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PBMR-SA LICENSING PROJECT ORGANIZATION

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Abstract

The South African nuclear regulatory authority, the Council for Nuclear Safety (CNS) is beginning the safety review of the Pebble Bed Modular Reactor (PBMR) design under development by the South African National Electrical Utility, Eskom. This paper describes the CNS licensing process, including the establishment of basic licensing criteria, general design criteria, and specific design rules, as well the safety assessment to be conducted in accordance with the established structure. It also summarises the CNS PBMR review project activities, including the overall organisational arrangements, licensing basis, safety and risk assessment, general operating rules and plant design engineering, and pre-operational testing.

1. INTRODUCTION

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 South African high temperature gas-cooled Pebble Bed Modular Reactor (PBMR).

Eskom, the National Electricity Utility, has officially submitted an application for a staged licensing process requesting that the first stage considers the concept design without any specific site. The CNS will evaluate the acceptability of the safety bases for the proposed PBMR.

The current PWR Koeberg operating reactors, were designed, manufactured, constructed and commissioned according to general design criteria and specific design rules and standards which were prevailing at the time e.g. US 10 CFR 50 and other French rules. These design standards have general international acceptance.

The CNS Licensing approach adopted at the time of licensing the Koeberg reactors required:

- That the design basis of the plant should respect prevailing international norms and practices (as indicated above) and
- That a quantitative risk assessment should demonstrate compliance with the CNS fundamental safety standards.

Based on the outcome of the safety assessment process to demonstrate compliance with the above criteria, conditions of licence were set which included requirements for maintaining a valid safety assessment, configuration and modification control and a series of general operating rules covering operation, maintenance, inspection, radiation protection, waste and emergency planning.

It is proposed that a similar approach should be adopted in respect of the PBMR.

However, unlike the light water reactor situation, the same level of international consensus has not yet been developed in respect of general design criteria and design rules which can be used as an "off the shelf" package for defining the design basis of the PBMR. Nevertheless rules and criteria have been developed during the licensing of some high temperature gas reactors (HTGR) e.g. in Germany.

Thus, as an integral part of the PBMR Licensing process it will be necessary to establish the general design criteria and associated design rules to assure that the PBMR design complies with the current CNS risk criteria which provide for, as a minimum, the same degree of protection to the operator, public and environment that is required for the current generation of nuclear reactors , and respects the observed societal trend to require higher levels of safety with time.[1].

The CNS made an estimate of the time and costs which will be incurred performing all the activities required to reach a decision on the feasibility of licensing a Pebble Bed Modular Reactor.

The activities associated with the fuel procurement or manufacture are not discussed in this paper.

2. LICENSING PROCESS

The process proposed for licensing the PBMR-SA is set down below. The chronology does not necessarily represent the sequence within which the various activities will be carried out. Many of the activities will be conducted in parallel and will be scheduled following further discussions with Eskom.

2.1 Establishment of Basic Licensing Criteria

The first step of the process is the establishment , agreement and documentation of the Basic Licensing Criteria to be applied to the PBMR. The following is proposed:

	SAFETY REQUIREMENTS	EVENT FREQUENCY	SAFETY CRITERIA
a	The design shall be such to ensure that under anticipated conditions of normal operation there shall be no radiation hazard to the workforce and members of the public. This must be demonstrated by conservative deterministic analysis.	Normal operational conditions shall be those which may occur with a frequency up to but not exceeding 10^{-2} per annum.	Individual radiation dose limits per annum of 20 mSv to workers and 250 µSv to members of the public shall not be exceeded. +ALARA+Defence in depth criteria
b	Design to 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 workers or the public. This must be demonstrated by conservative deterministic analysis.	Events with a frequency in the range 10^{-2} to 10^{-6} per annum shall be considered.	Radiation doses of 500 mSv to workers and 50 mSv to members of the public shall not be exceeded. +ALARA + Defence in depth criteria
c	The design shall be demonstrated to respect the CNS risk criteria. This must be demonstrated by probabilistic risk assessment using best estimate + uncertainty analysis	Consideration shall be given to all possible event sequences.	CNS risk criteria apply. $5X10^{-6}$ Individual risk 10^{-8} Population risk Bias against larger accidents. +ALARA

The above criteria are based on current CNS standards which are from time to time validated/benchmarked against internationally endorsed standards. In comparison with safety criteria for PWR plant defined by ANSI/ANS-51.1 standard [2], the criteria "a" covers Plant Conditions (PC) 1-3 and criteria "b" covers PC 4 and PC 5.

In defining the above criteria it will be necessary to establish interpretation statements pertaining to specific terms used in the above table e.g ALARA , Defence in depth , conservative analysis, best estimate , cut off criteria etc.. This will be undertaken by the following process.

Activity #	Description	Responsibility
1	Agree, establish and document the basis for the fundamental approach outlined above	CNS/Eskom

In addition to the above requirements consideration will be given to identify contingency measures for an Emergency Plan.

2.2 Establishment of General Design Criteria and Specific Design Rules

The next step of the process will be to establish the PBMR General Design Criteria and Design Rules. The following are the main steps of the process :

Activity #	Description	Responsibility
2	Set up and agree an event/accident classification scheme/process	CNS/Eskom
3	Concept design proposal	Eskom
4	Identify and agree list of event/accidents applicable to PBMR and classify according to 2 above	Eskom/CNS
5	Establish General Design Criteria for PBMR according to an agreed process	Eskom/CNS
6	Review and agree General Design Criteria	CNS/Eskom
7	Establish guidelines and interpretation of General Design Criteria leading to establishment of Specific Design Rules	Eskom/CNS

2.3 Detailed Design of Plant

The next main step of the process will be for Eskom to propose a plant design in accordance with the above design criteria and rules

Activity #	Description	Responsibility
8	Proposal of a plant design in accordance with above General Design Criteria and Specific Design Rules	Eskom

2.4 Safety Assessment

In accordance with the general CNS Licensing approach indicated in 1.0 above, it is expected that the proposed installation meets specific requirements. These will be formulated and demonstrated in the Safety Assessment.

Activity #	Description	Responsibility
9	Establish requirements to demonstrate compliance with agreed General Design Criteria and Specific Design Rules	CNS/Eskom
10	Establish requirements to comply with CNS risk criteria	CNS/Eskom

11	Establish code requirements and application methodology – e.g. benchmarking, validation etc.	CNS/**Eskom**
12	Carry out and document Safety Assessment to meet the above requirements in 9, 10,11	Eskom
13	Review and evaluate Safety Assessment	CNS

2.5 Establishment and Performance of Prototype Test Programme

Due to the limited operational experience feedback and data availability from this type of reactors it will be necessary to implement a comprehensive step by step test programme to verify/validate some of the critical safety assessment parameters.

Activity #	Description	Responsibility
14	Establish and agree the scope of the test programme	Eskom/CNS
15	Identify and agree on additional hardware to support the test programme	Eskom/CNS
16	Agree objectives and acceptance criteria for the various activities of the test programme	Eskom/CNS

2.6 Establishment of Testing and Inspection Programmes

This step is standard practice in the Nuclear Industry

Activity #	Description	Responsibility
17	Establish and agree Testing and Inspection programme for the manufacturing phase	Eskom/CNS
18	Establish and agree Testing and Inspection programme for the construction phase	Eskom/CNS

2.7 Establishment of the requirements for General Operating Rules - GORs

The outcome of the Safety Assessment will result in the identification and establishment of GORs requirements, which will have to be complied with upon the plant becoming operational:

Activity #	Description	Responsibility
19	Identify, establish and agree GORs requirements. This will include the standard GORs associated with a NPP e.g. Operating technical specifications In service inspection programme Maintenance programme Radiation protection programme Waste management programme Emergency planning Etc..	Eskom/CNS

2.8 Establishment of Quality Assurance Requirements

These QA requirements will apply at every stage of the Project.

Activity #	Description	Responsibility
20	Propose Licensing guidelines for QA requirements	CNS
21	Establish and agree QA requirements to be applied at every stage of the Project	Eskom/**CNS**

2.9 Documentation

As for the above QA step, documentation requirements will be identified at every step of the process

Activity #	Description	Responsibility
22	Establish and agree the format and content of the Safety Analysis Report - SAR	Eskom/CNS
23	Establish and agree documentation requirements	Eskom/CNS

3. PBMR PROJECT ORGANIZATION

To perform the required licensing activities, a corresponding Department has been created as an integral part of the Power Reactor Group of the CNS. The overall CNS Organigram is presented in Figure 1. The main objective of the Department is to undertake the overall control and management of Licensing activities for the Pebble Bed Modular Reactor.

3.1 Organisational arrangements

The organizational structure of the PBMR department and its integration with other CNS divisions is presented in Figure 2. A number of technical subprojects (Projects A-D) have been identified to reflect the project scope indicated in activities above. Each of these subprojects is lead by a Technical Project Leader (TPL), who will use, as required, different technical specialists from other CNS departments.

In order to establish a credible Licensing process, the CNS identified that, due to the lack of expertise in HTGR technology within the current staffing, specialised scientific and engineering services will have to be obtained from competent outside organisations. Thus contacts were established with various organisations who could possibly provide the CNS with the necessary expertise and experience with gas graphite reactor technology. The organisations were selected on the bases of advice solicited from contacts overseas and the involvment we have had up to date with the IAEA group on gas cooled reactors.

Following discussions with the various organisations the CNS is finalising Agreements for specialised technical support services within the particular disciplines key areas relating to HTGR technology and safety assessments with the companies from the following countries: France, UK, Germany and USA. Each company has been "allocated" a specific key discipline:

* Licensing Basis + Nuclear Engineering,
* Materials including Graphite
* Radiation Safety Engineering and Fuel
* Peer review of important safety issues on a case by case basis.

The main activities of the Licensing process as indicated above in Section 2, are reflected in the following sub-projects breakdown.

CNS Organigram

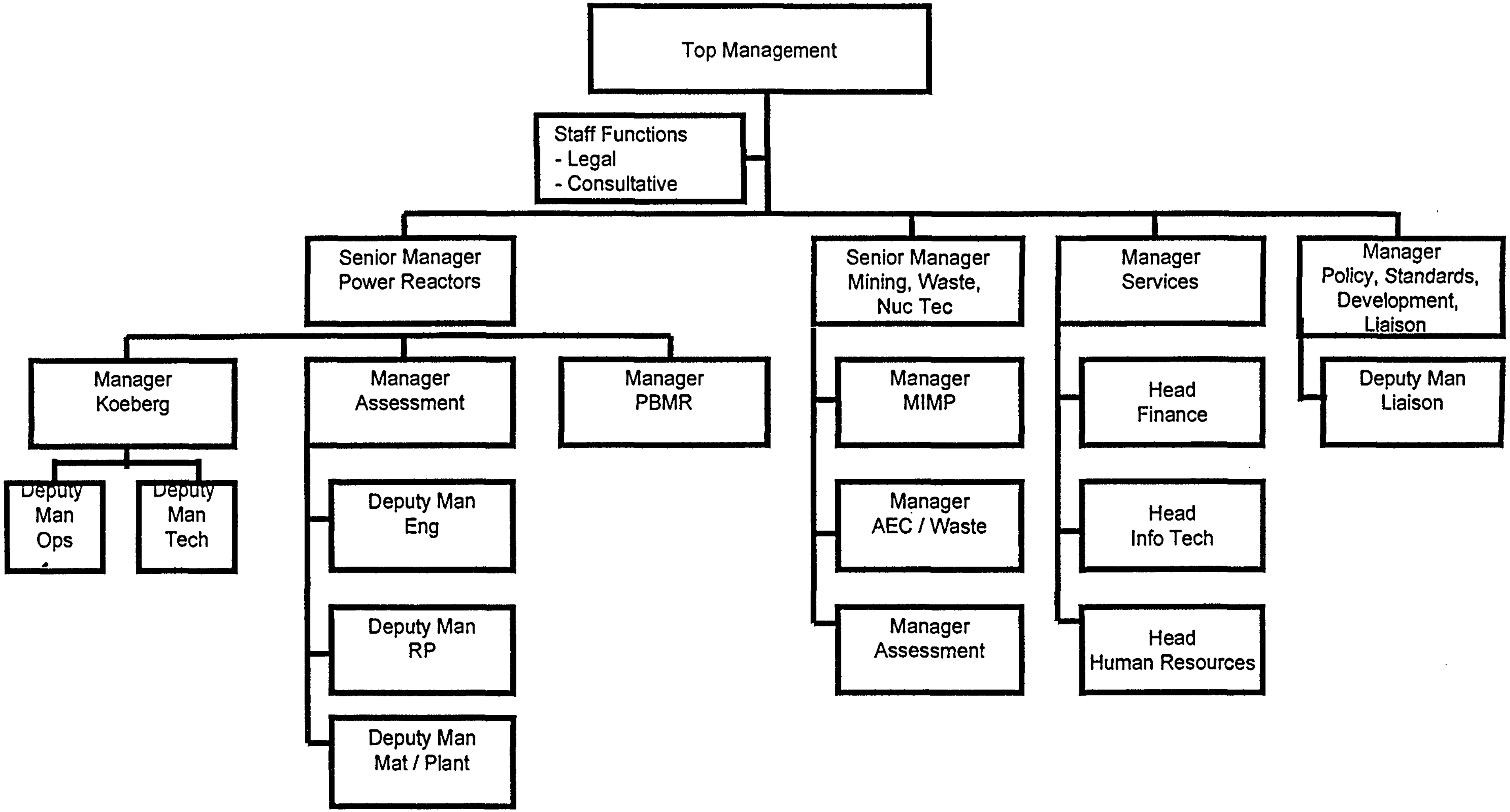

FIGURE 1

CNS PBMR Organisation

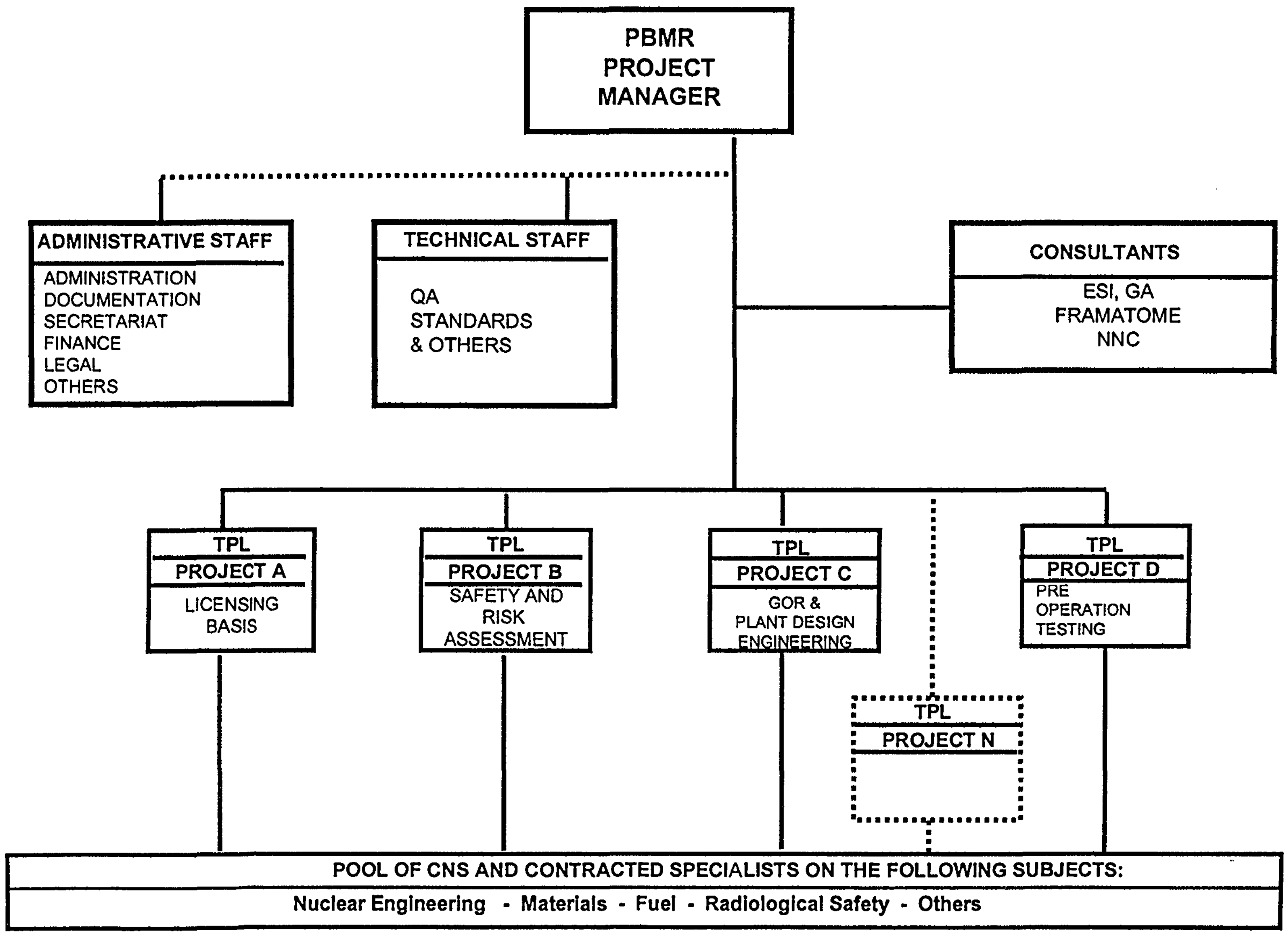

FIGURE 2

3.2 PROJECT A: Licensing Basis

Objective:

to establish rules which will assure that the PBMR complies with the CNS risk criteria.

Scope

- Basic Licensing criteria
- Quality Management
- PBMR design criteria
- Glossary
- Fuel design limits
- Acceptance criteria
- Licensing basis events
- Codes and standards
- Emergency planning requirements
- Format and content of SAR
- Safety Evaluation Review procedure
- Requirements to evaluation models and computer codes
- Treating of uncertainties
- Licence Draft
- Etc

3.3 Project B: Safety- and Risk Assessment

Objective:

Ensure the development, maintenance and evaluation of a valid safety- and risk assessment of the design and operation of the PBMR.

Scope:

- Safety standards
- PBMR-specific criteria, consistent with the CNS's fundamental safety standards and -criteria
- Thermodynamic and heat transfer analyses related to the nuclear safety of the design and operation and consequent thermodynamic behaviour of reactor core, fuel elements and peripheral systems
- Accident- and upset condition analysis (thermodynamics, determination of success criteria for the aversion of the onset of core damage, accident- and event categorization, etc.)
- Fission product behaviour (Release of fission products from fuel elements, fission product transport, dust behaviour [plate out and resuspension])
- Evaluation of defense-in-depth attributes and safety margins
- Accident management
- Emergency Planning
- Risk assessment (initiating events, component- and system failures [fault trees], accident sequences [event trees], plant damage states, accident progression [source terms], consequences, levels 1, 2 and 3 PRA, data analysis, uncertainty analysis) during both full power and low power/shutdown conditions
- Determine attributes and limitations of importance analyses and qualitative ranking methods that are most appropriate for use in screening analyses and in categorization of structures, systems, and components and human activities according to their contribution to risk and safety

- Computational analyses, computer codes evaluation
- Safety analysis report

3.4 PROJECT C: General Operating Rules & Plant Design Engineering

Identify, establish and agree General Operating Rules requirements. This will include the standard GORs associated with a NPP e.g:

- Operating technical specifications
- Operating procedures
- Accident Management
- In service inspection programme
- Maintenance programme
- Radiation protection programme
- Waste management programme
- Emergency planning

Plant Design Engineering:

- Overall safety concept for the plan
- System design
- Assessment of design and its integrity for structures, components, equipment and systems against criteria developed by Project A
- Materials properties and behaviour under operational and accident conditions
- Component performance and stress analyses.
- Maintainability
- Classification of structures, components, equipment and systems

3.5 PROJECT D: Pre-Operational Testing

The main tasks are:

a) Establishment of Prototype Test Programme
The first reactor is to be considered as a prototype plant for which an extensive step-by-step start-up and commissioning test programme will be required. The expected major testing areas are: fuel design, reactor physics, in-vessel-flow distribution and flow-induced vibration, the reactor vessel, the passive heat removal system, the assumptions and shortcoming of the safety analysis.

The main objectives of this test programme are to:

- resolve safety questions in order to proceed to the next licensing stage;
- decrease and justify uncertainties in the design and safety analysis;
- validate evaluation models and computer codes;
- demonstrate and validate expected inherent safety features of the PBMR-SA design.

A preliminary scope of this activity:

- Establish objectives and acceptance criteria for the various activities of the test programme
- Establish scope of programme
- Identify and agree additional hardware to support the test programme
- Identify the requirements for the commissioning program.

b) Establishment of Testing and Inspection Programmes covering the following scope:

- Identify the requirements for the Testing and Inspection Program, prior and during components manufacture, installation e.g. fuel, reactor vessel, graphite etc...
- Establish and agree programme for manufacturing
- Establish and agree programme for construction
- Pre- & In-service inspection.

Additional subprojects will be organised if need arises.

4. CONCLUSION

This paper represents the licensing project organization and conceptual approach which the CNS intends to follow in evaluation of licencability of the PBMR-SA concept. It is considered that this process will determine whether the concept design can meet the CNS licensing criteria and allow the design to be finalised and for Eskom to move on to the next stages of siting and construction.

The positions and conclusions on all matters discussed in this paper are preliminary and are subject to change.

REFERENCES

[1] LICENSING ASPECTS OF PBMR-SA, Paper presented by the CNS at the IAEA TCM on High Temperature Gas Cooled Reactor, "HTGR Applications and Prospects", 10-12 November 1997, Energy Research Foundation (ECN), Petten, the Netherlands. ECN-R—98-004.

[2] American National Standard Nuclear Safety Criteria for the Design of StationaryPresurized Water Reactor Plants, ANSI/ANS-51.1-1983.