Newsletter

NUCLEAR • ENERGY • AGENCY

1999, Vol. 17, No. 2

AEN
NEA

NEA Newsletter

1999 – Volume 17, No. 2

contents

Facts and opinions

NEA update

The NEA in brief

The *NEA Newsletter* is published twice yearly in English and French by the OECD Nuclear Energy Agency. The opinions expressed in the *Newsletter* are those of the contributors alone and do not necessarily reflect the views of the Organisation or of its Member countries. Material in the *Newsletter* may be freely used provided the source is acknowledged.

All correspondence should be addressed to:

The Editor
NEA Newsletter
OECD Nuclear Energy Agency
12, boulevard des Îles
92130 Issy-les-Moulineaux
France

Tel.: +33 (0)1 45 24 10 10
Fax: +33 (0)1 45 24 11 10

The OECD Nuclear Energy Agency (NEA) was established in 1958 as the OEEC European Nuclear Energy Agency and took its present designation in 1972 when its membership was extended to non-European countries. Its purpose is to further international co-operation related to the safety, environmental, economic, legal and scientific aspects of nuclear energy. It currently consists of 27 Member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. The European Commission takes part in the NEA's work and a co-operation agreement is in force with the International Atomic Energy Agency.

For more information about the NEA, see:

http://www.nea.fr

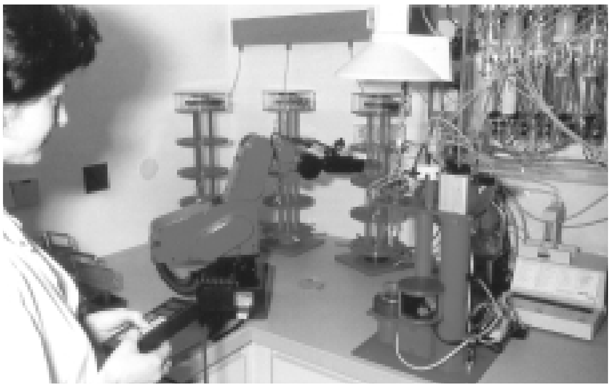
Cover page: Checking water quality on one of the retention ponds of the Ranger uranium mine in Australia. Credit: Energy Resources of Australia Ltd (ERA).

editorial


Economic competitiveness


Nuclear safety


Nuclear waste


Non-proliferation

Society's perception of nuclear energy: A major challenge

There is strong evidence that nuclear energy is a safe and viable energy option that meets sustainable development criteria. However, the perception that society has concerning the risks of nuclear power has led to significant controversy about its future use. For nuclear energy to continue to be chosen as a part of the energy mix in OECD countries, it is essential to communicate that key issues are being dealt with effectively.

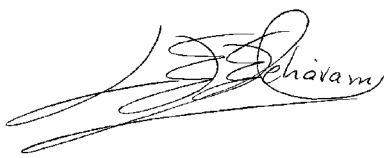
- ***Competitiveness.*** *The deregulation of the electricity market implies significant changes in the decision-making process for new investments in the electricity sector, particularly greater competition. If there is to be a major role for nuclear energy in the future, it will have to be competitive with other sources of electricity production. While mechanisms may be put in place to protect the environment that will favour nuclear investment, other factors such as the tendency of utilities to focus increasingly on the short term and nuclear energy's capital-intensive nature represent important challenges.*

- ***Nuclear safety.*** *While the safety record of reactors operating in OECD countries is very good, public concern remains. This makes it all the more essential to address effectively arising issues – ageing, safety culture, regulatory effectiveness, preservation of knowledge as well as plant life extension and decommissioning.*

- ***Nuclear waste.*** *The final disposal of high-level waste is possibly the main impediment to a more positive perception by the public concerning the future role of nuclear energy. Despite a clear scientific and technical consensus on the feasibility of safe and environmentally sound disposal of high-level waste in deep geological repositories, there is a widespread view that little progress has been achieved in implementing facilities. The Waste Isolation Pilot Plant (WIPP) repository, which began operation in New Mexico, USA early in 1999, is a very positive step in demonstrating the feasibility of such repositories.*

- ***Non-proliferation.*** *A clear perception by society that, thanks to existing control mechanisms, peaceful uses of nuclear energy do not contribute to nuclear proliferation, is important. There is an effective regime in place that has evolved to meet new challenges and it must continue to do so.*

Governments and industries are very conscious of the challenges that lie ahead and the need to keep working with the public to develop a sound understanding of the incentives to maintain an energy option which will be in a key position to help meet sustainable development objectives in the 21st century.



E. Bertel*

Are new reactor designs matching customers' requirements?

Although the criteria used to assess and compare costs may vary from country to country and from company to company, competitiveness is a cornerstone for selecting a technology and energy source for a new power plant.

Although nuclear power presently supplies nearly a quarter of the electricity consumed in OECD Member countries, the stagnation of nuclear power programmes in most of those countries is likely to lead to a lower nuclear share in the electricity supply after the turn of the century. This trend in nuclear power development may well impact on the capabilities of reactor designers to match future requirements of utilities and investors for new plants and, in turn, on the long-term viability of the nuclear option. In order to investigate those issues, the NEA organised a special session on the requirements of utilities for the next two decades as compared with the characteristics of new reactor designs being developed. The session, held in June 1999, included presentations by industry representatives. The present article summarises the key points addressed during the session and highlights the discussion's main findings and conclusions.

Context

Overall energy consumption, in particular in the form of electricity, will continue to increase in the years to come, and the progression of this demand is expected to be particularly drastic in developing countries. For economic reasons, energy providers world-wide will be tempted to turn to energy sources such as natural gas requiring low start-up costs and providing quick returns on investment. On the other hand, there is a growing awareness that energy production by fossil fuels has a detrimental impact on the environment and may affect global climate conditions, even when sophisticated methods for removal of carbon and sulphur oxides from the flue gases are applied.

While there are more than 300 nuclear units in operation in OECD countries, supplying nearly 25% of the electricity consumed, there are only 11 units under construction representing some 5% of the presently installed nuclear capacity. Nuclear power plants are in operation in 16 Member countries, but only three had nuclear units under construction at the beginning of 1999 and only three are planning to order and build nuclear units by 2010. The reasons for this stagnation of nuclear power programmes include the limited need for additional base-load capacity in most OECD countries, as well as the heavy capital expenditure required for building a

* *Dr. Evelyne Bertel is a member of the NEA Nuclear Development Division (e-mail: bertel@nea.fr).*

nuclear power plant, which reduces the competitive edge of nuclear as compared, for example, to gas. One of the consequences is the scarcity of on-going projects and new orders. Furthermore, comparisons of utility requirements with available designs show a number of gaps that would need to be overcome in order to enhance the attractiveness of the nuclear option in the present economic and policy-making landscape.

Electricity market deregulation and privatisation of the electricity sector are generic trends in OECD countries that lead utilities to place emphasis on competitiveness and rapid return on invested capital. On the other hand, sustainable development goals, although seemingly high on the agendas of national and company policy makers, are not yet fully internalised in energy policies through economic instruments (e.g. taxes and subsidies) and/or regulatory measures (e.g. norms and standards). Therefore, utilities are focusing on meeting current health and environmental protection regulations (e.g. sulphur-oxide and nitric-oxide emission limits) but are less interested in alleviating or mitigating impacts that have no market values (e.g. climate change).

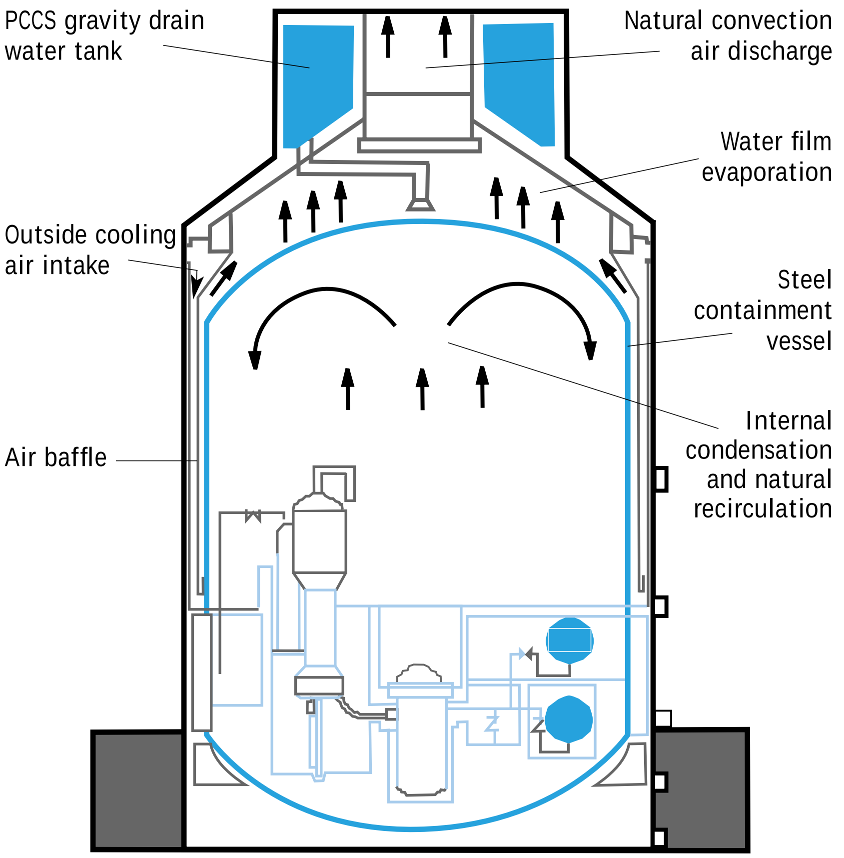
Utility requirements

To a certain extent, electric utilities and investors have country-and/or company-specific criteria for assessing and selecting electricity generation technologies. However, the main requirements of power plant owners and operators are similar irrespective of the country where they operate. As far as nuclear power is concerned, in many countries or regions, utilities or groups of utilities have formulated requirements to provide guidance to developers. The utility requirements incorporate the large base of experience from current plants as well as results of research and development programmes, for example on new safety systems. Common goals on the part of utilities include high availability, ease of operation, competitive economics, and compliance with stringent and internationally recognised safety objectives.

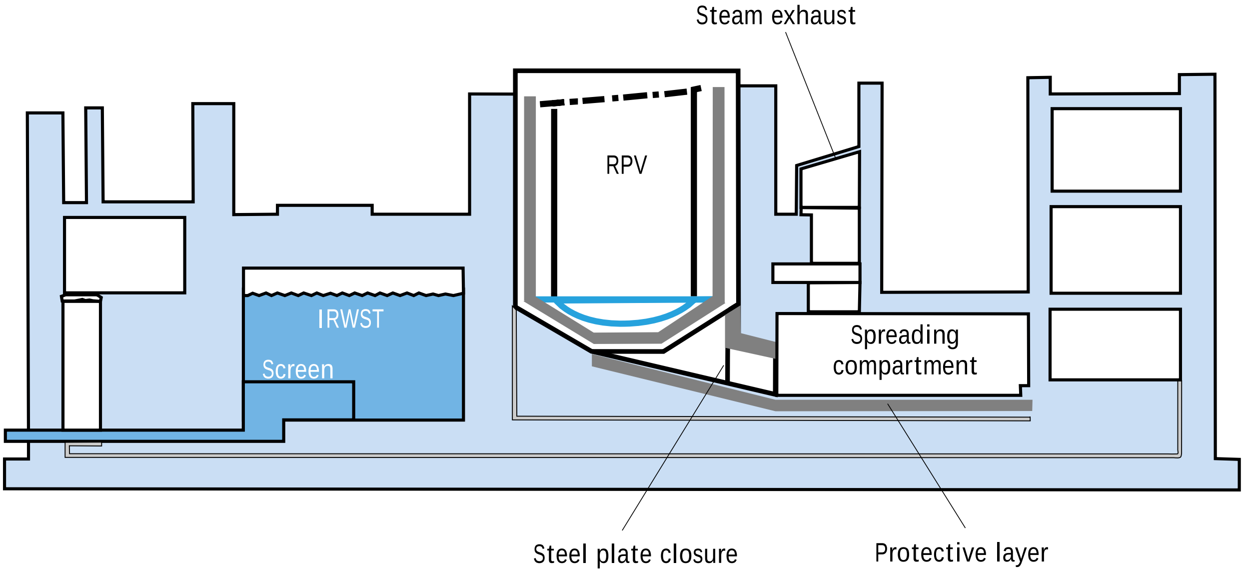
Capital cost, construction time and total generation cost are the key parameters in this regard. Beyond direct economic considerations, however, financial risks are important for utilities, especially if they are privately owned and operate in a deregulated market.

Capital costs of existing reactor designs that could be ordered today and connected to the grid by 2005-2010 are rather high as compared with those of non-nuclear alternatives. In the United Kingdom, for example, it is estimated that the capital cost of a combined-cycle, gas-fired power plant (CCGT) is about one quarter of the cost of a nuclear power plant of the same capacity, assuming a discount rate of 10%. As a result of the high capital cost it can take 25 years or more to pay back the original investment in a nuclear plant, whereas a gas-fired project is generally financed over a maximum of 15 years. Moreover, the size of nuclear units (typically around 1 000 MWe) and their construction time (four to five years in the best cases) are not very attractive as compared with those of modular gas turbines having unit capacities of some 250 MWe and that may be built in less than three years. Also, operation and maintenance costs are lower for CCGT than for nuclear units. At current gas prices, new nuclear designs should aim at capital cost reductions of 50% or more in order to be economically attractive.

Passive containment cooling system



Severe accident mitigation: Measures for retention of molten corium



Beyond direct economics, there are other considerations for a utility considering a new investment. Risk aversion leads utilities to avoid new technologies, which are generally more prone to breakdowns and may carry extensive development costs. Therefore, utilities generally would prefer to invest in reliable nuclear plants based on proven designs, standardised and licensable in more than one country, so that development costs can be shared, prototype technology risks reduced, and economies of scale exploited.

Flexibility in operation is also increasingly important. Since few customers have a demand for additional base-load electricity, utilities are looking for plants capable of operating flexibly and following demand for power. Although small plants offer some advantages in terms of adaptability to demand, grid interconnections between neighbouring countries could provide a basis for constructing large- and medium-size nuclear units, even though the individual national networks are limited in size.

New designs

Designers are aware of utility requirements and work actively on reactor and fuel cycle concepts that would meet those requirements. The designs being developed typically fall into two categories: evolutionary designs, and innovative concepts that require substantial development effort to reach the stage of commercial availability. Given the economic constraints and policies in the industry, most development efforts are devoted to evolutionary designs that are proven, reliable and involve low technical and financial risks. Evolutionary designs include large-size plants (capacities above 1 000 MWe up to 1 500 MWe or more) and medium-size plants (capacities around 600 MWe). The following examples are not exhaustive but illustrate ongoing developments in the field.

The advanced boiling water reactor (ABWR) developed jointly by Japanese and American manufacturers incorporates enhanced safety features and improved instrumentation and control systems. This 1 356 MWe reactor is a proven design that meets the utility requirements specified by the Electric Power Research Institute (EPRI) and has been certified by the USNRC (US Nuclear Regulatory Commission). Furthermore, several units have already been constructed in Japan, where they are competitive with alternative options. Another advanced boiling water reactor design (the BWR 90+ with a capacity of 1 500 MWe) has been developed by a Swedish manufacturer, as an evolution of the BWRs in operation in Finland and Sweden. This new design incorporates increased safety margins, advanced control systems and mitigation features for severe accidents.

The European pressurised water reactor (EPR), developed by Nuclear Power International (NPI), has a design based on the best experience from French and German operating plants, in particular from the most recent standard PWRs (the French P4 and the German Konvoy). The EPR is designed to satisfy the European Utility Requirements, and meet common safety requirements of French and German authorities. The EPR design relies primarily on well-proven active systems to ensure a high degree of safety, supplemented by specific features to ensure effective mitigation of severe accidents. Its 1 750 MWe capacity, although very large, is compatible with grid size and electricity demand in France, Germany and other countries of Western Europe, and allows the operator to benefit from economy of scale.

The 80+ System, developed by ABB Combustion Engineering in the United States, is a 1 350 MWe pressurised water reactor (PWR) designed to meet the EPRI Utility Requirements Document (URD), and it received design certification from the USNRC in May 1997. It relies primarily on well-proven, active systems to achieve a high degree of safety, and incorporates specific features to ensure effective mitigation of severe accidents.

The Korean next-generation reactor (KNGR) is an advanced PWR with a 1 350 MWe capacity, based on the Korea standard nuclear power plants (KSNP) already in operation and incorporating some features of other advanced designs. The KNGR design has been developed with the objectives of greater simplicity and reliability (90% availability), a high level of safety, reduced construction time, lower investment costs, and a longer lifetime (60 years).

The CANDU 9, being developed by Atomic Energy of Canada, Ltd., is an advanced pressurised heavy water reactor design with a capacity of 935 MWe. It is based upon the experience of the units in operation, with some adaptations to meet utility requirements including enhanced safety features and reduced construction costs.

The AP 600 of Westinghouse is designed to meet the EPRI URD, and it received final design approval from the USNRC in September 1998. Key developments of the AP 600 include: a passive core cooling system (depressurisation, safety injection, residual heat removal) and a passive containment cooling system that have been well-verified by tests, as well as in-vessel retention of a molten core.

The investigations and studies going on in South Africa relate to a small, high-temperature, gas-cooled reactor (PBMR) that could be deployed on a large scale. The South African studies are based on the assumption that safety demands can be reduced significantly, e.g. they claim that there is no need for containment and no need for permanent staffing at the plant site. If this assumption can be confirmed by safety analyses on an international level, this would indeed be a very attractive alternative for South Africa and other countries with limited grid sizes.

Conclusions

This brief overview of current reactor development activities shows that there are many interesting designs and concepts at various stages of development that would meet most utility requirements. However, in the present decision-making framework, the bottom line is the requirement to be economically competitive in deregulated electricity/energy markets, and very few, if any, evolutionary or innovative designs seem to be clear winners in this regard.

During normal operation, nuclear reactors can produce electric energy and heat with very small impacts on the environment. When the whole energy chain is considered – including construction, mining, operation, waste handling and decommissioning – nuclear compares favourably to fossil fuels and most renewables. The main challenges for nuclear reactor designers are to reduce costs while enhancing safety and user friendliness. If these challenges can be met, nuclear reactors enjoying low variable costs could be expected to become a viable option for meeting the electricity and heat needs in many countries in the world. ■

Unit 7 of the Kashiwazaki Kariwa nuclear power station in Japan.

Nuclear Information Center, CRIEPI, Japan

E. Lazo*

Decommissioning nuclear facilities: The issues at hand

As more nuclear installations begin to reach the end of their useful lives, and as more decommissioning regulations begin to be developed, dialogue between regulators and implementers will be key.

As more nuclear installations begin to reach the end of their useful lives, decommissioning projects have become more common, and the technical aspects of the decommissioning process have become better understood. With this better understanding of the technical issues, the decommissioning process has moved from case-by-case R&D programmes towards being a much more standardised industrial process, taking specific site characteristics into account as necessary. With this shift to more routine operations, interest has risen in more generically applicable regulations, guides and standards, both nationally and internationally.

As more regulations begin to be developed, dialogue between regulators and implementers is particularly helpful for ensuring that both sides fully comprehend the rationale behind, and the practical implications of, decommissioning regulations. To this end, the OECD Nuclear Energy Agency (NEA), the International Atomic Energy Agency (IAEA), and the European Commission (EC) co-sponsored a workshop to bring together regulators, implementers and waste-receiving organisations to identify those regulatory issues which are of most concern. Within the NEA, the Committee on Radiation Protection and Public Health (CRPPH), the Radioactive Waste Management Committee (RWMC), the Committee on Nuclear Regulatory Activities (CRNA), the Committee on the Safety of Nuclear Installations (CSNI), and the Nuclear Development Committee (NDC) all participated actively. The workshop was held on 19-21 May 1999, and was hosted in Rome, Italy, by the Italian National Environmental Protection Agency (ANPA). As a result of this workshop, and of other work being carried out at the NEA, several outstanding issues have been identified.

Exemption, authorised release and NORM

Exemption is broadly defined as the waiving of regulatory control of materials due to their radiological risk being trivial. Materials which are so exempted are free for unrestricted use. There has been, however, some confusion in the understanding of the concept of exemption, particularly with regard to its meaning relative to such terms as “clearance”, “exclusion” and “authorised release”. The precise definition of these concepts is essential before application issues can be addressed.

** Dr. Edward Lazo is the Deputy Head of the NEA Radiation Protection and Radioactive Waste Management Division (e-mail: lazo@nea.fr).*

In several reputable publications[1], trivial dose has been defined as being less than 10 μSv/y of individual dose, and less than 1 Sv/y of collective dose. There are two practical considerations in need of clarification. First, should the collective dose criterion be applied in practice, and if so, how should it be interpreted in a regulatory sense? Second, although the dose criterion is an essential basis for decisions, it is not practically applicable. It is necessary to establish exemption levels, in terms of specific activity (Bq/g) or surface activity (Bq/cm^2), based on which measurements can be made to determine compliance. The scenarios necessary to translate the dose criteria into these exemption levels are very important, and need to be much more clearly elaborated to represent appropriately as many different types of situations as necessary (high volume releases, low volume releases, releases of specific materials, etc.).

It should also be noted that materials which have been exempted from further regulatory control are free to be transported internationally. Guidance on exemption levels should thus be consistent with international regulations for the transport of radioactive materials.

The concept of authorised release refers to the release of materials from some or all regulatory control based on radiological considerations. No international consensus currently exists on the criteria to be used. Authorised release can include the release of gaseous and liquid effluents from nuclear facilities, or the release of radioactive materials for specified uses. Such authorisations are generally based on the concept of optimisation through cost-benefit analysis, not on the concept of triviality of radiological risk. The philosophical and practical links of this concept to that of exemption requires further elaboration, in particular whether these three types of releases (gases, liquids and solids) can be treated using the same regulatory approach.

Finally, in many countries raw materials containing radioactivity, often referred to as naturally occurring radioactive materials (NORM), are used in various industries. The fertiliser industry, the oil and gas industry, and the phosphor-gypsum industry are examples. In some countries these industries are regulated, but in many countries they are not. Quite often, the effluents from the processing of these ores, as well as the products produced and sold in a radiologically unregulated fashion, can be relatively radioactive. Such concentrations coming from a radiologically regulated industry would generally be controlled in some way by regulatory authorities. Although many countries are considering imposing some level of regulatory controls on currently unregulated industries, it is important as a first step to decide whether such situations should be included in the system of radiological protection.

Release and reuse of sites

Although land is almost never without some form of regulatory restriction in terms of use (industrial use, farm use, housing, commercial use, natural reserve, etc.), the release of land from regulation based on radiological considerations is an important question. At the present time, there is limited guidance regarding what type of radiological constraint criteria should be applied to the release of sites and facilities, particularly for unrestricted use. In general, however, releases of sites have thus far been authorised based on restricted reuse, generally within the nuclear industry.

The International Commission on Radiological Protection (ICRP) is currently discussing guidance which would recommend that the constraints used to regulate the release of a controlled site should not be

Remote dismantling of activated concrete (cold tests).

SCK•CEN, Mol, Belgium

higher than the constraints applied to the site during its operational lifetime. The constraint recommended in *ICRP Publication 77* for waste disposal is 300 µSv/y. Although the release of sites and facilities is conceptually related to the authorised discharge of liquid and gaseous radioactive materials, the above-mentioned numerical constraint may not have been developed based on considerations and scenarios which would be applicable to the release of sites. Societal considerations other than those used to define the 300 µSv/y criteria may need to be considered as well. However, it may be reasonable to suppose that, in some cases, non-radiological regulatory restrictions (such as zoning or land use laws), which can be assumed to be relatively long term (sometimes several hundred years), may provide sufficient population protection. Further developmental work in this area is nevertheless necessary.

Another important point to remember is that the release of sites and facilities for uses which are radiologically unrestricted implies the release of materials from those facilities. Such materials would then also be free for unrestricted use. Criteria for facility release should thus be consistent with those for the release of materials for unrestricted use, as well as with transportation regulations for radioactive materials.


Removal of the Belgian BR3 reactor pressure vessel for further dismantling.

SCK•CEN,Mol, Belgium

Waste considerations

Decommissioning and waste management are closely linked. Waste management aspects, such as national waste management infrastructures, and criteria and procedures for waste characterisation, must be considered when planning and performing decommissioning activities as they will influence the decommissioning strategy to be used. Close co-ordination between decommissioners, waste management organisations and regulators is highly desirable.

Radioactive waste volume reduction, in this context largely meaning avoiding the mixing of clean and contaminated waste streams, should always be considered during the decommissioning process. Direct disposal of waste is very expensive in most countries. A balance between spending on volume reduction and on direct disposal will help to achieve cost effectiveness.

Costs and funding of decommissioning

The total decommissioning cost of a facility can vary significantly over time – in particular due to unforeseeable radiological contamination within the controlled facility, or the evolving cost of waste disposal – and must be re-evaluated periodically to ensure that proper funding is available when needed. The development of an internationally standardised costing system is seen as a very positive step, not only allowing costs to be compared in a valid way, but also providing decommissioning projects with a tool for retrospective, current account and prospective costing analyses. Such a system has recently been jointly proposed by the NEA, the IAEA and the EC.[2]

Accurate costing is essential to ensure that appropriate funding is available for decommissioning, and that these funds can be collected during the operating period of the plant. Although many questions remain open in the area of financing, it is clear that the strategy followed for decommissioning will have an influence on the collection and dispensing of these funds. For example, the timing of the dismantling work will influence not only the time at which the funds should be available, but also how they should be invested in terms of liquidity.

The financial security of such funds is also a consideration, with investments at higher interest rates requiring less initial capital, but being generally less secure. Some of the questions that need to be asked are what latitude of investment freedom should the fund managers be allowed in balancing interest income against fund security and liquidity? And as the fund accumulates during the facilities' operating period, what types of financial securities should be required to cover the unfunded remainder of the total estimated cost?

Assuming that the cost of decommissioning can be estimated, and periodically updated, the schedules for the accumulation and dispersal of funds must be established. This will depend greatly upon the decommissioning strategy chosen, and thus cost, strategy and schedules must be addressed together.

The approach for financing decommissioning and other waste management activities is still undefined in many countries, while others already have arrangements in place. For those still developing their financing scheme, the type of control of the decommissioning funds will have a strong influence on the types of regulations to be put in place. Funds can be internally controlled by the decommissioner, or can be externally controlled. External controllers could include political, governmental bodies; governmental regulatory bodies; government-designated and regulated, but independently managed, private financial institutions; etc.

Safety of decommissioning

Human factors, from the time the decision to shut down has been taken, until the disposition of the plant's fuel has been finalised, are very important aspects of decommissioning safety. They include the morale of plant personnel, and the loss of competence within both the plant and regulatory organisations, particularly over what may be long periods of safe storage before final decommissioning for site free-release. Deferred dismantling may cause major problems if nuclear infrastructure is lost, especially in countries which have small nuclear programmes. To address these issues, there must be a competent organisation overseeing all steps of decommissioning.

A dedicated decommissioning group in the licensee's organisation is also needed. The change of the mission from operation to decommissioning must be well-clarified. The project organisation must be goal-orientated and focused on decommissioning rather than on the continuation of the operating organisation. To ensure that the organisation is properly focused, it may be desirable to minimise the number of operations personnel included in the decommissioning team. The decommissioning team should be composed primarily of individuals who understand the concepts and principles of decommissioning. It should be supplemented with a few (i.e. three to five) operations individuals who can provide facility history and system operating experience. If a team is composed mainly of operations personnel, it might tend to perform its duties following an operational way of thinking, using a level of procedural detail and caution which is no longer necessary. This can be time-consuming and very costly. Even if contractors are used during the decommissioning activities, the licensee must retain awareness and remain responsible for the decommissioning project.

As regards public information, the local community should be informed of the process and the status of the project. Other organisations that are interested in the decommissioning activities should also be kept informed.

In addition to these issues, experience concerning the criteria for, and process of, terminating a plant's operating license should be shared. This includes the process of modifying a plant's operating license to accommodate decommissioning activities, and then to free the decommissioned site from all or some regulatory control, depending upon the proposed site end-use. Generally speaking, it is useful for all decommissioning experiences to be shared, and international organisations can play an important role. ■

Cutting contaminated primary looping.

SCK•CEN,Mol, Belgium

References

1. IAEA Safety Series 89 *(1988)*, ICRP Publication 60 *(1990), the jointly sponsored* IAEA International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources *(1996), and the European Council Directive 96/29/Euratom on basic safety standards (1996).*
2. *European Commission, International Atomic Energy Agency, OECD Nuclear Energy Agency (1999),* Nuclear Decommissioning – A Proposed Standardised List of Items for Costing Purposes – Interim Technical Document, *OECD, Paris.*

J. de la Ferté*

Confidence building in radioactive waste management

The NEA[1] has recently completed an in-depth assessment of the progress made over the last decade in building confidence in the safe geologic disposal and management of long-lived radioactive waste. This review has pointed out the importance of closely integrating social values in the decision-making and development processes, and of continuously interacting with stakeholders.

Societal attitudes towards industrial risk and decision making have evolved dramatically in recent times under the combined influence of the rapid development of industrial activities, a more educated public, and the role of the media in projecting risks and benefits from applied science and technology.

Safety and environmental concerns have become central to industrial and community development and now account for as much as one-fourth of investment by industrial companies. This evolution is largely due to pressure exerted by powerful stakeholders and has led to new laws and regulations to protect the public and the environment. Much of this pressure is exerted at the state and local levels. However, while society as a whole demands a radical reduction of risks in life, a search for "zero risk" at all cost is not compatible with industrial development. Risk is inherent in innovation.

The second major factor which needs to be considered in the "cultural change" of recent decades is the emergence in the 1970s of "counter-powers". These have posed an abrupt challenge to the traditional democratic process under which the citizens elected representatives to whom they delegated their decision-making powers. Citizen groups, associations and public interest organisations, whether local, national or international, have taken advantage of the opportunities offered by the information society, strengthened their voice and acquired a part of decision-making power. Any important public decision, particularly if it involves risk choices and management, now requires public deliberation.

Some of the keys to confidence building are no doubt to be found in this process of public involvement. From this point of view, we must accept that people's concerns, even if based on inaccurate perceptions about the seriousness of the risk involved in a particular industrial activity, will have to be taken into account in order to come to a successful decision about that activity.

The role of confidence building in the decision-making process

The concept of permanently removing radioactive wastes from the human environment by

** Mr. Jacques de la Ferté is Head of NEA External Relations and Public Affairs (e-mail: jacques.delaferte@oecd.org).*

This article is based on a paper presented by the author at the 1999 Annual Canadian Nuclear Association/Canadian Nuclear Society Conference.

disposal in deep geologic repositories was developed several decades ago. Today, a wide consensus exists within the waste management community that this concept represents the preferred option for ensuring the permanent isolation of long-lived wastes from the human environment. The work of international groups of experts, notably at the NEA, has repeatedly confirmed the conviction of the waste management community that geologic disposal is ethical, environmentally safe and sound, and that other management options are, at most, complementary to disposal rather than complete long-term alternatives.

However, the confidence of the experts in the short- and long-term safety of the geologic disposal option is not necessarily shared by non-expert circles. Several programmes aimed at developing a repository have recently undergone increased public scrutiny, and despite notable exceptions such as the granting of an operating licence to the Waste Isolation Pilot Plant (WIPP) in the United States, this scrutiny has resulted in delays in programme implementation.

Clearly, decision making on the long-term safety of a future underground repository requires gaining the confidence of several categories of "stakeholders", throughout different stages of the process, from planning to implementation. Some decisions are the responsibility of technical specialists and managers within an implementing organisation, and the regulatory bodies that oversee their activities. For these decisions to be accepted by stakeholders, technical arguments are required that lend confidence to the feasibility and long-term safety of the proposed concepts. Other decisions may be the responsibility of political decision makers or the general public, for example under a local referendum. These non-technical stakeholders also require confidence in the technical aspects of repository development, but confidence may ultimately be based on other considerations, such as ethical, economic or political arguments.

Three types of confidence needed for repository development

General agreement regarding the ethical, economical and political aspects of the appropriateness of the underground disposal option.
Confidence in the practicality and long-term safety of disposal (including safety case and statement of confidence).
Confidence in organisational structures, legal and regulatory framework for repository development, including agreement on development stages.

The need for a flexible approach in repository development

The novelty and complexity of the tasks involved in developing a repository concept – evaluating its technological feasibility and long-term safety, developing the technology for its construction and operation (including its closure) – do not allow detailed planning of the entire process at once, even though technical experts have confidence in it. Although distinct stages can be defined initially, experience has confirmed that detailed planning must proceed iteratively, as information and experience are acquired. Completion of one stage can provide a basis for the decision whether to proceed to the next stage, to modify the development programme or, in an extreme case, to re-assess the programme as a whole.

This flexible approach allows planning to evolve, if necessary, in accordance with the available data on site characterisation, the findings of safety assessments, and the evolution of the legal and regulatory framework. The perception that this is the case is important in maintaining public confidence in the independence of the regulatory or licensing organisation in its role as "judge" of the acceptability of the project.

A flexible approach also means that alternative options are, where possible, kept open, for example by designing a repository in such a way that future attempts to change the repository or to retrieve the waste are possible. Complete flexibility cannot, of course, be retained undiminished throughout the development process, since progressively firmer decisions must be taken in proceeding from one stage to the next. Also, in order to preserve credibility and confidence in the stepwise approach itself, there must be an understanding, by all stakeholders, of what is to be achieved at each step.

In short, sufficient confidence for a decision to proceed does not imply that all relevant issues have been resolved, but rather that these issues are not judged as critical for the decision at hand and there exists a strong possibility that they will be resolved in future repository development stages.

Technical confidence alone is not enough

Beyond the need to master the process of confidence building in the technical stages of the design, licensing, construction and operation of a radioactive waste repository, there are broader requirements for achieving societal confidence. These stem from pressures from society, which has become more environment-conscious, and from the increasing concerns of individuals over the threats – actual or perceived – to their health, safety and welfare, including those of following generations. They also arise from the legitimate desire of public decision makers, politicians and stakeholders to understand and hence be able to evaluate alternative strategies.

Today's society is well aware of the possible adverse environmental impact of technology. Concerns include conservation of resources, long-term protection of the environment and sustainable development. There is therefore a need to explain more thoroughly to stakeholders the place of radioactive waste management within the broader debate on environmental, ethical and sustainable development issues.

While geological disposal is broadly accepted by decision makers as a technically safe, sound, and feasible solution, alternative options such as long-term storage and other potential approaches such as partitioning and transmutation in an overall waste management strategy must also be examined and understood within the context of sustainable development.

Likewise, the concepts of retrievability and reversibility in the early existence of a geological repository should be put in perspective, notably to show how far the present concept of deep geological disposal would need to be modified to ensure retrievability/reversibility at several time-scales. A related issue to be explained is how to determine the timing of closure based on environmental and ethical concerns. Although many related concepts, such as the principles of "the polluter pays", "reasonable assurance" and "not placing undue burdens on future generations", are already incorporated in policy statements for the management of long-lived waste, it would be helpful to clarify their meaning for radioactive waste management within the context of sustainable development.

Economic pressures that affect the whole nuclear fuel cycle (e.g. deregulation of the electricity market) may tend to favour short-term goals, at the expense of long-term objectives. In particular, even though a wide acceptance has been achieved by technical experts that deep geological disposal represents a safe and ethical path, short-term economic factors may tend to favour delaying final disposal. Also, political factors may tend to work in favour of indefinite or very-long-term surface storage of all types of long-lived waste or of approaches, such as partitioning and transmutation, misleadingly depicted as alternatives which would preclude the need to pursue disposal. The influence of such economic and political pressures needs to be incorporated into the understanding of the decision-making process.

Public involvement in the decision-making process

The radioactive waste management community is acutely aware that insufficient public confidence is a main cause of the slippage in the development schedules of deep repository operations envisaged a decade ago. The need for more public involvement and improved communication is widely acknowledged by this community as a major route towards confidence building.

A wide variety of means are available by which the public can give input to the planning and implementation process. The current practice in many countries of adopting a step-wise approach to repository development reflects the clear public aversion to large irreversible steps. In Switzerland, for example, a prime reason for a negative result of a public referendum relating to the Wellenberg site was that the public would have preferred the granting of an initial permit only for the construction of an exploratory tunnel, rather than for the final repository.

According to a survey conducted by the NEA of radioactive waste management organisations in 16 Member countries, many forms of stakeholder involvement in disposal programmes exist and different countries have differing approaches. The most straightforward form of public involvement is for the public to participate directly in the decision-making process leading to the acceptance of a specific proposal or to the granting of a license. In Switzerland, the possibility is given to opponents of a project to initiate public referenda on such issues. Referenda of a consultative nature have also been carried out in countries like Sweden.

While direct representation in public hearings is relatively uncommon, consultation in written form is widespread. A requirement for formal consultation with the public is sometimes associated with a generally applicable environmental protection act or similar law, e.g. in Hungary, the USA or Canada. In EU countries and the USA, an environmental impact assessment (EIA) must be carried out for facilities whose construction or operation might result in a significant impact on the environment. The EIA is carried out by the operator or proponent of the facility and made available for public information and comment.

Several countries have no formal requirement for public involvement in waste disposal projects. However, in almost all countries, public opinion is nevertheless actively elicited by governments, regulators and proponents to factor in comments for consideration before making final decisions.

At the international level, few legal texts provide for public information or public participation. However, the recent *Convention of 1997 on the safety of spent fuel management and on the safety of radioactive waste management*, while it does not contain specific provisions regarding public consultation and participation in relation to the siting or operation of a radioactive waste management repository, it provides for each Contracting Party to arrange for information on the safety of such installations to be made available to the public.

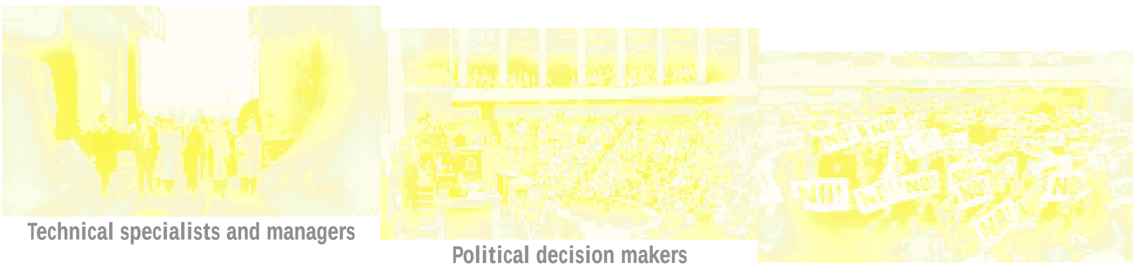
The step-wise approach to the design, siting, construction and operation of a repository offers many opportunities for a local community to express its opinion on a project, or even to block it as far as the location is concerned. Nevertheless, in an increasing number of countries (for example, France, United Kingdom, Sweden or Finland), it is the Parliament that, as guardian of the public interest, will ultimately make the decisions which will commit the nation to an overall radioactive waste management policy.

Conclusions

Radioactive waste management is still perceived as the "Achilles' heel" of nuclear energy. Confidence in the long-term safety of deep geological disposal for long-lived radioactive waste, and the way in which this confidence can be obtained and communicated, is indispensable to the future of nuclear power.

Several categories of stakeholders/decision makers

Each requires a specific type of confidence building.



Technical specialists and managers — Political decision makers — General public

The lessons learnt by the Member countries of the Nuclear Energy Agency, who have to manage nuclear waste, can be summarised as follows:

- Confidence of the technical community in the feasibility of safe deep geologic disposal must continue to be demonstrated to the wide community of stakeholders.
- Although recognised as indispensable, public involvement and communication efforts have not yet yielded sufficient results. Effective methods must continue to be developed in this respect.
- The pros and cons of longer-term monitoring, reversibility and retrievability, as well as the case for geologic disposal versus other suggested waste management options, such as extended or indefinite storage and partitioning and transmutation, must be openly discussed with stakeholders.
- A need also exists to approach radioactive waste management as part of the overall requirements for managing the waste produced by industrial society, and from a wider societal context including environmental sustainability issues, and intra- and intergenerational equity.

In spite of the many setbacks experienced, there is no ground for pessimism in the search for consensus building. Coherent policy, regulatory and decision-making frameworks are being defined and implemented in a number of countries, which show the way forward[2]. The rules of the game in society are changing. The radioactive waste management community must learn to adjust to them. It has the capability to turn the challenge into a success. ■

Notes

1. *See in this issue the NEA Update on "Geologic disposal of radioactive waste: What the last decade has taught us".*
2. *See also in this issue the NEA News brief on "Strategic directions for radioactive waste management programmes".*

B. Kaufer*

The NEA and the year 2000

The year 2000 (Y2K) problem, widely publicised during the past year, concerns possible date-related problems that may be experienced by computers at the turn of the century. While 1 January 2000 is considered the main date of concern, other dates (i.e. 29 February 2000) are also subject to these types of problems. The use of interconnected computer systems and reliance on embedded systems has grown to the point where today we find them in virtually all electronic appliances used in our homes and offices. Governments around the world are concerned with this problem and how it could affect all things from, for example, public transportation, such as safety on the roads or in air travel, to the basic soundness of our economic markets. Particular concerns arise with respect to the electric power industry because time-sensitive microchips are found in electrical transmission and distribution systems, communication systems, data systems, and equipment and components in power stations, including nuclear power plants.

Recognising the importance of Y2K and its international dimension, in 1997 the NEA, through its Committee on Nuclear Regulatory Activities (CNRA), began a programme to exchange information and experience among its Member countries. The programme was set up to review technical preparedness for addressing the potential impact of the "millennium bug" on the safe operation of nuclear facilities.

The NEA conducted a survey to acquire a better understanding of the actions being taken and the problems being detected. This survey, which was completed in early 1998, showed that all Member countries, via their national regulatory bodies, had already taken some steps by requesting licensees to provide information on Y2K activities underway or planned. After a review of the responses received and further discussion, a more specific programme was set up with three main elements: to establish an electronic exchange of information, to convene an international workshop in early 1999, and to co-ordinate activities on international contingency planning.

Electronic exchange of information

In mid-1998 the NEA set up an electronic "mailbox" for Y2K. This system, based on e-mail, allows participants (primarily nuclear regulators and operators) to send messages to everyone on the system through one common address. It also allows countries to transmit technical information on Y2K on a continuing basis. Over 20 countries provided one or more experts to this information exchange. Links were also established with other international organisations (for example the IAEA) to disseminate information to non-OECD countries.

It was recognised that the Y2K problem does not end with the New Year on 1 January 2000. Other dates are subject to computer problems in the coming years and changes made to systems may present problems in the future. For this reason, it was agreed that the electronic exchange "mailbox" would remain operational past the millennium to ensure that the exchange of information continues.

International workshop

Nuclear regulators and operators, government officials, consultants and software specialists from some 20 countries met in Ottawa, Canada on 8 to 10 February 1999 to review technical preparedness for addressing the potential impact of the "millennium bug" on the safe operation of nuclear facilities. Three main sessions were held: to discuss regulatory and industry strategies on Y2K issues; to discuss lessons learnt and corrective actions taken and planned; and to establish what still needs to be done in the area of contingency planning. These sessions were followed by two working group sessions in which participants discussed the international and global implications of the Y2K problem on nuclear installations.

The first working group session looked at which issues needed to be addressed in order to gain confidence that Y2K readiness would be achieved in time. These included: random testing; vendor evaluation; information data flow; roll forward (of date); roll back (of date); islanding of units; independent assessment of Y2K programmes; communications; and reviews of Y2K work done by other industries.

*Dr. Barry Kaufer is a member of the NEA Nuclear Safety Division (e-mail: barry.kaufer@oecd.org).

The second session focused on contingency planning and international co-operation. In the area of contingency planning participants discussed external risks; electric grid considerations; communication systems; human factors; and transportation. International co-operation issues included the exchange of information and experience (preceding the millennium period), and "roll-over day" (during the millennium period).

Dr. Shirley A. Jackson, Chairman of the US Nuclear Regulatory Commission, stated during the workshop that, "We have come to recognise that nuclear power plants are not islands… The ability of both onsite personnel and civic responders to act will be tied directly to the state of Y2K preparedness in each of the participating organisations. In the same way that each generating plant on a grid can be affected by other plants on the grid, the emergency response capabilities associated with one plant can be impacted in responding to other potential eventualities, such as events at neighbouring plants or other Y2K-related emergencies outside of the electricity industry. For this reason, ensuring continuity at the interfaces of regulator-to-licensee, regulator-to-public, and regulator-to-government is crucial, as such continuity is required to buttress emergency response, our last line of defence in protecting public health and safety…"

The main conclusions of the workshop were:

- Participants agreed that the continuing exchange of information through systems such as the NEA electronic "mailbox" was essential. There was also consensus that this mailbox should be expanded to include as many contributors (e.g. regulators, licensees, industry, etc.) as possible to assure maximum value.
- The methodologies being used (e.g. inventory of components, assessment and analysis, test and verification, etc.) are fairly common among all countries.
- Participation by several eastern European countries added valuable information on the status of Y2K preparedness in these countries. The exchanges of information would further facilitate progress through the numerous ongoing bilateral exchanges and in the work being carried out by the IAEA to assist eastern European countries in resolving Y2K issues.

Proceedings of the workshop will be published.

International contingency planning

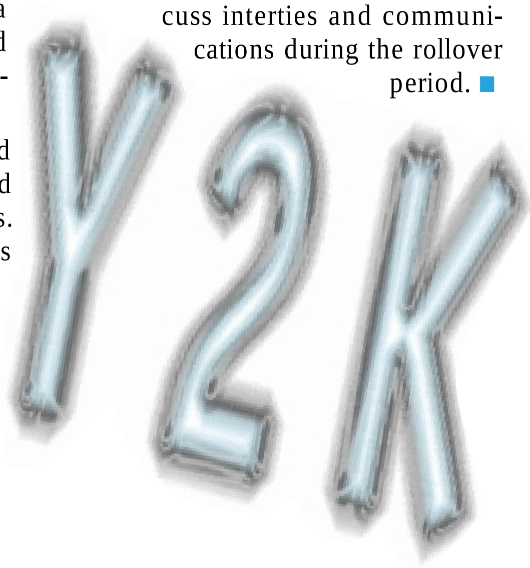
The need for contingency planning has been recognised by all NEA countries. To assist in international preparations, the NEA, based on a proposal made by the US Nuclear Regulatory Commission and under its sponsorship, has been developing the Y2K Early Warning System (YEWS). YEWS is being designed as a secure, proprietary, Internet-based communications system that allows for rapid transmission of information on the status of nuclear facility operations, local grid stability and telecommunications during the Y2K transition period. Regulatory authorities throughout the world have been invited to participate in this system. YEWS is a free service. Participation in YEWS is voluntary and open to all countries which agree to abide by its terms of use. For security reasons access to YEWS is restricted to participants which make a formal request for access and have a bonafide reason to participate.

So far 24 countries and organisations have nominated over 150 YEWS contacts. The countries/organisations involved include: Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Israel, Italy, Japan, Korea (Republic of), Mexico, Netherlands, Norway, Portugal, Romania, Spain, Sweden, Switzerland, United Kingdom, United States, the OECD Nuclear Energy Agency, the US Department of Energy and the US Nuclear Regulatory Commission. Efforts are currently underway to enlist other countries, both NEA Members and non-members.

The final prototype of the system became operational at the end of September 1999. A successful exercise of the system was carried out in mid-October. This international exercise, which included all participants, is being used to finalise preparations for the operation of the system during the millennium period.

Other NEA activities

The NEA has also been active in other areas regarding Y2K. It has been part of an overall effort in the OECD to keep Member countries informed of Y2K activities and problems. Recently the NEA co-sponsored a seminar in Prague with the International Energy Agency (IEA), the Central Dispatch Organisation (CDO) and the International Union of Producers and Distributors of Electrical Energy (UNIPEDE). This seminar was entitled "The Year 2000 Problem: Interdependencies in Contingency Planning within the Energy Sector and Across Borders". The seminar brought together participants from different industries (gas, electric, telecommunications, nuclear) and different countries (including eastern Europe) to discuss interties and communications during the rollover period. ■



W.R. Rodwell, B. Haijtink, P. Lalieux*

The impact of gas on the safety of underground waste repositories

Significant efforts have been, and continue to be, expended in numerous national and international programmes to analyse the potential impacts of gas generation, accumulation and migration on the performance and long-term safety of underground repositories for radioactive waste. In light of these efforts, and in order to help focus further work, the European Commission and the OECD Nuclear Energy Agency have jointly undertaken a review of the knowledge gained so far. This article reviews the rationale for the joint EC/NEA initiative and highlights some of the key conclusions of the review.

Rationale

In underground repositories for radioactive waste, significant quantities of gases may be generated as a result of several processes, notably the interaction of groundwaters and brines with waste and engineered materials present in the disposal system. In some cases, the gases may migrate through the engineered barrier system and the natural geological barrier. The potential impact of gas generation, accumulation and migration on the long-term safety of a repository will be dependent upon the waste types, the repository concept, the host geological environment and the long-term evolution of the system. It is therefore recommended that the potential impact of gas accumulation and migration on the performance of the various barriers be addressed and assessed in the development of safety cases for radioactive waste repositories.

Most investigations into gas migration through engineered and geological barriers of deep radioactive waste repositories have only taken place over the past 15 years, a shorter period of investigation than other issues affecting repository behaviour, in particular groundwater transport. In the development of most repository concepts, the "gas problem", for justifiable reasons, has also been assigned a lower priority and its investigation has commanded fewer resources than those issues regarded as most central to the safety case; all performance assessments include detailed analyses of the groundwater pathway, but only a few have so far addressed the gas problem in any detail. Nevertheless, a substantial body of work has been carried out in numerous national and international programmes and significant progress has been made, notably in the framework of the European Commission's Nuclear Fission Safety programme and its Pegasus project (see References). This progress has pointed to the need to improve fundamental understanding of gas migration in geological formations and engineering materials.

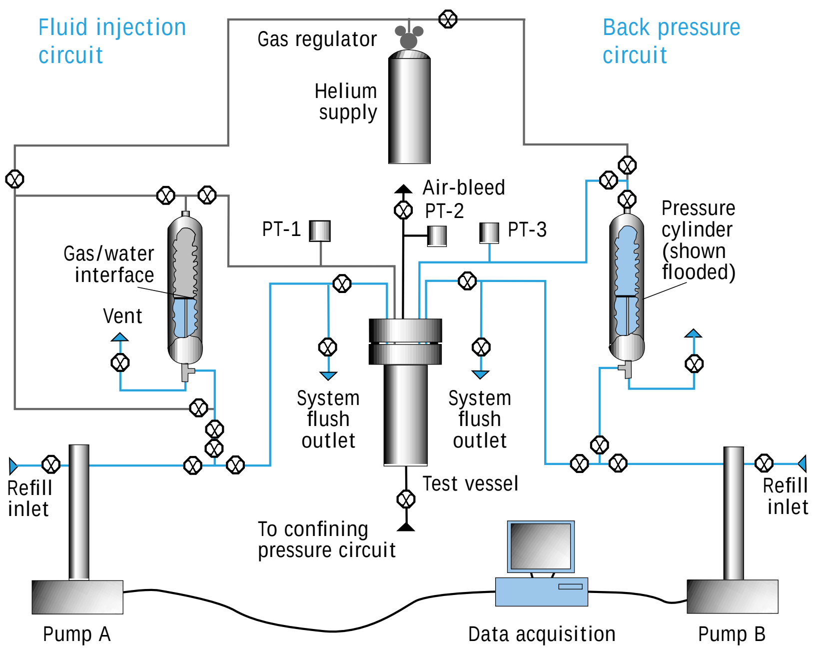
Consequently, it was decided to undertake a review of the knowledge gained so far and to establish the current status of the basic understanding of the topics concerned. To ensure proper coverage of all R&D work already carried out within national and international programmes and of most current disposal concepts, as well as to avoid duplication of effort, the resulting report (see References) was prepared under the joint auspices of the European Commission (EC) and the OECD Nuclear Energy Agency (NEA). The work was commissioned by the EC, in

* *Mr. William Rodwell works at AEA Technology (United Kingdom) as a specialist in gas migration through geological media. He is the co-ordinator and a co-author of the EC/NEA status report on the gas issue.*

Mr. Bertus Haijtink is in charge of research and development work on radioactive waste management co-funded by the European Commission. He also represents the European Commission in the NEA Co-ordinating Group for Site Evaluation and Design of Experiments for Radioactive Waste Disposal (SEDE).

Mr. Philippe Lalieux is a member of the NEA Radiation Protection and Radioactive Waste Management Division and is in charge of the SEDE activities. He is one of the co-authors of the EC/NEA status report (e-mail: lalieux@nea.fr).

Laboratory experimental device for testing gas and water permeability of clays



Courtesy of BGS, United Kingdom

the framework of its R&D programme on Nuclear Fission Safety, and by several national waste management organisations[1] represented within the NEA Co-ordinating Group for Site Evaluation and Design of Experiments for Radioactive Waste Disposal (SEDE).

Furthermore, GRS, Germany (Company for Reactor Safety) and SCK/CEN, Belgium (Nuclear Energy Research Centre) contributed to the status report by providing a thorough review of the draft versions.

Scope of the EC/NEA initiative

The status report addresses the following topics:

- The safety issues potentially associated with gas in repositories. These include overpressurisation and its consequences, the release of radioactive and flammable gases at the surface, effects on the movement of contaminated groundwater, the transport of attached particles at interfaces, and issues particular to an unsaturated site.
- Existing disposal concepts, and the development of a set of representative repository concepts to be used in subsequent discussions of gas migration. These repository concepts were intended to embrace those appropriate for different waste types and to cover the range of host rocks being considered for repository sites. The latter were categorised as water-saturated, low-permeability fractured rock; unsaturated fractured rock; plastic clay; indurated mudrocks; and rock salt formations. Unsaturated fractured rock referred specifically to Yucca Mountain as the only site of this type currently being considered.
- Gas generation in repositories. While flow processes involving gas were the central issue of the report, it was also important to understand the gas source term for repositories in saturated sites, and the dependence of this source term on both the waste and the site characteristics, as this affects the nature of the safety issues that might arise.
- Fundamental concepts in gas migration and two-phase flow. The basic physical processes and modelling assumptions in two-phase, porous-medium flow are summarised to provide the context for the more detailed discussion given in relation to engineered barriers and the different rock types considered.
- Gas migration and two-phase flow in engineered barrier systems. The barriers discussed are divided into bentonite or sand-bentonite buffers and cementitious materials.
- The mechanisms of gas migration and two-phase flow through the geosphere. These are discussed in detail in relation to the available experimental evidence and uncertainties for the defined categories of host rock.
- Modelling of gas migration and two-phase flows. Approaches that have been developed for and issues that arise in modelling gas migration are discussed for the different host rock categories that have been identified.
- Potential impacts on the performance of repository systems. The treatments that have been accorded to gas in previous performance assessments are reviewed, and the potential impacts of gas on the performance of the reference repository concepts that have been defined are discussed.

Potential impacts on the performance of the various disposal concepts

It is important to note that the main findings of the status report presented below are intended to provide only a generic overview of the status of the main gas issues for various reference disposal concepts. They should not be used to support definite conclusions for a specific repository and/or site; indeed, the importance of issues can be highly dependent on the particular circumstances and should be assessed in relation to these.

Amongst the repository concepts that are reviewed in the report, that for Yucca Mountain is unique in that disposal is envisaged in unsaturated rock in an arid region. The consequence of this is that two-phase flow issues are absolutely central to repository performance analysis, and have therefore required more resources and attention than gas migration in repository concepts developed for saturated locations. It is argued that the simultaneous pursuit of several alternative modelling approaches and concepts to describe unsaturated flow and transport behaviour on different scales, together with numerical, field, and laboratory studies, should lead to the degree of robustness in the engineering analysis and design needed to establish confidence in a repository project for this environment.

For other repository concepts (i.e. those involving emplacement in saturated rock), the scenarios involving substantive gas migration issues vary. Important factors in the evaluation of gas migration effects are the rate and period of gas generation.

For some waste types (notably low- and intermediate-level wastes, and particularly when there is the ready availability of water), significant quantities of gas are expected and their effects in migrating from the repository have to be addressed. For repositories in fractured crystalline rock, the consensus appears to be that there will be sufficient transport capacity in the rock to accommodate the expected flux of gas from such wastes without mechanical disruption, although some issues remain in demonstrating that the arguments on which this view is premised are applicable at the field scale. There remains a need for a proper range and quality of field data on gas migration through both fractured crystalline and other rock types. Topics requiring further understanding include the potential involvement of gas in the transport of both gaseous and water-borne radionuclides.

For repositories in very-low-permeability mudrocks or clays intended to receive wastes producing significant quantities of gas, conventional porous-medium flow concepts would suggest that gas pressure build-up in the repository would be likely to cause problems. However, alternative mechanisms of gas migration that would alleviate this situation are postulated to occur in mudrocks and other argillaceous materials (including bentonite buffers). The amount of data available on mudrocks is very limited, and further data are needed to rectify this situation. In such impermeable host rocks, the role of backfilled and sealed shafts or addits and engineering-damaged zones in providing a gas migration route is an issue for investigation.

In some waste concepts, notably for high-level waste or spent fuel in canisters made of non-corroding materials, or in a repository in salt, where water supply constraints will eventually inhibit gas production, insignificant gas production is predicted in the normal evolution of the repository. However, scenarios involving accidents or based on conservative assumptions can be envisaged in which gas could be formed, and thus gas migration needs to be addressed for these concepts as well. For gas migration in compacted bentonite or converging crushed salt (typically the main gas migration barriers for high-level waste and spent fuel), the investigation of complex processes (usually involving coupled thermo-hydro-mechanical effects) is underway to improve understanding in the field.

Conclusion

The joint EC/NEA initiative has resulted in the synthesis of a substantive body of multidisciplinary experimental, modelling and performance assessment work related to gas issues in underground radioactive waste repositories, and will help national and international programmes to improve the focus of their future work in these matters.

It has also demonstrated the interest in pooling efforts between international organisations in order to highlight the commonalities and differences between a wide range of waste types, disposal concepts and host rocks with regard to gas-related issues.

Note

1. *The national waste management organisations represented within the SEDE are the following: ANDRA, France (National Radioactive Waste Management Agency); ENRESA, Spain (National Agency for Radioactive Waste); IPSN, France (Nuclear Protection and Safety Institute); ONDRAF/NIRAS, Belgium (National Organisation for Radioactive Waste and Fissile Materials); Ontario Power Generation, Canada; NAGRA, Switzerland (National Co-operative for the Disposal of Radioactive Waste); NIREX, United Kingdom (Nuclear Industry Radioactive Waste Executive); SKB, Sweden (Swedish Nuclear Fuel and Waste Management Company); SKI, Sweden (Swedish Nuclear Power Inspectorate); UKEA, United Kingdom (Environment Agency); and USDOE/YMP, United States (Department of Energy, Yucca Mountain Project).*

References

1. *W.R. Rodwell, A.W. Harris, P. Lalieux, S.T. Horseman, W. Müller, L. Ortiz Amaya and K. Pruess (1999),* Gas Migration and Two-Phase Flow through Engineered and Geological Barriers for a Deep Repository for Radioactive Waste. *A Joint EC/NEA Status Report published by the European Commission, European Commission Report EUR 19122 EN.*

2. *B. Haijtink and W.R. Rodwell (eds.) (1998),* Projects of the Effects of Gas in Underground Storage Facilities for Radioactive Waste (Pegasus project). *Proceedings of a progress meeting, Mol, Belgium, 28-29 May 1997, European Commission Report EUR 18167 EN.*

A. Miller*

Reactor safety and fracture mechanics

Integrity of the reactor pressure vessel (RPV) is an important aspect of reactor safety. One of the most important challenges to the RPV integrity is during a loss-of-coolant accident (that is, a break or leak in the primary circuit piping), when cold water is injected into the RPV. This creates a thermal shock for the vessel walls, and corresponding thermal stresses. It must be demonstrated that there is an appropriately low probability of a defect in the wall that could propagate under such a thermal shock and affect the vessel-wall integrity.

Structural integrity safety cases usually have three pillars: non-destructive examination, which detects and sizes defects; materials property testing; and structural analysis (stress and fracture analysis). All three aspects are needed, but only the third aspect, structural analysis, is considered here.

A typical activity of NEA working groups is the organisation of international benchmarks, where the same problem (or problems) is analysed by experts from various countries. The diverse approaches used inevitably give a variety of results. The comparison and understanding of these results is a valuable way to improve the understanding of the analyses, providing a demonstration of the conservatism or non-conservatism of the methods, and a determination of their relative advantages and disadvantages. The NEA has carried out a large number of such thermal hydraulic studies (called for this purpose International Standard Problems) under the aegis of the Committee on the Safety of Nuclear Installations (CSNI).

Traditionally, fracture mechanics testing uses small-scale specimens in order to reduce costs and enable a larger number of tests to be carried out. However, in order to demonstrate the validity of this approach, a limited number of large-scale tests are also carried out. Initially it was thought that the most severe case was the largest thermal shock produced by large loss-of-coolant accidents (LOCAs), and the emphasis was on pure thermal shock tests with no mechanical loading. However, it was later realised that small LOCAs, where the thermal shock was not so great but the pressure was maintained by the injection system, were in fact more severe, and the emphasis was changed to the consideration of pressurised thermal shock tests. Such tests have been carried out at *Materialprüfungsanstalt* (MPA) Stuttgart in Germany; Oak Ridge National Laboratory in Tennessee (USA); Atomic Energy Authority (AEA) Technology Risley in the UK; Japan Power Engineering and Inspection Corporation (JAPEIC) in Japan; Central Research Institute of Structural Materials (CRISM) Prometey in St. Petersburg, Russia; and *Électricité de France* (EDF) Les Renardières Laboratories in France, amongst other institutions.

The *Gesellschaft für Anlagen- und Reaktorsicherheit* (GRS) and the Oak Ridge National Laboratory organised three series of tests over a ten-year period. In the first phase ductile fracture was considered, and in the second phase brittle fracture. (Fracture is classified as either ductile or brittle.) In the third (and current phase), the scope was changed to a purely numerical exercise, without reference to tests. However, the problem was three dimensional, as opposed to the essentially two-dimensional tests considered in the first two phases. Probabilistic aspects and thermal hydraulic aspects were also included.

FALSIRE I

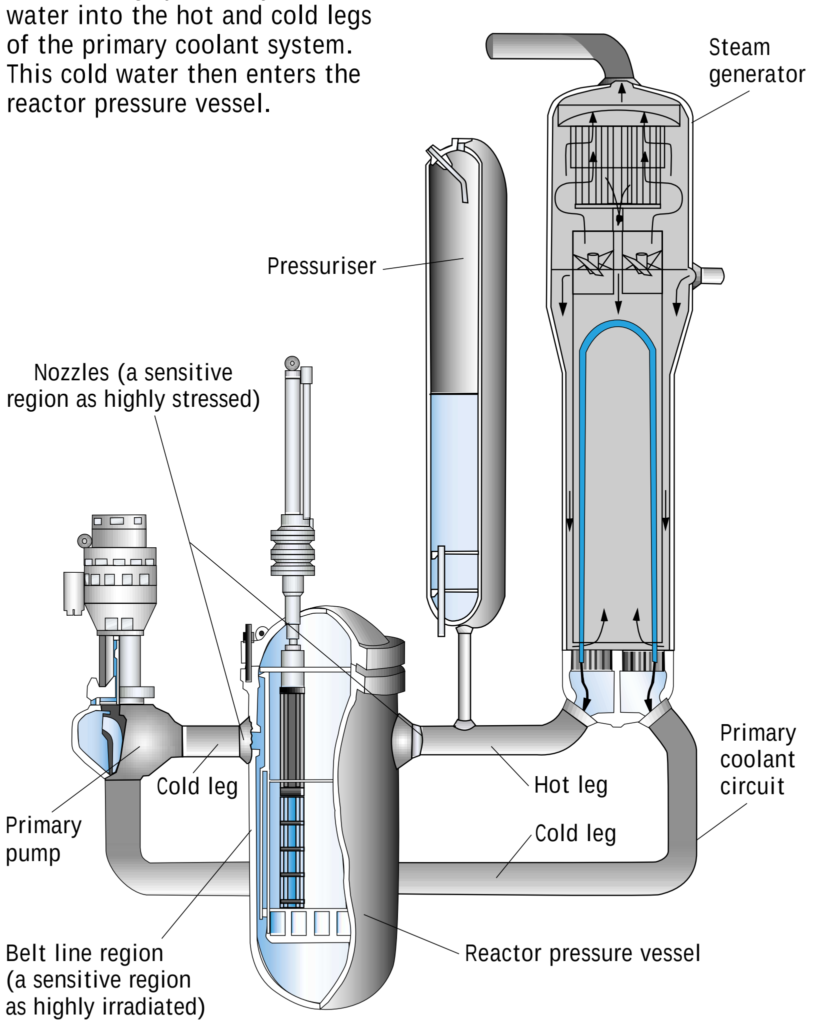
The first exercise was called FALSIRE I (Fracture Analysis of Large-Scale International Reference Experiments), and considered tests from Germany, Japan, the UK and the USA. A total of 37 participants representing 19 organisations performed 39 analyses of the experiments. The analysis techniques used by the participants included simplified engineering methods and more elaborate finite-element methods. These techniques were combined with applications of fracture mechanics models. The results provided estimates of both structural mechanics parameters (stress, strain, displacement) and fracture mechanics parameters. Conditions of crack stability and instability were identified in the experiments.

* *Dr. Alexander Miller is a member of the NEA Nuclear Safety Division (e-mail: alex.miller@oecd.org).*

Schematic diagram for a single-loop* pressurised water reactor

In a pressurised thermal shock (PTS) situation, the emergency core cooling system injects cold water into the hot and cold legs of the primary coolant system. This cold water then enters the reactor pressure vessel.

** There are normally several loops.*



EDF/Sonovision after Framatome

Where possible, computed values were compared with measured data. Details are given in the *FALSIRE Phase I Comparison Report* [1].

Generally, these experiments were designed to evaluate fracture methodologies under prototypical combinations of geometry and loading conditions. The complexities of the experiments did not permit a clear separation of the effects of the many variables involved. Hence, comparisons of analysis predictions with test results were expected to give significant variations. In fact, there were significant variations in the calculated values for the structural mechanics parameters of the uncracked structure which were greater than expected, while calculation of the fracture mechanics parameters displayed an even greater scatter. The results showed that it was essential to have well-characterised material property values, and pointed out some of the limitations of the simplified material property models used in the computer codes of the time. Part of the scatter was caused by the variety of methods, including deliberately conservative simplified methods, and more complicated best-estimate methods.

FALSIRE II

The FALSIRE II project concentrated on experiments which looked into the behaviour of relatively shallow cracks subjected to combined thermal and mechanical loading in the ductile/brittle transition temperature region, showing if possible two stages of extension (e.g. stable crack extension followed by unstable extension). Clad surfaces were also considered. The project is described in detail in the *FALSIRE Phase II Comparison Report* [2].

More than 30 participants representing 22 organisations from 12 countries performed 45 analyses of the 7 reference fracture experiments in FALSIRE II. Analysis techniques employed by the participants focused primarily on finite-element methods. The tests were from MPA Stuttgart, CRISM Prometey, St. Petersburg, AEA, ORNL, and EDF.

The following conclusions were made:

- The temperature distributions in the specimens loaded by thermal shock generally were approximated with high accuracy and small scatter bands.
- Structural response (crack mouth opening displacement, strains, etc.) of the test specimens was predicted reasonably well from best-estimate analyses. This outcome represents a significant change compared with some of the results achieved in FALSIRE I.
- Fracture mechanics parameters were calculated with small scatter bands.
- In tests where fracture could be described by a single parameter, there was reasonable agreement between analysis and experiment.
- In tests where the stress state had a significant effect on fracture, and a single parameter was not adequate, the scatter was increased, and better material

models and more information would be needed to give a good description.

- Almost all participants elected to use the finite-element method in addressing the problems of FALSIRE II. This represents a marked change from FALSIRE I, which included the application of a number of different estimation schemes. The detailed information that participants were asked to provide from the analyses in FALSIRE II encouraged the use of finite-element methods over estimation schemes. It should not be inferred from the outcome of FALSIRE II, however, that detailed finite-element analyses are always the preferred or necessary technique for structural integrity assessments.

The ICAS project

The International Comparative Assessment Study (ICAS) project grew out of a strong interest expressed by participants in the FALSIRE II project to proceed with further evaluations of analysis methods used in RPV integrity assessment. Special emphasis was placed on the interdisciplinary aspects of determining RPV loading conditions due to loss-of-coolant accidents. The calculations of fluid temperature and heat transfer to the structure using thermal-hydraulic analysis techniques was studied, with consideration given to models of fluid-fluid mixing and steam condensation. Results were provided by 25 organisations in 13 countries and compiled in a database. About 145 comparative plots were generated as a basis for discussions about the predictive capabilities of the analysis methods applied by the participants to the different tasks. Large variations were noted; detailed information concerning these variations may be found in the *ICAS Comparison Report* [3].

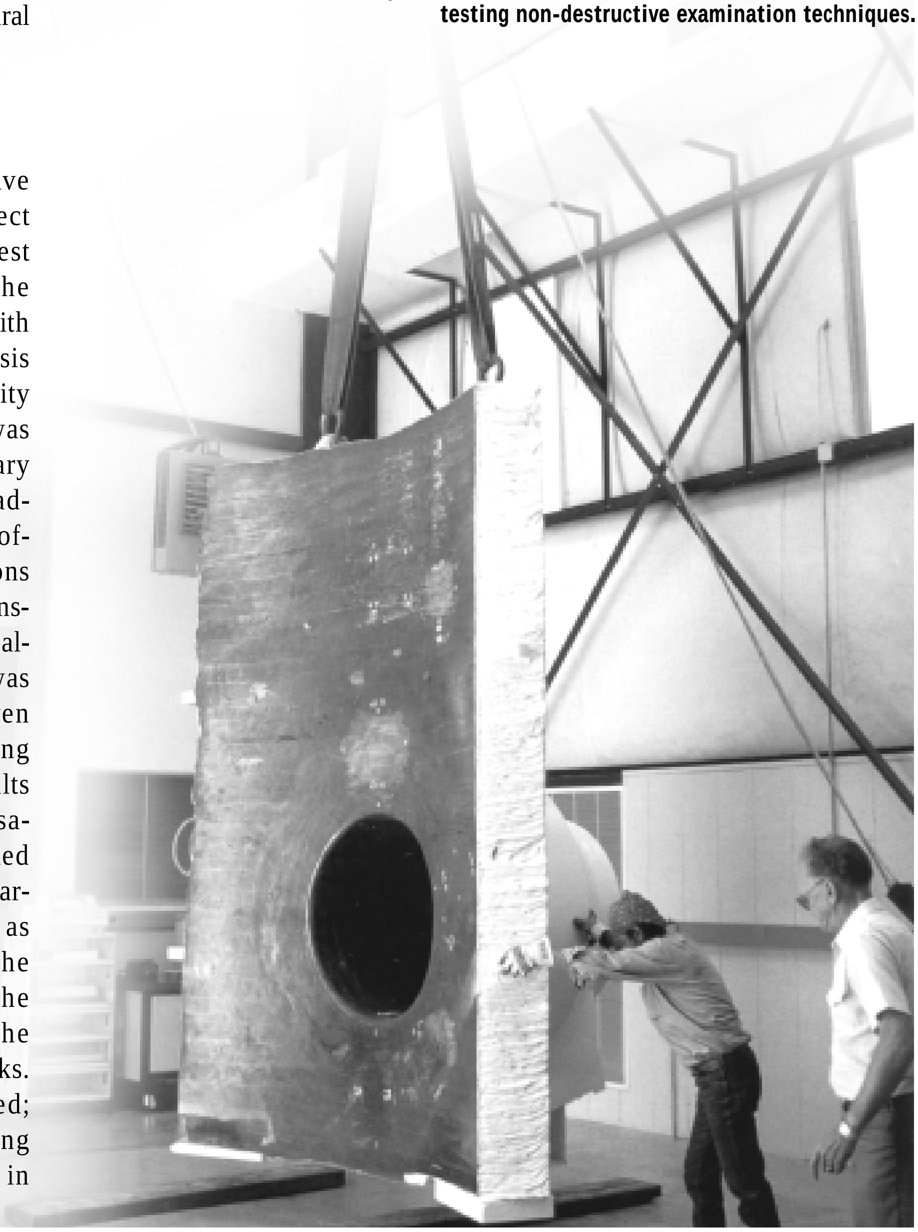
Summary

The three projects show that best-estimate methodologies for RPV integrity assessment need to reduce the uncertainties in each phase. A proposal for future work on the ICAS database is the selection of a set of consensus reference solutions from this exercise. This should include both estimation schemes and detailed methods of analysis. Recommendations concerning how to use the reference solutions should be prepared. The resulting product could be a valuable tool for future research in this field. ■

References

1. FALSIRE Phase I Comparison Report, *NEA/CSNI/R(94)12, GRS-108, NUREG/CR-5997, ORNL/TM-12307.*
2. FALSIRE Phase II Comparison Report, *NEA/CSNI/R(96)1, GRS-130, NUREG/CR-6460, ORNL/TM-13207.*
3. RPV PTS ICAS Comparison Report *(to be issued, also as NUREG), NEA/CSNI/R(99)3, GRS-152.*

Mockup of a reactor pressure vessel (RPV) nozzle fabricated from real pressurised water reactor vessel material and used for testing non-destructive examination techniques.



Bruce Jacobs, ISWT, United States

C. Pescatore*

Geologic disposal: What the last decade has taught us

Radioactive wastes of all kinds need to be managed responsibly to ensure public safety and protection of the environment now and in the future. The most challenging task involves managing the long-lived waste that must be isolated from the human environment for many thousands of years. The preferred option for eventual disposal is emplacement in repositories deep underground in well-chosen geologic media.

The concept of geologic disposal of long-lived radioactive waste involves deep underground repositories that ensure security, i.e. resistance to malicious or accidental disturbance, and containment of the waste over a very long time. The concept was developed after wide-ranging consultations, substantial thought and discussion, and consideration of other options.

Potential host geologic formations are chosen for their long-term stability, their ability to accommodate a waste disposal facility, and their ability to prevent or severely attenuate any eventual release of radioactivity. This natural safety barrier is reinforced by an engineered system designed to provide primary physical and chemical containment of the waste. The whole system is thus designed to ensure that no significant radioactivity from the waste returns to the surface environment and that no burden in terms of maintenance is placed on future generations.

Since the geologic disposal concept was proposed, research and development efforts world-wide have increased understanding of how underground disposal facilities will function over very long periods of time, and have enhanced confidence in the ultimate safety of the concept. In recent years, as the concept itself is nearing implementation in several countries, support is being voiced in some quarters for postponement of disposal and for a serious review of alternative waste management options. On the other hand, international groups of technical experts have repeatedly confirmed that geologic disposal is ethical, environmentally sound and safe, and other management options are, at most, complementary to geologic disposal rather than complete, long-term alternatives.

On the following principal points there is widespread agreement amongst those directly involved in waste management, be they developers, regulators, or policy makers.

Long-lived radioactive waste exists. Of the various disposal options considered, deep geologic disposal is the most appropriate means of long-term management.

A range of alternatives have been reviewed in the past and found to be wanting in some respect. On the other hand, geologic disposal conforms to ethical concerns, is technically feasible, and has been judged to provide a high degree of public safety, security from malicious intervention, and protection of the environment both in the short and long term.

Significant progress has been made in relevant scientific understanding and in the technology required for geologic disposal in the past ten years.

This includes a deeper scientific understanding of the processes which determine the effectiveness of repositories in isolating the waste over long periods; improved characterisation and quantitative evaluation of the ways in which the engineered barriers and surrounding rock contribute to safety; specific investigations at candidate sites; and also experience with practical aspects of underground engineering and implementation. As understanding has increased, no radical changes in philosophy of approach have proven to be necessary, confirming the soundness of the basic geologic disposal concept.

* *Dr. Claudio Pescatore is a member of the NEA Radiation Protection and Radioactive Waste Management Division (e-mail: pescatore@nea.fr).*

The technology for constructing and operating repositories is mature enough for deployment.

This is backed up by experience gained world-wide in underground research laboratories and, in several countries, in existing underground facilities for disposal of radioactive waste, including waste containing longer-lived radioactive components. In particular, the first purpose-built geologic repository of long-lived waste started operation in March 1999 in the USA.

The time-scales envisaged in the past for implementation of geologic disposal were too optimistic.

This was partly due to technical optimism, especially with regard to the difficulty of adequately characterising deep geologic environments, but was mainly due to an underestimation of the political, public and regulatory dimensions of disposal projects. From a technical point of view, there has been no urgent need for final disposal facilities because of the recognised high level of safety of interim storage facilities, the relatively small volumes of long-lived radioactive waste from civilian programmes, and the storage time needed to allow adequate cooling of the more radioactive waste before geologic disposal can take place.

There is a high level of confidence amongst the scientific and technical community engaged in waste disposal that geologic disposal is technically safe.

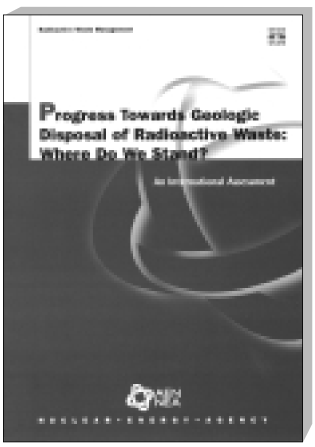
This is a consequence of the many years of work by numerous professionals in institutions around the world. There has been an extremely free exchange of information and knowledge between these professionals and there has been a strong tradition of open documentation available for peer and public review. The common perception amongst the public that there is a strong body of technical opinion challenging the feasibility of safe disposal does not reflect the realities of the debate. The number of sceptics is relatively small in the broader technical community, whereas there is a wide consensus on the safety and benefits of geologic disposal within the technical community of waste management experts.

The broader public, however, does not necessarily share the high level of confidence of the scientific and technical community.

Developments related to radioactive waste disposal are correctly subjected to detailed scrutiny by regulatory and planning authorities. Furthermore, because of ethical and political dimensions, they are a subject of wider-reaching and less-technical discussion. There are reservations in the broader public towards committing irreversibly to an action whose consequences are not fully understood. Lack of confidence by part of the public may also be connected to a lack of confidence in the safety of nuclear power, and sometimes to outright opposition to nuclear power and associated organisations, or even to a general lack of trust in scientific developments.

There is a need for continued, high-quality scientific and technical work.

Although the technology for geologic disposal is well-developed, its further refinement, testing, demonstration, implementation and quality control under reference conditions are challenging tasks extending over decades.



There is a need for coherent policy and strict regulatory frameworks, with identified decision points, which also allow for public dialogue.

As for controversial projects of any nature, universal or overwhelming support is not a realistic aim. On the other hand, society must be assured that every decision taken is a considerate one. A decision-making process characterised by intermediate milestones and decision points is necessary for such complex, long-term projects. This process of step-wise decision making should allow opportunities for comment and input from all affected and interested groups, and should include rigorous technical reviews and the discussion of topics of the public's choice. In particular, the waste disposal community must be ready to discuss the merits of other waste management strategies, including improving the flexibility in the implementation of geologic disposal. Moving ahead in a step-wise fashion towards implementation of deep disposal would assure that a decision to implement disposal fully is not taken irreversibly in one step and would allow the identification and development of other options. Ultimately, governments are responsible for making decisions that meet with an appropriate level of public support and provide the framework in which the necessary actions can be taken. ■

Note

1. *For more information on this subject, see http://www.nea.fr or request a free copy of* Progress Towards Geologic Disposal of Radioactive Waste: Where Do We Stand? *from neapub@nea.fr.*

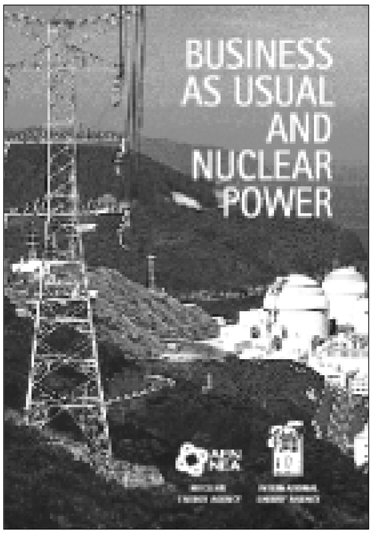
News briefs

Discussing the future of nuclear power in the OECD

With some 350 reactors in operation, supplying about a quarter of the total electricity requirements, nuclear power plays a significant role in OECD countries' electricity markets. Commercial nuclear power is a mature, established technology, having accumulated 6 400 reactor years of successful operation in OECD countries over a period of 37 years. Yet doubts remain in some countries and within some groups about the value of the contribution that nuclear energy makes today and its potential for the future. The central issue in the current, global, market-oriented world is the economic viability or competitiveness of the nuclear energy option. Beyond this point, policy decisions regarding the place of nuclear power in future energy supply must be made with full awareness of their implications for energy security and environmental sustainability.

It was in this context that energy policy makers from Member countries of the Nuclear Energy Agency (NEA) and the International Energy Agency (IEA) met in Paris on 14-15 October 1999 to assess the long-range implications of the current trends in nuclear power for energy policy in general, and the nuclear energy industry in particular. Presentations were made by officials from Member countries with widely differing policies regarding nuclear power. A select group of industry invitees addressed the implications for industry and what they saw as the role for governments.

The meeting, "Business as Usual and Nuclear Power", drew its title from the "business as usual" projections developed by the IEA which suggest that, if current trends continue, world nuclear output in 2020 will remain at about the level of 1995, but as a proportion of total electricity generated, nuclear power's share will be less than half the current percentage. The meeting addressed the impacts of this trend on:



- OECD energy security – particularly the diversity of fuels;
- economics of power generation and replacement sources;
- environmental implications of reduced use of nuclear power and increased use of its replacement sources;
- institutional challenges for nuclear safety regulators;
- maintaining the necessary industrial and educational infrastructure for nuclear power.

The meeting provided participants with a better appreciation of the issues facing governments as they consider the most appropriate role for nuclear energy in the future. The proceedings of this meeting, jointly prepared by the NEA and the IEA, will be published by the NEA at the beginning of 2000. ■

The Information System on Occupational Exposure – ISOE Programme

The Information System on Occupational Exposure (ISOE) was created by the NEA in 1992, and has since been co-sponsored by the International Atomic Energy Agency (IAEA) in order to involve countries which are not members of the NEA. The ISOE programme provides a forum for radiation protection experts from both utilities and national regulatory authorities to discuss, promote and co-ordinate international co-operative undertakings in the area of protection of workers at nuclear power plants.

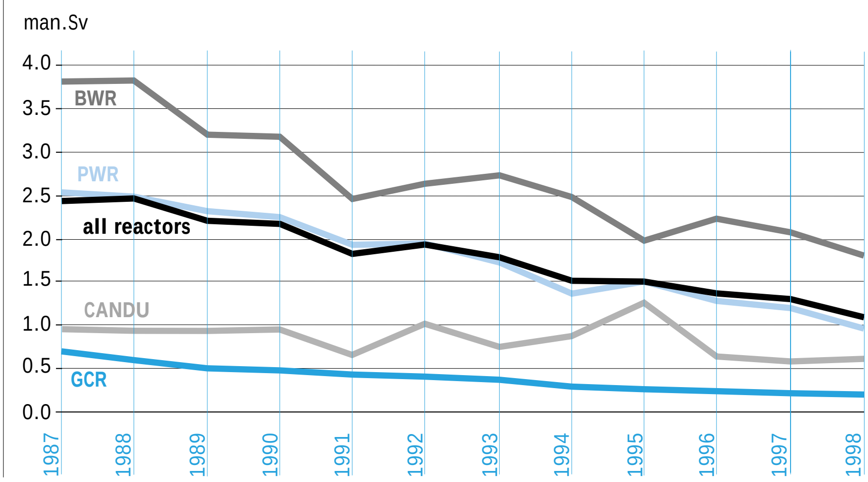
The ISOE database, the world's largest available database on occupational exposure, is divided into four parts including:

- Dosimetric information from commercial nuclear power plants in operation, e.g. annual collective dose for normal operation, maintenance/refuelling outage, unplanned outage periods, annual collective dose for certain tasks and worker categories (ISOE 1 database).
- Plant-specific information pertinent to dose reduction, such as materials, water chemistry, start-up/shutdown procedures, and cobalt reduction programme (ISOE 2 database).
- Radiation protection information related to specific operations, jobs, procedures, equipment or tasks, such as effective dose reduction, effective decontamination, and implementation of work management principles (ISOE 3 database).
- Dosimetric information from nuclear power plants which are shut down or in the process of decommissioning (ISOE D database).

The databases currently include information on occupational exposures for 422 reactors (in operation, in cold shut down or in some stage of decommissioning), managed by 77 utilities in 26 countries. National regulatory authorities from 21 countries also participate in the ISOE programme. Some 88% of the world's operating commercial nuclear reactors participate in the ISOE programme (383 out a total of 434). The reactors not participating in the programme are primarily in the Russian Federation (29 units) and in India (10 units).

The occupational exposure data from commercial nuclear power plants included in the ISOE database provide an excellent basis for studies on doses related to certain jobs and tasks in a nuclear power plant, such as refuelling or insulation work. In addition, dose trends, such as the evolution of annual collective dose per reactor for operating nuclear power plants, can be followed and evaluated. The following figure indicates that there has been a clear downward trend in dose over the last decade for pressurised water reactors (PWR), boiling water reactors (BWR), CANDU reactors and gas cooled reactors (GCR). More information and trends can be found in the recent publication *Occupational Exposures at Nuclear Power Plants: Eighth Annual Report of the ISOE Programme 1998* (OECD, 1999). ■

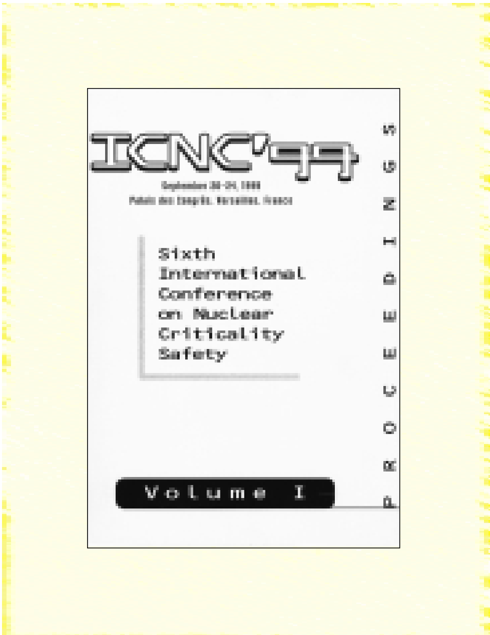
Average collective dose per reactor for operating reactors included in ISOE by reactor type



The sixth international conference on nuclear criticality safety

The Sixth International Conference on Nuclear Criticality Safety (ICNC '99), organised by the French *Institut de protection et de sûreté nucléaire* (IPSN), and co-sponsored by the OECD Nuclear Energy Agency (NEA) and the American Nuclear Society (ANS), was held in Versailles, France from 19 to 23 September 1999. This important gathering provided an opportunity to report on the technical progress that has been achieved over the last four years: previous conferences were held in Albuquerque in 1995, Oxford in 1991, Tokyo in 1987, Dijon in 1983 and Los Alamos in 1979. An ad hoc committee of the NEA Working Party on Nuclear Criticality Safety co-ordinates this series of conferences.

The Versailles conference brought together some 290 specialists from 25 countries. More than 120 papers and 100 posters were presented. The number of papers presented has generally increased significantly from one conference to the next, indicating the growing interest in this discipline.



Before fuel can be used in a nuclear reactor, it has to undergo special physico-chemical treatment processes (concentration, enrichment) at various stages from mining through to its fabrication into fuel assemblies in specialised plants and factories. Similarly, irradiated fuel is sometimes reprocessed to separate unspent uranium from plutonium and fission products. All of these operations, along with the transport and storage of fissile material, are referred to as the "fuel cycle". The fissile material is in different forms (solutions, oxides) and different concentrations at different stages of the fuel cycle.

Nuclear fuel containing fissile material (uranium or plutonium) differs from conventional fuel in that it poses a unique risk: the possibility that an uncontrolled chain reaction may be triggered. This risk is contingent upon both the chemical composition of the material (concentration of fissile nuclei, proportion of light nuclei, presence of neutron-absorbing nuclei) and the geometry of the structure in which it is placed. Depending on the combination of these factors, the fuel may be in a sub-critical state (in which it is impossible to trigger and sustain a chain reaction without a supply of neutrons from an external source), a critical state (steady-state production of energy, as in a nuclear reactor) or a supercritical state (in which a chain reaction is triggered and will continue, unless action is taken to halt it, resulting in either the dispersion of the material or a long series of fission peaks, which can last for several hours). Clearly, sub-criticality is the only state in which fissile material can safely be handled throughout the fuel cycle. The goal of criticality studies is to define conditions for the safe handling of nuclear material (to ensure the safety of workers) so that there is no risk of triggering a chain reaction. The main areas of study include:

- Understanding and modelling the physical phenomena (nuclear data, simulation of neutron transport within the material using computer codes, integral data testing for the qualification of simulation tools).

Several sessions of the conference were devoted to these topics and one special session dealt with the effects of nuclear data precision on criticality calculations. Representatives from major nuclear data evaluation projects (ENDF, JEF, JENDL) had been invited to attend this session, which showed that the evaluations performed quite well for the nuclei of the commoner elements (major actinides and light elements) but not so well for minor actinides, structural materials and absorbers. Strong emphasis was placed on the need for access to fuller information on the uncertainties of integral data and the correlation of differential data, in order to be able to explain the discrepancies between computer projections and experimental results.

- The analysis of normal and accidental operating conditions (failure effects, etc.) as a basis for defining envelope cases and evaluating safety margins. In the case of spent fuel, the safety margins are very conservative since criticality safety analyses are often conducted under the assumption that fuel is unirradiated. The use of burn-up credit has economic advantages, however quite extensive research is required to validate nuclear data and computer codes as well as the methods used, particularly for defining envelope cases that will ensure adequate margins. International information exchanges on these investigations are proving fruitful both as concerns methods, in the framework of the NEA Working Party, and as concerns the definition of joint experimental programmes.
- Experimental and theoretical analysis of situations which resemble criticality accidents, in order to understand the phenomena involved in various types of media.
- Analyses of the causes and effects of past criticality accidents (or near accidents), in order to learn lessons for the definition of envelope cases. A special conference session was devoted to the analysis of criticality accidents in fuel cycle plants and research reactors in the former USSR. It is important to note that the vast majority of criticality accidents (21 out of a total of 22) in fuel cycle facilities world-wide involved fissile material in aqueous solution. Many of them occurred in the 1950s and 1960s but the latest two (at the Novosibirsk chemical concentrate plant in Russia in 1997 and at the JCO conversion facility at Tokai-mura in Japan, barely one week after the end of the conference) are proof that it would be unwise to consider the criticality risk as highly improbable and that it is urgent to reinforce staff education and training initiatives. ■

Nuclear power plant life management in a changing business world

The decision-making framework and criteria for operating nuclear power plants are changing. With increasingly deregulated and competitive electricity markets, pressure is building on nuclear power plant owners to reduce generation costs in order to compete with fossil fuel generation and to maximise shareholder value.

It is in this context that the NEA will organise an international workshop in Washington, D.C., on 26-27 June 2000, to provide a forum for discussing decision making on nuclear power plant life and its management. The focus will be on enhancing the viability of safe and economic nuclear power in a changing business environment. The workshop will bring together senior executives and policy makers from utilities, nuclear industry, and governments from around the world and will be hosted by the United States Department of Energy (USDOE).

The workshop will provide an opportunity to exchange information on lessons learnt and to develop new ideas and strategies. The primary purpose of the workshop is to develop a set of recommendations that plant owners/operators, governments, industry organisations, and international organisations should consider for keeping the nuclear power industry viable through improved plant life management. The workshop will also examine technical, regulatory, and business environments and assess the effect of competitive markets on nuclear generation.

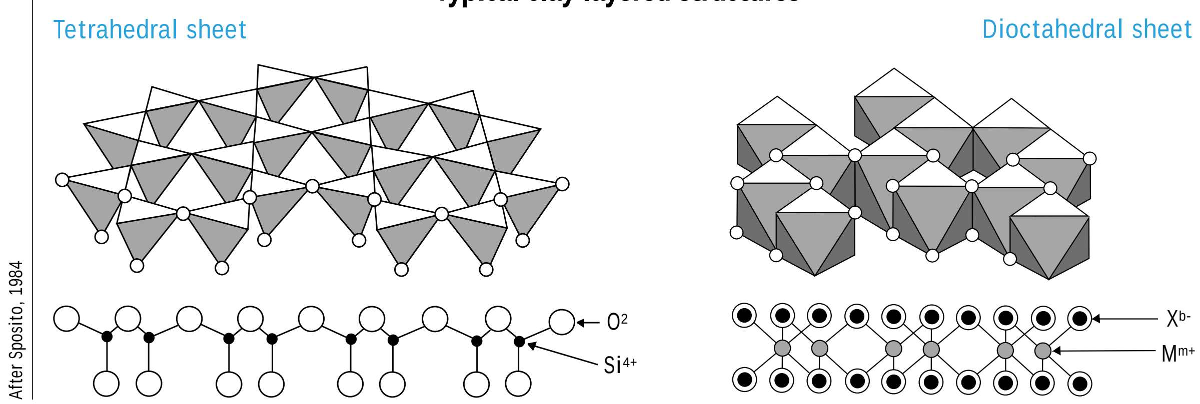
Presentations will be invited covering electricity market restructuring; regulations to control air emissions and global climate change; license renewal; plant life management practices and the technical state of the art; and business strategies which are likely to succeed in a competitive market. Participants should be nominated by their government representation to the NEA. (For more information, please contact hiroshi.yamagata@oecd.org.)

The proceedings of the workshop, including presented papers and findings, conclusions, and recommendations following the discussions, will be published by the NEA. ■

Geochemistry of clays and radioactive waste disposal

Many OECD Member countries with nuclear programmes are considering geological disposal of long-lived radioactive waste in argillaceous media (clays). In order to determine the suitability of such media for disposal, it is necessary to undertake evaluations of the various barriers they provide. These evaluations require not only site-specific data as part of a site-characterisation programme, but also a sound general understanding of the basic physical and chemical processes that govern solute transport through these media. The NEA Working Group on Measurement and Physical Understanding of Groundwater Flow Through Argillaceous Media (informally called the "Clay Club") addresses the many issues associated with this subject from an international perspective.

Typical clay layered structures



Defining the chemical and isotopic composition of the groundwater present in argillaceous formations is a crucial part of assessing the long-term safety of potential disposal systems. However, there are no standard protocols and certified norms on how to extract interstitial water from clay. Hence the decision by the Clay Club to commission a critical review of the relevant literature on current methods used to extract water and solutes, and on the various approaches to the interpretation of their results. The preparation of the review report was carried out by the *Laboratoire d'hydrologie et de géochimie isotopique* (*Université de Paris-Sud*, France) with a special contribution from the *Commissariat à l'énergie atomique* (France), and the support of a consortium of national organisations represented within the Clay Club[1]. The report, entitled *Porewater Extraction from Argillaceous Rocks for Geochemical Characterisation*, is currently at the press[2].

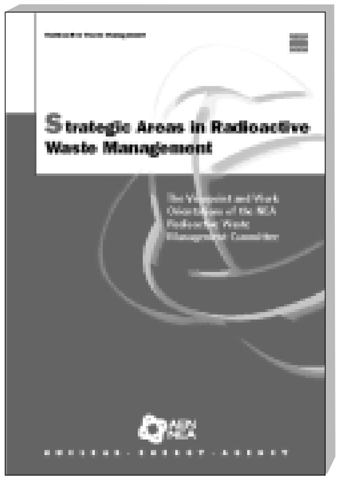
The report begins by reviewing the fundamental properties of clays. The second part of the report is based on an exhaustive bibliographical study of the available extraction techniques, with a focus on applications to clay-rich media. For each method, a description and examples of applications are presented in order to determine its advantages and disadvantages. The third part of the report analyses the mechanisms involved in water and solute extraction processes and the possible consequences on the isotopic and chemical composition of the extracted water. An approach to deriving the composition of the water indirectly, extensively based on geochemical modelling, is then presented. Finally, the report highlights unresolved issues and provides recommendations on ways to address them. The whole range of argillaceous media currently considered for deep disposal is covered, from soft, potentially plastic clays with relatively high water content, to hard, potentially fractured mudrocks with low to very low water content. ■

References

1. *ANDRA, France; CEA, France; CEN/SCK, Belgium; ENRESA, Spain; GRS, Germany; IPSN, France; NAGRA, Switzerland; and ONDRAF/NIRAS, Belgium.*
2. *E. Sacchi, J.-L. Michelot and H. Pitsch,* Porewater Extraction from Argillaceous Rocks for Geochemical Characterisation*, OECD/NEA, Paris (in press).*

Future strategic directions for radioactive waste management programmes

The NEA Radioactive Waste Management Committee (RWMC) has identified six strategic areas as priorities for work in the coming years. These strategic areas, listed below, are described in a new NEA publication[1]. The relative priority of these areas may vary in time.



I Overall waste management approaches

(a) Environmental concerns, safety and sustainable development – including demonstration that safe and environmentally acceptable strategies, that respect principles of sustainable development, can be applied.

(b) Comparison of the principles of radioactive and non-radioactive waste management and evaluation of their relative impacts – including evaluation of the consistency of management principles across different types of radioactive materials.

(c) Economic concerns – evaluation of the impact of financial pressures on waste management programmes, e.g. due to deregulation of electricity markets, as well as the impact of waste management on the continued economic sustainability of nuclear power.

II The process of repository development for long-lived radioactive wastes – particularly to continue present work on (i) assisting the resolution of technical issues to promote safety and provide grounds on which to base decision making, and (ii) developing common understanding between independent bodies such as implementers, regulators and policy makers on the goals to be achieved and respective responsibilities. The generation of societal confidence on how to move forward at the various stages of a repository development programme is also important.

III Management of materials from decommissioning and dismantling, and of very low-level waste – including technical information exchange and maintaining a dialogue between implementer and regulator, with a view to arriving at a consensus on safe, practicable, cost-effective and environmentally sound solutions.

IV Public perception and confidence – including understanding the concerns of stakeholders, communicating effectively, sharing practical experience from outreach/consultation exercises and public decision-making processes. Especially important are intermediaries between the public and the technical community, e.g. scientists in other fields and policy makers. Issues of public perception and confidence apply across the three previous topics.

V Implications of, and participation in, international guidance and agreements – identifying implications for waste management programmes of, for example, the new International Commission on Radiological Protection (ICRP) radiological policy applied to waste disposal and the forthcoming update of the ICRP 46 publication, as well as the Joint Convention on Safety of Spent Fuel Management and Radioactive Waste Management.

VI System analysis and technological advances – identifying emerging waste management and disposal technologies, for exchange of information and consideration of their implication at the system level.

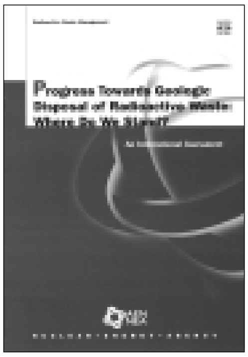
Overall, building upon the technical areas in which it has demonstrated strength in the past, the RWMC will extend its endeavours to the interfaces between technical advances, regulatory developments, societal concerns and their input to the decision-making process. ■

Note

1. *Nuclear Energy Agency (1999)*, Strategic Areas in Waste Management: The Viewpoint and Work Orientations of the NEA Radioactive Waste Management Committee, *OECD, Paris. Free on request from neapub@nea.fr.*

New publications

Progress Towards Geologic Disposal of Radioactive Waste: Where Do We Stand?



An International Assessment

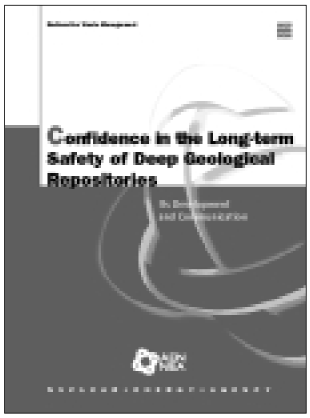
Free on request.

Radioactive wastes of all kinds need to be managed responsibly to ensure public safety and protection of the environment, as well as security from malicious intervention, now and in the future. The most challenging task involves management of the long-lived waste that must be isolated from the human environment for many thousands of years. The preferred option for eventual disposal is emplacement in repositories deep underground in well-chosen geologic media. This report presents an expert assessment of developments in the field of deep geologic disposal of radioactive waste over the past ten years. It reviews both technical and societal aspects, and should be of interest to decision makers responsible for radioactive waste management as well as to interested groups and individuals.

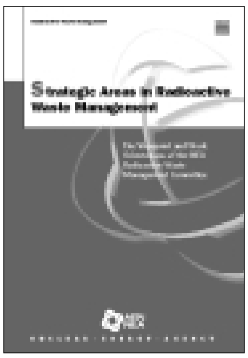
Confidence in the Long-term Safety of Deep Geological Repositories

Its Development and Communication

Free on request.



This report is aimed at safety assessors of deep geological repositories and at technical specialists concerned with radioactive waste disposal. It is intended to improve communication among interested parties by clarifying the concepts related to the development of confidence, and by placing the various measures that are employed to evaluate, enhance and communicate confidence in the technical aspects of safety in a clear, logical framework. These measures are increasingly embodied in actual procedures applied in today's safety assessments, and can be incorporated in a common framework, despite differences in approaches, practices and constraints both within and between repository projects.



Strategic Areas in Radioactive Waste Management

The Viewpoint and Work Orientations of the NEA Radioactive Waste Management Committee

Free on request.

The NEA Radioactive Waste Management Committee (RWMC) is a forum of senior operators, regulators, policy makers, and senior representatives of R&D institutions in the field of radioactive waste management. The Committee assists Member countries by providing objective guidance on the solution of radioactive waste problems, and promotes safety in the short- and long-term management of radioactive waste. This report identifies some of the major challenges currently faced by national waste management programmes, and describes the strategic areas in which the RWMC should focus its efforts in future years.

Water-conducting Features in Radionuclide Migration

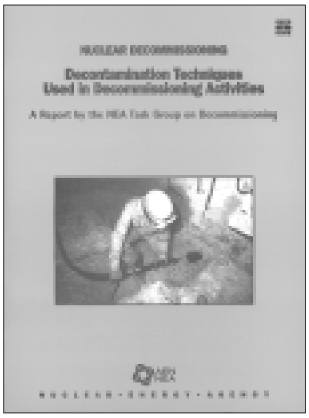
Workshop Proceedings, Barcelona, Spain, 10-12 June 1998

ISBN 92-64-17124-X

Price: FF 600 US$ 96 DM 180 £ 60 ¥ 11 600

GEOTRAP is the OECD/NEA Project on Radionuclide Migration in Geologic, Heterogeneous Media carried out in the context of site evaluation and safety assessment of deep repository systems for long-lived radioactive waste. Water-conducting features can, for example, determine the rate of radionuclide release from the near-field to the far-field, the rate at which radionuclides can migrate with flowing groundwater, and the degree of retention in the geosphere. Therefore, the characterisation of the structure and properties of water-conducting features is an important requirement for any performance assessment of deep repository systems. The third GEOTRAP workshop, "Characterisation of Water-conducting Features and Their Representation in Models of Radionuclide Migration" (Barcelona, Spain, 10-12 June 1998), addressed these issues and provided an overview of current developments in this technical field – both within national waste management programmes and the scientific community. These developments reinforce confidence in the concepts and models used for repository performance assessment. In addition to the material presented, this publication includes a technical synthesis of the workshop, reflecting the discussions that took place as well as the conclusions and recommendations made, notably during the working group sessions.

Nuclear Decommissioning



Decontamination Techniques Used in Decommissioning Activities

A Report by the NEA Task Group on Decontamination

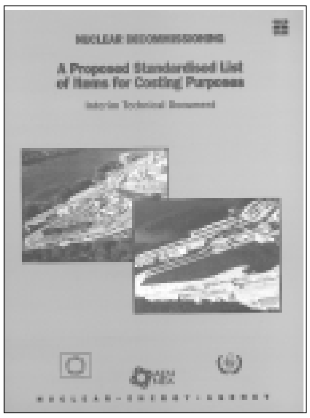
Free on request.

Decontamination is a major decommissioning activity that may be used to accomplish several goals, such as reducing occupational exposures, limiting potential releases and uptakes of radioactive materials, permitting the reuse of components, and facilitating waste management. The decision to decontaminate should be weighed against the total dose and cost. This report presents both proven and emerging techniques which may be used to accomplish these goals.

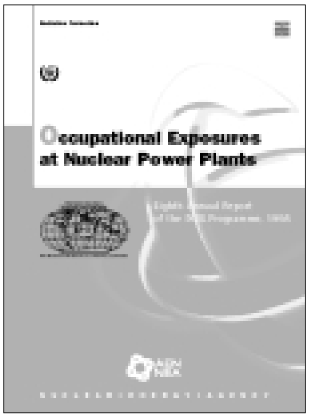
A Proposed Standardised List of Items for Costing Purposes

Interim Technical Document

Free on request.



Various international studies of decommissioning project costs have shown that there are substantial variations in cost estimates for individual installations. Studies attempting to understand the reasons for these differences have been somewhat hampered by the fact that different types of costing methods are used, having different data requirements. In order to improve this situation, the European Commission (EC), the International Atomic Energy Agency (IAEA), and the OECD Nuclear Energy Agency (NEA) agreed to prepare a common list of cost items and related cost-item definitions for decommissioning projects. It is hoped that the resulting standardised list will be widely accepted and used.



Occupational Exposures at Nuclear Power Plants

Eighth Annual Report of the ISOE Programme, 1998

Free on request.

The ISOE Programme was created by the OECD Nuclear Energy Agency in 1992 to promote and co-ordinate international co-operative undertakings in the area of worker protection at nuclear power plants. The programme provides experts in occupational radiation protection with a forum for communication and exchange of experience. The ISOE databases enable the analysis of occupational exposure data from the 422 commercial nuclear power plants participating in the programme (representing 88 per cent of the world's total operating commercial reactors). The *Eighth Annual Report of the ISOE Programme* summarises achievements made during 1998 and compares annual occupational exposure data. Principal developments in ISOE participating countries are also described.

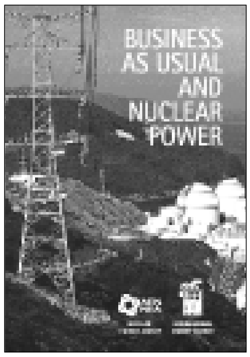
Business As Usual and Nuclear Power

A Joint IEA/NEA Meeting, 14-15 October 1999

ISBN 92-64-17175-4

Price: FF 160 US$ 26 DM 48 £ 16 ¥ 2 850

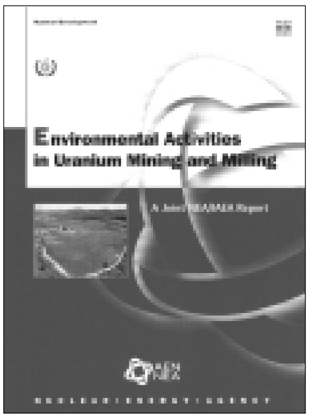
Energy and nuclear policy makers face many challenges as they evaluate options to ensure an adequate supply of electricity while pursuing environmental, economic and energy security goals. Many analysts suggest that nuclear's share of global energy supply could decrease in coming decades. If energy markets and national energy policies continue along "business as usual" lines, what are the issues that arise? What are the consequences for the long-term availability of nuclear technology and expertise? This book identifies the issues at stake



in a series of papers presented at a recent meeting jointly organised by the International Energy Agency and the OECD Nuclear Energy Agency. Senior energy policy makers and industry executives from OECD Member countries contributed these analyses. They offer a realistic assessment of nuclear's potential contribution, and the major challenges awaiting nuclear energy and energy supply in general. For those seeking a review of the current issues facing nuclear power within the broad context of energy policy, this is an essential report.

Environmental Activities in Uranium Mining and Milling

A Joint NEA/IAEA Report



ISBN 92-64-17064-2

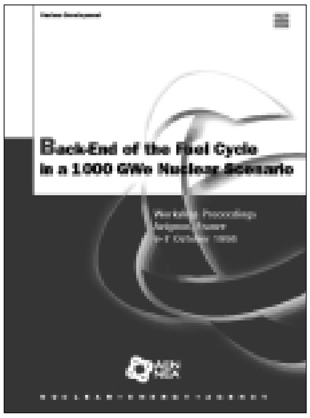
Price: FF 280 US$ 47 DM 84 £ 29 ¥ 5 550

Environmental activities in uranium mining and milling are becoming increasingly important owing to: the stricter requirements for new facilities being imposed by many countries in the form of environmental clearance approvals; the large number of uranium production facilities which have been taken out of operation recently; and the restoration and reclamation measures that are being considered for many old sites which have been closed permanently. This book provides an overview of environmental activities related to uranium production based on survey responses from 29 countries. It discusses environmental and safety activities related to the closure and remediation of formerly utilised sites; the operation, monitoring and control of producing sites; and the planning, licensing and authorisation of new facilities. It includes an overview of the reported interests of specialists working in the field, including sensitivity of ecosystems, environmental impact assessment, emissions to air and water, work environment, radiation safety, waste handling and disposal, mine and mill decommissioning and site restoration, and the regulation of these activities.

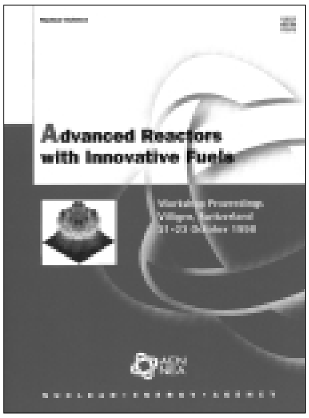
Back-end of the Fuel Cycle in a 1 000 GWe Nuclear Scenario

Workshop Proceedings, Avignon, France, 6-7 October 1998

ISBN 92-64-17116-9
Price: FF 210 US$ 34 DM 63 £ 21 ¥ 4 050



The optimisation of the nuclear fuel cycle is a key issue for the sustainability of nuclear energy. This book presents the papers from a workshop which investigated alternative nuclear energy futures, with emphasis on back-end of the fuel cycle options that could enhance the sustainability of nuclear energy in the long term, to 2050 and beyond. The papers lay out the conditions that need to be fulfilled for nuclear energy to remain a viable option and highlight the technological and strategic developments underway to address those issues. Subjects covered include natural resource management, radioactive waste minimisation, cost reduction and proliferation resistance aspects of alternative reactor and fuel cycle technologies.



Advanced Reactors with Innovative Fuels

Workshop Proceedings, Villigen, Switzerland, 21-23 October 1998

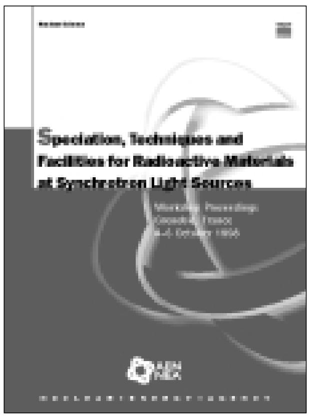
ISBN 92-64-17117-7
Price: FF 730 US$ 117 DM 218 £ 73 ¥ 14 100

Plutonium and minor actinide burning or recycling in thermal and fast reactors is being studied in many countries with the aim of maintaining and developing fuel cycle options which can be adjusted to changing demands and constraints. The challenge is to move towards an economically and socially sustainable nuclear energy system based on advanced reactors – advanced water-cooled reactors, fast reactors and perhaps accelerator-based, hybrid reactors – and new types of fuel cycles which help to minimise the waste arising. An additional issue concerns the availability of resources for the long-term future. This workshop introduced new ideas on R&D activities and identified areas and research tasks relevant for the deployment of new systems and in which international co-operation can be strengthened. The roles played by existing experimental facilities as well as possible needs for new ones are discussed. The conclusions of the technical sessions are synthesised and the results of a round table discussion on international co-operation are presented.

Speciation, Techniques and Facilities for Radioactive Materials at Synchrotron Light Sources

Workshop Proceedings, Grenoble, France, 4-6 October 1998

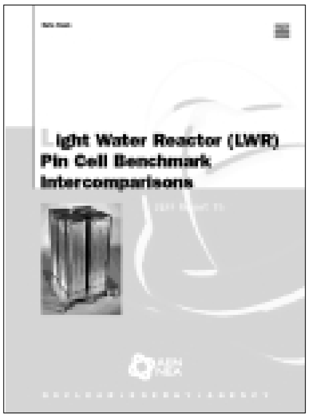
Free on request.



The NEA Workshop and Euroconference on this subject was held in order to introduce the applications of synchrotron-based analytical techniques to scientists working in the environmental field or working with radionuclides. It was also aimed at providing a forum for teaching and for scientific discussion, as well as for establishing a possible co-operative scientific network. These proceedings contain the abstracts and a selection of the papers presented at the meeting. They include introductions to synchrotron radiation techniques, results in the field of actinide chemistry and physics obtained at synchrotron light sources. Status reports on current and planned experimental activities at these installations are also provided.

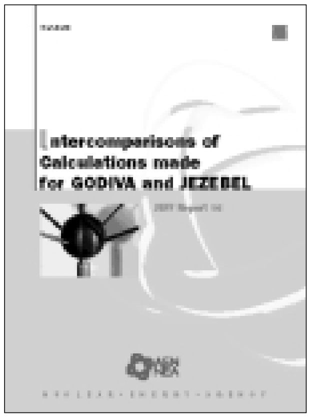
Light Water Reactor (LWR) Pin Cell Benchmark Intercomparisons

JEFF Report 15



Intercomparisons of Calculations made for GODIVA and JEZEBEL

JEFF Report 16

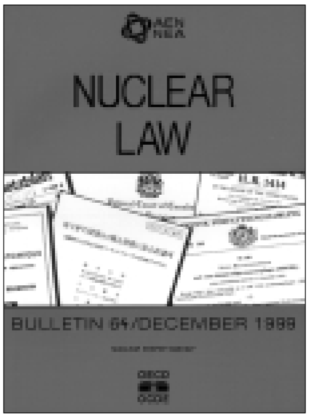


Free on request.

These reports give details of intercomparison studies undertaken to investigate the accuracy of calculation methods used for reactor physics studies. The same nuclear data library, JEF-2.2, was used in all the codes. The objective of the studies was to estimate the uncertainties arising from approximations in the cross-section processing and neutronics methods, as well as to provide guidance on the sources of the differences. The intercomparisons studied in *JEFF Report 15* were simple models: light water reactor (LWR) pin cells without leakage, and LWR pin cells with leakage treated by means of a buckling. Those studied in *JEFF Report 16* were the small Los Alamos fast spectrum critical spheres, GODIVA and JEZEBEL.

Nuclear Law Bulletin

No. 64 + Supplement (December 1999)



ISSN 0304-341X

2000 Annual subscription:
FF 460 US$ 80 DM 140
£ 48 ¥ 9 550

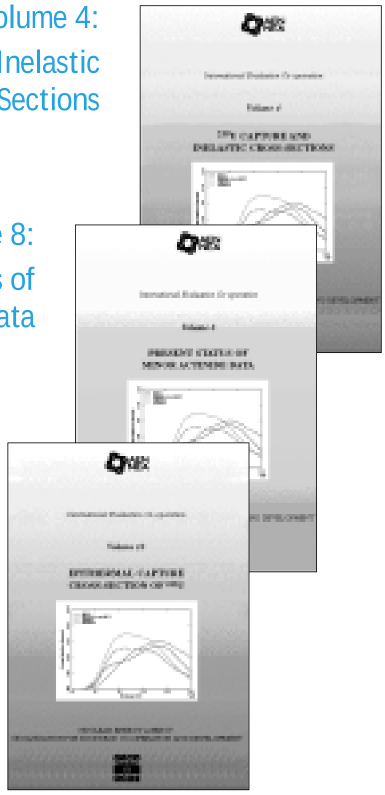
Considered to be the standard reference work for both professionals and academics in the field of nuclear law, the *Nuclear Law Bulletin* is a unique international publication providing its subscribers with up-to-date information on all major developments falling within the domain of nuclear law. Published twice a year in both English and French, it covers legislative developments in almost 60 countries around the world as well as reporting on relevant jurisprudence and administrative decisions, bilateral and international agreements and regulatory activities of international organisations.

International Evaluation Co-operation

Volume 4:
^{238}U Capture and Inelastic Cross-Sections

Volume 8:
Present Status of Minor Actinide Data

Volume 18:
Epithermal Capture Cross-Section of ^{235}U



Free on request.

Catalogue of Publications 1999

Free on request.

Also available on Internet:
http://www.nea.fr.

Where to buy NEA publications?

For customers in Austria, Germany and Switzerland

OECD Bonn Centre

August-Bebel-Allee 6, D-53175 Bonn, Germany
Tel.: +49 (228) 959 1215 – Fax: +49 (228) 959 1218
E-mail: bonn.contact@oecd.org – Internet: www.oecd.org/bonn

For customers in the United States

OECD Washington Center

2001 L Street NW Suite 650, Washington DC 20036-4922, USA
Tel.: +1 (202) 785 6323 – Fax: +1 (202) 785 0350
Toll-Free Number for Orders: +1 (800) 456 6323
E-mail: washington.contact@oecd.org – Internet: www.oecdwash.org

For customers in Asia

OECD Tokyo Centre

Landic Akasaka Bldg, 2-3-4 Akasaka, Minato-ku, Tokyo 107-0052, Japan
Tel.: +81 (3) 3586 2016 – Fax: +81 (3) 3584 7929
E-mail: center@oecdtokyo.org – Internet: www.oecdtokyo.org

For customers in Latin America

OECD Mexico Centre

Edificio INFOTEC, Av. San Fernando No. 37, Col. Toriello Guerra
Tlalpan C.P. 14050, Mexico D.F.
Tel.: +52 (5) 528 1038 – Fax: +52 (5) 606 1307
E-mail: mexico.contact@oecd.org – Internet: rtn.net.mx/ocde/

For customers in the rest of the world

OECD Paris Centre

2, rue André-Pascal, F-75775 Paris Cedex 16, France
Tel.: +33 [0(1)] 45 24 81 67 – Fax: +33 [0(1)] 49 10 42 76
E-mail: sales@oecd.org – Internet: www.oecd.org

Online Ordering: www.oecd.org/publications
Secure payment with credit card.

Where to order free NEA publications?

NEA Publications

12, boulevard des Îles, F-92130 Issy-les-Moulineaux, France
Tel.: +33 [0(1)] 45 24 10 15 – Fax: +33 [0(1)] 45 24 11 10
E-mail: neapub@nea.fr – Internet: www.nea.fr

Online Ordering: www.nea.fr

Employment Opportunities

OECD Nuclear Energy Agency

Vacancies occur in the OECD Nuclear Energy Agency Secretariat in the following areas:

- Energy Economics
- Nuclear Safety
- Radioactive Waste Management
- Radiation Protection
- Nuclear Energy Economics
- Nuclear Science
- Nuclear Law
- Nuclear Engineering
- Computing

Qualifications:

Relevant university degree; at least two or three years' professional experience; very good knowledge of one of the two official languages of the Organisation (English or French) and ability to draft well in that language; good knowledge of the other.

Vacancies are open to candidates from OECD Member countries. OECD is an equal opportunity employer.

Initial appointment:

Two or three years.

Basic annual salary:

From FF 318 000 (Administrator) and from FF 456 000 (Principal Administrator), supplemented by allowances depending on residence and family situation.

Applications, in English or French (specifying area of specialisation and enclosing detailed curriculum vitae) should be marked "NEA/NL" and sent to:

Human Resources Management
OECD
2, rue André-Pascal
F-75775 Paris Cedex 16, France

From the American Nuclear Society (ANS)

Radwaste Solutions

THE MAGAZINE OF RADIOACTIVE WASTE MANAGEMENT AND FACILITY REMEDIATION

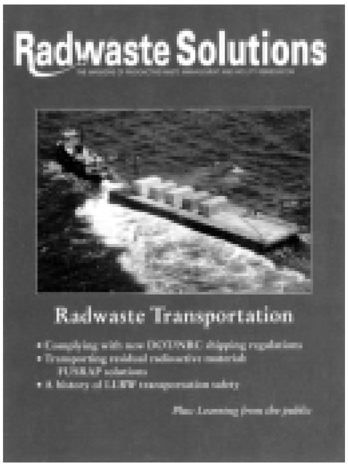
– A new name, a renewed commitment

Effective with the start of 2000, the name of *Radwaste Magazine* will be changed to *Radwaste Solutions*.This new name will capture the increased emphasis of the publication on practical solutions to everyday problems and issues in radioactive waste management.

The magazine covers all sectors – government, utility, private – that deal with radioactive waste. Also, it covers all elements of this work, including processing, packaging, storing, decommissioning, reutilization, transporting, and final disposal.

With each issue of *Radwaste Solutions* you get progress reports on cleanup/remediation/ decommissioning projects; news and views from industry leaders and professionals; coverage of industry conferences you can't find elsewhere; and technical information that can help your project.

Look at some of the articles that the magazine's recent issues have presented to our readers:



- A cold war legacy: The current status and challenges of radioactive waste management in the Russian Navy;
- Handling the unexpected: Connecticut Yankee's concrete block recovery effort;
- Radwaste management at U.S. nuclear power plants: Where we are today (and how we got there);
- Nuclear waste management in Sweden;
- Five sites, one team, one standard: The Entergy approach to radwaste management.

On top of great content and a new name, we make it easy to subscribe. Take your choice: Give us a phone call (708/579-8208); send us a fax (708/579-8314); or zip us an e-mail (accounting@ans.org). We'll get the process moving so that you start receiving your own copy of *Radwaste Solutions*.

Please enter a 2000 subscription to *Radwaste Solutions* for:

Name ______________________________

Company ______________________________

Street Address ______________________________

City______________________ State/Province ______________

Postal Code____________ Country ______________________

Tel.____________ Fax____________ E-mail ______________

Add $25 for each overseas subscription
Add $30 for funds drawn on non-U.S. banks
(All orders must be prepaid in U.S. dollars.)

Payment method:

❍ Check (payable to ANS) ❍ Money order ❍ MasterCard
❍ Visa ❍ AMEX ❍ Diners Club

Acct. no.______________________ Exp. date ______________________

Signature____

Check one:

❍ Yes! I want to subscribe to *Radwaste Solutions* at $35.00 per year. (I am a member of the American Nuclear Society.) ANS Membership ID no.______________

❍ Enter my library subscription at $355.

Send to:
Radwaste Solutions
American Nuclear Society
P.O. Box 97781
Chicago, IL 60678-7781
USA
(Make check payable to American Nuclear Society)

Credit card orders:
Facsimile 708/579-8314
ANS members call 708/579-8266
Nonmembers call 708/579-8208

OECD PUBLICATIONS, 2 rue André-Pascal, 75775 PARIS CEDEX 16
PRINTED IN FRANCE
(68 1999 02 1 P) ISBN 92-64-16177-5 – No. 51053 1999
ISSN 1016-5398