MEETING REPORT

17th Meeting of the International Working Group on Gas Cooled Reactors
Cape Town, South Africa

6-9 November 2001

The meeting was chaired by David Nicholls of South Africa and the topical sessions by Barry Marsden of the UK. The Scientific Secretary was Mabrouk Methnani of the IAEA. 34 participants attended the meeting from 11 Member States, of which one was an observer.

Member States:

China
France
Germany
Indonesia
Japan
The Netherlands
Russian Federation
South Africa
Turkey (Observer)
United Kingdom
United States

Organizations

European Commission
IAEA

A copy of the final meeting agenda is provided as Attachment 1, and the list of participants as Attachment 2. A brief overview of the meeting and its recommendations are provided below, followed by highlights of the various sessions.

Overview

The meeting was well attended with 34 participants representing 11 Member States and 2 international organisations. Discussions and presentations held during the meeting point to a sustained and growing level of activities in several Member States in support of gas cooled reactor development since the last TWG-GCR meeting of June 2000 in Vienna.

The first day was reserved for 3 topical sessions covering HTGR core internal design, code benchmarks and transient analysis and tests. On the second day, participants from various Member States plus the European Commission reviewed the status and progress of their HTGR national and international projects. On the third day, IAEA related activities were discussed, including actions on recommendations from the 16th meeting, recently published technical documents, current and pending coordinated research projects, the status of INPRO as well as recommendations to the Agency on future HTGR-related activities. Finally on day 4, PBMR has kindly arranged a tour of the Koeberg nuclear power plant for the participants.

Recommendations

1. The TWG has recommended that discussions with graphite experts should continue about the need for further irradiation experiments for the Graphite database.

2. The TWG has again voiced strong support for a new CRP on coated particle fuel technology, to be started as soon as possible. If feasible, it should be acted on within the IAEA regular budget. France supported by other Member States, has pledged to take a lead in this direction. It was proposed that details could be further discussed at a Technical meeting to be arranged by IAEA, during the HTR conference at Petten, NL (Apr 22-24, 2002).

3. The TWG has recommended that the Agency should plan a new CRP as follow-up to CRP-5 on evaluation of HTGR performance, which is due to end in 2004. The new CRP is meant to address HTGR code benchmarks not currently being considered in the scope of CRP-5.

4. The TWG has emphasised the importance and urgency of issuing safety and design standards specifically addressing gas-cooled reactors and especially in areas where current provisions have no reference to them.

5. The TWG has recommended that a survey of status and availability of historical gas-cooled reactor research information in Member States be made.

6. The TWG has voiced support for increased use of online information exchange and collaboration tools such as the HTGR web site and the Virtual Office tool "Business Collaborator".

Next TWG Meeting

Turkey has expressed its wish to host the 18th TWG meeting, which will be held in the period of May 13-16, 2003 and the participants have accepted Turkey's invitation.

SESSION HIGHLIGHTS

I Topical Sessions

1. Session 1: HTGR Core Internals Design

A few papers were presented on HTGR core structure design. Mulder presented the characteristics of the South African PBMR annular core layout while Davies overviewed the design of its graphite structure. Xu overviewed the design structure of the Chinese HTR-10 core stressing that it has been designed for a 20-year lifetime. Shiozawa overviewed the core internals design of the Japanese HTTR, focusing on design criteria for core and core support components. Sukharev then overviewed the Russian GT-MHR internals design and finally von Lensa presented an overview of the German experience on AVR internals design. There was general consensus that the lifetime of the inner graphite reflector is highly dependent on fluence and its replacement has to be accounted for in the design.

2. Session 2: HTGR Code Benchmarks

A presentation by Ms van Heek compared PBMR flux and temperature profiles predicted by the code PANTHERMIX to those of VSOP. Colak presented results of HTR-10 benchmarks using codes KENO V and VSOP and finally, Kadiroglu presented PBMR burnup tracking using ORIGEN coupled to KENO. The choice of cross-section library and group structure seems to have direct influence on the results and merits further study, as discussed by participants.

3. Session 3: HTGR Transient analysis and tests

Kemp overviewed the PBMR transient response using the systems code FLOWNET, which is coupled to SIMULINK for control studies. Xu reviewed the HTR-10 zero power and irradiation tests, including determination of maximum allowable power, fuel and control rod reactivity calibration, helium circulator characteristic curves and results of HTR fuel irradiation up to 40,000 MWd/t. Tachibana reported the progress on HTTR rise to power tests which have been conducted in three phases at power levels of 10, 20 and 30 MW. Currently, the third phase is in progress to reach rated power and an outlet coolant temperature of 850 °C. Included in the ongoing performance analysis are core physics parameters, power distribution, fuel and fission product behaviour, radiation shielding, control systems and thermal performance. High-temperature tests to achieve a core outlet Helium temperature of 950 °C are planned for 2004. Sukharev in his turn, presented results of the GT-MHR response to accident transients including loss of coolant, inadvertent control rod withdrawal and blackout without scram scenarios. Maximum fuel temperatures are shown to remain within safe limits under all accidents considered. Brinkmann overviewed licensing events studied by Siemens (now Framatome ANP) for the HTR-Module in the late eighties. Based on classification of accidents such as aircraft impact, seismic events, primary and secondary coolant leaks, reactivity insertion and ATWS into three main classes, it has been shown that fundamental objectives of radioactivity containment and operability of safety systems were always met. Finally, van Heek presented an overview of the transient behaviour and control of the ACACIA co-generation pebble bed concept, using RELAP5 coupled to PANTHERMIX and the ASPEN Custom Modeller simulator. Both operational and safety-related transients have been analysed including load following, load rejection, loss of flow and loss of coolant events. In order to meet the 1600 °C fuel temperature limit, the primary flow rate should be kept above a certain minimum (1 kg/s), according to the author.

II National & International Programs Status

China

- **HTR-10**:
  - Criticality was officially reached in Dec. 2000.
  - Good prediction of number of spheres sustaining criticality (within 1 %)
  - Rise to power planned for 2002 with Helium coolant in place.
  - INET and OKBM of the Russian Federation to cooperate on gas turbine cycle.
- **HTR-PM**:
  - 100 MWe pebble-bed HTGR subject to pre-feasibility study (start construction by 2005-6)

Indonesia

- Electricity demand is expected to more than double from 62.5 TWh in 2000 to 147.7 in 2010.
- Co-generation aspects of HTGRs are attractive for coal liquefaction, desalination, methanol production and Enhanced Oil Recovery (EOR).

Japan

- **HTTR**:
  - Currently in the process of reaching rated power (30 MWt) with He outlet temperature at 850°C.
  - Plans for increasing He outlet temperature to 950 °C
  - Emphasis on high-temperature heat applications such as Hydrogen production, mainly through steam reforming
- **GTHTR-300**:
  - Feasibility study initiated with a prototype planned for 2010 and commercialisation by 2020.
  - Main features include high-burnup (120 GWd/t), horizontal GT layout, a simplified single compressor system, special rotor seals for T/G, conventional steel for RPV, and a lifetime of 60 yrs.

Russian Federation

- **GT-MHR**:
  - Schedule for Pu-burning prismatic design with multi-national support, calls for final design by 2005 and construction at SCC-Severesk by 2009.
  - Technologies under development include PU O_2 ceramic coating, single-shaft turbo-machinery (shaft length: 29 m, weight: 105 tonnes), compact recuperator design, specs for graphite and RPV heat-resistant materials.
  - Co-generation could boost thermal efficiency from 48% to over 80%

South Africa

- **PBMR**:
  - The project, a consortium of Eskom, IDC, BNFL and Excelon, was given the go-ahead by the government in Apr. 2000.
  - Current design criteria: - US$1000/Kwe – 24 months construction – 400 m EZP
  - Key safety issues: Safety NOT He-coolant dependent – Short-term transients NOT a concern - 3.2 m-thick concrete separation ensures plant protection against external crashes.
  - Current issues:
    - Technology: Power upgrade from 268 to 302 MWt – Multi-shaft turbo-machinery layout with penalty to efficiency not exceeding 1% - Core geometry, containment, safety classification and Q/A issues.
    - Cost: 5-pack optimisation of modular design foreseen – Standard learning curves to be applied for fabrication and construction with costs expected to be halved by the 10^{th} unit.
    - Regulatory issues: NNR safety review planned – Environmental impact assessment due in Mar. 2002.
    - Schedule: Design status: long-lead items such as pressure boundary need to be negotiated early – Fuel fabrication issues

Turkey (Observer)

- Per-capita electricity consumption expected to double from 1966 KWh in 2000 to 3867 KWh in 2010.
- NPP project postponed by government in July 2000, due to economic difficulties.
- Merits seen for HTGRs in terms of economics, safety and effect on the environment

European Union

- **HTR-TN**:
  - Technology network created in April 2000.
  - Joint Research Centre (JRC) is the network operator with a membership of 18 organizations, half from the industry and half from research and educational institutions.
  - Initial activities based on projects co-sponsored y the European Commission under the 5^{th} EURATOM Framework Program (FP5) for the period 1998-2002.
  - Program envisions a long-term European HTR roadmap and opportunities for international cooperation.
- **European Commission**:
  - Current projects are ~ 50% funded by the EC and include:
    - HTR-N: Addressing core physics and fuel cycle issues

- HTR-F: Addressing fuel technology issues with the objectives of developing advanced high-performance HTGR fuel. Focus on fabrication methods with the PU option considered for eventual management of civilian inventory, as well as on high-fluence irradiation (up to 20% FIMA) and heat-up experiments (1600-1800 °C). A fuel performance code will also be developed and benchmarked.
- HTR-M: Addressing graphite and high-temperature material behaviour issues
- HTR-E: Addressing reactor components such as the Power Conversion System.
- HTR-L: Addressing licensing and safety issues
- HTR-C: Co-ordinating and integrating all projects

France

- **CEA**
  - 6 projects related to gas-cooled reactors, including system and core studies, fuel cycle, high-temperature materials, Helium circuit components and hydrogen production.
  - Emphasis on both thermal and fast neutron spectrum concepts. Planning includes:
    - Fuel fabrication capacity by 2004 and irradiation by 2006
    - Material studies and helium loop tests
    - Experimental reactor at Cadarache (20-40 MW) by 2012
    - Pre-qualification of fast GCR fuel by 2015
  - Coordination planned with COGEMA and EDF

Germany

- No commercial HTGR activity since 1992
- Activities tailored towards:
  - Participation in HTR-TN and PBMR projects
  - Know-how documentation and R&D on generic safety issues
  - Decommissioning work with THTR-300 now in safe store conditions and AVR under way

Netherlands

- HFR reactor and PIE facilities to be used for the European HTR-F irradiation program (EU1 and EU2)
- Long-term behaviour of spent HTR-fuel to be studied under the HTR-M program
- Computational studies to continue on core design, thermal hydraulics and shielding. Code qualification, co-generation, Pu fuel, use of burnable poison for long-life cores and fission product transport are among the issues tackled.
- Coordination planned between NRG, JRC-IE at Petten and IRI at Delft.

UK

- 28 % of UK electricity is nuclear.
- BE has 14 AGRs and 1 PWR – BNFL has 18 MAGNOX-type plants.
- BNFL is shareholder in PBMR. NNC and BNFL are members of EU FP5.
- UK is decommissioning 15 plants and AEA is getting out of nuclear.

US

- **DOE**
  - Generation IV Roadmap: (http://gen-iv. ne.gov)
    - GCRs are one of the concepts examined by the International Forum (GIF)
    - Concepts include pebble-bed, prismatic, very-high temperature and fast-spectrum types.
  - NERI and NEST projects are addressing HTGR-related R&D including:
    - 9 ongoing NERI (research initiative) projects
    - Fuel technology and irradiation programs
    - International cooperation R&D projects (I-NERI)
  - DOE and NRC are cooperating on HTGR safety and regulatory issues.
- **EPRI**
  - Research initiatives include:
    - Power conversion system (PCS) technology and maintenance issues such as static helium seals, auxiliary bearings and fission product plate-out.
    - Graphite and component material behaviour.
    - Fuel handling systems R&D

III Review Of IAEA Activities

- **CRP-5:** (Coordinated research project on HTGR performance evaluation)
    - The CRP, extended until 2004, involves 9 Member States and aims at:
        - Validating computational codes used for HTGR core physics and safety assessment, using selected benchmarks from HTR-10, HTTR and ASTRA tests
        - Documenting results in two stages (2 IAEA-TECDOCs).
    - The next RCM (RCM-4) will be held in Vienna in Oct. 2002.
- **CRP-6:** (Coordinated research project on HTGR conservation and application)
    - Von Lensa presented the SINTER network concept for HTGR online collaboration
    - There was no pledge of minimum support required to carry out activities of the pending CRP.
- **INPRO Project:** (International Project on Innovative Nuclear Reactors & Fuel Cycles)
    - Track 1 involves selection of criteria and development methodologies for innovative nuclear power plant concepts.
    - Track 2 will examine technologies made available by Member States against the criteria set in Track 1.
- **Meetings**
    - **16th TWG meeting**
        - Recommendations from the previous 16th meeting of the TWG were reviewed. All have been taken into consideration within the Agency program, with the exception of the pending CRP on conservation and application of HTGR technology, which has not secured enough support from Member States for its execution, and the CRP on HTGR fuel qualification. The latter has so far been delayed mainly by organization and budget constraints.
    - **Palo-Alto TCM**
        - Larry Brey gave a brief overview of the TCM on Gas Turbine Power Conversion Systems for HTGRs, held in Palo Alto, US (Nov. 2000)
    - **Graphite database TCM**
        - Recommendations from a Specialist Nuclear Graphite Meeting held in Rain, Germany in Sep. 2001, were discussed. They call for new graphite irradiation experiments to be considered. The TWG was of the opinion that there was no need for immediate concern and that discussions on further research needs for the Graphite database, should be held with experts in the field.
- **IAEA Publications**

- A CD with available TECDOCS has also been prepared for distribution to participants. Recently published TECDOCS have been highlighted and can be reached at the HTGR web site of the IAEA: **http://www.iaea.org/inis/aws/htgr**

Attachment 1 **AGENDA**

17th Meeting of the IAEA Technical Working Group on Gas Cooled Reactors (IAEA TWG-GCR)*

6-9 November 2001

Cape Town, South Africa

Tuesday, 6 November 2001

Welcome and Opening Remarks	PBMR/IAEA	10:00
1. Topical Session – HTGR Core Internals Design		
• Opting for an annular reactor layout	Mulder	10:20
• Passive HTR design: a PBMR perspective	Davis	10:40
• Structural design features of HTR-10 ceramic internals	Xu	11:00
• HTTR core internals design	Shiozawa	11:20
• Design performance of core internal elements in GT-MHR reactor	Sukharev	11:40
• AVR core internals design	Von Lensa	12:00
LUNCH		12:20
2. Topical Session – HTGR Code benchmarks		
• PBMR calculations: VSOP vs. Panthermix	van Heek	14:00
• Core physics benchmark for HTR-10	Colak	14:20
• Burnup-dependent core neutronics for PBMR	Kadiroglu	14:40
COFFEE BREAK		15:00
3. Topical Session – HTGR Transient analysis & tests		
• Transient analysis of the PBMR	Kemp	15:20
• HTR-10 zero power and fuel irradiation tests	Xu	15:40
• HTTR operation tests	Tachibana	16:00
• Behaviour of GT-MHR Reactor in Accident Transients	Sukharev	16:20
• HTR-MODUL licensing events	Brinkmann	16:40
• Transient behaviour and control of the ACACIA plant	Van Heek	17:00
DISCUSSION		17:20
Adjourn 1st Day		18:00

* Formerly the International Working Group on Gas Cooled Reactors, name changed in 2001

Attachment 1 **AGENDA**

Wednesday 7 November 2001

4. TWG-GCR Opening Session

• Introduction of TWGGCR Members and Observers	All	09:00
• Scientific Secretary's Remarks/Draft Agenda	Methnani	09:20
• Discussion and Finalization of the Agenda	Chairman/All	
COFFEE BREAK		09:40

5. Descriptions and Summary Status of National & International GCR Programmes

• China	Xu	10:00
• Indonesia	Lasman	10:20
• Japan	Shiozawa	10:40
• Russian Federation	Sukharev	11:00
• South Africa	Nicholls	11:20
• Turkey	Tanrikut	11:40
LUNCH		12:00
• European HTR-Network	Hittner	13:00
• European 5th Framework	Martin-Bermejo	13:20
• France	Chapelot	13:40
• Germany	Von Lensa	14:00
• Netherlands	Van Heek	14:20
• United Kingdom	Marsden	14:40
COFFEE BREAK		15:00
• United States	Feltus	15:20
• US DOE GIV & TWG-GCR		15:40
• US: EPRI R&D program on HTGR component technology	Brey	16:00
• Adjourn 2nd Day		16:20
Braai (Barbeque)		18:00

Attachment 1 **AGENDA**

Thursday 8 November 2001

6. Review of Activities/Meetings Within the Frame of the TWG-GCR

• Recommendations from the 16th IWGGCR	Methnani	09:00
• Recently published TECDOCs	"	
• TCM on Gas Turbine Power Conversion Systems for Modular HTGRs	"	
• Gas Cooled Reactor Internet Site	"	
• CRP on Conservation and Application of HTGR Technology	All	09:20
• CRP on HTGR Coated Particle Fuel Technology Development	All	
COFFEE BREAK		10:20
• CRP on Evaluation of HTGR Performance	Brey	10:40
• CRP-5 Discussion	All	11:00
• Irradiated Nuclear Graphite Properties Database	Marsden	11:40
LUNCH		12:00

7. Recommendations on Future IAEA GCR Activities

● Open Discussion	All	13:00
COFFEE BREAK		15:00

8. Meeting & Agreements Summary

● Next TWG-GCR Meeting	Chairman/All	15:20
● Summary & concluding remarks		15:40
Adjourn meeting	Chairman	16:00

Friday 9 November 2001

9. Tour of Koeberg/PBMR site 9:30-12:00