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Meeting of the
Technical Working Group on Fast Reactors (TWG-FR)

Hosted by

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Kyoto International Conference Center

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1. Introduction

The 40th Annual Meeting of the Technical Working Group on Fast Reactors (TWG-FR) was held from 14 – 18 May 2007 at the MONJU site and in Kyoto, Japan, at the invitation of the Japan Atomic Energy Agency (JAEA).

The first event of the 40th TWG-FR meeting was a Commemorative Symposium held in the MC Square Hall at the MONJU site. The overall objective of the Commemorative Symposium was to confirm the importance of the development and the utilization of nuclear energy, with particular emphasis on the achievements of fast reactor development and its future role towards meeting sustainability requirements as a necessary condition for securing nuclear energy an important role in the global energy mix. The Symposium had also the important objective of addressing the prospects of international collaboration within the framework of IAEA and the TWG-FR, including the expected role and contributions of MONJU to the benefit of worldwide FR development efforts.

After an extensive visit of the reactor, in which the TWG-FR representatives from Belgium, France, Germany, India, Italy, Japan, Republic of Korea, Russia and USA took part, followed by the presentation of the status of the MONJU restart activities, the Commemorative Symposium started with greeting remarks by IAEA (A. Stanculescu on behalf of Y. Sokolov, DDG-NE), and JAEA (Yuichi Hayase, Executive Vice President JAEA), followed by two congratulatory addresses by the Ministry of Education, Culture, Sports, Science and Technology MEXT (Akihiro Fujita, Director-General Research and Development Bureau), and by the Fukui Prefecture (Nobuaki Asahi, Deputy Governor).

In the first part of the Symposium, four leading scientists who were and still are instrumental in the development of the fast breeder reactor technology delivered the following lectures: “The role of fast reactors for long-term sustainable nuclear power” (M. Salvatores, CEA and ANL)”, “History of IAEA's IWG-FR/TWG-FR, and its Future Role in Fast Reactor Research and Technology development” (G. Heusener, former senior FZK scientist and IWG-FR/TWG-FR German representative), “FBR Development in Japan and Activities of TWG-FR” (K. Tomabechi, former senior JAEA scientist and IWG-FR/TWG-FR Japanese representative), and “Perspective on the Global and Japanese Fast Reactor Development” (Y. Fujiie, former JAEC Chairman).

The second part of the Symposium consisted in a Panel discussion, in which the four lecturers were joined by TWG-FR representatives and senior scientists from France (J.C. Astégiano, senior scientist CEA), India (P. Chellapandi, Associate Director Nuclear Engineering, IGCAR), Japan (K. Mukai, Director-General, Advanced Nuclear System Research and Development Directorate, JAEA), Russia (Y. Ashurko, senior scientist, IPPE Obninsk), and USA (E. Fujita, Deputy Division Director, ANL) to discuss possible collaboration projects within the framework of the TWG-FR and the expected role of MONJU for this collaboration. All panellists stressed the importance of international collaboration and “learning by doing”. The IAEA and the TWG-FR are seen as having a central role in ensuring that knowledge and experience are shared to ensure efficient and safe progress of fast reactor technology development. The closing remarks, after a lively discussion between panellists and the audience (noteworthy that many young people were present), were made by Tsutomo Yanagisawa, Executive Director, Deputy Senior Director of the JAEA Tsuruga Head Office.

The technical and scientific part of the 40th TWG-FR meeting was attended by the TWG-FR Members and Advisers from the following Member States (MS): Belgium (observer), France, Germany, India, Italy, Japan, the Republic of Korea, the Russian Federation, and the United States. Apologies for not being able to participate were received from Brazil, China, Kazakhstan, Switzerland, the United Kingdom, the European Commission, and OECD/NEA.

Mr. R. Nakai, from Japan (JAEA), was appointed chairman.

The objectives of the meeting were to:

- Exchange information on the national programmes on Fast Reactors (FR) and Accelerator Driven Systems (ADS);
- Review the progress since the 39th TWG-FR Annual Meeting, including the status of the actions;

— Consider meeting arrangements for 2007, 2008 and 2009;
— Reviewed the Agency's ongoing information exchange and co-ordinated research activities in the technical fields relevant to the TWG-FR (FRs and ADS), as well as coordination of the TWG-FR's activities with other organizations;
— Discuss future joint activities in view of the Agency's Programme and Budget Cycle 2008–2009 (and beyond).

2. Presentation and Discussion of FR and ADS Developments in the MSs

The participants made presentations on the status of the respective national programmes on FR and ADS development. A summary of the highlights for the period since the 39th TWG-FR Annual Meeting is given below:

Belgium

The Belgian activities in the field of "Fast Reactors and Accelerator Driven Systems (ADS) – Technical Working Group on Fast Reactors" are mainly related to ADS and in particular to the MYRRHA project development. MYRRHA is an accelerator-driven, multi-purpose fast neutron spectrum facility for R&D, cooled by a lead-bismuth eutectic.

The evolution of MYRRHA has been presented extensively in recent TWG-FR annual meetings, and in particular the spallation target and our collaboration network (May 2004), the core management, the primary systems design and the safety analysis (May 2005), the results obtained within the framework of the European FP6, and the perspective for implementation (May 2006).

SCK•CEN has started the MYRRHA project as a national programme with several national and international bilateral collaboration agreements; the project has now evolved as an European integrated project within the framework of the IP_EUROTRANS (European Commission, Sixth Framework Programme, FP6). The MYRRHA "Draft – 2" pre-design file (presented in 2005) has been proposed to the partners as a basis for the XT-ADS machine. After a detailed investigation of potential alternatives, the MYRRHA concept (for the sub-critical core, the primary coolant system, the accommodation of experimental rigs, the reactor vessel and the spallation target) has been kept with some modifications to achieve the XT-ADS objectives. The preliminary XT-ADS conceptual design has been presented at our topical meeting in December 2006. The most recent version of the XT-ADS design is presented in the detailed country presentation.

The R&D programme is also partly included in IP_EUROTRANS. The most recent results have been obtained in the domain of the WebExpIr experiment, where we study the interaction between the lead-bismuth free surface and a high-power DC electron beam (mainly the free flow distortion and the lead-bismuth evaporation due to surface heating).

Beyond 2008 (at the end of IP_EUROTRANS), perspectives are under consideration with several EU partners and the EC, for structuring the implementation and the deployment of the XT-ADS. SCK•CEN is considering Joint Undertaking for setting up this framework and has already declared its readiness to welcome a fast spectrum irradiation facility at its technical site in Mol, Belgium. For this purpose, several bilateral agreements have been signed or existing agreements are currently being refreshed, the most recent agreements being between SCK•CEN and CEA, France (4 October 2006) and between SCK•CEN and CIEMAT, Spain (17 April 2007).

Belarus

The Belarus activities in the field of "Fast Reactors and Accelerator Driven Systems (ADS) – Technical Working Group on Fast Reactors" are mainly related to ADS and in particular to the investigations performed at the sub-critical facility YALINA. Yalina is a zero power sub-critical facility to study neutronics of ADS and the transmutation reaction rates.

The first assembly YALINA-T was put into operation in 2000. Yalina-T is a multiplying system (k_{max}<0.98), located inside a graphite reflector of parallelepiped configuration that is composed of high purity "reactor graphite" blocks. The core of the assembly is of parallelepiped configuration too and consists of “bare” polyethylene sub-assemblies where fuel rods of the EK-10 type (UO_2 with 10% ^{235}U enrichment) are located. At the core center, a neutron-producing Pb target is located, having the shape and size of a fuel subassembly. On the outside, the graphite reflector is covered by Cd. Three experimental channels (25 mm diameter) are situated at R=50 mm, 100 mm, and 150 mm from the core center. These channels can hold samples of radioactive targets and/or various detectors for the measurement of the neutron flux density. For the same purpose, two axial channels (25 mm diameter) are also located in the graphite reflector at the distances 250 mm and 358 mm. A radial channel is located at Z=H/2 (25 mm diameter).

The YALINA-B (Booster) core is also an assembly of rectangular parallelepipeds. The fast (booster) zone consists of lead subassemblies, the thermal one of polyethylene subassemblies. The central part of the booster zone, containing highly enriched (90%) metallic uranium fuel and the lead target is encased into a separate stainless steel frame. An absorber (buffer) zone is located at the outer boundary of the booster zone. It consists of an inner layer of rods fuelled with metallic natural uranium fixed in lead blocks, as in the previous cases, and of an outer layer of rods filled with boron carbide powder. The boron carbide rods are located in the same lattice as the uranium fuel pins in the booster zone with pin pitch of 16 mm. This absorber zone enables fast neutrons to penetrate into the thermal zone, outside the absorber and fast zones, and prevents thermal neutrons from entering the booster zone from the thermal zone. The result is a fast neutron coupling of the fast and the thermal zones. The absorbing boron carbide powder rods with are fastened rigidly and may not be taken out accidentally, to prevent undesired reactivity insertions. The thermal zone surrounds the booster zone and the absorber zone. There are three experimental channels in the thermal zone. Finally, the thermal zone is surrounded radially by a graphite reflector. In the reflector there are three experimental channels. Axially, the core is surrounded by borated polyethylene. The external neutron source is provided by either neutrons of energies E_n = 13-15 MeV produced by the $d(^3H,n)^4He$ reaction, or by neutrons of energies E_n = 2.5-3.0 MeV produced by the $d(^2H,n)^3He$ reaction. Deuterium ions produced in a duoplasmatron are accelerated up to E_d = 250 keV in a linear accelerator. The accelerator magnet system separates the d+ ions, which are then directed by means of electromagnetic lenses towards a tritium target (Ti^3H) or a deuterium target (Ti^2H). At present, highly effective water-cooled targets with 230 mm and 45 mm diameters are used in the experimental programs.

The theoretical and experimental ADS neutronics investigations are performed within the framework of Belarusian scientific programs and international cooperation, i.e. the current IAEA Coordinated Research Project, the ISTC project #B1341, and the IP EUROTRANS. The research encompasses the following areas:

- Verification and validation of methods for sub-criticality monitoring;
- Experimental study of kinetics of sub-critical systems;
- Measurements of spatial distribution of neutron flux density;
- Influence of neutron pulse parameters on the time behaviour of the neutron flux;
- Measurement of long-lived fission products and minor-actinides transmutation rates.

France

General situation and national policy

Nuclear energy is a competitive, safe, environment friendly method of electricity generation, chosen by France since the 1970’s. To ensure that the next generations can also enjoy a stable and safe supply of energy, this strategy must be pursued. France is now building this strategy, which relies on new legal tools (such as bills and debates), a timetable for the future, and a constant involvement of the public in all the major steps of this strategy.

After the national debate organised in 2003 on energy policies for the next 30 years to come, the French government issued a White Book on Energy, which contributed to the debate and gathered many contributions from French national representative organisations. In 2005, the French government proposed a new bill, adopted by French parliament on 3 June 2005. This law, governing the orientations of the new energy policy provides for the continued support of the nuclear option in France, which is a decisive option for three of the objectives in terms of the new energy policy defined within the texts of the law, namely (1) safeguard the independence of the French national energy resources and security in their procurement, (2) fight against the Green House Gas Effect, and (3) ensure regular and competitive prices for electricity. This law calls to keep all options open for the replacement of present-day nuclear power plants, and to build an EPR power reactor before launching a series.

At the beginning of 2006, during his traditional New Year's Address to the Nation, the President of the French Republic, Jacques Chirac, announced the commissioning of a "Fourth Generation prototype reactor" for 2020. On this occasion, Mr. Chirac stated: "Many countries work on the new generation reactors, those planned for the years 2030-2040, which would produce less nuclear waste and would allow operators to improve their management of fissile matter. I have therefore decided to launch, as of now, the design of a Fourth Generation prototype reactor within the French Atomic Energy Commission (the CEA). This prototype will be commissioned in 2020. We shall, of course, include our industrial or international partners who wish to collaborate with us. The challenge to our national energy policy goes well beyond our borders. It is now on the European level that we must combine forces to build a bold energy policy." This declaration provides a compelling argument for setting up a correspondingly ambitious program.

From September 2005 to January 2006, the nuclear institutional context has been focused on public debates about the future radioactive waste bill. Among others, this public debate has permitted to identify the main current subjects of anxiety about nuclear power: terrorism, long term impact of radioactive waste on human health and environment, transparency of information, and to provide the answers. In conformance with the demands of the calendar and guidelines of the Law of 30 December 1991, the new law was drafted on the basis of results obtained from 15 years of research carried out by the National Agency for Radioactive Waste Management and by the French Atomic Energy Commission. Independent assessments were carried out by both French and foreign experts, and were based on the Report from the Parliamentary Office on the evaluation of scientific and technological choices, on the synthesis of the debate organised by the National Commission of Public Debate, and lastly by the authority of the Economic and Social Council. In June 2006, the new bill on the management of radioactive material and wastes was adopted by the French parliament. This law stipulates that studies and investigations shall be conducted in conjunction with those concerning the new generations of nuclear reactors referred to in the aforementioned 3 June 2005 French law setting the orientations of the energy policy, and in conjunction with those studies concerning accelerator-driven reactors dedicated to the transmutation of waste. The objective is to provide by 2012 an assessment of the industrial prospects of those systems and to commission a pilot facility before 31 December 2020.

From October 2005 to February 2006 a wide national debate on the Flamanville Nuclear Plant Project (EPR) was organised: 23 public debates were held in the major cities of lower Normandy, from the west and in many other sites in France. On 4 May 2006, EDF undertook the realisation of the EPR Project - a fact that constitutes an essential stage in the renewal of the French nuclear reactor infrastructure. Its commissioning, planned for 2012, will provide France with a reactor of high performance, and in time with a proven industrial organisation. The EPR is part of the continuity of existing technologies. It unites all recent progress to offer a great flexibility in its use and to guarantee safe electricity production, both competitive and low in its production of greenhouse gases. In the present economic conditions, the cost of this investment is estimated to be at about 3.3 billion euros, which translates (in 2005 euros) into 46 euros per MWh.

French nuclear energy

The EDF nuclear power plant infrastructure currently in operation consists of 58 PWR units, distributed over 19 sites, specifically thirty-four 900 MWe units (of which 20 loaded with MOX fuel), twenty 1300 MWe, and four 1450 MWe units for a total installed capacity of 63 GWe.

From a safety standpoint, certain safety indicators in 2006 were not as good as those of 2005, which was an exceptionally good year. This concerns in particular, the fact that the overall numbers of events declared to the Safety Authorities were on the rise, from 9.5 events per reactor in 2005 to 10.2 events in 2006. At the same time the number of events classified on the INES (International Nuclear Event Scale) increased from 0.76 in 2005 to 1.2 in 2006. The first aspect is of no cause for concern, it confirms EDF's policy of transparency. However, the second aspect must be closely watched. It should be pointed out that the year 2006 did not stand out with any serious safety event or any exposure higher than the legal doses. No event whatsoever was classified as Level 2 (or higher) on the INES scale, which is a positive development in comparison to the past ten years.

The radioprotection indicators continue to improve, and the availability of the nuclear infrastructure has never been higher (83.6% in 2006 versus 83.4% in 2005) despite technical difficulties and unpredictable weather conditions.

In 2006, French internal electricity consumption was down by 1% compared with 2005, with a cumulative total for the year of 478.4 TWh, some 4.8 TWh less than in 2005. The year 2006 was marked by very cold periods up until mid-April, with mild temperatures at the end of December.

French electricity generation in 2006 was down slightly (-0.2%), as compared to the previous year:

— Generation by nuclear power plants fell by 0.3% compared with 2005;
— Generation by hydro-electric plants rose by 8.4% compared with 2005, as a result of more favourable water conditions (rainfall, etc.);
— Generation from renewable sources other than hydropower rose by 27.7% or 1.2 TWh. In 2006, it accounted for a total of 5.5 TWh, with 2.2 TWh of that amount produced by wind farms. The volume of wind generation rose by 126% compared with 2005, in line with the increase in installed capacity connected to the grid;
— Generation by conventional thermal power plants, which are used to maintain the supply-demand balance, fell by 9.6%.

Status of French Fast Reactors

In 2006, the RAPSODIE plant was maintained safely under monitoring. A new strategy was elaborated for the dismantling of the plant consisting of two main steps: a cleansing period from 2004 to 2008 followed by a dismantling period lasting from 2009 to 2017.

In 2006 the annual availability factor of the Phénix plant was equal to 78%. The load factor was 56%.

The main event occurred at the end of the summer planned shutdown period, when a series of problems were experienced on the bearing n°3 of the turbine. This event led to approximately two months of delay in restarting the plant. There were two scheduled shutdowns for refuelling, maintenance and inspection. The 53rd cycle ended on 30 June 2006 after completion of 116 EFPD. The reactor operated at nominal power from October 2006 to the end of March 2007, except for one short shutdown following a trip that occurred during a maintenance operation. The plant record of continuous grid connected operation was broken in 2006: 151 days, from 14 October to 14 March (the previous record was 99 days achieved in 1999). The 54th operating cycle was completed on 30 March 2007 (105 EFPD). At this time, the availability and the load factor were 97%. A one-month shutdown is planned in April 2007, during which the main maintenance operation is the coating of the condenser tube for reinforcement. There are two more operating cycles planned (representing about 250 EFPD) until final shutdown of the plant in 2009.

Decommissioning work on the SUPERPHÉNIX reactor is going on. Since the end of 1999, six hundred-fifty subassemblies have been unloaded and safely stored in the water pool. Large dismantling activities were completed: the 400 kV line in 2001, the chimney stacks in 2002, and the dismantling of all components within the turbine hall in 2004. On the reactor block, a specific drilling machine drilled the core catcher plate in October 2003, to allow natural draining of the core catcher during the planned draining operation of the reactor block. Some of the small primary components were extracted from the primary sodium, then cut into small pieces, and cleaned in existing pits. In 2004, a public inquiry covering all decommissioning aspects was organized and successfully completed by the local authorities. New requests for regulatory authorizations have been submitted in 2004 by the Engineering Center for Decommissioning and Environment (EDF) to complete the dismantling of the plant (until 2025). The new final decree was issued in March 2006.

Future nuclear systems

Within the context already described, scoping studies carried out by the CEA and industrial partners led to the elaboration of a French R&D strategy for future nuclear energy systems for the medium and the longer term (> 2040). This strategy aims at three complementary objectives:

— The development of fast neutron systems with a closed fuel cycle (sodium or gas cooled fast reactors) for a sustainable energy supply through breeding in the long term, and for managing actinides from light water reactors spent fuel in the medium term;
— The development of key technologies for the nuclear production of hydrogen or the supply of high or very high temperature heat for the industry in close collaboration with industrial partners (high or very high temperature reactors and water splitting processes);
— Innovations for light water reactor fuels, systems and high conversion cores to further optimize LWRs until 4th generation fast neutron systems are mature for industrial deployment around 2040.

The R&D priority is clearly put on fast neutron nuclear systems with a closed fuel cycle, the Sodium cooled Fast Reactor (SFR) and the Gas cooled Fast Reactor (GFR), owing to the general recognition of their capability to meet sustainability goals that include optimizing the use of natural uranium resources and minimizing long lived radioactive waste production (minor actinides). In addition, at a lower but significant level, R&D is conducted on High or Very High Temperature Reactors (VHTR) in support to the AREVA project on multipurpose nuclear heat source ANTARES presently viewed at 850°C for potential market needs from 2025 onwards. In March 2005, the French Government formally approved this R&D strategy proposed by the CEA and its industrial partners AREVA and EDF.

The Gas cooled Fast Reactor (GFR) is considered by the French Atomic Energy Commission as a promising concept, potentially feasible and attractive according to GEN IV criteria. The helium cooled fast reactor is an innovative nuclear system with such attractive features as a chemically inert and optically transparent coolant, as well as a quasi-decoupling of the reactor physics from the state of the coolant. Other advantages of the GFR relate to its promise as a high/very high temperature reactor (VHTR) capable of producing hydrogen, synthetic fuels and process heat. On the downside, since gas is a poorer coolant than liquid metals, key aspects demonstrating the viability of the GFR include development of a refractory and dense fuel, and robust management of accidental transients, especially cooling accidents. Accordingly, the feasibility of the GFR is essentially linked to two demonstrations: the mastery (fabrication, thermo-mechanical behaviour) of a high fissile content refractory fuel, and the implementation of appropriate safety systems for the prevention, and a robust mitigation of accidental scenarios (especially depressurization). Because there is no experience available with the GFR, a first step for demonstrating its feasibility is the operation of a 50-100 MWth experimental reactor, the ETDR (Experimental Technology Demonstration Reactor), to qualify its specific fuel, materials and operating principles. Ideally, R&D results expected by 2012-15 could support a decision to construct the ETDR, possibly as a European Joint Undertaking, and commission by 2020.

The Sodium cooled Fast Reactor (SFR) is the reference technology for fast reactors. It may be considered for industrial deployment around 2040 since Europe, in cooperation with Japan, Russia and the United States, has acquired important expertise in this reactor type. However, innovations are needed for a Generation IV sodium cooled fast reactor to compete with Generation III LWRs in economics and safety. This will require system simplification to reduce investment cost, enhanced safety with improved prevention and management of severe accidents, improved operability (fuel handling, maintenance and repair) to achieve high capacity factors, and advanced closed fuel cycles with multiple recycling of actinides offering appropriate resistance to proliferation and optimized waste forms. Given the maturity of the technology, the prototype SFR planned in France for 2020 will in the range of 300 to 600 MWe to demonstrate the selected innovations aiming at upgrading sodium cooled fast reactor performance and to open the path to a “first of a kind” commercial SFR.

India

Total installed capacity in India at the end of March 2007 was ~129 GWe. The energy generated during the period April 2006 to March 2007 was 660 BU. Sixteen thermal reactors are in operation. The overall capacity factor achieved during the financial year 2006-07 was 74%. Seven nuclear power plants are under construction including the PFBR. The FBTR was in operation for 505 h. The peak burnup of the FBTR MK I driver fuel reached a value of 154.4 GWd/t without any fuel-clad failure. The PFBR test fuel subassembly (MOX) in FBTR attained a peak burnup of 59 GWd/t (to be compared with the target of 100 GWd/t). The construction of PFBR is progressing well to respect the scheduled date of commissioning in September 2010. R&D works in the fields of component development, thermal hydraulics, structural mechanics, materials and metallurgy, safety, fuel chemistry and reprocessing are progressing well. Preliminary activities are also in progress towards the design of future FBRs with improved economy and enhanced safety.

Details of the total installed electric capacity in MWe at the end of March 2007 are given in the table below.

Plant	Installed capacity at end of Mar 07 MWe	% Generation 2006-07 (BU)
Thermal	84405	80.0
Hydro	34086	17.2
Nuclear	3900	2.8
Renewable	6191	-
A. Total	128582	660

The operating performance of the nuclear power plants is tabulated below:

Unit	Capacity factor - %
TAPS-1&2	93
TAPS-3&4	51
RAPS (3 units)	66
MAPS	68
NAPS (1 unit)	54
KAPS	64
KAIGA	66
Average	66

TAPS-1 and 2 are boiling water reactors (BWR) and the rest are pressurized heavy water reactors (PHWR).

The following NPPs are under construction:

Plant	Capacity - MWe
PFBR	500
RAPS 5&6	2x220
KAIGA 3&4	2x220
KUDANKULAM	2x1000
Total (7 reactors)	3380

FAST BREEDER TEST REACTOR (FBTR)

FBTR is a 40 MWt / 13.2 MWe, mixed carbide fuelled, sodium cooled, loop type fast reactor with two primary and two secondary sodium loops. Each secondary loop has two once-through, serpentine type Steam Generators (SG). All the four SG modules are connected to a common steam-water circuit having a Turbo-Generator (TG) and a 100% steam Dump Condenser (DC). The first criticality was achieved in October 1985 with a small core of 22 fuel subassemblies (SA) of MK-I composition (70% PuC + 30% UC), with a design power of 10.6 MWt and peak linear heat rating (LHR) of 250 W/cm. Progressively the core was expanded by adding SA at peripheral locations. Towards increasing the core size and hence the reactor power, carbide fuel of MK-II composition (55%PuC+45%UC) was inducted in the peripheral locations in 1996. TG was synchronized to the grid for the first time in July 1997. The reactor has so far been operated up to a power level of 17.4 MWt by raising the LHR of MK-I fuel to 400 W/cm in 2002. So far 13 irradiation campaigns have been completed, with the core for the 13th irradiation campaign having 43 fuel SA- 29 MK-I, 13 MK-II and one test fuel simulating power reactor MOX fuel. The 14th irradiation campaign was started in February 2007 with a core of 49 fuel SA, viz. 27 MK-I, 13 MK-II, 8 MOX and one PFBR test fuel SA. FBTR has so far logged 1596 d of cumulative operation, of which 897 d were at high power with SG in service. The total thermal energy generated so far is 279 GWh. TG has so far operated for 5285 h, generating 5.468 MU of electricity.

During the current year, the reactor was in operation for 505 h, out of which 250 h of operation was at power (16.6 MWt max.) with the steam generators valved in. The power operation was for testing the steam generator safety valves, trial rolling of the turbine for rectification of some deficiencies, checking the performance of the large number of fresh fuel subassemblies which have been loaded for any beginning-of-life failure due to manufacturing defects and for testing the performance of the Delayed Neutron Detection system by loading a specially fabricated subassembly with 19 perforated pins of natural uranium. The low power operation was for calibration of control rods and measurement of critical heights after each stage of fuel handling for transition from the 43 SA core to 49 SA core.

The 13th irradiation campaign was completed in July 2006, when four MK-I SA in the first ring reached the peak allowable burn-up of 155 GWd/t. The campaign availability factor was about 95%, testifying to the efficacy of the modifications done in the steam-water system.

Safety clearance for the 14th irradiation campaign was obtained in September 2006. Transition from the 43 SA core to the 49 SA core involved discharging one high burn-up MK-I SA from the first ring for PIE, transferring three high burn-up MK-I SA from the first ring to the storage location (for possible reuse if PIE results are encouraging), transferring four MK-I SA from the third ring to the first ring, loading two fresh MK-I SA in the third ring, transferring two MK-II SA from the fourth ring to the third ring and loading eight MOX SA in the fourth ring. Due to the large uncertainties in estimating the core reactivity for these major changes, it was decided to effect the transition from 43 SA core to 49 SA core in four stages with intermediate measurement of critical heights after each fuel handling campaign. At the end of the second fuel handling campaign, the lower part of one Control Rod Drive Mechanism was replaced due to failure of its gripper bellows, and the fuel handling operations resumed. The transition to the 49 SA core was completed in Feb `07 and after a trial rolling of turbine at 16.6 MWt in March, reactor was shutdown for conducting plant walk-down as part of the seismic re-evaluation of the plant and for starting a series of experiments which have been lined up for the next few campaigns. The first of these involves loading a specially fabricated subassembly having 19 perforated pins of natural uranium to validate the performance of the DND system. With this assembly in the central location, reactor was operated upto 10 MWt. There was very good response in the DND signals, which was proportional to the power of the reactor. The cover gas activity monitors located in the CRD circuit and common cover gas reject circuit also responded very well. The special SA will be shifted to four more locations and contrast ratios from the two DND monitors observed to establish the core map of contrast ratio for locating a failed SA.

The performance of the reactor system, sodium system and other safety related and auxiliary systems was satisfactory. The primary and secondary sodium purity has been maintained below the plugging temperature of 105°C. Sodium samples taken from primary and secondary sodium loops were found to be conforming to that of nuclear grade. The four sodium pumps and their drive systems have been operating very well and they have logged 581,500 h of cumulative operation.

There was an incident of low flow through one of the Steam Generator Leak Detection Systems (SGLDS). Investigations revealed that the nickel diffuser tubes had flattened. Frozen sodium was found on the shell side of the diffuser and on the vacuum lines. Obviously, sodium has leaked from the tube side to the shell side and frozen on the vacuum lines. During subsequent heating of the diffuser, the sodium which melted in the immediate vicinity had exerted external pressure on the delicate nickel tubes and caused buckling. Modification to detect sodium leak from the diffuser tubes using a non-contact mutual inductance type leak detector was carried out in the affected channel and identical modifications will be carried out in the other channels in due course of time.

In December 2006, the gripper of one Control Rod Drive Mechanism (CRDM) could not be opened during change of state to fuel handling. This was found to be due to failure of the gripper bellows. The control rod was released by raising sodium temperature to 375°C; the lower part of the CRDM was replaced.

Replacement of one sub-system of the Central Data Processing System (CDPS) by a new embedded based system (ED-20) was completed and the system was commissioned. On-power testing is in progress. ED-20 has three separate and independent systems performing safety-critical, safety-related and non-safety functions. Non-availability of one system will not affect the operation of the other healthy systems. All the cards like CPU and the various Input/Output cards were designed in IGCAR conforming to VME bus standards. There is no operating system and hard-disk and hence there are no moving parts, thus making the system highly reliable.

The 14th irradiation campaign will be devoted to a series of experiments, viz. DND calibration, mapping of flux at the grid plate location and accelerated irradiation of grid plate material as a part of its residual life assessment and short-term irradiation of a single pin of PFBR fuel for studying the initial restructuring. Concurrently, long term irradiation of SS 316 and D-9 alloys will also be initiated. At the end of the 14th campaign, it is planned to isolate one SG module from each secondary loop to achieve the nominal temperatures with the present small core. The irradiation of PFBR test fuel will be continued to attain its target burn-up of 100 GWd/t in the next three campaigns. Seismic re-evaluation of the plant is in progress and is scheduled to be completed by the end of 2007.

FAST BREEDER REACTOR (PFBR) – DESIGN

PFBR is a 500 MWe capacity, pool type sodium cooled fast reactor with 2 primary pumps, 4 intermediate heat exchangers (IHX) and 2 secondary loops. There are 8 integrated steam generator (SG) units; 4 per secondary loop producing steam at 766 K and 17.2 MPa. Four dedicated safety grade decay heat exchangers (SGDHR) are provided to remove the decay heat directly from the hot pool. The hot and cold pool sodium temperatures are 820 K and 670 K respectively.

Detailed design has been completed for almost all the components. The specialists groups formed to check the compliance of the revised Preliminary Safety Analysis Reports (PSARs) have completed their review. Actions taken reports (ATR) have been prepared compiling the various critical issues raised by Project Design Safety Committee (PDSC). This process of review called for some experimental and theoretical investigations. PDSC is discussing the reports submitted by respective specialists groups and also ATRs towards recommending the clearance for equipment erection. The clearance is expected in May 2007.

Manufacture of main vessel, inner vessel, safety vessel & thermal insulation, grid plate, core support structure (CSS), primary sodium pipes along with spherical headers, roof slab, LRP & SRP, CSRDM, DSRDM, IHX, primary & secondary sodium pumps, steam generators, sodium and argon tanks, control plug, inclined fuel transfer machine, fuel, blanket & shielding subassemblies are progressing well. Manufacturing orders were placed for the variable speed drives for sodium pumps, RCB crane, sodium service valves, PI flask, diesel generators, large diameter sodium piping & pipe fittings, sodium to sodium and sodium to air heat exchangers, SGDHR tanks, cold traps, electrical cable penetrations in RCB and diesel generators. Purchase order for mega package on TG and associated systems will be placed in July 2007.

In order to monitor the manufacture of major components, task forces have been formed involving IGCAR (design organization) and BHAVINI (construction company). The task forces resolve various technical issues raised by industries on day to day basis, which helps to meet the overall time schedule of the project (the official commissioning date is Sep 2010).

The Department of Atomic Energy is planning to construct four 500 MWe FBRs by 2012 with improved economy and enhanced safety. In order to conceptualise the design, six task forces were formed and the final reports of task forces will be submitted in July 2007. The salient features to improve the economy are twin unit concept, reduction in main vessel diameter, in-vessel purification system, reduction in height of each components supported on top shield and entire reactor assembly by improved design of top shield, use of cost optimised materials of construction, enhanced burn-up to reduce fuel cycle cost, reduced construction time (7 y to 5 y), enhanced design life (40 y to 60 y) and higher capacity factor. With these features, the targeted unit energy cost is 50 mils (80 mils for PFBR). The reactors will also have many innovative features to enhance the safety. A few important features are reliable shutdown systems having distinctive designs incorporating passive features, passive featured decay heat removal system, rationalisation of design basis events to arrive at lower number of anticipated events, elimination of core disruptive accident (an attempt) and elaborate ISI and repair provisions. MOX fuel is the choice for the first four FBRs. However, for the further FBRs, metallic fuel would be the choice for the rapid realization of nuclear power in the country by way of attaining high breeding ratio. Nevertheless, the metallic fuel could be introduced in one of the four reactors, considered after getting sufficient technological maturity, especially on the fuel fabrication. It is worth to mention that the active participation of India in the IAEA-INPRO Joint Study on closed fuel cycle with fast reactor (CNFC-FR) has raised our confidence on the conceptual design features of future reactors.

The attached full Country Report from India summarizes in detail a few important design and analysis activities completed during the period April 2006 to March 2007.

<u>PFBR CONSTRUCTION</u>

The construction of super structures on the nuclear island interconnected building (NICB) raft has commenced and is in progress at various elevations. The construction of the Electrical Buildings 1 and 2, and of the Control Building is completed up to El 34.4 m. Finished floor level is EL 30 m. Construction of the Service Building which houses the service equipment like Air Compressors and Chillers has been completed up to roof level. Other peripheral buildings like Diesel Generator Building and Service Water Pump House and, Horton Spheres have been completed up to operating floor level. The construction of the actual Reactor Vault has been commenced and erection of metallic liner has been completed. The concreting of the Inner and Outer walls has been commenced. The Inner wall is completed up to EL 26 m, and of the Outer wall up to EL 24 m (the final elevation is 31.5 m). The excavation for the BOP has been completed. The work order for the construction of BOP buildings is issued. Construction of the open reservoir has been started.

As of March 2007, purchase orders and work orders worth Rs.12 Million have been placed for long delivery critical items and civil structures. Files worth Rs.17 Million are under process for various systems including main plant Turbo Generator package and I&C systems. The physical progress for the project as on 31 March 2007 was 26%. The financial progress achieved is 17%.

The manufacture of the Core Catcher, the first nuclear component, has been completed and delivered at the site. Manufacture of thermal baffles is completed at the site assembly shop (SAS). The safety vessel, which is the first major nuclear equipment to be erected is in advanced stage of fabrication and expected to be completed in May 2007. Reflective thermal insulation panels have been manufactured and received at the site and these will be mounted on the safety vessel before its erection in the reactor vault. Manufacture of main vessel and inner vessel is in advanced stage of progress at the SAS. Manufacture of nine sodium storage tanks is in progress at the site, of which three have been completed.

The attached full Country Report from India provides detailed summaries of the major research and technology development activities and their results obtained during the period covered by the report.

Italy

In Italy, nuclear activities are progressing mainly in the following fields:

- R&D is performed mainly by ENEA both in fission and fusion, and, more in general, in all others nuclear related fields, as well in the Universities of Pisa, Roma, Palermo and in the Polytechnic Schools of Milano and Torino, which are the five Universities entitled to graduate nuclear engineers;
- Decommissioning and waste treatment activities are performed by SOGIN and are progressing, even in the absence of a clear road-map for the national surface repository;
- ENEL is expanding its acquisition of power plants abroad, including nuclear power plants, and is building again a nuclear competence center;
- The industry (Ansaldo Nucleare, Ansaldo Camozzi, etc.) is involved in all above activities.

Italian R&D activities in the field of fast spectrum nuclear systems – both critical and subcritical – are being carried out in a European context.

As far as Accelerator Driven Systems are concerned, Ansaldo Nucleare (nuclear company), Del Fungo Giera Energia (SME), ENEA (Research Institute) and CIRTEN (University Consortium) are participating in the Integrated Project EUROTRANS (EUROpean research programme for the TRANSsmutation of high level nuclear waste in an Accelerator Driven System) of the 6th European Framework Programme (FP6). With this project, 52 European Organizations (including Industries, Research Centers and Universities) have the common strategic objective of advancing a European Transmutation Demonstration (ETD) project in a step-wise manner. The aim of the 4-year lasting EUROTRANS programme is twofold:

(i) Develop the conceptual design of the EFIT (European Facility for Industrial Transmutation), a pure lead-cooled ADS of several hundreds MW with MA burning capability and electricity generation at reasonable cost (design features will be worked out to a level of detail which allows the cost estimate study);

(ii) Carry out the detailed design of the smaller XT-ADS (eXperimental Transmutation in an ADS), a material test irradiation facility to be built around 2018, which is also intended to be, as much as possible, a test bench of the main components and of the operation scheme of EFIT, but at lower working temperature. XT-ADS is cooled by lead-bismuth eutectic and uses standard MOX-fuel, but it is designed to host also some MA-bearing fuel assemblies.

Ansaldo Nucleare is the leader of the Work Package “Development and Assessment of XT-ADS and EFIT Design”, whilst ENEA coordinates the EFIT core design as well as the Work Package devoted to large-scale integral tests to characterize crucial components of a heavy liquid metal cooled ADS. ENEA is also one of the main partners of the MEGAPIE experiment aiming to demonstrate the safe operation of a liquid metal spallation target at a beam power level of 1 MW, successfully operated in the SINQ target station at the Paul Scherrer Institut (Switzerland).

As far as the R&D activities in support to the development of GEN IV Fast Reactors in a closed fuel cycle, the effort of the involved Italian organizations – Ansaldo Nucleare, ENEA, CESI Ricerca, Del Fungo Giera Energia and CIRTEN - is mainly concentrated on the ELSY project, i.e. the European Lead-cooled System granted by Euratom within the 6th European Framework Programme. Within this 3-year project started in September 2006, Ansaldo Nucleare, ENEA, CESI Ricerca and CIRTEN - together with other 15 European Organizations (including Industries, Utilities, Research Centers and Universities) and 3 International partners - have taken the initiative to promote the design of a competitive and a safe critical fast reactor cooled by pure lead. Ansaldo Nucleare is leading the whole project and is mainly involved in the functional analysis and design of main systems and components, as well as in the definition of the requirements, safety approach and R&D needs. ENEA is the coordinator of the neutronic design, of the containment system and of the Work Package devoted to the lead technologies and significantly contributes, together with CESI Ricerca and CIRTEN, to the safety and transient analysis and to core thermal-hydraulics.

It is worth mentioning that ELSY has been assumed as the reference system for the large size lead-cooled fast reactor of GEN IV and the outcomes of the project will represent a substantial part of the EURATOM contribution to the development of the LFR concept within GIF.

Finally, ENEA is the coordinator of the Integrated Infrastructure Initiative VELLA - Virtual European Lead Laboratory - of the 6th European Framework Programme, funded by EC with 2.3 MEuro. VELLA complements EUROTRANS and ELSY as for development of the Heavy Liquid Metal (Pb and Pb-Bi) technologies and is intended to create a virtual European laboratory for lead technologies, with a view to creating a network of European laboratories that operate HLM infrastructures.

The overall effort at European level is being complemented by a three-year R&D national programme based on “strategic funding devoted to the National Electric System R&D”, focused on participation to international initiatives like INTD (International Near Term Deployment) and Generation IV nuclear systems. The programme is going to receive support by the Ministry of Economic Development and by a parallel project funded by the Ministry of University and Research.

Japan

Since the issuance of the Framework for Nuclear Energy Policy in October 2005 by the Atomic Energy Commission (AEC) of Japan, the significance of the development of fast reactor cycle technology has been recognized once again in the national fundamental nuclear energy policy. In March 2006, the Council for Science and Technology Policy of the cabinet office selected a fast reactor cycle technology as one of the key technologies of national importance in the third-term “Science and Technology Basic Plan.” After this, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Economy, Trade and Industry (METI), respectively, have investigated action plans for nuclear technologies and published their reports. In response to the action plans and the review by MEXT of the result of the Feasibility Study Phase-II, the AEC decided on 26 December 2006 the “Basic Policy on R&D of FBR Cycle Technologies Over Next Decade”.

Beginning with the 3rd duty cycle in 2006, JOYO has irradiated oxide dispersion strengthened ferritic steel (ODS), and MOX fuel containing 5% americium and also both neptunium and americium.

With regard to MONJU, the main modification work is in progress since September 2005. The works have achieved approximately 94% completion by the end of March 2007. Also, the function tests for the modified systems have been progressing since December 2006.

As for the “Feasibility Study on Commercialized Fast Reactor Cycle Systems”, the final report of Phase-II was compiled in March 2006. The Feasibility Study was finalized at the end of March 2006. The outcomes of Phase-II were evaluated by the MEXT Advisory Committee “on the R&D in the nuclear energy field.” To emphasise the shift in emphasis from concept to “fact”, JAEA changed the title of the project to “Fast Reactor Cycle Technology Development” (FaCT) project. The FaCT project was launched in 2006 and concentrates on the R&D for the main concept of FBR, reprocessing, and fuel fabrication.

JAEA is also proceeding with the R&D on accelerator driven systems (ADS) for the transmutation of long-lived radioactive nuclides. The ADS proposed by JAEA is a lead-bismuth eutectic (LBE) cooled fast sub-critical core with 800 MWth. Various R&D activities were conducted during the 2006 fiscal year to investigate the feasibility of the ADS from viewpoints of the accelerator, LBE as a spallation target and core coolant, as well as sub-critical core design. Moreover, the conceptual design study on the Transmutation Experimental Facility (TEF) to study the basic science and engineering of the transmutation technology was continued under the framework of the J-PARC (Japan Proton Accelerator Research Complex) project.

Republic of Korea

In 2005, nuclear power plants covered 28.4% of the total installed capacity, and generated as much as 40.3% of the total electricity in Korea. There are now 16 PWRs and 4 PHWRs in operation as of May 2006. According to the "Basic Plan for Long-term Electricity Supply and Demand," a total of 8 new nuclear power units will be constructed by 2017. Currently, four OPRs [Optimised Power Reactor, successor to the Korean Standard Nuclear Power (KSNP) Reactor] are under construction: 2 at the Kori, and 2 at the Wolsong site. Pouring the first concrete of 4 more APR1400s is scheduled for the timeframe between 2011 and 2012.

The fiscal year 2006 was the last year of the Phase 4 of the Fast Reactor Technology Development Project. During this year, the conceptual design of KALIMER-600 has been completed. The KALIMER-600 core is loaded with single enrichment fuel and configured without blanket assemblies with a strong emphasis on proliferation resistance characteristics. Passive residual heat removal, shortened intermediate heat exchanger (IHTS) piping and seismic isolation have been realized in the design. The KALIMER-600 safety analyses have been performed, whose results show that the KALIMER-600 design can accommodate various anticipated transients without scram (ATWS) events.

R&D has been performed for the development of design methodologies. A whole core thermal-hydraulics analysis code including the inter-assembly gap has been developed. The material properties of an advanced ferritic/martensitic steel (Mod.HT9) were analyzed, and the thermal creep strain model and the creep rupture model were developed. A system performance computer code for the evaluation of the passive decay heat removal system PDRC has been developed. The waveguide sensor visualization technology has been being developed to inspect the reactor internals by using some specific waveguides in hot sodium, which consists of a long strip plate, a wedge and ultrasonic sensors. A detailed three-dimensional fuel subassembly thermal-hydraulic model has been developed and it was implemented into the system transient analysis code. The experimental analysis of the sodium-water reaction phenomena and the acoustic leak detection were performed. An experimental study has been carried out to measure the critical conditions for the inception of an air entrainment by breaking the surface wave at the free surface in the water test apparatus.

KAERI has been participating in the INPRO joint study on the "Assessment of Innovative Nuclear Energy Systems based on a Closed Nuclear Fuel Cycle with Fast Reactors" since March 2005 and in the IAEA CRP "Benchmark analyses of sodium natural convection in the upper plenum of the Monju reactor vessel." There are two on-going I-NERI projects with ANL; 1) Supercritical Carbon Dioxide Brayton Cycle Energy Conversion (2005~2007) and 2) Core Design Studies for TRU Transmutation in a Sodium Cooled Fast Reactor (2006 ~2008). KAERI has also been participating in the Generation IV SFR Projects and is collaborating with CEA and JAEA through annual bilateral joint technical seminars, respectively.

In January 2007, the Korean 3rd Comprehensive Nuclear Energy Promotion Plan for the years from 2007 to 2011 was prepared. According to the Plan, the 3rd national mid- and long-term nuclear R&D Program started in March 2007 for the same period, and thereby the sodium cooled fast reactor (SFR) technology development in the Republic of Korea entered a new phase.

Within the framework of this new phase, and based upon the experiences gained during the development of the conceptual design for KALIMER, KAERI is developing advanced fast reactor design concepts. There are three main categories of R&D activities under consideration: 1) conceptual design of an advanced SFR, 2) development of advanced SFR technologies necessary for its commercialization and 3) development of basic key technologies.

For the development of advanced technologies, there are four areas: safety, fuels and materials, reactor systems and balance-of-plant. R&D work will be performed for the improvement of economics and assurance of safety. For the development of the basic key technologies, the main focus will be on validating the computational tools and developing sodium technologies.

Russia

In Russia, there are 31 nuclear power units in operation, which are located on 10 sites. The total electric power capacity of all the Russian nuclear power units amounts to 23.242 GWe. In 2006, the total electricity production by the nuclear power units in Russia was 154.654 billion kWh (an increase by 4.8% in comparison with 2005), which translates into a share of the nuclear power units of 17% of total electricity production (up from 15.8% in 2005).

The Russian Government set the target of 25-30% nuclear electricity share by 2025-2030. Meeting this objective will require commissioning, on average, not less than 2 power units per year. Short term construction projects include a 2nd unit at Volgodonsk, a 4th unit at Kalinin (both VVER-1000 reactors), a 5th unit (RBMK-1000) at Kursk, a power unit with VVER-2006 reactor at each LNPP-2 and NVNPP-2 sites, and a 4th power unit (BN-800) at the Beloyarsk site. Simultaneously with the construction of the new power units, work on NPP design lifetime extension is carried out for units in operation. To-date, lifetimes extension was realized for 11 first generation power units. It is planned to extend the design lifetime of operating power units by 10-15 years.

The long-term prospects of nuclear power development in the Russian Federation are defined by the "Strategy of Nuclear Power Development in Russia in the First Half of the XXI Century". The review of possible options for nuclear power development in Russia is showing that "in (the) case of intensive development of nuclear power, fast reactors, which have almost no restrictions in terms of fuel supplies, will play leading part". Therefore, the gradual deployment of innovative nuclear technology based on fast reactors with closed uranium-plutonium fuel cycle is envisaged, thus removing limitations with respect to fuel material supply.

In Russia, currently there are 2 fast reactors in operation, viz. the experimental reactor BOR-60 (RIAR, Dimitrovgrad), and the commercial sodium cooled power fast reactor BN-600 (unit #3 of the Beloyarsk NPP at Zarechny).

The research fast reactor BR-10 (IPPE, Obninsk) is in the preparatory stage for its decommissioning.

The # 4 power unit of the Beloyarsk NPP, viz. the sodium cooled fast reactor BN-800 is under construction.

BN-600 has been in operation for more than 27 years (as of 31 December 2006, the cumulative operation time on power is 185298 hours). BN-600 is the worldwide the largest operating fast power reactor. Its operation proves high levels of safety and reliability. In 2006, the BN-600 load factor attained 78.6%. The average load factor since 1983 is equal to 74.2%. The design lifetime of the BN-600 reactor expires in April 2010. Currently, preparatory activities in view of a 15-year lifetime extension of BN-600 are underway.

The experimental fast reactor BOR-60 has been in operation for more than 36 years. It is used for material tests, isotope production, fast reactor equipment testing, and also for heat and electricity generation. The BOR-60 experimental fast reactor has an operation license till 31 December 2009. Currently, activities in view of its lifetime extension are being implemented.

The fast research reactor BR-10 was finally shut down in 2002 after about 44 years of operation. Currently, BR-10 is in the preparatory stage of its decommissioning. It is also used as experimental facility for the development of the various technological processes proposed to be used for sodium cooled fast reactor decommissioning.

The construction of the 4th power unit at the Beloyarsk NPP site, i.e. of the BN-800 fast reactor is carried out in accordance with the “Program of Development of Nuclear Power in the Russian Federation for the 2000-2005 Period and Up to 2010”. Construction completion and commissioning are planned for 2012. Based on extensive studies aiming at the improvement of the technical and economical characteristics of BN-800, the reactor’s electric power was increased from 800 MW to 880 MW (with the thermal power unchanged at 2100 MW), and its lifetime extended from 30 to 40 years. Currently, pouring concrete for the foundation plates of the reactor compartment and the turbine hall of the main building is underway. Manufacture of the major equipment, in particular, the main and guard reactor vessels is also underway.

Currently the following fast reactor research and technology activities are ongoing in Russia:

- Justification of the lifetime extension for the BN-600 and BOR-60 reactors;
- Materials studies within the framework of the detailed BN-800 design;
- Development of the pilot plant design for the BN 800 MOX-fuel manufacture;
- Development of advanced sodium cooled fast reactors, specifically:
  - ✓ Continuation of R&D work on development of the conceptual design of the large-size commercial sodium cooled fast reactor BN-1800;
  - ✓ Continuation of the conceptual development of small-size modular-transportable two-circuit NPPs with sodium cooled fast reactor and gas turbine (concept of the BN GT nuclear co-generation power plant);
- Research and development work for heavy liquid metal cooled fast reactors, i.e.:
  - ✓ R&D aiming at the justification of the design of the lead cooled BREST OD 300 reactor;
  - ✓ Development of basic design of the lead-bismuth cooled SVBR-75/100 reactor concepts;
- Conceptual research activities on gas-cooled fast reactors.

USA

The U. S. status report summarizes the new U.S. led initiative: Global Nuclear Energy Partnership (GNEP) and the status of the 3 U.S. Generation-IV Projects. In particular the role of fast reactors for a closed fuel cycle is presented and a summary of the initial design studies for the Advanced Burner Test Reactor (ABTR) is given. The Generation-IV discussion focuses on three activities: Gas cooled fast reactors (GFR), Leas cooled fast reactors (LFR), and small sodium cooled fast reactors (SFR).

A key roadblock to development of additional nuclear power capacity is the concern over management of the nuclear waste produced by the plants, which requires disposal. Commercial spent nuclear fuel is the major contributor to high level radioactive waste generated in the United States. With projected growth of nuclear energy, some estimates suggest the nation will accumulate more than 300,000 metric tons of spent fuel by 2100. But the proposed Yucca Mountain Repository, by statute, can receive only 70,000 metric tons of waste. Worldwide projections of nuclear power growth suggest that eventually a new repository of similar size will have to be built somewhere in the world every three to four years. It is envisioned that GNEP (utilization of SFR in a closed fuel cycle) will result in better utilization of the geologic repository, namely, minimizing the need for additional repositories.

ANL working with other U.S. national labs and DOE are developing the initial R&D plan for the ABTR. The primary mission of the ABTR is to demonstrate actinide transmutation in a fast spectrum. In addition, the ABTR needs to demonstrate innovative technologies and design features that could be applied to follow-on commercial demonstration plants. The plant size should be small enough to result in an affordable plant cost, but large enough to enable the demonstration of key design features. The presentation discussed the following innovative technologies and design features that are being evaluated for inclusion into the ABTR: metal fuel, inherent passive safety, pyroprocessing, single rotating fuel transfer plug, seismic isolation system, electromagnetic primary pump technology, and supercritical CO_2 Brayton cycle.

The U.S. GFR discussion focused on the GFR reference design features, safety systems capable of decay heat removal, GFR fuel development, high temperature in-core materials, and reference fuel cycle. The GFR material performance issues are driving the reference coolant temperatures to lower values (i.e. 1000°C, 850°C, 600°C, and 550°C). A short discussion of the GFR material was presented (e.g. Alloy 800H, ferritic steel T-12, oxide dispersion strengthened alloys, ceramics, and Zr-based ceramics). In the area of GFR fuel development, it is envisioned that substantial R&D is needed for deployment.

The U. S. lead cooled fast reactor (LFR) R&D has been focused on a 20 MWe (45 MWth) small secure transportable autonomous reactor (STAR). These reactors are Pb cooled fueled with nitride fuel. Its main features are natural circulation heat transport and long core life (e.g., 30 core life). Other important features of the LFR Generation-IV concept are: small power outputs, proliferation resistance by long core lifetime, fissile self-sufficient, passively safe small LFR reactor concept for deployment at remote sites.

Five different variations of the STAR concept were discussed. Advanced LFR materials results from the LANL Delta loop were also presented.

The design characteristics of U. S. SMFR are very similar to the LFR (e.g., long life, small size, proliferation resistant, inherently safe, deployable for remote locations, etc.) except that the coolant is sodium. This concept was accepted as a distinct third track in the most recent Generation-IV SFR system research plan. The design characteristics and the plant layout were presented.

3. Review of Activities; Conclusions and Actions

The meeting reviewed national and international research and technology development activities in the area of fast neutron systems (critical and sub-critical). The meeting further reviewed the status of the activities performed within the framework of the TWG-FR, and discussed possible future activities in view of IAEA's Programme and Budget cycle 2008-2009 (and beyond).

The following conclusions and actions were agreed upon:

1. The TWG-FR members express their gratitude to the Japanese hosts for the warm welcome and hospitality during the Commemorative Symposium and the 40th TWG-FR annual meeting.
2. Final contributions to the CRP reports on "Updated Codes and Methods to Reduce the Calculational Uncertainties of the LMFR Reactivity Effects" and on "Studies of Innovative Reactor Technology Options for Effective Incineration of Radioactive Waste" to be submitted by the end of June 2007.
3. US to consider participation in CRP on "Analyses and Lessons Learned from the Operational Experience with Fast Reactor Equipments and Systems (Scientific Secretary to send the meeting report of the kick-off RCM to the US TWG-FR member who will contact INL). TWG-FR Scientific Secretary to contact UK, German, and Kazakh TWG-FR members, submit the meeting report of the kick-off RCM and ask for a decision concerning their participation in the CRP. Deadline: within two weeks after the 40th TWG-FR meeting.
4. With regard to the implementation of the TWG-FR's extra-budgetary activity on "NE Societal Aspects/FR Acceptance", the following contact persons were identified by Member States: Mr. P. Kumar (India), Mr. Dohee Hahn (ROK), J. Knebel (Gernany, tentatively), Ms. F. Bazile (France), and Mr. M. Mori (Japan, tentatively). The TWG-FR members from Belgium, Italy, Russia, and the US will inquire and notify IAEA (Mr. T. Aso) within two weeks after the 40th TWG-FR meeting. Action on the TWG-FR Scientific Secretary to contact China, UK and Kazakhstan about experts from their country.
5. TWG-FR members to review the IAEA draft publication on "Improving Economics of FR Designs by Reducing the Amount of Plant Materials" and submit their comments and suggestions for improvements to the TWG-FR Scientific Secretary by the end of July 2007.
6. The TWG-FR Scientific Secretary asked the members of the TWG-FR to consider sending letters of interest to IAEA in hosting the large IAEA international conference on "Fast Reactors and Closed Fuel Cycles – Challenges and Opportunities" (planned for 2009). Deadline: end of July 2007. The Indian participants have shown their interest in hosting this conference, possibly in conjunction with the 2009 TWG-FR Meeting.
7. Upon request by the TWG-FR Scientific Secretary, the members have agreed to investigate possibilities to support IAEA's activities in the area covered by the TWG-FR through extra-budgetary contributions (e.g. in-kind contributions to IAEA extra-budgetary activities, staff secondments, sabbaticals, etc).
8. With regard to the preparation of the publications "FR Status Report" and "ADS Status Report":

- The responsibilities as chapter and section focal points (responsible for requesting Member States write-ups) were mostly confirmed;
- The author assignment spread sheets were updated to reflect the new commitments (important actions marked in red);
- Members of the TWG-FR were asked to notify the new authors of their responsibilities; deadline: immediately after this meeting. Please notify the chairmen of the document preparation committees (E. Fujita and D. De Bruyn for the FR and ADS Status Report, respectively) and the TWG-FR Scientific Secretary if the newly assigned authors cannot complete their assignments;
- The chairmen and the TWG-FR Scientific Secretary will have to find contributors for unassigned chapters and/or sections;
- The chapter and section focal points must contact the contributors and provide guidance for their contributions; deadlines: end of May 2007 for the chapter, and mid June for the section focal points;
- The TWG-FR Scientific Secretary was asked to contact the TWG-FR members from Kazakhstan and UK, submit to them the available material (e.g. CD from December Vienna meeting, updated spread sheet, etc) and request their collaboration; deadline: immediately after this meeting
- All write-ups to reach the chapter and section focal points as soon as possible, but not later than end of September 2007. The section focal points to merge the materials by the end of October 2007, and the chapter focal points to merge the materials by the end of November 2007. Back-to-back consultants meeting to draft the two Status Reports are tentatively planned to be held in Vienna in the week 3 to 7 December 2007.

9. Interest in participating in the “PHENIX End-of-life Tests” CRP was expressed by the TWG-FR representatives from France, India, Japan, Russia and the US. The TWG-FR Scientific Secretary was asked to contact (immediately after this meeting) the representatives from China, the UK and Kazakhstan for their possible participation in this CRP. A preparatory consultants meeting is planned for the 39^{th} or 40^{th} week 2007 in Marcoule, France. CEA contact points for this preparatory consultants meeting are Mr. A. Vasile and Mr. L. Martin. The TWG-FR Scientific Secretary was asked to set the date for the consultants meeting before the end of May 2007 and start preparation of the meeting as soon as possible.

10. The TWG-FR member from India submitted proposals for CRPs and topical Technical Meetings for IAEA’s consideration in P&Bs after 2008-2009. The meeting arrived at the following conclusions:

- The proposed CRP on “Optimisation of Fast Sodium Cooled FR Plant Layout” is considered to be an activity best implemented as IAEA Technical Meeting or Workshop;
- With regard to the proposed CRP on “Optimum Plant Parameters with Metallic and MOX Fuelled FBRs”, the TWG-FR member from India was asked to provide a short write-up (to be included as annex to the 40^{th} TWG-FR Meeting Report) with more details about scope, objectives, and tasks of the CRP. Deadline: end of June 2007;
- With regard to the proposed CRP on “Analysis of Negative Reactivity Incident in Phenix”, the TWG-FR decided to discuss this topic during the preparatory consultants meeting on the PHENIX CRP in September 2007;
- With regard to the following 6 proposals for information exchange activities, viz., (i) Seismic Design of Nuclear Island and Components;
(ii) Innovative Design Concepts for Decay Heat Removal Systems;
(iii) Mitigation Means of Gas Entrainment; (iv) Improving Economics of FBR Through Advanced Materials for Structural Components (e.g. reactor vessels, pipings, heat exchangers,

SGs） and Core Materials (clad, wrapper); (v) Design of FBR Components (control plug, IHX, inner vessel and SG) Operating at High Temperature; (vi) Design Criteria for Issues Not Covered in Current Design Codes, the TWG-FR decided to include them into its activities running list. The TWG-FR members are asked to inform the potentially interested experts and identify the level of interest for each of the proposals, as well as prioritize them. Deadline: TWG-FR meeting 2008.

11. Next TWG-FR meeting is planned for the week of 19 May 2008 at IAEA Headquarters in Vienna.

ANNEX I

“Meeting of the Technical Working Group on Fast Reactors (TWG-FR)”
Tsuruga/Kyoto
14 - 18 May 2007

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ANNEX II

List of IAEA products (reports, computer software, database) prepared within the framework of the LMFR/Hybrid Systems project since 1996

2007

IAEA-TECDOC-1569	**Liquid Metal Fast Reactors: Experience in Design and Operation**
IAEA-NE-NG-T-6.3	**Fast Reactor Knowledge Preservation System: Taxonomy and Basic Requirements**
Working Material TWG-FR/133	**Consultants' Meeting (Preparatory Meeting) on the IAEA Coordinated Research Project on Benchmark Analyses of Sodium Natural Convection in the Upper Plenum of the MONJU Reactor Vessel**
Working Material TWG-FR/132	**Third Research Coordination Meeting of the Coordinated Research Project on Studies of Advanced Reactor Technology Options for Effective Incineration of Radioactive Waste**
Working Material TWG-FR/131	**Kick-off Research Coordination Meeting of the IAEA Coordinated Research Project on Analyses of, and Lessons Learned from the Operational Experience with Fast Reactor Equipment and Systems**
Working Material TWG-FR/130	**Meeting Report of the 39th Meeting of the Technical Working Group on Fast Reactors (TWG-FR)**

2006

IAEA-TECDOC-1531	**Fast Reactor Database 2006 Update**
Working Material TWG-FR/129	**Report of the Consultancy on Studies of Innovative Reactor Technology Options for Effective Incineration of Radioactive Waste**
Working Material TWG-FR/128	**Meeting Report of the Technical Meeting on Decommissioning of Fast Reactors After Sodium Draining**
Working Material TWG-FR/127	**Meeting Report of the First Research Coordination Meeting of the Coordinated Research Project on Analytical and Experimental Benchmark Analyses of Accelerator Driven Systems**
IAEA-TECDOC-1520	**Theoretical and Experimental Studies of Heavy Liquid Metal Thermal Hydraulics**

2005

Working Material TWG-FR/126	**Consultancy on the Potential of Fusion/Fission Sub-critical Neutron Systems for Energy Production and Transmutation**
IAEA Priced Publication, ISBN 92-0-107404-2 (2005)	**The Role of Nuclear Power and Nuclear Propulsion in the Peaceful exploration of Space**
Working Material TWG-FR/125	**Hydrodynamics and Heat Transfer in Reactor Components Cooled by Liquid Metal Coolants in Single/Two Phase, 11th Meeting of the International Association for Hydraulics Research (IAHR) Working Group, IPPE, Obninsk, 5-9 July 2004**
IAEA-RC-870.2 Working Material TWG-FR/124	**Technical Meeting (Research Coordination Meeting) of the Coordinated Research Project (CRP) on Studies of Advanced Reactor Technology Options for effective Incineration of Radioactive Waste**
IAEA-TM-27172 and TM-26984 Working Material TWG-FR/123	**Back-to-Back Technical Meetings (TMs) on the "Coordinated Project (CRP)** ***Analyses of and Lessons Learned from the Operational Experience with Fast Reactor Equipment and Systems*** **" and to "Coordinate the Agency's Fast Reactor Knowledge Preservation International Project in Russia"**
IAEA-622-I3-TR-26091 Working Material TWG-FR/122	**IAEA Workshop on "Technology and Applications of Accelerator Driven Systems (ADS)"**
IAEA-CT-12719 Working Material TWG-FR/121	**Consultancy on "IAEA Initiative to Establish a Fast reactor Knowledge Base"**

2004

TECDOC-1406	**Primary coolant pipe rupture event in liquid metal cooled reactors**
TECDOC-1405	**Operational and decommissioning experience with fast reactors**
IAEA-RC-803.5 Working Material TWG-FR/120	**The Fifth Research Coordination Meeting on "Updated Codes and Methods to Reduce the Calculational Uncertainties of Liquid Metal Fast Reactors Reactivity Effects"**
IAEA-TM-25809 Working Mat. TWGFR/119Version 2	**Technical Meeting to "Preserve Fast Reactor Knowledge"**

IAEA-TM-26677 Working Material TWG-FR/118	**Technical Meeting on "Review of National Programmes on Fast Reactors and Accelerator Driven Systems"**
IAEA-TM-26241 Working Material TWG-FR/117	**Technical Meeting on "Review of Solid and Mobile Fuels for Partitioning and Transmutation Systems"**
IAEA-03CT12953 Working Material TWG-FR/116	**Consultancy to Review and Finalize the IAEA Publication "Compendium on the Use of Fusion/Fission Hybrids for the Utilization and Transmutation of Actinides and Long-Lived Fission Products**
IAEA-03CT13095 Working Material TWG-FR/115	**Consultancy on "Implementing Thorium in Nuclear Reactor Fuel Cycles: Potential Benefits and Challenges"**

2003

IAEA-TM-26241 Working Material TWG-FR/117	**Technical Meeting on "Review of Solid and Mobile Fuels for P&T Systems"**
TECDOC-1365	**Review of national accelerator driven system programmes for partitioning and transmutation,**
TECDOC-1356	**Emerging nuclear energy and transmutation systems: Core physics and engineering aspects, (2003)**
IAEA-TM-25614 Working Material TWG-FR/114	**Technical Meeting "Review of National Programmes on Fast Reactors and Accelerator Driven Systems (TWG-FR 36th Annual Meeting)"**
IAEA-RC-803.4 Working Material TWG-FR/113	**The forth Research Coordinatiomn Meeting (RCM) on "Updated Codes and Methods to Reduce the Calculational Uncertainties of Liquid Metal Fast Reactors reactivity Effects"**
IAEA-TM-26027 Working Material TWG-FR/112	**Technical Meeting on "Primary Coolant pipe Rupture Event in Liquid Metal Cooled Fast Reactors"**
TECDOC-1349	Potential of Thorium-based Fuel Cycles to Constrain Plutonium and Reduce Long-term Waste Toxicities
TECDOC-1348	Power Reactor and Sub-critical Blanket Systems with Lead and Lead-Bismuth as Coolant and/or Target Material

2002

TECDOC-1319	**Thorium fuel utilization: Options and trends**
TECDOC-1318	**Validation of Fast Reactor Thermomechanical and Thermohydraulic Codes**

TECDOC-1289	**Comparative Assessment of Thermophysical and Thermohydraulic Characteristics of Lead, Lead-Bismuth and Sodium Coolants for Fast Reactors**
TECDOC-1288	**Verification of Analysis Methods for Predicting the Behaviour of Seismically Isolated Nuclear Structures**
IAEA-RC-870 Working Material TWG-FR/111	**Technical Meeting – First Research Coordination Meeting (RCM) of the Co-ordinated Research Project (CRP) on "Studies of Advanced Reactor Technology Options for Effective Incineration of Radioactive Waste"**
Working Material TWG-FR/110	**Characterization and Management of Radioactive Sodium and Other Reactor Components as Input Data for the Decommissioning of Liquid Metal-cooled Fast Reactors**
IAEA-TM-25332 Working Material TWG-FR/109	**Technical Meeting on "Operational and Decommissioning Experience with Fast Reactors", Cadarache, 11-15 March 2002**
IAEA-TM-25032 Working Material TWG-FR/108	**Technical Meeting to "Review of National Programmes on Fast Reactors and Accelerator Driven Systems (ADS)", Karlsruhe, Germany, 22-26 April 2002**
IAEA-02CT-02060 Working Material TWG-FR/107	**Consultancy on "Knowledge Preservation in the Area of Fast Reactor Technology", ANL-West, Idaho Falls, USA, 2-4 April 2002**
IAEA-RC-803.3 Working Material IWG-FR/106	**The Third Research Co-ordination Meeting (RCM) on "Updated Codes and Methods to Reduce the Calculational Uncertainties of Liquid Metal Fast Reactor Reactivity Effects", Cadarache, 12-16 November 2001**

2001

IAEA-TCM-1168 Working Material TWG-FR/105	**Technical Committee Meeting on "Review of National Programmes in Fast Reactors and Accelerator Driven Systems (ADS)" (34th Annual Meeting of the TWG-FR)**

2000

IAEA-AG-1076 Working Material IWG-FR/104	**Design and Performance of Reactor and Sub-critical Blanket Systems with Lead and Lead-Bismuth as Coolant and/or Target Material**
IAEA-RC-803.2 Working Material IWG-FR/103	**Updated Codes and Methods to Reduce the Calculational Uncertainties of Liquid Metal Fast Reactor Reactivity Effects**
IAEA-TC-385.72 Working Material IWG-FR/102	**Liquid Metal Fast Reactor (LMFR) Developments** 33rd Annual Meeting of the International Working Group on Fast Reactors (IWG-FR)
IAEA-TC-385.72 Working Material IWG-FR/101	**Summary Reports of the Meeting Held in the Period May 1999-April 2000, Background Material, and Some Room Documents in Preparation of the 33rd IWG-FR Annual Meeting**
IAEA-RC-803 Working Material IWG-FR/100	**Updated Codes and Methods to reduce the Calculational Uncertainties of the LMFR Reactivity Effects**
TECDOC-1180	**Unusual Occurrences During LMFR Operation** Proceedings of a TCM held in Vienna, 9-13 November 1998
TECDOC-1157	**LMFR Core Thermohydraulics: Status and Prospects** Review of data, codes and methodologies for LMFR core thermohydraulic calculations.
TECDOC-1155	**Thorium based fuel options for the generation of electricity: Developments in the 1990s.** Review of the current status of the thorium fuel cycles, world-wide applications, economic benefits, and perceived advantages with respect to other nuclear fuel cycles.

	These results of this updated evaluation are summarized in this publication as a contribution toward documenting past experience.
TECDOC-1139	**Transient and accident analysis of a BN-800 type LMFR with near zero void effect** Final report of an international benchmark programme support by the IAEA and EC, 1994-1998.

1999

TECDOC-1060	**LMFR core and heat exchanger thermohydraulic design: former USSR and present Russian approaches** This document includes the methodology and philosophy of the analytical and experimental investigations in their application to the core and heat exchanger thermohydraulic design of LMFRs.
TECDOC-1083	**Status of liquid metal cooled fast reactor technology** Present status report which intends to provide comprehensive and detailed information on LMFR technology with the following topics: experience in construction, fast reactor engineering, reactor physics and safety, core structural material and fuel technology, fast reactor engineering.
IAEA-TC-385.71 Working Material IWG-FR/99	**Status of National Programmes on LMFR**
no reference number	**Summary Report of the Advisory Group Meeting on the Evaluation of Fast Reactor Core Physics Tests**

1998

TECDOC-1039	**Influence of high dose irradiation on core structural and fuel materials in advanced reactors** Proceedings of the TCM held in Obninsk, Russian Federation 16-19 June 1997
TECDOC-1015	**Advances in fast reactor technology** Updated and new information on the status of LMFR development, as reported at the 30th meeting of the International Working Group on Fast Reactors, held in China in May 1997.
Internet	**Fast Reactor Database**
IWG-FR/98 (Published by Cadarache Centre, France)	**Sodium Removal and disposal from LMFRs in normal operation and in the framework of decommissioning** Proceedings of a TCM held in Aix-enProvence, France, 3-7 November 1997

1997

TECDOC-985	**Accelerator driven systems: Energy generation and transmutation of nuclear waste Status Report** The report presents the state of the art of the ADS technology: it reviews the current status and progress of national and international R&D programmes.
TECDOC-946	**Acoustic signal processing for the detection of sodium boiling or sodium-water reactions in liquid metal fast reactors** A summary of the work performed under a CRP carried out from 1990 to 1995. It was the continuation of an earlier CRP entitled Signal Processing Techniques for Sodium Boiling Noise Detection (1984-1989).
TECDOC-933	**Creep-fatigue damage rules for advanced fast reactor design** Proceedings of a TCM held in Manchester, United Kingdom, 11-13 June 1996
IWG-FR/92 (Published by PNC, Japan)	**Evaluation of radioactive materials release and sodium fires in fast reactors** Proceeding of a TCM held in O-arai, Japan, 11-14 November 1996

1996

TECDOC-908	**Fast reactor fuel failures and steam generator leaks: transient and accident analysis approaches** A survey of activities on transient and accident analysis for LMFRs.
TECDOC-907	**Concepetual design of advanced fast reactors** Proceedings of a TCM held in Kalpakkam, India, 3-6 October 1995

ANNEX III

International Atomic Energy Agency

TECHNICAL WORKING GROUP ON FAST REACTORS (TWG-FR)

Technical Meeting – 40th Annual Meeting of the TWG-FR

Tsuruga/Kyoto, Japan 14 – 18 May 2007

List of Proposed Topics for TWG-FR Technical Meetings and Collaborative R&D

	Title	Country	Proposed at TWG-FR meeting. in	REMARKS
	Primary sodium pipe rupture event in LMFR	India	1999	A.1. TM 13-17 Jan. 2003, Kalpakkam
	Design and performance of reactor and sub-critical blanket with Pb and Pb-Bi as coolant and/or target material		1998	AGM 23-27 October 2000, Moscow
	Evaluation of fast reactor core physics tests	Japan	1998	AGM, 22-24 Nov. 99, Vienna
	Management of sodium from FBR dismantling	France	2000	Touched upon at TM Cadarache 11-15 March 2002
	Co-ordinated studies on “generalization and analysis of the operational experience with fast reactor equipment and systems” (include also the topic of complex mass exchange in LMFR (primary and secondary circuit))	Russia	2000	TCM “Feedback from Operational and Decommissioning Experience with Fast Reactors”, Cadarache, March 2002 Kick-off TM for CRP in 2006
	Fast reactor knowledge preservation	France	2000	AGM, 22-24 Nov. 99, Vienna; coop. with NEA CT ANL West 2-4 April 2002, follow-up mtg. in 2003 (in conj. 36th TWG-FR Annual Mtg.)
	First TM of the CRP on “Studies of Advanced Reactor Technology Options for Effective Incineration of Radioactive Waste”	TWG-FR	2000	5-8 Nov. 2002, Karlsruhe
	First TM of the CRP on “Benchmark Analyses on Data and Calculational Methods for ADS Source Related Neutronic Phenomenology with Experimental Validation”	TWG-FR	2001	2004-2005 Kick-off RCM Minsk, Belarus, 5-9 Dec. 2005 CRP renamed “Analytical and Exp. Benchmark Analyses of ADS”
	First RCM of the CRP on “An Assessment Based on an Unified Methodology of Thorium Fuel in Fast Neutron Spectrum Systems”	TWG-FR	2001	CRP proposal submitted Interest of TWG-FR waned; CRP to be restricted to fuel cycle issues and implemented in the Division of Nuclear Fuel Cycle and Waste Technology
	TM on “Theoretical and Experimental Studies	TWG-	2001	28-31 Oct. 2003, Karlsruhe

0	of Heavy Liquid Metal Thermal Hydraulics"	FR		
1	TM on "Review of Solid and Mobile Fuels for Partitioning and Transmutation Systems"	TWG-FR	2001	15-18 Dec. 2003, Madrid
2	Joint OECD/NEA – IAEA meeting "7th P&T Information Exchange Meeting"	TWG-FR	2001	14-16 October 2002, Cheju, Rep. of Korea
3	Third TM of the CRP on "Updated Codes and Methods to Reduce the Calculational Uncertainties of the LMFR Reactivity Effects"	Russia	1999	12-15 Nov. 2001, Cadarache
4	Fourth TM of the CRP on "Updated Codes and Methods to Reduce the Calculational Uncertainties of the LMFR Reactivity Effects"	Russia	1999	19-23 May 2003 IPPE/Obninsk, Russia
5	Fifth RCM of the CRP on "Updated Codes and Methods to Reduce the Calculational Uncertainties of LMFR Reactivity Effects"	Russia	1999	1–5 November 2004 Vienna, Austria
6	Sixth RCM of the CRP on "Updated Codes and Methods to Reduce the Calculational Uncertainties of the LMFR Reactivity Effects"	Russia	1999	Vienna, 3-7 April 2006
7	Second TM of the CRP on "Studies of Advanced Reactor Technology Options for Effective Incineration of Radioactive Waste"	TWG-FR	2000	Implemented 22-26 Nov. 2004, Hefei, China
8	TM on "Assessment of ADS Dynamics and Safety Physics"	TWG-FR	2001	To be decided 5-8 Nov. 2002; TM submitted to the IAEA P&B 2006-2007 (to wrap up the results of the CRP on "Studies of Advanced Reactor Technology Options for Effective Incineration of Radioactive Waste"); planned for 2007, if funding available
9	Technical Meeting "Review of National Programmes on FR and on ADS and Consultation with Member States" (annual TWG-FR meeting)	TWG-FR	2001	22-26 April 2002, Karlsruhe May 2003, Daejon, ROK
0	New CRP "Generalization and Analyses of Operational Experience with Fast Reactor Equipment and Systems"	TM Cadarache 11-15 March 2002, endorsed at 35th TWG-FR	2002	CRP proposal submitted
1	TM on Handling of Sodium Coming from Decommissioned Fast Reactors and from Shutdown Experimental Facilities	35th TWG-FR		Rename as "Decommissioning of Fast Reactors after Sodium Draining", held 26-30 Sept. 2005, in Cadarache, France
2	Technical Meeting "Review of National Programmes on FR and on ADS and Consultation with Member States" (annual TWG-FR meeting)	TWG-FR	2002	12-14 May 2003, Daejon, ROK
3	Technical Meeting to "Preserve Fast Reactor Physics Knowledge"	TWG-FR	2002	15-16 May 2003, Daejon, ROK
4	Proposal on the Monju Project relevant to FR knowledge preservation	Japan	2003	New proposals to be discussed at the 37th TWG-FR; TM convened 1-2 Dec. 2004, Tsuruga, Japan
5	TM to discuss Russia's FR data and knowledge preservation activities and prepare the CRP on "Generalization and Analyses of Operational experience with Fast Reactor	TWG-FR	2004	Discussed at 37th TWG-FR: preparatory TM held 24-28 January 2005 in Obninsk, Russia (see also #5 and #6)

	Equipment and Systems"			
6	Kick-off RCM of the CRP on "Data and Calculational Methods for ADS Source Related Neutronic Phenomenology with Experimental Validation"	TWG-FR	2004	Discussed at 37th TWG-FR: strong support, offers to host kick-off RCM in May-June 2005 from Belarus and China CRP renamed and Kick-off RCM held in Minsk, Belarus, 5-9 Dec. 2005 (see #8)
7	TM on "Utilization of MONJU for International Cooperation in Fast Reactor R&D"	Japan	2004	Follow-up to #22; TM held 1-2 Dec. 2004 in Tsuruga, Japan
8	TM on "Fuel Failure and Failed Fuel Detection"	India	2003, 2004	Discussed at 37th TWG-FR: include in IAEA P&B 2006-2007, for January 2006, IGCAR offers to host TM held in Kalpakkam, India, 1-3 March 2006
9	TM on "Innovative Concepts for In-service Inspection and Primary Coolant Pipe Leak Detection"	India	2003, 2004	Discussed at 37th TWG-FR: little interest at this time, keep in running list for future consideration at TWG-FR meetings
0	Joint OECD/NEA – IAEA meeting "8th P&T Information Exchange Meeting	TWG-FR	2004	9-11 Nov. 2004, University of Nevada, Las Vegas, NV, USA
1	CRP on "Analytical Benchmark for Validation of Computer Codes for Calculation of Thermal Hydraulics Consequences of LMFR Primary Pipe Ruptures"	India	2004	Discussed at 37th TWG-FR: little interest at this time, keep in running list for future consideration at TWG-FR meetings
2	CRP on "Comparative Assessments of the Performance of Various Thorium-based Reactor and Fuel Cycle Concepts"	TWG-FR	2004	Discussed at 37th TWG-FR: supported by the TWG-FR members; proposal submitted by IAEA; preparatory TM possibly in 2005, kick-off RCM in 2006
3	Technical Meeting "Review of National Programmes on FR and on ADS and Consultation with Member States" (38th annual TWG-FR meeting)	TWG-FR	2004	Brazil offers to host; dates 23-27 May 2005 (alternative: 9-13 May 2005)
4	39th Annual Meeting of the TWG-FR	TWG-FR	2005	China offers to host the 39th Annual Meeting, 15-19 may 2006, in Beijing
	Technical Meeting to prepare TECDOC on "Status of Fast Reactor R&D and Technology"	TWG-FR	2006	To be convened in 2006
	Technical Meeting to prepare TECDOC on the "Status of ADS R&D and Technology"	TWG-FR	2006	To be convened in 2006
	Technical Meeting on Member States Activities in fast reactor knowledge preservation	TWG-FR	2006	To be convened in 2006 and in 2007
	Third Research Coordination Meeting (RCM) of the CRP on "Studies of Advanced Reactor Technology Options for Effective Incineration of Radioact. Waste"	TWG-FR	2006	Planned for December 2006, Kalpakkam (?)
	Kick-off RCM of the CRP on "Analyses of and Lessons Learned from the Operational Experience with Fast Reactor Equipment and Systems"	TWG-FR	2006	Planned for 3rd quarter 2006, Vienna
	RCM of the CRP on "Analytical and Experimental Benchmark Analyses of ADS"	TWG-FR	2006	Second RCM planned for 2007, venue?
	40th Annual Meeting of the TWG-FR	TWG-FR	2006	May 2007, venue? (Japan?)

	Joint IAEA/ICTP Workshop "ADS Technology and Applications"	TWG-FR	2006	Planned for fall 2007
	Seismic Design of Nuclear Island and Components	TWG	2007	
	Innovative Design Concepts for Decay Heat Removal Systems	TWG	2007	
	Mitigation Means of Gas Entrainment	TWG	2007	
	Improving Economics of FBR Through Advanced Materials for Structural Components (e.g. reactor vessels, pipings, heat exchangers, SGs） and Core Materials (clad, wrapper)	TWG	2007	
	Design of FBR Components (control plug, IHX, inner vessel and SG) Operating at High Temperature	TWG	2007	
	Design Criteria for Issues Not Covered in Current Design Codes	TWG	2007	

ANNEX IV

Commemorative Ceremony for 40th Anniversary of IAEA´s TWG-FR (formerly IWG-FR)

International Atomic Energy Agency (IAEA)
Japan Atomic Energy Agency (JAEA)

STATEMENT OF INTENT

The *Technical Working Group on Fast Reactors (TWG-FR)* is a standing working group within the framework of the IAEA. It is IAEA's oldest Technical Working Group, having been created in 1967 as *International Working Group on Fast Reactors (IWG-FR)*.

The TWG-FR provides a forum for exchange of non-commercial scientific and technical information, and a forum for international cooperation on generic research and development programmes in the area of advanced fast reactors (FR) and fast spectrum accelerator driven systems (ADS).

The TWG-FR regularly reviews the status of and results achieved within the framework of the national research and technology development programmes relevant to the TWG-FR's scope, and recommends activities to the Agency which are beneficial for these national programmes. It furthermore assists in the implementation of corresponding IAEA activities, and ensures that all the technical activities performed within the framework of the TWG-FR are in line with expressed needs from Member States. The scope of the TWG-FR is broad, covering all technical aspects of FR and ADS research and development, design, deployment, operation, and decommissioning. It includes, in particular: design and technologies for current and advanced FRs and ADS; economics, performance and safety of FRs and ADS; associated advanced fuel cycles and fuel options for the utilization and transmutation of actinides and long-lived fission products, including the utilization of thorium. The TWG-FR has documented the results of its activities in numerous IAEA technical publications (e.g. IAEA-TECDOC).

Commemorating 40 years of continued activities of the TWG-FR, an Anniversary Symposium will be held by gathering the domestic and foreign influential individuals to deliver lectures and hold a panel discussion. The overall objective of this event is to confirm the importance of the development and the utilization of nuclear energy, with particular emphasis on the achievements of fast reactor development and its future role towards meeting sustainability requirements as a necessary condition for securing nuclear energy an important role in the global energy mix.

Last but not least, this event will be held to address the prospects of international collaboration within the framework of IAEA and the TWG-FR, including the expected role and contributions of MONJU to the benefit of worldwide FR development efforts.

PROGRAM

1. Date and Time: May 14th(Mon.), 2007, 13:00 - 17:30

2. Place: JAEA MC Square (Tsuruga Fukui), Japan

3. Organizer: International Atomic Energy Agency (IAEA)

Host: Japan Atomic Energy Agency (JAEA)

4. Agenda

13：00- Greeting remarks（IAEA, JAEA)

Congratulatory address (MEXT, Fukui-pref.)

13：30 Session-1: Lectures

Stable energy supply is indispensable to establish long-term sustainability of the society. Nuclear energy is a promising option to meet this demand. FRs have an important role to play in the long-term utilization of nuclear energy.

In the beginning of this session, looking back at the world-wide FR development activities from its dawning period, the expected role of FRs and need for R&D are addressed. How IAEA/TWG-FR activities so far contributed to the global and Japanese FR developments are reviewed next. Necessity for coming generations and prospective of future FR development are then discussed, referring to the Japanese policy on FR development.

- M. SALVATORES (CEA (France) and ANL (USA))
  “The role of fast reactors for long-term sustainable nuclear power”
- G. HEUSENER (former FZK (German), German IWG-FR/TWG-FR representative)
  "History of IAEA's IWG-FR/TWG-FR, and its Future Role in Fast Reactor Research and Technology development"
- K. TOMABECHI (former JAEA (Japan) and former Japanese IWG-FR/TWG-FR representative)
  "FBR Development in Japan and Activities of TWG-FR"
- Y. FUJIIE (former JAEC Chairman)
  "Perspective on the Global and Japanese Fast Reactor Development"

15:30 - 15:50 Coffee Break

15：50 Panel Discussion:

“Prospective for international collaboration: IAEA and TWG-FR role”

Each representative of the TWG-FR member state is to introduce the role and perspective of FR development in the national nuclear energy policy, taking over the discussions in Session-1. Thereafter, the representatives and lecturers in Session-1 jointly discuss on possible collaborations within the framework of IAEA/TWG-FR, with expected role of Monju.

<u>Panelists</u>:

- Y. ASHURKO (Leading Researcher, IPPE, Russia)
- J. ASTEGIANO (CEA, France)
- P. Chellapandi (Associate Director of Nuclear Engineering Group, India Gandhi Centre for Atomic Research, India)
- E. FUJITA (Deputy Division Director NE, ANL, US)

- K. MUKAI (Director of Advanced Nuclear System R&D Directorate, JAEA, Japan)
- Y. FUJIIE (former JAEC Chairman)
- G. HEUSENER (former FZK (German), German IWG-FR/TWG-FR representative)
- M. SALVATORES (CEA (France) and ANL (USA))
- K. TOMABECHI (former JAEA (Japan) and former Japanese IWG-FR/TWG-FR representative)

Chairman: A. STANCULESCU (Unit Head of FR&ADS Technology Advances, on behalf of IAEA),

17 : 30 Closing Remarks (JAEA)

Atoms for Peace: The First Half Century
1957–2007

Draft Agenda
for the
Fortieth Meeting of the Technical Working Group on Fast Reactors (TWG-FR)
hosted by the
Japan Atomic Energy Agency (JAEA), Tsuruga and Kyoto, Japan, 14 – 18 May 2007

Monday, 14 May 2007: Commemorative Symposium for the 40th TWG-FR Anniversary at the MC Square Hall in Shiraki, Tsuruga, Fukui Province

10:00 Technical Tour to MONJU

12:00 Lunch

13:00 Greetings remarks by IAEA and JAEA; congratulatory address by MEXT

13:30 Lectures (titles are preliminary)

- M. Salvatores (CEA, FZK, ANL): “Long-term Role of the Fast Reactor, Innovation and R&D Needs”
- G. Heusener: (former FZK and German IWG-FR / TWG-FR representative): “History of IAEA’s IWG-FR / TWG-FR, and its Future Role in Fast Reactor Research and Technology Development”
- Tomabechi (JAEA, former Japanese IWG-FR / TWG-FR representative): “TWG-FR Activities in Japan”
- Y. Fujiie (former JAEC Chairman): “Perspective on the Future FBR Development”

15:50 Panel discussion “Prospective for international collaboration: IAEA and TWG-FR role” (panellists: to be decided)

17:30 Closing remarks (JAEA)

18:30 Reception

Tuesday, 15 May 2007

09:00 Opening by the TWG-FR Scientific Secretary and introduction of the TWG-FR Chairperson
Chairperson’s remarks
Self-introduction of the participants
Discussion and adoption of the agenda

09:30 Progress reports on national programmes on fast reactors and accelerator driven systems, and identification of areas and topics of interest for future cooperation within the TWG-FR framework *[Approximately 30 – 40 minutes presentation including discussion by each Member State representative, in country name alphabetical order.* ***The delegates are kindly***

requested to bring along their full paper progress reports (both as hardcopy and on electronic support) for publication in the meeting report]

12:00 *Lunch*

13:00 Progress reports on national programmes on fast reactors and accelerator driven systems, and identification of areas and topics of interest for future cooperation within the TWG-FR framework, cont'd

18:00 *Adjourn*

Wednesday, 16 May 2007

09:00 Progress reports on national programmes on fast reactors and accelerator driven systems, and identification of areas and topics of interest for future cooperation within the TWG-FR framework, cont'd

12:00 *Lunch*

13:00 Summary of TWG-FR activities, status of the actions and report on TWG-FR documents by the Scientific Secretary

Discussion of the Scientific Secretary's report

Status of ongoing Coordinated Research Projects (CRPs)

- Studies of Innovative Reactor Technology Options for Effective Incineration of Radioactive Waste
- Analytical and Experimental Benchmark Analyses of Accelerator Driven Systems (ADS)
- Analyses of, and Lessons Learned from the Operational Experience with Fast Reactor Equipment and Systems

Status of planned Coordinated Research Projects (CRPs)

- Benchmark Analyses of Sodium Natural Convection in the Upper Plenum of the MONJU Reactor Vessel
- PHENIX End-of-Life Tests and Expertise

Status of the preparation of TWG-FR technical publications

- Accelerator Driven Systems: Energy Generation and Transmutation of Nuclear Waste; Status Report
- Status of Liquid Metal Cooled Fast Reactor Technology
- Status Report on Lead and Lead-Bismuth Cooled Fast Reactors
- Fuel Failure and Failed Fuel Detection Systems for Fast Reactors
- Final Report of the CRP on *Updated Codes and Methods to Reduce the Calculational Uncertainties of the LMFR Reactivity Effects*
- Final Report of the CRP on *Innovative Reactor Technology Options for Effective Incineration of Radioactive Waste*

Presentation of the new Terms of Reference of the TWG-FR by the Scientific Secretary

18:00 *Adjourn*

Thursday, 17 May 2007

09:00 Discussion of the TWG-FR activities planned within the framework of IAEA's Program and Budget 2008 – 2009

- Large International Conference on *Fast Reactors and Closed Fuel Cycle – Challenges and Opportunities*
- Large International Conference on *Materials Research and Utilization of Accelerators*
- Topical Technical Meeting (TM) on *Design Features of Advanced Sodium Cooled Fast Reactors with Emphasis on Economics*
- Topical Technical Meeting (TM) on *Fuel Handling Systems of Sodium Cooled Fast Reactors* (unfunded)
- Topical Technical Meeting (TM) on *In-service Inspection and Repair of Sodium Cooled Fast Reactors* (unfunded)
- Topical Technical Meeting (TM) on *Advanced Sodium Heated Steam Generators and Sodium/Gas Heat Exchangers for Fast Reactors* (unfunded)
- Publication on *Public Acceptance of Fast Reactors* (extra-budgetary)

12:00 Lunch

13:00 Discussion of future TWG-FR activities (beyond 2009): proposals for new CRPs, TMs, symposia/seminars, identification of possible NE Series Documents on topics relevant to the TWG-FR work scope *(**To ensure distribution among all participants, the delegates are kindly requested to inform the Scientific Secretary ahead of the meeting of intended proposals**)*

Discussion and updating of the list with "Proposed Topics for TWG-FR Technical Meetings and Collaborative R&D"

18:00 Adjourn

Friday, 18 May 2007

09:00 Drafting of conclusions and recommendations of the TWG-FR Technical Meeting

Miscellaneous, date and venue of next TWG-FR Technical Meeting

13:00 Lunch

14:00 Adjourn meeting