Pebble Bed Modular Reactor
Project Overview

October 10, 2002

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Purpose of Discussion

- To familiarize US NRC with the ongoing progress of the PBMR project, and to share PBMR's plans for design certification for consideration in NRC long term planning

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Agenda

- PBMR History
- Key Strategies
- Recent Design Improvements
- Plant Summary Description
- Design Process
- Major Development Testing
- Fuel Supply Strategy
- Project Status and Milestones
- Investors
- Strategic Suppliers
- Licensing Status
- Business Case Summary
- Suggested Cooperative Development

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PBMR History

- 1993 PBMR evaluation in RSA begins based on HTR technology and 3 shaft, direct cycle design
- 1995 Pre-feasibility study
- 1998 Formation of Project Team
- 1999 Start Detailed Feasibility Study
- 1999 Eskom LOI for Demonstration Plant & 10 Modules
- 2000 RSA Cabinet support and Commercial Partners
- 2000 License & EIA submission
- 2001 SAR Rev 1 submitted to NNR
- 2002 Uprate to 400 MWth
- 2002 September Business Case Completed (McKinsey)

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Key Strategies

- Competitive economics
- Strict adherence to standardization
- Use of international strategic suppliers
- Module repetition on 3-4 months timescale; rapid learning curve
- Short construction period
- Minimum market disruption
- Deployment of distributed generation
- Use of simple systems and operations
- Minimum required maintenance
- Achieve inherent safety
- Small emergency planning zone

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Recent Design Improvements

- Uprate to 400 MWth (165 MWe)
- Fixed Central Graphite Reflector rather than Dynamic Reflector
- Three refueling exit paths/chutes together with a simplified and more maintainable Fuel Handling System
- Dry gas seal between turbine and generation
- Conventional oil thrust and catcher bearing on generator rather than magnetic bearings
- Preliminary multi-module (8-pack) general arrangement design
- Revised core structure design with stainless steel core barrel and carbon fiber composite restraints

Plant Target Specification

• Rated Power per Module	165 MW(e)
• Eight-pack Plant	1280-1320 MW(e)
• Continuous Stable Power Range	40-100%
• Load Rejection w/o Trip	100%
• Construction Schedule (nominal)	24 months (first module)
• Short and Infrequent Outages	30 days per 6 years
• Seismic	0.4g
• Overnight Construction Cost	$1000-1200/kWe
• Fuel Costs	$4.1/MWh
• O&M Costs	$5/MWh
• Emergency Planning Zone	<400 m
• Availability	>95%

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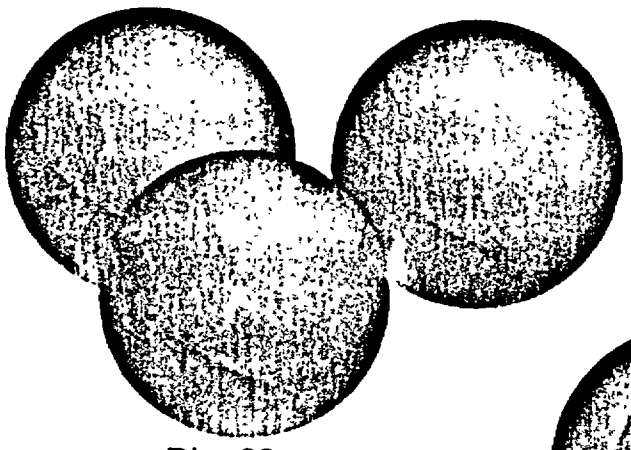
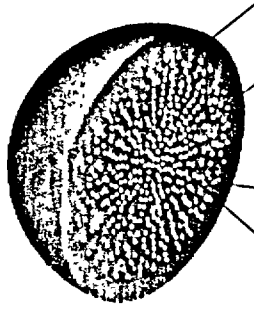
Fuel Element Design for PBMR



Dia. 60mm

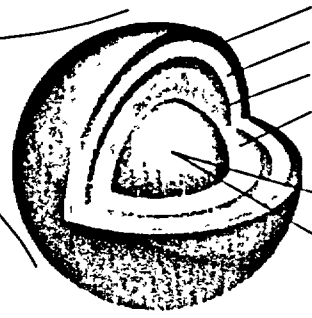
Fuel Sphere



5mm Graphite layer

Coated particles imbedded in Graphite Matrix

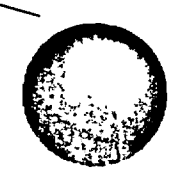
Half Section



Pyrolytic Carbon 40/1000mm
Silicon Carbite Barrier Coating 35/1000mm
Inner Pyrolytic Carbon 40/1000mm
Porous Carbon Buffer 95/1000mm

Dia. 0,92mm

Coated Particle



Dia.0,5mm
Uranium Dioxide

Fuel

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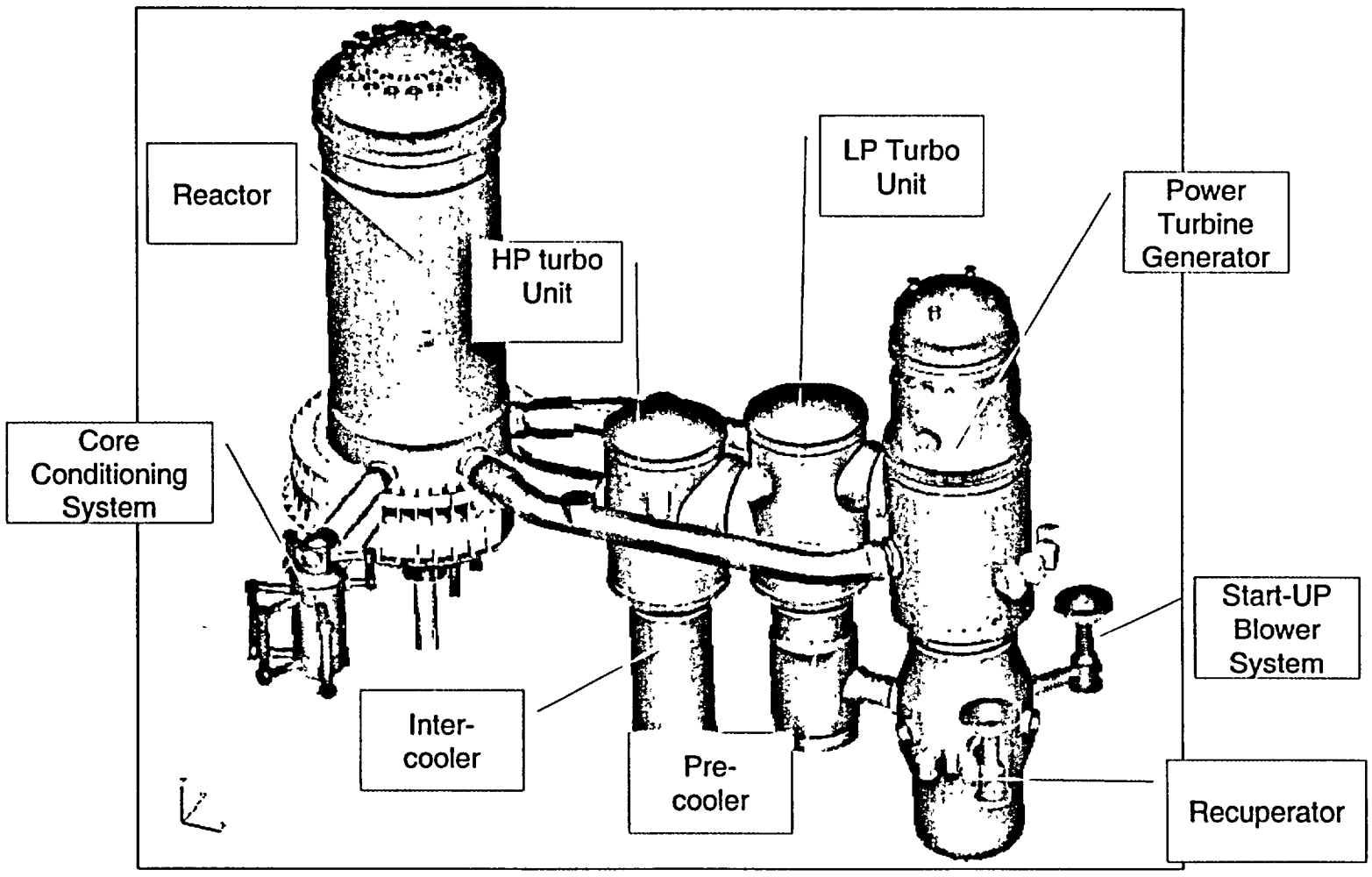
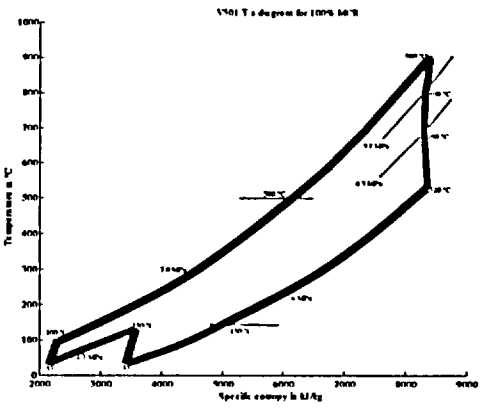
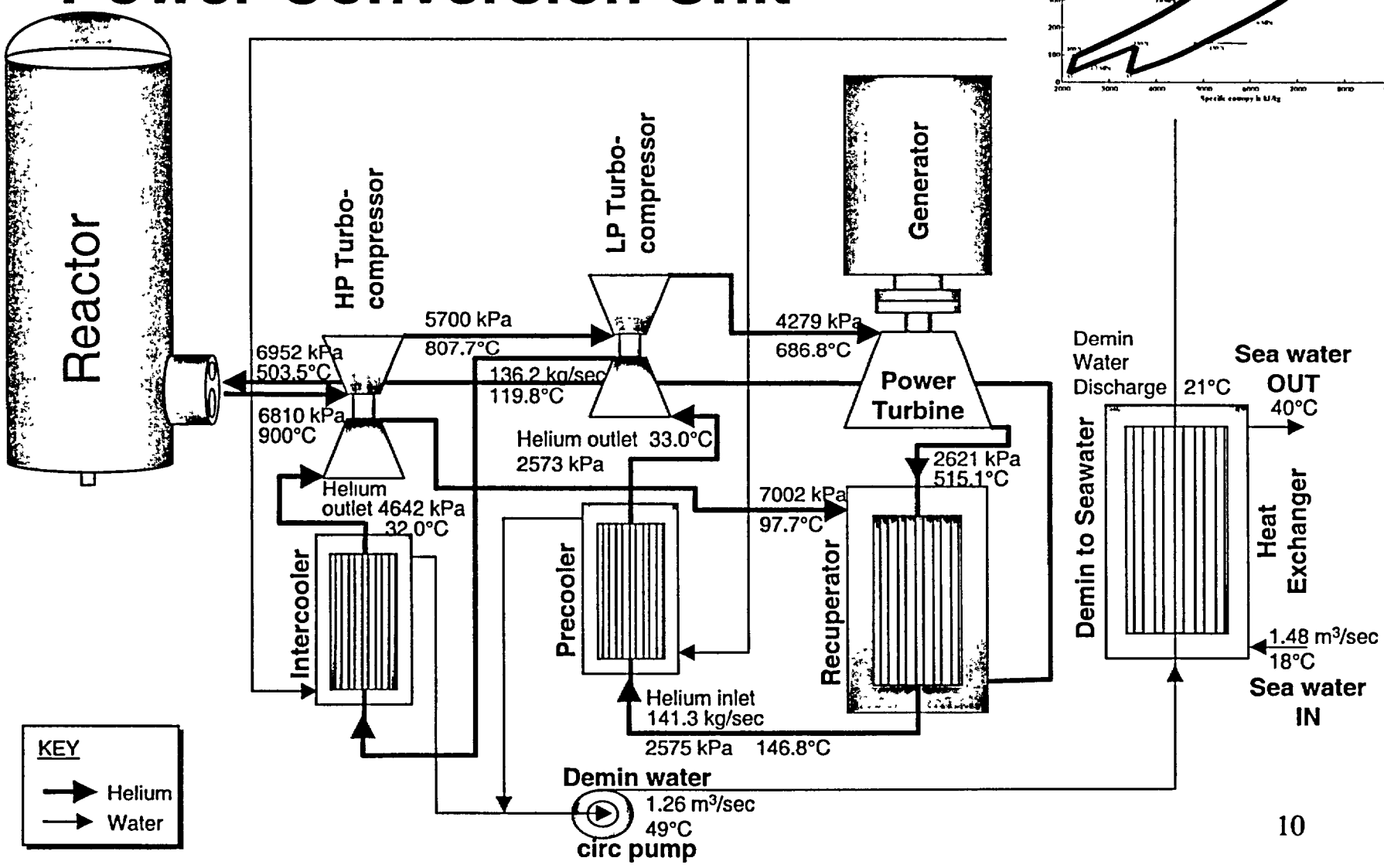
Main Power Systems



PBMR Thermal Cycle
Power Conversion Unit





PBMR Single Module

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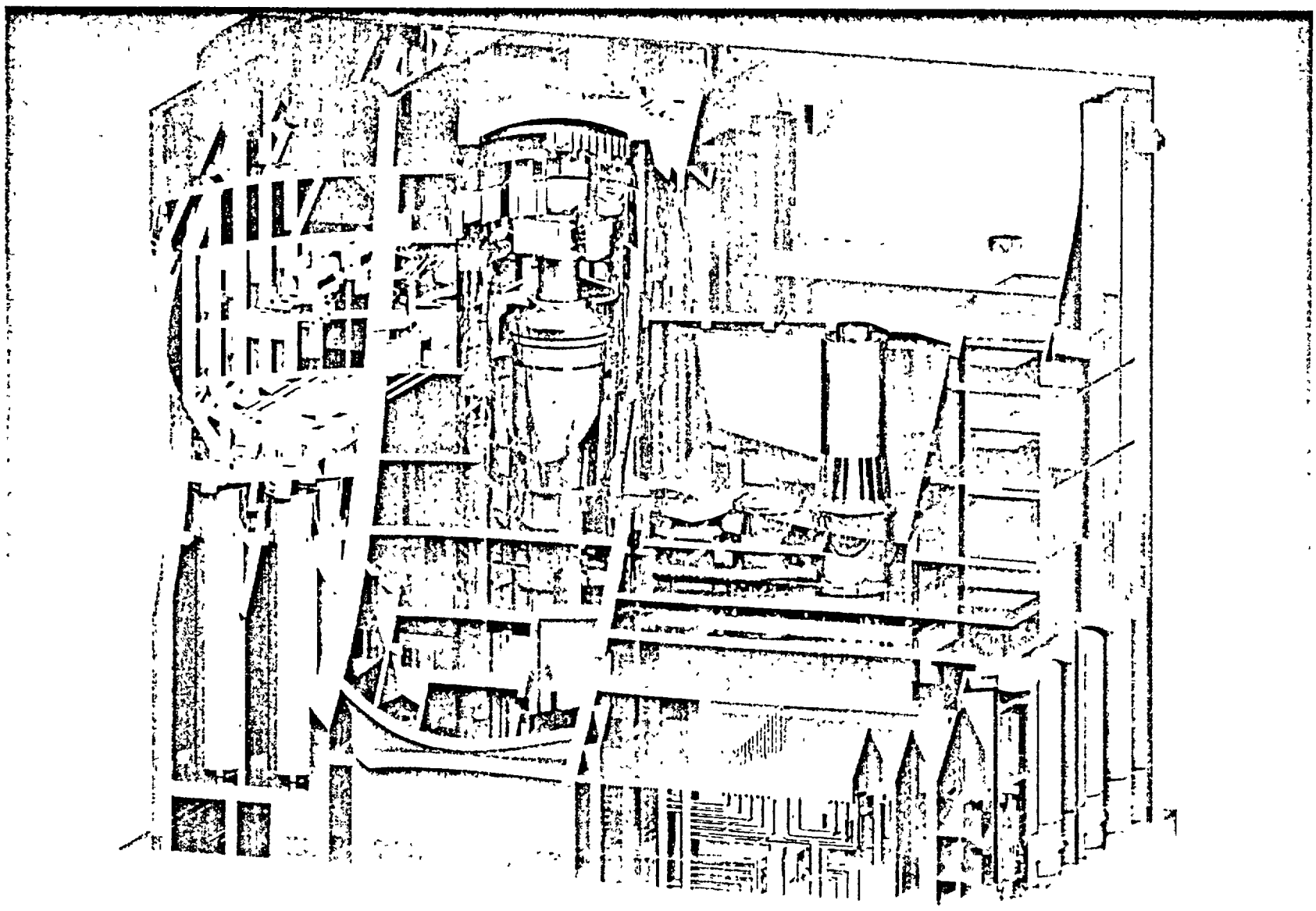

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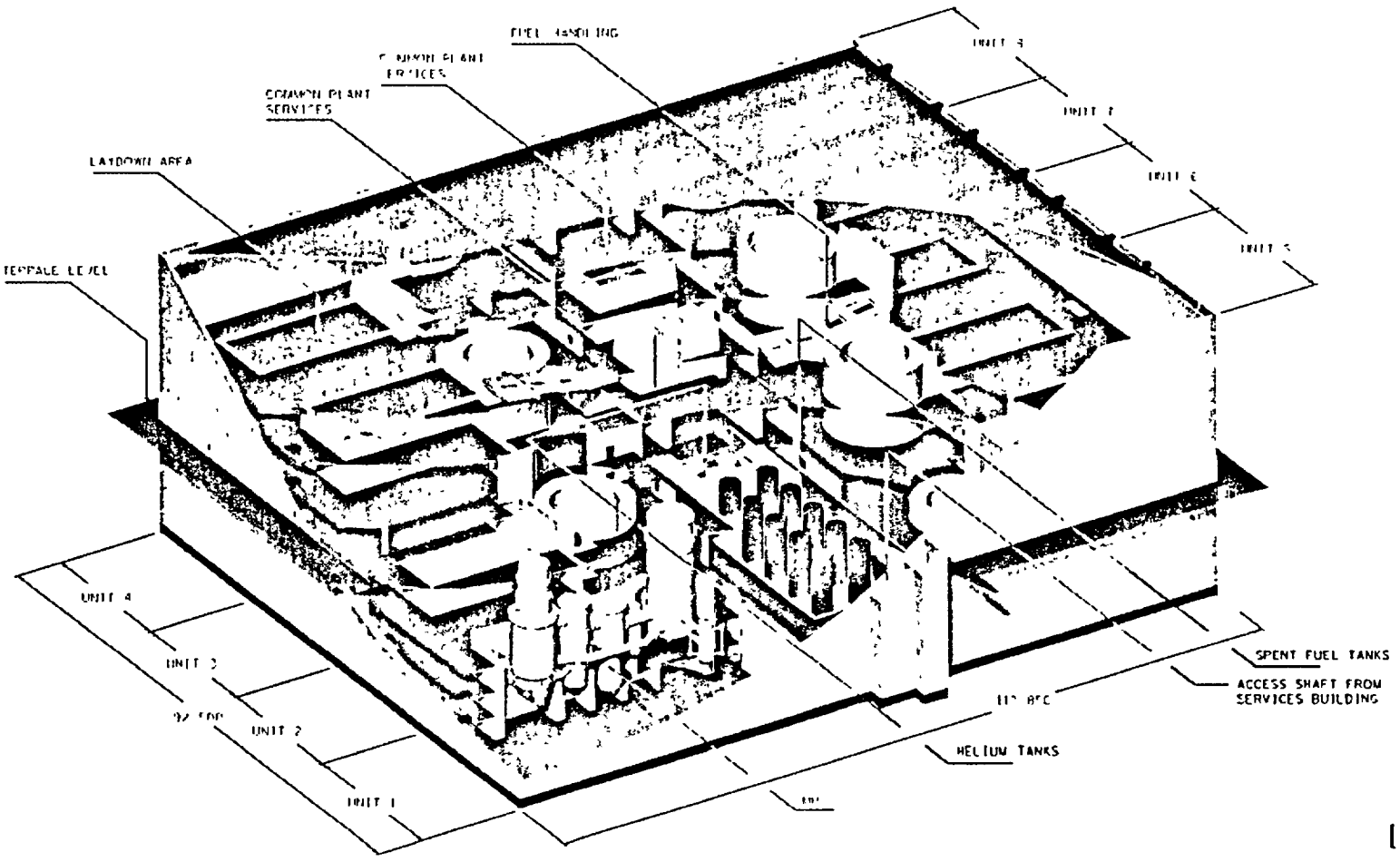
PBMR Multi Module

CUT AWAY ISOMETRIC OF PBMR MULTI MODULE CONCEPT



Multi-Module Layout

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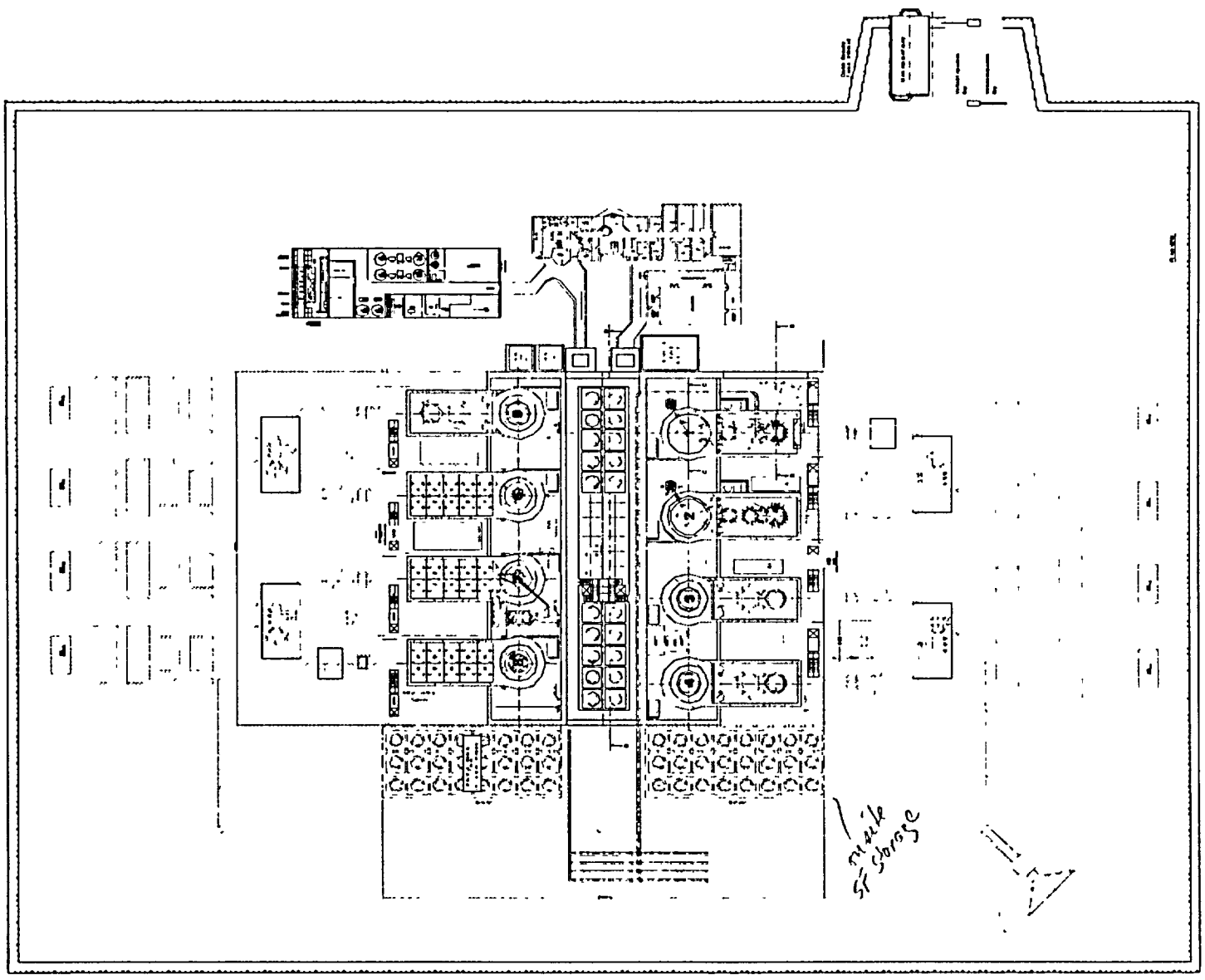

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Key Safety Characteristics

- The safety of the reactor is not dependant on the presence of the coolant (cooling or criticality).
- In no accident scenario is the early insertion of control rods required (early means in the first few days).
- There is no meaningful limit on transient power levels – only long term power level.
- The principal barrier to radioactive release is fuel integrity; a conventional containment is not required technically.
- Emergency Planning Zone (EPZ) less than 400 m

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Major Development Testing (Ongoing and Planned)

- Code Validation
  - Critical Core Test Facility — ASTRA (Moscow)
  - Micro Turbine Model — Potch. U.
  - Single Effect Test Rigs — Potch. U.
- Equipment Test Rigs
  - Fuel Handling Systems — IST
  - Control Rod Drive Systems — IST
  - Burn-up Sensor — Gamma-Metrics
- Fuel Manufacturing Equipment
  - Kernel Formation Column — NECSA
  - Kernel Coater — NECSA
  - Sphere Presses — NECSA

Major Development Testing (Ongoing and Planned) Cont'd

PBMR

- Helium Test Loop — IST @ NECSA
  - Systems
  - Components
  - Special Tools
  - Graphite Erosion
- Fuel Qualification and Testing — @ NESCA, Russia, SAFARI (RSA)
  - Pre-Irradiation
  - In-Reactor
  - Post-Irradiation
- Materials Testing
  - Graphite Irradiation Life
  - Carbon Fiber Composite Irradiation Life

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Fuel Supply Strategy

- Fuel Design
  - Based on German Pebble Bed Reactor using equivalence approach (fuel specification, starting material, critical processes, and quality control)
  - Perform confirmatory tests to prove fuel within German envelope
- Fuel Fabrication Technology
  - NFI for particle fabrication
  - NUKEM for pebble fabrication
- Fuel Fabrication
  - Pilot Plant for PBMR Demonstration plant fuel and possibly first PBMR commercial plant fuel
  - Commercial Plant once sufficient orders obtained

Fuel Particle Coater Laboratory

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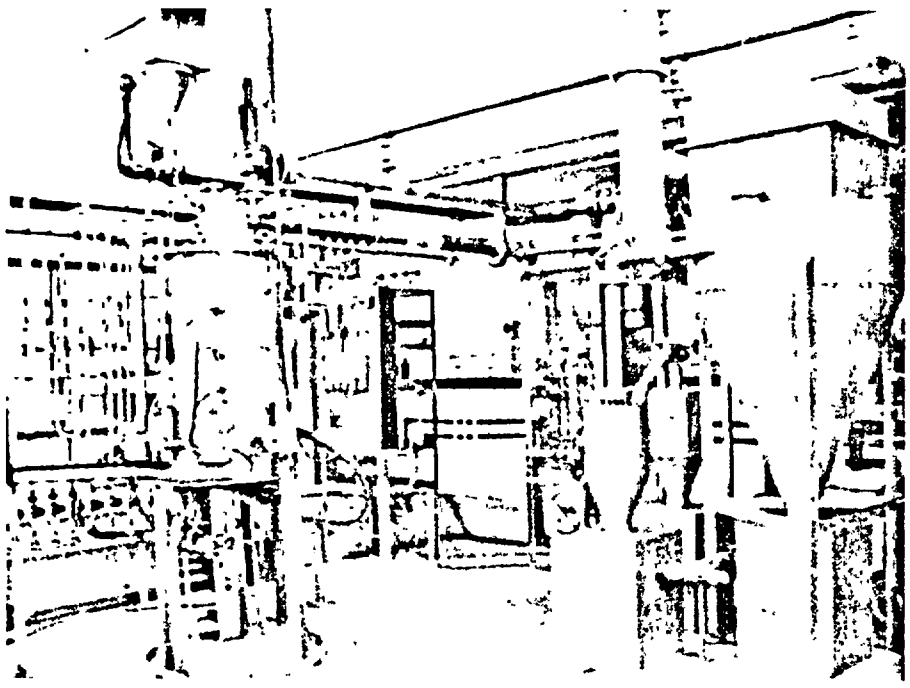

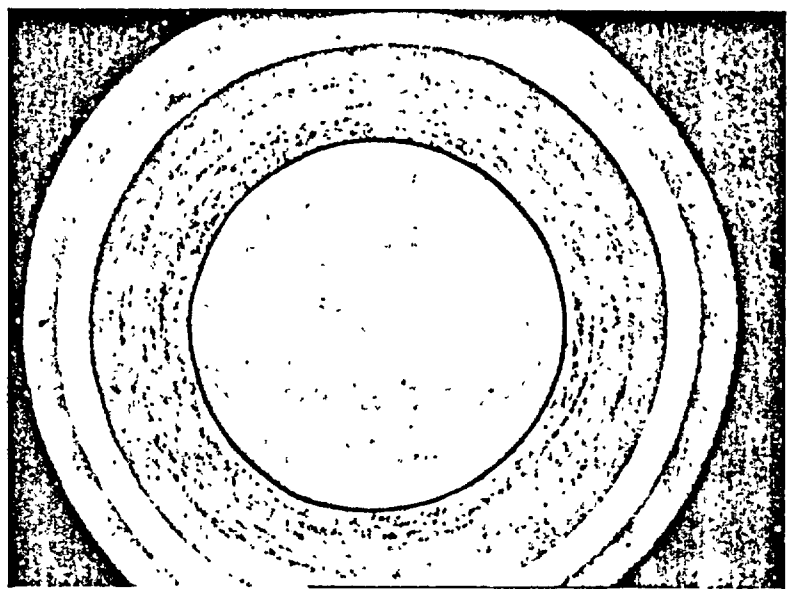

Fuel Sphere Laboratory

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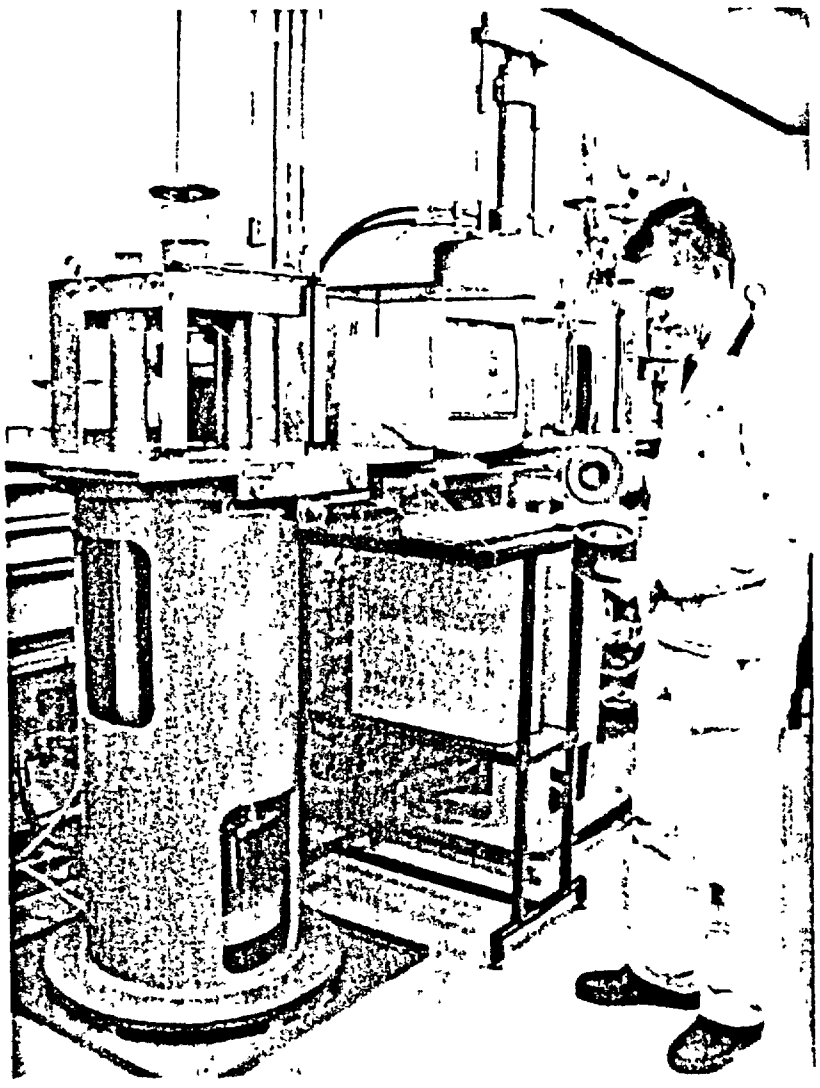

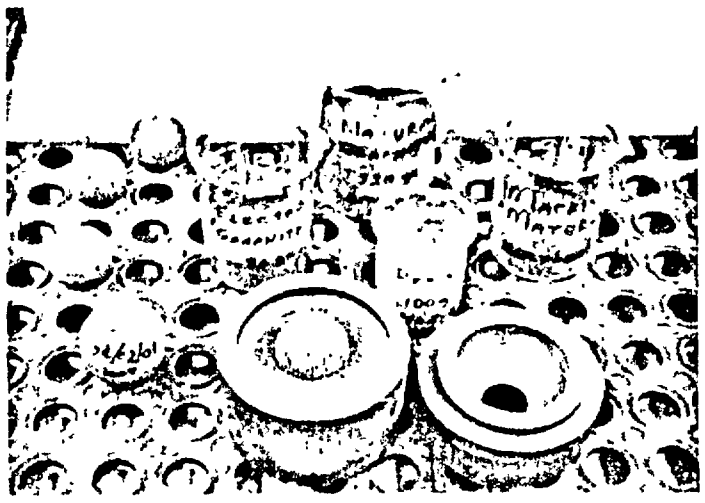

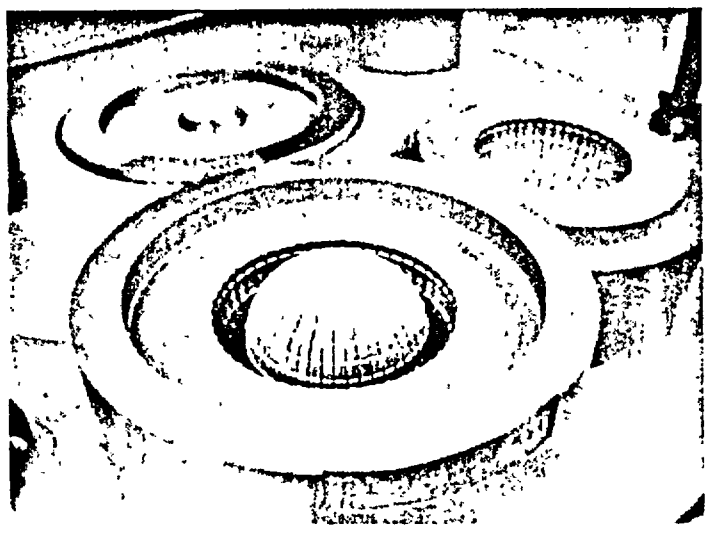

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Fuel Qualification and Testing Program

- Establish rigorous quality control of fabrication process and fuel product
- Early fuel compacts and pebbles from NFI to be tested in Russia
- Early fuel compacts from NFI to be tested in South Africa SAFARI reactor
- Pilot Plant fuel pebbles to be tested in SAFARI reactor
- Commercial plant pebbles to be tested in Russia and/or the SAFARI reactor
- Post Irradiation Examinations (PIE) to be conducted on all tests
- Long term fuel development and irradiation program to be conducted in SAFARI reactor

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Current Full Time Staffing Resources

• PBMR	280
• Sargent & Lundy/Murray & Roberts	40
• IST	60
• Mitsubishi Heavy Industries	50
• Eskom	35
TOTAL	465

Total Manhours to date ~1,500,000

Total costs to date ~$100M

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Investors

- Eskom
  - South African government-owned electric utility
- Industrial Development Corporation (IDC)
  - South African government-owned investment bank
- British Nuclear Fuels Ltd (BNFL)
  - British government-owned nuclear reactor, fuel and services supplier
- Exelon*
  - US electric and gas utility
- Future Investors

* Announced that it will not be an investor beyond current feasibility phase but remains a potential customer

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Strategic Suppliers

• MHI (Japan)	Turbo-Machinery
• NFI(Japan)/Nukem(Germany)	Fuel Technology
• SGL (Germany)	Graphite
• Ingersoll Rand (US)	Recuperator
• IST (RSA)	Nuclear Auxiliaries
• Westinghouse (US)	Instrumentation
• Ensa (Spain)	Pressure Boundary
• Sargent & Lundy (US)	Architect Engineer
• Murray & Roberts (RSA)	EPCM

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South Africa Licensing Status

- Agreed licensing process and stages
- Agreed scope of submittals and schedule
- Agreed list of key licensing issues; strategy to address these in process
- Formal questions from NNR on SAR Rev 1 issued July 31, 2002
- Environmental Impact Assessment (EIA) Record of Decision (RoD) expected in November 2002
- NNR review of SAR Rev 1 scheduled for completion on October 31, 2002; public participation will follow RoD
- Government approval of project after positive RoD and acceptable Business Case (expected by end of 2002)
- Site preparation license expected at end of March 2003

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US Licensing Status

- NRC agreement on proposed approach
- Phase 1 of the Regulatory Guidance Review completed
- Fuel Test and Qualifications program progressed
- US Licenseability Assessment completed
- Pre-application activities documented
- Ready for reactivation by PBMR
- Multiple Module Reactor Issues responded to by NRC
- Start of Design Certification planned for 2006; completion after startup of the Demonstration reactor

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Summary of Business Case

- Effort led by McKinsey & Company, with input from all four investors and PBMR Pty (8 month effort)
- High Impact Teams established for critical area input

Area	Lead
– Construction Cost and Schedule	Exelon/Murray & Roberts/Stone & Webster
– Fuel Plant and Fuel Cost	BNFL
– Capital Cost Reduction	Sargent & Lundy
– First of a Kind Engineering	Sargent & Lundy
– Turbo-M achinery	PBMR/MHI
– Legal and Commercial	PBMR
– Organization Assessment and Transition	PBMR

PBMR Business Case (Cont'd)

- Detailed Project Plan based on Work Breakdown Structure
  - Demonstration Plant
  - Commercial 8-Pack
  - Fuel Pilot Plant
  - Commercial Fuel Plant
  - PBMR First of a Kind Design
  - PBMR Pty Infrastructure Development
- Detailed Cost Estimate for Above Six Activities
- Risk Assessment using probabilistic techniques Performed on Both Schedules and Costs
- Focused on 14 key worldwide markets, including U.S., Japan, U.K., RSA, Korea and China (all current nuclear programs)

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Suggested Development Efforts in Cooperation with US NRC

- Follow through on the cooperative fuel testing program proposed by Exelon for PBMR licensing in the U.S.

- High Temperature Gas Reactors would benefit from NRC approval of Code Cases N-201 and N-499.

- As part of the pre-application review, PBMR will define, and review with the NRC, the proposed testing program, including that on the South African demonstration plant.