

## PBMR CHRONOLOGY

- Late 1950s: The late Prof Robert Schulten started the development of the pebble bed reactor. Schulten is recognized as the “father” of pebble bed technology. Spent a number of years with BB Company (today ABB).
- Early 1960s: Schulten and his team started the design of the AVR experimental reactor. Schulten appointed as Head of FZJ (Forschungszentrum Jülich), a major research centre in Jülich.
- 1963 – 1965: Construction and commissioning of AVR in Jülich. The AVR runs very successfully for 22 years until 1989.
- Early 70s: Schulten and team start work on development of a commercial reactor, the THTR, based on research and operational results of AVR. A consortium known as Hochtemperatur Reaktorbau (HRB) was formed between several of German utilities, to build the THTR.
- 1978: Start construction of THTR.
- Later 70s: KWU (Siemens) starts design and development of Modul reactor as a commercial reactor, also based on pebble bed technology.
- 1985/1986: German Government orders ABB and Siemens to co-operate on pebble bed technology. The company HTR (Hochtemperatur Reaktoren) is established with 50/50 shareholding between ABB and Siemens. All German pebble bed IP (intellectual property) vests in HTR.
- 1986: THTR commissioned, starts generation of electrical power into German grid. The Chernobyl disaster strikes in Russia, and the green movements in Germany demand closure of all nuclear power stations in Germany.
- 1989: After only 3 years of operation, THTR is shut down. AVR also shut down. Siemens Modul research development abandoned. End of development work on pebble bed reactors in Germany.
- 1982 – 1988: Department of Reactor Development of AEC works on two major projects. The first was the design and development of a small South African Pressurized Water Reactor (PWR) to serve as a benchmark for PWR technology development in support of Koeberg. This reactor was intended to be built at the Gouriqua site in the Southern Cape which was being developed for this purpose. A feasibility study was also launched of a small PWR (500 kW) for submarine propulsion.
- Late 80s: As part of the reactor system studies done jointly with ESKOM for the “bridging program” the HTR was identified as a possible candidate and its excellent safety characteristics were highlighted in the draft report.
- At the completion of the basic design baseline of the small PWR design a more detailed costing analysis was prepared and presented by Johan Slabber to the AEC board which felt that, in the nuclear “climate” existing in South Africa at that stage, the extra funding required could not be motivated and the project was cancelled with immediate effect.
- Johan Slabber set off to Europe to cancel contracts with a number of companies and during this trip he set up a meeting with Professors Rudolf Schulten and Kurt Kugeler of Aachen University. During this meeting a proposal was formulated for a SA pebble bed based HTR development program. This proposal was for a small pebble fueled, direct cycle reactor with a steel cable re-inforced cast steel reactor vessel built up from sections, which could be manufactured by the SA industry.
- This proposal was presented by Johan Slabber to the chairman of the AEC Board who was not willing to take it to the Board.
- 1988/1989: The reactor projects at the AEC stopped. Johan Slabber and a number of AEC staff joined IST.
- 1989: One of the senior Engineers (Dr. C.V. [Chris] Oberholzer) at AEC joined Armscor and was appointed manager of the South African submarine propulsion program. A nuclear propulsion system had to be investigated as one of the options.

- April 1990 : Armscor appointed IST to do a preliminary design and feasibility study on nuclear submarine propulsion (500 kW) by means of a pebble bed reactor. This study was concluded in March 1991. It showed that the low power density and therefore the physical large size of the reactor made it not a good candidate for submarine propulsion. At that time, the SA submarine program was also disbanded.
- 1988/1989: The appointment of the senior members of the ex-AEC Reactor Development team established IST's nuclear capability in 1989.
- 1990 - 1992: Armscor instructed IST to do a feasibility study on the utilization of pebble bed reactors as a power pack (5 MWe) for remote sites. The IST nuclear team investigates the practicability of utilizing high temperature high-pressure helium gas in a direct cycle arrangement (similar to the configuration presented to the AEC Chairman), where the power conversion unit consists of helium gas driven turbo-compressors and a power turbine-generator for the generation of electrical power. This power conversion cycle was identical to the one developed for the 5 MWe power pack). This cycle – known in thermodynamics as a Brayton cycle – existed as a theoretical (text-book) cycle, but had never been utilized in a practical application. Prof Schulten and a fuel specialist, dr. Milan Hrovat visited IST a number of times during this period to offer assistance and add German experience. It is to be noted that – although the pebble bed reactor as a heat source was designed and developed by Prof Schulten and his team – the German power conversion unit in both the AVR and the THTR consisted of a high-temperature high-pressure helium primary circuit with a heat exchanger to a secondary steam cycle power conversion unit. This latter unit consisted of a conventional steam turbine driving a generator to produce electrical power. The overall thermal efficiency of the IST direct cycle concept is substantially higher than the German secondary steam cycle system. This constitutes a major improvement compared to the German cycle, and provides an important competitive advantage. During this work specialists on reactor and radiation analysis and turbo-technology were sub-contracted from the AEC to assist in the design work.
- March 1992: IST obtains Armscor approval to use the study as a basis for investigation of possible commercial applications. Dieter er Matzner was instrumental in arranging the deal with Armscor.
- 1993 During an IST Top Management marketing visit to the Koeberg Nuclear Power Station the reactor concept was also presented as something to take note of. Mr. Dave Nicholls was in the audience and after the meeting, during the tea break, remarked that the concept could be demonstrated at the Koeberg by using it to replace one diesel generator set. In this way the concept could be demonstrated and also used to supply, when not in use as an emergency generator, power into the grid. Mr. Nicholls then started his association with IST.
- 1992 – 1995: IST further develops the concept and does an initial power upgrade from 5 Mwe to approximately 50 Mwe to enhance the commercial viability of the unit. All design and development work is carried at IST's own cost and risk. During this period, IST in conjunction with Dieter Matzner keeps on marketing the pebble bed concept to various organizations: Eskom Koeberg, Eskom Megawattpark, various mining houses, AEC, Framatome and others.
- February 1994: Johan Slabber receives an offer to join IAEA in Vienna, Austria and resigns from IST. He would, however, remain available to IST for a limited number of hours per year to consult on the concept. After more than 5 years in Vienna, Johan returns to IST in July 1999.
- July 1995: IST is appointed by Eskom to perform the Study Definition and Quotation for the first two phases of the PBMR development project.
- April 1996: IST is appointed by Eskom to perform the Conceptual Design and Costing, as described in the study definition.
- April 1997: IST delivers Techno-Economic Feasibility Study reports.
- April 1997 – July 1998: IST receives a number of consecutive short-term contracts from Eskom to perform Special Studies and Technology Establishment, and preparation work for the Basic Design Phase.
- October 1997: A Heads of Agreement (HOA) between IST Holdings (Pty) Ltd and Eskom was signed. The HOA in essence determines that IST and Eskom have agreed to form a Joint Technology Company (JTC) which would further develop the intellectual property required to build and license PBMR power plants in South Africa and other parts of the world. The shares in the JTC would be held 51% by Eskom and 49% by IST. The detailed

agreement between the two parties and the formation of the JTC never took place, and the HOA was eventually cancelled and substituted by the Enabling Agreement.

- October 1998: The IST technical team working on the PBMR project (approximately 20 persons) relocates to PBMR Company's offices in Centurion. The Eskom PBMR team members also relocate from Megawattpark to Centurion, thus forming an integrated project team.
- August 1998 – March 2000: IST receives contracts from Eskom to perform the Basic Design.
- July 1999: Johan Slabber returns to IST from IAEA in Vienna, and joins the IST team in Centurion. By now, the IST team located in Centurion has grown to a total of 36 members.
- March 2000: The IST team in Centurion has grown to 42 members. By agreement between PBMR Company and IST, 20 members transferred to Centurion and were employed by PBMR Company as subcontractors (including Matzner). Four persons (Marius Fox, Holger Finken, Eric Beyer and Kurt Prinsloo) returned to IST's offices in Menlyn. A total of 14 people remained on IST's payroll but were seconded to PBMR Company's offices in Centurion.
- April 2000 – April 2001 : During the remainder of the year 2000, IST was awarded the following contracts:
  - 1 April 2000: Fuel Handling Supply and Storage System (FHSS) Basic Design.
  - 1 July 2000 : Reactivity Control and Shutdown System (RCSS) Basic Design
  - 18 September 2000 : Core Conditioning System (CCS) Basic Design
  - 18 September 2000 : Reactor Pressure Vessel Conditioning System (RPVCS) Basic Design
  - 18 September 2000 : Helium Inventory and Control System (HICS) Basic Design
  - 3 November 2000 : Start-up Blower System (SBS) Basic Design
  - The latter four systems would collectively be described as the "Gas Systems". All systems described above are referred to as the Main Support Systems (MSS) and are also known as the "IST Subsystems" (for future reference). Work on the Basic Design of the IST Subsystems continued until April 2001 and beyond.
- October 2000: In the period April – October 2000, another seven IST staff members were transferred to PBMR Company. Five members remained on IST's payroll but performed their daily tasks at PBMR Company's offices in Centurion.
- May – December 2001: The Pre-Detail Design of the IST Subsystem was performed.
- September 2001: The decision to establish IST Nuclear Power Systems (Pty) Ltd was taken. The company was registered in November 2001.
- 14 December 2001: The Enabling Agreement between PBMR Company and ISTN was signed. The agreement stipulates that ISTN will be the key supplier on a turnkey basis of the ISTN Subsystems for the Demonstration Module as well as for the first ten Production Plants (i.e. a grand total of 11 sets). At the same time, the Heads of Agreement between IST Holdings (Pty) Ltd and Eskom, signed in the last quarter of 1997, was cancelled.
- January – June 2002: ISTN participates in the PBMR capital cost reduction and improved constructability exercise for the multi-module plant. Good results were achieved: capital cost of ISTN Subsystems reduced by approximately 35% per series-production module. As part of the exercise, PBMR Company decides to utilize a fixed centre graphite reflector in the reactor, leading to an eventual power upgrade to 400 MW<sub>th</sub>.
- January – September 2002: User requirements of Helium Test Facility obtained, and conceptual design and costing performed. Howden Power of Scotland selected as supplier of HTF blower design.
- August 2002 – June 2003: The Basic Design upgrade of all IST Subsystems due to the PBMR power upgrade to 400 MW<sub>th</sub> is performed. In addition the basic and detail design of the HTF is performed.