Meeting report of the first RCM of a CRP on Small reactors without on-site refuelling.
IAEA, Vienna, 21 – 25 November 2005

Group 3 "Design and technology development for lead, lead-bismuth, and molten salt cooled reactors"

Task description and the objective

The general objective of the activities of Group 3 is to collect available data on properties of lead, lead-bismuth and molten salt coolants, as used by different design teams, and to compile a handbook of those properties of these coolants that are important for the neutronics and thermal hydraulics calculations of the relevant small reactors. The specific tasks include benchmark analysis of the neutronic and thermal-hydraulic characteristics of proposed models. Future work will also include safety and sensitivity analyses (for safety related studies). Also included are works related to the development of several enabling technologies, such as material compatibility studies, studies for coolant purification technologies and development of special components related to these coolants.

Participants of the RCM

For Group 3, the participants of the meeting were:
G.I. Toshinsky (IPPE, the Russian Federation);
H. Sekimoto (Tokyo Tech, Japan);
D. Wade (ANL, USA);
Zaki Su'ud (ITB, Indonesia);
A. Dedul (EDO Gidropress, the Russian Federation);
A. Sedov (RRC "Kurchatov Institute", the Russian Federation);
I.V. Dulera, Chairman of Group 3 (BARC, India).

Status of activities

Work plans have been successfully fulfilled and first-year reports submitted by the participants of Group 3 who completed their first year of work by the time of this meeting.
Coordination for future work was defined during the meeting and will be elaborated after the meeting through communication of all participants.

Plan for the second year and beyond

The activities to be performed within the next year are as follows:

- Development of a consolidated database related to the neutronic and thermo-physical properties of Pb, LBC and molten salt. The database also aims to include results of various material compatibility studies and thermal-hydraulic correlations at different temperatures (up to 1000^{o}C).
  To initiate this activity, a mutually agreed format will be prepared under the guidance of Dr. David Wade, ANL; the possibility of accessing a similar database being developed at the OECD/NEA will also be examined; the initial effort would be to compile data from all relevant sources; BARC would carry out translation work for literature available in Russian to English.
- Reactor physics analysis as a benchmarking exercise for two mutually agreed reactor concepts (reactors based on fast neutron spectrum on intermediate neutron energy spectrum) with the exchange of information on codes and methodologies used for the analysis. For this, the reactor specifications will be decided with mutual agreement through further correspondence;
- Thermal-hydraulic analysis (specifically, for natural circulation) as a benchmarking exercise for a mutually agreed reactor / loop concept(s) with the exchange of information

on codes and methodologies used for the analysis; the reactor/ loop specifications to be decided with mutual agreement through further correspondence.

Additional activities for next two years would be:

- Structural material compatibility studies with these coolants for the extended temperature ranges (up to 1000^{o}C) – for metals, carbon, ceramics, coatings; and exchange of data for the same
- Studies of general behaviour of the coolants during planned/ unplanned "freezing-defreezing" due to reactor returning to cold conditions.
- Studies of natural circulation behaviour of coolant with and without assistance of the injection of gas or water;
- Development of the enabling technologies related to lead, lead-bismuth, and molten salt based coolants. This includes
  - Development of primary components, instrumentation and sensors, such as centrifugal and electromagnetic (EM) pumps, EM flow meters, oxygen sensors, sensors to monitor Pb as well as Po activity in the environment;
  - Corrosion control technologies;
  - Purification technologies (to remove corrosion products, and polonium etc.)
- Safety analysis under postulated accident scenarios;
- Sensitivity analysis for the neutronics and safety related studies.

Schedule for the activities in 2006

(1) Exchange of data on Pb, Pb-Bi and molten salt thermo-physical characteristics as well as exchange of information on the used computer codes would be the first step towards the compilation of a handbook.

The data on the properties, among others, would include:

(a) Data used for the neutronic calculations of Pb, Pb-Bi, and molten salt cooled reactors (variation with respect to temperature up to 1000^{o}C or more);
(b) Data used for thermo-hydraulic calculations of Pb, Pb-Bi, and molten salt cooled reactors (variation with respect to temperature up to 1000^{o}C or more);
(c) Heat transfer correlations and coefficients;
(d) Compatibility data for structural materials with coolant and results of the corrosion behaviour studies;
(e) Mechanical properties of structural materials with respect to temperature and fluence;
(f) Description of the computer codes used for neutronics, thermal-hydraulics and safety analyses.

The contributors are requested to include the details of references (sources of data).

Milestones: Mid December 2005 - First suggestion of the database format by Dr. D. Wade;
End of January 2006 - Finalization of the format (by all members)
End of April 2006 - Submission of available data by member states for the compilation of a handbook; (by all members)
End of June 2006 – Translation of data from Russian to English by BARC, India
End of August 2006: - Compilation of data.

(**Action**: Initially Dr. Wade to suggest an initial format and then all the participants to decide format and then contribute towards database). BARC has volunteered to carry out translation work, if required, from Russian language to English

(2) Neutronics-related benchmark analysis. There will be two types of neutronic benchmarks for Pb-Bi/ Pb/ molten salt cooled systems:

- For reactors with fast neutron energy spectrum;
- For reactors with intermediate neutron energy spectrum.

Milestones: By January 2006 - First suggestion on reactor configurations; (Action: Dr. Zaki Su'ud and Dr. Sedov)
By April 2006 – Final definition of reactor configurations; (Depending on feedback from all participants)
May-early September 2006 – Calculations/ analysis of results by each design team; repeated calculations, if needed. (Action: All participants)

Action

- Dr. Zaki Su'ud will provide the geometry, configuration and other necessary data for benchmark analysis of fast reactor systems.
- Dr. A. Sedov will provide the geometry, configuration and other necessary data for benchmark analysis of intermediate spectrum reactor systems.

The characteristics to be benchmarked are:

(a) At BOL: - Keff;
- Power distribution;
- Breeding ratio;
- Point wise isotopic reaction rates (for important nuclides: ^{238}U, ^{239}Pu, etc.)

(b) Depletion analysis (0 ~ 30 years):
- Keff changes with depletion (0 ~ 30 years);

(c) At EOL: - Power distribution;
- Breeding ratio;
- Point wise isotopic reaction rates (for important nuclides: ^{238}U, ^{23}9Pu, etc.)

(3) Fission products analysis model

Milestone:

- Dr. Zaki Su'ud will distribute partial results of his fission products analysis model studies by April 2006. (Action Dr. Zaki Su'ud)

(4) Benchmark analysis for natural circulation of the coolant

The model selected and agreed upon by everybody would give all the details necessary for carrying out analysis such as:

- Core details including overall dimensions;
- Pool or loop geometry;
- Details on heat removal path/steam generator. etc.

} Action: All participants are requested to suggest model/ models

Attempt will be made to select a model for which experimental results are either available or can be found out experimentally.

Milestones:

- It is expected that initial suggestion as regards model would come in January 2006.
  Action: All participants are requested to suggest model/ models
- The model to be analysed will be decided by April 2006 after mutual exchange of information by the group members and discussions;
  Action: All participants to help in deciding the model

- May-early September 2006 – Calculations/ analysis by each design team; repeated calculations, if needed. (Action: All participants)

TECDOCs to be prepared

Group 3 plans to prepare a TECDOC on Status of the neutronics benchmark analyses after completing the second year of work.

(All participants are requested to suggest as whether we can also plan to accommodate results of thermal hydraulic analysis in the TECDOC)