Materials Selection

Carbon Based and Ceramic High Temperature Materials in the PBMR Core Structures

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Meeting Approach

- **Issue definition and outcome objectives as described at 1st planning meeting**
- **Materials selection considerations**
  - Carbon-based and ceramic materials
- **Exelon RAIs approach**
- **Next steps**

Philosophy

- **PBMR structures, systems and component material selection shall (in order of preference):**
  - use materials within the limits of a code or standard that the NRC has accepted, or
  - use materials within the limits of a code or standard that has been accepted by a standards body but the NRC has not yet accepted, or
  - use materials that are not incorporated in a code at this time and design from first principles with appropriate supporting qualification programs.

Issue Definition

- **Background**
  - PBMR makes extensive use of materials that conform with codes and standards found acceptable by the NRC in prior applications.
  - PBMR utilizes several materials that, while known to the NRC, are used outside limits previously accepted.
  - In select cases, PBMR uses materials that the NRC has not reviewed.
- **Issue**
  - Demonstrate adequacy of materials selection program by confirming:
    - *Materials selection and operating environment process*
    - *Materials qualification process*
  - Demonstrate adequate understanding of helium chemistry and the impact on component lifetimes and reliability

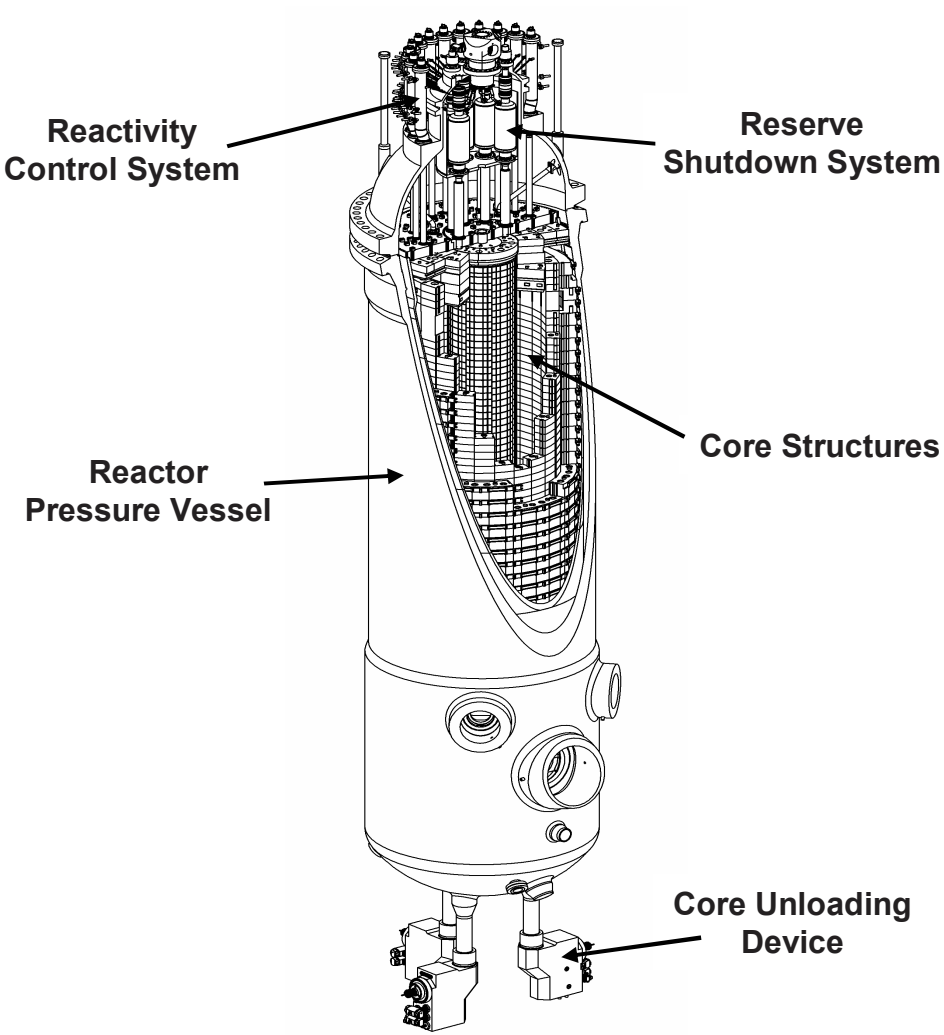
Issue Focus

- **Agreement is required on a suitable process for material selection and qualification.**
- **This issue can be subdivided as follows:**
  - Metallic materials
  - Carbon-based and ceramic materials
- **Processes to be addressed:**
  - Process for material selection, including consideration of operating environment and its effect on the performance of the material, and
  - Process to determine material qualification requirements.
    - *Focus on materials with required performance that falls outside existing codes and standards*
    - *Particular emphasis on confirming adequacy of performance of materials designed to first principles.*

Outcome Objectives

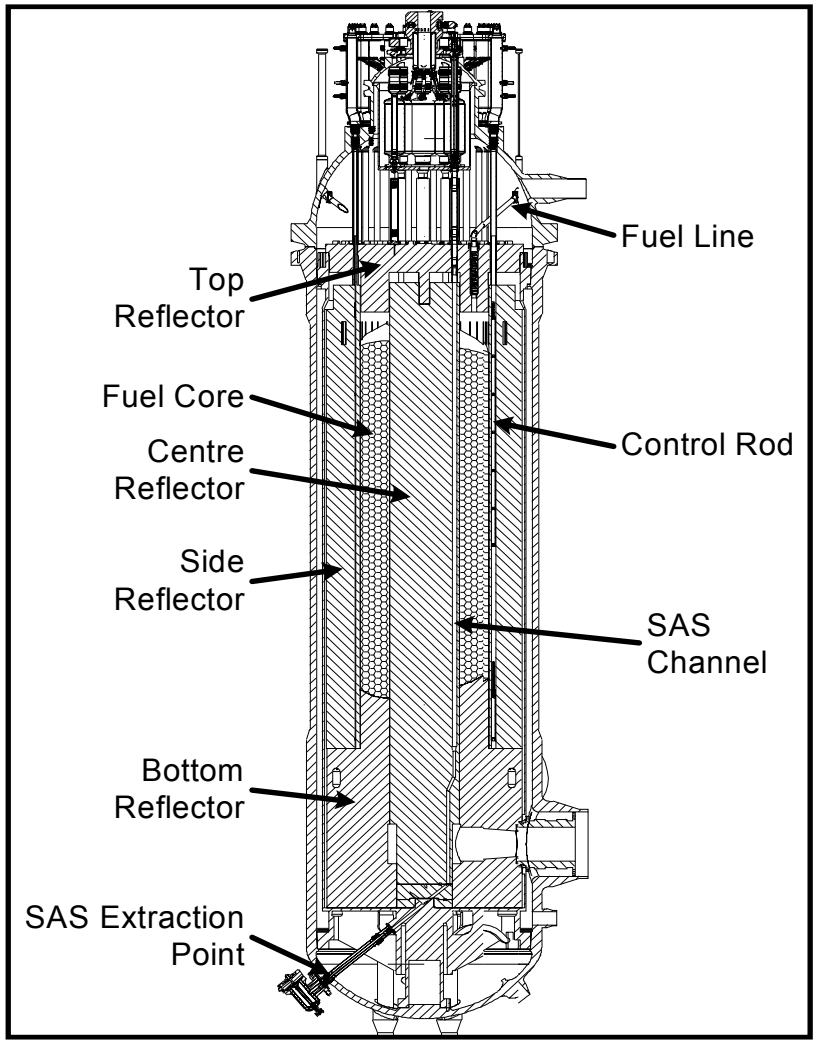
- Agreement on the PBMR approach to materials selection and qualification
- Understanding of acceptance criteria for material qualification programs
- Understanding of the extent of documentation required on the effects of helium chemistry impurities during normal and upset conditions on material performance lifetimes and reliability
- Tied closely to the Outcome Objectives for the Codes and Standards focus topic

Reactor Unit Layout



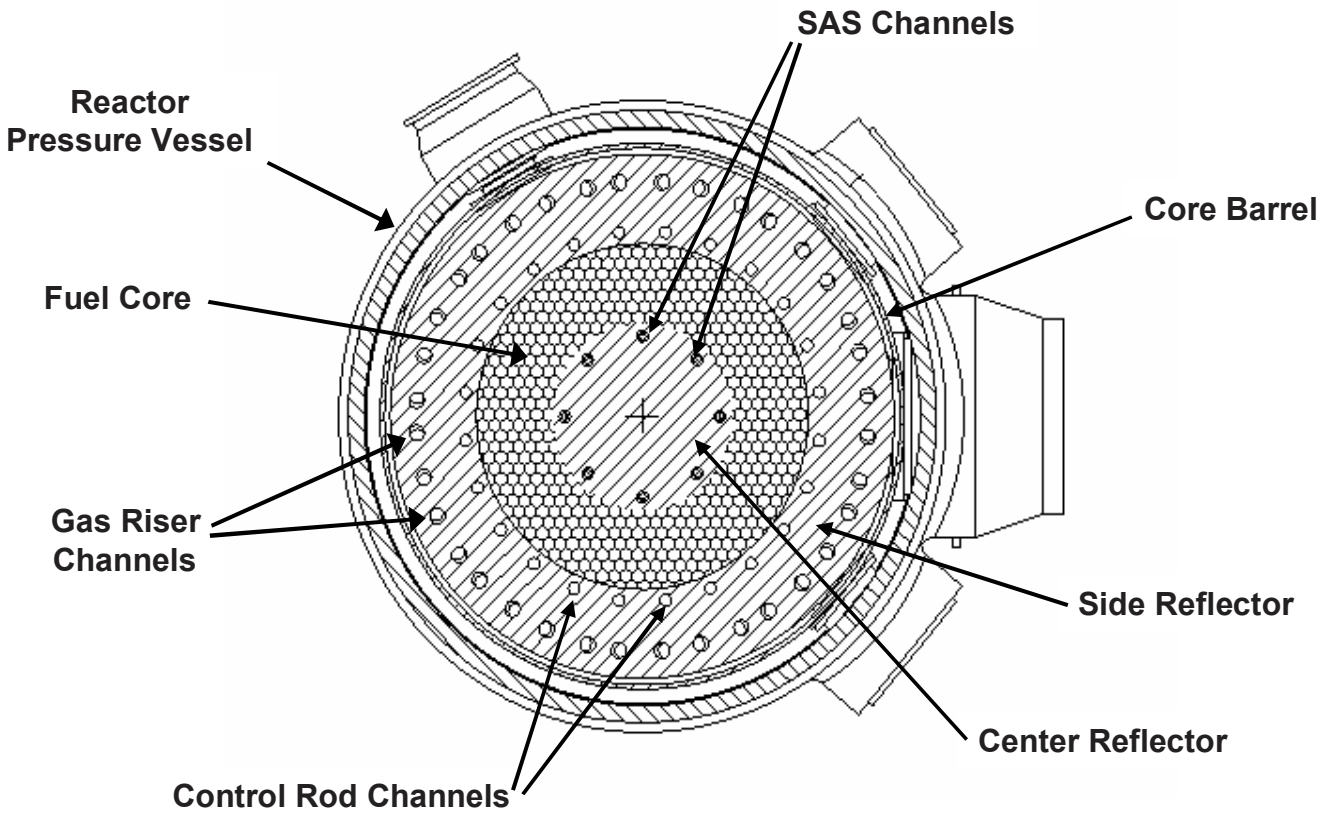
System	Function
Core Structures (CS)	To form and maintain the core geometry
Reactor Pressure Vessel (RPV)	To contain the helium under pressure
Reactivity Control System (RCS)	To control reactivity and shutdown the reactor
Reserve Shutdown System (RSS)	To shutdown the reactor
Core Unloading Device (CUD)	Remove the fuel elements from the core

Reactor Unit Vertical Section

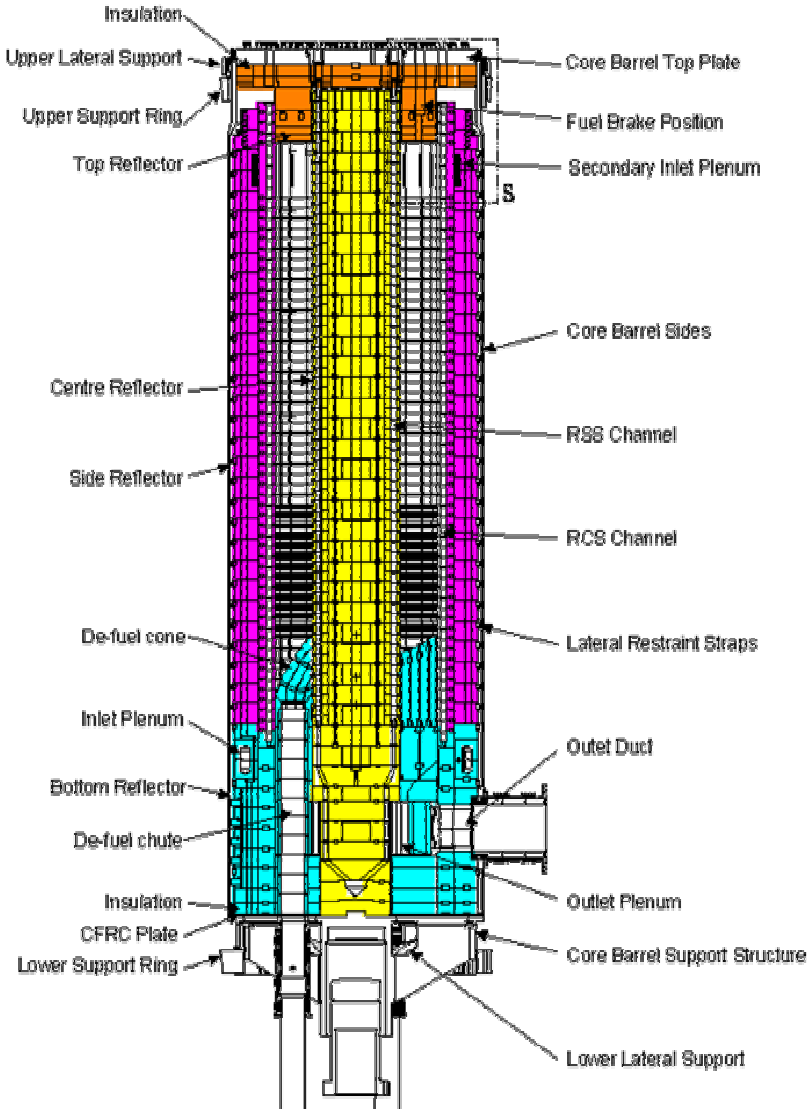


System	Function
Fuel Line	**To feed fuel spheres to the core**
Fuel Core	**The generate heat by nuclear fission**
Bottom, Centre, Side & Top Reflectors	**To reflect neutrons back to the core**
Control Rod (RCS)	**To control the reactivity**
Small Absorber Sphere (SAS) Channel	**To shutdown the reactor**
SAS Extraction Point	**To extract the SAS from the SAS channel**

Reactor Unit Horizontal Section



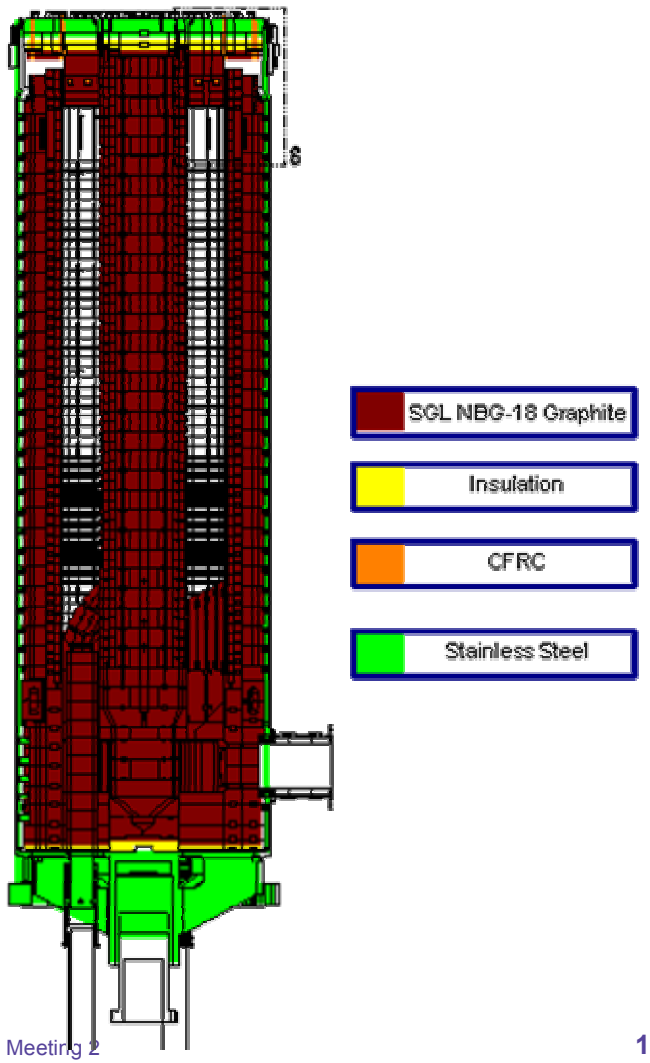
General Arrangement of the Core Structures



Core Structures Materials

Candidate Materials:

- Graphite
  - NBG-18
- CMC's (specifically C-C)
  - SIGRABOND 1501 YR
  - SIGRABOND 2001 YR
- Insulation
  - Carbon
  - Fused quartz
  - Alumina



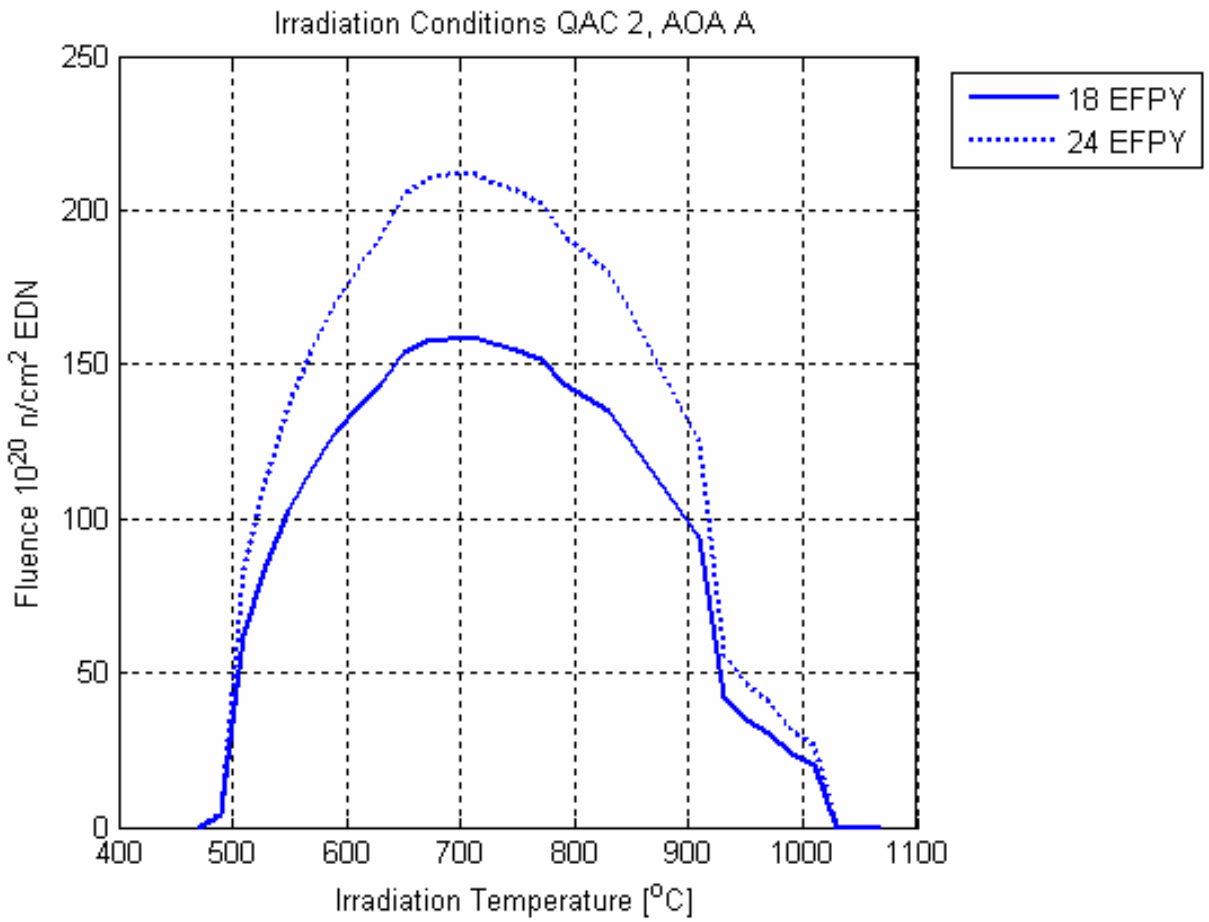
Material Service Conditions

Illustrative temperature and fluence ranges for the PBMR materials (Fluence is based on a 24 FPY target life.)

Component	Material	Temperature (ºC)		Fluence ($x10^{20}$ n/cm^2 EDN)
		Normal	Accident	
Outer Central Reflector	NBG-18	500-1050	1600	220
Side Reflector	NBG-18	500-900	1300	170
Tie Rods	CFRC SIGRABOND 1501-YR	500	1000	< 2
Restraint Straps	CFRC SIGRABOND 2001-YR	500	700	< 2
Rigid Insulation	SiO_2	550	1000	< 0.1

Fluence and Temperature Envelope

Peak reflector fluence values at 18 and 24 FPY



PBMR CSC Material Selections

Material	Type	Usage	Design Code/ Methodology	Material Qualification Required
NBG-18	Graphite	Reflector structures	PBMR Internal – Based on KTA 3232 draft rule	Yes
SIGRABOND 1501-YR	CFRC	CFRC plate for tie rods and protection of insulation	PBMR Internal	Yes
SIGRABOND 2003-YR	CFRC	Lateral restraint straps about the side reflector	PBMR Internal	Yes
Rigid Thermal Insulation	SiO_2 Based	Insulation between the CSC and the core barrel top and bottom plates	PBMR Internal	Yes

Exelon RAIs

Area of Review	Timing	Pre-application Work Item(s)
High Temperature Materials – Graphite		
RAI 1.1.1	1	Workshop discussion topic
RAIs 1.2.1-1.2.23, 1.2.25, 1.2.27-1.2.39	2	
RAI 1.2.40	N/A	This RAI is no longer relevant as the design has changed.
RAIs 1.2.41-1.2.45	2	
Control of Chemical Attack		
I. Graphite		
RAIs 2.2.7-2.2.16, 2.2.18	1	Workshop discussion topic

Proposed Strategy

- **Develop white papers on core design, ceramic material selection; material qualification programs; code development; ISI and component replacement strategy**
- **Items requiring early interaction**
  - The qualification of the materials to be used in the Core Structures Ceramics, specifically the Material Test Reactor programme that is in use for the graphite.
- **Schedule technical workshop(s) addressing the following:**
  - Design Overview
    - *General overview of the CSC, including the design requirements, description of the design and overview of the qualification of the design.*
  - Materials Selection and Qualification
    - *Detail the selection and qualification of the materials that are used for the construction of the CSC.*

Proposed Strategy (Cont'd)

- **Technical Workshop(s) (Cont'd):**
  - Assessment Methodology
    - *The design of most of the CSC components are not provided for in design codes or standards that are in use in the U.S.*
    - *The approach to the design and methodology used for assessments of the parts and components are established, based on various international inputs, by PBMR.*
  - Operations and Maintenance
    - *Description of the operation and maintenance actions required for the operation of the CSC, including:*
      - The surveillance, testing and inspection that will be completed in the course of operating the plant.
      - The maintenance activities, specifically the replacement of highly irradiated CSC components.

Proposed Strategy (Cont'd)

- NRC review and provide RAI's
- Workshop to preview/discuss RAI responses
- Revise white papers and resubmit for NRC final consideration
- NRC complete topic analysis to reach closure on outcome objectives