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Exelon Generation

Project No.: 713

June 6, 2002

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

Subject: Submittal of Preliminary Safeguards Criteria Regarding the Pebble Bed Modular Reactor

Exelon Generation Company (EGC), LLC submits the attached preliminary safeguards criteria requirements information prepared by the International Atomic Energy Agency (IAEA). This submittal of this information fulfills a commitment made by EGC during a February 14, 2002 conference call between the Nuclear Regulatory Commission and EGC. The attached documentation supports our discussions regarding the preliminary work to assure safeguards parameters could be applied to the Pebble Bed Modular Reactor. EGC does not request the NRC to perform an in-depth technical review of the material since it is preliminary and EGC will be concluding pre-application activities.

If you have any questions or concerns regarding this matter, please contact R. M. Krich or me.

Sincerely,

Kevin F. Borton
Manager, Licensing

Attachment

cc: Farouk Eltawila, Office of Nuclear Reactor Research
James Lyons, Office of Nuclear Reactor Regulation
Amy Cubbage, Office of Nuclear Reactor Regulation
Stuart Rubin, Office of Nuclear Reactor Research
Joseph Giitter, Office of Nuclear Material Safety and Safeguards

D064

Attachment

Project number 713

Preliminary Safeguards Information Regarding
The Pebble Bed Modular Reactor

International Atomic Energy Agency (IAEA) letter from Mr. Dirk Schriefer to Mr. J.S. Maritz - NECSA, file reference number MB-SAF-31, and IAEA interoffice office memorandum OB2/2001/035, "PBMR Safeguards Approach."

Submitted by Exelon Generation
June 6, 2002

12 Pages

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DEPARTMENT OF SAFEGUARDS, DIVISION OF OPERATIONS B

Addressee(s):
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File Reference (Please quote in return correspondence): MB-SAF-31

Dear Mr Maritz

I refer to the discussions of the Agency representatives Messrs J Fager and R Fagerholm with the designers of the PBMR reactor from ESCOM during the February 2001 visit.

It was requested that the specific safeguards requirements effecting the design features of this project should be communicated to you in June 2001. As this type of the reactor is a completely new project, the specific safeguards criteria for the application of safeguards are under discussion in the Agency. The draft criteria requirements are prepared, pending final approval.

The following are the safeguards parameters that could be applied to the PBMR facility and should be considered at the design stage of the project:

1. Fresh Fuel

Each fresh fuel pebble contains approximately 9g uranium of 8% U235 enrichment. The maximum fresh fuel inventory is expected to be 70,000 pebbles (0.7 SQ LEU) which represent a 6 month supply of fuel.

1.2 Facility Design Requirements for Safeguarding Fresh Fuel

No PBMR design changes are foreseen to implement safeguards on fresh fuel. Safeguards measures currently applied at LEU item facilities would be implemented. The containers of fresh PBMR fuel would be item counted and verified with medium detection probability for gross defects.

2. Core Fuel

Direct verification of the core fuel inventory is not possible.

Indirect core fuel verification would require logging pebble flow and correlating the flow with other declared reactor operational parameters. The pebble flow and other parameters would also be compared with spent fuel tank fill heights and radiation levels measured during regular inspections.

A possible safeguards approach for verification of core fuel discharges was discussed during the meeting in February 2001. This approach requires independent pebble flow verification by the Agency.

Two options were identified:

1. Development and implementation of an independent Agency controlled pebble flow verification system. While the technology exists for such a system, an extensive and very costly implementation project would be required to adapt the technology to PBMR safeguards.

2. An alternative approach would be to use selected authenticated signals from the operators instrumentation for safeguards purposes.

Either route would have facility design implications, but the latter would be less intrusive and should not require the Agency to develop and maintain independent instrumentation in a high radiation zone.

2.1 Facility Design Requirements for Verification of Core Fuel Discharges

The Agency would require that selected data from the pebble counter be sent to a safeguards data logging device. The data would be collected during routine inspections along with spent fuel tank NDA measurements.

A detailed analysis system for the measurement data and operational parameters should be designed and used for drawing safeguards conclusions.

3. Spent Fuel

During reactor operation fuel spheres and carbon spheres continually circulate through the core. After each core cycle, fuel spheres are separated from the carbon spheres and an automated burn-up measurement will direct high burn-up pebbles to the spent fuel storage tanks.

It is assumed that all spent fuel will be stored in the PBMR facility for the life cycle of the plant, estimated to be 40 years plus an additional 40 years after final shut down. Ten storage tanks will be filled with spent fuel pebbles at the rate of 2 tanks every 6-7 years (380,000 pebbles per tank).

It should be noted that each tank is fitted with a valve on the bottom of the tank that can be used to move pebbles into transfer containers. A seal should be attached to this valve and, if possible, verified during scheduled inspections.

NDA techniques can be used to verify the fill level of tanks, radiation characteristics, and that tanks declared to be empty remain unused. The Agency supports the operator's proposal to design special access tubes in the shielding surrounding the tanks for introducing NDA measurement instruments (neutron, gamma-ray, and/or temperature detectors). The PBMR engineers have indicated that access tubes could be designed into the spent fuel storage tank shielding. Inside tube/tubes are for consideration and discussion. The spent fuel tank access tubes should allow positioning of NDA measurement equipment.

3.1 Facility Design Requirements for Safeguarding Spent Fuel

Verification measurements would require the placement of 3 to 5 access tubes along the sides/ inside of each spent fuel tank. These tubes must be of sufficient diameter and depth to allow insertion of an instrumentation module. The instrumentation module must be able to "view" the entire length of the tank at each tube position. Initial design ideas estimate that each tube would be about 10cm in diameter. Provision for placing IAEA seals on each tube as well as the transfer valve on the bottom of the tank would be required.

4.0 Support Program Task Required to Implement PBMR Safeguards

The Agency intends to propose a support programme task for the Pebble Bed reactor project in South Africa. Australia, Germany and USA have so far expressed their interest in the participation in this project.

The task to be undertaken is specified to determine plant operational parameters and NDA measurement data, including data from facility instrumentation, that should be collected for safeguards evaluation. This task should review all available facility data and determine the following:

- Safeguards relevant data for the PBMR
- Determine what data should be recorded/ measured
- Determine the frequency of data recording/measuring
- Determine how to authenticate and collect the operational data from facility instrumentation for safeguards evaluation.
- Develop a model for correlating NDA measurement data and safeguards relevant operational parameters to confirm operator declaration of nuclear material inventories.
- Identify NDA detector systems that will be used to measure the spent fuel tanks (neutron, gamma-ray, temperature detectors)
- Identify the locations in the tank shielding for placement of the access tubes for NDA measurement systems.

After your discussions with ESCOM during our meeting in Vienna 2001-06-18/22, we intend to work out together the action plan for the planning stage and implementation of the project.

Kind regards

Dirk Schriefer, DIR-SGOB

Clearance:

A.Gil-Ramos, SH-SGOB2

A.Kulichenkov, SH-SGOBP

D.Hurt, SH-SGPSS

M.Aparo, SH-SGTIE *

for A.Pietruszewski/R.Fagerholm/spf-26242)
\\SG_F2\SGOB_Data\2001\OB2\Suzanne\Fax\SAF PBMR.doc
Pages = 3 + 0 attached

cc:
DIR-SGOB
SH-SGOB2
SH-SGOBP
SH-SGPSS
SH-SGTIE
Mr A Pietruszewski
Mr R Fagerholm
Mr J Fager
Master/Chrono
RCS
File

* With the understanding that we will be involved at an early stage for the definition of SG device to be used and the way to authenticate operator instruments.

International Atomic Energy Agency
INTEROFFICE MEMORANDUM

To: Ms Jill Cooley
DIR-SGCP

Date: 2001-03-29

Reference: OB2/2001/035

Through:

Clearance: Andrzej Pietruszewski
A/SH-SGOB2

From: Dirk Schriefer
DIR-SGOB

Tel: 26270

Subject: PBMR Safeguards Approach

Planning for the eventual construction of the first PBMR is continuing in South Africa. At a meeting with the IAEA in February 2001, ESCOM requested that facility specifications needed to implement safeguards be determined by the IAEA before the PBMR engineers complete the initial design phase of the project. They expect to have this phase completed by June 2001. Our safeguards approach need not be approved by June 2001, but by then we should notify South Africa of all safeguards-driven facility design requirements that may be needed to safeguard the PBMR.

Considering this situation, SGOB requests assistance in formulating the requirements of a safeguards approach for the PBMR. The safeguard approach should consider adapting the present criteria to safeguarding the facility as well as criteria changes that may be required by Integrated Safeguards and Additional Protocol implementation.

Jon Fager (SGOB) has been assigned to follow the PBMR safeguards approach development and implementation. Robert Fagerholm (SGCP) has been of great assistance in following development of the PBMR and has already given consideration to various safeguards implementation scenarios. His continued assistance will be appreciated.

Please find attached a brief description of PBMR details pertaining to safeguards implementation.

ATTACHMENT

2 page IOM
JFager/spf-26242
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cc: File
RCS
Master/Chrono
SA-OBF

M-13 Dec 99

ATTACHMENT 1

The following are ideas that may influence the requirements of a safeguards system applied to the PBMR facility:

Fresh Fuel:

Each fresh fuel pebble contain approximately 9g uranium of 8% U235 enrichment. The maximum fresh fuel inventory is expected to be 70,000 pebbles (0.7 SQ LEU) which represent a 6 month supply of fuel.

No PBMR design changes are foreseen to safeguard the fresh fuel but the fresh fuel should be considered in applying safeguards to the facility.

Pebble Flow:

A detailed approach for safeguarding pebble flow has been suggested. This approach requires the development and implementation of an independent pebble flow verification system. While the technology exists for such a system, an extensive and very costly implementation project would be required to adapt the technology to PBMR safeguards. An alternative approach would be to use selected authenticated signals from the operators instrumentation for safeguards purposes. Either route would have facility design implications that must be specified and communicated to South Africa before June 2001.

Spent Fuel:

All spent fuel will be stored in the PBMR facility for the life cycle of the plant, estimated to be 40 years plus an additional 40 years after final shut-down. The spent fuel will contain about 1 SQ of Pu per year of reactor operation. Ten storage tanks will be filled with spent fuel pebbles at the rate of 2 tanks every 6-7 years (380,000 pebbles per tank).

NDA techniques could be used to verify the fill level of tanks and that tanks declared to be empty remain unused. The shielding surrounding the tanks could contain channels for introducing NDA measurement instruments (neutron, gamma, temperature). The PBMR engineers have indicated that if necessary, this type of safeguard system could be designed into the spent fuel storage tanks. To implement this safeguards approach specific design details (size and location of measurement channels) need to be developed and communicated to South Africa before June 2001.

PRE-PRINT

OF

PRELIMINARY ASSESSMENT OF THE EASE OF DETECTION OF ATTEMPTS AT DUAL USE OF A PEBBLE BED REACTOR

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Accepted for Presentation at the American Nuclear Society 2001 Winter Meeting, November 11-15, 2001, Reno, Nevada

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Introduction

The Pebble Bed Reactor (PBR) concept is receiving emphatic renewed interest. In particular, an international consortium[1] is intent on developing and deploying such a reactor within a few years, with the ultimate goal of international commercialization and deployment of large numbers in developing countries and elsewhere. This optimistic business assessment stems from the numerous inherently and passively safe features of the design. Modular design allows high technology fabrication to be shifted to centralized locations with deployment in low technology markets. The routine recirculation of the fuel pebbles and the online de-fueling and refueling of these reactors raises questions about their potential use as production facilities for weapons materials. However, this feature also allows the reactors to operate with very little excess reactivity. In this paper we demonstrate that the dual use of a PBR (simultaneous production of power and weapons materials) would be easily and promptly detected.

Methodology

The PEBBED code[2] computes directly the asymptotic (equilibrium) fuel-loading pattern of a PBR, given the fresh fuel composition. This asymptotic pattern is that which is established well after (>3 years) the initial loading and persists for the remainder of the operating life of the reactor. The pattern and its properties are highly predictable. Presumably the result of extensive optimization, it is expected that reactor owners will stick to it. Departures from this pattern could be viewed as suspicious and as possible attempts at diversion of fuel for dual use. Any departure from the pattern will result in noticeable changes in fresh fuel requirements, power production, and/or discharge isotopics. All three attributes could easily be monitored via an instituted safeguards regime and via spent fuel re-purchase. As continuous burnup monitoring of discharged pebbles is part of the fuel management policy, the information on the isotopics could also be made available on-line or via the transmission of recorded data sets to the safeguards authority. Uninterrupted fuel supply would be contingent upon acceptable reactor use.

The PBR owner is assumed to be a low technology country without front-end fuel cycle facilities (i.e. enrichment capability) and thus dependent on a supplier country for its fresh fuel needs. The supplier country is party to a non-proliferation regime and agrees to enforce safeguards on its fuel customers. Either the spent fuel is re-claimed or information on discharged pebbles average isotopics is required. Finally, it is assumed that for economic reasons the on-hand fresh fuel inventory of the PBR owner is maintained as low as practical. In this paper, we assume that after the initial loading the fuel supplier periodically provides ninety days of fresh fuel to the PBR owner, just prior to stock exhaustion.

The PEBBED code is first used to estimate the fresh fuel requirements of a PBR operated following the asymptotic pattern with no attempt at dual use. The code is also used to estimate the fresh fuel requirements of a similar reactor operated with dual use intent. The modeled legitimate reactor is loosely based on the Kraftwerk Union HTR Modul 200, with a 10.0-m core height and a 3.0-m diameter. Graphite reflectors surround the core. The void space between the top of the pebble bed and the top reflector is about 80 cm. The fresh fuel pebbles contain 7 g of uranium enriched to 7.8%. They travel through the core with a mean velocity of 15 cm/day. The core produces 200 MWt of power. In the illicit use cases, target pebbles containing natural uranium (NU) are assumed inserted into the core in the proportions of 0.1% and 0.4% of the overall fuel mix, respectively. The 0.4% content is a physical limit corresponding to the highest number of NU pebbles that can be incorporated into the core while retaining the same critical multiplication factor via the addition of supplementary fresh fuel pebbles. This hypothetical limit corresponds to the plenum above the pebble bed being filled. It cannot be achieved in practice because there is no mechanical means for filling the plenum uniformly to its top, and it would be precluded from acceptance because of its hindrance of coolant flow. Nevertheless, this model provides an upper assessment of the highest Pu-239 rate production possible with this reactor. The 0.1% NU pebbles loading was chosen arbitrarily with the goal of dissimulating the dual use. Reactivity is maintained by the addition of about 18-cm of fuel mix. The PEBBED code explicitly models the two types of pebbles and assumes different circulation patterns for each. The regular fuel is recirculated a sufficient number of times to achieve the normal nominal burnup. The NU pebbles are circulated once then removed (OTTO) in order to maximize the Pu-239 quality. The results from the PEBBED runs are used to assess the likelihood of detection of dual use attempts.

Results

Results from PEBBED runs were used to generate the information presented in Table 1. In the 0.1% NU case, the fresh fuel supply would run out about 19 days prior to the predicted exhaustion of the on-hand fresh fuel. This will result in an outage of the reactor, an unexpected and highly detectable event. Similarly, if the PBR operator were to lower the power in order to extend operation until the receipt of a new supply of fresh fuel, the nearly 21% power decrease would be noticeable and would require explanation under safeguard agreements. Furthermore, the power decrease would imply lower fuel consumption than originally anticipated and would, under a rational safeguards regime, imply a reduced delivery of fuel at the following supply date. If the performance is repeated, it would eventually lead to increasingly shorter fuel reserves. Such a mode of operation would be uneconomical and politically questionable, as the dual use would become apparent. The illicit patterns of performance would be discovered during the first three months fuel-use-period of their occurrence provided the on-hand supply is replenished to result in stocks meant to last only three months. In contrast, the time required for accumulation of the Pu-239 is very long: 92 years with continuous operation (unlimited fuel supply) and as high as 118 years if fuel shipments are restricted to the requirements of power production. In the 0.4% NU case, the detection would occur after only four days of operation as the fuel supply would be exhausted. The accumulation time would be 23 years (continuous) or 492 years (intermittent).

The last data entry line in Table 1 shows the residual U-235 content of the discharged fuel pebbles for each case. Although the differences appear small, they are well within the detection limits of modern assay methods. Therefore, the discharge isotopics could also provide an effective tool for detecting attempts at dual use. However, this application will require the prior establishment of a database for legitimate discharge isotopics based on measurements, thus eliminating the error in prediction that can arise from the uncertainty in cross section data.

Table 1: Prediction of Fuel Cycle Needs for Three PBR Operation Modes.

	Regular PBR Core	PBR Core with 0.1% NU Pebbles	PBR Core with 0.4% NU Pebbles
Number of pebbles in core	382979	389872	413617
Fraction of NU pebbles	0	0.001	0.004
Core Height (m)	10.0	10.18	10.80
Pebble transit speed (cm/day)	15	15	15
Transit time (days)	67	68	72
Daily discharge (mix)	5745	5745	5745
NU pebbles in daily discharge	0	6	23
Number of passes (regular pebbles)	17	17	17
Number of passes (NU pebbles)	NA	1	1
Regular pebbles in daily discharge	5745	5739	5722
Daily fresh fuel requirement (number of pebbles)	338	338	337
Re-supply required for 90 days operation	30413	30383	30291
Number of extra required regular fuel pebbles at initial loading	0	6504	28984
Number of days fuel supply will be short	0	19	86
Pu-239 content of one discharged NU pebble (mg)	NA	26	26
Estimated number of NU pebbles needed for one weapon (5000g)	NA	192160	191278
Time to accumulation (years, continuous operation)	NA	92	23
Time to accumulation (years, interrupted operation)	NA	118	492
Residual U-235 content of discharged fuel (mg/pebble)	251.9	251.7	251.0
Numbers of pebbles, days and years are rounded to integers			

Conclusions

It is clear that the PBR is a poor tool for production of Pu-239 in all circumstances, even if a continuous fresh fuel supply is assured. Indeed the lowest accumulation period of 23 years for a single device cannot be construed as the basis for a successful proliferation program. Furthermore, any attempt at dual use would be detected promptly and long before the significant accumulation of prohibited materials. Detection would occur within the first three months of illicit use in both cases considered. The results presented here apply to a hypothetical reactor similar in many of its features to the HTR-Modul 200. The models assumed random circulation. The method should be applied to other reactor designs with a comprehensive examination of recirculation patterns.

References

1. Nichols, D. R., "Status of the Pebble Bed Modular Reactor," Nuclear Energy, 2000, 39, No.4, Aug., 231-236.
2. Terry, W. K, H. D. Gougar, H. D and A. M. Ougouag "Deterministic Method for Fuel-Cycle Analysis in Pebble-Bed Reactors," Trans. ANS 83, pp. 278-279, Nov 12-16, 2000