Advanced High Temperature Reactor Project – PBMR relaunch

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• PBMR was based on demonstrated German High Temperature Gas Cooled Reactor (PBMR) technology.

• The business case developed by McKinsey & Co in 2002, based on the 400MWth design developed by PBMR (Pty) Ltd, showed a large international market, being competitive with fossil fuelled plant at the then hydrocarbon prices (~$20/ton coal and ~$3/GJ natural gas).

• The nuclear safety level for the PBMR was significantly higher than is claimed for any current nuclear power plant (in service or under construction) such that engineered safety systems and off site emergency planning were not required.

• The construction schedule for the PBMR was in the order of 24 months from pouring concrete to synchronization (Sargent & Lundy).
Options for Future Development

• When the PBMR was defined in the mid 1990s it was based on the German industrially demonstrated technology.

• The PBMR approach was to avoid any fundamentally new technologies and to move directly to the “demonstration” reactor which would by essentially a first of class of the commercial design.

• One of the key elements of the PBMR work was the confirmation that fuel to the required specification could be built locally at NECSA.

• Many lessons were learned from the development of the design of the PBMR. Given the South African fuel performance and the technological advances since the original German work, there is great potential to build on the PBMR technology base to achieve higher safety and economic performance.
Options for Future Development

PBMR Migration Path in ~2004

Current Technology Regime

- 400 MWe 950°C
  - Safety Case
  - IHX Hydrogen Process
  - Codes and Standards (60 y)
  - Demonstration Plant

Future Technology Regime

- 400 MWe 1200°C
  - Fuel
  - Control Rods
  - Graphite Lifetime
  - RPV and Core Barrel Material
  - Reactor Outlet Pipe Liner
  - Turbine Blade/Disc Material Development
  - Material and Component Qualification
  - Codes and Standards (60 y)

- >500 MWe
  - >1200°C
  - Fuel
  - Graphite Lifetime
  - Optimization of Commercial Margins
Design a nuclear reactor for the grid demands of the future.

- Plant should fit various size grids.
- Flexible to follow load changes.
- Adaptable to various demand side requirements.
- Simplified construction and maintenance.
- Safe without engineered safety systems.
- Economic – maximise efficiency, reduce costs.

*Advanced High Temperature Reactor - AHTR*
Combined cycle - He and super-critical Rankine

55-60% eff.
AHTR 100: Process diagram with direct Helium Brayton Cycle, Molten Salt Energy Storage, Steam Turbine and Dry Cooling Tower.
Example of Impact of Molten Salt “Battery”

Electrical Production over 24 Hours
100MW Nominal Plant, 30MW GT, 70MW ST (ave)
6 hours MS Storage, 140MW installed ST

Variable Output from Steam Turbine using molten salt storage
Steady State Output from Helium Gas Turbine
PCPV with Power Conversion Unit (GT & Hx) above the Pebble Bed Reactor Core
Turbine, compressor and Hx

- Generator unit
- HX2 and compressors
- Turbine unit & HX1
Pre-stressed Concrete Pressure Vessel opening with PCU unit - simplify maintenance
PCPV – vertical and horizontal stresses at 9MPa

Brick Stress: TT (MPa)
-1.378 [Bk:31736,Nd:5350]
-4.125
-15.133
-26.140
-37.148
-48.156
-59.163
-70.171
-81.178
-92.186
-103.193 [Bk:55152,Nd:4]

Brick Stress: ZZ (MPa)
2.665 [Bk:33856,Nd:41306]
-2.873
-3.950
-25.026
-36.102
-47.179
-58.255
-69.331
-80.408
-91.484
-102.551 [Bk:55152,Nd:4]
AHTR concept guiding principles

Achieved through:

- Pebble Bed Reactor – Proven concept, simple core, limited dynamic requirements, no load following with reactor.
  - No active safety systems – reduce costs
- Combined cycle – use of He turbine to provide plant base-load, bottoming HX-combination to provide secondary circuit load following.
  - Almost double efficiency.
- Heat storage in secondary circuit for plant flexibility.
  - Heat storage allows nominal 66% load following without change in reactor power. (Plant maintains full power output on average – ideal for base and peak supply). Can be expanded.
  - Modular for adapting to different grid demands.
AHTR concept guiding principles

Achieved through:

- Use of pre-stressed concrete pressure vessel at proven at 9MPa.
  - Factor 5 cost reduction of pressure vessel - local construction.
  - Complete PCPV civil construction before core structure installation.
  - PCPV allows for cost reductions and removes core reconfiguration failure mode.
- He up flow allows deep burn-up with once-through fuel cycle.
- Modular power conversion unit, allows 5 day maintenance outage.
- Online refueling – no refueling outage.
- Increase efficiency, reduce capital costs.
- Ideally suited for heat applications – Desalination, Hydrogen production, supports reducing carbon emissions in the fossil fuel industry.
AHTR Work Packages for 2016 focused on establishing design concept. 2017 focus on material qualification and developing design concept.

2016 focused on design concept:
1. System modelling
2. Physical design
3. Fuel Characterisation
4. Pre-stressed Concrete Pressure Vessel development
5. Licensing Framework
6. Passive Cooling System
7. Cycle Optimisation

2017 will focus on material qualification and developing design concept:
1. Material selection and qualification
2. Core physics design
3. Power Conversion Unit Design
4. Pressure Vessel Design
5. Control Systems Design
8. Manufacturing processes, including 3D printing.
9. Auxiliaries
10. Centre for High Performance Computing to implement HTR codes