International Conference on Research Reactors:
Safe Management and Effective Utilization
5-9 November 2007
Sydney, Australia

CONFERENCE REPORT

Session 1: Welcome and Opening Address

The Conference was opened by Mr. John Loy, Chief Executive Officer of ARPANSA. He welcomed the delegates to Australia and noted that Australia is firmly committed to the IAEA and its programmes, including conferences, which are important in promoting exchange of information and experience. The legislation that created ARPANSA requires that it adhere to international best practices, and they depend on the IAEA Safety Standards, especially the Safety Fundamentals and Requirements, as representing the best practices. ARPANSA plays a strong role in development of the Standards. Mr. Loy also expressed his gratitude for the various IAEA missions to Australia. He committed the continued support of ARPANSA for the work of the Agency.

Mr. Yuri Sokolov, Deputy Director General and Head of the Department of Nuclear Energy of the IAEA, presented the opening address on behalf of the Agency. He congratulated the Australian Government and the Australian Nuclear Science and Technology Organization (ANSTO) on the recent start-up of the new OPAL research reactor, a state-of-the-art multi-purpose facility for radioisotope production, irradiation services and neutron beam and advanced materials research. He noted that many IAEA Member States are requesting assistance in acquiring a research reactor or entering into cooperative arrangements as a first step towards a nuclear power programme. Research reactors may be crucial in supporting informed decisions on establishing a power programme, as well as supporting advances in reactor and fuel cycle technology.

Mr. Sokolov reviewed some critical issues in utilization, safety, the fuel cycle and security that the research reactor community now faces, and the Agency's response to these issues. The first is effective utilization in an economically competitive and safety-, reliability- and security-conscious world. The IAEA is encouraging facilities to become 'regional centres of excellence' where cooperative research and training can be carried out by neighbouring countries at a single research reactor, and creation of cooperative arrangements between operating research reactors. The Agency is also encouraging regional sharing of research reactor facilities.

The second key issue is safety of research reactors. Safety concerns arise because of aging of facilities, lack of resources and underutilization, out-of-date or incomplete safety documentation and inadequate regulatory supervision. The Agency is addressing these issues through the Code of Conduct on the Safety of Research Reactors, development of Safety Standards and by providing assistance for establishing effective aging management programmes. Integrated Safety Assessment of Research Reactors (INSARR) and Integrated Regulatory Review Service (IRRS) missions help to improve safety of facilities and regulatory supervision. The Incident Reporting System for Research Reactors (IRSRR) supports exchange and dissemination of information on incidents.

The third key point is the need to deal effectively with the research reactor fuel cycle. The IAEA actively supports the Global Threat Reduction Initiative (GTRI), the Reduced Enrichment Research and Test Reactor (RERTR) programme, and the HEU fuel return programmes. A solution is needed about final disposal of spent fuel or the high-level waste that results from reprocessing.

The fourth point is the need to deal with the threat of nuclear terrorism. Strong measures must be taken to provide adequate physical protection for all nuclear and radioactive materials and facilities,

including transportation. The Agency assists Member States through the Nuclear Security Series documents, security advisory missions, human resource development and facility security upgrades.

The IAEA expects comprehensive findings and recommendations of this Conference, which will contribute fresh ideas and creative approaches to maintain and improve the safe and sustainable operation of research reactors worldwide.

Safety Sessions

Session 2: Experience with the Code of Conduct on the Safety of Research Reactors

In the initial presentation in this session, Mr. Loy outlined the evolution and nature of the Code of Conduct on the Safety of Research Reactors. The Code is a non-binding international instrument having the objective to achieve and maintain a high level of safety in research reactors worldwide through national measures and international cooperation. It provides guidance for the State, the Regulatory Body and the Operating Organization. States are encouraged to apply the Code through national regulations, making use of IAEA Safety Standards, using a graded approach based on the hazard potential of their research reactors.

For the Code to be fully effective in achieving its objective, Member States must commit to following the guidance in the Code. An accepted, pragmatic mechanism for Member States to share experience and learn from one another must be implemented. Regional meetings on application of the Code have gone some way towards this end, and an International Conference is planned in mid-2008.

Mr. Abou Yehia (Lead Scientific Secretary) presented the feedback from the regional meetings, along with results of safety review missions and information from the Incident Reporting System for Research Reactors (INSRR). These elements have been used to update and focus the Agency's research reactor safety programme. Some near-term actions include incorporating application of the Code as a review area in safety review missions, providing practical guidance on safety of modifications and experiments, convening a technical meeting for members of safety committees and a series of regional meetings to improve the capabilities for safety assessment, and assistance in developing aging management and safety culture in operating organizations.

Two presentations provided open assessments of application of the Code for benchmarking the safety regime in a regulatory body (Mr. Sapozhnikov, Russia) and in an operating organization (Mr.Tozser, Hungary). These presentations confirmed that the Code is useful in benchmarking legislative frameworks, regulatory systems, safety standards and operational safety regimes. Self-assessments against the Code help to identify shortcomings and provide a positive contribution to improving safety.

It was also noted that it is necessary to demonstrate safety and to convey the fact that a research reactor is safe through a public information strategy. An INSARR is the best independent evidence to demonstrate safety.

Experience in application of the Code of Conduct confirms that:

- It serves as an example of international best practice and assessments against the Code provide a systematic way of benchmarking against best practice;
- The Code can shape further development of Agency Safety Standards; and
- The Code provides high level guidance for IAEA programmes in enhancing research reactor safety.

Possible areas for improvement of the Code were noted, such as:

- Including the idea of an overall safety management system;
- Stronger emphasis on periodic safety reviews;

- More emphasis on human factors;
- Definition of mandatory safety documentation.

Session 4: Safety Management and Operational Safety (Part I)

The initial papers in this session focused on safety management. The first paper by Mr. Voth (USNRC) discussed sharing of experience and best practices from power reactors with research reactors, recognizing that a graded approach is needed to reflect the differences in the size of organization, the function of the facility and the hazard potential. However, there are many areas in which NPP best practices are applicable, such as the need for a strong safety culture and a management system that includes policy, documentation, procedures, maintenance and surveillance programmes, radiation protection and training. Suggested programmes included a standardized writer's guide, expanded training of all personnel, design and configuration control, work control, corrective action programmes and QA oversight.

The next papers discussed the safety management systems used at the NRG Petten and at the Indian reactors APSARA, CIRUS and DHRUVA.

Mr. Boogaard (NRG-Netherlands) concluded that outstanding safety management is of paramount importance and that the effectiveness of safety management is a combination of the implemented safety management system and the safety culture. Their system includes all ISO, nuclear safety, environmental and occupational health requirements in one dedicated system. Safety culture is an essential part of the defence-in-depth philosophy. There is emphasis on visibility and transparency to all, management, workers and stakeholders, and on education, training and continuing improvement.

Mr. Shulka (BARC-India) discussed a management system that has evolved over 50 years of safe operation. It is a structured system with the technical specifications document at its centre. This document includes the safety policy, operational limits and conditions, surveillance requirements and administrative controls. It is approved by the regulatory body. Strict adherence to the technical specifications is the key to operational safety. Every proposed experiment or modification is performed under the same principles that apply to the reactor.

The preceding papers illustrate that different organizations and different cultures can achieve effective safety management using different methods that suit their preferred style.

Mr. Bignon (France) discussed the 10-year safety reassessment of research reactors in France. The process begins with assessment of the current state of the facility against its initial safety basis to determine any degradation. The initial safety basis is compared against current requirements and upgraded as necessary to meet new requirements. Any gaps between the current state of the facility and current requirements is identified and necessary refurbishment and upgrading is defined. In this way, the safety level of the facility is increased. The upgrades can be extensive and costly, so there must be a need for the reactor to justify the expense. He also emphasized that France is open to international collaboration in technical projects and safety reviews, through exchange of senior scientists and training of young people.

Mr. Repussard (France) addressed the compatibility of safety and security. Both have a common goal, protection of people and the environment from harm, but they have different cultures. Safety is based on openness and transparency, while security is based on confidentiality. The two cultures should complement and support each other. Both safety and security should be considered in a single integrated management system. It was suggested that security should be considered in the context of the Code of Conduct (although physical protection is specifically excluded in the current Code).

Mr. Ciocanescu (Romania) presented operational safety experience at the 14 MW TRIGA research reactor at the INR Pitesti. His presentation included the use of PSA integrated into the SAR, with fault

trees and event trees based on specific event report data for the reactor. The experience data are used to develop a probabilistic set of performance indicators. Learning from analysis of past events and from events reported by other installations (for example, through the IRSRR) will help prevent recurrence and thereby improve safety.

Ms. Persic (Slovenia) reported that there have been no significant events in 40 years of operation of the TRIGA reactor at Ljubljana. They expect to operate to 2016 or longer with existing fuel. A periodic safety review is planned to confirm the condition of all major reactor components. They anticipate new experiments related to fusion research, material, measurement methods and benchmark experiments. The reactor will have an important education and training role in view of their nuclear power programme.

Ms. Nitiswati (Indonesia) presented an investigation of the swelling (bulging) observed at the bottom of the tank liner of the Kartini reactor, conducted with international cooperation from ANSTO. The investigation used a replica technique suggested by ANSTO to follow the changes in height and extent of the swelling. It was determined that the swelling has stabilized and does not appear to be growing, but it will be monitored every three months by visual inspection and every six months using the replica and ultrasonic inspection. This is an example of using IAEA and regional cooperation to deal with a technical issue.

Session 4: Safety Management and Operational Safety (Part II)

Mr. Rive (France) focused on the central role of the Periodic Safety Review (PSR) in the life of an installation, emphasizing its importance in improving the safety level and in informing a decision for the continuation of the reactor operation for the next decade. The presentation mainly focused on the two basic parts of PSR, the conformity check and the safety reassessment. It was noted that the main improvements resulting from the French experience feedback concerned: the seismic resistance, the reliability of the safety systems, aging management, and improvements in defence-in-depth applications. Many examples were presented to illustrate this point. While the main safety principles applied for the safety evaluation of research reactors are very similar to those used for NPPs, adaptations and graded approaches are used, due to specific features of research reactors.

Discussions following this presentation focused on 3 subjects:

- The improvement of the safety level: It was indicated that in France, PSA is not used for research reactors. Evaluation of safety improvement is consequently based on analysis of the defence-in-depth principles and on a qualitative approach.
- The relation between PSR and WENRA activities: It was stated that PSR was not influenced by a WENRA initiative.
- The graded approach for research reactors: Agreement on the need for a graded approach was confirmed, but it was recognized that more examples to illustrate that subject would be useful.

Mr. Vieira Neto (Brazil) delivered a presentation on the main results of the experience gained in the first phase of the Safety Culture Enhancement Programme at the IEA-R1 Brazilian Research Reactor. The role of the Safety Culture Enhancement Working Group of the research reactor centre in acquiring knowledge about the state-of-the-art in safety culture and in developing a proper methodology to be used in the first stage of the programme was reviewed. The presentation detailed the 3 steps of this methodology, including:

- Identification and assessment of the safety culture at IAE-R1 reactor. This step is based on 3 questionnaires: a survey of the employees' safety perception, a safety culture self- assessment by the working group and the safety culture assessment based on the "3 level model of culture;
- Identification of tacit problems related to safety; and
- Elaboration of an action plan (corrective actions) aiming at enhancement of the safety culture in the organization. It was stated that a similar programme was started at the IPEN/MB-01 reactor.

Mr. Wu (Korea) discussed development of safety performance indicators for HANARO. He noted that operational safety performance indicators (SPI) help an organization to define and measure a progress with regard to safety goals. The categories of operational safety attributes of HANARO were presented, including facility operates smoothly, facility operates with low risk, facility operates with a positive safety attitude and facility operates with a safe utilization. He emphasized the importance of these indicators for reviewing the safety performance of the reactor operation. While the usefulness of these indicators was confirmed, it was recognized that some indicators may need to be modified. It is also necessary to pursue the trends of the operational safety attitudes for an effective safety management of HANARO. During the discussion, one participant identified that a major challenge was to determine criteria or procedures to review the SPI.

Mr. Margenau (Romania) presented the emergency intervention plan for the 14MW TRIGA Pitesti research reactor. Establishing an emergency intervention plan was considered essential for protecting the public in the event of an incident, and for helping the decision-making process. The hypotheses and premises for intervention were widely presented. Flexibility must be maintained in emergency response to reflect the actual circumstances encountered (for instance: weather conditions). He detailed the framework of the emergency plan (4 sections). The schematic structure of activities covered by emergency intervention plan was also presented, including the planning, the management of intervention in the early phase and the intervention in the intermediate and late phase. Finally, it was noted that the TRIGA reactors were operated in a satisfactory way (without severe incidents) during more than 45 years.

A number of additional contributions were made during discussion following this presentation. They focused on:

- Utilization of the emergency intervention plan;
- The need to develop information to the public;
- Legal aspects and liability regarding the implementation of this plan.

From this session, it is recommended that more specific workshops concerning performance indicators for research reactor safety and regulatory activity be organized to improve these indicators and their application. Also, information exchange related to emergency preparedness and response at research reactors should be developed.

Session 7: Regulatory Aspects and Experience with Current Research Reactor Issues Including Safety Aspects of Core Conversion

Eight papers were presented in the two parts of this session. In six of the papers, presenters described the objectives, challenges faced and regulatory approaches being taken to strengthen regulatory oversight of research reactors of various designs, age (some up to 50 years), power level and utilization in light of recent changes to modernise legislation and improve regulatory frameworks. All of the presentations were from countries having well-established regulatory systems. Some of these changes were aimed at improving the power and effectiveness of regulatory bodies, giving greater transparency and increasing public input to regulatory decision making, requiring financial guarantees for decommissioning and requiring formal management and quality systems for research reactors.

It was emphasized that periodic reassessment of all aspects of research reactors safety is needed to reflect new concepts related to safety and updates of standards to meet modern requirements. Regulatory requirements for periodic safety reviews for research reactors are increasingly being formalized in legislation, with periods ranging from five to ten years. In some cases, reviews must be submitted to the regulatory body as part of an application for re-licensing.

It was also noted that in many Member States, research reactors are being regulated using the same processes and standards as applied to power reactors using a graded approach, with international practices and IAEA Safety Standards often forming a foundation.

Mr. Mikulski (Poland) discussed the role of the regulatory authority in safe operation of research reactors with reference to Poland. He raised the transfer of experience from old to new generations of regulators as an important issue. He concluded that regulatory activity must be continuous, that regulators should be active in suggesting changes and improvements in safety of a research reactor, and that regulatory activities have a positive influence on improvements in nuclear and radiological safety.

Mr. Perrin (Argentina) described the development and value of guidance for systematic evaluation of causal factors of incidents in research reactors. The guidance addresses evaluation of equipment vulnerabilities, human factors and organizational management as contributors to incidents. Investigating and managing events is an important regulatory tool for improving safety through feedback of lessons learned into operations management and accident prevention.

Mr. Howden (Canada) discussed the approach of the Canadian Nuclear Safety Commission in applying new laws, regulations and standards to existing research reactors. The new approach is risk-based, using risk ranking and balancing potential risk reduction against the time and effort needed to make improvements. Both licensees and the regulator have made particular efforts to bring licensed activities up to the new standards.

Ms. Conte (France) presented the French approach to regulation of research reactors. Regulatory control of changes to the facility and the management systems, including operating procedures, without unduly limiting the flexibility of the operating organization was discussed as an important issue. Generally, proposed changes that do not have significant implications for safety or do not alter the licensing basis can be approved internally by the operating organization using a formal change control process involving competent and independent internal review. Otherwise, prior regulatory approval is required. This process will make more resources available in the regulatory body to deal with important safety issues.

Mr. Ward (ARPANSA-Australia) discussed the operational readiness review of the OPAL reactor. This is the first reactor licensed by ARPANSA through every stage. He noted that 430 documents were received by ARPANSA, which presented a significant challenge to already stretched resources. An effective review system was evolved, which provided well founded advice to the CEO of ARPANSA for decision making. The ongoing regulatory challenge is to ensure that the management system continues to assure safe operation, provide continuous improvement and reflect international best practices in nuclear and radiation safety.

Mr. Schneider (Germany) gave an overview of research reactors in Germany. He noted that the nuclear phase-out mandated in current German law applies only to nuclear power plants, not to research reactors. In principle, the legislative and regulatory framework is the same for research reactors and nuclear power plants.

In addition to the papers on regulatory matters, two papers addressed other safety topics. Mr. Couturier (France) discussed the use of research reactors in programmes for research and development in safety for nuclear power plants, including studies of pellet-cladding mechanical interaction in power transients and fuel behaviour in a control rod ejection accident and loss-of-coolant accident. Experiments in research reactors have been essential to define linear power thresholds for various types of PWR fuel rod to prevent cladding rupture in certain power transients, define new criteria for rod ejection and loss-of-coolant accidents, and contribute to related code development and validation.

Mr. Krzysztoszek (Poland) presented a paper on conversion of the MARIA reactor to LEU fuel. Because of the unique type of fuel (concentric tubes) and the required uranium density, it will be necessary to irradiate two lead test assemblies in the reactor to a fuel burnup in the range 40-60%. This irradiation is anticipated to begin in the fourth quarter of 2008.

Session 10: Core Safety and Utilization Parameters

In the first paper of this session, Mr. Snelgrove (ANL-USA) discussed the status of the forthcoming IAEA document on good practices for qualification of research reactor fuels. The document is nearing completion and should be published in 2008. It will recommend good practices to any organization undertaking a research reactor fuel development programme in the future. Also, it will bring manufacturers of research reactor fuel, users of such fuel and regulatory bodies up-to-date on the information expected to be available to support licensing of newly developed LEU fuels for core conversion and future use. It should provide a common understanding of what is meant by 'fuel qualification'.

In another paper, Mr. Braoudakis (ANSTO-Australia) discussed the reactor physics testing of the new OPAL research reactor and compared measured parameters with the contractual requirements. He concluded that the preliminary test results indicate that the reactor fulfilled (or nearly fulfilled) the requirements for absolute scalar flux, and axial flux uniformity and thermal- to fast-flux ratio (for silicon doping). Spatial uniformity and spectral characteristics of neutron beams were found to be acceptable. A number of measurements remain to be completed, and some measurements will be repeated after the purity of the heavy water reflector has stabilized.

Two other papers presented discussions of comparisons of calculations and experimental measurements. In one paper, Mr. Park (Korea) compared calculations of the flow distribution in the reactor pool of the HANARO reactor with measurements. The calculations were done using the MARS system analysis code with multi-dimensional thermal-hydraulic analysis capability and a computational fluid dynamics code. In the other paper, Mr. Sevdik (Turkey) presented experimental data on fuel temperatures in MTR plate-type elements during a sudden loss-of-flow event and compared the results with calculations using the PARET code. Differences found were attributed to the decay heat calculations in PARET overestimating the decay heat deposited in the experimental assembly located on the periphery of the core. Both these papers emphasized the need for correct modelling of the situation being calculated (i.e., using a sufficient number of nodes in CFD calculations or correct modelling of radiation transport near a boundary) to obtain reliable results. Detailed computer simulations can give insights into the steady-state and transient behaviour of the reactor, but verification by measurements is needed.

<u>Safety Posters</u>

Four poster presentations showed the use of MCNP calculations for core behaviour prediction, addressing core conversion to LEU fuel, criticality and reactivity calculations for standard cores and flux estimates for experimental positions. The latter calculations were used for safety assessment of experiments and evaluation of material irradiations. It was noted that MCNP calculations are very powerful and reliable, but they require detailed modelling of the core and experimental setups to achieve good results.

Another poster presented an analysis of a reactivity insertion incident using the PARET code. This code has proven to be a powerful tool for thermal-hydraulic analysis of cores containing MTR-type fuel elements with pressure less than 5 bar.
Some general key points: For operational safety of research reactors, the following attributes are essential:

- Proper core calculations and measurements;
- Timely upgrading of safety systems;

- Adequate training and qualification of operating personnel;
- Management networks for safety and quality of operation.

Utilization Sessions

Session 3: Sustainable Utilization and Strategies

Four papers on specific utilization programmes were presented in this session: Mr. Chaplot (BARC-India) discussed utilization programmes at low-and medium-flux research reactors in India; Mr. Saxena (Brazil) presented the operating experience and utilization programme at the IEA-R1 reactor; Mr. Yuldashev (Uzbekistan) discussed utilization of the 10 MW reactor in Tashkent; and Mr. Nyarko (Ghana) presented the utilization at their 30 kW MNSR facility.

The utilization programmes presented varied greatly depending on the needs of the countries and the capabilities of the facilities, but all were vigorous and productive. Generally, the programmes being pursed include neutron beam research and beam applications, neutron radiography, radioisotope production, neutron activation analysis, neutron transmutation doping of silicon, testing to support development of nuclear energy programmes, and human resource development. Some reactors are being used to support a wide range of monitoring and diagnostic tasks using neutron activation analysis, including monitoring of drinking water and food, pollution from vehicle exhaust, archaeological studies and forensic investigations.

Mr. Saxena advocated a continuous modernization and refurbishment programme, with small steps taken to improve the performance of the reactor with small budgets and short shutdown times. An integrated management system including quality assurance, safety culture and environmental consciousness is essential. A strategic plan for effective utilization of the reactor is an essential step.

Mr. Itoh (Japan) presented the utilization of research reactors (the JMTR, HTTR and JOYO) and related facilities of the JAEA for research and development in fuel behaviour and advanced materials for innovative power reactors and fuel cycles. The O'arai R&D Centre brings together the facilities for fabrication, irradiation and post-irradiation examination of experiments, and for waste management. The centre also supports university research and provides an excellent example of cooperative use of research reactors to support national R&D programmes.

Experience in the Halden project was presented by Mr. Beere (Norway). The Halden project has a long-standing international program in fuels and materials research, human factors research, control room and I & C system design, and in-core instrumentation development, along with experiments on fuel behaviour in transients and accidents in power reactors. They attribute their success to a flexible organization that adapts to user needs with joint funding by an international consortium and strong links to industry. Simply stated, international collaboration is a key to success.

It was pointed out that many of the research reactors are aging and many countries cannot afford the cost of construction of new reactors. The cost of fuel is rising and decisions at a regional or international level are needed on how the older reactors should be operated and maintained. An approach to maintain the capability and continue to provide the products and services of the research reactors in the light of economic realities is needed. (See Session 6 for some ideas along this line.)
In addition to the papers on utilization programmes, two papers on specific aspects of utilization were presented: Mr. Ramanathan (Brazil) presented a corrosion monitoring programme for spent fuel basins; and Mr. Rosa (Italy) discussed subcritical measurements in the TRIGA RC-1 reactor at Casaccia conducted in preparation for an accelerator coupling experiment.

Session 5: Fast Flux Test Reactors

A presentation by Mr. Guidez (France) focused on the main incidents that have occurred in sodium cooled reactors worldwide, with a view to identifying the specific risks involved, the lessons learned and the solutions which were brought. In this respect, a list of operating problems relative to this type of reactor was identified, including sodium leaks, sodium fires, water/sodium reaction in steam generators, incidents in handling operations, intakes of air and impurities, sodium ejection and material behaviour problems. A discussion of each problem was presented. He noted that a significant experience has been accumulated and taken into account in the safe operation of these reactors and pointed the way to several improvements which should be included in the design of future plants.

During the discussion, it was noted that many of the problems encountered in sodium-cooled reactors were mainly due to the fact that they are prototypes being used to develop technology, and that some fast reactors (EBR-II in the U.S., for example) have had good operating experience over many years.

Mr. Gopala Iyengar (India) described India's three-stage nuclear programme and focused on the fast breeder reactors, which constitute the second stage, and more particularly on the characteristics of the Fast Breeder Test Reactor (FBTR) - a 40 MWt sodium-cooled, loop-type fast reactor, which was built to develop the technology of sodium-cooled fast reactors. The evolution of the core and the performance of the fuel chosen were widely presented. He pointed out that the experience with sodium systems was very good, emphasizing that the sodium purity was well maintained. He noted that the present mission of the FBTR is to irradiate the mixed oxide fuel chosen for the 500 MWe Prototype Fast Breeder Reactor being built at Kalpakkam. He detailed a list of problems that have occurred in the course of the reactor operation, and the solutions. It was emphasized that the encouraging experience feedback with FBTR operation has been a major factor in the launching of the 500 MWe prototype.

Session 6: Networking for Research Reactor Utilization

In the first paper of this session, Mr. Adelfang (IAEA) reviewed the Agency's Subprogramme D on research reactor technology and non-proliferation. He noted that the subprogrmme is conducted with a 'one house' approach involving the nuclear applications and nuclear safety. Among other activities, assistance is provided for planning new facilities that reflect modernization and innovation. Fuel cycle issues are an important part of Subprogramme D, with consideration given to the whole fuel cycle, including core conversion to LEU fuel, return of fresh and spent HEU fuel to the country of origin (where it was enriched) and to regional solutions to the back end of the fuel cycle. Dealing with degraded spent fuel is part of this activity, including a large technical cooperation project at the Vinca site in Serbia.

He reported that a Technical Working Group on Research Reactors (TWGRR) is to be formed to provide advice and guidance to the Agency in programme planning and implementation. This group will be appointed by the Deputy Director General for Nuclear Energy, and will also report its findings and recommendations to the Standing Advisory Group for Nuclear Energy (SAGNE). He also reported that the Agency will facilitate an initiative to replace low utilization, low capability research reactors with regional high capability reactors in the 2020 time frame or beyond.

In the next paper, Mr. Nigel Mote discussed developing research reactor coalitions and centres of excellence. He noted that many research reactors were at one time viewed as a national asset but many are now viewed as liabilities, and have lost much government support. Many of these reactors are now underutilized and underfunded, making it more difficult to continue to meet safety and security standards. However, there remain many societal needs for research reactors, leading to a need for financially strong institutions to operate research reactors. Enhanced cooperation among research reactor operators will provide access to customers, expand the market, increase utilization and financial security, and promote meeting safety and security standards. He emphasized that if a

coalition works, everyone benefits, but there is a need to overcome parochial interests and competitive behaviour. The IAEA can facilitate, but it cannot make coalitions work.

Session 8: Specific Utilization Applications

Six papers were presented in this session. Mr. Delorme (Netherlands) described new developments in on- and off-line detection and monitoring of small releases of fission products from fuel elements at the HOR reactor (Delft). Three new instruments developed for the detection of small releases of fission products from spent fuel were presented. These consist of a wet sipping device, a device to measure pool water activity and an on-line air borne activity measurement device consisting of a number of plates arranged in a cascade arrangement to circulate pool water. The standard used in new instruments described above for the detection of fission products is iodine activity of 20kBq/m3 whereas the presence of cesium from sip tests is used as the indicator for fission products in other reactors.

Mr. Medel Ruggerio (Chile) discussed calculations of the neutronics and fission product activities to determine the ideal position in the RECH-1 reactor for 99Mo production with LEU-foil targets using transport and diffusion codes. The advantage in the use of a uranium foil as opposed to a uranium fuel plate is to significantly reduce the quantity of waste produced during the Mo-99 extraction process. The results show that irradiating an LEU-foil annular target having 13 grams of metallic uranium for 48 hours at 5 MW would produce sufficient product to satisfy the demand.

Mr. Syarip (Indonesia) discussed a root cause analysis of the bulging in the pool liner of the Kartini reactor. The probable root cause was determined to leakage of water behind the aluminium pool liner leading to saturation of the concrete and corrosion of the steel reinforcing rods. Every effort should be made to ensure that the area behind the pool liner remains dry. Any seepage of pool water could lead to the swelling of pool liners and corrosion on metal components. The quality of concrete should be carefully monitored during construction. It is important to undertake periodic inspections of pool liner and concrete for early detection of any potential water seepage. For the Kartini reactor, it is concluded that the bulging issue is one of maintenance, not safety.

Mr. Pesic (Serbia) discussed preparations for repackaging and shipment of spent fuel in cooperation with the Russian Federation and the IAEA. A number of fuel preparatory activities, infrastructure modifications and system upgrades at the RA reactor building and Vinca site are needed.

Mr. Perets (Israel) discussed a new ultrasonic NDE system for detection of thickness variations, corrosion and other flaws in an aluminum research reactor tank without removal of the vessel top cover. Operation of the newly developed system was tested on a full-scale mock-up and approved.

Mr. Foulon (France) presented the utilization of the ULYSSE and ISIS reactors for education, training and professional qualification of personnel. As a large proportion of experienced engineers are due to retire in the next 10 years, it is essential to train junior engineers for operational positions and to take up key positions in research reactor organizations. Training of engineers should be given priority and there is a need to identify the reactors having training facilities such as simulators. Training in theory and on simulators is complemented by experimental work on a research reactor to provide insight into reactor physics and ensure a practical and comprehensive understanding of safe reactor operation.

In addition to the above six papers, a presentation (in session 5) by Mr. Khalil (Egypt) focused on the comparison of methods used (relative, absolute and K0-IAEA) to determine the value of the budget uncertainty and sensibility of the INAA laboratory measurements. Concentrations of 9 elements (Ca, Co, Cr, Cs, Fe, K, Mn, Na and Rb) were measured against a certified test sample. The results of this work gave an uncertainty, which ranged from 2-11% for the relative standardization method, 3-15% for the K0-IAEA standardization method and 6-27% for the absolute standardization method.

Session 12: New Research Reactor Projects

Three papers were presented in this session, two of which dealt with construction, commissioning and licensing of the OPAL reactor. In the first paper, Mr. Irwin (ANSTO-Australia) presented a summary of the commissioning process for OPAL, a success story. Commissioning of a new research reactor is now a rare event and ANSTO and INVAP have made a major accomplishment. Some of the key points leading to successful commissioning include:

- A strong commissioning organization, following IAEA guidelines;
- Early staffing and training efforts;
- A strong relationship between the designer and customer.

The commissioning stages followed the IAEA Safety Guide, which was acknowledged to have been helpful in the commissioning process. Extensive testing procedures were performed during each stage. There were few technical problems encountered. A few licensing issues arose, which were resolved without undue delay (see below). The key lesson learned is that effective coordination of all parties, customer, designer and regulator, is essential to a successful new reactor project. (A problem that has recently appeared is upwards displacement of some fuel plates in their fuel assemblies, apparently under hydraulic forces, due to inadequate swaging of the fuel plates into the side plates of the fuel elements. This problem is under investigation.)

In a second paper, Mr. Summerfield (ANSTO-Australia) reviewed the licensing issues and resolution of OPAL during construction and commissioning. During construction, discovery of a geological fault during site excavations led to a 4 month delay. Other issues included excessive concrete cracking in the reactor building basement, and unauthorized work on heavy water penetration cut-out and repairs to the reactor pool liner. These issues were resolved. Issues arising during commissioning included: unanticipated regulatory hold points; problems with core outlet temperature measurements; and high activity in the primary coolant. These problems were resolved without undue delay. Key factors in an effective and efficient licensing process included:

- Well organized and clear submissions and approval process;
- A single working-level point-of-contact;
- Frequent, periodic meeting for open communication;
- Involvement of top and middle management in the licensing process;
- Coordination between regulatory bodies to ensure clarity as to who approves what.

The third paper was given by Mr. Konoplev (PNPI-Russia), who discussed the status of construction of the PIK reactor at Gatchina. This reactor is scheduled for completion in 2012 and is funded by the Russian government. His key points were:

- Russia is currently deficient in neutron beam research facilities and there is a great need for the PIK reactor;
- The design is state-of-the-art, and is very flexible;
- PNPI plans to commission PIK and become an international centre for neutron beam research.

<u>Utilization Posters</u>

There were 16 posters presented on utilization of research reactors, some of which covered utilization of individual facilities, and some of which discussed specific applications. Two posters from Brazil discussed use of the IPEN reactor for radiography using a sensitive digital system and for structural investigations using a new powder diffractometer. A poster from Italy discussed an improved collimator for radiography, while two papers from Romania discussed specific techniques for stress determination and a small angle neutron scattering facility. Three posters from Korea discussed utilization of irradiation holes, a fuel testing loop and design of a new cold neutron source at HANARO. Posters from the Czech Republic discussed materials research at their 10 MW reactor and the training programme at their low-flux reactor.

Posters on medical applications included discussion of boron neutron capture therapy in Finland, and a feasibility study of 125I radiotherapy in Indonesia. Posters from Bangladesh provided details of their operational experience with the TRIGA reactor, including isotope production, neutron activation analysis of environmental pollutants such as arsenic and chromium, and research and training activities. A poster from Bulgaria discussed possible use of their reactor now under reconstruction for training and radiological characterization work. A poster from Thailand discussed their training programme in nuclear engineering.

Fuel Cycle Sessions

Session 9: Decommissioning and Waste Management

Three papers were presented in this session. Mr. Dinner (IAEA) described the new International Decommissioning Network (IDN) initiative, Mr. Rowling (ANSTO-Australia) gave an overview of the status of research reactor decommissioning with emphasis on decommissioning of the HIFAR reactor. Mr. Pesic (Serbia) described the process of removal of steel structures from the spent fuel storage pool of the RA reactor at Vinca.

Mr. Dinner described the vision and expectations of the newly-launched IDN: to provided prompt, open and efficient worldwide sharing of practical decommissioning experience leading to safe, economic and timely dismantlement of disused nuclear facilities. This initiative was received with great interest by the audience and was considered to be very important in promoting decommissioning. It is recommended that the Agency strengthen its efforts to facilitate sharing of practical, hands-on decommissioning information among practitioners.

Mr. Rowling emphasized key issues pertaining to the transition to decommissioning: staffing the decommissioning team, maintaining a strong safety culture and ensuring knowledge retention. Decommissioning activities should be seen as an important opportunity to train staff for new facilities throughout the industry in the required safety culture. He pointed out that the risk profile of a facility changes in the transition from an emphasis on reactor safety and radiation protection to an emphasis on industrial safety concerns.

Mr. Pesic described decommissioning work in the spent fuel pool at the RA reactor which emphasized the importance of understanding how potentially corrosive conditions in the pool water can evolve, and illustrated the role that mock-ups can play in planning difficult remediation activities. His presentation demonstrated how difficult and dangerous the dismantling process could be if decommissioning activities are not carried out in a timely manner.

Session 11: Programmes for Minimization of the Use of HEU

In the first paper in this session, Ms. Dickerson (DOE/NNSA-USA) reviewed the accomplishments and plans for removing and disposing of civilian high-enriched uranium under the Global Threat Reduction Initiative (GTRI). She reported that the programme is making good progress in returning U.S - and Russian-origin fresh and spent HEU research reactor fuel to the country of origin. There has also been important progress in disposition of high-risk, vulnerable nuclear material not covered by other removal efforts (‘gap material’). Advanced planning and preparations have been made to deal with emerging threats, including provisions for in-country stabilization, packaging and removal of material by rapid response teams in independent, self-sufficient operations.

Mr. Roglans (ANL-USA) provided an overview and status report on the Reduced Enrichment Research and Test Reactor (RERTR) programme. This programme has expanded and accelerated

under the GTRI, and is now expecting to maintain a rate of 6 reactor conversions per year. The current scope of the programme is 129 reactors, of which 55 have been converted or were shutdown before conversion, 46 are planned for conversion with existing LEU fuels, and 28 are planned to be converted with new LEU fuels. The scope of the programme includes conversion analysis, fuel development and procurement and development of 99Mo targets and processes. The programme has developed a successful approach to establishing feasibility of conversion and supporting licensing of converted reactors. It relies on close collaboration with multiple organizations, including reactor operating organizations and regulators. IAEA support is important, in particular for conversion of specific facilities and multi-national coordinated projects (i.e., conversion of the MNSRs in several countries), development and documentation of fuel qualification, development of LEU-based 99Mo production and material return programmes.
Encouraging progress in development of high-density fuels for research reactors was reported by Mr. Lemoine (CEA-France) and Mr. Wachs (INL-USA). A high-density fuel is essential to conversion of high-power-density reactors; the developers are now confident that U-Mo fuel will be capable of meeting the high-density fuel performance objectives. For both dispersion and monolithic U-Mo fuels, promising solutions to problems observed in irradiation testing in the early stages of development have been devised. A target of 2011 for qualification of the first U-Mo fuel is probably ambitious, but considerable international effort is being applied to meet this goal.

Finally, Mr. Harbitz (Norway) presented a global perspective on HEU reduction. Over the thirty year period 1978-2007, he reported a net reduction of 130 research reactors using HEU fuel, and a net reduction of 598 kg/yr in HEU consumption. All 22 HEU-fuelled reactors outside of the U.S., Russia and France are currently part of the international HEU minimization programmes. He suggested that only a small number of the existing 130 HEU-fuelled research reactor still in operation should be converted. Rather, a large number of these should be decommissioned with provisions for assisting the operator and the country with the decommissioning process. Access to similar research facilities elsewhere should be established through regional cooperation. He noted that 68 of the operational HEU-fuelled reactors are critical assemblies or pulsed reactors, which have little or no fuel consumption, but may have a significant fuel inventory. Removal of this fuel should receive appropriate attention. He concluded that a final phase-out of HEU fuel in research reactors may not be achieved before the end of the next decade.

Fuel Cycle Posters

Poster presentations covered topics related to fuels, waste management and decommissioning. One paper discussed the conversion of the HIFAR reactor (Australia) to LEU fuel. Spent fuel regulation in Australia was covered, as were studies of spent fuel corrosion, construction of a new decay pool at the IAN-R1 reactor (Columbia) and preparation for shipment of spent fuel from the Vinca site (Serbia). Two papers were presented on gamma assay of low-level radioactive waste drums. A report on the International Project on Evaluation and Demonstration of Safety during Decommissioning of Nuclear Facilities (DeSa) was presented.

Session 13: Panel Discussion

The final technical session of the Conference was a panel discussion on the main issues and trends in safety management and utilization of research reactors. Panel members included Ms. Keen (Canada), Mr. Harbitz (Norway), Mr. Repussard (France), Ms. Dela Rosa (Philippines), Mr. Rowling (Australia), Mr. Saxena (Brazil), Mr. Snelgrove (USA) and Mr. Yuldashev (Uzbekistan). Chair of the session was Mr. Loy (Australia).

Participants were invited to submit questions and suggest topics for discussion by the panel. The chair organized the suggestions into five topics:

- The Code of Conduct on the Safety of Research Reactors;
- International and Regional Cooperation and the IAEA;

- Issues in Safe Management and Utilization of Research Reactors;
- The Future; and
- The Next Conference.

The Code of Conduct on the Safety of Research Reactors

Mr. Harbitz started the discussion with comments on the question of how to ensure the quality and capability of the regulator. Implementation of the recommendations in the Code is a good place to start. The regulator can do a self-assessment unilaterally, and can also ask for external evaluation. In Norway, an INSARR mission conducted in June 2007 evaluated not only the Halden facility and operating organization, but also the regulatory body. This mission was very important to the regulator and corrective measures are being implemented. In the future, joint INSARR and IRRS missions could be extremely important.

Mr. Harbitz also commented that he is pleased at the Agency's follow-up on the recommendations of the December 2005 Open-ended Meeting to hold periodic meetings to exchange experience and lessons learned, and to identify good practices. This Conference is a good example, and the regional meetings on application of the Code of Conduct are also of great importance. Both operators and regulators are looking forward to the international follow-up meeting in 2008.

The question of whether the Code should cover physical protection was raised. The current Code excludes physical protection on the basis that it is covered in the Convention on Physical Protection and to include it in the Code would be redundant. The general view was that the Code need not be modified, but that physical protection and security in general may be discussed in meetings and should be included in missions.

Topics suggested for consideration in any revision of the Code included: recommendations for a management system, minimum required safety documentation, and delegation of responsibility and accountability. However, there was no call to revise the Code at this time.

International and Regional Cooperation and the IAEA

There was broad support on the panel for regional and international cooperation among research reactor operators and regulators. Ms. Dela Rosa and Mr. Rowling mentioned that regional cooperation in Asia is improving. For example, the Philippines get 99Mo targets from Indonesia and process them internally. ANSTO would like to expand regional cooperation and partner in research reactor safety, utilization and other issues. Mr. Repussard noted that a regional approach can maintain reactors in the face of economic difficulty. There remains a need for research reactors in many applications, including training and support for design and innovation. Mr. Harbitz suggested that the Halden experience would be valuable in organizing regional cooperation.

Mr. Yuldashev suggested that regional competition should be avoided and that a database of capabilities would facilitate regional cooperation. Mr. Saxena noted that sharing is an important factor. No single institution can do everything. Regional centres of excellence and regional resource sharing are needed. Mr. Snelgrove noted that tensions between cooperation and commercial interests must be addressed. In the RERTR programme, this was done early, and it has not been a problem.
Finally, the need to harmonize national application of international transport regulations was raised. This is an important issue for movement of research reactor products in international commerce.

Safe Management and Effective Utilization

This discussion focused on safety culture. Mr. Rowling discussed significant improvement of the safety culture at the HIFAR reactor during the two years preceding decommissioning. He noted that development of safety culture is a difficult and expensive process. He suggested that safety

performance indicators should be developed. Mr. Repussard suggested that transparency in the organization is essential to developing good safety culture; it is a good investment.

Mr. Harbitz pointed out that an INSARR (or combined INSARR and IRRS) mission can be very helpful and that good advice to both operator and regulator is available. There was also a general discussion of the value of information exchange on funding and organization of utilization programmes.

The Future

The theme of this discussion was that there is a future in research reactors and that the community should prepare for it. It was suggested that there must be a change in management thinking to more emphasis on renewal.

Mr. Yuldashev suggested that the IAEA organize a meeting, probably in 2009, to discuss the future of research reactors. Topics for discussion could include demand for research reactors services and products in various regions, use of research reactors in furthering the development of nuclear technology, designs for new research reactors, training of new experts in nuclear technology, etc., and a path forward for organizing regional cooperation and centres of excellence.

Mr. Rowling commented that research reactors must meet the demands of the users, and the outlook for user demands is not clear. There is no use providing unneeded capabilities. Any discussion of the future of research reactors should involve the user community.

Mr. Yuldashev also called for a more active programme of education and training on research reactors for new people, with training courses of 3-4 weeks duration aimed at conveying deep knowledge, not just broad overview information. He also suggested an annual IAEA school for young people of several weeks duration, with a different topic being emphasized each year on a rotating basis.

Mr. Saxena also expressed concern about staff aging and the need to involve students and inform them about the capabilities of research reactors in their fields of interest. He recommended that the IAEA prepare an audio-visual presentation with an introduction to research reactors and their utilization in different areas of science and technology, addressing safety issues and other aspects of safety and security. This audio-visual presentation would be distributed to research reactors in different countries to be shown to the many students that visit these reactors.

Another issue for the future of many research reactors is core conversion to LEU fuel. Mr. Harbitz renewed his call for the Agency to encourage an accelerated HEU minimization programme and play a more pronounced role in minimization. Mr. Snelgrove recommended that the IAEA consider convening a workshop of research reactor regulators to discuss the properties of new research reactor fuels relative to licensing, as reflected in the soon-to-be-published document on good practices for qualification of research reactor fuels.

The Next Conference

The focus of this discussion was on the next quadrennial international conference on research reactors.

Mr. Repussard suggested that there should be more emphasis on engaging young people in the conference, and shaping the sessions and discussion around good examples and good practices.

A suggestion that the next conference be structured with working groups and particular topics and few plenary sessions did not receive much support.

Another participant suggested (in writing) that, given the use of four projection screens in the current conference, that electronic transmission via the Internet might be used to broadcast the sessions of a future conference to Member States around the world. This proposal was not discussed.

Session 14: Conclusions and Recommendations

Mr. Deitrich (USA), Principal Rapporteur of the Conference, presented the recommendations of the Conference to the IAEA. These recommendations are found at the beginning of this report. Comments from the floor on the draft are incorporated into the final version presented above.

The Conference was closed by Mr. Philippe Jamet, Director of the Division of Nuclear Installation Safety. Mr. Jamet expressed the Agency's thanks to the Government of Australia and to ARPANSA for the excellent organization and success of the Conference. He also highlighted the great value of the results of the Conference to enhance the safety and the effective utilization of research reactors worldwide.