



# PBMR Design Certification Pre-Application Meeting

US Nuclear Regulatory Commission  
Rockville, Md  
November 3, 2004

# Agenda



- |  |                                |
|--|--------------------------------|
| 1. Agenda and Objectives   | E. Wallace                     |
| 2. Introductory Comments   | Dr. R. Matzie / Dr. A. Ruiters |
| 3. Design Development and<br>Program Status of the PBMR<br>in South Africa | D. Matzner                     |
| 4. Utility and Other Interest in<br>the PBMR                               | Dr. R. Matzie                  |
| 5. PBMR Pre-application<br>Objectives and Planning                         | E. Wallace                     |
| 6. Closing Comments  | E. Wallace                     |



Dr. Regis Matzie

Member, PBMR Board of Directors  
Chairman, Board Technical Committee

# Background



- Global electricity needs are rising at 2.3% per year (2% in US). US supply must increase by 300,000 MW by 2025
- International economic and political stability is dependent on abundant, affordable energy supplies, including electricity without the threat of supply disruptions
- Global warming is increasingly driving the energy choice agenda and nuclear is being recognized as the primary option for minimizing carbon emissions
- Transmission system capacity, reliability, cost and environmental opposition are increasingly influencing supply decisions
- Not all solutions are best met by large capacity plants
- South Africa and China are leading the development of advanced gas reactors using pebble fuel form

# Background



- PBMR is the most advanced commercial gas reactor design on-going in the world, and fits very well in the future US energy supply picture
- There is considerable interest in the US in gas reactors by utility and non-utility companies as a future energy supply option for:
  - Electricity
  - Hydrogen
  - Process Heat
- Utilities won't consider a COL for a plant that won't have Design Certification.
- The US regulatory infrastructure is not currently prepared to license gas reactors and the infrastructure to do so will take a number of years to put in place regardless of the specific gas technology of interest
- Issues surrounding licensing advanced reactors can be more efficiently resolved and tested during the certification review of a real design, e.g.
  - New Regulatory Framework
  - Generic gas reactor topics
  - Safety goals
  - NRC Staff capability and development
- Regulatory effectiveness can be further enhanced through involvement in international programs, facilities and projects focused on gas reactor development



Dr. Alistair Ruiters

Director General, Department of  
Trade and Industry, South Africa

Chairman,  
Board of Directors PBMR Pty LTD

# South African Perspective



- Disappointment of Exelon withdrawal left NRC and PBMR in an awkward position
- PBMR is now a National Strategic Project in South Africa that is going forward
- Serious intentions of SA government
  - Minister of Public Enterprises, Mr. Alec Erwin, was quoted (Sunday, 24 October) in the South African National Sunday Times: *"The government has accepted the proposal to develop and market modular 200MW pocket nuclear power stations using the pebble-bed technology developed in South Africa, and hopes to have the first pilot unit operating, probably at Koeberg near Cape Town, by 2012."* Erwin says the plan is, *"eventually, to produce 4 000MW to 5 000MW of power from pebble-bed reactors around the country. He says initial public offerings (IPOs) will form a crucial part of the funding program, but reiterated that Eskom, Transnet and Denel would remain majority state-owned."* According to the Times, Erwin is expected to make a second round of announcements around January, pertaining to SA Airways, Denel and the Pebble Bed Modular Reactor Program.
- Long standing cooperation between NRC and South African National Nuclear Regulator (NNR) strengthened through PBMR Design Certification
- South Africa is an original member of the International Generation IV Forum and supports the long term peaceful use of nuclear energy
- Multiple government to government nuclear technology agreement discussions reaching final conclusion that will enable greater technical cooperation between US and RSA
- South African government is supporting the participation by PBMR in the DOE INL Next Generation Nuclear Plant project to strengthen scientific cooperation between the two countries

# South African Government Initiatives



- Realigned ownership of PBMR Pty to Department of Trade and Industry (DTI) under the Industrial Development Corporation (IDC)
- Installed Dr. A. Ruiters as the new PBMR Board Chairman. Dr. Ruiters is also Director General, DTI
- Installed Mr. Jaco Kriek as Chief Executive Officer of PBMR. Mr. Kriek is the former Executive Vice President, Projects for IDC
- Reconstituted the Board with additional independent directors
- Committed through the Department of Science and Technology to building the national nuclear capability at university level through the creation of multiple Centers of Excellence for relevant nuclear disciplines
- Committed to nuclear power, in the form of PBMR, as a significant portion of the long term national electric supply plan and response to Kyoto Protocol commitments



# PBMR Customer Value Proposition



1. Overnight construction costs <\$1500/KWe
2. 400 meter emergency planning zone
3. 24 month construction period from first concrete to fuel load
4. Modularity, standardization and life cycle support
5. Proliferation resistant
6. Levelized generation cost <\$35/MWh “all-in”
7. Demonstrated technology
8. Licensed technology
9. Inherent and passive safety, i.e., no active components or AC power
10. International alliances in supply chain and marketing



# Design Development and Program Status in South Africa

Mr. Dieter Matzner

General Manager,  
Power Plant Division

# History of PBMR

## Germany



**AVR (1967-88)**  
**15 MWe**



**THTR (1985-89)**  
**300 MWe**



## South Africa

- 1993** - PBMR evaluation in RSA begins at Eskom
- 1998** - Formation of PBMR Project Team
- 2000** - PBMR ISO9001 Certified
- Eskom LOI for Demonstration Plant & 10 Modules
- Industrial Partners sign Cooperation Agreement
- License & EIA submission
- 2003** - S. African National Nuclear Regulator (NNR) favorable Licensibility Report Issued
- Eskom re-confirms commitment to PBMR publicly as “national strategic project”
- Favorable EIA RoD issued on Demonstration and Fuel Plants
- Preliminary Plant Design Completed
- 2004** - PCU simplified based on results of key supplier tests, new technology



# Current Full Time Staff

PBMR	280
M&RES / S&L	20
IST Nuclear	60
MHI / SGL...	60
Eskom (Client Office)	30
	===
	~450

Total manhours to date	>3,000,000
Total costs to date	~\$175m
	(>\$300m US equivalent)

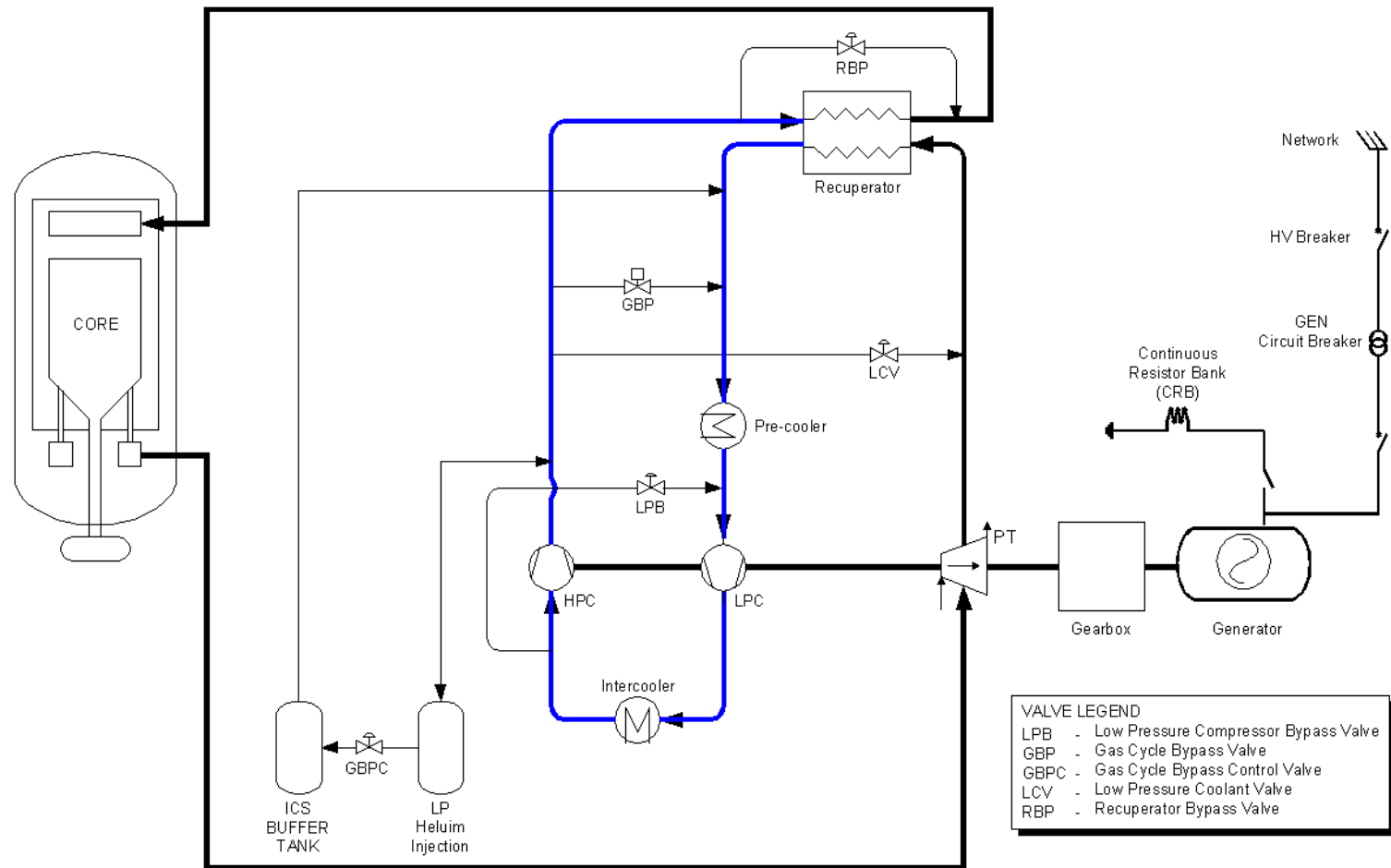
Future staffing levels will be approximately 900 by the end of 2005



# Key Suppliers In a Global Effort

- |   |   |
|---|---|
| <ul style="list-style-type: none"><li>• <b>Mitsubishi Heavy Industries (Japan)</b></li><li>• <b>Nukem (Germany)</b></li><li>• <b>IVV-2M (Russia)</b></li><li>• <b>PBMR Fuel Co. (RSA)</b></li><li>• <b>SGL (Germany)</b></li><li>• <b>BES/Heatric (USA/UK)</b></li><li>• <b>IST Nuclear (RSA)</b></li><li>• <b>Westinghouse (USA)</b></li><li>• <b>ENSA (Spain)</b></li><li>• <b>Hydra (RSA)</b></li><li>• <b>Sargent &amp; Lundy (USA)</b></li><li>• <b>Shaw Group/SWEC (USA)</b></li><li>• <b>Gammametric (USA)</b></li></ul> | <ul style="list-style-type: none"><li><b>Turbo-Machinery</b></li><li><b>Fuel Technology</b></li><li><b>Fuel Testing</b></li><li><b>Fuel Supply</b></li><li><b>Graphite</b></li><li><b>Recuperator</b></li><li><b>Nuclear Auxiliaries</b></li><li><b>Instrumentation</b></li><li><b>Pressure Boundary</b></li><li><b>Gas Cycle Valves</b></li><li><b>Architect/Engineer</b></li><li><b>Construction Consultant</b></li><li><b>Radiation Monitoring</b></li></ul> |
|---|---|

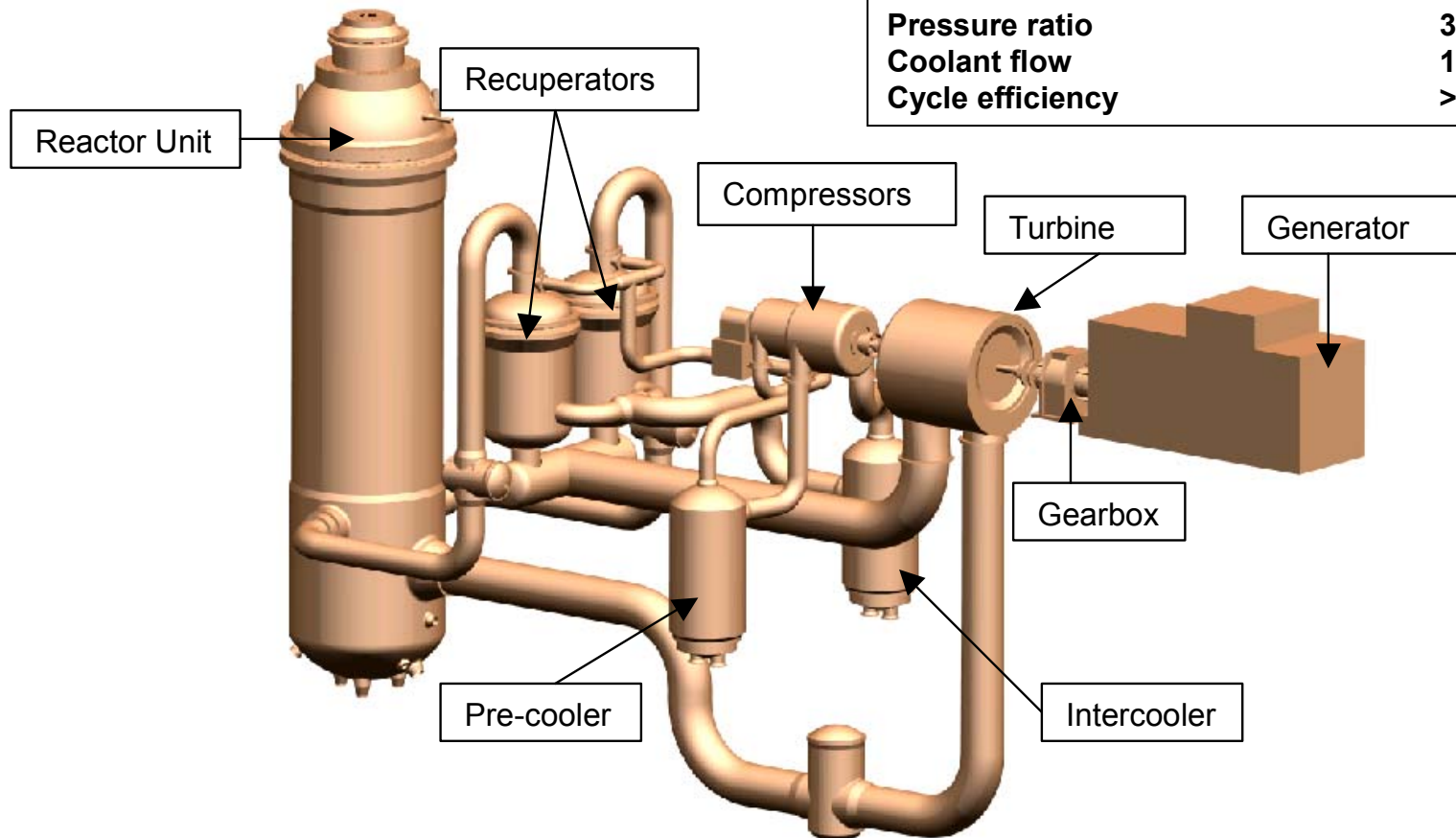
# PBMR Direct Brayton Cycle



# PBMR Main Power System



Power Output	400 MWth >165 MWe
Coolant pressure	9 MPa
Coolant temperatures	900°C outlet 503°C inlet
Pressure ratio	3.2
Coolant flow	193 kg/sec
Cycle efficiency	>41% conservative



# Reactor Unit Vessel Assembly

Control rod drives (RCS)

Side reflector

De-fueling chute

Fueling  
tubes

Small absorber sphere  
containers (RSS)

Central reflector

Annular core

Cold gas inlet

Hot gas outlet

## SPECIFICATION

Total height RPV	30 m
Inside dia. RPV	6.2 m
Coolant	Helium
Max. helium pressure	9 MPa
Normal Ops. temp. of RPV	300°C
RPV vessel material	SA 508 Forgings
RPV mass assembled	~1700 t
RPV vessel mass	1000 t (lid included)

US NRC PreApplication

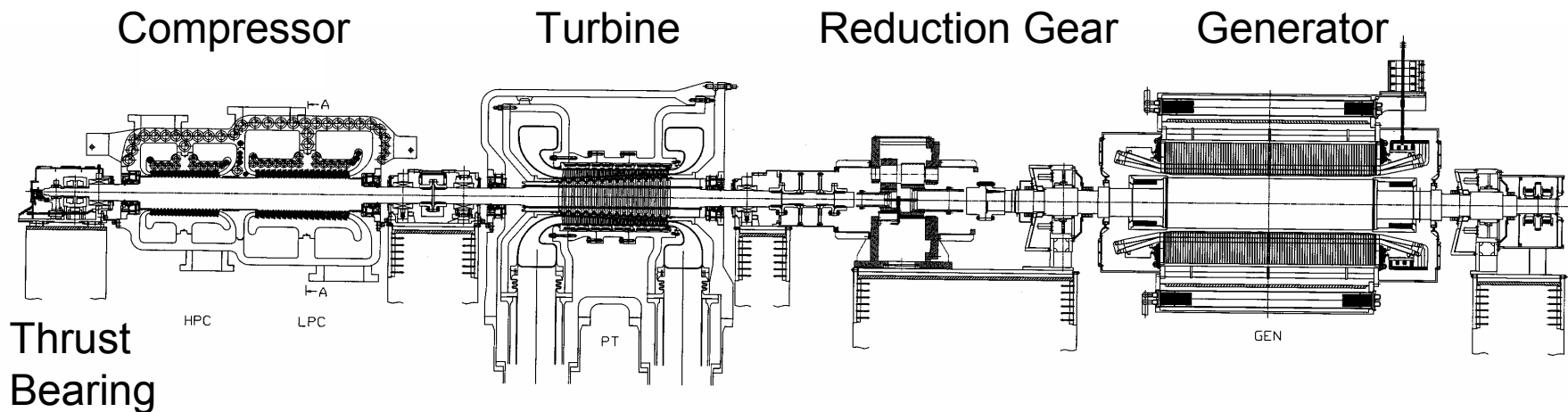
SECTION A-A



# PBMR Power Conversion Unit Design



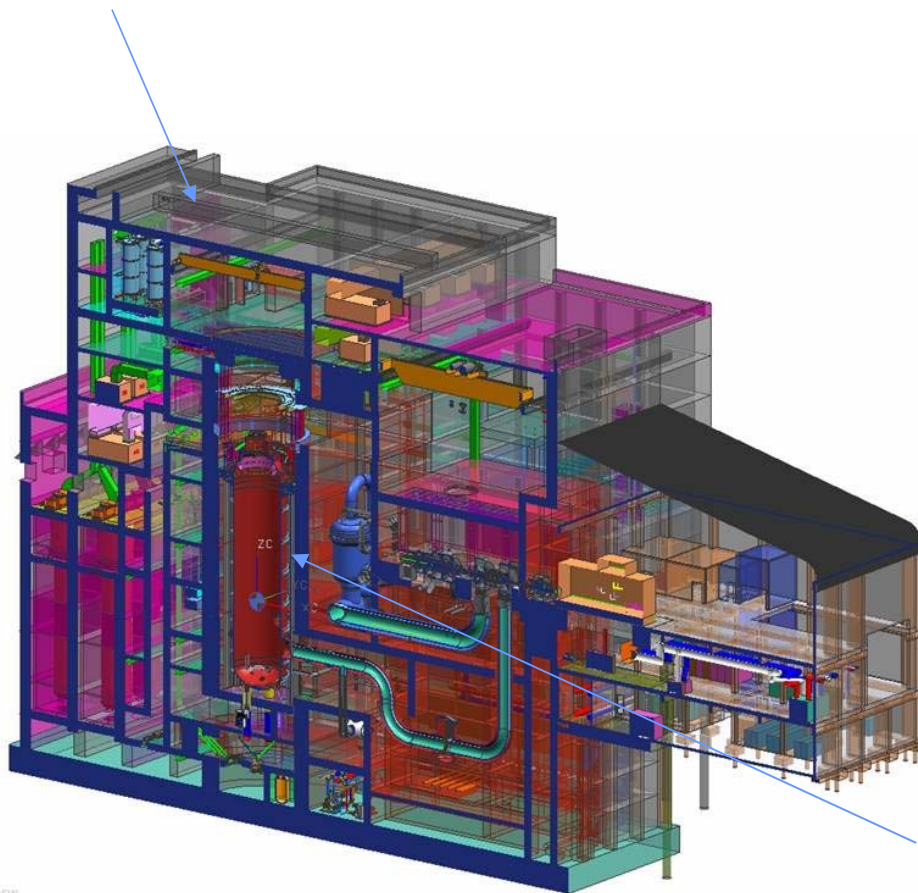
- Single-shaft horizontal arrangement
- Shaft operating at 6000 rpm with reduction gear to 3000 rpm for generator
- Dry gas seals and oil bearings on entire shaft



# PBMR Single Module Building



Outside barrier against  
externally generated  
pressure & impact loads



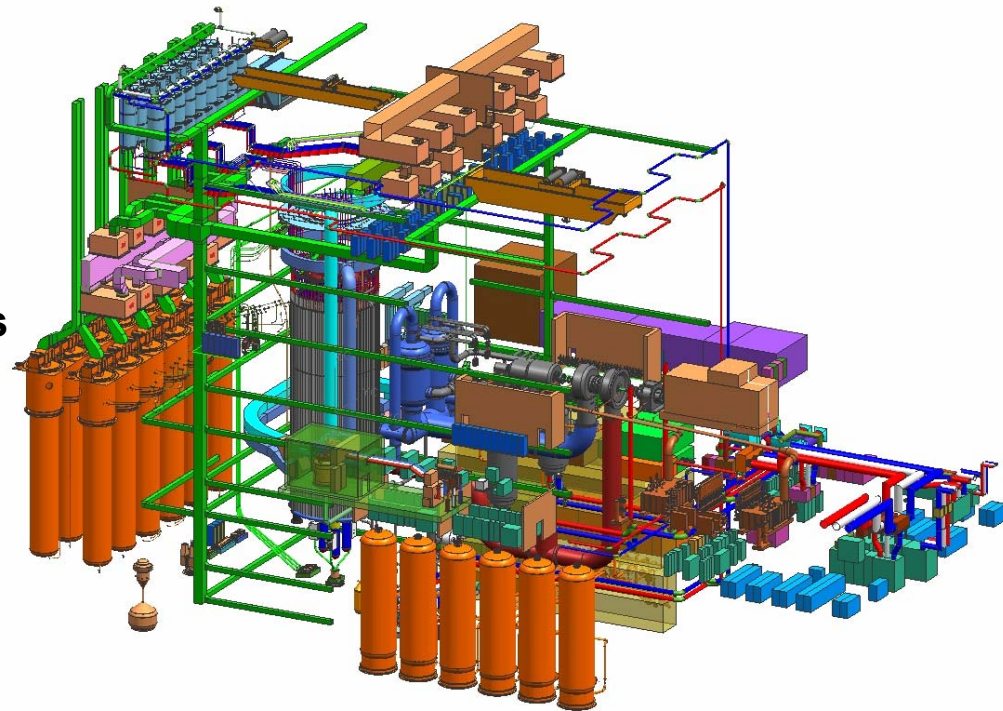
Height total	62.9 m
Height above ground	40.9 m
Depth below ground	22 m
Width	37.0 m
Length	66.1 m
Levels (floors)	11
Material	40 MPa concrete
Seismic acceleration	0.4 g Horizontal
Aircraft crash	< 2.7 ton no penetration; 777 penetration outside barrier; nuclear safety not compromised

Reactor Cavity provides shielding to personnel, provides passive heat sink & acts as a barrier against internally generated missiles

# PBMR is a Mature Design



- Functional design baseline complete
- Detailed P&IDs, bill of materials, component specifications and layout drawings
- Integrated 3D model with over 76,000 model components
- Thermodynamic modeling with state-of-the-art CFD Codes
- Operational modes and states analysis
- Preliminary PRA completed
- Passive safety confirmed by complete set of analyses
- International design and supply team in place



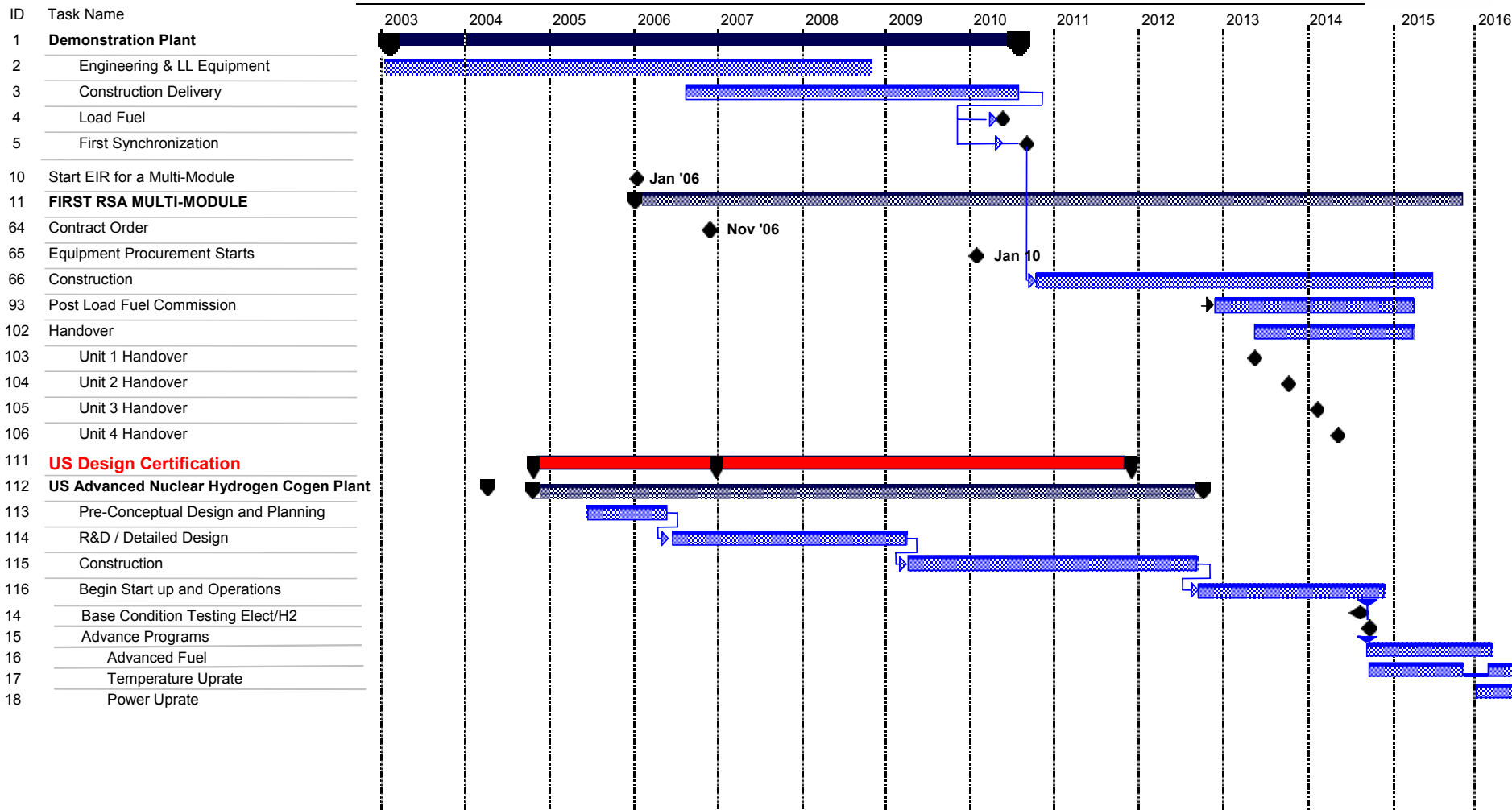
TFR-ISO WORK

# Demonstration Plant Licensing Progress



- South African licensing process is similar to 10CFR50 process
- Initial SAR submittal in December 2001 to NNR
- Revised SAR submittal structure to US R.G. 1.70 format
- Supporting documents (topical report equivalents) are part of the licensing review process
- Agreement on SAR submittal content developed through Key Licensing Issue process; similar to US Pre-Application objectives
- Based on extensive interaction with Eskom and NNR, the revised SAR redraft began in March 2004
- Schedule for complete integrated SAR to South African Regulator by January 2006

# Integrated PBMR Program Plan





# PBMR Development and Testing Program

Mr. Dieter Matzner

# PBMR Development & Testing Program



- The PBMR Development program is an international effort committed to the future of gas reactors. PBMR also supports the development of advanced gas reactor codes and standards under ANS, ASME, IAEA and other nuclear standards committees.
- PBMR has conducted extensive technology transfer program, including prototype testing to assure the application of the prior German experience is a sound foundation for this new direct cycle configuration
- There is an on-going testing program to confirm that all of the PBMR engineering parameters are underpinned and verified
- The large scale PBMR test facilities provide a world class set of platforms for advanced gas reactor testing and open the door for further cooperative efforts in the future.
- The PBMR Development program is an important component of the US Design Certification of the PBMR design
- VHTR potential will be exploited in INL NGNP and follow-on commercial development



# PBMR Development and Testing Philosophy



- Base the PBMR on the technology demonstrated on the AVR, THTR, and other early gas reactors where sufficient successful experience exists
- Utilize materials, components and processes that have a proven nuclear industry track record or proven industrial record to the maximum extent
- Conduct development and testing to address technology applications new to the PBMR nuclear applications or where PBMR conditions go beyond existing industry experience data
- Develop test facilities that are capable of additional confirmatory benchmarking of PBMR Pty analytical codes for the PBMR design conditions
- Utilize the Demonstration Plant for final integrated plant performance and testing and providing the final confirmation of the plant performance and safety



# PBMR Development and Testing Program Elements



## A. Basic Development Testing

- Part and full scale testing of systems and components for PBMR conditions to confirm design approach

## B. Component Development Testing

- Full scale testing of components to confirm performance, reliability and maintenance capabilities

## C. Validation Testing Programs

- Part scale test programs to validate design assumptions and safety codes
- Full scale Demonstration Plant integrated startup and testing program

## D. Advanced R&D Programs

- Focus on improvements in basic plant capabilities and upgrading of design to full VHTR conditions

# Development and Test Program

## Major Elements

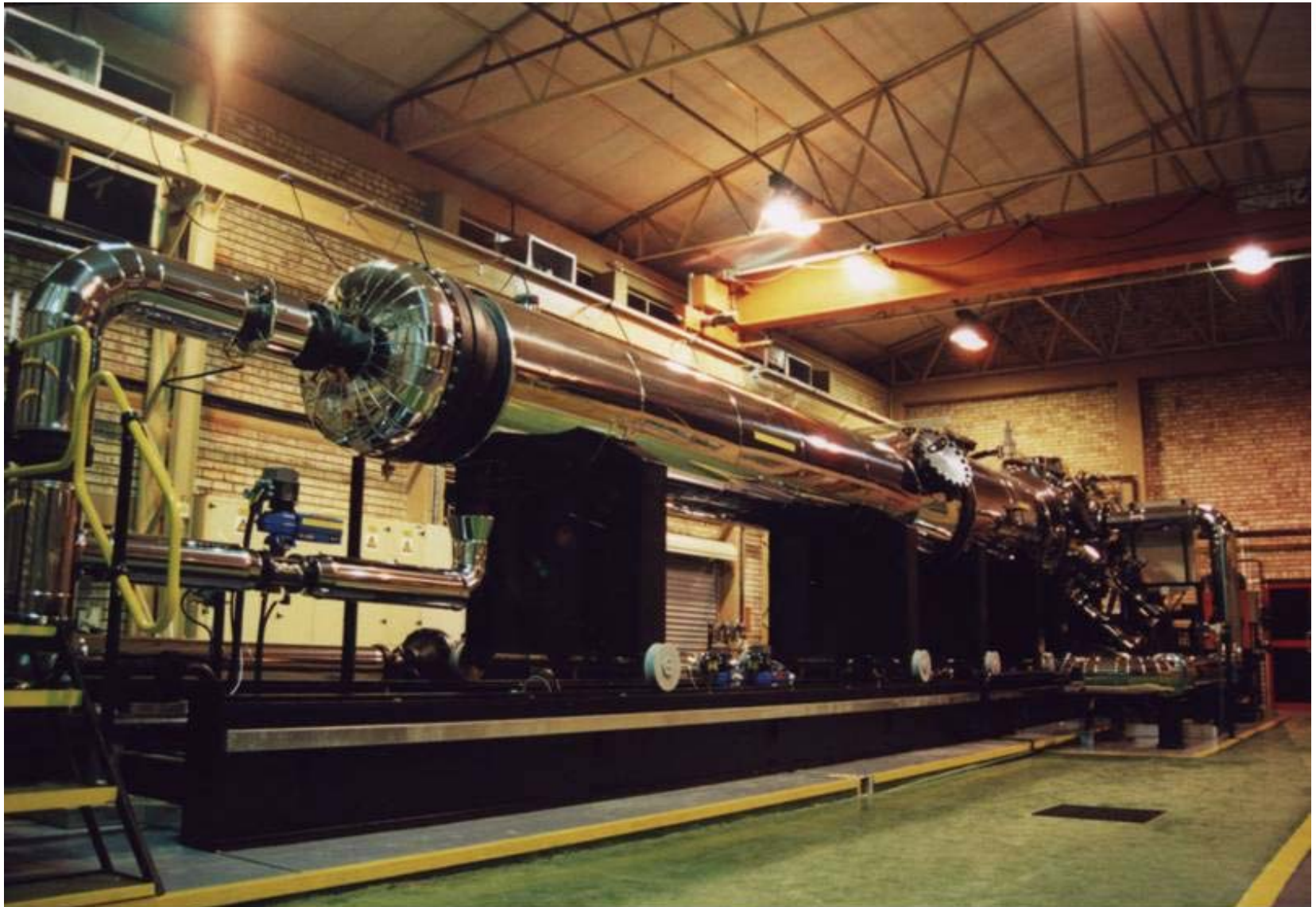


<u>Facility/Test</u>	<u>Test Objectives</u>	<u>Status</u>
Helium Test Facility (HTF)	Reliability, Life Cycle, Steady state and Transient testing of the Reactor Support systems and components in a High Temperature, High Pressure Helium environment	Detail Design Completed – Procurement & Construction to start in late 2004
Fuel Pebble Handling	Pebble Fuel Handling tests included: <ul style="list-style-type: none"> <li>• Demonstrate the operations of a sphere transport system using compressed air (Air Test Loop)</li> <li>• Demonstrate the effective working of the Core Unloading Device (CUD) in the Reactor Unit</li> <li>• Test and verify the double isolation valve for helium applications</li> <li>• Demonstrate performance and accuracy of the Sphere counter</li> </ul>	All tests successfully completed
Valves	Test for valve stiction in a high temperature helium environment	Test was successfully completed and demonstrated
NACOK (Natural Convection in Core with Corrosion)	To investigate the oxidation (corrosion) of hot graphite cores by oxygen under natural circulation following an air ingress event	First two tests in a series of three successfully completed. The third is scheduled for the end of 2004
Heat Transfer Test Facility (HTTF)	To conduct separate effects tests of the heat transfer phenomena in a pebble bed. These tests will provide pebble bed heat transfer correlations to be used in the PBMR analyses software and to build knowledge and experience of the phenomena in a pebble bed.	Pre-conceptual design completed. Awaiting funding for contract placement
Fuel and Materials Irradiation Testing	Add confirmatory data on the performance of PBMR fuel under PBMR reactor normal and accident conditions. Verify PBMR manufactured fuel is of requisite quality and performance. Extend graphite materials knowledge base for long-term performance.	Laboratory Development and Testing (on-going); Pilot Fuel Plant (PFP) design nearing completion. Construction beginning in 2005; Coated Particles testing 2005-7; Pebble testing in 2006+. Graphite testing 2005-7.

# PBMR MicroModel



R





# High temperature CRD SCRAM Shock test



# Power Turbine Dry Gas Seal



	Leakage (l/min)			
	Ductile		Tungsten Carbide	
	IB	OB	IB	OB
<b>Air</b>	137	9.0	102	3.0
<b>He</b>	208	12.4	146	6.7



# Helium Test Facility

## Main Loop Characteristics

### Scheduled Test

Pressure Range 3.2MPa to 9.5MPa

### Main Loop

Temperature Range up to 660°C\*\*

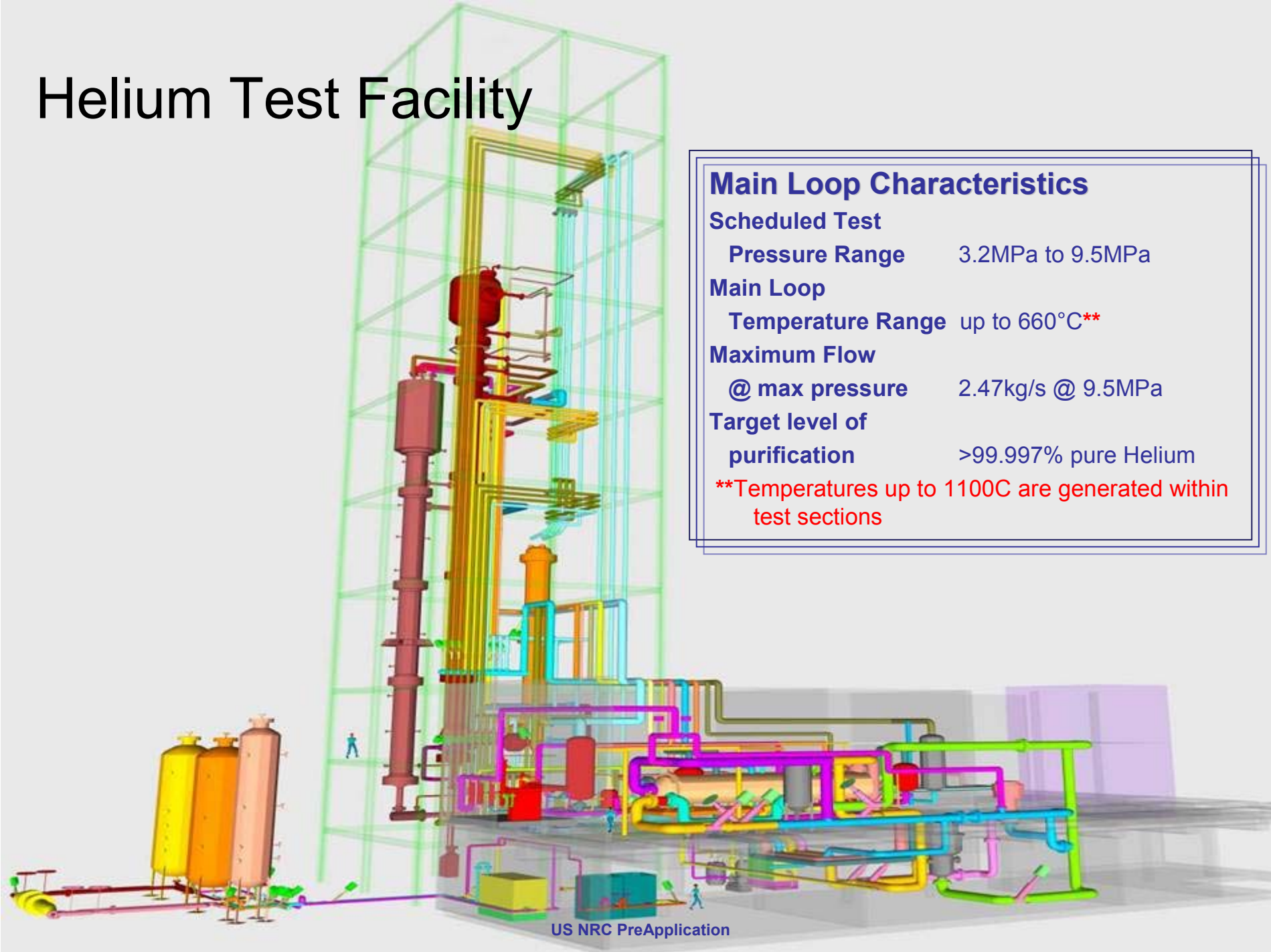
### Maximum Flow

@ max pressure 2.47kg/s @ 9.5MPa

### Target level of

purification >99.997% pure Helium

**\*\*Temperatures up to 1100C are generated within test sections**

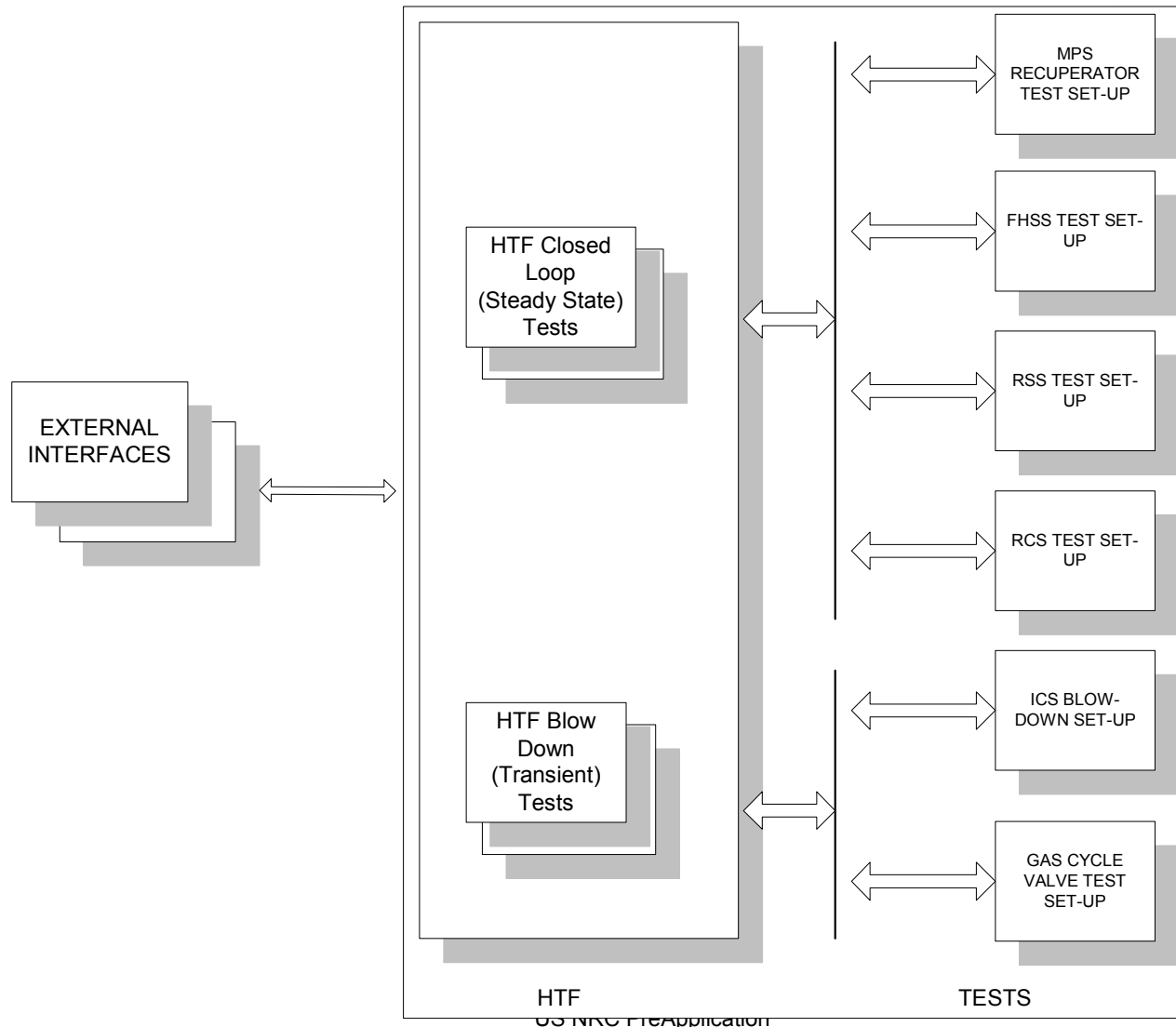


# The Helium Test Facility (HTF)



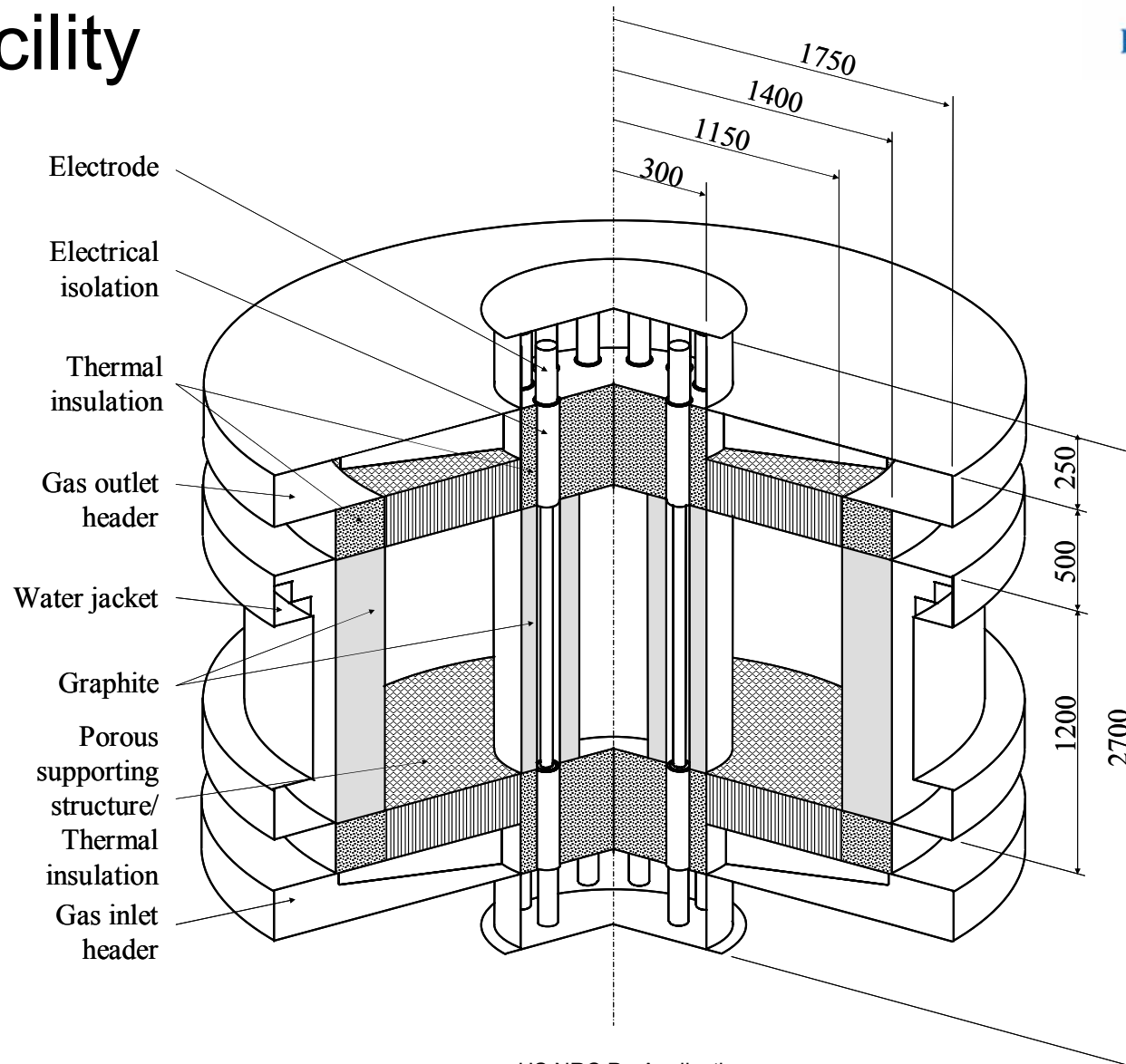
- Objectives of the HTF
  - Steady state and transient tests of functionality in the operating helium environment
  - Life cycle tests
  - Reliability tests
- Test rigs that can be coupled to the main facility are:
  - Fuel Handling System prototype test rig
  - Reactivity Control System prototype test rig
  - Reserve Shutdown System prototype test rig
  - Helium Inventory Control Heat Capacitance
  - Blow Down test rigs
  - Valve test rig

# Helium Test Facility





# Proposed Heat Transfer Test Facility

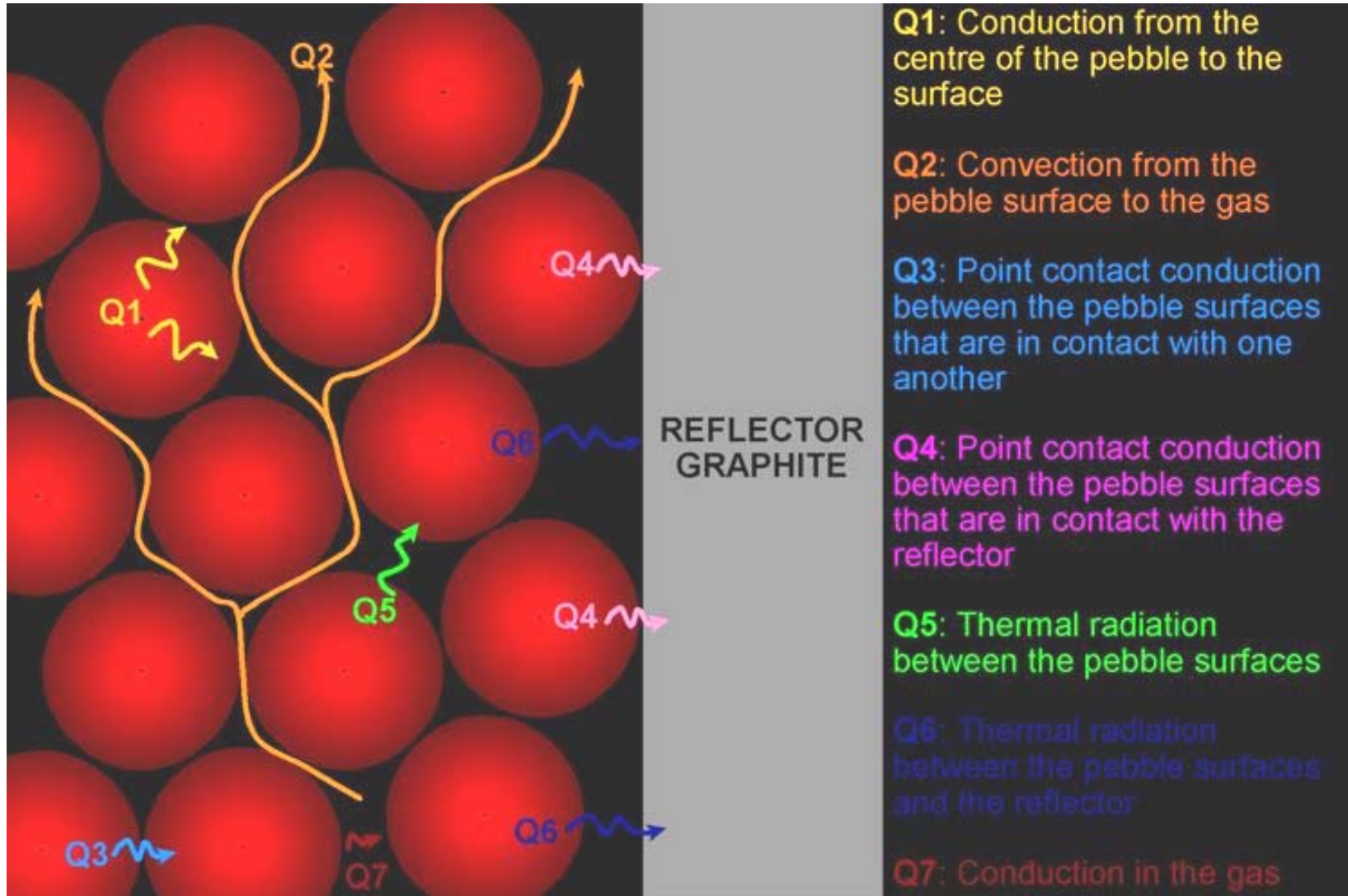


# Heat Transfer Test Facility



The objective of this test is to determine the heat transfer properties of packed graphite pebble beds with heat generation under various cooling conditions.

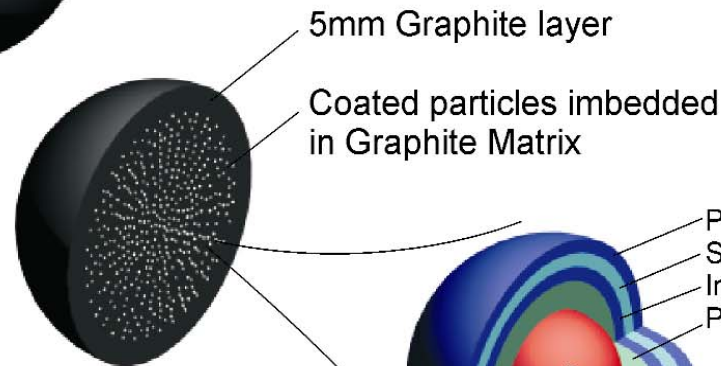
# Pebble Bed Heat Transfer Validation



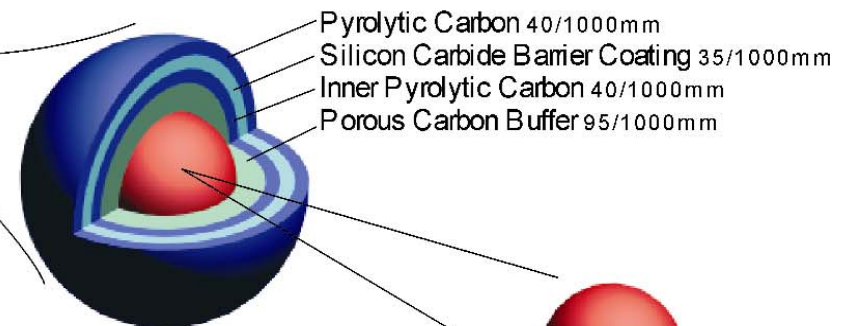
# Fuel Sphere



Dia. 60mm  
**Fuel Sphere**



**Section**



Dia. 0,92mm

**TRISO**  
**Coated Particle**

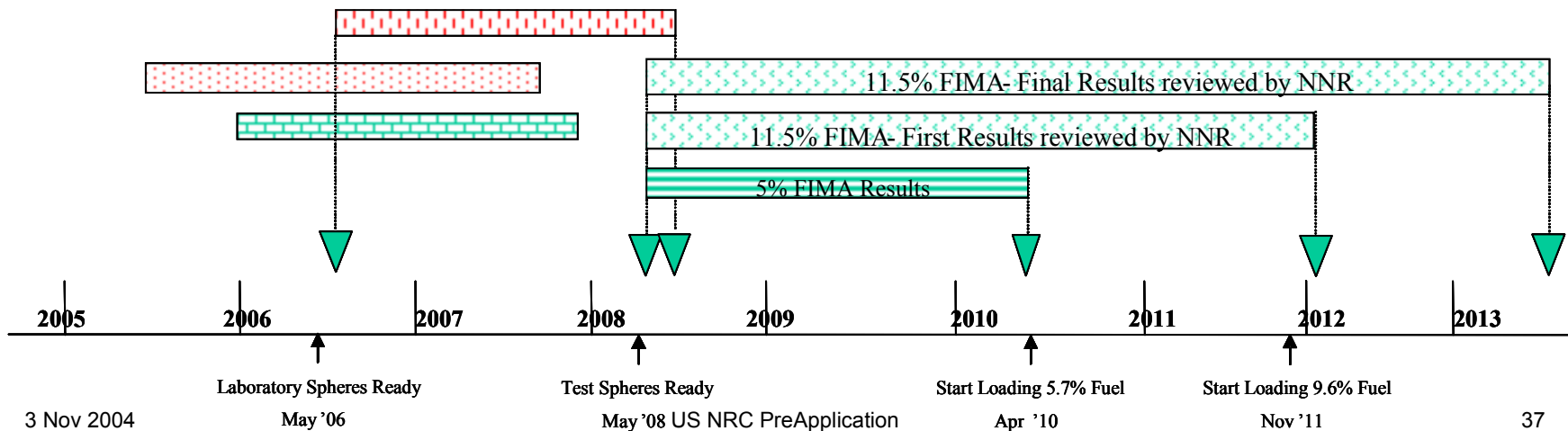


Dia. 0,5mm  
Uranium Dioxide  
**Fuel Kernel**

# Fuel Irradiation Testing Program



Production Fuel	
Allow Reactor Burnup to 5% FIMA	Allow Normal operation of Reactor with Equilibrium Core
4 x FE 5% FIMA Burnup PIE + Heating Mar '08 - Sep '10	12 x FE 11.5% FIMA PIE + Heating Mar '08 - Jul 2013 (1 <sup>st</sup> results reviewed by NNR Feb '11)
Graphite Samples Qualification	
4 x FE 10% FIMA Burnup Pre-production Irradiation (May '06 - July '08)	
Coated Particle Characterisation	



# In Closing on Development and Testing....



- The PBMR D&T program is an essential component for US Design Certification of the PBMR design and must satisfy NRC Staff questions
- The PBMR D&T program is a very substantial, on-going international effort committed to the future of gas reactors. PBMR also supports the development of advanced gas reactor codes and standards under ANS, ASME, IAEA and other nuclear standards committees.
- The large scale PBMR facilities provide a world class set of platforms for advanced gas reactor research and open the door for further cooperative efforts in the future.

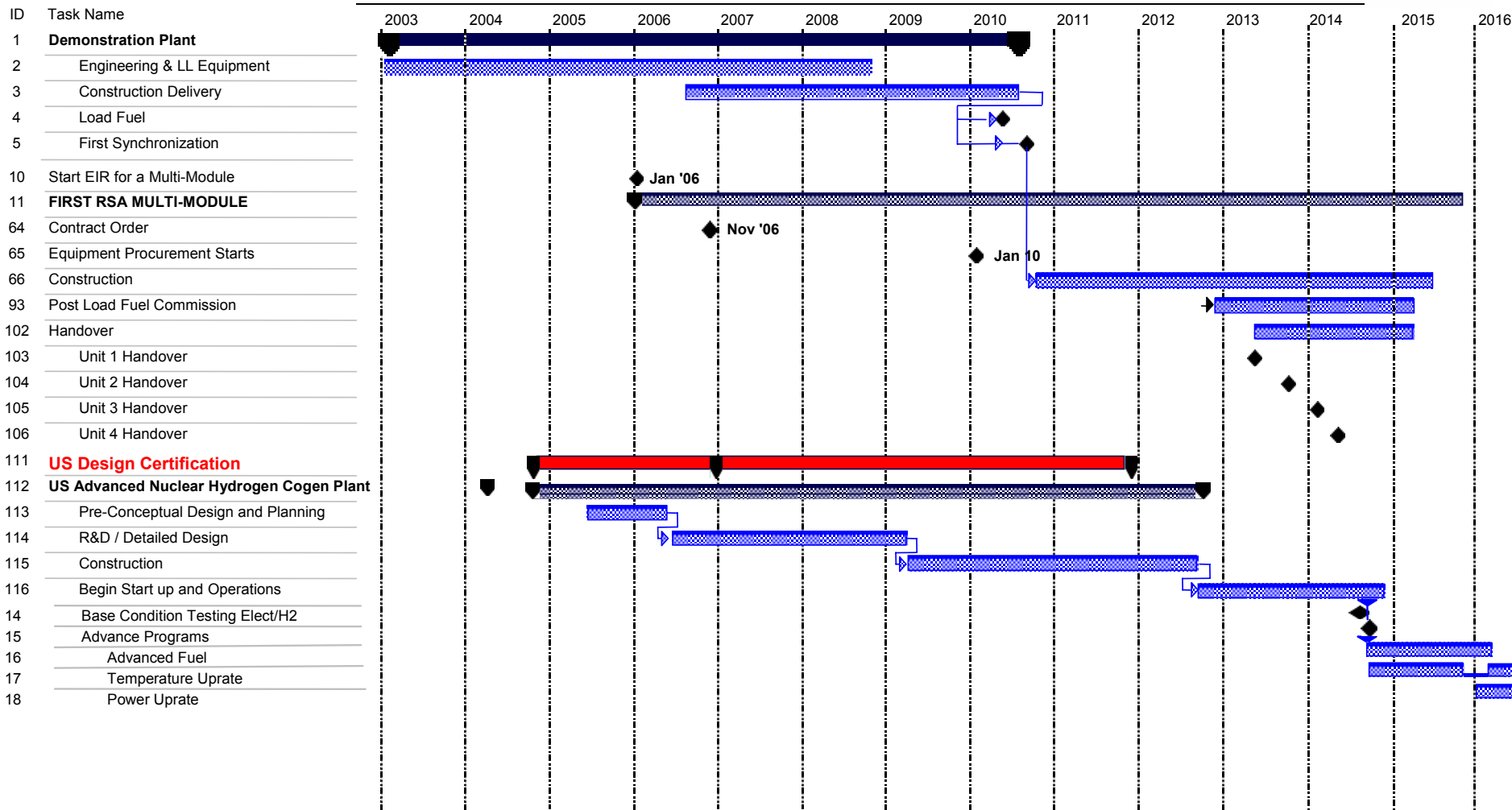


# Utility and Other Interest in the PBMR

Dr. Regis Matzie

Member, PBMR Board of Directors  
Chairman, Board Technical Committee

# Integrated PBMR Program Plan





# US Utility Interests in PBMR



- Utilities are interested in advanced, safer plants with short construction times and improved economics
  - Near term focus on advanced LWR designs via industry initiatives under DOE 2010 Initiative
  - More advanced reactor concepts are of interest when available
- PBMR adds complementary capability where large increments of new capacity are inappropriate
- PBMR design data is included in the 3 Early Site Permit application Power Plant Envelope data sets to allow maximum site flexibility in future supply decisions
- Utilities have expressed continuing interest in the DOE NGNP program including hydrogen generation potential. PBMR is a candidate design for the NGNP project
- PBMR creation of US Utility Advisory Group with 7 US participants; first meeting begins this evening, November 3, 2004

# Other Interests in PBMR



- Department of Energy-NGNP Program
  - PBMR among candidate designs for NNGP per DOE Independent Technology Review Group report in 2004; viable designs all HTGRs
  - DOE intent to license the NNGP with the latest revised NRC processes as though it is a commercial plant
  - Congressional interest in NNGP/hydrogen economy could bring the NNGP delivery earlier than DOE's published plans compressing the time for NRC to build capabilities in gas reactor licensing
  - PBMR pre-application and design certification would identify and in many cases resolve generic issues that NNGP would face later
- Non-utility energy consumers are studying nuclear options for process heat applications
- US and International Standards Organizations
  - ANS, ASME, IAEA all proactively developing codes and standards for high temperature gas reactor applications in support of new advanced gas reactor designs
  - The new global supply market drives the need for maximizing common standards to allow the most efficient regulatory environment



# Pre-Application Planning

Mr. Edward Wallace  
Sr. General Manager – US Programs

# Design Certification Pre-Application Objectives



- Complete a Design Certification application for commercial PBMRs as soon as possible to support US utility long range planning evaluations
- Establish a clear path forward for PBMR / HTGR licensing in US
- Completely clarify key issues identified in Exelon pre-application work relevant to a PBMR Design Certification application
- Identify any new issues that require pre-application work
- Identify any further development and testing required for PBMR certification in the US

# Benefits to NRC of PBMR Design Certification Review



- NRC staff resources and capability for gas reactor licensing can be developed over a manageable period working with a real applicant, a complete design and ultimately, a working demonstration plant
- Effective pre-application planning and issue clarification lead to more efficient and effective regulatory process, and the early identification of long term rulemaking requirements
- PBMR design certification would be the first opportunity to utilize and test a New Regulatory Framework that is risk-informed, technology-neutral and performance based
- Prepares NRC to support a national initiative for advanced gas reactors and hydrogen cogeneration
- NRC review supports the development of international cooperation with Gen IV countries that are also interested in HTGR development and regulation; and leverages scarce NRC Research resources
- Continues to support NRC leadership position in global nuclear safety regulation
- Provides a ready opportunity to develop the NRC Chairman's international regulatory cooperation initiatives

# Pre-Application Planning



- Focus on limited issues unique to PBMR; much more limited than Exelon scope
- Rely on industry / generic initiatives where appropriate
- Conduct effective resource planning with NRC Staff to avoid start/stop events by either party
- Multi-phase DC approach
  - Scope and Resource Plan Nov 04 - Jun 05
  - Focused Technical Exchange Jul 05 - Jun 06
  - Staff Position Papers Jul 06 - Dec 06
  - Complete Pre-Application Dec 06
  - PBMR Prepare DC Submittal Jan 06 - Dec 06
  - Submit DC Application 1Q 2007
  - Conduct DC Review 2Q 2007 – 4Q 2011
- Minimal impact on NRC Staff during pre-application phase
  - Estimated resources in FY05 for planning ~1-1.5 FTE
  - Estimated resources in FY06 for pre-application reviews ~3-5 FTE (less than Exelon review as Owner Issues not part of scope, and RAI base exists to work from on key issues)

# Potential Pre-Application Topics



- SSC Classification/Defense-in-Depth
- LBE selection methodology and analysis assumptions
- Fuel Design and Qualification
- Applicable Codes and Standards & Materials Selection
- Analytical Codes V&V Methodology
- Single Module vs. Multi-module Certification



# Specific Follow-On Activities



- PBMR – NRC conduct preliminary planning meetings beginning in January 2005 to:
  - Confirm pre-application scope of individual issues
  - Identify any additional NRC Staff issues for pre-application work
  - Establish review objectives and outcomes for each issue to guide DC application content
  - Establish preliminary schedules for submittals, reviews and position papers
  - Estimate resources based on agreed scope
  - Identify any early policy issues for Commission consideration

# Closing Comments



- Gas reactors are going to be built globally; US Utilities will want to have a gas reactor option once demonstrated
- The NRC regulatory infrastructure for gas reactors and advanced reactors requires long term development; and dealing with a real, completed design will be the most effective way to complete that development
- Other NRC initiatives are benefited by engaging in PBMR DC
  - Technology neutral framework
  - International regulatory cooperation
  - Preparedness for INL NGNP licensing



# Exelon / Other Issues List



## **Technical Items that exclude owner issues:**

- Fuel Design and Qualification - 3
- Materials Qualification, Codes and Standards – 6, 7
- Analytical Codes V&V - 4
- Core Design and Heat Removal - 5
- Air and Water Ingress - 14
- Radiological Source Term - 10

## **Additional HTGR Issues that are generic that PBMR will engage in with Industry**

- Containment -16
- Prototype Testing -12
- Security
- Licensing Approach/Framework - 1
  - Deterministic and Probabilistic processes
  - Regulatory Guide Compliance
  - Identification of new RG for HTGR
  - New policy or rulemakings needed

# Exelon / Other Issues List



**Other issues dealt with by Exelon that are of interest to owners and should be brought to the NRC by Utility Owners include:**

- Decommissioning Funding – 2d
- Anti-Trust Reviews – 2f
- Decommissioning Cost - 2e
- Fees – 2b
- Multi-module License Type / Durations - 2c
- Operator Staffing -2g
- Price Anderson Insurance – 2a
- Fuel Cycle and Transportation – 2h

**Issues raised by Exelon that are not being addressed:**

- Safeguards - 9
- Control Room Design - 8
- Operational Modes and States - 13
- Control Room HFE / Staffing -2g
- Spent Fuel Characteristics - 11
- In-service Inspection / Testing – 15