Topical Issues Paper No. 4

SAFETY OF RESEARCH REACTORS

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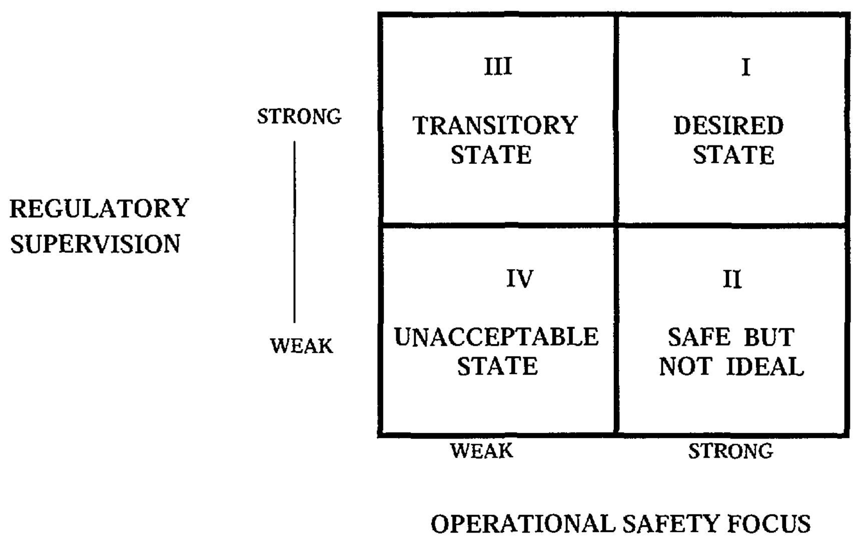
1. RATIONALE

The number of research reactors that have been constructed worldwide for civilian applications is about 651. Of the reactors constructed, 284 are currently in operation, 258 are shut down and 109 have been decommissioned. More than half of all operating research reactors worldwide are over thirty years old. During this long period of time national priorities have changed. Facility ageing, if not properly managed, has a natural degrading effect. Many research reactors face concerns with obsolescence of equipment, lack of experimental programmes, lack of funding for operation and maintenance and loss of expertise through ageing and retirement of the staff. Other reactors of the same vintage maintain effective ageing management programmes, conduct active research programmes, develop and retain high calibre personnel and make important contributions to society.

Many countries that operate research reactors neither operate nor plan to operate power reactors. In most of these countries there is a tendency not to create a formal regulatory body. A safety committee, not always independent from the operating organization, may be responsible for regulatory oversight. Even in countries with nuclear power plants, a regulatory regime differing from the one used for the power plants may exist. In some countries there is a lack of human resources and expertise for the regulatory body, in comparison with the operating organization, which leads to a lack of efficiency and credibility of the regulatory body. Again, by contrast, some countries have very effective regulatory supervision programmes in place for research reactors.

Concern is therefore focused on one tail of a continuous spectrum of operational performance. The challenge is to implement improvements where needed without undue adverse impact on well managed operations. Pictorially, the population of research reactors might be characterized as a combination of their operational safety focus and regulatory supervision, as shown below. The desired state is



one of a strong operational safety focus monitored by strong regulatory supervision (Zone I). A strong operational safety focus but weak regulatory supervision (Zone II) is not ideal but may be adequate, at least until put to the test. Strong regulatory supervision with a weak operational safety focus (Zone III) is a transient state; the regulator will either insist on improving the facility's operational safety focus or shut it down. Facilities with a weak operational safety focus *and* weak regulatory supervision (Zone IV) are the real concern. Unfortunately, certain processes move in that direction. The operator's acceptance of unabated ageing of equipment, loss of staff expertise and underfunding constitutes a shift to the left; the regulator's condoning and acceptance of the same constitutes a shift down; and the combination is a shift of *some* research reactors into the unacceptable zone.

The 258 research reactors that are no longer operating are in some form of shutdown (hereinafter termed 'extended shutdown'). Some of these are expected to restart sometime in the future, some are awaiting decommissioning with or without nuclear fuel in the facility and for the remaining reactors there is no clear definition about their future. All these situations present concerns related to safety, and the most frequent concerns are related to the loss of corporate memory, personnel qualification, maintenance of components and systems and the preparation and maintenance of documentation.

Many reactors face concerns with funding for operation; generally funding of an appropriate utilization programme is then even more restricted. Frequently the utilization programme shifts from a science based to a profit based programme and in some cases safety may not remain a top priority.

The number of operating research reactors in industrialized countries has decreased by about one-third in the last 15 years, while the number in developing countries has remained fairly constant over that period. As a result, the proportion of operating reactors in developing countries is steadily increasing while the funding available for operation and utilization in these countries is steadily decreasing.

The IAEA has been sending missions to review the safety of research reactors in Member States since 1972. Some of the reviews have been conducted pursuant to the IAEA's functions and responsibilities regarding research reactors that are operated within the framework of Project and Supply Agreements between Member States and the IAEA. Other reviews have been conducted upon request. All these reviews are conducted following procedures for Integrated Safety Assessment of Research Reactors (INSARR) missions. The prime objective of these missions has been to conduct a comprehensive operational safety review of the research reactor facility and to verify compliance with the IAEA's Safety Standards. The methods used during an INSARR mission are discussed in Ref. [1] and the results of many INSARR missions have been collected and analysed in Ref. [2]. Some of the important issues identified are the following:

- General ageing of the facility;
- Uncertain status of many research reactors (in extended shutdown);
- Indefinite deferral of return to operation or decommissioning;

- Inadequate regulatory supervision;
- Insufficient systematic (periodic) reassessment of safety;
- Lack of quality assurance (QA) programmes;
- Lack of an international safety convention or arrangement;
- Lack of financial support for safety measures (e.g. safety reassessment, safety upgrading, decommissioning) and utilization;
- Lack of clear utilization programmes;
- Inadequate emergency preparedness;
- Inadequate safety documentation (e.g. safety analysis report, operating rules and procedures, emergency plan);
- Inadequate funding of shutdown reactors;
- Weak safety culture;
- Loss of expertise and corporate memory;
- Loss of information concerning radioactive materials contained in retired experimental devices stored in the facility indefinitely,;
- Obsolescence of equipment and lack of spare parts;
- Inadequate training and qualifications of regulators and operators;
- Safety implications of new fuel types.

These issues have been addressed by the IAEA Secretariat and the chairman of the International Nuclear Safety Advisory Group (INSAG). The INSAG chairman reported to the Director General "...that in spite of the prompt reaction of the Secretariat ..., the problem remains very serious... INSAG has identified three major safety issues that are:

- The increasing age of research reactors,
- The number of research reactors that are not operating anymore but have not been decommissioned, and
- The number of research reactors in countries that do not have appropriate regulatory authorities." [3]

In addition, INSAG has expressed concern with "...the level of safety culture surrounding these reactors. ...INSAG considers that adding a Protocol to the Convention on Nuclear Safety to cover research reactors would be a major contribution towards a better, international safety framework for these reactors."

The IAEA's General Conference subsequently passed Resolution GC(44)/RES/14 [4], which:

"1. <u>Calls upon</u> all Member States with research reactors to ensure that those reactors are subjected to strict safety and radiation protection arrangements;

2. <u>Invites</u> the Board of Governors and the Director General of the IAEA to continue to maintain its emphasis on the safety of research reactors, particularly in assisting Member States to implement relevant Safety Standards;

3. Requests the Secretariat to continue to monitor closely research reactors subject to IAEA Project and Supply Agreements, and to assist relevant Member States in fulfilling all relevant safety obligations;

4. Requests the Secretariat, within its available resources, to continue work on exploring options to strengthen the international nuclear safety arrangements for civil research reactors, taking due account of input from INSAG and the views of other relevant bodies; and

5. Requests the Director General to report to it at its forty-fifth (2001) regular session on the implementation of this resolution."

This issue paper discusses the concerns generated by an analysis of the results of INSARR missions and those expressed by INSAG. The topic is timely and important because a large number of research reactors currently face not only these concerns but also the problem of spent fuel disposal following completion of the current US take-back programme, and the Russian take-back programme which is expected to commence in the near future. Many countries will need to make decisions soon concerning the future of their reactors to take advantage of these spent fuel options.

2. STATUS OF THE TOPICAL ISSUE

Research reactor safety is gaining importance within the general scope of nuclear installation safety worldwide. Generally, all nuclear reactors that do not generate commercially used electricity are considered to be research reactors. This results in a large variety of designs, a wide range of power levels, a wide range of utilization programmes with a broad range of benefits to humanity (e.g. research, training, medical isotope production or commercial services) and different modes of operation for research reactors. Again, the safety concern for research reactors is primarily that subset characterized in the previous section; there are many well operated and maintained research reactors outside the subset of major concern.

2.1. SAFETY OBJECTIVES FOR RESEARCH REACTORS

Despite the differences between research reactors and power reactors, the safety objective is common [5]. However, these differences require flexibility in the implementation of the requirements to achieve the safety objective in research reactor facilities.

The general nuclear safety objective stated in Ref. [5] is "To protect individuals, society and the environment from harm by establishing and maintaining in nuclear installations effective defences against radiological hazards." This objective for the safe operation of research reactors is expanded in Refs [6, 7]. While Member States may express this objective differently, there is general agreement on the concept.

A justification principle was applied before construction and operation of the reactors currently in existence; that is, each facility had a utilization programme that justified the commitment of resources. That principle should continue to be applied to newly planned and constructed reactors. For reactors that are in extended shutdown with no plans for ultimate restart, this principle is clearly not met.

The radiation protection objective [5–7] relies on accident mitigation resulting from design measures (e.g. engineered safety features) incorporated into the reactor and in the appropriate emergency plans. As demonstrated by INSARR missions, there are some deficiencies in these areas at some research reactors.

2.2. REQUIREMENTS TO MEET SAFETY OBJECTIVES

In order to achieve these objectives, a number of safety requirements and recommendations have been considered by Member States at the national level and by the IAEA at the international level.

2.2.1. Member States

Many Member States, especially those having nuclear power programmes, have produced laws, regulations, standards and guides for the safe operation of research reactors. In addition, in these States, with a few exceptions, an independent regulatory body administers the regulations and ensures the control of safety at nuclear installations. However, even in Member States with nuclear power programmes the regulation of research reactors is not always thorough and independent.

Some Member States have incorporated the IAEA standards and guidance discussed below into their national regulations. On occasion over the past decade, the IAEA Safety Standards have been incorporated into the contractual requirements of suppliers of new research reactors.

Not all developing Member States have detailed regulations based on legislation. In addition, in developing Member States without nuclear power plants an independent regulatory body may not exist. In these cases a safety committee, independent of the operating organization, may provide the regulatory oversight for the research reactor.

2.2.2. International organizations

The IAEA has produced safety requirements, recommendations and guidance [6–9]. These documents provide worldwide consensus on the topics covered, since international committees prepare them and resolve comments from Member States. These documents are designed to address all safety aspects of research reactor design, operation, utilization and decommissioning. They include, inter alia, items of concern for the IAEA Secretariat, INSAG and the IAEA's General Conference such as regulatory supervision, operation by suitably qualified and experienced persons, safety analysis, utilization, emergency planning, safety culture, quality assurance and decommissioning. As new areas of concern have emerged (e.g. decommissioning, regulatory oversight, quality assurance, safety culture), the IAEA has produced additional consensus documents on these subjects which are applicable to research reactors. As new material is developed that will eventually be incorporated into formal IAEA documents it is made available in draft form; examples of this are recommendations concerning aspects of reactor operation including commissioning, operational limits and conditions, maintenance, operating procedures, and source term and radiological consequence analysis.

There is general agreement worldwide on these requirements and recommendations for safe operation. However, a wide disparity exists in their application to operating and shut down reactors.

The IAEA has continued to provide safety missions to industrialized and developing Member States to review application of its standards and guides to individual reactor facilities. These safety missions have been performed at the request of the operating organization or the regulatory body of the Member State. The mission may consist of a full scope INSARR review of the reactor design and operation against the requirements and recommendations of the IAEA documents. Alternately, it may be restricted to the review of a specific topic such the Safety Analysis Report or one or more of its chapters. In addition, the Agency provides technical assistance to Member States through expert missions on a variety of safety related topics.

Recently, the IAEA has put into operation an Incident Reporting System for Research Reactors (IRSRR). The system is modelled after a similar reporting system for nuclear power plants. Although not all Member States have agreed to participate in IRSRR, incident reports are being collected and distributed, and meetings were held in 1999 and 2000. Efforts are under way to increase the number of participating countries and to ensure that all events with lessons for safety are reported.

3. PROBLEMS IDENTIFIED, ISSUES TO BE RESOLVED

The following is a detailed discussion of the problems and issues identified in Sections 1 and 2 for the subset of research reactors as characterized there. Specific actions for the resolution of the issues are recommended in Section 4. Because the problems and issues identified are interrelated, they may be classified according to the five groups discussed below.

3.1. AGEING FACILITIES

Ageing is defined as a general process in which the characteristics of components, systems and structures gradually change with time or use. If unabated, the ageing process eventually leads to degradation of materials under normal service conditions. These include normal operation and transient conditions under which the component, system or structure is required to operate. Changes in characteristics because of accident and post-accident conditions are not usually considered part of the ageing process and are evaluated on a case by case basis. Physical and non-physical effects can bring about ageing.

Research reactors were generally not designed, constructed and operated for a specific lifetime. If proper preventive and corrective maintenance is performed and obsolete equipment replaced, the reactor facility may operate safely and efficiently for an extended period of time. Maintenance is not a priority in many regions where research reactors are located. A facility in such a culture may be heavily impacted by ageing, whereas the same facility in a different country may not.

In research reactor facilities, the effects of physical ageing such as corrosion may be degradation, which results in the reduction or loss of the ability of components, systems and structures to function within the expected criteria. Typically, the ageing process may reduce the reliability of components, structures and systems. It may reduce the defence in depth and affect the safety of the facility unless preventive and corrective measures have been implemented.

3.1.1. Lack of ageing management

The degradation through ageing is counteracted through a programme of ageing management for appropriately selected components and systems that usually consists of four stages.

(a) The use of a methodology, usually surveillance and in-service testing, that will detect degradation early enough to prevent failure;
(b) The collection of data;
(c) The evaluation of data to determine the extent of degradation;
(d) Corrective actions, usually maintenance, to correct deficiencies;

In some cases, physical and non-physical ageing effects have become so prevalent that it is impractical to correct them individually. This may lead to complete refurbishment of the reactor facility. This is, of course, an expensive process and lack of financial support and a heavy utilization programme are impediments to refurbishment.

3.1.2. Obsolescence and lack of spare parts

During the lifetime of a research reactor, technological advances will occur resulting in the introduction of new components and techniques. This may lead to difficulties in getting spare parts because the component or system is no longer manufactured. In such cases, failure in the obsolescent component can only be remedied by replacement of the entire system.

3.2. DEFICIENCIES IN REGULATORY SUPERVISION

A number of research reactors operate in countries that do not have appropriate regulatory authorities and, therefore, have poor regulatory oversight for both operating and shutdown reactors. To have effective regulatory supervision, an adequate infrastructure should be developed which is made up of several components. Inadequacy in any one of them may seriously affect the usefulness of the regulatory regime.

3.2.1. Deficiencies in regulatory infrastructure

A legal framework that defines the subjects covered by the law (or regulation), that appoints the regulatory body and that spells out its responsibilities and authorities is required to ensure that the regulatory body will have the power to exercise its duties and enforce compliance with its decisions.

The regulatory body that is set up under the provisions of the appropriate law must have sufficient staff to carry out its functions, a sufficient budget to maintain this staff on a continuous basis, and the ability to solicit external help when necessary. The regulatory body should be effectively independent from the organizations and activities it regulates. Of even greater concern, some countries have no regulatory body at all.

3.2.2. Lack of experience and competence

Often regulatory bodies are inadequately staffed so that they cannot perform periodic compliance inspections and safety reassessments at research reactors. Independent expertise is often not available locally and difficult to obtain internationally. In some cases the regulatory body is not separated at all from the operating organization.

It is clear that the regulatory authority should possess adequate knowledge and experience in matters, both legal and technical, under its jurisdiction. Regulatory bodies in some countries with medium or small reactor programmes or with no nuclear power programme find it extremely difficult to maintain competence and experience in the full range of expertise needed to fulfil regulatory responsibilities. In some countries a newly created or a reconstituted regulatory body has difficulty in establishing its authority over a reactor that has operated for many years without regulatory oversight.

3.3. RESEARCH REACTORS IN EXTENDED SHUTDOWN

A large number of research reactors are in a period of extended shutdown awaiting decisions on their future. There can be many reasons for this extended shutdown such as lack of funds for operation or utilization, lack of scientific utilization and interest, need for a large investment to provide necessary refurbishment, national political uncertainties, uncertainties in the disposition of the irradiated spent fuel, obsolescence of the facility and lack of funds for decommissioning. Often the decision making authority to restart or decommission is out of the hands of the operating organization and rests with higher levels of government.

3.3.1. Indefinite deferral of return to operation or decommissioning

If not maintained, the safety of a reactor in extended shutdown will deteriorate. Therefore, the reactor must be maintained in accordance with the operational limits and conditions of the operating license, often amended to reflect the shutdown condition of the reactor. In several cases the ownership and responsibilities for the shut down reactor have not been well established. Members of the operating staff seek other employment and there can be gross evasion of responsibility and loss of knowledge concerning the facility. This can lead to the deterioration of reactor systems and equipment, a loss of safety culture and a consequent decrease in the level of safety.

Two thirds of the reactors that no longer operate have not been decommissioned. The most common reasons for not decommissioning a reactor that is in extended shutdown are the hope that the reactor will be returned to operation and the presumed high costs of alternatives. Research reactors should not be allowed to remain in extended shutdown for a very long period of time. As soon as possible, the operating organization should prepare a long term strategic plan which shows the pros and cons of the options available for the reactor, including decommissioning.

The cost for returning to operation or for decommissioning can be substantial. In some cases research reactors are not restarted after a long period of extended shutdown because of the costs to refurbish and the obsolescence of the reactor and experimental equipment. Experience has also shown that these reactors are rarely decommissioned promptly because of the perceived high cost for decommissioning, which have often been over-estimated. As more and more reactors are decommissioned, the true costs will become evident. It should be noted that Agency funds have not been provided for decommissioning.

The technology for decommissioning research reactors is well established, as demonstrated in Ref. [10]. The first step in the decommissioning process is the removal of nuclear fuel from the facility. This is often a problem for the operating organization because there is no facility to receive the fuel. If the fuel must remain at the reactor facility after shutdown and decommissioning, provision must be made for its safe storage. Facilities considering removal of nuclear fuel are well advised to do so when the opportunity exists. Until May 2009, the USA is accepting spent research reactor fuel of US origin that has not been irradiated beyond May 2006. The Russian Federation is expected to initiate a similar programme in the near future.

3.4. INADEQUACIES IN THE OPERATING ORGANIZATION MANAGEMENT

Among the issues which require attention relating to the operation of research reactors are those associated with responsibilities in management, (staffing, training and retraining, quality assurance, safety culture), long term planning, safety review of operation through self and peer reviews, emergency planning and safety of experiments.

3.4.1. Loss of expertise and corporate memory

Responsibility in management requires that there is sufficient staff with appropriate levels of education and training to ensure safety. Knowledgeable personnel are retiring at many research reactors. In addition, experienced personnel at research reactors often seek more attractive employment elsewhere. This results in a loss of expertise and corporate memory. Compounding this is the difficulty in recruiting knowledgeable and experienced replacement personnel because of the decreased number of students in the field and the competition among facilities for competent individuals. Funding to cover the overlap between outgoing and incoming personnel is rarely available.

While most facilities provide adequate initial training for their staff, retraining (continuous training or re-qualification) is not widely utilized to maintain efficiency and effectiveness.

3.5.2. Inadequate QA programmes and safety culture

While most research reactors incorporate some aspects of quality control in their operation, few low and intermediate power level reactors incorporate a complete QA programme based on national or international guidelines. Recognition of the need for a QA programme for these reactors is a recent development at most reactors. Reactor managers need to be shown that a QA programme graded to the needs of the facility will be an effective and time saving management tool. They also need to recognize that safety must be 'grown' into an organization and not be seen as a product of regulatory compliance.

One concern affecting all safety issues is the level of safety culture surrounding a research reactor. In many cases, the concept of 'safety culture' is new and perceived as being qualitative because of the difficulties in defining the concept and demonstrating its existence. Operating organizations often have not taken advantage of the guidance literature on the subject. The lack of properly trained staff, the loss of institutional memory through staff attrition and inadequate regulatory supervision are all human factors that contribute to a lack of safety culture and therefore safety.

3.4.3. Insufficient financial support

The lack of financial support is the greatest problem facing research reactors. In the past, a budget was often provided by a governmental agency. Presently, many of these same facilities are required to generate income to support their programmes, even though the facility staff lacks experience on techniques to generate income, the facility cannot provide profitable services or there is a very limited possibility of contacting commercial companies. Except for operating budgets, strategic utilization plans that match and promote resources with the needs of the user community have not been extensively utilized by operating organizations.

3.4.4. Inadequate emergency preparedness

In some research reactors, especially with intermediate power levels, emergency plans and preparedness are inadequate. Procedures are not well demonstrated because drills and exercises are seldom conducted.

3.4.5. Lack of strategic long term planning

Strategic long term planning in the management of the reactor is inadequate at many research reactors and may jeopardize its safety. Such planning has become essential, especially at those reactors that are now required to generate some of the funds for operation. These funds can only come from utilization. Lacking these funds there will be a shortfall in the available operating budget.

Most reactors constructed in the past were considered multi-purpose reactors in that they would support utilization programmes in many technical disciplines. From a practical point of view, however, an individual reactor facility cannot usually support programmes in all areas. To generate income it is therefore necessary for the facility to specialize in areas where there is a need and where the facility has appropriate technical and human resources. The generation of a strategic, long term plan matching the needs of the experimental community, the capabilities of the reactor and the financial resources available has become indispensable for the successful operation of a reactor.

Even if the reactor management cannot meet the quota for its portion of the operating budget, the safety of the reactor cannot be allowed to deteriorate. In this case the operating organization must provide the funding for maintaining the safety of the reactor.

3.4.6. Lack of systematic reassessment of safety

The existence of up to date safety documentation (Safety Analysis Report) is important to ensure that all safety issues at a reactor have been considered. Recently, through the efforts of Member States and the IAEA, some research reactors have produced or are in the process of producing a current Safety Analysis Report. These reports consider changes in the reactor site, new operating modes, new forms of utilization, modifications and the use of new fuels. Many research reactors still have outdated, superficial or incomplete Safety Analysis Reports that should be improved.

Reassessment of safety has traditionally occurred at research reactors at the time of major upgrades, modifications, installation of safety significant new experimental facilities and at license expiration and renewal. Reassessments of safety have recently accompanied the back-fit preparation of a new Safety Analysis Report at many facilities. Absent these motivations, however, there has been little inclination at research reactors to periodically reassess safety. In the meantime, the configuration of the reactor may have changed significantly through a long series of individually minor changes.

An area of reassessment needing special attention is the siting of existing reactors. In many cases, the land use and other siting factors around the reactor facility have dramatically changed, requiring that the suitability of the site be reassessed against the current configuration and operational mode of the reactor. One important issue for the safety of old operating research reactors is the difficulty of verifying the facility's resistance against earthquakes, especially if the seismic spectra has been updated and the accelerations increased due to improved knowledge of the site characteristics. This difficulty is due mainly to the uncertainties concerning the mechanical resistance of the old buildings and to the lack of knowledge concerning the eventual corrosion of the iron reinforcement inside the concrete. It is very important to reach an international consensus and to adopt a clear and justified approach on this subject. Such an approach may be based on the inventory of radioactive materials, on the duration of the reactor operation and on the various risks associated with the facility. In the future, a probabilistic safety analysis may be expected in the Safety Analysis Report of a research reactor, but the state of the art does not support it as being a requirement at this time.

Peer review is an area of co-operation being promoted by the IAEA that has not reached its full potential. A peer review may take many forms. Such reviews are offered in some countries for domestic reactors. For example, a peer review, especially at a reactor facility facing regulatory compliance issues, may speed the return to full compliance. In other cases, peer reviews may be performed in order to show that the reactor is operated based on internationally recognized practices. A peer review may be organized at a reactor facility using a group of local science and engineering professionals who are not members of the operating organization. Finally, a peer review may be an INSARR mission organized by the IAEA at the request of a Member State.

The practice of a self-evaluation for the reassessment of the safety of a research reactor is also encouraged by the IAEA and is becoming more widespread. A reactor that is to undergo a peer review may wish to perform a self-evaluation in order to compare the results of the two reassessments.

3.5. INADEQUATE INTERNATIONAL CO-OPERATION

While international co-operation does occur in areas of interest to research reactors, issues requiring attention include the development of low enriched fuel, exchange of information on operating experience and accidents, preparation of standards and guides, peer reviews and regional use of reactors. The development of a protocol for research reactors similar to the Convention on Nuclear Safety, as well as other arrangements, is being widely discussed at present.

3.5.1. Inadequate use of new fuel development

The development and use of new low enriched uranium (LEU) fuels has been a co-operative effort involving several countries and international organizations, including the IAEA. Silicide LEU fuel has been developed and successfully utilized in many reactors worldwide. However, in order to reach higher density fuels and to solve some issues associated with the back end of the fuel cycle, development of molybdenum-uranium fuels is under way. To achieve widespread use of LEU molybdenum fuel in research reactors, an international effort for its certification may be required.

3.5.2. Inadequate participation in the exchange of information on research reactors

There is free and open exchange of research reactor technology among research reactor operators around the world. These exchanges consist of training courses, fellowships and conferences organized in specific Member States, regions of the world and around single reactor types. Many such forums are conducted by the IAEA.

While these activities are widespread, operators in developing countries often do not take advantage of these exchanges for many reasons. For most developing countries sufficient travel funds are not available. The lack of sufficient staff to permit a person to be away from the facility is another problem. The relevance of the subject matter may be another reason developing countries may not attend; a conference may be discussing facility upgrades and installation of sophisticated experimental equipment and instrumentation when discussion of basic facility maintenance is what would be of most benefit. A solution may be for the IAEA to continue and increase the offering of national and regional workshops tailored to the needs of the nation or region.

National organizations exist for exchange of information about research reactor incidents. Until recently, there has not been a formal international system of information exchange for research reactors. The establishment of the IRSRR by the IAEA provides the framework for information exchange about incidents. However, while operational, the IRSRR still lacks extensive participation by Member States who should be encouraged to join; success of the programme is proportional to participation.

3.5.3. Inadequate regional use of reactors

Regional sharing of research reactors is most cost effective where a small number of users share costly experimental facilities. Shared facilities are less cost effective where a large number of users must frequently travel to share inexpensive facilities.

While regional use of reactors is already taking place, it will probably become more popular as reactors age and funding for reactors decreases. Operating systems and experimental facilities become obsolete and upgrades of these systems and facilities at all reactors becomes too costly, resulting in financial pressures for the creation of regional centres of excellence.

The number of reactors in extended shutdown should determine whether the use of another reactor in the region is the preferred way to meet the needs of the user community based on safety, economics and efficiency.

3.5.4. Lack of international convention or arrangement for research reactors

INSAG has suggested the development of an international protocol or some other legal instrument or arrangement to cover the safety of research reactors in a similar way that nuclear power reactors are covered by the Convention on Nuclear Safety. The IAEA General Conference, recognizing the significant benefits as well as the potential adverse impact of such an arrangement, requested the Secretariat to continue exploring options to strengthen international nuclear safety.

4. RECOMMENDATIONS FOR STRATEGIC ACTIONS/PRIORITIES FOR FUTURE WORK

The recommendations for strategic actions are divided in three groups; international arrangement, regulatory supervision and other issues. While the recommendations apply to all research reactors, they address the problems of that subset of facilities described in Section 1 so as to bring them in line with their peer facilities. A general recommendation is addressed both to Member States and the IAEA on the benefits of developing an international arrangement for research reactors. The term 'Member States' refers to both the applicable government unit and the research reactor operator. Frequently, the operator is a unit of the Member State government but in other cases the operator may be an independent body.

4.1. INTERNATIONAL ARRANGEMENTS

The General Conference has asked the IAEA Secretariat to take an active role in exploring the possibilities for the development of an international arrangement for the safety of research reactors.

Authorities from Member States should start thinking about the modality, format and features of such an arrangement.

The benefits of such an international arrangement for research reactor safety will depend on the scope, modality, format and features that may be adopted by the participating Member States.

The IAEA Safety Standards should be recognized as a framework for the international arrangement, which should serve to achieve the following objectives:

- Better understanding of the current practices applied by Member States to all stages of the lifetime of a research reactor facility;
- Greater assurance that common practices based on international consensus standards are applied to all research reactor facilities participating in the arrangement;
- Improved information exchange, credibility and openness among Member States participating in the agreement;
- Creation of a forum for discussing specific issues such as ageing, extended shutdown, regional use of research reactors and common solutions to spent fuel disposal;
- Creation of a systematic, consensus framework for benchmarking the safety of research reactor programmes in Member States

4.2. REGULATORY SUPERVISION

The following are proposed recommendations to solve issues related to regulatory supervision.

To Member States:

- Organize group activities (e.g. workshops, training events) on specific regulatory issues or issues related to specific reactor types;
- Share experience through symposia or international organizations of regulators;
- Ensure adequate funding for regulatory activity;
- Endorse IAEA Safety Standards (or the equivalent) if adequate national safety standards are not available.

To the IAEA:

- Improve regulatory personnel competence through group and individual training;
- Expand International Regulatory Review Team (IRRT) services to Member States operating research reactors;
- Provide for an enabling network between research reactor regulators to examine co-operation, mutual assistance, and sharing of specialists on regional and bilateral bases.

4.3. OTHER ISSUES

The following are proposed recommendations to resolve technical issues:

Ageing facilities

To Member States:

- Share information on the management of ageing from operational and regulatory activities;
- Establish a programme for physical and non-physical ageing as is discussed extensively in Ref. [11].

To the IAEA:

- Strengthen group activities such as Co-ordinated Research Projects, workshops and seminars dedicated to ageing phenomena;
- Develop further guidance documents on relevant ageing aspects and address ageing issues in any reassessment of safety at research reactor facilities.

Research reactors in extended shutdown

To Member States:

- Share experience with other Member States also having shut down research reactors;
- Provide funds to manage shutdown as well as decommissioning if this option is chosen;
- Perform a feasibility study concerning early restart and begin decommissioning if the feasibility of restart appears remote.

To the IAEA:

- Complete guidance document on extended shutdown;
- Co-ordinate group activities, meetings and workshops on extended shutdown and decommissioning;
- Advise Member States on keeping an extended shutdown as short as possible because experience shows that skilled personnel will leave the facility and the amount of deterioration is proportional to the shutdown duration.

Operating organization management

To Member States:

- Develop a strategic plan with expectations of the research reactor and resources required.
- As a provision of research reactor ownership, provide resources (funds and personnel) for operational state or decommission.
- Train personnel in specific activities such as maintenance during extended shutdown, periodic reassessment, etc.
- Ensure that peer reviews are conducted.
- Ensure that a QA programme is established and implemented.

To the IAEA:

- Develop training and tutorial material for self-assessment of safety management practices, safety culture, QA and strategic long term planning.
- Develop guidance on emergency planning and emergency procedure preparation and implementation specific for research reactors.
- Expand peer review services.
- Develop guidance material on the preservation of corporate memory.
- Develop short workshops on specific topics such as (1) the development of an affordable, practical, graded QA programme for the small facility operator; (2) safety culture for the uninitiated: how to generate it and recognize it; and (3) retraining made easy.

International co-operation

To Member States:

- Explore options for and desirability of an international nuclear safety arrangement for research reactors;
- Take advantage of INSARR services both by receiving the service and by supplying experts;
- Participate in the IRSRR.

To the IAEA:

- Sponsor and participate in activities related to the safety implications of new fuels developed for research reactors;
- Initiate and organize meetings, workshops and courses on a regional basis and on specific topics to encourage sharing of experience between groups that face similar problems;
- Expand the number and scope of review services to reactors under agreement;
- Work to strengthen and increase participation in the IRSRR.

5. QUESTIONS TO THE CONFERENCE

- What is the most appropriate modality for an international arrangement which will both be effective in increasing the overall safety of research reactors and also will induce maximum participation of Member States worldwide?
- What is an effective approach to resolve the issue of research reactors in extended shutdown? How can a quick decision be made by authorities on whether to restart or decommission? If there are regional centres which could be used by several Member States, would this help to improve the situation?
- What is the best way of transferring knowledge and know-how from the nuclear power community to the research reactor community, e.g. in the fields of QA, safety culture, etc.?
- How can well-run research reactors help problem research reactors?

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