CURRENT STATUS OF THE PBMR LICENSING PROJECT

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Abstract

The CNS is currently reviewing the PBMR conceptual design from a licensibility point of view. The PBMR concept is based on a High Temperature Gas Cooled Reactor - pebble bed reactor type. It is anticipated that the PBMR design will rely on inherent safety characteristics to contain fission products within fuel over the full range of design basis events. This feature combined with the high temperature integrity of the fuel and structural graphite, allows the safe use of a high coolant temperature, which allows consideration of the future development of this reactor for non-electrical applications of nuclear heat for industrial use. The CNS licensing approach requires that the licensing and design basis of the plant should respect prevailing international norms and practices and that a quantitative risk assessment should demonstrate compliance with the CNS fundamental safety standards. The first stage of the licensing process is now ongoing; this is a pre-application phase, which will result in a statement on licensibility being issued. Identification of the specific documentation requirements and information needed is required across every step of the licensing process. Top level regulatory requirements have been established for the PBMR. They include the CNS fundamental safety standard and basic licensing criteria, which describes requirements on licensees of nuclear installations regarding risk assessment and compliance with the safety criteria and define classification of licensing basis events.

INTRODUCTION

The PBMR licensing project started in South Africa in July 1997 when ESKOM, the National Electricity Utility, "opened" a project to start investigation into the licensing of the South African high temperature gas-cooled Pebble Bed Modular Reactor (PBMR) concept. The South African nuclear regulatory authority, the Council for Nuclear Safety (CNS) is currently at the first licensing stage of the safety review of the PBMR. Formal application for PBMR stage license was received by the CNS from ESKOM at the end of July '98, where ESKOM requested for the issuance of the licence defining and approving the safety bases for a proposed PBMR. The CNS is evaluating now the acceptability of the safety bases for the proposed PBMR concept.

The PBMR concept is based on High Temperature Gas Cooled Reactor — pebble bed reactor type. The proposed PBMR design reference is German "HTR Module" design, which was reviewed by German Regulatory Authorities and declared "licensable".

Central features that provides inherent (passive) safety of this type reactor design is a nuclear fuel in the form of spheres with the coated uranium particles inside, which are distributed in the graphite matrix covered by an unfuelled graphite coat. This inherent safety is based on the ability of the coated particles to retain all key radionuclides as long as a maximum fuel temperature of about 1 600°C is not exceeded. Therefore, this reactor design has the possibility to exclude reliance on any active safety systems inside the primary circuit for postulated accident scenarios. A few changes to this "original" reference design have been made in Eskom's design [1], to increase the electrical power to about 110 MW(e). The main differences are direct Brayton cycle, higher temperature and an annular core. Helium, which is chemically inert and cannot be activated, is used as a coolant and medium driving the turbo generator. This, combined with the high temperature integrity of the fuel and structural graphite, allows the use of a high coolant temperature about 900°C.

The possibility to achieve high temperature and passive safety in the PBMR design allows consideration of future development of this reactor for non-electrical applications of nuclear heat for industrial use. A heat source provided by a Pebble Bed Nuclear Reactor could be used for district heating, seawater desalination, heavy water production, hydrogen production and other industrial applications. Therefore the current status of the licensing of the PBMR (still with electrical power production) is presented.

CNS LICENSING APPROACH

South Africa operates the Koeberg Nuclear Power Plant (NPP) with two Framatome design PWR units, 900 MW(e) each, commissioned in 1983 and 1984 and situated near Cape Town. A 20 MW ORNL swimming pool research and isotope production reactor is also licensed to operate. The majority of previous experience of the CNS has been based mainly on licensing of the PWR reactor type. To acquire additional expertise in the HTGR area the CNS approached international companies for specialised consultant services to back up its existing technical specialists. The CNS is currently also investigating the necessary additional staff complement.

The Licensing approach, which is similar with one used for the Licensing of the Koeberg Reactors has been adopted in respect of the PBMR. It requires that the licensing and design basis of the plant should respect prevailing international norms and practices. It also requires that a quantitative risk assessment should demonstrate compliance with the CNS fundamental safety standards. The establishment and maintenance of an adequate emergency plan is required based on the outcome of the safety assessment process. Conditions of licence will be established on the outcome of the assessment including requirements for General Operating Rules.

From July 1997 to date, discussions with ESKOM took place to plan the overall Licensing process to be adopted. These include all the activities required to develop the licensing basis, perform the safety assessment, issue and update the nuclear licence for the PBMR plant during all stages of the project and plant life cycles: design, construction and installation, commission, testing, operation and decommission of the plant. It is subdivided into the following main phases:

- A Pre-Application Phase, which is a current first licensing stage.
- An Application Phase, when the PBMR licence will be granted and updated for every sub-stage of the licensing process e.g. construction, start-up, commission and operating.
- Operation Phase.
- Decommission Phase.

LICENSING PROJECT MANAGEMENT

The detailed licensing project specifications including the licensing processes, project scope and project organisation are documented in the CNS PBMR Project Management Manual, which was officially issued at the end of the last year. The overall Project is managed by the CNS PBMR Project Manager.
In order to ensure an "orderly" and efficient Licensing process the various activities have been grouped in Sub- Projects. Each Sub-Project is in turn managed by a Technical Project Leader. Four Sub projects have been identified this far:

- Project A: Licensing Basis
- Project B: Risk Assessment
- Project C: General Operating Rules & Plant Design Engineering
- Project D: Pre-operational testing programmes.

Agreement for licensing fees, which covers CNS expenditure concerning overseas consultants, CNS local staff and optional local consultants, has been agreed with ESKOM. Agreement with overseas consultants have been finalised for support in the following disciplines:

ESI (Germany) - Radiation Safety Engineering and Fuel
NNC/BEI (UK) - Materials
Framatome (France) - Design Criteria and Rules and Nuclear Engineering.

An agreement with US General Atomics is expected to be signed in a few weeks time. The main licensing activities are currently being carried out by consultants, which are being shadowed by CNS staff.

The CNS has established quality management requirements, which apply at each stage of the project, and a few initial audits on ESKOM activities have been already performed to ensure that the PBMR project follows the required processes.

Regular Licensing meetings are held with ESKOM. During these meetings, the project status, licensing progress review, problems raised and ways to resolve them are discussed.

CURRENT STATUS OF THE LICENSING PROCESS

As was already mentioned the project is currently in a pre-application phase of the licensing process, which was described in the CNS paper presented last year at the TCM " Safety Related Design and Economic Aspects of High Temperature Gas Cooled Reactors", here at INET [2].

The main activities during this stage include:

a) establishment of the licensing basis,
b) safety review and assessment of the PBMR Safety Analysis Report (SAR) Rev 0 and supporting documents,
c) issue of the licensibility statement.

The documentation forming the PBMR licensing basis is indicated in Figure 1.

The first two documents have been developed by the CNS and they define "Top Level Regulatory Requirements to the PBMR". The CNS Risk Criteria [3] describes the requirements on licensees of nuclear installations regarding risk assessment and compliance with the safety criteria and it is applicable to any nuclear installation licensed in the South Africa. The second document has been developed specific for the PBMR. It is currently under review and will be officially issued during the next month. The document "CNS PBMR Basic Licensing Criteria" is the CNS Licence Document, which sets out the safety criteria of the CNS and the requirements on licensees to demonstrate compliance with these criteria. These criteria apply to events or combinations of events, which lead or could lead to exposure of

either the plant personnel or members of the public. Three groups of event are considered which are defined in terms of the annual frequency of occurrence, ranging from those leading to exposures which are considered to be part of normal operation and those which are less likely to occur. For the three groups considered, safety requirements and numerical safety criteria are provided (See Table 1). Amongst the safety criteria specified in addition to the numerical criteria, are the application of the ALARA principle and the principle of defence-in-depth. The application of the ALARA principle involves, through the application of one of a range of simplistic to complex techniques, the choice of the option that gives the optimum level of safety among the feasible alternative safety options. In addition to this, the most important technical principle is that of defence-in-depth. This principle requires that there should be layers (structures, components, systems, procedures, or a combination thereof) of overlapping safety provisions. Accident prevention and accident mitigation are natural consequences of the defence-in-depth principle.

Unfortunately unlike the LWRs, e.g. Koeberg NPP, broad international consensus has not been developed in terms of internationally acceptable general design criteria and design rules for the PBMR. No international "off the shelf" package is available for defining the design basis of the PBMR. Of course some rules and criteria were developed during the licensing of HTGRs in Germany, USA have investigated design bases for MHTGR Project, etc., but because there is no commercial HTGR plant existing in the world this work has not yet been finished. Therefore the CNS requested ESKOM to establish and document the General Design Criteria (GDC) and associated design rules for the PBMR using existing documents as guidelines.

Identification of specific documentation requirements and information needed is required across every step of the licensing process and because of the lack of expertise in the development of this documentation for PBMR. ESKOM were advised to use existing documents, mainly from USA and Germany, as guidance for development not only of the general design criteria, but also for a set of others needed for development of the licensing basis. The CNS also requested ESKOM to develop and submit for CNS review, documents describing processes and methodologies used to develop licensing basis documents. Many licensing documents concerning the HTGR have been requested and received by the CNS from US NRC and forwarded to ESKOM.

The CNS itself is currently developing a PBMR Safety Assessment Review Guide for the guidance of CNS reviewers in performing the safety review of application to construct or operate the PBMR nuclear power plants and the review of applications to approve standard design for PBMR nuclear power plants. It also serves the purpose of assuring the quality and uniformity of staff safety reviews. The PBMR Review Plan is being developed by, inter alia, considering the light water reactor edition of the "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants", NUREG-0800, customised to the needs of the PBMR. It was clear that the manpower effort required to undertake a complete, thorough review and modification of NUREG 0800 for application to the PBMR would be substantial, but it was decided that such an effort would be worthwhile. Therefore a significant number of items, which covered a representative range of technologies including fuel and its storage, core, residual heat removal, fission products, radioactive waste management, radiation protection, accident analysis, specific components and structural materials, were completely modified.

The proposed PBMR design is quite different from any other plant operating anywhere in the world today. Thus, although a standard review plan can be produced for this

Table 1: PBMR Basic Licensing Criteria

EVENT	SAFETY REQUIREMENTS	SAFETY CRITERIA
CATEGORY A Category A events (or combinations of events) are those which lead to exposure and which occur with a frequency not less than one in one hundred years (10^{-2} y^{-1}). Such events are treated as part of Normal Operation.	The design shall be such to ensure that under anticipated conditions of Normal Operation, which includes exposures resulting from minor mishaps and misjudgements in operations, maintenance and decommissioning, there shall be no radiation hazard to the workforce and members of the public.	Limitation of individual radiation dose to : **20 mSv** to plant personnel and **250 □Sv** to members of the public All doses shall be kept **ALARA** The principle of **defence-in-depth** shall be applied
CATEGORY B Category B events (or combinations of events) are those which lead to exposure and which occur with a frequency of between one in one hundred years (10^{-2} y^{-1}) and one in one million years (10^{-6} y^{-1}).	The design must be such to prevent and mitigate potential equipment failure or withstand externally or internally originating events which could give rise to plant damage leading to radiation hazards to plant personnel and members of the public in excess of the safety criteria. The analysis performed to demonstrate compliance with this requirement must be conservative.	Limitation of individual radiation dose to : **500 mSv** to plant personnel and **50 mSv** to members of the public All doses shall be kept ALARA The principle of defence-in-depth shall be applied
CATEGORY C Category C events (or combinations of events) are all possible events that could lead to exposure with the exception of those which are treated as part of Normal Operation. As such, Category C events will include Category B events as well as events which occur with a frequency of less than 10^{-6}.	The design shall be demonstrated to respect the CNS risk criteria for plant personnel and members of the public The analysis performed to demonstrate compliance with this requirement must use best estimate data with a supporting uncertainty analysis	Limitation of risk to the values set by the CNS risk criteria. Plant Personnel 5×10^{-5} peak individual risk 10^{-5} average risk Members Of The Public 5×10^{-6} peak individual risk 10^{-8} population risk per site a bias against larger accidents **and** ALARA and defence-in-depth Principle

plant it must be recognised that its development will continue. There are specific aspects that will require additional consideration when reviewing the safety case, because the PBMR is designed to operate at temperatures well in excess of those experienced in other commercial plant, has a fuel embedded in graphite spheres with no metallic cladding, has a helium coolant with no specified impurity limits as yet, and is a direct cycle plant. Thus there are many potential material selection problems and this CNS document will provide guidance as to what additional information the reviewer must seek from the applicant to enable him to complete his review with the necessary level of confidence.

Documentation presented on Figure 1 below the "Top Level Regulatory Requirements" is being developed by ESKOM and fall under the CNS review and acceptance process. The Estimate PRA planed to be submitted in July of this year. The PBMR Safety Analysis Report will be the main document that demonstrates how the PBMR meets the required nuclear safety criteria. The guidance on format, scope and content of Safety Analysis Report was provided to ESKOM and will be discussed in detail during the next month. Revision 0 of the SAR is planed to be submitted at the end of October of this year.

Up to now the first issue of the following documents have been submitted by ESKOM:

- Licensing Manual, containing ESKOM's "Overall Licensing Philosophy for PBMR"
- Glossary of Terms
- PBMR Technical Description
- Proposed General Design Criteria for PBMR
- Proposed list of events/accidents.

These documents have been reviewed and assessed by the CNS. A few briefings and workshops between the CNS and ESKOM have been organised to improve and speed up the review process. Some deficiencies and concerns have been found and forwarded to ESKOM. The main concerns are caused by limited data availability and operational experience feedback for this type of reactor. The CNS has issued a safety evaluation report on the PBMR technical description.

Development of the radiation protection programme has started. It will include:

Staffing and training needs, surveillance requirements, controlled zone classification, demarcation, access control requirements, external and internal dosimetry requirements, protective clothing, change room and laundry specifications, respiratory programme, instrumentation requirements, radioactive material control, decontamination programme, ALARA programme, shielding requirements, computer system requirements, procedures, reporting and record retention, etc.

An emergency plan basis will be produced by ESKOM in the middle of this year.

According to national environmental legislation (Environment Conservation Act, 1989), for any industrial construction an Environmental Impact Assessment (EIA) shall be performed and accepted by Department of Environmental Affairs and Tourism (DEAT). It has been agreed between DEAT and the CNS that CNS will provide technical support to DEAT in evaluation of the radiation impact of the PBMR plant. ESKOM is currently busy preparing an EIA report and two public hearings are already planned for June and September of this year.

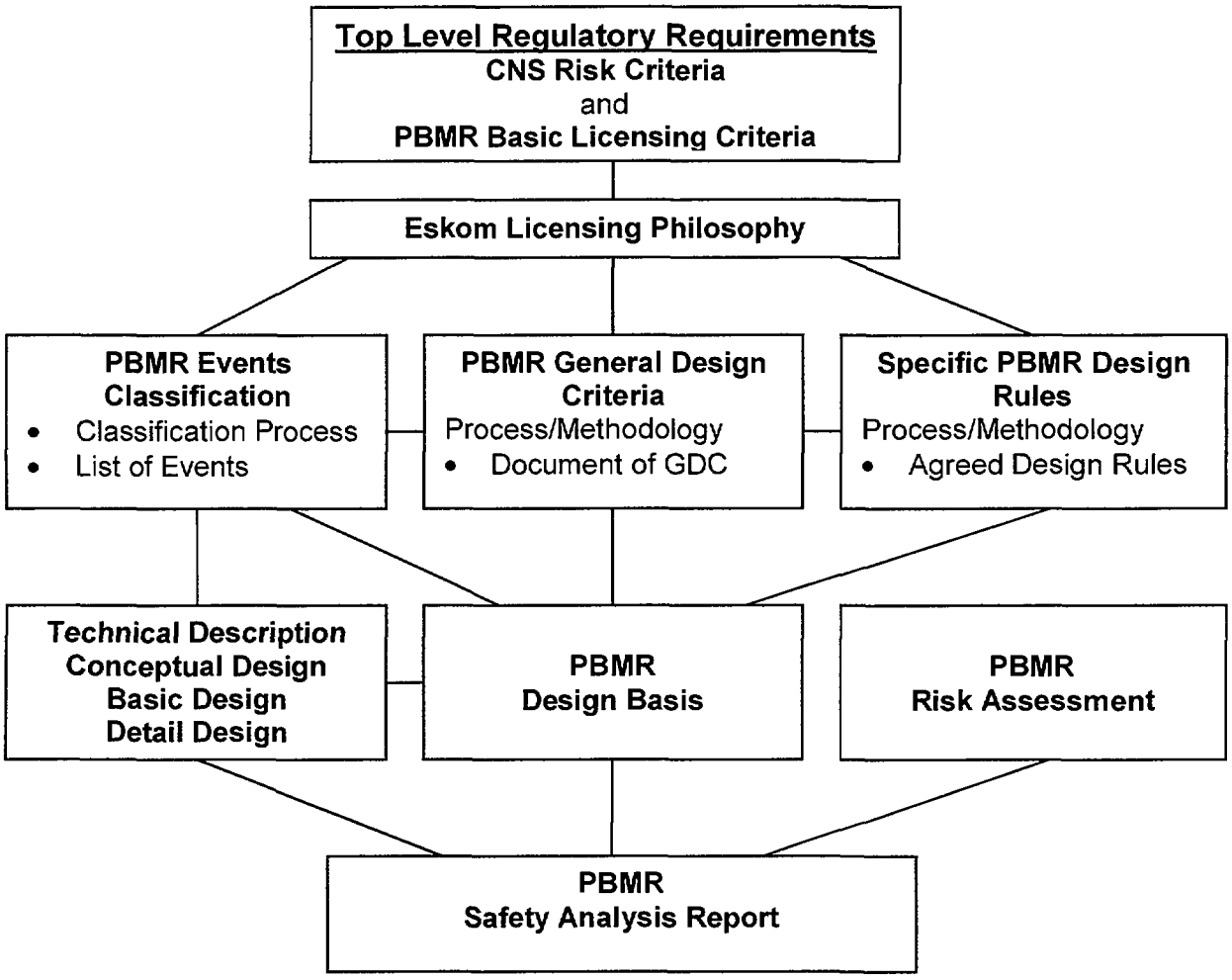

FIG. 1. Documentation forming the PBMR licensing basis.

CONCLUSION

In spite of some inevitable minor delays in the PBMR project development, significant progress has been achieved. Expected completion of the first stage of the licensing process is the end of 1999. The issue of a licensibility statement defining acceptability of the safety bases for the proposed PBMR is expected at the beginning of 2000. This target date is optimistic although not unattainable and is very much dependant on the availability of documentation and information required during the licensing process.

REFERENCES

[1] Eskom Sees a Nuclear Future in The Pebble Bed, Nuclear Engineering International, Vol 43, No 533, December 1998, 12–16.
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[3] Licence Document (LD-1091), Requirements on Licensees of Nuclear Installations Regarding Risk Assessment and Compliance with the Safety Criteria of the CNS.