Pebble Bed Modular Reactor Program Overview

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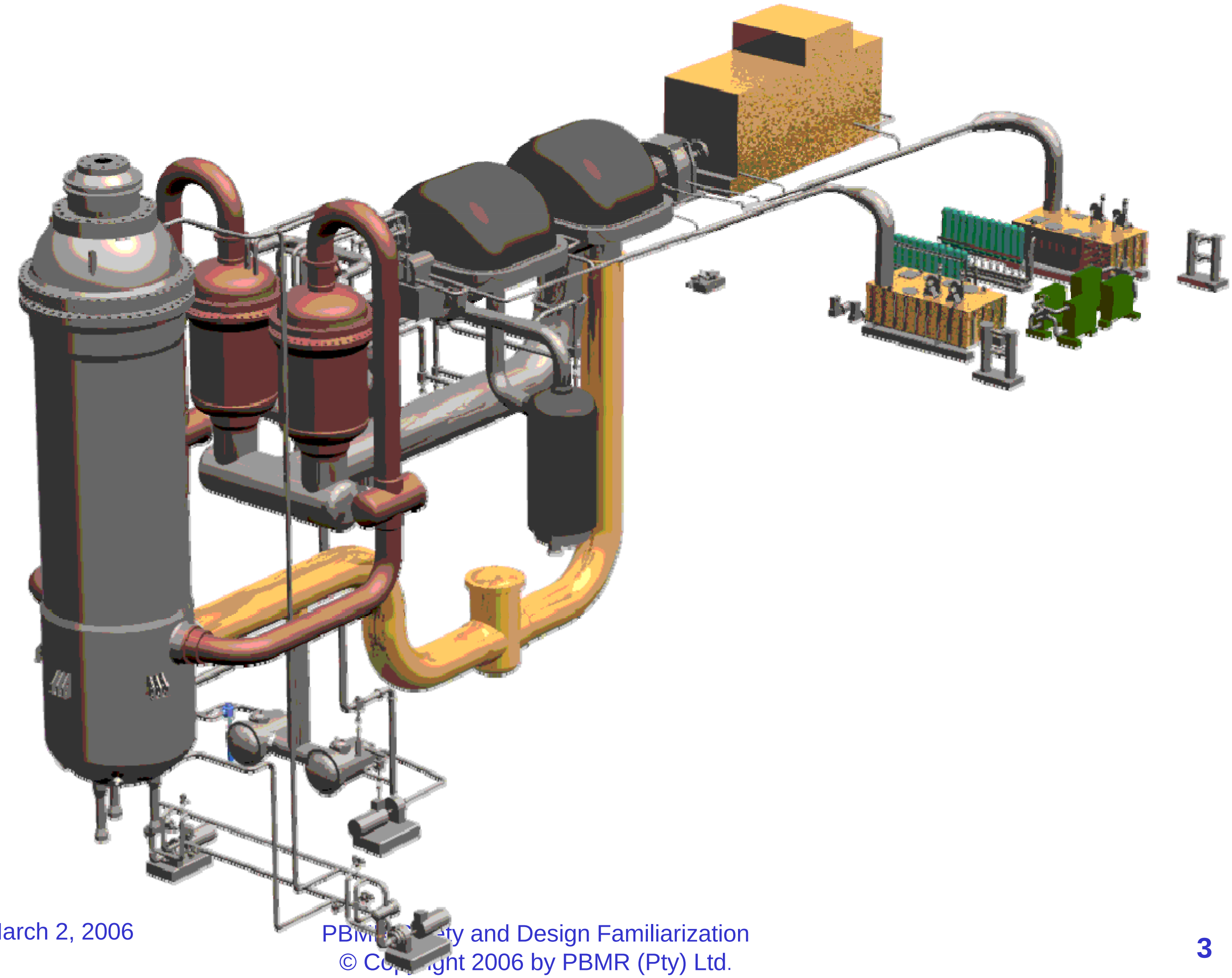
Program Overview

- **Project Elements and Schedule**
- **Koeberg Site Plant Location**
- **PBMR Test and Development Facilities**
- **PBMR Distinguishing Characteristics**
- **Pilot Fuel Plant**
- **Multi-Module Power Plant**

The Demonstration Power Plant



Electricity Demonstration Project Has Been Launched

- **Currently over 700 equivalent full-time staff working on project at PBMR and at strategic suppliers**
- **Basic design being completed and detailed design started**
- **Revised Environmental Impact Assessment (EIA) submitted and updated Safety Analysis Report (SAR) nearing completion**
- **Helium Test Facility (HTF) and Heat Transfer Test Facility (HTTF) under construction**
- **Construction Manager mobilized**
- **Contracts with key suppliers for critical components being placed now**
- **Firm construction schedule established at Koeberg-South Africa**

➢ Site Access	1 Qtr 2007
➢ Construction Excavation Starts	3 Qtr 2007
➢ Fuel Load	3 Qtr 2010
➢ Plant Turnover to Client	3 Qtr 2011

Eskom – The Host Utility

- **Eskom is host utility for Demonstration Plant at existing site next to Koeberg Nuclear Power Station (KNPS) within the security area on the South African West Coast near Cape Town.**
- **Active client office that is responsible for EIA and SAR.**
- **Launch customer for follow-on commercial plants (Letter of Intent)**

Comprehensive Test Program Established / Underway

- ASTRA Critical Facility benchmarked core physics/neutronics codes.
- Micro-Model demonstrated operation of closed cycle recuperative Brayton Cycle.
- Helium Test Facility (HTF) to verify codes and equipment reliability
- Heat Transfer Test Facility (HTTF) to validate thermo-hydraulic properties of pebble bed (2 loops)
- IVV-2M Test Reactor (plus others) to obtain confirmation of fuel performance
- Plate Out Test Facility (POTF) to confirm fission product transport in helium systems
- NACOK facility investigating oxidation of graphite during postulated air Ingress

Pebble Bed Reactor Designs

Reactor	Reactor Power	Status
HTR-10 (China)	**10 MW**	**Built and running**
AVR (Germany)	**46 MW**	**Built, run and decommissioned**
HTR Modul (Germany)	**200 MW**	**Designed, licensability review completed, not built**
HTR 100 (Germany)	**250 MW**	**Designed**
PBMR (South Africa)	**400 MW**	**In Design / Pre-construction**
THTR 300 (Germany)	**750 MW**	**Built, run and decommissioned**
HTR 500 (Germany)	**1390 MW**	**Designed**

Different Design Approaches for Modular HTRs

- **Direct vs. Indirect Cycles**
  - **Direct Brayton Cycle**
    - *Helium reactor coolant drives Brayton power conversion cycle*
      - Intercooled cycles
      - Non-intercooled cycles
  - **Indirect Cycles**
    - *Indirect Brayton Cycle*
      - Helium to helium IHX driving Brayton cycle power conversion cycle
    - *Indirect Steam Cycle*
      - Helium to water IHX driving conventional steam power conversion cycle
    - *Indirect / Indirect Combined Cycle*
      - Helium to Gas (Helium/Nitrogen) IHX with direct Brayton Topping cycle and Gas to Water IHX driving conventional steam bottoming cycle (combined cycle)

Different Design Approaches for Modular HTRs

- **Basic Issues driving design approaches**
  - Simplicity
  - Efficiency
  - Safety
  - Economics
  - Local Industrial Capacity
  - Schedule
  - Evaluated Risks
  - Development Costs
  - Co-product Applications
- **Different designs emphasize different combinations of drivers.**
- **All designs based on inherent, passive safety principles and TRISO fuel coated particle design concept**

Definition of Inherent

Inherent

- ***"Existing in something as a permanent or essential attribute"***

Concise Oxford English Dictionary 11th Edition 2004

- ***"Existing in someone or something as a permanent and inseparable element, quality or attribute"***

Random House Unabridged Dictionary 1997

Permanent:

- ***"Lasting or remaining unchanged indefinitely, or intended to be so"***

Concise Oxford English Dictionary 11th Edition 2004

P B M R

Definition of Passive Design Features

- **Design features engineered to meet their functional requirements *without***
  - Needing successful operation of systems with mechanical actions such as pumps, blowers, HVAC, sprays
  - Depending on availability of electric power
  - Relying on operator actions
- **PBMR passive design features utilize inherent characteristics.**

Important Paradigm Shifts

- **The fuel, helium coolant, and graphite moderator are chemically compatible under all conditions.**
- **The fuel has very large temperature margins in normal and accident conditions.**
- **The safety of the PBMR core is not dependent on the presence of the helium coolant.**
- **The response times of the reactor are very long (days as opposed to seconds or minutes).**
- **There is no inherent mechanism for runaway reactivity excursions or power excursions.**
- **The PBMR has three concentric radionuclide barriers.**
- **Accident phenomena can be modeled mechanistically.**
- **An LWR-type containment is not advantageous or necessarily conservative.**

Basic Technology Differences

- Fuel Form
- Fuel Performance Record
- Core Design Simplicity
- Inherent Passive Safety & Safety Margins
- Relative Design Simplicity
- On-line Fueling
- Component Designs Within Known Industrial Capabilities
- Direct Cycle vs. Indirect Cycle
- Non-proliferation
- Waste Disposal / Spent Fuel
- Process Heat Potential

Pilot Fuel Plant

- **Production scale facility to verify manufactured fuel is of requisite quality and performance**
  - Planned capacity ~ 270,000 spheres / year
- **Building refurbishment underway**
  - Operational – 2008

Concept of Multi-Module Power Plant