. Contractor assistance will be used to develop and give the training, which will be targeted to be available in approximately one year. DOE has indicated that they would be willing to fund development and conduct of the program for their staff and the NRC staff.

Regulatory Framework and Process Assessment

- approach to licensing
- identification of regulatory requirements, safety and policy issues and a proposed approach for resolution

Approach to Licensing

Exelon has proposed an approach to licensing the PBMR in the United States. The approach includes building a single module in the United States under the combined license provision of 10 CFR Part 52 and, based upon that experience and the results of a test program using a prototype to be built in South Africa, subsequently certifying the design. Licensing and certification of a PBMR design may raise process questions regarding issues such as:

– with fuel quality an integral part of the safety case, should the fuel fabrication be tied to the design certification?
– is an application required for each module?
– is a decommissioning trust fund required for each module?
– application of Price-Anderson

Early interaction to identify and address such issues with Exelon would be part of the plan.

Regulatory Requirements, Safety and Policy Issues

An important output from the preapplication interactions with Exelon will be the identification of applicable requirements, safety and policy issues. This will involve looking at the requirements in 10 CFR (and their supporting regulatory guides) and identifying those that are unique to LWRs (and thus not applicable to the PBMR), as well as looking at the PBMR design and the technology and safety issues and identifying unique aspects that are not covered by current requirements.

The interactions with Exelon and our foreign partners, the domestic experience described above as well as the experience with the Ft. St. Vrain reactor, the review of a DOE-sponsored modular HTGR in the late 1980s, and the ALWR reviews would be utilized in reviewing the applicability of the requirements and in identifying unique issues associated with the PBMR.

It is expected that the technology, safety and regulatory assessments will lead to the identification of certain safety and policy issues that would need to be resolved in order to proceed with an actual licensing review. It is likely that the issues that stem from the preapplication activities will include:

- how to ensure fuel quality over the life of the plant
- acceptability of the use of fuel enrichments greater than 5%
- what accidents should the plant be designed for?
- containment vs. confinement
- an acceptable approach to the source term
- control room design and staffing
- transportation and on-site spent fuel storage
- extent of necessary prototype testing
- reduced emergency planning zone.

Policy issues would be provided to the Commission for guidance. A combination of traditional engineering and a risk-informed approach to addressing the issues would be utilized.

It is expected that an approach for resolving such safety and policy issues could be provided to the Commission in approximately 18 months. As an interim step, a preliminary set of the key safety and research issues associated with HTGRs including the PBMR would be provided to the Commission for information in approximately 12 months.

Conduct of Interactions and Documentation

Meetings with DOE and Exelon on specific topics related to HTGR and PBMR design, safety, technology, regulatory requirements and licensing process issues will be held. Following each meeting DOE and Exelon will be requested to document the information presented, any additional information identified by the staff, and their request for NRC feedback. On specific technical issues, requirements and process issues a response from the Director, RES, or the Executive Director for Operations, as appropriate, will be sent back to DOE and Exelon via letter. ACRS/ACNW and stakeholder input will be sought on technical and requirement issues prior to preparation of the EDO response. An approach for resolving policy issues would be provided to the Commission for guidance and would include consideration of ACRS/ACNW and stakeholder input. After Commission guidance is received, it would be provided to DOE/Exelon.

Coordination, Resources and Schedule

The preapplication activities will be a joint RES/NRR/NMSS effort. Although RES will have the lead, this effort will involve close coordination with and support from NRR and NMSS. The staff will also interact with ACRS and other stakeholders. Interoffice coordination and responsibilities will include:

- RES Role (overall lead for project)
  - organize, coordinate, conduct, and document meetings
  - organize and participate in ACRS presentations and stakeholder workshop
  - draft SECY papers, letter reports to DOE and letters to Exelon
  - preliminary identification of issues, research needs, applicable requirements, etc.

- NRR Role (overall lead for process issues related to the actual application)
  - participate with RES on preparing papers and participate in meetings, giving presentations and identifying technical issues
  - concur on correspondence to Exelon, DOE, ACRS, EDO, or the Commission

- NMSS Role (overall lead for fuel fabrication, transportation, waste and safeguards issues)
  - participate with RES on team preparing papers and participate in meetings, giving presentations, and identifying technical issues
  - concur on correspondence to Exelon, DOE, ACNW, EDO, or the Commission involving fuel fabrication, transportation, waste or safeguards issues

- OGC Role (overall advice on legal matters)

NRC staff work would focus on the review of applicable requirements and the identification of important accident scenarios, infrastructure, research, and resource needs. Contractor work would focus on review of HTGR analytical tools, training, and engineering analysis support.

A preliminary schedule for the activities described above is shown in the attached figure. It is recognized that this schedule is dependent upon many factors, however, it represents the approximate time (18 months) necessary to accomplish the preapplication activities.

To accomplish the preapplication activities, it is expected that approximately 7 FTE will be necessary over the 18 month period. This will include 4 FTE in RES, 2 FTE in NRR and 1 FTE in NMSS. Also, it is estimated that $1000K will be needed over the 18-month period for contractor support in providing training, reviewing analytical tools and providing calculational assistance to the staff. DOE funds to cover the technology assessment and transfer activities are estimated to amount to $800K and 3 FTE over the 18-month period. Exelon would be assessed fees under 10 CFR 170 consistent with the Commission's 1995 fee policy for advanced reactor designs, for NRC's preapplication activities that are specific to the PBMR.

Preliminary Schedule for

PBMR Preparatory Activities

(in months)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Technology Assessment and Transfer

! Interactions with:

— DOE/Exelon [redacted]

— Foreign partners [redacted]

— Domestic organizations [redacted]

Assessment of:

Safety and research issues [redacted] ▼Information SECY on safety and research issues

▲ ACRS ▲ ACRS

! Development of Infrastructure:

— Analytical tools [redacted]

— Contractor support [redacted]

— Staff training [redacted]

Regulatory Process and Framework Assessment

! Assessment of:

— Exelon proposed approach to licensing [redacted]

— Applicable requirements [redacted]

— Policy issues and approach for review [redacted] ▼ SECY on policy issues and approach for review

▲ Public workshop ▲ ACRS