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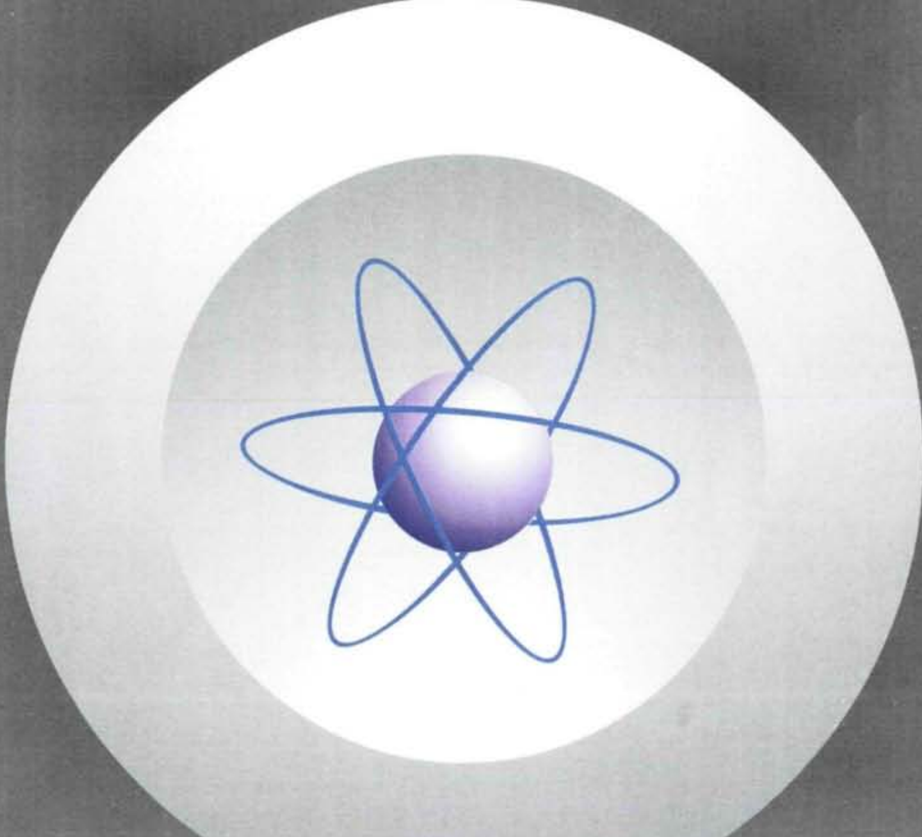

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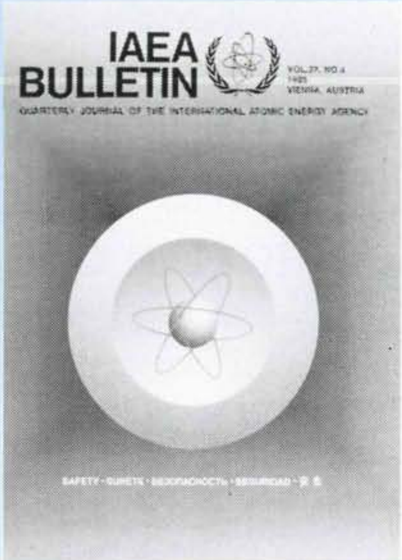

Front Cover: The year ahead promises to bring issues of nuclear safety into sharper focus. On many fronts, international experts are working through IAEA-supported programmes to help raise levels of nuclear safety — at power plants, waste sites, and research institutes. Some are putting into practice better systems for ensuring even safer nuclear operations, while other experts lay the groundwork for safety standards of future plants. In other fields, specialists assess national plans for deep underground disposal of radioactive wastes, even as teams of scientists from around the world pool their expertise to move closer toward the goal of obtaining electricity from fusion, the process powering the sun.
(Cover design: Hannelore Wilczek, IAEA; Stefan Brodek, Vienna.)

Facing Page: In many countries relying on nuclear power for electricity generation, people are able to visit plants and nearby information centres. At the El Park Public Information Centre in Ohi, Japan, the world of nuclear power and energy is vividly on display.
(Credit: Kepco, Japan)

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Nuclear energy & the environmental debate: The context of choices

Through international bodies on climate change, the roles of nuclear power and other energy options are being assessed

by Evelyne Bertel and Joop Van de Vate

Environmental issues are high on international agendas. Governments, interest groups, and citizens are increasingly aware of the need to limit environmental impacts from human activities. In the energy sector, one focus has been on greenhouse gas emissions which could lead to global climate change. The issue is likely to be a driving factor in choices about energy options for electricity generation during the coming decades. Nuclear power's future will undoubtedly be influenced by this debate, and its potential role in reducing environmental impacts from the electricity sector will be of central importance.

Scientifically there is little doubt that increasing atmospheric levels of greenhouse gases, such as carbon dioxide (CO_2) and methane, will cause climate change on a global scale. However, the natural climate variability is still larger than the estimated anthropogenic contributions to climate change.

Despite uncertainties, the threat of climate change remains a serious long-term global risk. Scenarios with time horizons of 2100 and beyond have to be developed, requiring insight into long-term development of life-styles, socio-economics, and technology. Such scenarios are of a normative character and therefore are inherently subjective. What is known is that energy consumption is one of the major sources of greenhouse gases, and nuclear power nowadays avoids more than 8% of the worldwide CO_2 emissions.

Two major international bodies are involved in climate change matters: the Conference of Parties to the Framework Convention on Climate Change (CoP/FCCC), which had its First Session in March/April 1995, and the Intergovernmental Panel on Climate Change (IPCC), which has been active since 1988. Since the energy sector is responsible for the major share of anthropogenic greenhouse gas emissions, international organisations having expertise and mandate in the field of energy, such as the IAEA, are actively involved in the activities of these bodies. In this connection, the IAEA participated in the preparation of the second Scientific Assessment Report (SAR) of the Intergovernmental Panel on Climate Change (IPCC).

The IAEA has provided the IPCC with documented information and results from its ongoing programmes on the potential role of nuclear power in alleviating the risk of global climate change. In particular, the IAEA prepared, jointly with the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD/NEA), sections on nuclear power of the SAR chapter dealing with energy supply mitigation options. This chapter includes a description of different options to reduce greenhouse gas emissions; a presentation of illustrative low CO_2 emission energy supply scenarios; and a discussion on measures for implementing low carbon emitting technologies and strategies. The IAEA and OECD/NEA also prepared a supporting document to the SAR, *Nuclear Power in the Context of Alleviating Greenhouse Gas Emissions*, which was published in the IAEA TECDOC series in April 1995.

This article describes the main functions of these two international bodies and reports on the IAEA's contribution to the IPCC's second Scientific Assessment Report, which is being submitted in early 1996 to the CoP/FCCC .

Global bodies related to climate change

In 1992, the UN Conference on Environment and Development (Earth Summit) in Rio dealt with the sustainability of the Earth in terms of

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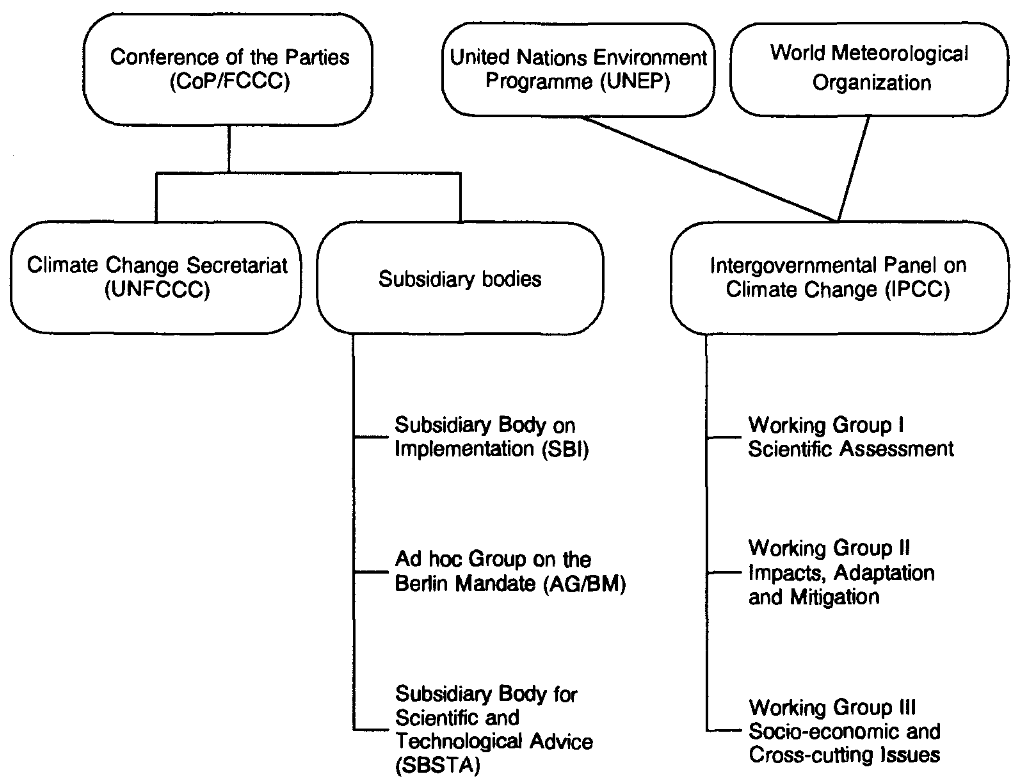
avoiding climate change, environmental pollution, and resource depletion. In Rio, the Framework Convention on Climate Change (FCCC) was signed. It entered into force in 1994 after being ratified by more than 50 countries. The FCCC's objective is to lower the atmospheric greenhouse gas concentration to non-hazardous levels. This will require draconian measures, especially by the industrialized countries where *per capita* CO_2 emissions are more than ten times those of developing countries. Industrialized countries will have to compensate for the increased CO_2 emissions that are inherent to the socio-economic development and rising populations of the developing countries. This equity consideration, laid down in the FCCC, is a frequent political discussion point in inter-governmental meetings related to climate change.

The CoP/FCCC, the supreme body of the Convention, was established by the Earth Summit in 1992 and had its first session in Berlin, in March and April 1995. It reviews the implementation of the FCCC and makes decisions necessary to promote the Convention's implementation. Several subsidiary bodies also have been established: the Convention established the Subsidiary Body for Implementation (SBI) and the Subsidiary Body for Scientific and Technological Advice (SBSTA). In Berlin, the CoP/FCCC set up the Ad hoc Group on the Berlin Mandate (AG/BM) to draft a protocol for the period beyond 2000. SBI will develop recommendations to assist the CoP in its review and assessment of the Convention's implementation. SBSTA will be the link between the scientific and technological assessments and the information provided by international bodies on the one hand, and the policy-oriented needs of the CoP on the other hand. The IAEA will be involved in activities carried out by these FCCC-related bodies.

The IPCC is an independent, scientific, and technical body with a mission to help policymakers mitigate global climate change. As part of its work, the IPCC produces Scientific Assessment Reports on climate change. Its first report was published in 1990 and updated in a supplement in 1992. The second report was endorsed in late 1995 at the IPCC meeting in Madrid, and is expected to be published in early 1996. A third assessment report is scheduled for 1998.

In a co-operative project with the OECD, the IPCC has also produced *Guidelines for National Greenhouse Gas Inventories.* They will assist gov-

Organizations related to the Framework Convention on Climate Change



ernments in reporting regularly to the CoP/FCCC about the implementation of the national measures to lower their emissions of greenhouse gases.

The Scientific Assessment Reports are drafted by experts from a broad spectrum of scientific disciplines. They are subject to review by national and international experts before being submitted for approval by plenary meetings of IPCC and its three Working Groups. Working Group I, on Scientific Assessment, deals with climatology. Working Group II, on Impacts, Adaptation and Mitigation, covers topics such as the rise of sea levels, energy, and desertification. Working Group III, on Socio-economic and Cross-cutting Issues, assesses socio-economic literature related to climate change. Working Groups I and II have evaluated CO_2 emission scenarios with time horizons up to 2100.

In contributing to these evaluations, the IAEA has emphasized the potential role of nuclear energy in the context of comprehensive comparative assessments.

The context of choices

All electricity generation options involve some environmental impacts. However, when they are fitted to state-of-the-art technologies, the options are able to deliver electricity at relatively low risks to the environment. In particular, a number of technical options exist for alleviating or mitigating greenhouse gas emissions from the power sector. Policy measures such as taxes, subsidies, and emission permits can also be used as a means to reflect the estimated full cost to society of alternative options. The challenge for decision-makers in the power sector is to design and implement timely strategies based upon energy mixes that aim towards minimizing adverse environmental, health, and social impacts at the lowest total cost for society.

The technical options that can be considered in the power sector range from efficiency improvement to CO_2 sequestration through shifting to fuels with low or no carbon content. However, at the decision-making level, technico-economic factors and barriers to implementation have to be recognized and taken into account. Energy efficiency improvements are not infinite and have a cost which tends to increase very rapidly once the straightforward savings have been achieved.

Some technological options — which might seem extremely attractive on scientific grounds — are far from having reached the stage of industrial development or even technical feasibility demonstration. Therefore, these options are not likely to make any significant contribution to reducing greenhouse gas emissions or other health and environmental burdens in the short and medium terms. For example, carbon dioxide capture and disposal in deep oceans, or energy systems based upon hydrogen as a carrier, might contribute substantially to greenhouse gas reduction in the long term. But they will by no means be industrially mature and economically competitive within the coming decades. Renewable sources, with the notable exceptions of hydropower and biomass, do not offer realistic prospects for large-scale baseload electricity generation.

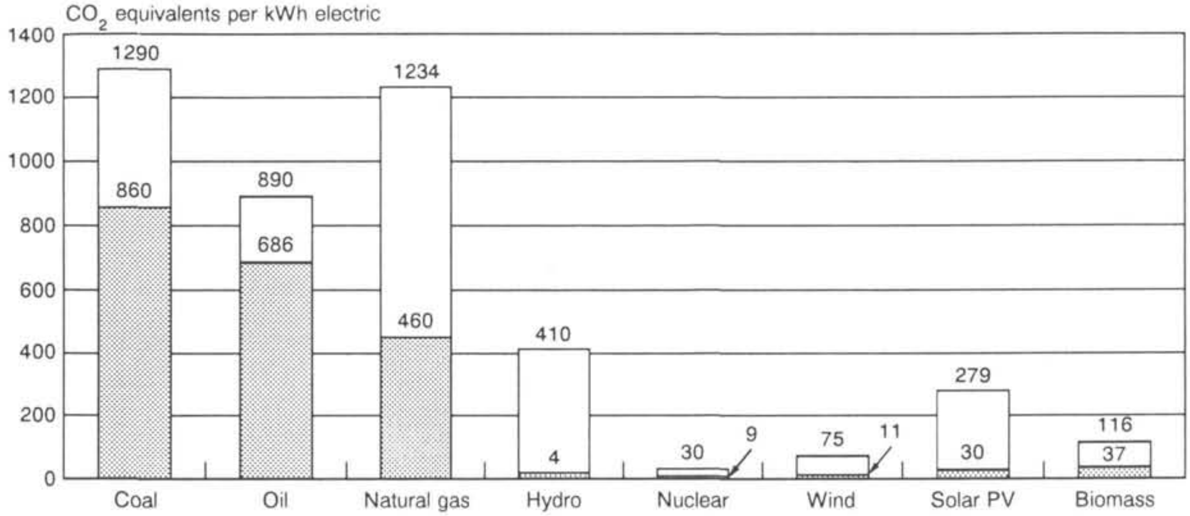
Nuclear power and electricity options

Nuclear power is a proven technology available today that can contribute significantly to reducing greenhouse gas emissions and other environmental burdens from the energy sector and to meeting environmental protection objectives. In the long term — as the executive summary of the SAR chapter on energy supply mitigation options states — "nuclear energy could replace baseload fossil fuel electricity generation in most parts of the world, if generally acceptable responses can be found to concerns about reactor safety, radioactive waste disposal, and proliferation".

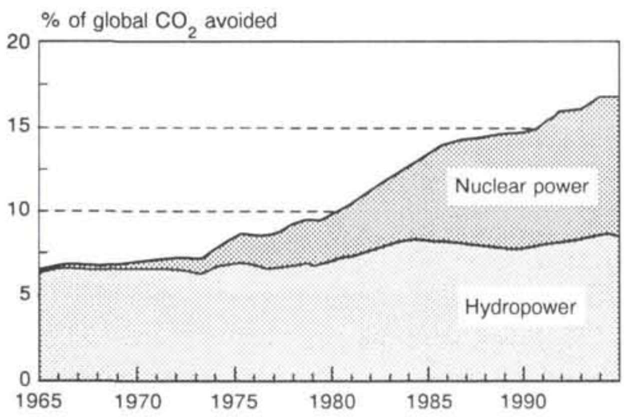
The use of nuclear energy for electricity generation dates back to the late 1950s and it has reached a stage of industrial maturity. At the end of 1994, there were 432 nuclear units connected to the grid with a total installed capacity of some 340 gigawatts-electric (GWe). In 1994, the nuclear electricity generated worldwide exceeded 2300 terawatt-hours (TWh), supplying 17% of the total electricity consumption. The accumulated operating experience of nuclear power plants is now over 7200 reactor-years and the average operating performance is improving continuously with an energy availability factor above 70% since the mid-1980s. This experience places nuclear power among the technologies that decision-makers can consider for sustainable electricity system expansion in the coming years and decades.

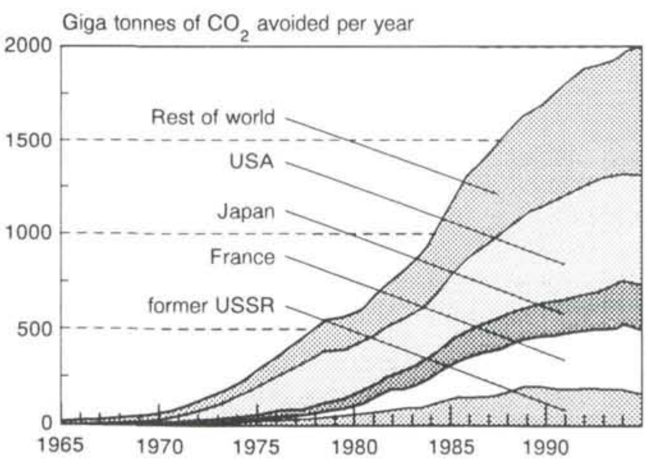
While environmental concerns are likely to be major driving forces in choices about electricity generation, the economic competitiveness of options will remain a cornerstone in assessing and choosing alternative sources. Although there are indications that technical breakthroughs could reduce significantly the costs of electricity generated by some renewable energy sources other than hydropower, such as solar photovoltaic and wind power, these options are unlikely to be competitive with fossil fuels or nuclear power for baseload generation before the second or third decade of the next century. In most

CO_2 Equivalent Emission Factors of Different Energy Sources (full energy chain; maximum and minimum values)



Avoidance of Global CO_2 by Nuclear and Hydropower





Trends in CO_2 Emission Rates 1965-93

	Emission rate in 1993 (Pg/y)	Annual increase (Pg/y per year)	Percentage increase (%)
European Union	3.5	0.025	0.8
OECD countries	12.1	0.15	1.4
Non-OECD Europe	5.5 (1988)	0.11 (1965-88)	2.6 (1965-88)
Less developed countries	7.7	0.21	4.4
World	24.0	0.39	2.1

Trends in CO_2 emission rates vary regionally, reflecting differences in development of nuclear power programmes since the mid-1960s. Overall, nuclear power production has increased much faster than hydropower, and their present contributions to avoidance of CO_2 are nearly equal. Comparing the emission of all greenhouse gases from all energy sources reveals low emission factors for nuclear, hydro, and wind power. The top bar graph shows maximum and minimum values as compiled from studies conducted by the IAEA and other organizations. The low CO_2- equivalent emission factor for nuclear power is an international consensus value.

Source: British Petroleum Statistical Review of World Energy, 1995.

countries, oil is not considered for baseload electricity generation owing to the volatility of market prices and concerns on security of supply. Therefore, in most countries the choices for baseload electricity generation plants to be commissioned within one or two decades will essentially be limited to fossil fuels, mainly coal and gas, nuclear power, and, where favourable sites exist, hydropower.

The relative costs of electricity generation by coal, gas, nuclear, and hydro power plants vary from country to country and are highly dependent on local conditions, discount rates, and expectations regarding the future coal and gas price trends. Coal is and will remain an economically attractive option in a number of countries having access to cheap domestic resources. As a result of the development of highly efficient combined cycle technologies, gas has become competitive for baseload electricity generation in a number of countries. However, gas-generated electricity costs are very sensitive to gas prices that might increase significantly if market demand grows rapidly. Where favourable sites exist, hydropower projects offer opportunities for low-cost electricity generation. However, the number of these sites is limited and, in many countries, social and environmental impacts of large dams are preventing the implementation of hydropower plants. Moreover, recent publications indicate that hydropower generation could be unfriendly to the climate because of emissions of greenhouse gases from the water reservoirs.

In spite of their high investment costs, nuclear power plants compete favourably with fossil-fuelled units in most countries. This is especially the case where nuclear programmes have been soundly implemented and managed and where fossil fuels are not accessible at low prices. Ongoing research and development is expected to bring further enhancement of the performance of nuclear power plants that will lead to lower costs of nuclear electricity generation. Moreover, owing to the comprehensive approach adopted for calculating nuclear electricity generation costs, the non-internalized social, health, and environmental costs are very small relative to the direct estimated costs, and they are much smaller than in the case of fossil-fuelled systems. Factoring in these costs should reinforce nuclear power's competitive margin.

Environmental Impacts. With regard to environmental impacts, nuclear power offers specific benefits. In routine operation, nuclear power plants and the fuel cycle facilities do release small quantities of radioactive materials. However, the rules developed and implemented several decades ago for limiting radioactive emissions satisfy criteria for protecting human health and are more than adequate to protect the environment. The other emissions, residuals, and burdens from nuclear power plants and fuel cycle facilities are lower than those arising from fossil-fuel electricity generation chains and comparable or lower than those from renewable energy systems. Taking into account the entire up-stream and down-stream energy chains for electricity generation, nuclear power emits 40 to 100 times less carbon dioxide than currently used fossil-fuel chains. Greenhouse gas emissions from the nuclear chain are due mainly to the use of fossil fuels in the extraction, processing, and enrichment of uranium and to fuels used in the production of steel and cement for the construction of reactors and fuel cycle facilities. These emissions, which are negligible relative to those from the direct use of fossil fuels for electricity generation, can be reduced even further by energy efficiency improvements. Such improvements at the enrichment step include, for example, replacing the gaseous diffusion process by less energy-intensive processes such as centrifugation or laser isotope separation.

The role that nuclear electricity already plays in alleviating the risk of global climate change is notable. It is illustrated by the fact that if the nuclear power plants in operation worldwide would be substituted by fossil-fuelled power plants, the CO_2 emissions from the energy sector would increase by more than 8%. This level — which almost equals the avoidance of emissions by hydropower — has been achieved in a number of countries in about two decades of nuclear power development.

The analysis of statistical data in different countries over the last 20 years shows that countries which implemented large nuclear programmes, such as Belgium, France, and Sweden, achieved simultaneously significant reductions of their CO_2 emissions. In France, for example, both CO_2 and sulphur dioxide emissions were reduced by more than three between 1982 and 1992, although electricity production nearly doubled, owing to the share of nuclear power in electricity supply. In the United States, if nuclear energy would not have been used between 1973 and 1994, some additional 1750 million metric tons of CO_2 would have been released in the atmosphere. Countries and regions which do not deploy nuclear power on a large scale — for example, developing countries — had a relatively high increase rate of CO_2 emissions.

A long-term perspective

Over the long term, nuclear fuel resources and existing industrial infrastructures can support a broad deployment of nuclear power programmes in many countries. If the barriers to the implementation of nuclear power were alleviated, nuclear electricity generation could grow steadily from now on and throughout the next century. The long-term nuclear scenario developed by the IAEA in co-operation with the OECD/NEA for the IPCC illustrates this point.

This scenario was set up in the context of the global energy and electricity demand projections outlined in IPCC's SAR chapter on energy supply mitigation options. It assumes that nuclear power would be deployed widely for alleviating the risk of global climate change and would penetrate the market on grounds of its economic competitiveness. It implies that the present policy barriers to nuclear power deployment — such as moratoria on construction of new nuclear power plants and political decisions to ignore the nuclear option — will be progressively removed, and that nuclear projects in developing countries will be facilitated by enhanced technology adaptation and transfer, and financial support from development banks.

The assumptions adopted for estimating the penetration rates of nuclear power in different regions reflect the need for diversity of supply and the availability and competitiveness of alternative options. The options include oil and gas in the Middle East and, in the long term, biomass and other renewable sources. Potential uses of nuclear power for heat and hydrogen production have not been taken into account because of the uncertainties regarding the competitiveness of nuclear power for such applications.

By 2100 in this scenario, the share of nuclear power in total electricity generation would range from less than 20% in Africa, Australia and New Zealand, and the Middle East to 75% in Western Europe. The total installed nuclear capacity would grow from the present 340 GWe to some 3300 GWe in 2100 and nuclear power would provide 46% of the worldwide electricity consumption, as compared to 17% today.

The technical constraints taken into account in estimating potential nuclear capacity growth rates include construction lead times and industrial capabilities for building nuclear power plants and fuel cycle facilities. The availability of sites for nuclear installations, including radioactive waste repositories, was also considered by region, taking into account seismicity, cooling water requirements and the need to build nuclear facilities in areas with relatively low population density. The availability of natural resources for nuclear fuel would not place any major constraint on the development of nuclear power, taking into account known uranium and thorium resources and expected technological progress in fissile material utilization. This scenario would require the deployment of breeder reactors by 2025 in order to support nuclear electricity generation over the period up to 2100 with the presently known uranium resources. However, within that time frame, additional uranium resources would likely become available whenever necessary. Moreover, other types of nuclear power plants, such as thorium fuelled reactors, hybrid systems, and even fusion reactors, might be developed and commercially deployed.

The implementation of this nuclear scenario would allow reductions in carbon dioxide emissions worldwide by a factor of three as compared to the present level. A similar reduction would be feasible without nuclear power only if renewable energy sources, which have not yet reached the level of commercial development, would enter into the market early in the next century and would be deployed at very high rates throughout the next century.

Sustainable energy development

The years ahead will see increasing demand for energy, and in particular the need for additional electricity generation capacity. These challenges will be combined with the necessity to reduce the health and environmental burdens induced by the burning of fossil fuels. Taken together, they call for the development of all available energy sources and technological options that can meet environmental protection and economic efficiency goals in the short, medium, and long term.

Nuclear power is one option for reducing emissions and residuals from electricity generation and for mitigating health and environmental impacts from the energy sector. In order to make a significant contribution in the implementation of sustainable electricity supply strategies worldwide, nuclear power should reinforce its competitiveness versus fossil-fuel based systems and, in the long term, versus renewable sources. The barriers to nuclear power deployment should be alleviated by continuing demonstration that reactors and fuel cycle facilities can be operated in a reliable and safe manner and that technical solutions already existing for final disposal of all radioactive wastes can be implemented wherever needed.

Continuing progress is being achieved in terms of technical performance, safety, and competitiveness of nuclear power plants. These advances should enhance the viability of the nuclear option in an increasing number of countries. The continuation or renaissance of nuclear power programmes in all countries where it is a viable option — based upon the assessment of its economic and environmental benefits as compared to alternative energy sources — would contribute significantly to enhancing the sustainability of energy supply systems. ❐

Nuclear power plant safety: Steps toward better performance

At many nuclear plants, self-assessment processes are helping management to review and improve levels of safety

by Keith Hide

As part of the nuclear industry's response to the accidents at Three Mile Island (TMI) in 1979 and at Chernobyl in 1986, programmes to evaluate and encourage improvements in the operational safety performance of nuclear power plants were initiated. In the United States, the Institute of Nuclear Power Operations (INPO) was founded by nuclear utilities. It performs periodic operational safety evaluations of all nuclear power plants in the USA. INPO also provides a number of other services to help US and volunteer international utilities improve their safety performance.

On a broader international scale, the IAEA initiated the Operational Safety Review Team (OSART) programme for voluntary reviews of operational safety performance at power plants worldwide. The IAEA also initiated other voluntary programmes — such as those on the Assessment of Safety Significant Events (ASSET), Assessment of Safety Culture in Organizations (ASCOT), and the Incident Reporting System (IRS) — to assist nuclear plant operators in evaluating and strengthening their safety performance.

In September 1994, IAEA Member States began the process of ratifying a new Convention on Nuclear Safety. This convention will establish, for the first time, internationally agreed obligations for ensuring the safety of nuclear power plants and the commitment of the signatory States to meeting them. Under the Convention, Member States with nuclear power plants will report periodically to their peers on the measures taken to meet their obligations.

Although the exact nature of the reports to be made under the Convention has yet to be determined, Member States will need to determine, in some way, the degree to which the performance of their own nuclear power plant programme is in accordance with the obligations of the Convention. Operational safety performance reviews performed by independent organizations such as the IAEA could provide information for this purpose, but the substantial outside resources they require limit their availability.

Many utilities have chosen to use self-assessment processes to help their management obtain current information about safety performance. Regulatory authorities are increasingly recognizing and using self-assessments to judge nuclear power plant safety performance. Experience has shown that when organizations objectively assess their own performance, understanding of the need for improvements and the motivation to achieve them is significantly enhanced. Such self-assessments might also contribute substantially to the periodic reports required by the Convention.

For purposes of discussion, self-assessment practices can be grouped into three general areas as follows:

- frequent or continuous monitoring of performance against established management performance expectations;
- periodic, in-depth reviews of the effectiveness of selected activities or programmes by in-house teams of experienced reviewers and technical experts; and
- one-time, in-depth reviews to probe the full extent and basic causes of known weak performance areas.

This article outlines these self-assessment practices and the benefits they are providing.

Performance monitoring

Many utilities now use a variety of performance indicators to set and communicate their goals or expectations for performance of plant equipment, programmes, and personnel in areas

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that affect safety, production and efficiency. Performance indicators are best expressed in clear, numerical terms that relate to performance in a variety of areas. They normally include the ten major performance indicators that are reported to the World Association of Nuclear Operators (WANO) by nuclear utilities worldwide and a substantial number of others that are based on the particular needs of individual plants and groups, such as chemistry, radiological protection, and maintenance, within plant organizations. Many plants use the results achieved by top-performing plants or established industry standards as benchmarks to set their own goals for performance and improvement.

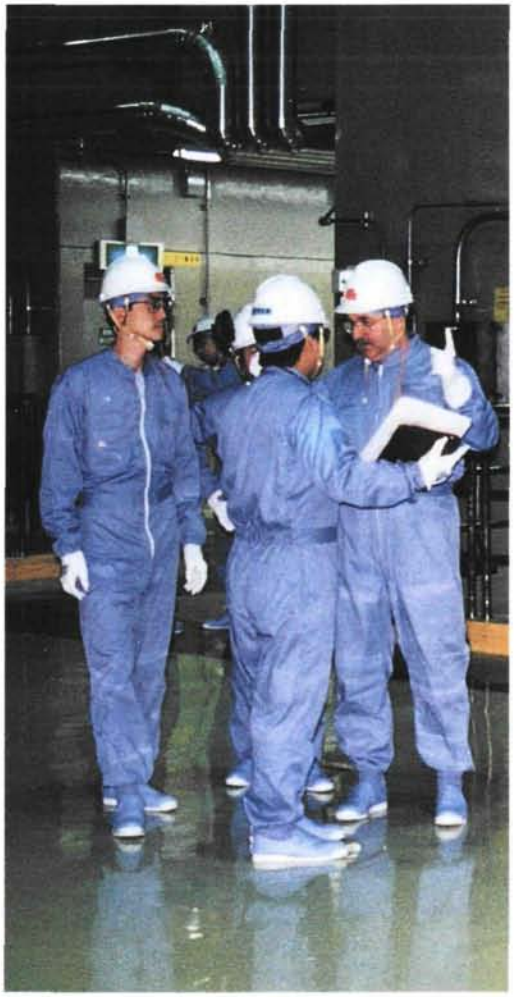
Structured monitoring of actual performance results against the agreed performance indicator goals helps provide management and other plant personnel with useful information on the current performance and areas in need of additional attention. Some utilities establish, for each performance indicator or related groups of indicators, a series of numerical values that reflect significant weakness, the need for some improvement, satisfactory performance, or significant strength. Periodic reports to management on performance can then be tailored to reflect not only the current level of performance, but the trend in performance. Colour-coding is sometimes used to help highlight results and trends in these reports.

Performance monitoring against goals provides management with frequent, objective information on the quality of plant operations in the areas addressed by the performance indicators. It further allows managers to address their attention to the areas where assistance or additional support may be needed to meet station performance goals. Another major advantage of this type of monitoring is that reports of performance can be easily shared, by means of graphs and visual presentations, with all plant personnel. This helps keep all personnel aware of current performance in their own areas and in areas that they support. Some utilities format these reports in the form of annunciator panels colour-coded to reflect the results according to specified performance categories, and display them throughout the plant. Many have found that the use of such systems significantly enhances understanding and support within the plant staff of management's goals for performance and how they relate to their own activities.

Periodic effectiveness reviews

Though performance indicators and goals provide information on a frequent basis, their value is limited to the specific areas selected for monitoring, and they do not give much insight into the causes of performance weaknesses. Effectiveness reviews that look into qualitative as well as quantitative information have also proven to be valuable self-assessment tools. These reviews do examine adherence to regulatory or external requirements, but the most effective reviews go well beyond that to examine the effectiveness and efficiency of programmes and activities in achieving their intended purpose. Effectiveness reviews of major plant evolutions, such as outages and plant startups, often provide valuable insights into plant and staff performance. They may also be useful in assessing the effectiveness of corporate support or support from other organizations that can impact plant operation and safety performance.

Effectiveness reviews may be accomplished by teams of individuals who are independent of the activity being reviewed, by those who are closely involved in the activity on a day-to-day basis or, ideally, by teams including both. Such reviews may be done well by quality assurance personnel, if they have current expertise and expe-



Members of an OSART team at the Hamoaka nuclear plant in Japan.
(Credit: Taylor/IAEA)

rience in the area to be reviewed. However, many utilities have discovered the advantages of using personnel who are directly involved in or responsible for the activity under review as members of these teams. Such individuals bring valuable insights into the review process and improve the quality of review results. But perhaps more importantly, they often gain fresh perspectives and understanding from their participation that increases their awareness of problems, the importance of correcting them and possible ways of correcting them. In addition, the training they receive in review techniques by virtue of their participation often significantly improves their ability to assess performance in their own areas of responsibility on a day-to-day basis.

Strong support from management has been shown to be an essential factor in achieving good effectiveness reviews. This can be shown by selection of capable review team members including appropriate management and supervisory personnel, support of each team's efforts to identify all contributing problems and their causes, and responding to the results of reviews in a positive way that supports improvement without punitive action or embarrassment. These factors are important to obtaining the open sharing of information and opinion between reviewers and those being reviewed that is needed to produce good results.

Quality assurance programmes have traditionally provided a framework for review or audit of station programmes and activities, using review schedules that provide periodic examination of important performance areas and focusing on adherence with quality programme requirements and regulations. However, many current self-assessment efforts expand considerably on this framework by performing reviews at the request of managers or staff personnel and focusing more on overall effectiveness of programmes and activities in achieving their intended purpose. In some plants, more than 50% of the assessments performed are a consequence of plant staff requests, and managers and other personnel at all levels participate in assessment teams.

One-time reviews of problem areas

Most utilities recognize that focusing self-assessments or effectiveness reviews on known or suspected problem areas is one of the most effective ways of improving performance. At least one utility senior manager has stated that his manager's primary responsibility is finding problems and opportunities for improvement and making the appropriate improvements. Opportunities for improvement may be identified through performance indicator monitoring, plant and industry operating experience, comparison with other nuclear power plants, and a variety of other means. The principles for achieving good reviews are the same as those stated above for periodic reviews.

An example of the use of one-time problem reviews concerns the system used at one nuclear power plant to tag equipment that was out-of-service for maintenance work. After a few minor cases of errors in tagging, plant managers decided to conduct an in-depth review of its tagging procedures and related activities. They formed a team that included members of the maintenance staff, operations staff, technical support staff, and others, and required them to examine all aspects of the tagging system. The team attempted to flow-chart the tagging process and found that they were unable to do so. At the conclusion of their work, the team had identified many deficiencies in the effectiveness of the system, foremost of which were its complexity and the lack of understanding of it by those who used it on a day-to-day basis. The plant then developed a completely new, simpler process that could be more easily understood and used more reliably.

In another example, a utility that had experienced several indications of deteriorating performance in broad areas elected to perform a comprehensive review of the management and effectiveness of all station activities. In this case, the problems were considered to be so pervasive that the utility decided the team should be comprised of experienced plant operations experts from outside the company. A team of senior experts with excellent knowledge and current experience in plant operations and management was assembled by the utility and given strong support in identifying the fundamental causes of the plant's malaise. The results initiated many fundamental improvements in the management of plant activities and the responsibilities given to plant personnel. It was recognized by the national regulatory authority as an effective identification of fundamental problems at the plant. As a result, an extensive regulatory review was avoided. Both the regulatory authority and the plant considered the self-assessment more useful than a regulatory inspection, because of the expertise of the reviewers and because of the plant's positive recognition and ownership of the results.

Peer review programmes

Utilities in at least four countries have implemented their own peer review programmes and are using their own expertise to assess performance in each of their nuclear power plants. They have organized programmes for peers from other stations to assess each of their nuclear stations at regular intervals. These programmes provide valuable training in proven review techniques to numerous plant personnel who participate as peer reviewers. The knowledge and experience they gain pay dividends when they return to their own plants. They can view performance in their own areas more objectively and with a fresh perspective. Often, they get ideas from the plant being reviewed that they use to strengthen their own performance.

Regulatory overview

Some regulatory agencies believe that encouraging self-assessment and checking on the thoroughness and results of such efforts provides valuable insight for the regulator and promotes a sense of ownership for problem identification and correction within the utility, where it is most important. As a result, they are increasing their efforts to ensure that all utilities implement effective self-assessment programmes to detect operational weaknesses and identify the fundamental causes early. It is believed that review of self-assessment results can be an improved alternative to regulatory inspections as a means of ensuring that plants maintain high standards of performance.

International initiatives

Those involved in the use of self-assessment programmes agree that self-assessments represent one of the most powerful tools for improvement because of the following benefits:

- They are performed by individuals who are most knowledgeable of the people and practices at the nuclear power plant.
- They can be easily tailored to the needs of individual plants.
- They minimize the potential for embarrassing exposure of plant weaknesses to outside persons, and maximize the opportunity for candid, frank discussion of problem areas between reviewers and staff members.
- They strengthen insight into performance problems, their causes, and their effects at all levels, and thus strengthen support for improvement.
- They can be performed on a frequent or continuous basis, giving management current information on the effectiveness of a wide variety of programmes and activities.

The IAEA is considering how it might best support the development and use of self-assessments as a means of strengthening nuclear power plant operational safety. Activities in progress or under consideration include the following:

- providing guidance on self-assessment activities for utilities and regulators. An IAEA Safety Guide is being developed;
- supplementing the OSART process and OSART guidelines (IAEA TECDOC-744, May 1994) to provide for reviewing the effectiveness of plant self-assessment activities;
- using the OSART process to identify and collect best practices in self-assessment and sharing them with the industry through the OSART Mission Results data base (OSMIR) and other methods;
- sponsoring international conferences and workshops on self-assessment;
- assisting Member States in implementing self-assessment programmes, upon request;
- reviewing self-assessment processes and the results of self-assessments upon request.

Expectations for operational safety performance are reaching higher and higher levels, and international interest in the performance of individual nuclear utilities and power plants is increasing. In this climate, the use of effective self-assessment processes is expected to become more important in both well-developed and developing nuclear programmes. Frequent, critical self-examinations of safety performance will be required to ensure that acceptable levels of performance are achieved and maintained. As part of its safety services to Member States, the IAEA will do its best to support and encourage the use of self-assessments in nuclear utilities and power plants. ❒

Leibstadt nuclear plant, Switzerland.

Future nuclear power plants: Harmonizing safety objectives

Through a number of co-operative avenues, technical features of tomorrow's nuclear reactors are drawing close attention

by Leonid Kabanov

Today's generation of nuclear power plants that are designed and operated to current safety objectives and principles achieve a high level of safety. Even though the majority of operating plants have a good safety record, there is considerable debate among safety and nuclear power experts on how to do even better.

This quest for excellence rests upon several factors. First, there is a tendency for any industrial activity to become safer and more efficient as it develops over time. For the nuclear industry, this has meant upgrading plant safety levels by incorporating the lessons learned from the many accumulated reactor-years of operating experience, including accidents that have occurred. Additionally, safety issues are being identified through research, testing, and other analysis, such as probabilistic safety assessment (PSA). Second, there is a desire to maintain the current low level of risk to the public from nuclear power, as the number of nuclear plants grows in the future. Third, there is a desire to further reduce the likelihood and radiological consequences of any potential large off-site release. By minimizing the potential impact on public health and safety, the need for off-site protective actions can be reduced. Finally in some countries, efforts to raise the level of safety is a prerequisite for public acceptance of a new or expanded nuclear power programme.

In 1992, the International Nuclear Safety Advisory Group (INSAG), a body advising the IAEA Director General on safety issues, proposed desirable features for enhancing the safety of future nuclear power plants.* They incorporate improved safety concepts including those addressing human factors and specific design features.

In the area of human factors, the features state that the design should be user friendly, consider operating and maintenance procedures, and reduce dependence on early operator actions. The implementation of these features will allow operators more time to perform safety actions and thus provide even greater protection against any possible release of radioactivity to the environment.

Regarding plant design, the features state that it should, in particular, reduce the probability and consequences of severe accidents, have confinement systems to cope with pressures and temperatures occurring during severe accidents, and adequately protect against sabotage and conventional armed attacks. Consideration should also be given to passive safety features that are based on natural forces, such as convection and gravity, making safety functions less dependent on active systems and components like pumps and valves.

In practice, some of these features are already being incorporated into modern plants that are under construction or have been recently commissioned. Incorporation of other features are envisaged in new designs being developed now.

This article reviews efforts that are being made internationally to develop safety objectives and principles for future nuclear power plants. The work is directed towards contributing to an international harmonization of safety approaches and to help ensure that future reactors worldwide meet a high standard of safety.

Types of future nuclear plants

Tomorrow's nuclear power plants are being referred to in a number of different ways: "next generation", "advanced", or "future" nuclear plants are the terms most often used. The terms,

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*See *The Safety of Nuclear Power*, INSAG-5, published by the IAEA (1992).

which are used interchangeably in this article, are primarily time-related and generally refer to plants that comply with national or international safety objectives and principles being developed for nuclear power reactors that are not yet operating or under construction.

Advanced designs under development comprise three basic types:

- water-cooled reactors, utilizing water as coolant and moderator;
- fast reactors, using liquid metal, e.g. sodium, as coolant; and
- gas-cooled reactors, using gas, e.g. helium, as coolant and graphite as moderator.

Most, about 85%, of today's operating nuclear power reactors are water-cooled reactors. Most advanced designs that are well developed also are water-cooled reactors. They are of two basic types: light-water reactors (LWRs) with ordinary water as moderator and coolant, and heavy-water reactors (HWRs), which use deuterium oxide (D_2O). LWRs are in turn subdivided into boiling and pressurized water reactors (BWRs and PWRs). Advanced LWRs (ALWRs), sometimes called *evolutionary* reactors, are being developed along two lines: large units in the size range of 1300-1500 megawatts-electric (MWe), and medium-size units of about 600 MWe. As being developed mainly by Atomic Energy of Canada Ltd., advanced HWRs similarly can be divided into large-size units, those with a power level of some 900 MWe, and smaller units with a power level of about 500 MWe.

The first class of large ALWRs comprises many designs and some of them are a joint effort of different countries. In general, the large units are similar to existing ones but incorporate advanced features (relevant to safety, control, etc.) and design changes to make the plant more resistant to severe accidents. Examples of some advanced PWRs and BWRs which are at a developed stage of design and are under regulatory consideration include: the Advanced Boiling Water Reactor (ABWR), a 1300-MWe plant being developed by General Electric in the United States; the System 80+, a 1300-MWe PWR being developed by ABB Combustion Engineering in the United States; and the European Pressurized Water Reactor (EPR), a 1500-MWe plant being developed by Nuclear Power International, France, and Germany. The final safety evaluation reports and design approvals for the ABWR and System 80+ were issued in 1994 by the US Nuclear Regulatory Commission (NRC).

The second class of ALWRs are plants which mainly use current technology but include significant changes in order to make intensive use of passive safety features. Some of them are at an advanced stage of design and can be considered representative examples. They include the Advanced Passive PWR (AP-600), a 600-MWe plant being developed by Westinghouse in the United States; the Simplified Boiling Water Reactor (SBWR), a 600-MWe plant being developed by General Electric in the United States; and the WWER-640 (V-407), a 640-MWe plant being developed by Atomenergoproject and Gidropress in Russia. The AP-600 and SBWR are presently under review for design certification by the NRC, and the WWER-640 is in the stage of preliminary licensing by the Russian regulatory body, Gosatomnadzor.

From the standpoint of nuclear plant safety, this *evolutionary* process of development has gained wide acceptance. At the same time, there is an ongoing discussion on the need to create a new generation of *innovative* plants that incorporate radical changes in design philosophy to avoid severe accidents. Such proposals are still in early design stages, and their development particularly faces problems associated with financial and technical requirements for testing and verifying the designs.

Harmonizing safety objectives

Global efforts to harmonize safety objectives for future nuclear power plants involves many countries and organizations. In addition to the IAEA, inter-governmental organizations including the Nuclear Energy Agency of the Organization of Economic Co-operation and Development (OECD/NEA) and the European Commission are closely involved in the work.

One of the IAEA's tasks is the development of nuclear safety standards for all nuclear activities. In the nuclear power field, these standards are developed with assistance from Member States as part of efforts to bridge different points of view and obtain consensus. The agreed safety standards are hierarchically organized in four levels: at the highest level are Safety Fundamentals, followed by Safety Standards, (or NUSS codes), Safety Guides and Safety Practices.

The exchange of information on nuclear safety research takes place within the working groups of OECD/NEA. Within the EC, a Reactor Safety Working Group (RSWG) of representatives of safety authorities, vendors, and utilities is active in exchange of information and promoting harmonization in the field of rules and guidelines for the design and operation of nuclear power plants. Bilateral and multilateral exchanges among regulatory bodies also occur, often under the auspices of the IAEA, OECD/NEA and Nuclear Regulators' Working Group (NRWG) of the EC.

A special effort on harmonization of safety approaches has been made by the Institute of Nuclear Protection and Safety (IPSN), France, and the Gesellschaft für Anlagen und Reaktorsicherheit (GRS, the nuclear reactor safety institute) in Germany. The work includes publication in 1993 of the document *GPR/PSK Proposal for a Common Safety Approach for Future Pressurized Water Reactors.*

Among nuclear utilities, many operators are interested in defining their needs and goals for nuclear plants to be ordered in the future. Toward this end, many utilities have looked to co-operative approaches, both at the national and international levels. In 1985, US utilities started an industry-wide effort to establish the technical foundation for the design of ALWRs. This ALWR programme is being managed by the Electric Power Research Institute (EPRI) and includes participation and sponsorship of several international utility companies and close co-operation with the US Department of Energy (DOE). The cornerstone of the programme is a document setting out utility design requirements (URD). Elsewhere, utilities also worked together to issue European Utility Requirements (EUR).

The URD and EUR define utility requirements, including safety goals set by them, in particular to promote licensing of new reactor designs. The URD, for example, presents a complete statement of utility desires for next generation nuclear plants and in particular addresses ALWR safety policy. The ALWR safety policy features an integrated design approach to safety based on defense-in-depth philosophy. It includes three overlapping levels of safety protection: accident resistance, core damage prevention, and accident mitigation. Top-tier safety design requirements are developed on the basis of the safety policy statement for each level of safety protection and for a specific type of ALWR.

The EUR is a product of major European electricity producers and associations and focuses on common requirements for future LWRs to be built in Europe. It is intended to be a tool for promoting harmonization, in particular of main safety objectives and safety requirements.

In drafting and reviewing both sets of requirements, many utilities in Asia, Europe, and North America have taken part. Even though these documents cover requirements in general for the entire plant, they deal specifically with main safety objectives and detailed safety approaches. These efforts also can be seen as an important contribution to global harmonization of safety approaches and objectives for future nuclear power plants.

Activities through the IAEA

The IAEA's efforts in this area received impetus in 1991 through a resolution of its General Conference. The resolution invited initiation of activities on safety principles for the design of future nuclear power plants using a step-by-step approach based *inter alia* on INSAG's work.

Since then, the Agency has convened a series of meetings aimed at achieving agreement on safety definitions, terminology, and classification of future reactors. The meetings identified desirable safety enhancements and topics relevant to the development of new principles. INSAG safety reports were reviewed as they relate to safety principles for future plants. Parts of these documents requiring clarification and parts requiring amplification were identified.

In June 1995, following INSAG's review and comment from its Member States, the Agency published a technical document, *Development of Safety Principles for the Design of Future Nuclear Power Plants* (IAEA TECDOC-801). The document proposes updates to existing safety objectives and principles which could be used as a basis for developing those recommended for the design of future nuclear power plants. Accordingly, it is intended to be useful to reactor designers, owners, operators, researchers and regulators. The proposals are intended to provide general guidance which, if carefully and properly followed, will result in reactor designs with enhanced safety characteristics beyond those currently in operation. They are derived from lessons learned from recent operational experience, research and development, design, testing, and analysis, as well as from attempts to reflect current trends in reactor design, such as the introduction of new technologies.

The proposals represent a contribution to the growing international consensus on what constitutes an appropriate set of technical principles for the design of future reactors. The document's starting point was the well-established set of objectives and principles for nuclear plants laid down in the INSAG safety report, *Basic Safety Principles for Nuclear Power Plants* published by the IAEA in 1988. According to definitions in this document, safety objectives state *what* is to be achieved. Safety principles are statements of *how* the objectives are to be achieved.

The safety objectives and principles for today's plants are to a large extent also valid for future designs. However, the 1995 technical document proposes some modifications of the technical safety objective and some new principles. The key proposal is that severe accidents beyond the existing design basis will be systematically considered and explicitly addressed during the design process for future reactors.

The document also emphasizes the need to further lower the risk of any serious radiological consequences and to assure that the potential need for prompt off-site protective actions can be reduced or even eliminated. Defense-in-depth remains the main strategy to deal with severe accidents for future nuclear plants and it is founded on measures for effective prevention and mitigation.

Areas of greater co-operation

A number of areas call for greater efforts to harmonize technical and policy matters related to future nuclear power plants. While many of these areas present promising opportunities, others do not. Some areas where a harmonized approach is lacking are likely to remain that way for many years because of large national differences in geography, culture, policy, and regulation. Other areas are likely to remain flexible because of market forces.

Overall, greater co-operation is needed to resolve important technical and policy differences. Increased harmonization would likely improve the safety, cost, and availability of future nuclear power plants, and would likely improve the consistency and efficiency of the licensing process. It might also have indirect benefits in the area of public acceptance. The technical convergence of safety experts, regulators, and utility operating organizations around the world on a consistent set of principles would likely increase confidence that the right conclusions have been reached.

Specific opportunities for greater harmonization lie in the field of safety assessment, including severe accident assessment. Primarily needed is agreement among the many organizations that conduct safety assessments on more common approaches. Specific areas that need concerted co-operative efforts include:

- probabilistic safety assessment (PSA) methods, and the role of PSA in safety decision making, including the appropriate balance among PSA, deterministic methods, and engineering judgment;
- methods and criteria for selecting those severe accident sequences to be addressed in the design of future plants;
- methods and criteria for treating uncertainties, and on the practical implementation of policies that require analysis for all severe accident considerations;
- approaches concerning the distinction between design basis accidents, as analyzed for the licensing case, and severe accidents that are also considered in the design and considered by the regulator;
- safety assessment procedures within the licensing process from country to country, including technical documentation requirements; consideration also should be given to harmonization steps that ease the complications inherent in licensing a plant designed to the codes and standards of a different country;
- improved consistency in source-term evaluation methods, and other methods for calculating radiological consequences of accidents.

It should also be noted that national approaches for dealing with external hazards vary substantially. Harmonization of practices for future plants seems to be difficult because types and levels of external hazards are site-specific. The issue of external hazards has emerged as an increasingly important one as greater safety levels are achieved for internal hazards, leaving the relative contribution from external hazards more relevant.

Additionally, high-level safety goals should be defined that allow safety targets unique to nuclear power plants to be derived from and compared to the broader issues of public health and safety protection for other enterprises. A step in this direction is the IAEA's publication of the technical document, *Policy for Setting and Assessing Regulatory Safety Goals* (IAEA TECDOC-831). It reflects peer group discussion of senior regulators from 22 Member States.

The work is part of the Agency's continuing effort to contribute to the process of wide international discussion on the harmonization of safety goals, objectives, and principles for future nuclear power plants. The process can help ensure that diverse and different views are fully considered and balanced through greater international co-operation in this important field. ❑

Global co-operation in nuclear fusion: Record of steady progress

Working together to pool resources and expertise, countries are moving ahead to design an experimental fusion reactor

by T. J. Dolan,
D. P. Jackson,
B.A. Kouvshinnikov,
and D. L. Banner

Enough potential energy is locked in the earth's oceans to last millions of years. Their waters contain deuterium, a heavy isotope of hydrogen and the main fuel for a nuclear fusion reactor. Once extracted, the deuterium from just one litre of water could generate as much energy as the combustion of 300 litres of gasoline.

While it will take decades for the potential to become reality, important strides already have been made. Technological and scientific advances today are bringing the technology of nuclear fusion closer to demonstration. To a large extent, the progress in fusion research and development is driven by the world's growing energy needs, environmental concerns, and population trends.

Burning fossil fuels for energy and electricity production has its limits. Four factors in particular limit utilization:

- the human health effects of fossil fuel combustion (emphysema, cancer)
- the environmental effects (acid rain, greenhouse effect, etc.)
- the need to save hydrocarbons for convenient fuels and chemical feedstocks
- the finite reserves of fossil fuels (coal, oil, natural gas).

In estimating global energy supplies, the World Resources Institute (WRI) has placed the world's total proven energy *reserves* at about 3.5×10^{22} joules (J). Of the total, proven coal *reserves* are estimated to be about 2.44×10^{22} J; proven oil reserves about 0.56×10^{22} J; and proven natural gas reserves about 0.50×10^{22} J.

There are additional fossil fuels available called *resources*. They are more difficult to recover, however. Consequently their price will escalate significantly during the transition from the use of *reserves* to the use of *resources*.

In 1994, the world's rate of primary energy consumption was about 11.6 terawatts (TW), about 87% of which was from fossil fuels. At that rate of consumption, the world's fossil fuel reserves would last about 120 year. However, in spite of effective conservation measures, the energy consumption rate is growing, as developing nations improve their standards of living. At a growth rate of 2% in energy consumption per year, these reserves would last only 61 years.

In the coming decades, many new power plants will be required to increase the total capacity for meeting electricity demands, to replace ageing power plants, and to replace fossil fuel plants for reasons related to environmental, health, and cost concerns. Even under the most optimistic scenarios, researchers have projected a shortfall in energy supply by the year 2030 exceeding 5 TW. This is a staggering amount equivalent to 5000 power plants, each capable of generating 1000 megawatts of electricity. Major non-fossil sources of energy must be developed and deployed to provide more than 10% of the world's energy within the next 40 years.*

Most renewable energy sources — although making valuable contributions in specific situations — will be inadequate to produce the large quantities of electric power required. Three sources, however, can potentially meet world needs: solar, fission, and fusion. Each has advantages and disadvantages.

Solar energy is diffuse, intermittent, and not suitable for use in some climates, and it is usually expensive. Fission breeder reactors could extend the world's supply of fissile fuels, but they are not universally welcomed by the public. Fusion

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*See "The need for research and development in fusion: Economical energy for a sustainable future with low environmental impact", by B.G. Logan, L.J. Perkins, R.W. Moir, and D.D. Ryutuv, *Fusion Technology 28*, pgs. 236-239 (1995).

reactors could have many desirable features, but much more work is needed to bring them to fruition. If fusion reactors are successfully developed, as many believe they will be, they could significantly brighten the world's energy picture. *(See box.)*

It is also possible to develop a hybrid fusion-fission reactor by putting uranium in the blanket of a fusion reactor, in order to boost the power output and breed fissile fuel. Such a hybrid reactor could have economic advantages, but it would be more difficult to license because of safety, environmental, and security concerns.

The world needs to pursue nuclear power vigorously, to facilitate both the deployment of advanced fission reactors and then fusion reactors before shortages of fossil fuels cause an escalation of fuel prices. Moreover, the nuclear options will have an essential role in counteracting the threat of global climate change that is increasingly being recognized as a consequence of the use of fossil fuels. Fission power already is partially replacing some carbon-based fuels, and in the future fusion power could be even more attractive. For these reasons, fusion research and development is carried out worldwide in some 40 Member States of the IAEA. The work includes fusion safety studies to ensure that the potential safety and environmental advantages of fusion power will be realized.

For many reasons, global co-operation has characterized the research and development of nuclear fusion. The collaboration has moved from small experiments to the design of a large thermonuclear reactor. This article presents an overview of co-operative efforts and updates the status of current work.

Potential Positive Characteristics of Fusion Power

In terms of many energy and environmental issues, nuclear fusion has a number of attractive characteristics:

Fuel supply: Deuterium extraction from water without harmful by-products; available inexpensively to all countries. Enough deuterium in oceans to last millions of years.
Mining: Limited mining of lithium, used to breed tritium for fusion reactors. (Seawater also contains 0.17 ppm lithium.)
Environmental issues: Fusion is environmentally safe.
Nuclear weapons proliferation: No plutonium or uranium present.
Safety: The amount of fuel in the plasma is so small that even complete burnup would not cause an explosion. Heat removal is not difficult because of low level of decay heat, spread over a large volume. Tritium inventory can be minimized by careful design. Potential off-site radiation dose during accidents may be low enough that no evacuation plans are required.
Radioactive by-products: Generation of long-lived radioactivity in the structure can be minimized by careful choice of materials. The vanadium alloy, lithium coolant, and unburned deuteriuim-tritium fuel could be recycled.

A history of international co-operation

There are several reasons why global co-operation has been particularly valuable in fusion research. They include the need to pool expertise and share the cost of large projects; the desire to speed progress by sharing knowledge of plasma theory, experimental results, computer codes, materials properties, and technology developments; and the desire to help developing countries build up expertise in fusion physics and technology.

In the 1950s, nuclear fusion experiments were small, employed a few people, and cost on the order of a million US dollars. Nowadays, some of the experiments are much larger, they employ hundreds of highly-skilled people (who might not all be available in one country), and they can cost billions of dollars. There are also many small- and medium-scale fusion experiments that provide valuable contributions to the worldwide effort.

Nevertheless, because of the potential importance of fusion power in the future, countries also require strong domestic fusion programmes, so that the science and technology results flowing from international collaboration can be applied at home. While most fusion research is at a pre-competitive stage, there are technical areas where the protection of intellectual property of contributing countries is necessary, and this requirement must be respected in establishing collaborative arrangements. There is also some concern about sharing technology that could have possible military applications, such as inertial confinement fusion.

In the early 1950s nuclear fusion research began independently in several countries, cloaked in military secrecy. Magnetic pinches, mirrors, and toroidal devices were studied, and some neutrons were observed. There was optimism of "fusion power within 20 years." Then the initial optimism was tempered by the realization that the neutrons were not from thermonuclear reactions and that plasma instabilities were spoiling confinement. A better understanding of plasma behaviour would be required, and could be facilitated by sharing results with other countries.

The Soviet Union led the way in 1956 by sharing its fusion research results with Western countries. The first major international co-operation occurred at the Geneva Conference on Peaceful Uses of Atomic Energy in 1958. In that same year, the IAEA began its operations. The first IAEA Conference on Plasma Physics and Controlled Thermonuclear Research was held in Salzburg in 1961, and today this meeting (now renamed the "IAEA Fusion Energy Conference") is held at 2-year intervals. In 1972, the IAEA established the International Fusion Research Council (IFRC), which advises the Agency on its wide scope of fusion research activities.

In parallel with the Agency's activities, many bilateral and multilateral agreements for collaboration in fusion research have developed among countries over the years. Historically, such agreements were often the first steps in bringing new players into international fusion co-operative work. In other cases, they have proved particularly useful when a high level of mutual collaboration is envisaged in specific work areas. Examples of such collaboration are the participation of Japan in the US Tritium Systems Test Assembly and Doublet-III projects, and the participation of Canada in ITER through agreements with the European Union.

The International Energy Agency (IEA), part of the Organization for Economic Co-operation and Development, was formed by the Western industrialized countries in the 1970s as a response to the oil price shocks of 1973. The IEA covers all areas of energy R&D including fusion, while its sister organization, the Nuclear Energy Agency, covers areas of fission.

IEA collaboration is organized by means of implementing agreements with annexes referring to specific work areas. In principle, any IEA member country can participate in any of these agreements by sharing in associated costs as a Contracting Party; other, non-member countries can now also join as Associate Contracting Parties, as Russia has done with a number of the fusion agreements. Currently, there are active implementing agreements covering large tokamaks; TEXTOR; ASDEX-upgrade; stellarators; reversed field pinches; fusion materials; fusion nuclear technology; and the environmental, safety and economic aspects of fusion power.

These activities are overseen by the Fusion Power Co-ordinating Committee, which is the IEA counterpart of the IFRC, and the two committees have several members in common. In recent years increasing efforts have been made through these oversight committees to co-ordinate the fusion activities of the two agencies, in order to avoid overlap and duplication.

Origins of the ITER project

In 1978, the IAEA organized the International Tokamak Reactor (INTOR) workshop to define the next major experimental tokamak, as recommended by the IFRC. This work assembled information on plasma behaviour, cross sections, and materials properties, produced a reference reactor design, and defined the key issues to be resolved. The results were documented in a series of IAEA reports issued from 1982-88.

The success of INTOR in demonstrating the feasibility of sustained technical collaboration was one factor that influenced the subsequent establishment of the International Thermonuclear Experimental Reactor (ITER) project. *(See figure, next page.)* An additional factor was the G-7 ("Western Economic Summit") meetings that had identified fusion as one of the areas with potential for increased economic growth by mutual co-operation. These and other factors provided a fertile background to the immediate political impetus for the ITER project, which was proposed by General Secretary Gorbachev (USSR) to President Mitterand (France), and then to President Reagan (USA) at their 1985 Geneva Summit Meeting.

Ultimately, in 1988, the ITER Conceptual Design Activity (CDA) was launched by four Parties: the European Community, Japan, the Soviet Union, and the USA, which all have major fusion research programmes. After completing the CDA, the four Parties agreed to proceed with the Engineering Design Activity (EDA) from 1992-98.

The Agency played a crucial enabling role in the inception of ITER, and it now provides the auspices for the four-Party collaboaration and certain facilitators, including administration of the ITER joint funds and co-ordination with pertinent technical work conducted by the Agency's Nuclear Data Section.

IAEA fusion-related activities

In addition to providing support to ITER, the IAEA has a variety of other activities that promote the development of international collaboration in nuclear fusion research. *(See box page 21.)* In essence, the IAEA is a major focal point for such multinational collaboration in fusion research.

The monthly journal *Nuclear Fusion* has been published since September 1960. The Agency's biennial conference, which covers a broad spectrum of topics in fusion research, typically has about 500 attendees. The IAEA Nuclear Data Section staff update the data libraries, distribute the new information to researchers

Renewed Consensus of ITER Council

Following three decades of steady progress in design and experiments, the four leading participants in world fusion research agreed in 1992 on the objectives and requirements of the optimum next step in the development of fusion as a source of energy. ITER was conceived as the project to achieve these objectives through the equal partnership of the four Parties. The width and depth of fundamental physics, technology, know-how, and research required to support ITER, as well as its cost, speak for this step to be undertaken through international cooperation. In July 1995, about halfway through the ITER Engineering Design Activities, a renewed consensus in the ITER Council reaffirmed that ITER is a necessary step; that its objectives remain attainable and must not be changed; that the design can meet the objectives; that the quadripartite co-operation has shown itself to be an efficient frame; and that the right time for such a step is now. The success of fusion worldwide depends on this step, and ITER should continue to benefit from full international co-operation, so that fusion physics and technological know-how can be focused and consolidated in support of ITER, making the optimum use of large but limited resources.

Computer-generated model of the International Thermonuclear Experimental Reactor (ITER), the fusion device that when built would be about 30 meters high. Shown are 1) the cryostat vacuum vessel; 2) vertical access port; 3) central solenoid; 4) blanket/shield; 5) plasma chamber; 6) port to provide access to plasma chamber; 7) divertor; 8) poloidal field magnet; 9) vacuum pump duct for exhaust; 10) toroidal field magnet.

around the world, and plan research to fill gaps in existing knowledge. The Atomic & Molecular and Plasma-Material Interaction data collected and evaluated by the IAEA are especially useful to the ITER project.

The IFRC provides liaison with member states, contacts with experts in various fusion research specialities, and guidance on planning the IAEA fusion research activities. The IFRC members are appointed by the IAEA Director General.

Some technical committee meetings are held annually, such as the one on research using small tokamaks. Others are held every two or three years, such as those on fusion reactor design and on fusion safety. Held less frequently are some technical committee meetings, as well as advisory group meetings, such as those on alpha particle physics and on H-mode physics.

Co-ordinated Research Programmes (CRP), which may last two to five years, lead to scientific reports summarizing the status of research in a particular field. There are usually several fusion-related CRPs in progress, each with five to 10 participants from both developed and developing Member States. The Agency's technical co-operation program further includes activities such as fellowships for scientists from developing countries to work in major laboratories. More requests are being sought from IAEA Member States to more fully make use of this programme in the fusion research field.

Status of the ITER engineering design

ITER's work and Joint Central Team (JCT) are spread among three electronically-connected Joint Working Sites: Garching, Germany, in the European Union (in-vessel components); Naka, in Ibaraki Prefecture, Japan (ex-vessel components); and San Diego, California, in the USA (design integration, environment, safety, and health). The formal seat of the supervisory ITER Council is in Moscow, Russia.

In addition, each of the four Parties has a Home Team that contributes to the design effort and undertakes the associated R&D tasks. The ITER Council, consisting of two representatives from each of the four Parties, governs the project and appoints the ITER Director, who manages the project. A Technical Advisory Committee, consisting of four leading scientific and technical persons from each party designated by the ITER Council, provides advice to the Council on all technical matters requested by the Council. A Management Advisory Committee, having three representatives designated by each Party, provides advice to the Council on management and administrative matters. This system, although complicated and spread around the globe, is working well.

The six-year ITER Engineering Design Activity involves *design* work with a total professional manpower of 1340 person-years plus basic technology and specific engineering research and development totaling US $750 million (in 1989 US dollars). The *ITER Interim Design Report, Cost Review and Safety Analysis* was prepared by the ITER JCT and accepted in July 1995 by the ITER Council for consideration by the ITER Parties. This report is supported by detailed technical documentation: the *Interim Design Report* and *Design Description Documents* totalling about 4350 pages and 1400 drawings.

In the early Spring of 1996 the IAEA will issue the *Interim Design Report* as a separate technical publication in the ITER Documentation Series. There is good progress towards resolution of most of the technical issues.

The construction phase of ITER is estimated to take about 10 years from the construction decision to the first plasma.

Prospects for future collaboration

In the field of nuclear fusion, there will still be major research projects conducted primarily by one party, but even those projects will employ some experts from other countries. Researchers around the world have learned to respect each other's unique skills and to appreciate the value of exchanging viewpoints. The ITER project has achieved great strides in international collaboration, demonstrating that the problems created by national interests and pride, geographical separation of research teams, and cultural differences can be successfully overcome. Thus, the ITER experience in the management of a large, multinational project could also be helpful to other projects in the future.

Since other potential new fusion devices, such as a 14-MeV neutron source for materials testing and a tokamak Demonstration Reactor, will be very expensive, it is probable those projects will also seek joint funding from several parties. Because of the worldwide political pressures to cut budgets, cost-sharing is encouraged for large fusion research projects.

Another beneficial aspect of international collaboration is the potential for increased participation in major projects by innovative scientists from developing countries. Bringing these scientists together to participate in a laboratory can serve to speed up progress in fusion research, in addition to helping the developing countries.

IAEA Activities Related to International Collaboration in Fusion Research

Publication of the monthly scientific journal *Nuclear Fusion* and its supplements, such as the *World Status of Activities in Controlled Fusion Research* (periodically) and *Atomic and Plasma-Material Interaction Data for Fusion* (annually)

Publication of the *International Bulletin on Atomic and Molecular Data for Fusion* (biannually), distributed to more than 800 institutions and researchers among Agency Member States.

Organization of the Biennial IAEA Fusion Energy Conference and publication of the conference proceedings

Development of libraries of nuclear data (such as FENDL), atomic & molecular data, and plasma-material interaction data that are relevant to fusion research. These data have been internationally recommended for use in fusion research and reactor design work. They are stored in the Agency's Nuclear Data Information System (NDIS) and Atomic and Molecular Data Information System (AMDIS), and are on-line accessible via Internet. The IAEA's International Nuclear Information System (INIS) also includes a fusion specialist.

International Fusion Research Council (IFRC)

Technical Committee Meetings (TCM) on relevant topics, such as:
- Research using small tokamaks
- Advances in computer modelling of fusion plasmas
- Alpha particle physics
- Steady state operation of tokamaks
- H-mode physics
- Fusion safety
- Fusion reactor design

Advisory Group Meetings (AGM)
- Third World Plasma Research
- Inertial Fusion Energy
- Technical Aspects of Atomic and Molecular Data Processing and Exchange

Co-ordinated Research Programmes (CRP), such as:
- Software development for numerical simulation and data processing
- Plasma heating and diagnostics systems in developing countries
- Lifetime prediction for a fusion reactor first wall
- Plasma-interaction induced erosion of fusion reactor materials
- Radiative cooling rates of fusion plasma impurities
- Reference data for thermomechanical properties of fusion reactor plasma facing materials
- Tritium retention and release from fusion reactor plasma facing components
- Atomic and plasma-wall interaction data for fusion reactor divertor modelling

Coordination of the activity of an International Atomic and Molecular Data Centre Network, comprising 15 national data centres.

Book, *Energy from Inertial Fusion (1995)*

Status Report on Controlled Thermonuclear Fusion, Executive Summary prepared by the IFRC on the current state of research around the world, Anniversary Issue of *Nuclear Fusion*, Vol.30, No. 9 (1990).

Technical Co-operation projects with developing countries, such as fellowships

Provision of auspices for the International Thermonuclear Experimental Reactor (ITER) Engineering Design Activity (EDA)

Industrial applications of plasmas are being commercialized around the world. These applications include plasma spray coatings, surface modification, synthesis of new materials, chemical reaction enhancement, and processing of chemical contaminants. The IAEA is starting a CRP to promote collaboration in this area.

The needs of the world fusion research programme include completion of the ITER project; an inertial fusion energy ignition experiment; alternative fusion concept research; development of fusion reactor materials (a powerful neutron source is required for irradiation testing); a strong plasma theory and simulation programme; and support for university research and graduate student education in plasma sciences and fusion technology. International collaboration can help fulfill most of these needs more efficiently than individual countries can on their own.

In summary, the world needs nuclear fusion research to provide a complementary energy source to solar energy and nuclear fission reactors. International collaboration can pool expertise and share the cost of large projects; accelerate progress by sharing knowledge; and help developing countries build their infrastructure in plasma sciences and fusion technology.

The IAEA, the IEA, and various bilateral agreements promote such collaboration. The IAEA is conducting a broad scope of activities, including its monthly journal; the biennial conference; atomic, molecular, and plasma-material-interaction data coordination; technical committee meetings; and Co-ordinated Research Programmes.

Over the past half century, the worldwide nuclear fusion research programme — from the first Soviet initiative through the IAEA activities to the ITER EDA — has become a premier example of scientific co-operation. It should serve to benefit all people, if fusion power plants are deployed to help meet the world's energy and electricity needs. ❐

Nuclear fusion: Targeting safety and environmental goals

Analyzing fusion power's potential for safe, reliable, and environmentally friendly operation is integral to ongoing research

by
Franz-Nikolaus Flakus, John C. Cleveland, and T. J. Dolan

For some decades, people have looked to the process powering the sun — nuclear fusion — as an answer to energy problems on Earth. Whether nuclear fusion can meet our expectations remains to be seen: technological problems facing a fusion power plant designer are complex and a fusion power plant has not yet been built. Remarkable progress has been made, however, toward realizing fusion's potential.

Research in fields of nuclear fusion has been pursued in various countries for decades. The efforts include the JT-60, which has provided important results for improving plasma confinement; the D-IIID tokamak experiment, which has achieved record values of plasma pressure relative to the magnetic field pressure; and the Tokamak Fusion Test Reactor (TFTR), which has generated 10 million Watts of thermal power from fusion. The Joint European Torus (JET) is expected to approach breakeven conditions, where the fusion power generated exceeds the input power. Unresolved physics issues, such as plasma purity, disruptions, and sustainment of current, should be resolved by the International Thermonuclear Experimental Reactor (ITER), which is being designed by experts of the European Community, Japan, Russian Federation, and the United States. *(See related article beginning on page 16.)*

There is confidence that the engineering design issues — including those concerning superconducting magnets, vacuum systems, cryogenic systems, plasma heating systems, plasma diagnostic systems, and blanket cooling systems — can eventually be solved. Other important aspects in designing a fusion power plant relate to safety and economics. This article looks at safety aspects of fusion power plant designs, and reviews efforts in safety-related areas that are being made through international co-operative activities.

Safety-related goals and considerations

Reliable predictions of the cost of electricity from fusion power cannot be performed until design details of commercial fusion power plants have been established. Currently, this cost is not projected to be significantly less than the costs of other energy sources.

In areas of safety, however, fusion holds potential advantages over other energy sources. In nearly all studies related to the design of a fusion power plant, safety and environmental considerations are being increasingly emphasized, and safety goals for fusion have been extensively discussed. The safety and environmental goals of a fusion power plant design are to protect workers from radiation, electromagnetic fields, and other hazards; the public from radioactive and toxic materials; the environment from pollutants and waste; and the investor from damage by accidents.

The fusion process. At sufficiently high temperature, nearly all light nuclei undergo fusion reactions and could in principle be used to fuel a fusion power plant. However, technical difficulties increase rapidly with the nuclear charge of the reacting isotopes. For this reason, only deuterium, tritium and isotopes of helium, lithium, and boron have been proposed in practice.

The first generation of fusion power plants will very likely use deuterium-tritium (DT) fuel because it is the easiest to ignite. The main reaction product, helium-4, does not pose a health hazard. The principal energy output from a DT fusion event is a 14 MeV neutron.

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Nearly all materials become activated to some degree by energetic neutron bombardment. Neutron reactions in DT fusion reactors will inevitably create radioisotopes. The principal radioactive materials present in a DT fusion reactor will therefore be tritium and neutron-activated structural materials surrounding the reaction volume.

Safety-related considerations. Specific fusion power plant safety studies, which are complementary to many other safety studies, include those related to tritium safety, the assessment of tritium releases, activation product safety, radioactive waste disposal, and analyses of potential accidents and their consequences.

The release rate of tritium during plant operation has to be kept well within an acceptable safe range. This release of tritium is modeled by computer codes that account for tritium permeation through the materials present in the power plant. Major tritium research laboratories are in Canada, Germany, Italy, Japan, the Russian Federation, and the United States.

The generation of neutron activation products is not a serious problem if they can be contained and if they have short half-lives. They are a byproduct of the fusion reaction, not a direct reaction product. Therefore, their generation in the blanket and structure of the reactor is under the control of the designer and can be minimized by proper design and appropriate choice of materials. The use of a variety of low activation materials is being extensively studied.

There is no potential for a runaway fusion reaction; indeed, the problem is making the fusion reaction proceed adequately at all. Virtually all hardware problems lead to fusion shutdown, and there are inherent limits in any case because of the limited amount of fusion fuel present and the nature of the fusion reaction. However, a particular focus of work in fusion safety is the analysis of various other potential accidents, such as magnet accidents, and "consequence calculations" are performed. For categorization of accidents into event groupings and estimation of the frequency of accidents, specific component reliability data are required.

The approach for conducting a general safety analysis for fusion plants is similar to that used for the design of other large nuclear installations. *(See box, page 25.)* The results of safety analyses indicate that fusion power plants can meet the desired safety goals. For example, the *ESECOM* study compared the safety and economic aspects of many fusion reactor designs.* The general safety issues of ITER were discussed and a draft report has been issued giving preliminary results of the ITER safety analysis.

Fusion power plant safety studies have been evolving for more than 20 years. They are steadily adapting to the evolution of internationally agreed radiation safety concepts and requirements.

In 1994 the IAEA, jointly with five other international organizations issued revised *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources.* The Basic Safety Standards — issued jointly with the Food and Agriculture Organization (FAO), International Labour Office (ILO), Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD/NEA), Pan-American Health Organization (PAHO), and World Health Organization (WHO) — take account of new recommendations on radiation protection of the International Commission on Radiological Protection (ICRP). A central part of the dose limitation system is the "optimization of protection" principle. Fusion is a good candidate for the successful application of this principle. Optimization is best achieved when safety assessment is already built into the early design stages of a project.

As pointed out earlier, the first fusion power plants will most likely use the DT fuel cycle. Once a fusion power plant based on the DT reaction has been built, advanced fuels could be further pursued for energy exploitation. This would bring about a lower tritium inventory. Later fusion power plants may evolve to fuels (such as deuterium + ^{3}helium) that generate fewer neutrons, and hence produce less radioactivity in surrounding materials. Thus, during the evolution to advanced fuel cycles, the safety advantages of fusion may increase with time. It may be possible in the future to design power plants with low enough radionuclide inventories so that emergency planning and preparedness are unnecessary.

Practical realization of fusion

It has been estimated that an investment of the order of US $50-100 billion is needed to bring fusion power to fruition. The rate of progress in fusion research is limited by the funding rate, which is estimated to be about US $1.5 billion per year worldwide.

* See "Report of the Senior Committee on Environmental, Safety, and Economic Aspects of Magnetic Fusion Energy", by J.P. Holdren, D.H. Berwald, R.J. Budnitz, et.al., UCRL-53766 (1989).

Currently, expectations are that ITER could begin significant DT operation around 2005-2010, followed by construction of a demonstration power plant. A demonstration fusion power plant could then begin operation about two decades later. If the demonstration reactor is successful, i.e. if sufficient operational experience warrants financing of a commercial power plant, then early commercial fusion power plants could begin operation by about 2050.

This estimated timetable could be delayed or accelerated. It could be delayed by funding shortages or by unforeseen difficulties with plasma phenomena or technology. The schedule could be accelerated by a breakthrough in understanding of plasma behavior (such as, perhaps, the recent success with the "reversed shear mode" of tokamak operation), by a new invention that enhances plasma confinement, and by providing an increased funding rate.

Non-tokamak types of plasma confinement are also being studied, to develop reactors that can produce electricity at a lower cost. For example, large stellarator experiments are under construction in Japan and Europe. It is clear that safety studies will play a major role in earning and keeping public trust, desire, and acceptance of fusion power.

Fusion Safety Philosophy

The fusion safety philosophy now includes the following concepts:

- passive systems and inherent safety features;
- fail-safe design;
- reliability (including redundancy of components (pumps, valves, etc.); diversity (such as two different ways of supplying back-up power); independence (if one component or system fails, it does not cause an adjacent one to fail); simplicity; and surveillance, to detect flawed components before an accident occurs);
- consideration of human factors;
- remote maintenance capability;
- safety culture in worker attitudes;
- quality assurance (including codes and standards; verification and validation; and safety analysis);
- operational controls (fault detection, automatic corrective response);
- safety systems to reduce consequences of failures;
- accident preparedness and management, to preserve confinement integrity;
- emergency planning to mitigate effects of radioactive releases, if needed.

IAEA activities in fusion safety

Guided by the International Fusion Research Council (IFRC), the IAEA is conducting a range of activities that promote international co-operation and help to enhance the safety and environmental advantages of fusion power. They include supporting the ITER project, whose Engineering Design Activity has passed the halfway point. The ITER experiment will have safety built into the design, to ensure that no fatalities can arise during a serious accident by release of radioisotopes. In 1995, the Agency published a discussion of safety in inertial fusion reactors.

Many IAEA activities in the area of radiation safety are relevant to fusion safety. They cover topics such as safety standards for radiation protection, safe transport of radioactive materials and management of radioactive waste, guidelines for safe handling of tritium, and limitation of radioactivity releases into the environment.

Since 1973, fusion safety has been a special item on the Agency's agenda of safety activities. Over the past two decades, the Agency has organized several technical committee meetings on fusion safety which discussed progress, research needs, and future plans. Typically about 50 experts from a dozen Member States have attended these meetings, which were held about every three to four years. The proceedings of the latest meeting in this series, held in 1993 in Toronto, Canada, were published in the *Journal of Fusion Energy* in June 1993. The next meeting is planned in October 1996 in Japan.

Prospects and future directions

Fusion reactors have a significant potential for safe, environmentally benign operation. Safety aspects of fusion power plants, which have been designed on paper, cannot yet readily be compared with safety aspects of fission power reactors or other operating energy sources. In fusion, the bulk of radioactive material is a secondary product resulting from neutron activation, leaving room for optimization of protection through materials development and selection, or by using advanced fuels.

To ensure that the potential safety and environmental advantages of fusion can eventually be utilized, safety engineering must be integrated into fusion reactor designs. This is being done by

Fusion Safety Analysis

As in safety studies of other large nuclear installations, various steps are involved in accident analysis of a fusion power plant.

Each sequence of events may be represented by an "event tree", and each branch of the tree has an associated probability of occurrence. For example, if a valve is ordered to close, it has a finite probability of failing to do so. For loss-of-coolant and loss-of-flow events, the temperature rise in the first wall and blanket must be calculated as functions of time. Then the mobilization of various elements can be estimated, based upon data from laboratory tests.

The amount of a radioisotope that is mobilized during an accident constitutes the "source term". Sometimes the source consists of an oxide aerosol, of which most would plate out inside the building. During a severe accident with damage to the containment, a fraction of the aerosol might leak out of the containment to the atmosphere. Sophisticated computer codes are used to model:

- neutron and gamma ray transport in the first wall, blanket, and shield;
- generation of radioisotopes by neutron absorption;
- temperature rise due to afterheat and chemical reactions during accidents;
- mobilization of radioisotopes during accidents;
- transport of aerosols inside the confinement building (and reaction released);
- transport of released particles and gases to the site boundary;
- radiation dose to the "maximum exposed individual" at the site boundary.

the ITER Project, although ITER is an advanced experimental fusion reactor and should not be viewed as a prototype fusion power reactor.

As fusion safety studies progress, more and more interdisciplinary work will be required. Over the long term one can confidently expect that safety will be strengthened as progress is made in fusion power plant design. A statement made by C.M. Braams, Chairman of the IFRC, 20 years ago in an introductory note to a review elaborated at that time, remains valid today:

"... although the prospects for taking advantage of the environmental merits of fusion are good, it is clear that fusion reactors, if they become a reality, will have an environmental impact - including radiation hazards - whose magnitude will depend on the progress of research, on the availability of materials and on how much society is prepared to spend on minimizing the impact". ❐

Steps of Fusion Power Plant Accident Analysis

I. Consideration of the potential hazards

These include:

- gamma radiation
- routine releases of tritium
- accidental releases of radioactive material from
  - structure
  - coolant
  - corrosion products
  - dust
  - tritium in walls, blanket, coolant, vacuum system, fueling system
- toxic materials, such as berylium, vanadium, lead
- electromagnetic fields
- vacuum
- cryogenic fluids
- asphyxiants (gases such as N_2, He)
- chemical reactions
  - liquid metals with water, air, or concrete
  - hot surfaces with water or air
  - hydrogen generation and explosion
- high voltage
- rotating machinery
- lifting heavy masses
- missiles generated by turbine blades, magnet coil arcs, or high-pressure gases.

II. Analysis of energy sources available to "mobilize" radioactive materials

Examples of estimated values:

● decay heat	[910] GJ in first week
● chemical reactions	[800} GJ
- coolant	
- water/air + hot plasma-facing components.	
● coolant stored energy	300 GJ
● magnet coil stored energy	120 GJ
● fusion reaction full power	1.5 GJ/second
● plasma magnetic energy	1.3 GJ
● plasma thermal energy	1.2 GJ
● vessel thermal energy	small
● vacuum	small

III. Analysis of possible accidents, such as:

- plasma events
  - fusion overpower
  - disruptions
  - delayed shutdown
- loss of coolant event
- loss of flow event
- loss of vacuum event
- magnet events
- loss of cryogen
- tritium plant events
- auxiliary system events

Radioactive waste management: International peer reviews

Countries are evaluating their programmes through the IAEA's Waste Management Assessment and Technical Review service

by Ernst Warnecke and Arnold Bonne

International peer reviews have become a central feature of the IAEA's safety-related services. In areas of radioactive waste management, they are gaining greater attention among countries as an effective tool for objective technical feedback and assessment.

The Agency's peer review service for radioactive waste management — known as the Waste Management Assessment and Technical Review Programme (WATRP) — started in 1989, building upon earlier types of advisory programmes. WATRP's international experts today provide advice and guidance on proposed or ongoing radioactive waste management programmes; planning, operation, or decommissioning of waste facilities; or on legislative, organizational, and regulatory matters. Specific topics often cover waste conditioning, storage, and disposal concepts or facilities; or technical and other aspects of ongoing or planned research and development programmes. The missions can thus contribute to improving waste management systems and plans, and in raising levels of public confidence in them, as part of IAEA efforts to assist countries in the safe management of radioactive wastes.

This article presents a brief overview of recent WATRP missions and the review process itself. *(See box.)*

Recent peer reviews

Norway. In December 1994, the Norwegian Radiation Protection Authority requested a WATRP review of its work toward establishing a combined storage/disposal facility for low- and intermediate-level waste. The mission's main objective was to review safety-related aspects of the approach to the selection of the site, the technical concept, and the long-term safety of the facility.

A team of five experts from Canada, France, Germany, Switzerland, and the United States was formed to conduct this review. The team received background documents in June and July 1995. After reviewing the documents, the team prepared a questionnaire for the Norwegian experts in advance of a review meeting with them during the last week of September 1995. The team's final report has been prepared and submitted to the Norwegian Radiation Protection Authority.

The team found that the legal system and the licensing process as they are applied to the projected facility correspond to international standards. The criteria which have been applied for the selection of the site for the planned facility are comprehensive and consider the important factors for both environmental protection and long-term safety.

The team recommended that it would now be important to select a final design for the facility and to develop the detailed plans. These plans should also address the later conversion of the storage part of the facility into a repository for the plutonium-bearing waste or the removal of this waste from the facility.

Slovak Republic. In December 1993, the Nuclear Regulatory Authority of the Slovak Republic requested a review of the Mochovce disposal facility for short-lived low- and intermediate-level radioactive waste. As requested, the review's scope was limited to parts of Slovakia's Pre-operational Safety Report that are related to the evaluation of the facility's safety. The team's work was based on written material provided, discussions with Slovak experts and their consultants, and the evaluation of some of the archived design and construction records.

Five experts from Canada, Finland, France, Germany and Spain conducted the review. The

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INSIDE

TECHNICAL CO-OPERATION

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CONTENTS

Sri Lanka sets sights beyond the human eye

A large facility to irradiate and store a variety of human tissues for medical use on the Island and throughout the region is now near completion in the Sri Lankan capital of Colombo. A 10, 000 curie US-built irradiator provided from IAEA Technical Co-operation (TC) funds is now in place and the tissue bank is already in operation.

Tissue banking in Sri Lanka began nearly 20 years ago with one man and his home refrigerator when Dr. Hudson Silva launched his campaign to preserve eyes donated by his patients so that others who had lost their sight might see again.

The non-governmental organization (NGO) that Silva set up, Sri Lanka Eye Donation Society, popularly known as the Eye Bank, has since been approved by the government as a tax-free charity. Over 10,000 people in Sri Lanka have regained their vision with the aid of the society. In the last 30 years the bank has sent more than 30,000 sight-restoring corneas to

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The "right" stuff

In the rugged Peruvian highlands around Acobamba District, about 350 kilometres east of Peru's capital Lima, some unusual things have been happening this summer and autumn, even though the tenor of everyday work and life may not have been disturbed too much. The centre of activity has been four schools and especially 300 primary school 6-to-11 year old children who are being nutritionally evaluated using stable isotopes.

The exercise is the first part of a Technical Co-operation Model Project which began in July. TC's $700,000 funding is riding piggy-back on an on-going $15 million government programme that provides 524,000 breakfasts each day to poor school children; a number which President Alberto Fujimori

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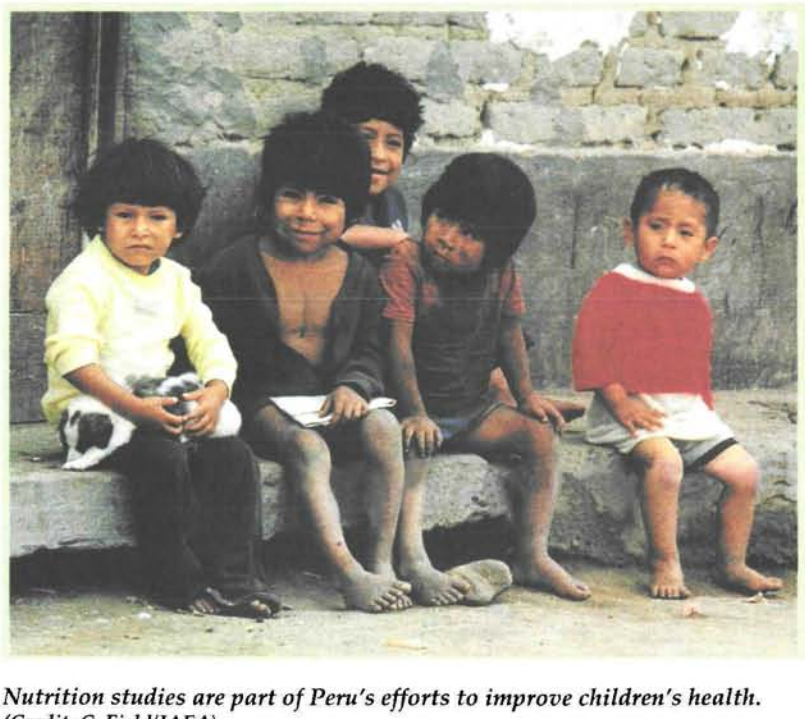

Nutrition studies are part of Peru's efforts to improve children's health. (Credit: C. Fjeld/IAEA)

Nuclear methods detect infant diseases

Congenital diseases can kill babies and cause lasting disability to infants who survive them. *Neonatal hypothyroidism* is one which can occur when the mother's diet is short of iodine — not uncommon in communities where nutrition is inadequate. In some places farm soil depleted of natural iodine is the principal cause. Neonatal hypothyroidism is seldom fatal but, arguably a fate worse than death for the victims and their families if it seriously retards the child's physical and mental growth.

Happily, if diagnosed in the **first days of life**, it can be treated with hormonal replacement regimes that allow the child to lead a near-normal productive life. How to detect it so soon? A nuclear technique called radioimmunoassay (RIA) can do it. This simple, safe, and relatively inexpensive diagnostic tool is now widely used to detect a large number of conditions, before classical symptoms surface.

Technical Co-operation has helped transfer this technology to many developing countries. There are variations on the RIA theme and each disease needs its own reagents and diagnostic know-how. Two of the most recent TC Model Projects, in **Tunisia and Uruguay**, target neonatal hypothyroidism. Both satisfy all the basic criteria of such projects: they are in tune with national policy; they dovetail into the country's health programme; they are sure to reach the end-users; and they are assured of support and commitment by the government.

Both countries have cleared the legal and bureaucratic hurdles for maximum project impact: Tunisia by Ministerial directives and Uruguay by a law that mandates the screening of newborn infants for hypothyroidism. Both countries have experience in the use of RIA, from earlier Agency and RCA (see back page) programmes. Both have adequate infrastructure in place to screen, analyse samples and prescribe treatment.

Both countries, too, have high neonatal hypothyroidism incidence rates (estimated at one in every 1000 live births in Tunisia, 1 in 3500 in Uruguay) which is ample economic justification for the effort. In Tunisia, in the early months of the project this year, one case of hypothyroidism was found (and is being treated) among 1500 newborn babies screened. Given an expectancy of working 30 years and Tunisia's per capita income of US $2000 a year, the child now has the potential to contribute $60,000 to the economy. This almost equals the total investment in the project's first nine months.

In Asia, nurses draw blood from an infant's heel to detect a thyroid disorder causing retardation.

Uruguay began a much less intensive screening programme some years back and identified seven positive cases among 21,500 newborns screened between 1990-94. Without the follow-up treatment, these children would have grown up mentally and physically impaired, possibly unproductive and a burden to both family and State. So, with an estimated occurrence rate of 1 in 3500, a large-scale screening programme was begun with Agency support involving more than 60 hospitals and clinics. About 33,000 newborns (60% of all newborns) were screened last year. On this basis, about 18 cases of neonatal hypothyroidism every year can be expected. Early treatment will permit these children to develop normal and productive lives. From a modest IAEA contribution of US $150,000, the expected economic benefit in Uruguay is US$1.4 million (assuming a working life expectancy of 30 years and average GNP of US $2,560).

The RIA procedure does not introduce anything radioactive into the babies. Instead it uses reagents — chemicals that produce chemical reactions in blood samples — that show whether the infant has the specific disease. The nasty part is the pinprick in the heel to draw out a few drops of blood for the test. It's in a good and healthy cause, and someday the 4-day old babies may just learn to appreciate that.

School children in Peru proudly show how a blood test is done.

The "right" stuff: **continued from page 1**

has promised would rise by 3,000,000 in 1996. The TC project goes beyond simply measuring what nutritional benefits the children derive from the special meals, and hopefully will contribute to intervention strategies for other undernourished regions in the developing countries.

Hunger is widespread in many developing countries. Many affected populations benefit from supplemental feeding programmes, often with bilateral and international support. These may assuage hunger but do not always provide proper nourishment. The World Health Organisation (WHO) calls it **hidden hunger**. This is especially true for susceptible groups such as nursing mothers, infants and children.

Nutritionists know a lot about which nutrient deficiencies cause what health problems, and doctors increasingly prescribe diets to treat individual patients. But it is a lot less easy when feeding whole communities, or target groups like women of childbearing age or young children as in Peru's school breakfast programme. While foods are fortified with vitamins and proteins, it is often uncertain whether the supplements meet the requirements for proper nutrition.

The essence of the TC project is to investigate definitive answers by using isotopic methods to evaluate the nutritional quality of foods and diet relative to nutritional status.

For example, WHO and most nutritionists recommend that green and yellow plant foods be eaten to combat vitamin A deficiency – the most common cause of childhood blindness. But, too often, intervention to improve vitamin A does not yield anticipated results. This is probably because of a shortage of dietary fat or poor conversion of the pro-vitamin to vitamin A.The shortage of this nutrient not only causes early blindness, it also undermines the immune system and retards growth and mental development.

The Peruvian project is assessing which ingredients (the right amount of fat and the best sources of pro-vitamin A) will optimize the conversion of the pro-vitamin into vitamin A. Another isotopic application will measure the vitamin A in the whole body. Local communities prepare and distribute the supplement to children and some parents even help with monitoring and sampling. On average, 87% of the parents in these four communities have agreed to participate.

The measurements and evaluations carried out in the project use isotopic methods because no other approach could provide answers as quickly or with as much assurance. The list includes measurement of total body water and body composition, from which nutritional status can be determined and decisions taken on which nutrients would be needed in dietary intervention. It also includes measuring total daily energy expenditure as a basis for planning the amount of calories required, and to determine whether an intervention would increase productive energy. Such measurements could be done with conventional tools in well equipped hospitals, but not in rural communities of the Peruvian highlands.

Measurement of the amount and rate of protein deposition in the body will allow selection of dietary ingredients that most efficiently convert food into growth — that is, the rate at which body protein becomes new tissue. The sensitive isotopic method can be applied without interfering with people's everyday activities. Conventional methods cause inconvenience (require people to be confined in special rooms for days and be asked to breathe into bags and the like), are costly, and/or need special expertise and time. Long-term growth of the children could be tracked of course, but it takes a long time and the results could be confounded by many factors unrelated to the dietary supplement.

The Acobamba evaluations also include iron, zinc, iodine, folic acid and immune status. Of the four schools, two are receiving the breakfast from the national programme, the other two, used as "controls", will get it in the following six months.

The project will be extended to other parts of Peru during its 4-year life. At the end it will provide solid field data that will contribute to improving fortified foods and nutritional supplements in the future. This information can also be used globally to help governments, donor agencies and the food industry plan and design effective interventions for children and other "at risk" groups.

The TC activity in Acobamba is already linked with a WHO vitamin A supplement programme, and an immunization campaign in Peru and Ghana.

Other organizations are involved as well. The United Nations' Food and Agriculture Organization (FAO) currently has an expert working with the IAEA on nutrition projects in Vienna. Other international bodies showing interest in isotopic evaluations include UNICEF and UNFPA.

In October, the Agency hosted an expert meeting to plan nutrition research and evaluation programmes within the IAEA in the coming decade. In attendance were nutrition experts from the US, the Netherlands, and the UN agencies who also collaborated to provide advice on how to accelerate the process by which nutrition science is used as a basis for food production and public policy.

A "gel" route in China

Half a million more patients in southwest China could have the organ scans and diagnostic health care they need when an unconventional method for producing **technetium** "generators" reaches industrial scale, possibly as early as next year. IAEA Technical Co-operation has been assisting with expertise and materials since 1994 to help the Chinese ensure product quality.

Technetium (Tc) — the most widely used tracer element in nuclear medicine — is extracted, from a so-called generator by a simple chemical process. Its parent "generator" is molybdenum-99 (Mo-99), which is commonly produced by fissioning uranium in a nuclear reactor. This process provides "gold standard" Mo-99, which is very expensive and requires a reactor of at least 5 megawatts.

It takes sophisticated technology to fish out the six per cent of Mo-99 from the hot fission soup which includes hundreds of other products including plutonium. Costs of imported Mo-99 are vastly increased because the radioactive isotope must be heavily shielded. Production of Mo-99 also results in a large amount of high-level waste which is difficult and costly to handle.

Recently, a simpler and less costly route has been developed by irradiating stable molybdenum (Mo-98) in a research reactor with a high neutron flux. Essentially, scientists have added a neutron to Mo-98 to get Mo-99, which is then held in a special gel rather than in the bulky lead shielding used for conventional generators. The very short-lived technetium tracer is extracted from the gel by the same process used to obtain it from fission-produced Mo-99. Gel generators have now been used in more than 100 Chinese hospitals. Clinical results have been as good as those when the technetium is obtained from fission process generators.

Both Chinese and IAEA experts anticipate that production and quality improvements will need to be made before the gel process generators can be produced on an industrial scale and be as readily acceptable as the fission-made ones.

However, several obstacles remain: gel production must be standardized, contamination with stable molybdenum reduced and the production process streamlined to enable generators to be turned out in large numbers. TC's three-year Model Project that started in 1994 has helped correct four weaknesses and introduced several improvements to the production system. Current efforts focus on improving generator performance in several ways — by experimental comparison of different processes; improving equipment and methods of quality control; enhancing the conditions and environment of the laboratory; and changing the design and construction of the production line for greater efficiency.

A technical report now is being prepared on the comparative studies of the performance of the gel-type generators. The reports also looks at the behaviour of the technetium to labelled sensitive molecules for its utilization in clinical health-care practice.

China has committed human resources, facilities (including two research reactors), and more than US $500,000 to the project. IAEA TC, with a budget of just over $300,000 over three years (1994-96), is helping with expert services and training. Chinese scientists have been able to visit foreign scientific centres, and two fellowships were completed late this year in India and Norway.

Why is all this important? The health and economic gains that could result are very significant. China now imports 1800 fission-produced generators a year. Demand is projected to rise to nearly 10,000 by the turn of the century.

continued on next page

The atom and human health

The quality of health care available to our families and friends is a common concern for the global community.

The medical diagnostics and treatment available over the lifetime of the young "tiger" shown here will shape the quality of life he enjoys and may well influence his opportunities for success in the future. Communities and governments around the world strive to improve standards of health care in order to provide a better future for their citizens.

The IAEA's mandate is to support its Member States in finding solutions that help address national needs and priorities using nuclear applications. The Agency's human health programme gives top priority to the curative and palliative treatment of cancer, establishment of comprehensive quality assurance programmes for radiation dosimetry, the detection of diseases prevalent in children and the assessment of nutritional status and the planning and evaluation of applied nutrition programmes tailored to the needs of women and children.

Its activities span many disciplines — including radioimmunoassay, radiotherapy (especially teletherapy and brachytherapy), radiopharmaceutical production, human nutrition, sterilization techniques for organ and skin transplants as well as for medical instruments — and applications of nuclear medicine techniques and procedures.

One immediate objective of the project is to meet generator demand in southwestern China. So its immediate impact will be on the people of this region — 500,000 more could have bone scans, liver scans, and other diagnostic interventions a year — and on the productivity and cost effectiveness of health services. Equally important, this breakthrough could have similar impact on many other developing countries by providing a low-cost simpler source for technetium.

When the gel route in China to technetium production is perfected, it will progressively reduce China's imports of fission-produced generators. It will also provide a technology transferable to other developing countries where patients are now deprived of this ideal diagnostic aid. One avenue of transfer might be through TCDC (Technical Co-operation among Developing Countries) — an activity within the Agency sponsored Regional Co-operative Agreement (RCA). (See related story on last page).

Sri Lanka sets its sights:
continued from page 1

eye surgeons in 60 countries around the world. These are without charge, but recipient institutions have made cash donations which have enabled the bank to thrive. The Sri Lanka Eye Donation Society has 325 branches all over the country with the active involvement of 15,000 volunteers.

Given such a track record, and the fact that tissue banking is now a proven and demonstrably viable technology, TC had no hesitation about helping Sri Lanka set up the new facility, which is sited on land in a prime residential area of Colombo provided by the Health Ministry. The Agency will contribute some US $375,000 over four years (1995-98). Apart from the governmental inputs, the Eye Bank and local charities will donate nearly $150,000.

Oblation of one's body is inherent in Sri Lanka's religious-cultural traditions. The Eye Bank has never been short of cornea donations. Since the processing of **amnion** began this summer, at least a dozen cadavers have been offered for the extraction of tissue and long bones.

Two young ladies from Lebanon are obviously happy about their restored vision, thanks to the Sri Lanka Eye Bank.

Amnion is the inner membrane of the placenta that cocoons the fetus. This opaque material, as thin as "clearwrap" is immensely rich in hormones but is usually thrown away after the baby is delivered. Pharmaceutical companies procure it from maternity hospitals to extract hormones. It is also widely used to treat wounds and secondary burns, but its full range of medical applications is still being explored (see related report on back page).

The Colombo tissue bank has begun providing amnion to public and private hospitals. Its capacity to prepare, double package and irradiate amnion is about 350 pieces a month, while current local needs are estimated at 200 pieces. The rest can be sent abroad to meet urgent needs elsewhere. In time the Bank will similarly process and store skin and bone tissues as well as brain and spinal cord membranes, intramuscular tissue, heart valves, arterial and cardiovascular graft material.

Apart from equipment, IAEA technical co-operation will provide the expertise to establish a total quality assurance system for maintaining manufacturing practices at the highest international standards, as well as training of top staff to ensure that the activity is sustainable after the project ends. So far TC has provided five training fellowships in Germany, India, Japan and the United Kingdom, as well as scientific visits abroad.

The bank will undoubtedly have tissue stocks in excess of the country's needs. Like the Eye Bank, it will respond to foreign requests, free of charge. While some religious and cultural mores inhibit donation of body parts in many countries, a continuous demand for human tissues is projected within the Asia and Pacific Region and beyond.

The Sri Lanka Tissue Bank is a model project. As such it satisfies stringent criteria such as environmental and economic sustainability and cost benefit or effectiveness advantages over conventional approaches. It must also address priority needs of the country. Perhaps most importantly, it must receive solid support from national or local governments or communities. Over the years the Agency has supported several modest-scale tissue banking facilities, but the Sri Lanka Eye Donation Society has the proven experience and international network to assure that the new facility for sterilizing tissue for human transplantation will have significant impact both nationally and internationally.

The primary social and economic benefits of the project will be increased availability of tissue grafts to victims of traumatic accidents, disease and congenital defects. The very low income portion of the population, which currently has almost no access to such treatment, will benefit most. Sri Lanka currently spends an average of US $200,000 per year on imported tissue grafts. Savings of an equivalent amount can be expected as a direct economic benefit to the country, plus the invaluable benefits to international recipients of donated tissue for transplantation.

Combatting cancer in the developing world

The IAEA is directly involved in the campaign against cancer because treatment of tumours with radiation — often the most effective therapy — requires radioactive materials and training. The Agency is the only UN body that has the expertise to transfer this technology and ensure that it is applied safely and efficaciously. TC activities in radiotherapy -- slow at first while the focus was on building national infrastructures -- have increased rapidly in the past decade from fewer than 10 projects to nearly 50 today.

A number of developing countries, especially in Africa, still have no radiotherapy facilities. This is primarily because the costs of equipment, training and infrastructure are high. In other countries, facilities have become obsolete and skills have been lost.

A national committee headed by the First Lady of Ghana, Her Excellency Mrs. Nana Konadu Agyeman-Rawlings, will monitor the progress of the radiotherapy center. (Credit: P. Pavlicek/IAEA)

Ghana and Mongolia are typical of the two situations, and the TC Department has developed Model Projects to help resolve some major problems being faced.

TC assistance is delivered through technology transfer by experts, the provision of equipment and materials, and through training via scientific visits and fellowships abroad as well as workshops and hands-on experience at home. Special attention is invariably given to developing indigenous skills, so that the activity is sustained after the project's conclusion. This is why all Model Projects demand a strong governmental commitment to the achievement of objectives.

Mongolia has had cancer radiotherapy capability for many years but facilities have been neglected in the past few years. The overall need is for both the facilities and skills to be upgraded.

In August 1995, a modern Chinese-built teletherapy unit (with a new Cobalt-60 source) began treating patients in Ulan Bator. It was provided by TC to replace a machine which was beyond repair. Some staff are being retrained at home with the help of experts from more advanced neighboring countries; and radiotherapists, medical physicists and other key practitioners are being sent abroad on TC fellowships — mostly in China, India and Thailand — to catch up on recent advances in cancer treatment.

The regional emphasis in training is a deliberate part of TC policy. It is clearly more economical, and the experience gained from neighbours is often more valuable. Most importantly, regional ties tend to be more personal and longer lasting, and direct links with nearby centres make it much easier for the recipient country to sustain projects after the IAEA links end.

By 1998, when the TC project is due to be completed, 10-12 fellowships will have been completed, staff capability will be upgraded, and essential equipment will be repaired or replaced. Based on this programme, the government is already planning to set up a second radiotherapy facility, without any support from the Agency.

In Ghana, the radiotherapy Model Project reflects the objectives of TC policy to extend project benefits to neighboring countries. But the situation is very different from the one in Mongolia. Ghana and most of its neighbours have no radiotherapy facilities whatever, and the possibility for surgery and chemical treatment of cancers is further curtailed by the absence of oncology (study of tumours) sources.

But Ghana is committed to improving its human health by building on its capability to manage nuclear applications, methodically advanced with the IAEA's help over many years. It also has a good medical infrastructure and two medical schools and teaching hospitals in Accra and Kumasi. Centered in these two cities, the project is designed to provide bracytherapy and teletherapy for the needs of Ghana's patients, as well as those in its neighboring countries.

One important project component is training for personnel from Ghana and the region. Until now, there has been no training centre in the region for medical personnel in the fields of radiotherapy or medical oncology, not even in Nigeria. Training of Ghanaians to manage the centres has already begun. Radiotherapists, radiographers, medical physicists, and other nuclear medicine and nursing staff will receive training in China, South Africa, India and the United Kingdom.

Caspian cruise

The TC-chartered Azerbaijan hydro-meteorological research ship ***Alif gadgiev*** took to the Caspian Sea for the first time in September 1994. The scientific cruise 12-27 September for training and investigation returned with samples that, on analysis, are expected to shed light on why the level of the enclosed sea has been dramatically rising over the past 15 years.

The expedition's three principal objectives were: to provide basic training in use of environmental isotope methodologies to study the water cycle; to gather data on current levels of natural and human-induced isotopes and physical and chemical parameters of the Caspian; and to provide a new platform for the riparian countries to cooperate in solving the environmental crisis in the region.

Water samples were gathered from various depths at 13 locations covering the entire sea area. Results of sample analysis are expected to make a significant contribution to the comprehensive international project being coordinated by the UN Environment Programme to investigate and to help mitigate the consequences of the Caspian's rising waters.

Seawater samples hold answers to some key questions.
(Credit: IAEA-MEL)

Operation tsetse

The battle is some way from being won, but the TC Model Project to rid the island of Zanzibar of the tsetse fly — a threat to both human and animal health — has made major advances recently. The breeding colony of females at the Tsetse and Trypanosomiasis Research Institute in Tanga, Tanzania is now around 340,000 — up from fewer than 23,000 this time last year — and is now the world's largest production system.

Average weekly releases of the mass-reared and radiation-sterilized flies have now climbed to about 40,000. Soon they will total 50,000. Even at current release rates, a significant decline in the wild population is being registered. As a result, the ratio of sterile to wild males is increasing exponentially and reached 200:1 in November. The induced sterility rate of 60% in the wild female population confirms the competitiveness of the sterile males and forecasts good prospects for success by 1997, when the project's completion is expected.

Safety upgrade

TC has reformulated its twin Model Projects to ensure high radiation safety levels and proper management of radioactive wastes in all IAEA Member States. This step will strengthen the Agency's co-ordination and support in both areas.

Analyses during the past 12 months has shown that the previous strategy of phased implementation of the two projects in five-to-six countries each year will not achieve the required objectives soon enough. The new strategy aims to have adequate radiation protection and safe radwaste management infrastructures in place in all countries receiving TC assistance, preferably by the year 2000.

The reformulation of the two Model Projects aims to rationalize all the distinct and disparate activities in both fields into one consolidated approach. Among other benefits, this would obtain a single set of common data, to be managed by one group of managers covering all infrastructure requirements and developments. This will streamline TC efforts to achieve greater management efficiency and enhance impact, and make it more cost-effective as well. A key feature of this new managerial approach is the co-operation and assistance among developing countries themselves, notably involving IAEA Member States in the African, European, East Asian & Pacific, Latin American and West Asian regions.

TC in Cyberspace

In September 1995, the IAEA's Technical Co-operation Department established its home page on the INTERNET. Placed on the global computer network were full project write-ups for the 1995/1996 TC programme as well as the first issue of **INSIDE Technical Co-operation.** In addition, the pages provide direct links to TC-related *IAEA Bulletin* articles. This medium provides a much wider access than printed media and eventually will significantly reduce mailing costs. During 1996, TC plans to greatly expand its on-line information services, allowing limited access to the TC databases.

Please visit the TC home page at the following address on the Internet's World Wide Web network services: **http://www.iaea.or.at:80/programs/tc/index.htm.**

Pioneers of regional cooperation

More than 30 years ago, the IAEA, India and the Philippines came together under a three-way agreement to jointly operate an Indian neutron diffraction machine in the Philippines. Other inter-country activities on nuclear technology applications followed. Their success begged the question: why not develop a *structure* for promoting inter-country collaboration?

So the first **Regional Co-operative Agreement** (RCA) was formalized in 1972, involving the Agency and eight countries of the Asia and Pacific region. Now there are 17 countries in the RCA, and this model of collaboration — a pioneering approach in the United Nations — has been replicated in two other regions: first in Latin American (ARCAL), then in Africa (AFRA) in 1990. Now, the region of West Asia is preparing to set up a similar alliance.

The IAEA has an unusual role in these compacts. It is typically a **partner** in projects, which run the gamut of nuclear applications in agriculture to industry to energy, hydrology and health. But the Agency is usually not a **party** of such agreements. Though TC funds help initiate and support projects and the Agency is a conduit for additional resources, all projects are owned and run by regional partner countries.

A key indicator of regional **ownership** of projects is that country partners pay for them not just by "in kind" contributions of personnel, materials, services and the like, but in hard cash. More than a third of the cash funding for RCA activities now comes from members, the rest from donors elsewhere and TC in roughly equal shares. The concept of Technical Co-operation among Developing Countries (TCDC) is an ever prominent feature of the regional co-operative agreements, by which many advanced countries in the region assist the less-developed in the region in specific activities.

Thus Thailand is making available its Gammatron irradiator for region-wide demonstration and training. China and Pakistan supply reagents for radioimmunoassay of thyroid hormones, free or at low cost. In Latin America, there is a trend to develop bilateral relationships to the same end. Links in radiation protection activities have been set up between Mexico and Guatemala, Argentina and Costa Rica, Chile and Bolivia, Brazil and Ecuador; and in the use of radioimmunoassay between Argentina and Guatemala.

Synergy characterizes the regional co-operative agreements: national activities are fostered and the regional whole becomes greater than the sum of the national parts. The experience and success of modest-scale tissue banks set up within the RCA Member States has spurred tissue banking in the Asia/Pacific region and, in turn, led to the TC-assisted Model Project (outside the RCA) to set up the Sri Lanka tissue bank in Colombo (see related story on page 1). In this instance, the RCA has successfully pooled national experiences. Now being finalized is the manual, **Tissue Banking: A Distance Learning Package**, which could be used in other regions to develop this increasingly important aid to surgical intervention.

The logical next stage is interregional co-operation, and steps towards it have already been taken. Representatives of the regional agreements met at IAEA headquarters in Vienna in 1994 to exchange experiences in reaching and involving end-users of their projects — medical personnel and private and public health services — and to consider how know-how may be exchanged among regions. As a result, an interregional TC project was started this year, to facilitate regular exchanges among the regions.

Camera upgrade

IAEA regional projects can sometimes be extended as part of a regional co-operative agreement.

A current example is ARCAL assuming control for Agency activities to upgrade aging medical instruments in the region. A large number of the Gamma cameras used in medical centres in Latin America need to be upgraded. A survey completed in late 1994 found that 261 of 723 cameras used in diagnostics were not up to present standards.

A TC Model Project launched this year will upgrade 91 of the problem cameras in public hospitals. The project will demonstrate and transfer Agency technology, which is based on the personal computer, interface cards and portable image processing software, to counterpart institutes who will do the upgrading. That leaves two-thirds of the poor performing instruments in need of attention. The new technology can be used by ARCAL members — sixteen of them now are participating in the IAEA Model Project — to upgrade the other 170 cameras.

The costs are modest. A 20-year-old unit, mothballed for eight years, was returned to clinical service in Argentina at a cost of only US $3000.

But project funds are short and new support must be found from governments and private clinics, within and beyond the region. This is now the objective of the ARCAL project, to find the funds and deploy the needed regional expertise and complete the job.

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team's review meeting was held in May 1994 with Slovak experts at the Mochovce nuclear power plant. Slovak experts provided additional information on issues and questions raised by the team, and arranged for a technical visit to the Mochovce Radioactive Waste Disposal Facility.

The team considered the disposal facility's concept a good one. It recognized the various components of the total waste management system that are important to ensuring safety. The team noted, however, that the degree of emphasis and safety assessment work done on the various components of the repository varied considerably. Research now is being done to develop a comprehensive and fully integrated approach for safety. The desire of both the regulator and the disposal facility operator to benefit from the expertise of other countries has been an important element towards achieving safety goals.

The review team encouraged authorities responsible for the implementation of disposal at Mochovce to continue with their programme to further refine safety aspects of the disposal facility. Specific recommendations were detailed in the review report, taking into consideration the limited information reviewed. The review and recommendations covered the legal framework and waste disposal strategy; characterization and inventory of waste; design, site characteristics and construction; operation, closure and monitoring of the repository; performance assessment for the operational and post-operational phases; waste acceptance criteria; and specific quality assurance issues.

Czech Republic. The WATRP review in the Czech Republic was in response to a request in May 1993 from the State Office for Nuclear Safety and focused on the programme for the development of a deep geological repository. The main task was the assessment of the study of required research and development for the programme, which has been funded equally by the Czech and Slovak power companies. This study is limited to the deep underground geological disposal of high-level and long-lived low- and intermediate-level waste and described the planned technical programme for waste disposal.

In view of the early stages of the country's plans for deep geological disposal, the WATRP review was limited to considering the general approach to the development of the planned repository and did not include detailed critique of methodology and experimental procedures. The review team of five experts from France, Germany, Sweden, Switzerland, and the United States evaluated documents supplied by the Czech Republic and held discussions with Czech and Slovak scientists and engineers. The mission also included a technical visit to the Litomerice-Richard II facility for radioactive waste from institutional sources.

The WATRP team made recommendations on the legal framework and organizational structure for radioactive waste disposal in the country, in particular the necessity for a definitive separation between the operational and regulatory functions. It also recommended that the responsibilities of the regulatory body, the waste generators, and the operator of the disposal facility be clearly defined; that a comprehensive set of regulations be prepared to include clear guidance on the responsibilities and limits of each party in the national high-level disposal programme; that the assignment of responsibilities for specific research and development tasks should be considered a priority; and that a clear method of funding for the programme be determined.

Requests for IAEA Waste Management Advisory Reviews, 1978-95

Sweden: 1978, 1979, 1983, 1987. The reviews focused on programme reports of research and development activities associated with the handling and disposal of high-level reprocessing waste and spent fuel.

United Kingdom: 1988. The review focused on the NIREX research and development programme for a repository, specifically topics related to post-closure safety and site assessment.

Republic of Korea: 1991. The review focused on siting criteria for a disposal site for low- and intermediate-level radioactive waste.

Finland: 1992. The review focused on the overall nuclear waste management programme.

Czech Republic: 1993. The review focused on the programme for deep geological disposal.

Slovak Republic: 1993. The review focused on the near-surface disposal facility at Mochovce.

Norway: 1994. The review examined work being carried out on a combined storage and disposal facility for low- and intermediate-level waste.

The team's technical recommendations included the need to obtain the maximum possible information from international experience, particularly on the design of waste packages, the design of geological repositories, underground test facilities, backfill and closure techniques, and the use and validation of computer codes for safety assessments. It recommended that dose/risk criteria appropriate to the chosen repository site be established in line with international practice, and that the establishment and implementation of a quality assurance programme be given priority as an essential part of the regulatory framework. The team's final report, submitted to Czech authorities in 1994, further highlighted the need for public interaction and involvement in the development and licensing of the waste repository.

Finland. The Finnish nuclear waste management programme was reviewed following a request in November 1992 from the Finnish Ministry of Trade and Industry. The mission principally addressed the work being done to site and build an encapsulation facility for spent nuclear fuel, and a repository to be located on the same site. The review also covered the plans and activities for conditioning and disposal of the low- and intermediate-level waste from Finland's nuclear power plants; and the plans for decommissioning Finland's reactors when that becomes necessary.

Four experts from Canada, Belgium, Germany, and Switzerland carried out the WATRP review. During the early summer of 1993, they reviewed a large amount of documentation supplied by the Finnish industry, government, and research organizations. In August 1993, the team met in Helsinki for detailed discussions with staff of several Finnish organizations involved in radioactive waste management. The meeting included a site visit to Olkiluoto, where two of Finland's four nuclear power plants are located and the repository for shortlived low- and intermediate-level waste (LILW) is in operation. Finland is among several countries studying sites for geological repositories, and its efforts, relating to the LILW repository were profiled in the *IAEA Yearbook* for 1992.*

During the WATRP review of Finland's programme for high-level waste disposal, the team was impressed with the high standard of work being done in Finland, and urged its continuance. It noted that although the Finnish nuclear power programme is younger than those of many other countries, Finland has recorded notable achievements in developing its technologies and capabilities for radioactive waste management.

WATRP experts further noted that Finnish scientists actively participate in many international working groups and committees, both contributing to the international understanding of a difficult subject and obtaining knowledge that they can apply to their own national programme.

In some cases, the team recommended modifications to the programme. For example, it suggested that the full-scale steel/copper canister for the disposal of spent fuel be manufactured and tested so that any difficulties in its manufacturing, loading, sealing, and subsequent emplacement in the repository can be identified as early as possible in the programme. The team also recommended that the Finnish regulatory body's resources should be at least maintained and possibly increased; that work should proceed to produce detailed regulations and guides on the criteria for obtaining approval to dispose of spent fuel; and that the proposed microbiological method of treatment of organic waste at the Loviisa nuclear power plant be tested at full scale as soon as possible with a complete range of organic compounds.

In reviewing the methodology of the planned repository's preliminary safety report, the team found it satisfactory. It noted that while some data was generic in nature, the final report would contain site-specific data. Overall, the team noted the prodigious amount of work performed within the site characterization programme and urged that the same effort and quality be continued.**

Benefitting from global peer reviews

As past experience has shown, issues of radioactive waste management attract considerable attention, particularly from the standpoint of safety of health and environmental safety. International peer reviews can be valuable components of national efforts to obtain objective assessments of their programmes and plans.

At the IAEA, the WATRP programme is one of a number of advisory and technical services through which countries can benefit from the exchange of international experience in this important field. For years ahead, the IAEA is working to promote international co-operation for the safe and sound management of radioactive waste through its full range of programmes and services. ❐

*The *IAEA Yearbook* is published annually by the Agency and is available for purchase from the Division of Publications or sources in IAEA Member States. See the "Keep Abreast" section of the *IAEA Bulletin* for ordering information.

**The Finnish Ministry of Trade and Industry has published the WATRP report, "Evaluation of the Finnish Nuclear Waste Management Programme, Report of the WATRP Review Team", *Reviews* B:181, Painatuskeskus Oy, Helsinki (1994).

Overview of WATRP Review Process

WATRP's main objective is to provide IAEA Member States with an independent international peer review of their radioactive waste management programmes. Reviews are made by teams of international experts in the field.

Three principal elements are involved in the review process: a) evaluation of technical documentation and other programme-related material, b) technical discussions and exchange of information with experts of the requesting Member State or organization, and c) preparation of a report with the team's conclusions and recommendations. Reviews generally are tailored to the needs of a particular country at its request, and they may include technical visits to sites. Requests from a Member State for a WATRP review of its radioactive waste management programme must be made in writing to the IAEA.

Once the review's scope and terms of reference are determined by the requesting organization, the IAEA initiates the selection and recruitment of international experts for the review team. Selected experts serve in their individual capacities and their opinions are not necessarily those of their respective governments or the Agency. For each WATRP review a different team is formed. The size and expertise of the team depends on the scope of the review and subject areas to be covered. Normally, the WATRP team is composed of five experts. though particular requests for investigations of specific areas in greater depth or of many issues may require a larger team. The Agency selects a WATRP team leader from among the experts who is responsible for the co-ordination and liaison with other team members, as well as for conducting the WATRP review meeting and drafting the final report. Also on the team is an IAEA staff member from the Agency's Waste Management Section, who provides overall assistance and guidance.

Before the mission takes place in the requesting country, team experts review technical documentation and materials about the country's waste management programme. From their evaluation of this information, the team prepares a questionnaire that details areas requiring clarification. Once finalized, the questionnaire is sent to the national counterpart in the requesting country before the actual review meeting takes place.

Using the questionnaire and the country's response to it as a basis, the WATRP review meeting, typically one week long, focuses on any open questions, and on discussions of the team's findings and recommendations. Normally attending the review meetings along with the WATRP team members are national representatives from the requesting country or organizations and representatives of firms or organizations responsible for particular technical documentation submitted for review and related research and development activities. Following the meeting, the WATRP team completes its final report, which is submitted through the IAEA to the national organization requesting the review. The report is the property of the requesting organization, for use at its own discretion.

A WATRP team visits the proposed site for storage and disposal of low- and intermediate-level waste at Himdalen, Norway. From left, M. Bell, USA; J.-I. Kim, Germany; D. Delattre, France; A. Bonne, IAEA; D. Metcalfe, Canada; E. Warnecke, IAEA; and A. Zurkinden, Switzerland.

Radioactive waste disposal: Radiological principles and standards

An overview of national and international efforts to establish criteria for the safe disposal of spent fuel and high-level waste

by Dr. J. O. Snihs

The first large-scale geological repositories for the final disposal of spent fuel from nuclear plants are not expected to be in operation until well into the next century. Such repositories will demand high levels of safety to protect the environment and the public from potential radiological risks.

While national policies differ in classifying spent fuel as a waste product or as a resource for recycling fuel, the safety of spent fuel storage and radioactive waste disposal has been extensively studied at the national and international levels. The work includes criteria developed by Nordic countries in 1989 and subsequently revised and published in 1993. This article briefly reviews these criteria in the context of international and national studies on the disposal of high-level waste including spent fuel.

Major national and international reports

In 1984, the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD/NEA) published the report, *Long-Term Radiation Protection Objectives for Radioactive Waste Disposal.* It stands as one of the first international reports on the special problems connected with disposal of long-lived radioactive waste. Among questions discussed in this report are the limitations of individual dose or risk, the application of optimization of protection, and the use of collective dose for future assessments.

In 1985, the International Commission on Radiological Protection (ICRP) published *Radiation Protection Principles for Disposal of Solid Radioactive Waste* (ICRP publication 46). It discusses the concept of risk constraint for a source, probabilistic events, and uncertainties about the future. The principle of optimization should be applied but it is only one input in the process of deciding a strategy and option for waste management and disposal. Particularly emphasized are ethical considerations in weighing the significance of future detriments.

The IAEA, already in 1983, published an advisory report on criteria for underground disposal of radioactive wastes (Safety Series No. 60). In 1989, it was followed by the publication *Safety Principles and Technical Criteria for Underground Disposal of High-level Wastes* (IAEA Safety Series No. 99). It took into account recommendations and discussions in NEA and ICRP publications.

The IAEA Radioactive Waste Management Safety Standards (RADWASS) programme started in 1991 and is aimed at establishing a coherent and comprehensive set of principles and standards for the safe management of waste and formulating the guidelines necessary for their application. RADWASS publications will provide Member States with a comprehensive series of internationally agreed documents that reflect an international consensus. Within the RADWASS programme the following documents of relevance to waste management have been published:

- *The Principles of Radioactive Waste Management*, IAEA Safety Series No. 111-F (1995);
- *Establishing a National System for Radioactive Waste Management*, IAEA Safety Series No. 111-S-1 (1995);
- *Siting of Geological Disposal Facilities,* IAEA Safety Series No. 111-G-4.1 (1994); and
- *Classification of Radioactive Waste*, IAEA Safety Series No. 111-G-1.1 (1994).

The set of publications in the RADWASS programme is now being reviewed to ensure a harmonized approach throughout the Safety Series.

The IAEA is also supporting the work on drafting an international convention on radioactive waste safety. Progress made so far is encouraging and if the pace is maintained a draft convention could be finalized towards the end of 1996.

Dr. Snihs is Acting Director-General of the Swedish Radiation Protection Institute in Stockholm.

In the ICRP's new recommendations on radiological protection (ICRP Publication 60, 1990), radioactive waste problems are not particularly addressed. However, in the general system of radiological protection, the optimization of protection, as well as dose limits, now include the concept of potential exposure. It is expressed as the likelihood of incurring exposures where these are not certain to be received. They should be kept as low as reasonably achievable (ALARA).

Another important publication on the development of criteria for disposal of high-level waste is the proceedings of an NEA workshop in Paris. The report — *Disposal of High-Level Wastes, Radiation Protection and Safety Criteria,* published in 1991 by the NEA in Paris — features an informative overview of existing national and international approaches to problems and the current status of guidelines and criteria. In the report, collective dose or risk limits are used more for comparison of repository design alternatives. Among other points are the following: Individual dose limits or risk limits as safety indicators are generally in the range of 0.1 to 1 mSv per year or 10^{-6} to 10^{-5} per year, respectively. Optimization of protection is generally agreed as a principle but its application has to be adapted to what is achievable in practice. A similar level of safety should be provided for all future generations as that provided for current generations. A special problem discussed in the report is how to demonstrate compliance with safety criteria. There is no straightforward answer to that question, which has to do with an understanding of the whole waste disposal system. High-quality and good engineering practice are needed throughout the process, using validated models and site-specific data, and appropriately selecting scenarios and scrutinizing uncertainties.

National reports. At the national level, there has been considerable work as well. For instance, in a joint 1990 Swiss-Swedish report, *Regulatory Guidance for Radioactive Waste Disposal — An Advisory Document* (SKI Technical Report 90, Stockholm), a number of principles and problems are discussed. It addresses problems concerning uncertainties over long time periods and urges the validation of all models used for performance assessments of assumed repository systems.

Other national documents include the *French Basic Safety Rules* in 1991; a 1992 report by the National Radiological Protection Board (NRPB) in the United Kingdom, *Radiological Protection Objectives for Land-based Disposal of Solid Radioactive Wastes,* and the US Environmental Protection Agency (EPA) regulations, *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste,* published in the US *Federal Register* 20 December 1993.)

In the French Rules, ALARA is applied as a principle in the criteria for a repository. The individual dose equivalents are limited to 0.25 mSv per year for extended exposure associated with events which are certain or highly probable. For a period of at least 10 000 years, the stability of the geological barrier must be demonstrated. Beyond this time period, the quantitative assessments may be supplemented by more qualitative assessments. The risk concept is introduced for potential exposure situations.

In the NRPB's publication, it is recommended that future populations shall have an equivalent protection as that for populations today. Moreover, the radiological risk to a critical group, attributable to a single waste disposal facility, shall not exceed the risk constraint of 1 in 100 000 per year, and the ALARA principle should be applied. However, if the individual risk to an average member of the critical group does not exceed a design target of 1 in 1 million per year, then the ALARA principle would be required only for the detailed design of the facility and not in comparison of various sites or options. Site-specific calculations relating to the biosphere and human behaviour should not continue beyond about 10 000 years into the future. For times greater than that, reference models of biosphere and human behaviour can be used in combination with constraints on radionuclide release rates from the geosphere.

The 1993 EPA regulations stipulate that disposal systems for spent nuclear fuel, high-level and transuranic waste will have to be designed so that, 10 000 years after disposal, the undisturbed performance of the system will not deliver an annual committed effective dose of radionuclides greater than 15 mrem to any individual in the accessible environment.

The EPA regulations took effect 19 January 1994. Under them, the protection period has been lengthened from 1000 years to 10,000 years. The EPA noted that wastes placed in the disposal systems will remain radioactive for thousands of years. Results of EPA studies show that potential radionuclide releases resulting in exposures to individuals would not occur until more than 1000 years after disposal because of the containment capabilities of the engineered barrier system.

The EPA regulations do not apply, however, to the Yucca Mountain Site Characterization Project. The EPA will develop a separate standard for the potential disposal of spent fuel and high-level waste at Yucca Mountain, under the guidance of the National Academy of Sciences, as directed by a 1992 congressional mandate.

The Nordic criteria. In parallel with these national and international developments, the Nordic countries developed criteria issued in 1989 and subsequently revised in 1993 after extensive review by international and national experts, among others. (*Disposal of High Level Waste — Consideration of Some Basic Criteria,* the Radiation Protection and Nuclear Safety Authorities in Denmark, Finland, Iceland, Norway and Sweden.)

They are in many parts very similar to those found in international and other national documents. This is not surprising, since Nordic specialists have taken active part in international work in this field. The Nordic criteria include:

- ***General considerations and objectives.***

General objective: The objectives of disposal of high-level waste shall be to protect human health and the environment and to limit burdens placed on future generations.

Objective 1 - Long-term safety: The risk to human health and the effects on the environment from waste disposal, at any time in the future, shall be low and not greater than would be currently acceptable. The judgment of the acceptability of a disposal option shall be based on radiological impacts irrespective of any national boundaries.

Objective 2 - Burden on future generations: The burden on future generations shall be limited by implementing at an appropriate time a safe disposal option which does not rely on long-term institutional controls or remedial actions as a necessary safety factor.

- ***Radiation protection principles.***

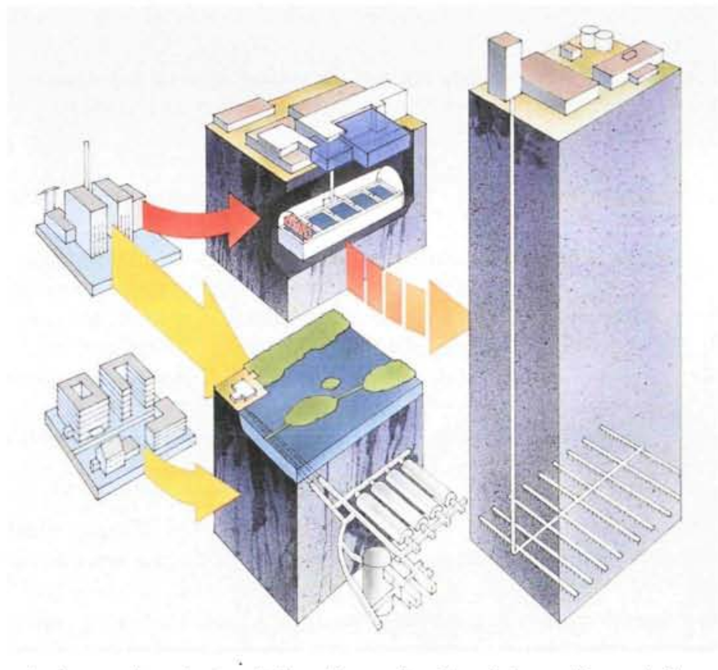
Applied principle 1 - Optimization: The system of waste disposal shall be optimized. In doing so radiation doses and risks must be compared and balanced against many other factors that could influence the optimized solution.

Applied principle 2 - Individual protection: Up to reasonably predictable time periods, the radiation doses to individuals from the expected evolution of the disposal system shall be less than 0.1 mSv per year. In addition, the probabilities and consequences of unlikely disruptive events shall be studied, discussed and presented in qualitative terms and whenever practicable, assessed in quantitative terms in relation to the risk of death corresponding to a dose of 0.1 mSv per year.

Because of different diets, living habits and environmental conditions, there is always a "tail" in individual dose or risk distribution. Sometimes this tail may exceed the respective constraints though the average value in the critical group remains low. This is not specific to waste disposal. Acceptance of the tail is not contrary to present practices and is consistent with the individual protection principle.

In general, dose assessments beyond about 10,000 years are very uncertain. Dose assessment in the relative sense can be made for longer time

Swedish System for Disposal of Spent Fuel and Radioactive Waste



In Sweden, radioactive wastes from nuclear plants and other sites, such as hospitals, are disposed of in specially built repositories. Low- and intermediate-level wastes from hospitals and nuclear plants are sent to a repository built 50 meters below ground. Spent fuel from nuclear plants is currently stored in a storage facility. Plans call for it to be sent to a repository that will be built 500 meters underground early in the next century.

periods assuming hypothetical critical groups. In that case the resulting doses or risks should be interpreted as safety indicators (relative measures of safety), not as predictions of really occurring doses.

Applied principle 3 - Long-term environmental protection: The radionuclides released from the repository shall not lead to any significant changes in the radiation environment. This implies that the inflows of the disposed radionuclide into the biosphere, averaged over long time periods, shall be low in comparison with the respective inflows of natural alpha emitters. The activity inflow should be averaged over long-term periods, i.e. 10^4 years or more, as it is not possible to determine accurately when releases or their peak values occur.

The activity inflow constraint should be such that: the resulting peak individual doses should not be in excess of the dose limit and even in the most extreme cases well below the level of deterministic health effects; the resulting activity concentrations in primary recipients at the disposal site fall within the range of the typical concentrations of long-lived natural alpha emitters in similar environments; the activity inflow from all wastes to be disposed of globally is low compared with the respective inflow of long-lived natural alpha emitters.

Calculations indicate that an appropriate constraint probably would fall within the following ranges: 10 to 100 kBq/per year for the long-lived alpha emitters; and 100 to 1000 kBq/per year for the other long-lived nuclides per amount of waste, which is produced when one ton of natural uranium is processed into nuclear fuel and then used in a reactor.

- ***Assurance principles.***

Assurance principle 1 - Safety assessments: Compliance of the overall disposal system with the radiation protection criteria shall be demonstrated by means of safety assessments which are based on qualitative judgment and quantitative results from models that are validated as far as practicable.

Assurance principle 2 - Quality assurance: A quality assurance programme for the components of disposal system and for all activities from site confirmation through construction and operation to the closure of the disposal facility shall be established to achieve compliance with the design bases and pertinent regulations.

Assurance principle 3 - Multibarrier principle: The long-term safety of waste disposal shall be based on passive multiple barriers so that deficiencies in one of the barriers do not substantially impair the overall performance of the disposal system and realistic geologic changes are likely to affect the system of barriers only partly.

Furthermore, the Nordic criteria contain technical and geological recommendations on site geology, repository design, backfilling and closure and waste packaging.

Ongoing work and challenges

Continuing work on criteria is being done at the international level through an IAEA Working Group on Principles and Criteria for Radioactive Waste Disposal. The group's experts are addressing issues concerning dose versus risk, post-closure monitoring, safety indicators in different timeframes, the applicability of optimization, retrievability, and safeguards in the context of waste disposal.

One question of interest is the time frame for which it is meaningful to consider the assessments of environmental consequences of a repository for high-level waste or spent fuel. Some experts argue that the safety of the near generations should be the paramount concern. Others believe that all future generations must be equally protected. In my view, every generation has the right either to control safety by itself or to be ensured by earlier generations that the repository is safe. Various tools and models may be used in the efforts to illustrate the radiological safety of a repository over long time periods. The first report of the IAEA Working Group on Principles and Criteria for Radioactive Waste Disposal was published in 1994 with the title, *Safety Indicators in Different Time Frames for the Safety Assessment of Underground Radioactive Waste Repositories*, (IAEA TECDOC-767).

In Sweden, the programme on disposal of spent fuel is proceeding. There is extensive research carried out by the Swedish Nuclear Fuel and Waste Management Co. (SKB) that includes suitability studies on potential sites and planned geological, hydrological, and other research in a laboratory 500 meters underground. Remaining problems include those related to the criteria and methods for selecting suitable sites, and in planning all the radiation safety analyses that must be made. Another concern is how to make information available to local decision-makers and citizens that they can use for their decisions on the acceptability of proposed repository plans. On the regulatory side, applied requirements and regulations based on, among others, the Nordic criteria are being prepared for issuance. Directives will also be issued on how to make appropriate environmental impact assessments.

The resolution of issues in Sweden will receive continuing attention, as the country moves ahead with plans to start building its final repository for high-level waste and spent fuel by about 2010 and take it into operation a decade later. ❐

IAEA Board of Governors meetings

At its meetings in March 1996, the Agency's 35-member Board of Governors is expected to continue its consideration of proposals for strengthening the effectiveness of the nuclear safeguards system and for improving its efficiency. The proposals are part of the Agency's safeguards development programme known as "93+2", which includes provisions that would broaden the Agency's access to relevant information and sites.

During 1995, the Board approved the implementation of certain measures (part-1) and began its discussion of others, notably those requiring complementary authority (part-2 measures). At its meetings in December 1995, the Board discussed part-2 measures in more detail and welcomed the Agency's efforts in consultation with Member States towards finalizing them. Discussions focused on a Secretariat draft paper explaining the various proposed measures and showing how the necessary complementary authority could be defined in a protocol to existing comprehensive safeguards agreements. In his remarks to the Board, IAEA Director General Hans Blix said that efforts are continuing to work out details of the proposals and noted that a good deal of success had been achieved to date. He said the challenge has been one of striking a balance between measures that would strengthen safeguards and the technical, legal, and administrative constraints facing governments.

Ambassador Tengbergen, IAEA Board Chairman

Board Membership for 1995-96

The IAEA Board of Governors for 1995-96 is chaired by Ambassador Johan Th.H.C. van Ebbenhorst Tengbergen of the Netherlands, who in September 1995 was elected to succeed Dr. R. Chidambaram of India. Mr. Tengbergen is Ambassador to Austria and Resident Representative to the IAEA.

The 35 Member States on the Board for 1995-96 are Algeria, Argentina, Australia, Belgium, Brazil, Bulgaria, Canada, China, Chile, Denmark, Egypt, France, Germany, Ghana, India, Japan, Republic of Korea, Kuwait, Mexico, Morocco, Netherlands, Nicaragua, Nigeria, Pakistan, Romania, Russian Federation, Saudi Arabia, Slovak Republic, South Africa, Spain, Thailand, Turkey, United Kingdom of Great Britain and Northern Ireland, United States, and Uruguay.

In his Board statement, Dr. Blix addressed a number of other matters. They included the Agency's implementation of safeguards in the Democratic People's Republic of Korea (DPRK), which remains in non-compliance with its safeguards agreement; the possible roles of the IAEA under a Comprehensive Test Ban Treaty (CTBT), which is being negotiated at the Conference on Disarmament in Geneva; and a study to assess the radiological situation in the Mururoa and Fangataufa atolls, which France has requested the Agency to co-ordinate.

In reviewing developments concerning the DPRK over the past months, the Director General said that while limited progress had been made on some issues, others must still be resolved so as to enable the Agency to verify the correctness and completeness of the DPRK's initial declaration of its nuclear material subject to safeguards. These issues remain on the agenda of technical talks with DPRK authorities, he said. In expressing its concern over the situation, the Board welcomed the Agency's further efforts and expressed its desire to see agreement reached on outstanding issues.

Regarding the CTBT, the Director General said that at the request of governmental delegates in Geneva the Agency had provided factual information and assessment concerning legal, organizational, and financial matters relative to the role, if any, it could play in the implementation of the Treaty. He pointed out that if and when the Agency is asked to perform certain tasks within the framework of a CTBT, any substantive functions to be undertaken by the IAEA would require prior approval by the Agency's policy-making organs.

Concerning the Mururoa study, Dr. Blix said the Agency has informed the French Foreign Ministry that it is ready in principle to co-ordinate the study, which would assess the radiological situation in the Mururoa and Fangataufa atolls and evaluate any potential long-term radiological impact. He said it could be carried out within the framework of an International Advisory Committee of highly qualified experts after the end of nuclear testing in the atolls and the formalization of an agreement on the study with French authorities.

Technical Co-operation. Considering a report by its Technical Assistance and Co-operation Committee, the Board approved modifications to previously approved projects for 1996; and items related to the implementation of model projects; the evaluation of technical co-operation; and the forecast of training courses.

In its report, the Committee had recommended the Board's approval of projects funded in 1996 at a level of US $62.5 million. In welcoming initiatives the Agency has taken to strengthen the technical co-operation programme by increasing the impact of projects on national development, the Committee emphasized the need for adequate resources to implement the programme and urged Member States to make their full and timely contributions.

Chernobyl Conference in April 1996

More than 400 governmental delegates are expected to comprehensively review the radiological consequences of the Chernobyl accident at an international conference in Vienna 8-12 April 1996.

The conference — One Decade After Chernobyl: Summing up the Radiological Consequences — will take stock of the consequences of the 1986 accident, taking particular account of the findings of two prior conferences. These meetings are the International Conference on the Health Consequences of the Chernobyl and other Radiological Accidents, which was convened by the World Health Organization (WHO) 20-23 November 1995 in Geneva, and the First International Conference of the European Union, Belarus, Russian Federation, and Ukraine on the Consequences of the Chernobyl Accident, which is being held in Minsk 18-23 March 1996.

The April conference in Vienna is being organized jointly by the IAEA, European Commission, and WHO, and in co-operation with the United Nations Department of Humanitarian Affairs (UNDHA), United Nations Educational, Scientific and Cultural Organization (UNESCO), and United Nations Environment Programme (UNEP). Important objectives will be to clearly separate the scientific facts of the accident's consequences from "myths" and speculation; to clarify and quantify its radiological and other effects on health; and to review its social, economic, and political consequences.

The health and environmental effects attributed to the 1986 Chernobyl accident have been subject to extensive scientific examination. Although few accidents have been so thoroughly investigated, there still remain widely differing opinions on the accident's actual consequences. The Vienna conference is intended to seek a better understanding of the nature and magnitude of these consequences.

Nuclear Safety Forum. Before the conference, the IAEA will be convening in Vienna a nuclear safety forum 1-3 April 1996 in co-operation with UNDHA. It will review the remedial measures for improving the safety of Chernobyl-type (RBMK) reactors and the Chernobyl containment structure, known as the sarcophagus. The forum's conclusions and recommendations will be presented at the Chernobyl conference.

New laboratory inaugurated at Seibersdorf

With the objective of enhancing capabilities for measuring and analyzing environmental samples, the IAEA in December 1995 inaugurated a new "clean" laboratory near its existing Safeguards Analytical Laboratory (SAL) facilities at Seibersdorf in Austria.

Scientists at the new laboratory, constructed over the past year and funded by extrabudgetary contributions, will analyze soil, water, vegetation, and other samples collected by Agency safeguards inspectors in the course of their work.

Operating under extremely stringent conditions, the new facility houses instrumentation and expertise capable of detecting minute quantities of radioactive materials in samples which might be indicative of nuclear activities.

Present for the inauguration were Ambassador John B. Ritch III of the United States; IAEA Director General Hans Blix; Mr. Bruno Pellaud, Deputy Director General for Safeguards; and Mr. Pier Roberto Danesi, Director of the IAEA Seibersdorf Laboratories. The United States contributed more than US $1 million for the construction of the new laboratory.

The new facility augments analytical services being provided by SAL, which the IAEA set up in the 1970s at its Seibersdorf Laboratories. SAL today handles more than 1000 samples of uranium, plutonium, and other types of nuclear material each year.

Studies of radioactive pollution in seas

Following their participation in recent expeditions, experts at the IAEA's Marine Environment Laboratory (IAEA-MEL) in Monaco are investigating the effects of radioactive pollution in the Kara Sea in the Arctic and the Far Eastern Seas in Asia.

Kara Sea Expedition. In August and September 1995, an IAEA-MEL expert participated in a month-long Kara Sea expedition known as EPOCA 95 (Environmental Pollution and Oceanography in the Arctic Seas), a joint Russian/American/Norwegian investigation. It marked the fifth expedition to the region involving IAEA-MEL's participation as part of the IAEA's International Arctic Seas Assessment Programme (IASAP). Initiated in 1992, IASAP was established to evaluate the risks posed by dumped nuclear wastes in the Kara Sea, a shallow Arctic sea located adjacent to the former Soviet Union. The latest expedition departed Hammerfest, Norway, on the Norwegian Defense Research Establishment ship *H.U. Sverdrup II* 25 August and returned 25 September 1995 after travelling more than 3000 nautical miles along cruise tracks within the Kara Sea.

During the expedition, water and sediment samples were retrieved from as many as 40 locations, including samples close to sites of the fuelled reactors dumped by the former Soviet Union. Instrumentation was also deployed to understand circulation patterns and predict the primary transport pathways of pollutants. During the expedition, the IAEA-MEL expert conducted a novel investigation to determine, *in situ*, the uptake potential of radioactive contaminants to sediments. The results of the investigation will be used in models evaluating the dispersion of radionuclides released from nuclear waste sites.

Far Eastern Seas. IAEA-MEL also participated in the second stage of the Japanese/Korean/Russian joint expedition aboard the R/V *Ocean* to investigate dumping sites in the Far Eastern Seas from 12 August to 12 September 1995. The extensive investigations supported by the Government of Japan were conducted to assess the level of radioactive contamination in sea areas at which radioactive wastes were disposed of by the former Soviet Union and the Russian Federation, Japan, and the Republic of Korea. During the expedition, samples of seawater, seabed sediment, zooplankton, and benthos were collected; preliminary spectrometric measurements of seawater and seabed sediments were done aboard ship; and intercomparison of analytical techniques used by participating countries was organized and performed with satisfactory results. Preliminary results of onboard measurements showed that concentrations of caesium-137 in seawater and seabed sediments were low 24 Bq/m^3 and below 10 Bq/kg dry weight, respectively. These values do not differ significantly from levels elsewhere in the northwest Pacific Ocean arising from global fallout. Detailed analyses of all samples will be performed on land and the evaluated data will be exchanged and published in 1996. Some 3.6 tonnes of seawater and 20 kg of sediments collected at 13 stations were sent to IAEA-MEL in Monaco for radionuclide analysis.

Research on improved cancer treatment

Medical experts from 10 countries recently met at the IAEA to review the status and potential of a new phase in the evolution of radiotherapy for improved treatment of cancer. The radiation treatment involves the use of beams of heavy-charged particles, namely protons and heavy ions, targeted to control the growth of many types of localized malignant tumours. The experts represented countries participating in a newly organized Agency Co-ordinated Research Programme (CRP) on the subject. Participating countries include Austria, Belgium, France, Germany, Italy, Japan, South Africa, Switzerland, the Russian Federation, and the United States.

Over the past decade, considerable advances in cancer treatment have occurred and a cancer cure now can be regarded as a realistic therapeutic objective. Yet cancer still claims the lives of 5.4 million people a year worldwide, and the number of new cancer cases is rising at the rate of 3% annually.

Radiotherapy, alongside surgery, has become one of the two most successful cancer treatment modalities. Current treatment methods in any combination, however, fail to control cancer in more than half of all patients. Additionally, morbidity from current treatment methods remains a very serious clinical problem. The main cause for failure in cancer treatment is insufficient local control of tumour growth.

Heavy-charged particles offer the chance of improving this picture because of their physical properties and biological advantages for the localized control of tumour growth while reducing the morbidity of the treatment process. They thus offer doctors and patients a chance for achieving a therapeutic gain superior to that offered by conventional radiotherapy.

More than 14,000 cancer patients have been treated with heavy-charged particles to date, with encouraging results achieved in treatment of tumours of the eye, salivary glands, brain, liver, and prostate. The IAEA's CRP aims to promote co-operative efforts in the radiotherapeutic application of heavy-charged particles by evaluating their potential benefit and by identifying the mechanisms through which benefits can be achieved. It is further expected that the programme can provide a needed forum for reviewing and co-ordinating different national programmes at the global level. A co-operative effort is considered essential for exploiting the clinical benefits from applications of heavy-charged particles and for avoiding decades of unsatisfactory trial and error.

International Nuclear Event Scale

Already being successfully used to classify events at reactors, the International Nuclear Event Scale (INES) should now be applied for non-reactor installations, national INES representatives have recommended. The recommendation was made at a meeting of INES National Officers at the IAEA in October 1995 attended by representatives from 59 countries now applying the scale.

"This recommendation, when adopted, means that INES will apply to nearly all civil nuclear installations around the world," Dr. Dick Taylor, Chairman of the meeting, said. "Development and acceptance of a simple scale has been a remarkable achievement and it will allow the public and media to understand the significance of any events within a short time of their occurrence. This should provide considerable reassurance in simple and intelligible terms about the safety of nuclear installations."

The meeting reviewed progress in the scale's use worldwide, agreeing that it is working well technically and gaining increased media and public acceptance. In reviewing global experience, no reported events were registered above level 2 (on the 7-level scale) during 1994-95.

Representatives at the meeting decided to initiate work to further improve the scale's use. They recommended that new publicity material explaining the scale be developed, and they emphasized that even though no changes to INES would be made, efforts to simplify some technical procedures underlying the rating of events would continue.

Global hydrology data network

A new framework is being designed for the operation of a global network providing key data for hydrological studies related to assessing the availability of water resources and studying climate conditions.

In late 1995, the IAEA Section of Isotope Hydrology convened a meeting on the operational aspects of the Global Network of Isotopes in Precipitation (GNIP). The meeting, 7-10 November 1995, was attended by representatives of the World Meteorological Organization (WMO), International Geosphere-Biosphere Programme-Past Global Changes (IGBP/PAGES), World Health Organization (WHO), Austria, Canada, Chile, Germany, Republic of Korea, Israel, Portugal, Russian Federation and the United States.

The GNIP database contains isotope data (oxygen-18, deuterium and tritium) in precipitation from more than 500 meteorological stations worldwide. Long used for hydrological assessments, the data also have been found highly useful to link present climatic conditions to paleoclimate archives, to validate atmospheric circulation patterns, and to study water balance in the continents. During the last 15 years, GNIP has gained international recognition as a key resource for studies of global changes related to the water cycle and climate.

The meeting aimed to design a new framework for the operation of the network, which has been a joint activity of the WMO and IAEA for more than 30 years. All participants reaffirmed the need to continue the IAEA/WMO-operated stations and national networks which measure isotopes in precipitation. Since other organizations have expressed interest in participating in this activity, the meeting resolved to strengthen the programme through a Steering

Committee, to be composed of representatives from interested organizations.

The Steering Committee, of which the IAEA is a member, will be responsible for the design, operation, support, and maintenance of the data networks. The Committee will also ensure the collaboration of the different organizations involved.

GNIP data is distributed through diskettes and IAEA publications. It can also be globally accessed through the IAEA's Internet site at *http://www.iaea.or.at/programs/ri/gnip.*

Director General addresses United Nations

Addressing the 50th session of the United Nations General Assembly in New York, IAEA Director General Hans Blix emphasized the importance of international efforts to secure the safe and peaceful development of nuclear energy. He specifically reviewed areas of nuclear safeguards and verification; nuclear safety; nuclear power development; and technical co-operation. Dr. Blix addressed the General Assembly 1 November 1995.

In reviewing global nuclear developments, Dr. Blix stressed the Agency's response to new challenges in the field of safeguards and verification. The stronger safeguards system now being developed, he said, focuses on a number of essential elements: increased access to information about a State's nuclear activities; broader access to sites and locations within a State; short-notice inspections; and the maximum use of new and available technologies to increase detection capacity.

He further pointed out that IAEA verification of States' compliance with their nuclear arms-control pledges is becoming an more important factor in global security and nuclear disarmament. He noted expanded efforts in verifying nuclear material released from the military programmes of nuclear-weapon States, and he cited possible new IAEA verification roles, including those related to the Comprehensive Test Ban Treaty (CTBT) which States seek to conclude in 1996. He noted that the IAEA already verifies such a ban in more than 170 States accepting comprehensive safeguards on all their nuclear activities.

The Director General also addressed Agency efforts against illicit trafficking in nuclear materials. "It is clear that greater efforts are needed and that States must pay increased attention to the physical protection of all radioactive material, and especially weapons useable nuclear material, whether in use, transport, or storage," he said. While the States concerned carry the primary responsibility in combatting illegal trafficking, Dr. Blix said that steps are being taken to improve international co-ordination of efforts. The Agency's actions, he noted, include establishing a database of trafficking incidents in support of factual analyses and technically assisting States in areas of nuclear material accountancy and control, and in physical protection methods and technology.

Nuclear and Radiation Safety. Also commanding greater attention are issues of nuclear and radiation safety, he said. Building on the IAEA's long-standing work in the field, States have developed binding international safety standards, he noted, notably in adopting the Convention on Nuclear Safety that is nearing entry into force, and in moving to finalize preparation of a Convention on Radioactive Waste Safety. "There is a clear manifestation of the increased interest of the international community that nuclear safety be at a high level everywhere," he said.

Nuclear Power. The Director General further called for an expansion of nuclear power for electricity generation to help meet the world's growing needs for environmentally clean and economically proven energy sources. He noted the Agency's co-operative work with inter-governmental organizations for comparatively assessing the benefits and risks of different options for electricity production.

"Only an analysis of different options side by side can tell us which energy policy is economically and ecologically least burdensome", he said.

Technical Assistance. In underlining the high interest of States, particularly developing countries, in peaceful nuclear applications, Dr. Blix reviewed initiatives to strengthen the IAEA's technical co-operation programme. Emphasis is being placed on nuclear techniques and targeted projects that will contribute to sustainable development, food production and preservation, the harnessing of fresh water resources, industrial applications, and the promotion of human health, he said.

Copies of the statement may be obtained from the IAEA Division of Public Information or through the IAEA's World Atom Internet services at http://www.iaea.or.at.

UN General Assembly commends IAEA

The United Nations General Assembly adopted a resolution in November 1995 commending the IAEA for its nuclear verification efforts in Iraq and the Democratic People's Republic of Korea (DPRK) and welcoming the measures being taken to strengthen the Agency's safeguards system. The resolution was adopted in New York 1 November 1995.

The General Assembly further affirmed its confidence in the role of the IAEA in the application of nuclear energy for peaceful purposes; it urged all States to strive for effective and harmonious international co-operation in carrying out the work of the Agency; and it stressed the need for the highest standards of safety in the design and operation of nuclear installations so as to minimize risks to life, health and the environment.

The resolution further stated that the General Assembly: ●"Welcomes the measures and decisions taken by the Agency to strengthen and fund its technical co-operation activities, and calls upon States to cooperate in implementing the measures and decisions pursuant thereto;" ●"Appeals to all States to ratify or accede to the Convention on Nuclear Safety;" ●"Welcomes the measures taken by the Agency in support of efforts to prevent illicit trafficking in nuclear materials or other radioactive sources;"

In commending the Agency's work in the DPRK, the resolution stated that the General Assembly: "Commends the Director General and the Secretariat of the Agency for their continuing impartial efforts to implement the safeguards agreement in force between the Agency and the Democratic People's Republic of Korea, including their efforts to monitor the freeze of specified facilities in the Democratic People's Republic of Korea as requested by the Security Council, expresses concern over the continuing non-compliance of the Democratic People's Republic of Korea with the safeguards agreement and urges the Democratic People's Republic of Korea to cooperate fully with the Agency in the implementation of the safeguards agreement and to take all steps the Agency may deem necessary to preserve, intact, all information relevant to verifying the accuracy and completeness of the initial report of the Democratic People's Republic of Korea on the inventory of nuclear materials subject to safeguards until the Democratic People's Republic of Korea comes into full compliance with its safeguards agreement;"

In commending the Agency's work in Iraq, the resolution stated that the General Assembly: "Also commends the Director General of the Agency and his staff for their strenuous efforts in the implementation of Security Council resolutions 687 (1991) of 3 April, 707 (1991) of 15 August and 715 (1991) of 11 October 1991, expresses deep concern that Iraq has, since 1991, withheld from the Agency information about its nuclear-weapon programme in violation of its obligations under Security Council resolutions 687 (1991), 707 (1991) and 715 (1991), and stresses the need for Iraq to cooperate fully with the Agency in achieving the complete implementation of the relevant Security Council resolutions".

Recent IAEA meetings

Sustainable energy production and electricity generation were in the forefront at the IAEA's International Symposium on Electricity, Health and the Environment, convened in Vienna 16-19 October 1995. International experts focused on the ways and means of comparatively assessing the health and environmental impacts of different energy sources for electricity generation, specifically reviewing results of an inter-agency global project called Decades on databases and methodologies for such assessments. The symposium was co-organized by the IAEA, the European Commission, the Economic and Social Commission of Asia and the Pacific, the International Bank for Reconstruction and Development, the International Institute for Applied Systems Analysis, the Nuclear Energy Agency of the Organization for Economic Co-operation and Development, the Organization of Petroleum Exporting Countries, the United Nations Environment Programme, the United Nations Industrial Development Organization, and the World Meteorological Organization.

In opening the symposium, IAEA Director General Hans Blix stressed the need for examining electricity options in the context of growing energy demand and environmental concerns. He noted that since the Earth Summit in 1992, only small progress had been made worldwide in reducing greenhouse gas emissions and that reliance on fossil fuels had not been minimized. He called for a rational assessment of all available energy supply options, renewable, fossil, and nuclear, to help guide energy planners and decision-makers in choices they must make. Nuclear power by itself, he said, cannot solve all problems involved in achieving a secure and sustainable energy supply worldwide, but it can play a significant role, along with renewable sources and energy conservation, in strategies toward this goal.

Nuclear Safeguards and Verification. At an Agency seminar exploring future directions for safeguards 16-17 November 1995, IAEA Director General Hans Blix participated in discussions with international specialists and policymakers on a wide range of topics. Attending the seminar — Verifying Nuclear Non-Proliferation Pledges: The Future Role of IAEA Safeguards — were senior IAEA officials, invited journalists, and leading experts from research institutes and governmental bodies on issues of nuclear verification, safeguards, arms control, and disarmament. Sessions focused on various themes, including strengthening safeguards; nuclear trafficking; safeguarding nuclear material released from military programmes; verifying a fissile material production cut-off; verifying a Comprehensive Test Ban Treaty; and compliance with non-proliferation pledges. A concluding panel discussion looked at nuclear verification in the years ahead. Panelists included Mr. Leonard S. Spector of the Carnegie Endowment for International Peace, United States; Mr. Jasjit Singh, the Institute for Defence Studies and Analyses, India; Mr. Shai Feldman, Senior Research Fellow, Center for Science and International Affairs, Harvard University, on leave from the Jaffee Center for Strategic Studies, Tel Aviv University, Israel; and Mr. Harald Mueller, Director of International Programmes, Peace Research Institute Frankfurt, Germany.

Resolutions of IAEA General Conference

Member States meeting at the IAEA General Conference 18-22 September 1995 adopted resolutions in key areas of global nuclear development. The adopted resolutions include those related to:

Safeguards in the DPRK. The resolution commends the IAEA for its efforts to monitor the freeze of specified facilities in the DPRK as requested by the UN Security Council, and to implement the IAEA-DPRK safeguards agreement. In calling upon the DPRK to comply fully with the IAEA-DPRK safeguards agreement, the resolution urges the DPRK to take all steps the Agency may deem necessary to preserve, intact, all information relevant to verifying the accuracy and completeness of the DPRK's initial report on the inventory of nuclear material subject to safeguards until the DPRK comes into full compliance with its safeguards agreement.

Nuclear Inspections in Iraq. The resolution condemns Iraq for having, since 1991, withheld from the Agency information about its nuclear-weapon programme in violation of its obligations under Security Council resolutions, and it demands that Iraq hand over to the Agency without further delay any currently undisclosed nuclear-weapon-related equipment, material or information, as called for in Security Council resolutions. The resolution stresses that the Agency will continue to exercise its right to investigate further any aspects of Iraq's past nuclear weapons capability, in particular as regards the new information obtained by the Agency in August 1995 and any further relevant information that Iraq may still be withholding from the Agency.

Nuclear Testing. The resolution expresses grave concern at the resumption and the continuation of nuclear testing and calls upon those States which have active nuclear testing programmes in place to desist from testing until a Comprehensive Nuclear Test Ban Treaty CTBT) enters into force. In the resolution, the Conference states its expectation that the negotiations for a CTBT will be completed and the Treaty signed in 1996 as may be further specified by the Fiftieth Session of the United Nations General Assembly, and it urges all participants in the negotiations to further intensify their efforts to this end.

Strengthening the Safeguards System. Expressing the conviction that the Agency's safeguards can promote greater confidence among States and thus contribute to strengthening collective security, the resolution addresses measures proposed under the IAEA Programme 93+2 for strengthening the effectiveness and improving the efficiency of the safeguards system. The resolution requests the IAEA to continue to develop the measures proposed under Programme 93+2 in order to bring about a more effective and efficient system covering all nuclear material in all peaceful nuclear activities within the territory of a State which has concluded a comprehensive safeguards agreement, and to make the necessary arrangements to implement the first part of the proposed measures after consulting individual

States. It further requests the IAEA, taking account of views expressed in the Board of Governors and the General Conference and the outcome of consultations with Member States individually or collectively, to put before its Board of Governors as soon as possible clear proposals for the second part of the proposed measures.

IAEA Safeguards in the Middle East. The resolution requests the IAEA's Director General to continue consultations with the States of the Middle East to facilitate the early application of full-scope Agency safeguards to all nuclear activities in the region as relevant to the preparation of model agreements, as a necessary step towards the establishment of a nuclear-weapon-free zone in the region.

Illicit Trafficking. The resolution welcomes the measures taken by the IAEA in support of efforts to prevent illicit trafficking in nuclear materials, and invites the Agency to continue working in accordance with the conclusions of its Board of Governors.

African Nuclear-Weapon-Free Zone (NWFZ). Noting the adoption in June 1995 of the text of the Treaty on an African NWFZ, the resolution commends the African States for their united efforts toward the establishment of an NWFZ and requests the IAEA to continue to assist them in this regard.

Nuclear Safety. The resolution expresses the hope for the widest possible adherence to the Convention on Nuclear Safety. It appeals to all Member States which have not yet done so to sign the Convention, and it appeals to signatory States which have not yet done so to ratify, accept or approve the Convention so that it may enter into force as soon as possible.

Technical Co-operation. The resolution requests the IAEA to pursue, in consultation with Member States, efforts to strengthen the Agency's technical co-operation activities through the development of effective programmes aimed at improving the scientific and technological capabilities of developing countries in fields of peaceful nuclear applications, and achieving sustainable development. The resolution defined these fields as including both applications of nuclear methods and techniques and the production of electricity, and it noted that account should be taken of the infrastructure and the level of technology of the countries concerned. It further requests the IAEA to take account of the view of the General Conference on this question when requesting Member States to pledge their respective shares of the Technical Co-operation Fund targets and to make timely payments to the Fund.

Plan for Producing Potable Water Economically. In emphasizing the need to solve water shortages in Member States, the resolution stresses the vital importance of producing potable water and urges the IAEA to secure sufficient funding, through appeals to international organizations and prospective donor countries, to ensure completion in 1996 of the second phase of a programme in this area. It further requests the IAEA to include the nuclear desalination of seawater in future programmes of the Agency, with appropriate priority.

Isotope Hydrology for Water Resources Management. Citing the importance of clean drinking water to human health and the optimum use of economic resources, the resolution requests the IAEA to continue to integrate the available resources of the Agency and its Member States and to direct them towards concrete programmes for producing a visible impact by improving the quality and availability of water.

IAEA Budget for 1996 and Target for Technical Co-operation Fund. The adopted resolution allocates expenditures of US $219 million in 1996 (at an exchange rate of 12.70 Austrian schillings to the US dollar). The Conference also approved the 1996 target amount of US $64.5 million for voluntary contributions to the Technical Co-operation Fund.

Staffing of the IAEA Secretariat. Two resolutions were adopted. One resolution requests the IAEA to intensify efforts to increase, particularly at the senior and policymaking levels, the number of staff members from developing countries and other Member States that are under-represented. The second resolution requests the IAEA to continue efforts to increase substantially, particularly at the senior and policy-making levels, as well as for scientific and technical posts, the number of female staff members, particularly from developing countries and from those other Member States which are under-represented. It further calls upon the IAEA to examine the Platform for Action developed at the UN Fourth World Conference on Women and to integrate, where applicable, the elements of this platform into the Agency's relevant policies and programmes.

The full texts of resolutions adopted by the IAEA General Conference, as well as other documents and statements, are globally on-line through the IAEA's World Atom Internet address, http://www.iaea.or.at/GC.

Austria: Vienna honours Dr. Blix

At a ceremony in December 1995, IAEA Director General Hans Blix received Vienna's Golden Merit Award. The presentation, made by Municipal Councillor Dr. Hannes Swoboda, took place 15 December 1995 at Vienna City Hall.

In accepting the award, Dr. Blix extended his appreciation to Viennese officials and citizens for their support and hospitality to the IAEA, which opened its doors at the city's downtown Grand Hotel in 1957 before moving to the Vienna International Centre near the Danube river in 1979. The Agency was the first organization of the United Nations system to set up headquarters in Vienna.

Marshall Islands: Radiation safety

At the request of the Marshall Islands, the IAEA convened an advisory group meeting in Vienna 11-14 December 1995 on the radiological situation in the Bikini atoll, once the site of nuclear tests. Attending were experts from Australia, France, Japan, New Zealand, Russia, the United Kingdom, the United States, the World Health Organization, and the IAEA. The meeting examined scientific studies on the atoll's radiological condition and discussed possible remedial actions that would enable people to live there again. The Bikinians, then numbering 167, evacuated the atoll in 1946, when it became a US nuclear test site until 1958. They have not returned permanently because of concerns over radioactive contamination of their homelands and crops.

The advisory group closely considered studies that have been done in the United States and the Marshall Islands on the atoll's radiological conditions. Guided by the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), the group concluded that if people were to return to live on the isles, current annual dose levels were sufficiently high — up to about 15 millisievert per year for a diet drawn from local foods only — to justify taking intervention measures to reduce them.

Two remediation strategies were examined from a radiation protection perspective. One is the removal and replacement of contaminated soil, which the group considered undesirable because of adverse environmental and social consequences. The second strategy, which US scientists have tested on Bikini through extensive field trials, is the application of potassium to the soil, preferably through fertilizers, to greatly reduce the uptake of radioactive caesium-137 by tree fruits and other crops. The plants would take up the potassium in preference to caesium, whose levels would fall most rapidly over the first 4 years and steadily thereafter through repeated applications. This strategy additionally could entail removal of surface soil in villages and around housing sites and its replacement with a layer of crushed coral. This would minimize the possibility of human exposure to radioactive contaminants in the soil.

No definite recommendations on a course of action were made to the Marshall Islands. The group pointed out the need to ensure that remedial measures are carried out adequately and that the radiological condition of the atoll remains satisfactory after remediation. Toward this end, experts suggested establishing post-remediation monitoring programmes with the IAEA's technical assistance and support.

Viet Nam and Japan: Seminars on nuclear information

Viet Nam and Japan recently hosted seminars to broaden awareness and understanding of nuclear energy. The meetings were organized under an extra-budgetary IAEA public information programme funded by Japan.

In Viet Nam, topics covered related to national energy strategies, nuclear power development, and the peaceful applications of nuclear energy. The seminar, held 4-6 October 1995, was co-organized in Hanoi by the IAEA and Viet Nam Atomic Energy Commission (VINATOM). In addition to experts from the Agency and Viet Nam, participants included invited specialists, journalists, and government and industry officials from Austria, China, France, Japan, and Republic of Korea. Sessions featured presentations on national nuclear power development strategies and approaches, nuclear safety and radiological protection, public information about nuclear energy, and nuclear applications and technical co-operation activities.

In Japan, the seminar was held 29 November to 1 December in Kyoto, in co-operation with Japan's Ministry of Trade and Industry and the Science and Technology Agency. Its focus was on the symbiosis between nuclear facilities and local communities. Sessions featured presentations from local Japanese officials, as well as invited officials from the Netherlands, United Kingdom, Germany, Sweden, and Republic of Korea. Additionally, technical tours were arranged, including one to the Spring-8 synchrotron radiation facility.

India: Sculpture to the IAEA

India has presented the IAEA with a sculpture of Dr. Homi Jenegir Bhaba, the first Chairman of the Indian Atomic Energy Commission (AEC) and a member of the first IAEA Board of Governors until his untimely death in 1966. The sculpture, a bust of Dr. Bhaba, was presented to IAEA Director General Hans Blix by Dr. R. Chidambaram, India's AEC Chairman and the 1994-95 Chairman of the IAEA Board, at a ceremony at IAEA headquarters in Vienna 25 September 1995. Also attending was Dr. Sigvard Eklund, Dr. Blix's predecessor and Director General *emeritus* of the IAEA.

"The IAEA started moving through the initiative of a group of nuclear pioneers who saw in nuclear energy the great hope for satisfying the energy needs of mankind even when all other conventional sources are exhausted," Dr. Chidambaram said. "Dr. Bhaba was one such pioneer." Dr. Bhaba started the Indian programme in 1944 with the establishment of the Tata Institute of Fundamental Research and, soon thereafter, the atomic research centre in Bombay, which is now named after him. He, along with India's Prime Minister Jawaharlal Nehru, saw science and technology as the only route to growth in developing countries and especially emphasized contributions of nuclear science and technology, Dr. Chidambaram said, a vision Dr. Bhaba's service carried to the IAEA and international community.

Moldova: Joining IAEA

The IAEA Board of Governors in December 1995 endorsed the application of Moldova for IAEA membership, recommending approval to the IAEA General Conference, which next meets in September 1996.

In September 1995, the Republic of Bosnia and Herzegovina became a member of the IAEA, following approval by the General Conference and the country's deposit of the necessary legal instruments. The Agency's membership was 123 States at the beginning of 1996.

France: Food irradiation workshop

Emerging developments in food trade could greatly influence the use of irradiation for sanitary and health-related reasons. At a workshop in Marseilles in November 1995, governmental delegates from 23 countries examined the picture. The meeting was organized by the International Consultative Group on Food Irradiation (ICGFI), a body under the aegis of the IAEA, Food and Agricultural Organization (FAO) of the United Nations, and the World Health Organization (WHO).

Dr. Eklund (centre) and Dr. Blix applaud the presentation of the Bhaba sculpture by Dr. Chidambaram of India.

The workshop particularly looked at changing developments tied to new trade agreements. Specifically, trade in food and agricultural commodities is expected to increase significantly through the agreements on the application of sanitary and phytosanitary measures (SPS) and technical barriers to trade (TBT) adopted during the Uruguay Round. The SPS recognizes relevant international standards, guidelines, and recommendations of international organizations such as the Codex Alimentarius Commission (CAC), the International Plant Protection Convention (IPPC), and the International Office of Epizootics that would assist the World Trade Organization (WTO) in settling disputes that might arise. Governments having regulations that do not conform with the standards, guidelines, and recommendations of these organizations may be asked to justify their position to the WTO. With respect to food irradiation, the CAC adopted a General Standard for Irradiated Foods in 1983, and regional plant protection organizations within the framework of the IPPC endorsed irradiation as an effective quarantine treatment of fresh agricultural commodities in 1991.

Delegates noted that irradiation already is accepted for processing food in some 40 countries, with 28 of these countries using the technology for commercial purposes. In 1994, the use of irradiation as a replacement for fumigation of food and food ingredients, especially spices and dried vegetable seasonings, increased to more than 40,000 tonnes, double the amount in 1992. With the global phase-out of methyl bromide as a food fumigant by the year 2000 because of its ozone-depleting properties, the role of irradiation to control insect infestation in traded foods is likely to expand greatly. In the United States, the Department of Agriculture has announced its intention to approve irradiation's broad use as a quarantine treatment for fresh fruits and vegetables.

Japan: Spent fuel technologies

Experts from 11 countries attended a technical committee meeting and workshop hosted by Japan on the handling and safe storage of spent fuel from nuclear power plants. The meeting, held 23-27 October 1995 at the Ministry of Trade and Industry in Tokyo, focused on storage options and selection principles of dry storage technologies for WWER and RBMK reactors, within the framework of the IAEA's extrabudgetary programme on the safety of such reactors being supported by Japan and other countries. Participating experts represented nuclear organizations and utilities in Bulgaria, Canada, Czech Republic, Germany, Hungary, Japan, Slovak Republic, Spain, Russia, Ukraine, and the United States.

From both financial and technical perspectives, experts at the meeting presented and discussed case studies of the selection process and principles applied in various countries for spent fuel storage. Technical visits further were arranged to Japan's Central Research Institute of the Electric Power Industry and to the Tokyo Electric Power Company's Fukushima-Daiichi nuclear power station.

Brazil: Radiation protection

Brazil's Association for Non-Destructive Testing (ABENDE) in co-operation with the National Nuclear Energy Commission is sponsoring its first international meeting on industrial radioprotection 17-20 March 1996 in São Paulo.

Scheduled sessions include panel discussions and technical presentations on national and global developments in the field. Papers include those from invited experts in Argentina, France, and the IAEA. Dr. Abel González, Acting Director of the IAEA's Division of Radiation and Waste Safety, will review the implementation of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. More information may be obtained from ABENDE, Rua Luiz Góes 2341, São Paulo, Brazil 04043-400. Facsimile: 55-11-581-1164.

United Kingdom: Becquerel's legacy

French scientist Henri Becquerel's discovery of radioactivity a century ago is being marked by an international conference at the Royal Society of Arts in London 29 February to 1 March 1996. It is being organized by the National Radiological Protection Board (NRPB) and the British Association for the Advancement of Science.

Sessions will explore the nature and beneficial uses of radioactivity, the depth of its scientific understanding, and the regulation and control of its attendant risks. More information may be obtained from the Becquerel Conference Secretariat, NRPB, Chilton, Didcot, Oxon OX11 0RQ. Facsimile: 01235-822630.

IAEA APPOINTMENT. The IAEA has announced the appointment of Mr. Victor M. Murogov, of the Russian Federation, as Deputy Director General, Head of the Department of Nuclear Energy. Mr. Murogov, who took up the position in January 1996, succeeds Mr. Boris Semenov.

NEW IAEA DEPARTMENT. The IAEA has restructured its former Department of Nuclear Energy and Safety. Effective 1 January 1996, the Department has been split into two separate departments, the Department of Nuclear Safety and the Department of Nuclear Energy. Head of the Department of Nuclear Energy is Mr. Victor M. Murogov. It includes three divisions: the Division of Nuclear Power, the Division of Scientific and Technical Information, and the Division of Nuclear Fuel Cycle and Waste Management. The Department of Nuclear Safety, headed by Mr. Morris Rosen, includes the Division of Nuclear Installation Safety and the Division of Radiation and Waste Safety. A second step in the restructuring will take place effective August 1996, when the Nuclear Fuel Cycle and Materials Section and the Waste Technology Section will be transferred to the Division of Nuclear Power, then to be the Division of Nuclear Power and the Fuel Cycle.

ASA AWARD. The American Statistical Society has presented two IAEA staff members — David Donahue and Rudolf Fiedler — with its Statistics in Chemistry award. The honour is in recognition of the publication of their paper, "Multi-detector Calibration for Mass Spectrometers", which appeared in the *International Journal of Mass Spectrometry and Ion Processes* in 1994 (Vol. 134). The paper represented a collaboration with Charles Bayne of the Oak Ridge National Laboratory, who as a co-author also shared the award. The work was carried out under the US Support Programme to IAEA Safeguards. Messrs. Donahue and Fiedler are staff members at the Agency's Safeguards Analytical Laboratory in Seibersdorf.

INFORMATION BOOKLETS. New public information booklets have been issued by the IAEA on topical issues related to nuclear applications and global co-operation. *The IAEA and the UN, Partnerships for Development and Peace* features a series of brief reports highlighting nuclear co-operative efforts for sustainable development and for safeguarding nuclear materials. *Isotopes in Water and Environmental Management* looks at how nuclear and related techniques are helping countries to identify, assess, and optimize their water resources. Both booklets also are on-line through the IAEA's *World Atom* Internet services at *http://www.iaea.or.at/worldatom.*

FUSION ENERGY CONFERENCE. The 16th IAEA Fusion Energy Conference, formerly called the International Conference on Plasma Physics and Controlled Nuclear Fusion Research, will be held in Montreal, Canada 7-11 October 1996. The conference is aimed at encouraging the exchange between nations of scientific and technical information on fusion research, with emphasis on fusion technology.

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Plasma Physics and Controlled Nuclear Fusion Research 1994, *Proceedings Series, Volume 2280 Austrian schillings, ISBN 92-0-10229-6, Volume 4, 280 Austrian schillings, I SBN 92-0-101895-9*

Safety and Engineering Aspects of Spent Fuel Storage *Proceedings Series, 1320 Austrian schillings, ISBN 92-0-101695-6*

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Publications in Production

Isotopes in Water Resources Management, *Proceedings of an International Symposium, Vienna, March 1995* (STI/PUB 970)

Environmental Impact of Radioactive Releases, *Proceedings of an International Symposium, Vienna, May 1995* (STI/PUB 971)

Induced Mutations and Molecular Techniques for Crop Improvement, *Proceedings of an International Symposium, Vienna, June 1995* (STI/PUB 972)

Tomography in Nuclear Medicine, *Proceedings of an International Symposium, Vienna, August 1995*

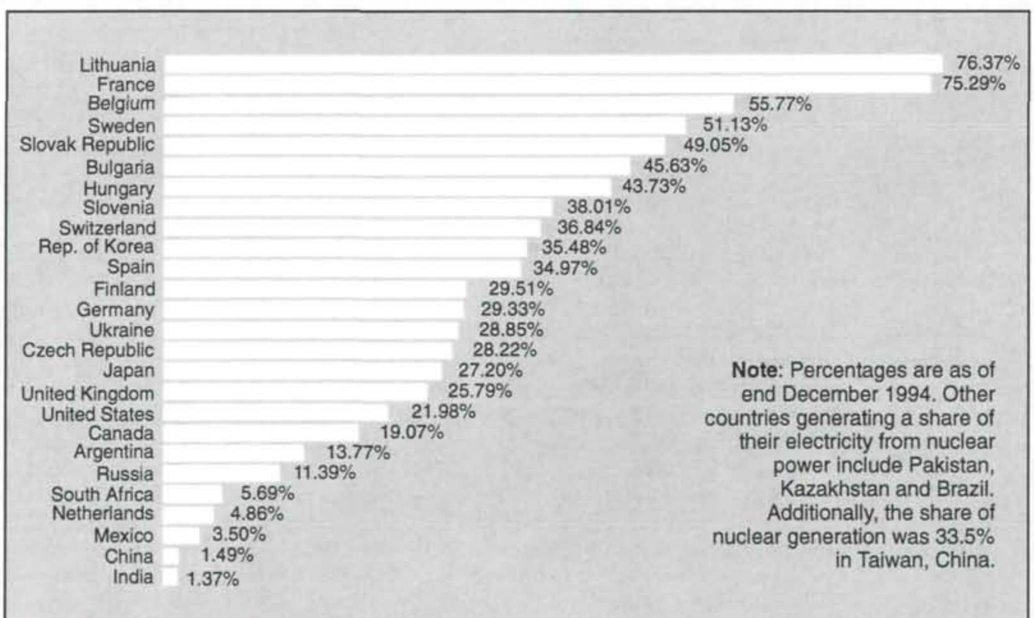
The Nuclear Fuel Cycle Information System: A Directory of Nuclear Fuel Cycle Facilities *Reference book/statistics*

Nuclear power status around the world

	In operation		Under construction	
	No. of units	Total net MWe	No. of units	Total net MWe
Argentina	2	935	1	692
Belgium	7	5 527		
Brazil	1	626	1	1245
Bulgaria	6	3 538		
Canada	22	15 755		
China	3	2 100		
Czech Republic	4	1 648	2	1 824
Finland	4	2 310		
France	56	58 493	4	5 810
Germany	21	22 657		
Hungary	4	1 729		
India	9	1 493	5	1 010
Iran			2	2 392
Japan	49	38 875	5	4 799
Kazakhstan	1	70		
Korea, Rep. of	10	8 170	6	4 820
Lithuania	2	2 370		
Mexico	2	1 308		
Netherlands	2	504		
Pakistan	1	125	1	300
Romania			5	3 250
Russian Federation	29	19 843	4	3 375
South Africa	2	1 842		
Slovak Republic	4	1 632	4	1 552
Slovenia	1	632		
Spain	9	7 105		
Sweden	12	10 002		
Switzerland	5	2 985		
United Kingdom	34	11 720	1	1 188
Ukraine	15	12 679	6	5 700
USA	109	98 784	1	1 165
World total*	432	340 347	48	38 876

* The total includesTaiwan, China where six reactors totalling 4890 MWe are in operation.

Nuclear share of electricity generation in selected countries



Note: Percentages are as of end December 1994. Other countries generating a share of their electricity from nuclear power include Pakistan, Kazakhstan and Brazil. Additionally, the share of nuclear generation was 33.5% in Taiwan, China.

POSTS ANNOUNCED BY THE IAEA

RESEARCH SCIENTIST (96-002), Marine Environment Laboratory, Monaco. This P-3 post plans and carries out studies on the development and use of Inductively Coupled Plasma Mass Spectrometry (ICPMS) techniques for radionuclide and multi-elemental analysis, among other duties. The post requires practical experience in running and maintaining an ICPMS instrument, basic experience in the field of marine radioactivity or trace element studies, and an ability to interact as a member of a multi-disciplinary, multi-cultural team. An advanced university degree is required, preferably a Ph.D, in the relevant discipline, and at lease 6 years of experience with ICPMS techniques. *Closing date: 24 May 1996.*

TECHNICAL WRITER (96-003), Safety Co-ordination Section, Department of Nuclear Safety. This P-3 post prepares policy documents, technical reports, and journal articles on nuclear, radiation protection, and waste management safety on major issues and topics, among other duties. It requires a university degree in a scientific field and at least 6 years of experience in writing and substantive editing of scientific material, including at least 2 years experience in the nuclear field.. *Closing date: 24 May 1996.*

SECTION HEAD, INIS (95-070), Division of Scientific and Technical Information, Department of Nuclear Energy. This P-5 post is principally responsible for management of the International Nuclear Information System. It requires an advanced university degree or equivalent in information science, natural science, computer science, mathematics, or related field, and at least 15 years of total experience including at least 5 years in the documentation and information field. Also required is good knowledge of large-scale computerized bibliographic information systems and technical and administrative management experience. *Closing date: 15 March 1996.*

DIRECTOR (95-069), Division of Languages, Department of Administration. This D-1 post carries responsibility for activities of the IAEA's language division, which consists of six translation sections and support services. It requires an advanced university degree or equivalent and a minimum of 15 years of experience relevant to carrying out the responsibilities of a language service of a large international organization, and adequate administrative and supervisory experience. Also required is knowledge of human resource and financial management principles and ability to apply these principles in allocating resources. *Closing date: 15 March 1996.*

MARINE CHEMIST (95-708), Marine Environment Laboratory, Monaco. This P-3 post develops and optimizes analytical procedures for the determination of inorganic contaminants in marine samples, including specification of organo-metallic compounds and supervises activities of the Inorganic Laboratory. It requires a Ph.D. in marine chemistry and at least 6 years of experience in analytical chemistry of various marine matrices for a wide range of inorganic contaminants. This is an extrabudgetary post and the duration of the appointment is subject to availability of extrabudgetary funds. *Closing date: 6 March 1996.*

SOIL SCIENTIST/PLANT NUTRITIONIST (96-004), Soil Fertility, Irrigation, and Crop Production Section, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. This P-3 post, among other duties, co-ordinates the activities of participants in IAEA Co-ordinated Research Programmes and provides technical support for technical co-operation projects. It requires experience as a soil scientist/plant nutritionist and a Ph.D or equivalent in the field, and at least 6 years of research experience in the use of isotopes and nuclear techniques in plant physiology. *Closing date: 24 April 1996.*

RADIATION CHEMIST (95-067), Industrial Applications and Chemistry Section, Department of Research and Isotopes. This P-4 post organizes scientific symposia and technical seminars and meetings, and provides technical advice and support on aspects of radiation technologies, among other duties. It requires a Ph.D. or equivalent in engineering, physical sciences or chemical sciences and a minimum of 10 years of research/developmental experience involving industrial applications of radiation technology, comprehensive knowledge and practical experience with industrial applications of electron accelerators and isotope sources. Also required is experience in the management and evaluation of international projects, effective representational skills, and ability to contribute to the achievement of organizational goals. *Closing date: 1 March 1996.*

REFERENCE LIBRARIAN (96-005), Vienna International Centre Library, Division of Scientific and Technical Information, Department of Nuclear Energy. This P-2 post provides reference, research, and information services to library users, co-ordinates the duty roster of the reference team, and supervises the serials group, among other duties. It requires an advanced university degree in librarianship or information science, at least 2 years of experience in a library with automated information retrieval and circulation systems, good working knowledge of major printed reference sources, and familiarity with external on-line databases. *Closing date: 24 May 1996.*

DEVELOPMENT PROGRAMMER (96-006), Division of Scientific and Technical Information, Department of Nuclear Energy. This P-2 post participates in the planning and design of technical and administrative computer information systems and develops computer application programs, among other duties. It requires a university degree in computer science or related fields and at least 2 years of practical programming experience. *Closing date: 24 May 1996.*

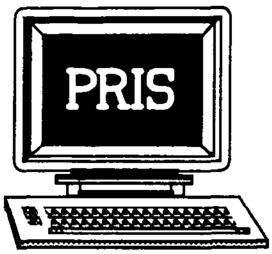
READER'S NOTE:

The ***IAEA Bulletin*** publishes short summaries of vacancy notices as a service to readers interested in the types of professional positions required by the IAEA. They are ***not*** the official notices and remain subject to change. On a frequent basis, the IAEA sends vacancy notices to governmental bodies and organizations in the Agency's Member States (typically the foreign ministry and atomic energy authority), as well as to United Nations offices and information centres. Prospective applicants are advised to maintain contact with them. Applications are invited from suitably qualified women as well as men. More specific information about employment opportunities at the IAEA may be obtained by writing the Division of Personnel, Box 100, A-1400 Vienna, Austria.

ON-LINE VACANCY NOTICES. IAEA vacancy notices for professional positions, as well as application forms, now are available through a global computerized network that can be accessed directly. Access is through the Internet. The vacancy notices are located in a public directory accessible via the normal Internet file transfer services. To use the service, connect to the IAEA's Internet address NESIRS01.IAEA.OR.AT (161.5.64.10), and then log on using the identification *anonymous* and your user identification. The vacancy notices are in the directory called *pub/vacancy_posts*. A *README* file contains general information, and an *INDEX* file contains a short description of each vacancy notice. Other information, in the form of files that may be copied, includes an application form and conditions of employment. Please note that applications for posts cannot be forwarded through the computerized network, since they must be received in writing by the IAEA Division of Personnel.

ON LINE DATABASES

OF THE INTERNATIONAL ATOMIC ENERGY AGENCY



Database name
Power Reactor Information System (PRIS)

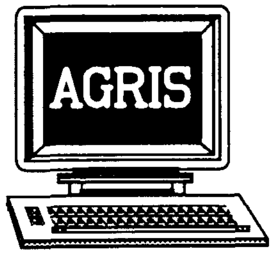
Type of database
Factual

Producer
International Atomic Energy Agency in co-operation with 29 IAEA Member States

IAEA contact
IAEA, Nuclear Power Engineering Section, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2060
Telex (1)-12645
Facsimile +43 1 20607
Electronic mail via BITNET/INTERNET to ID: NES@IAEA1.IAEA.OR.AT

Scope
Worldwide information on power reactors in operation, under construction, planned or shutdown, and data on operating experience with nuclear power plants in IAEA Member States.

Coverage
Reactor status, name, location, type, supplier, turbine generator supplier, plant owner and operator, thermal power, gross and net electrical power, date of construction start, date of first criticality, date of first synchronization to grid, date of commercial operation, date of shutdown, and data on reactor core characteristics and plant systems; energy produced; planned and unplanned energy losses; energy availability and unavailability factors; operating factor, and load factor.



Database name
International Information System for the Agricultural Sciences and Technology (AGRIS)

Type of database
Bibliographic

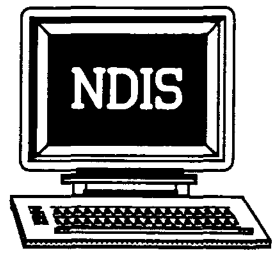
Producer
Food and Agriculture Organization of the United Nations (FAO) in co-operation with 172 national, regional, and international AGRIS centres

IAEA contact
AGRIS Processing Unit
c/o IAEA, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2060
Telex (1)-12645
Facsimile +43 1 20607
Electronic mail via BITNET/INTERNET to ID: FAS@IAEA1.IAEA.OR.AT

Number of records on line from January 1993 to date
more than 130 000

Scope
Worldwide information on agricultural sciences and technology, including forestry, fisheries, and nutrition.

Coverage
Agriculture in general; geography and history; education, extension, and information; administration and legislation; agricultural economics; development and rural sociology; plant and animal science and production; plant protection; post-harvest technology; fisheries and aquaculture; agricultural machinery and engineering; natural resources; processing of agricultural products; human nutrition; pollution; methodology.



Database name
Nuclear Data Information System (NDIS)

Type of database
Numerical and bibliographic

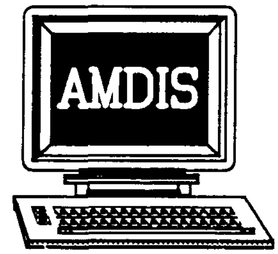
Producer
International Atomic Energy Agency in co-operation with the United States National Nuclear Data Centre at the Brookhaven National Laboratory, the Nuclear Data Bank of the Nuclear Energy Agency, Organisation for Economic Co-operation and Development in Paris, France, and a network of 22 other nuclear data centres worldwide

IAEA contact
IAEA Nuclear Data Section, P.O. Box 100
A-1400 Vienna, Austria
Telephone (43) (1) 2060
Telex (1)-12645
Facsimile +43 1 20607
Electronic mail via BITNET/INTERNET to ID: RNDS@IAEA1.IAEA.OR.AT

Scope
Numerical nuclear physics data files describing the interaction of radiation with matter, and related bibliographic data.

Data types
Evaluated neutron reaction data in ENDF format; experimental nuclear reaction data in EXFOR format, for reactions induced by neutrons, charged particles, or photons; nuclear half-lives and radioactive decay data in the systems NUDAT and ENSDF; related bibliographic information from the IAEA databases CINDA and NSR; various other types of data.

Note: Off-line data retrievals from NDIS also may be obtained from the producer on magnetic tape



Database name
Atomic and Molecular Data Information System (AMDIS)

Type of database
Numerical and bibliographic

Producer
International Atomic Energy Agency in co-operation with the International Atomic and Molecular Data Centre network, a group of 16 national data centres from several countries.

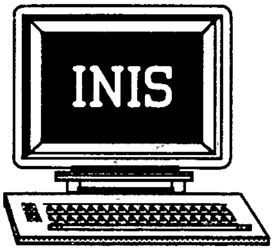
IAEA contact
IAEA Atomic and Molecular Data Unit, Nuclear Data Section
Electronic mail via BITNET to: RNDS@IAEA1;
via INTERNET to ID: PSM@RIPCRS01.IAEA.OR.AT

Scope
Data on atomic, molecular, plasma-surface interaction, and material properties of interest to fusion research and technology

Coverage
Includes ALADDIN formatted data on atomic structure and spectra (energy levels, wave lengths, and transition probabilities); electron and heavy particle collisions with atoms, ions, and molecules (cross sections and/or rate coefficients, including, in most cases, analytic fit to the data); sputtering of surfaces by impact of main plasma constituents and self sputtering; particle reflection from surfaces; thermophysical and thermomechanical properties of beryllium and pyrolytic graphites.

Note: Off-line data and bibliographic retrievals, as well as ALADDIN software and manual, also may be ob-tained from the producer on diskettes, magnetic tape, or hard copy.

For access to these databases, please contact the producers.
Information from these databases also may be purchased from the producer in printed form.
INIS and AGRIS additionally are available on CD-ROM.



Database name
International Nuclear Information System (INIS)

Type of database
Bibliographic

Producer
International Atomic Energy Agency in co-operation with 91 IAEA Member States and 17 other international member organizations

IAEA contact
IAEA, INIS Section, P.O. Box 100, A-1400 Vienna, Austria
Telephone (+431) 2060 22842
Facsimile (+431) 20607 22842
Electronic mail via BITNET/INTERNET to ID: ATIEH@NEPO1.IAEA.OR.AT

Number of records on line from January 1976 to date
more than 1.6 million

Scope
Worldwide information on the peaceful uses of nuclear science and technology; economic and environmental aspects of other energy sources.

Coverage
The central areas of coverage are nuclear reactors, reactor safety, nuclear fusion, applications of radiation or isotopes in medicine, agriculture, industry, and pest control, as well as related fields such as nuclear chemistry, nuclear physics, and materials science. Special emphasis is placed on the environmental, economic, and health effects of nuclear energy, as well as, from 1992, the economic and environmental aspects of non-nuclear energy sources. Legal and social aspects associated with nuclear energy also are covered.

IAEA UPCOMING CO-ORDINATED RESEARCH PROGRAMMES

Development of Computer-Based Troubleshooting Tools and Instruments
To develop computer-based tools and instruments to assist in maintenance, troubleshooting and repair of nuclear electronic equipment.

Treatment of Liquid Effluent from Uranium Mines and Mills During and After Operation (post decommissioning/rehabilitation)
To identify basic concepts for innovation and integrated combinations of mining, processing and waste management technologies that can potentially achieve both environmental compatibility and economic improvements.

Corrosion of Research Reactor Aluminum-Clad Spent Fuel in Water
To assess corrosion rates of aluminum cladding alloys in good, typical and poor water chemistry regimes, to give guidance to those faced with extending pool storage of research reactor spent fuel, and to identify the basic corrosion mechanisms involved.

Case Studies on Comparing Alternative Sustainable Energy Mixes for Electricity Generation
To carry out case studies on analysing and comparing alternative options and strategies in the power sector, through the use of data bases and analytical software developed by the Agency in connection with the DECADES project, aiming at sustainable energy mixes meeting atmospheric emission standards and regulation.

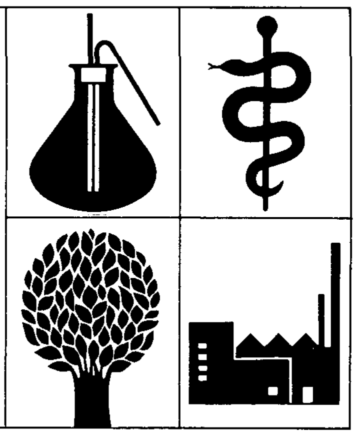
Intercomparison of *In-vivo* **Counting Systems Using a Reference Asian Phantom**
To provide each participating personal dosimetry service the opportunity to assess its ability to measure the internally deposited thorium, uranium and transuranic radionuclides with sufficient accuracy for radiation protection purposes. The CRP will also provide the participants specific information on steps that they can take to improve their performance, and give them the opportunity for information exchange with other dosimetry services.

The Use of Isotope Techniques in Studies on the Management of Organic Matter and Nutrient Turnover for Increase, Sustainable Agricultural Production and Environmental Preservation
To conduct isotope-aided studies that will assist in devising appropriate management options to slow down soil organic matter decomposition rates and thereby synchronize nutrient release with nutrient demand by crops for maximum yields.

The Diagnosis and Follow-Up of Prostatic Cancer by Radioimmunoassay (RIA)
To ascertain the sensitivity and specificity of measurements using an IRMA technique for early diagnosis of primary as well as recurrent prostate cancer. The overall diagnostic accuracy of the test will be compared with alternative diagnostic modalities.

Nuclear Imaging for Infection and Inflammation
To determine the role of radionuclide imaging for infection and inflammation among other non-nuclear investigations for the same purpose, such as X-ray computed tomography and ultrasonography.

These are selected listings, subject to change. More complete information about IAEA meetings can be obtained from the IAEA Conference Service Section at the Agency's headquarters in Vienna, or by referring to the IAEA quarterly publication ***Meetings on Atomic Energy*** (See the *Keep Abreast* section for ordering information.) More detailed information about the IAEA's co-ordinated research programmes may be obtained from the Research Contracts Administration Section at IAEA headquarters. The programmes are designed to facilitate global co-operation on scientific and technical subjects in various fields, ranging from radiation applications in medicine, agriculture, and industry to nuclear power technology and safety.



IAEA SYMPOSIA & SEMINARS

FEBRUARY 1996
FAO/IAEA/IIR/ITC/WHO Regional Seminar on Food Irradiation to Control Food Losses and Food-Borne Diseases and Facilitate Food Trade
Rabat, Morocco
(26 February - 1 March)

MARCH 1996
International Seminar on Enhanced Utilization of Research and Test Reactors
Bombay, India (11- 15 March)

APRIL 1996
International Conference
One Decade after Chernobyl:
Summing Up the Consequences of the Accident
Vienna, Austria (8 - 12 April)

JUNE 1996
International Symposium on Experience in the Planning and Operation of Low-Level Waste Disposal Facilities
Vienna, Austria (17 - 21 June)

JULY 1996
FAO/IAEA Symposium on the Use of Nuclear and Related Techniques for Studying Environmental Behaviour of Crop Protection Chemicals
Vienna, Austria (1 - 5 July)

AUGUST 1996
Seminar on Nuclear Techniques for the Detection and Management of Cancer
Colombo, Sri Lanka (12 -16 August)

SEPTEMBER 1996
IAEA General Conference, 40th session
Vienna, Austria
(16 - 20 September)

OCTOBER 1996
16th IAEA Fusion Energy Conference
Montreal, Canada (7 - 11 October)

Symposium on Reviewing the Safety of Existing Nuclear Power Plants
Vienna, Austria (8 - 11 October)

NOVEMBER 1996
Symposium on Harmonization of Health-Related Environmental Measurements Using Nuclear & Isotopic Techniques
Hyderabad, India (4 -7 November)

Seminar on the Use of Isotope Techniques in Marine Environmental Studies
Venue to be announced
(4-15 November)

95-03750

IAEA BULLETIN

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Tel: (43-1) 2060-21270
Facsimile: (43-1) 20607
E-mail: iaeo@iaea1.iaea.or.at

IAEA MEMBER STATES

1957
Afghanistan
Albania
Argentina
Australia
Austria
Belarus
Brazil
Bulgaria
Canada
Cuba
Denmark
Dominican Republic
Egypt
El Salvador
Ethiopia
France
Germany
Greece
Guatemala
Haiti
Holy See
Hungary
Iceland
India
Indonesia
Israel
Italy
Japan
Korea, Republic of
Monaco
Morocco
Myanmar
Netherlands
New Zealand
Norway
Pakistan
Paraguay
Peru
Poland
Portugal
Romania
Russian Federation
South Africa
Spain
Sri Lanka
Sweden
Switzerland
Thailand
Tunisia
Turkey
Ukraine
United Kingdom of Great Britain and Northern Ireland
United States of America
Venezuela
Viet Nam
Yugoslavia

1958
Belgium
Cambodia
Ecuador
Finland
Iran, Islamic Republic of
Luxembourg
Mexico
Philippines
Sudan

1959
Iraq

1960
Chile
Colombia
Ghana
Senegal

1961
Lebanon
Mali
Zaire

1962
Liberia
Saudi Arabia

1963
Algeria
Bolivia
Côte d'Ivoire
Libyan Arab Jamahiriya
Syrian Arab Republic
Uruguay

1964
Cameroon
Gabon
Kuwait
Nigeria

1965
Costa Rica
Cyprus
Jamaica
Kenya
Madagascar

1966
Jordan
Panama

1967
Sierra Leone
Singapore
Uganda

1968
Liechtenstein

1969
Malaysia
Niger
Zambia

1970
Ireland

1972
Bangladesh

1973
Mongolia

1974
Mauritius

1976
Qatar
United Arab Emirates
United Republic of Tanzania

1977
Nicaragua

1983
Namibia

1984
China

1986
Zimbabwe

1991
Latvia
Lithuania

1992
Croatia
Estonia
Slovenia

1993
Armenia
Czech Republic
Slovakia

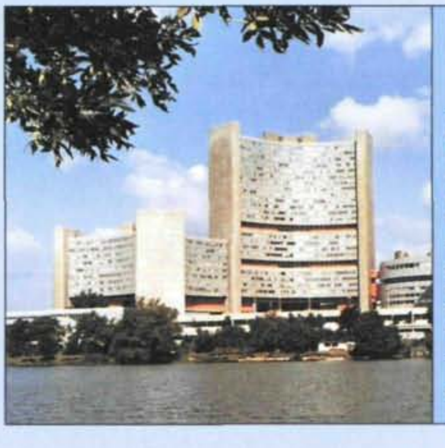
1994
Former Yugoslav Republic of Macedonia
Kazakhstan
Marshall Islands
Uzbekistan
Yemen

1995
Bosnia and Herzegovina
Georgia

Eighteen ratifications were required to bring the IAEA's Statute into force. By 29 July 1957, the States in bold face had ratified the Statute.

Year denotes year of membership. Names of the States are not necessarily their historical designations.

For States in italic, membership has been approved by the IAEA General Conference and will take effect once the required legal instruments have been deposited.



The International Atomic Energy Agency, which came into being on 29 July 1957, is an independent intergovernmental organization within the United Nations System. Headquartered in Vienna, Austria, the Agency has more than 100 Member States who together work to carry out the main objectives of IAEA's Statute: To accelerate and enlarge the contribution of atomic energy to peace, health, and prosperity throughout the world and to ensure so far as it is able that assistance provided by it, or at its request or under its supervision or control, is not used in such a way as to further any military purpose.

IAEA headquarters, at the Vienna International Centre.

Until now, one of the biggest problems with reading personal exposure doses has been the size of the monitoring equipment. Which is precisely why we're introducing the Electronic Pocket Dosimeter (EPD) "MY DOSE mini™" PDM-Series.

These high-performance dosimeters combine an easy-to-read digital display with a wide measuring range suiting a wide range of needs.

But the big news is how very small and lightweight they've become. Able to fit into any pocket and weighing just 50~90 grams, the Aloka EPDs can go anywhere you go. Which may prove to be quite a sizable improvement, indeed.

Model	Energy	Range	Application
PDM-101	60 keV ~	0.01 ~ 99.99 μSv	High sensitivity, photon
PDM-102	40 keV ~	1 ~ 9,999 μSv	General use, photon
PDM-173	40 keV ~	0.01 ~ 99.99 mSv	General use, photon
PDM-107	20 keV ~	1 ~ 9,999 μSv	Low energy, photon
PDM-303	thermal ~ fast	0.01 ~ 99.99 mSv	Neutron
ADM-102	40 keV ~	0.001 ~ 99.99 mSv	With vibration & sound alarm, photon

SCIENCE AND HUMANITY

ALOKA

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