The Mihama Nuclear Power Plant was one of the top performing Japanese plants in 1988. Nuclear power plays a key role in Japan, due to its lack of other domestic energy resources.

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Can international co-operation play a major role in the development of nuclear energy?

P. Strohl
Pressurized water reactors, such as Dampierre, in France, together with boiling water reactors, account for most of the plants in operation or under construction throughout the world and have accumulated over 4,000 years of operating experience.
The end of the 1980s is being marked by contrasting situations on the energy scene. Abundant oil supplies and sinking prices followed two oil price shocks, while vast efforts have been undertaken to diversify energy patterns and learn to cope with scarce energy resources. In the industrial world, governments and public opinion are beginning to realise the serious implications which pollution from the combustion of fossil fuels creates for the environment and the climate. A wide-ranging debate is underway, in which nuclear energy appears to attract special attention because of its intrinsic ability to be produced abundantly, cost-effectively and to be environmentally benign.

The use of nuclear fission to generate electricity, in spite of the continuing public debate, has steadily gained in importance in the last 30 years; today it represents an average 16 per cent of the world's consumption, and some 23 per cent in the OECD area. This energy source now produces 70 per cent of the total electricity generated in France, 66 per cent in Belgium, 45 per cent in Sweden, 38 per cent in Switzerland, 36 per cent in Finland, 31 per cent in the Federal Republic of Germany and almost 30 per cent in Japan. Reliance on nuclear energy has now reached a point of no return in some of these countries. Furthermore, energy ministers in Western countries have stated on several occasions that any limitation of the nuclear energy option as a whole would increase demand for other energy sources and thus the costs of achieving energy security. However, in spite of the recognized past success of the nuclear industry, it has been clear for some years that the rate of growth of nuclear power will be lower in the 1990s than in the last two decades. As yet, there are few firm orders for plants to come into operation later in the 1990s and successive overall projections of nuclear capacity in the year 2000 have continued to decline in recent years.

There are many inter-related factors for this, including a lower growth in electricity demand than anticipated in the OECD (partly due to a period of widespread economic recession), protracted policy making and public acceptance difficulties, with resulting plant construction delays and sometimes prohibitively high costs. Perceptions of the competitive position of nuclear power have altered, as the fall in fossil-fuel prices has been accompanied by widely held expectations that these prices will increase only slowly. The severe accident at Chernobyl resulted from a combination of mismanagement, human error and design deficiencies, a situation which would be unlikely in Western countries, if only because their safety approaches and reactor designs are largely different from those prevailing in the USSR. Even so, the accident, by the range of issues it has raised, has provoked doubts amongst policy makers and the public about the future of nuclear energy in a number of countries, and caused several of them to delay decisions regarding the further development of their nuclear energy programmes. Although some countries with significant programmes in the OECD area (such as France and Japan) as well as outside the OECD area (such as USSR and Korea) have no intention of reducing their commitment to nuclear power, it is now under severe scrutiny in many countries. If nuclear energy is to be more than an "energy of transition" and is to fulfil its expected role in future energy supply, it must regain lost confidence by vigorously demonstrating its ability to maintain and enhance its past record of good performance in all aspects of research, development, design, engineering, construction and operation of nuclear plants.

The International Symposium, which the OECD Nuclear Energy Agency and the Atomic Energy Commission of Japan will be conducting in Tokyo from 17 to 20 April 1989 in co-operation with the International Atomic Energy Agency, will offer a unique opportunity to demonstrate the achievements and the commitment of the nuclear industry to high standards in all phases of the nuclear fuel cycle, and to exhibit the large measure of attainment of those standards. Indeed, many records exist in the nuclear industry which testify to the high level of performance reached by nuclear projects: economic viability, planning and execution of design and construction, plant operation, plant availability, maintenance and quality assurance. Let us also not forget that the nuclear industry is contributing substantially, through its research and development capabilities, to the emergence of new materials and techniques, and to the spin-off of technology to other industrial sectors.

It has often been said that nuclear energy needs to be handled with particular care. This view may stem, in part, from concern about the original uses to which nuclear fission was put. Be that as it may, the nuclear industry does expect to show an exemplary record in safe operation and efficient management. There can be no resting on previous achievements, however good they have been. I therefore expect this meeting to draw attention to areas where improvement can and should be achieved, and to provide valuable examples of know-how to be widely shared.

It is a privilege for the Nuclear Energy Agency to be at the genesis of this important Symposium. The fact that we have been able to assemble a distinguished panel of speakers is an indication that intergovernmental co-operation can go a long way toward helping to meet the criteria of excellence which should remain the hallmark of nuclear power.

On behalf of the NEA, I should like to express our deep appreciation for the efforts of the Japanese Atomic Energy Commission as co-organiser of the Symposium, for the co-operation of the International Atomic Energy Agency, and for the support of other organisations: Japan Atomic Industrial Forum (JAIF), Atomic Energy Society of Japan (AESJ), American Nuclear Society (ANS) and European Nuclear Society (ENS), in preparing for what I am sure will be a highly successful conference.

Dr. Kunihiko Uematsu is Director General of the Nuclear Energy Agency.
The role of political and institutional factors in fostering good performance in the nuclear industry

Moichi Miyazaki

Although the world’s nuclear industry as a whole is experiencing a degree of stagnation, there are many aspects of the industry which still compare favourably, in terms of overall performance, with other industrial sectors.

There are presently over 600 nuclear reactors around the world. While some are still under construction or on the drawing board, approximately 65 per cent are in commercial operation, and with the exception of Three Mile Island 2 and Chernobyl 4, their operating performance has been excellent. As for future expansion, Japan and France in particular are actively promoting development programmes.

The Tokyo Symposium will serve as a forum to present past achievements and future plans for the development and use of nuclear power, to exchange experiences in nuclear fuel cycle projects and to discuss factors which have contributed to the success of these projects from both the technical and managerial viewpoints. Through this programme, the NEA Symposium is intended to enhance the ability of interested countries to promote the peaceful use of nuclear energy. The selection of Japan to host this Symposium can be seen as an indication of this nation’s achievements in the nuclear field, as measured by international standards.

Last June, the Atomic Energy Commission of Japan established the “New Long-term Program for Development and Utilization of Nuclear Energy.” Based on this Program, my country intends to improve even further the level of safety, reliability and economy of nuclear energy and to establish the nuclear fuel cycle by promoting uranium enrichment, spent fuel reprocessing and development of the Fast Breeder Reactor. Special emphasis will be placed on radioactive waste management technology, particularly the research and development (R&D) for group separation and transmutation of high-level waste; international co-operation will play an important role in the success of this project. We also intend to sponsor R&D in other creative and innovative areas on the “nuclear energy frontier”.

Japan intends to pursue the development and utilisation of nuclear energy under strict compliance with the principle of its exclusive peaceful use. To maintain steady progress in this field, we must establish a solid technological foundation, supported by vigorous R&D activities and by the sound development of our domestic nuclear industry. To do so, Japan considers close co-ordination and co-operation in industrial and academic circles to be indispensable, from a long-term standpoint. Accordingly, a national system is being developed to organise R&D efforts and strengthen the nuclear industry. The basic directions of these future efforts are described below.

Establishment of a national system of R&D organisations

Under government leadership, R&D projects have been developed with a view toward future practical applications. Some of these projects have already attained the level of economic performance which will enable their evolution toward commercial operation. It is therefore expected that a private entrepreneurial entity will take over their commercial development. The Power Reactor and Nuclear Fuel Development Corporation (PNC), through the use of the technology and facilities developed so far, will be responsible for the transfer of this technology, working in close cooperation with the private sector. Acting together, they will establish an efficient system of co-operation which will enable each party to take advantage of the other’s role and technological assets.

From a long-range point of view, the government will consolidate technological developments, support R&D activities which can become the basis for innovative concepts and encourage the active use of results obtained from technology in other fields. To this end, the functions of such institutions as the Japan Atomic Energy Research Institute (JAERI), the PNC, other national research institutions and universities will be strengthened; new possibilities in nuclear energy will be pursued through such co-operative measures as the exchange of researchers and technical personnel and the initiation of joint research projects. Depending on the specific field of R&D, a flexible research organisation could be established which could

His Excellency Mr. Moichi Miyazaki is Minister of State for Science and Technology, and Chairman of the National Atomic Energy Commission of Japan.
extend beyond the framework of individual institutions. Provisions will also be made for the proper evaluation of these research projects.

To encourage international contributions to these endeavors, measures will be taken to internationalise Japanese R&D activities. Thus it will be necessary to improve the research environment in Japan to encourage the acceptance of foreign scientists and engineers in our R&D institutions, as well as to ensure that the R&D activities at these institutions are worthy of an international reputation. On the other hand, it is important to facilitate the assignment of Japanese scientists and engineers to foreign research institutions and international organisations. Such measures will advance the internationalisation of Japanese R&D institutions and help develop the human resources needed for internationally oriented joint R&D projects with foreign countries.

**Strengthening the foundation of the nuclear industry in Japan**

The nuclear industry in Japan is comprised of both a supply industry, which provides nuclear reactors, other equipment and services to the electric power companies, and a fuel cycle industry, which handles uranium enrichment, fuel fabrication, reprocessing, etc. Although this industrial output has been of the highest quality, the nuclear industry has recently been confronted with problems due to a downward revision of projections for future power demand, competition between nuclear and fossil power, and a high Yen exchange rate. Under these circumstances, it is especially important that the nuclear supply industry maintain and improve its technological and development capacity and strengthen its business foundation.

As far as the nuclear fuel cycle industry is concerned, private entrepreneurial entities should provide the necessary R&D in such fields as uranium enrichment and reprocessing, in co-operation with PNC and other institutions. By industrialising the domestic technology, a strong foundation can be established for an industry that is self-supporting and internationally competitive. The nuclear industry will need to infuse its R&D activities with high morale and volition if it is to continue to lead the way in the development and use of nuclear energy. As users, the electric power companies are expected to play a major role in this connection. Close co-operation between the nuclear industry and governmental R&D institutions will also be an important element in improving the technological capacity of the industry.

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Japan is one of the leading nuclear power users among industrialised countries, with almost 30% of its electricity produced by nuclear plants like the Tsuruga Power Station shown here.
Understanding and acceptance by the public

The fact that more than 400 nuclear power reactors are already operating in the world today shows that the peaceful use of nuclear energy has steadily developed. This, together with efforts to promote energy-saving measures, has ensured a stable energy supply in these countries and, by restricting oil consumption, has contributed to the stabilization not only of oil supply and demand but of energy as a whole, throughout the world.

In order to pursue peaceful uses of nuclear energy, it is imperative to obtain the understanding and acceptance of the public. As the safety of nuclear power generation has attracted much public attention worldwide, public concern has also increased. A very important task before us is to respond fully to this concern and attempt to achieve wider understanding and co-operation in this area.

In accomplishing this task, we have high hopes for a positive response by the parties concerned in each country. It is equally important to strengthen international ties within the nuclear energy community by closer co-operation, for example by a frequent exchange of information between countries.

By such means, we hope to increase public understanding of the need for nuclear power; to that end, Japan is ready to cooperate to the fullest extent.

Promotion of International Co-operation

Nuclear power generation today constitutes about 16 per cent of the total world electricity generation. It has become an indispensable energy source for the growth of the economy in the major industrialised countries. To continue development and utilisation of nuclear energy as a major power source, however, constant effort must be made to improve its safety, reliability and economy. This will also contribute towards the maturity of nuclear fuel cycle technology as a whole. As for safety, one does not need to refer to Chernobyl to recognise that an accident in one country can cross borders to affect another country's nuclear policy. It is important, therefore, that everyone involved in nuclear power make every effort to accumulate a record of safe operation for nuclear facilities.

In the course of nuclear safety studies, the nuclear industry should actively promote an exchange of the results of R&D activities and other technical information in order to achieve maximum efficiency and other mutual benefits on a world-wide scale. Such an exchange facilitates the promotion of nuclear power development from a global standpoint, and encourages international co-operation and role-sharing. To achieve such a goal, further activities in multilateral co-operation such as meetings of specialists and international co-operative projects through OECD/NEA and other international agencies, as well as bilateral co-operation, must be actively pursued.
Good performance in the nuclear industry: needs, achievements and challenges

Lord Marshall of Goring

The nuclear power industry, worldwide, has begun to enter one of the most challenging periods in its history. It does so against a background of trends and statistics which show that, globally, output is rising and performance improving.

Last year, there was an increase of nearly 6 per cent in the amount of electricity generated by nuclear power stations in member countries of the Organisation for Economic Co-operation and Development from 1240 TWh to 1313 TWh.

A recent analysis by the International Atomic Energy Agency shows that nuclear power plant load factor and availability trends maintained a steady increase during the 1980s. This was both in worldwide average values, and in the number of plants with good or excellent performance records.

Over twenty nuclear plants have started to produce power in the last 18 months and work has begun on new plants in several countries. Worldwide there are now over 400 nuclear power stations producing electricity. The capacity exceeds 300 000 MW(e).

Together with Russia, Britain was the first country to connect a nuclear reactor to the national electricity grid — at Calder Hall in 1957. The first two commercial Magnox stations started to produce power in 1962. One of them, Berkeley in Somerset, ceased generation in 1989, 27 years later. Based on a planned life of 30 years, all but one of the Magnox stations (Wylfa in North Wales), will be retired by the year 2000.

The Magnox stations have been the nuclear workhorses for the UK Generating Boards. The Advanced Gas Cooled Reactor stations which followed have had mixed performances.

Hinkley “B”, Somerset and its sister station in Scotland, Hunterston B, have performed well and we have confidence in the future performance of the latest AGRs to be connected to the Grid — Heysham II in Lancashire, and Torness in Scotland.

In between, however, getting sustained, substantial output from the Dungeness, Heysham I and Hartlepool stations is proving very difficult and costly.

This underlines the wisdom of the CEGB’s decision to switch from gas-cooled reactors to pressurised water reactors. Getting that policy implemented against considerable opposition took many years. At last, however, the United Kingdom has started to use a reactor technology in widespread use in the world — an important achievement.

Construction of our first PWR, Sizewell B in Suffolk, is going well. A Public Inquiry has started on the second PWR station — Hinkley “C” in Somerset. We expect, in due course, to apply for consent to build two further PWRs. This will fulfill a policy of building over the next decade a small family of PWRs based on the Sizewell B design to gain the economic advantages of replication.

Today nuclear power accounts for about 15 per cent of the electricity produced by CEGB. I would expect this to increase to about a fifth. Thus nuclear power in the United Kingdom should continue to make a significant contribution to fuel diversity.

World-wide nuclear power saves some 600 million tonnes of coal annually. Without nuclear power the world price of fossil fuels would be higher with considerable follow-on effects on the economies of the industrialised and third-world countries. Also the impact on the environment of burning fossil fuels — a matter of increasing concern — would be that much greater.

However, while the performance of nuclear power stations is improving, and despite concern about the impact of fossil fuels on the environment, the biggest challenge facing nuclear power in most countries is public acceptability.

The accident at Three Mile Island in 1979 and, most importantly, the Chernobyl accident in 1986 have undermined public confidence.

In some countries nuclear power is under siege. In most countries the public are worried about safety — concerned about the possibility of accidents and frightened of their consequences. Chernobyl has made the public look not only at the safety of their own nuclear stations, but those of their neighbours also.

“...in the safety of nuclear plants world-wide. Another major accident would be fatal for nuclear power in many countries.”

Lord Marshall of Goring is Chairman of the Central Electricity Generating Board in the United Kingdom.
The post-Chernobyl situation called for a new initiative in international co-operation. Last year world electricity utilities operating nuclear power plants agreed to form the World Association of Nuclear Operators (WANO). The aim is to exchange information on safety aspects of nuclear power station operation and improve safety by emulating the best practices.

More than 150 delegates from 29 countries around the world representing almost all of the world’s nuclear electricity producers attended a preliminary meeting in Paris which confirmed their determination to work together to improve safety. There was unanimous agreement to strengthen existing links and co-operation.

The delegates agreed to a number of Key Organizational Principles which form the basis for the development of the Association. In particular, they decided to establish regional centres in Atlanta, Moscow, Paris and Tokyo, together with a small co-ordinating centre for the collection of technical information and its distribution among participating organisations.

The inaugural meeting of WANO will be held in May 1989 in Moscow, and the Soviet Ministry of Nuclear Power will host the meeting and act as co-sponsor together with utilities from the USA, Japan and Europe.

This important international occasion will provide an opportunity for the leaders of nuclear utilities to make a formal commitment to inform, help and emulate each other by providing and adopting the best operating practices. The Moscow meeting will be remembered as a key date in the history of the development of nuclear power.

Arrangements for forming the four regional centres, where most of the work will be done, are proceeding.

The co-ordinating centre is already operating from London on an interim basis. Several technical exchange visits have also been made. Western engineers have visited the Paks nuclear power plant in Hungary and Cuban engineers have visited the McGuire plant in the United States.

The formation of WANO will not provide a panacea, but it is a significant initiative which cuts across political and cultural barriers to enhance the safety of nuclear plants. If WANO had existed at the time, the TMI and Chernobyl accidents would not have happened.

The International Atomic Energy Agency also has an important international safety programme, through the series of visits by operational safety review teams — OSARTs — to nuclear power stations.

Their investigations cover areas such as health physics, quality assurance, clear definitions and understanding of responsibilities, good procedures, good working environments and good housekeeping.

Ten OSART missions visited nuclear power plants in seven countries in 1987 and a report on the results of the first eighteen missions has been prepared. The first OSART mission to the United Kingdom is planned for 1989 at Oldbury in Gloucestershire.

In addition to the need to regain public confidence in safety standards, an increasing challenge arises from the decommissioning of the early commercial nuclear stations.

Around the world, more than 80 reactors, mainly small prototypes, have been shut down already and are in the various stages of the decommissioning process. Through the OECD Nuclear Energy Agency, information is exchanged on experience gained with the decommissioning of selected prototype reactors.

Next year, following the cessation of generation at Berkeley, decommissioning will start.

A key priority will be to keep the public fully informed on the work being undertaken. Nuclear power has no future unless the public and governments are satisfied that the risks are tolerable in relation to the benefits.
Maintenance aspects of nuclear power performance: the lessons from the past two decades

William F. Conway

Although production of electricity by nuclear power began in the United States in the 1960s, it was the massive construction programme of nuclear plants in the 1970s that presented many utilities with the challenge of operating and maintaining nuclear plants. Staff for these nuclear plants, who often came from the utility's fossil plants and were highly experienced in maintaining them, considered the maintenance of nuclear power plants to be very similar. Maintenance activities, viewed as performing surveillances and repairing equipment that failed, followed the tradition established at fossil sites in that each nuclear site was responsible for its own maintenance work.

One operational practice brought from the fossil sites to some nuclear plants was to "run them till they broke". This was a sound economic practice prior to nuclear generation because many of the fossil units were smaller and did not provide base load generation. Preventive maintenance activities were, therefore, not encouraged.

What these relocated fossil plant people found was that nuclear plants were very different. For example, they have technical specifications which require surveillances for ensuring operability of safety-related equipment through functional, administrative or visual verification. These technical specifications are part of the nuclear plant license granted by the Nuclear Regulatory Commission (NRC), the Federal agency responsible for regulating the nuclear industry. Thus, a group from outside the utility has some authority over part of the nuclear plant's maintenance activities.

This control was very foreign to many plant people. Understandably, they had many years of hands-on experience in running power plants and felt comfortable and proud of the performance of the fossil plants. There was a great reluctance by utilities to allow the NRC to have any role in the balance-of-plant components. The NRC was encouraged to focus only limited attention on plant maintenance, and then only on safety systems.

Lessons from the first decade

The view of maintenance as a site concern changed during the 1970s due to a number of events. First, the accident at Three Mile Island, while limited to the site, sent shock waves through the industry. An analysis of this accident found that the initiating event involved maintenance on the condensate polisher system. The NRC began focusing its attention on a number of areas, including maintenance activities, even though it was involved in an extensive programme to license new plants. Utilities began to feel pressure from their shareholders and customers about the operation and safety of their nuclear units. The Institute of Nuclear Power Operations (INPO) was formed by nuclear utilities to evaluate performance and provide assistance in plant operation.

The second event that occurred during this time frame was the decline in demand for electricity. Proposed nuclear plants were cancelled and plants in operation or construction were being viewed not as one of a series of new plants but as power plants that were expected to produce electricity for many decades without replacement. This view was strengthened when the cost of construction of nuclear plants became astronomically high.

As the U.S. nuclear industry entered the 1980s, its attention began to turn toward the maintenance of the projected one hundred plus operating plants. This was in recognition of the importance of having effective maintenance programmes to support safe, successful operation of the nuclear generating stations.

Lessons learned in the second decade

The approach toward maintenance taken by the industry was originally at the utility level. Each utility assessed its plants' maintenance programmes and evaluated how it would approach the issue. Most utilities surveyed those businesses (e.g., airlines) where reliability was a necessity for successful operation, as well as foreign utilities who had a reputation for availability and reliability. Maintenance programmes were examined for their effectiveness, cost, and ability to be incorporated into the maintenance/operation activities of the plant.
Widespread changes began to take place in industry maintenance programmes, with the biggest change being the implementation of a preventive maintenance programme at plant sites. Some utilities incorporated other programmes into their maintenance activities, such as:

- reliability-centered maintenance
- root cause analysis of failures
- diagnostic testing
- analysis of mean time between failures
- analysis of failure mode effects

The majority of U.S. plants began by servicing equipment in accordance with the vendor's technical recommendations, procuring appropriate spare parts and tools for required repairs, hiring better qualified personnel to perform maintenance, controlling work-in-progress, and performing quality checks on completed jobs.

Although various utilities recognised the need to improve aspects of their maintenance programmes, initiatives at the industry level encouraged change. A Working Group under the leadership of the Nuclear Management and Resources Council (NUMARC) was formed to initiate industry self-improvement efforts in the area of maintenance. The Working Group composition of 20 senior utility officers and managers reflects the level of interest and commitment of the industry to this issue.

To assess the state of maintenance within the industry, the Working Group asked INPO to analyse the significant industry events related to maintenance activities. A study was carried out to determine the root causes of 650 significant events which were reported from 1980 to 1984. As seen in Figure 1, the data analysis found:

- human performance problems were the most frequent (51 per cent) cause of significant events; and
- 38 per cent of all root causes were maintenance-related.

The analysis showed that the industry needed to improve the conduct and execution of maintenance activities if it wanted to improve overall performance. While the U.S. industry as a whole knew how to perform effective maintenance, it became a challenge to reach the stage where all plants would continue to improve and the outliers would accelerate their improvement.

Several specific actions were taken to try to accomplish the needed improvement. NUMARC assisted INPO in developing "Guidelines for Conduct of Maintenance at Nuclear Power Stations" to provide valid criteria to assess a utility's maintenance programme. The Working Group then sponsored a pilot self-assessment programme at four utilities. The results of the pilot effort demonstrated the value of the self-assessment approach in identifying needed improvements and confirmed the validity of the INPO maintenance guidelines.

An analysis of NRC Systematic Assessment of Licensee Performance (SALP) Reports from 1980 through 1986 was performed. The study showed that the composite of maintenance SALP performance for all U.S. plants was apparently improving at a rate of 0.2 SALP points per 5 years (see Figure 3). While this is a positive trend, the rate of overall improvement was unsatisfactory. This data was used as the basis for conducting an industry-wide maintenance self-assessment initiative. Upon reviewing the results of this initiative, the Working Group found no programmatic voids in maintenance. Because of differences in plants, locales and area cultures, the INPO guidelines were employed to varying degrees.

Figure 2 shows that 43 per cent of the human performance problems were attributable to deficient procedures or documentation. In response to this problem, NUMARC assisted INPO to develop guidelines for writing maintenance, test and calibration procedures.
The Working Group developed a set of indicators to measure maintenance performance against valid criteria. These indicators are:

- a corrective maintenance backlog greater than 3 months old
- ratio of highest priority maintenance work requests (MWRS) to total requests completed
- preventive maintenance items overdue
- ratio of preventive to total maintenance
- maintenance overtime worked
- maintenance radiation exposure (BWR)
- maintenance radiation exposure (PWR)
- lost-time accident rate for personnel involved in maintenance
- unplanned automatic scrams which are critical and are associated with maintenance activities.

These indicators are now being used to monitor maintenance in the industry, on an individual plant basis and collectively, through reports to INPO by each utility on a quarterly basis.

Since existing lines of communication among utilities have been less than effective for addressing technical problems as they occurred, the Working Group assisted the Electric Power Research Institute (EPRI), a research facility funded by electric utilities, in establishing the

Figure 3  All U.S. Units
NRC Maintenance Reviews
Nuclear Maintenance Assistance Center (NMAC). The single purpose of this Center is to assist utilities in improving their maintenance efforts. In addition to providing solutions to technical maintenance problems, NMAC will be a vehicle for communicating proven solutions to technical maintenance problems and will assist in helping allocate maintenance resources.

In the area of maintenance evaluation, the Working Group assisted INPO to institute the maintenance peer evaluation programme in which maintenance managers or supervisory-level personnel accompany INPO teams on plant evaluations or maintenance assistance and review visits to other plants.

In summary, the industry has worked toward raising the level of maintenance performance by using industry experience and innovation. Reviews and analysis have been conducted in areas of concern identified by the industry. Indicators have been developed to follow progress and to guide the industry to areas that may be deficient. Through NMAC, a central point has been established to obtain maintenance assistance and expertise.

In parallel with the industry’s initiative in the area of maintenance, the NRC issued its 1984 Policy Planning Guide (NUREG 0885) which identified forty broad issues to be scheduled for rulemaking. It included the Maintenance and Surveillance Plan Program (MSPP), with a plan for five phases of implementation that would result in regulatory requirements. This led to many meetings between the NRC and the Working Group to discuss the industry’s collective actions to improve performance of the nuclear plants and the MSPP.

The first phase of the MSPP was to survey the current status of maintenance in the U.S. commercial nuclear power industry. The results of one survey (NUREG-1212) were:

"While overall trends are positive, there is a need to improve performance of maintenance and surveillance in order to reduce challenges to safety systems and improve safety systems availability and reliability." (Volume I, page vi)

The NRC has stated that plant maintenance plays a central role in keeping both safety systems and balance-of-plant components (that can affect safety systems) in reliable condition. For this reason, the NRC was interested in developing ways to measure maintenance performance that can identify performance trends and alert them to developing problems. A report was published (NUREG/CR-4611) that described industry performance on thirty-one measures pertinent to plant operating and maintenance performance.

The NRC is considering issuing a rule on maintenance in an effort to improve licensee maintenance programmes, where warranted, and maintain a satisfactory level of performance. The intention is to set a comprehensive standard which reflects those attributes of a good maintenance programme determined by previous experience and judgement to contribute to an effective, overall maintenance programme.

What has happened in the past decade in the United States is a dual effort, by the industry and the regulator, to improve maintenance at nuclear power plants. This was done first by understanding the issue, analysing the industry practices to see if there were needed programmatic changes, identifying maintenance indicators so that performance could be monitored, and raising the level of performance.

Lessons for the next decade

The area of maintenance has shown the U.S. industry that issues that may seem plant specific may truly be an industry-wide concern, not only for the people who own and operate the plants but for those who regulate them as well.

Thus, the industry has learned that it shares common concerns and goals with those who regulate it. The challenge for the next decade demands an ever increasing path to improved maintenance practices.
Managing a nuclear power programme: the utility viewpoint

Hermann Krämer

In the second half of the sixties, Germany decided, for several reasons, to build its first two fully commercial nuclear power plants in northern Germany: in the northern federal states, primary energy resources for electricity production usually had to be imported and electricity prices exceeded the Federal Republic average by up to 25 per cent, partly as a consequence of disadvantageous conditions concerning large industrial consumers and of low population density.

At the same time, the two German electrical equipment companies, AEG and Siemens, had, on the basis of license agreements with General Electric and Westinghouse, demonstrated their ability to construct Boiling Water Reactors (BWR) and Pressurised Water Reactors (PWR) by adapting the US Light Water Reactor (LWR) technology to German standards and licensing requirements. The nuclear option was also considered because at that time in some parts of the northern provinces, the annual consumption rates of electricity had increased by as much as 14 per cent. So, by 1967, the utilities Hamburgische Electricitäts-Werke (HEW), Nordwestdeutsche Kraftwerke (NWK) and Preussische Elektrizitäts-AG (PE) had decided to go nuclear and to co-operate in the construction and management of a nuclear power programme for northern Germany.

Since then, this co-operation has proved advantageous for all parties and is continuing. The two companies Preussische Elektrizitäts-AG and Nordwestdeutsche Kraftwerke were merged into PreussenElektra.

Dr. Hermann Krämer is Chairman of the Board at PreussenElektra AG, Federal Republic of Germany.

The 1335 MW Brokdorf Plant is one of the largest nuclear power stations in the Federal Republic of Germany.
(PE) in 1985. HEW is responsible for electrical power production and distribution in the Hanseatic City of Hamburg; PE produces electricity for Schleswig-Holstein, the majority of Lower Saxony and for the northern parts of Hesse, while the distribution in these regions is under the responsibility of distributing companies.

In 1967, two plants were ordered:

1. Stade nuclear power plant (KKS)
   
   Reactor type: Siemens-PWR
   
   Capacity: 640 MWe (net)
   
   Start-up: 1972

   Owned jointly by PE and HEW, operated by PE.

2. Würgassen nuclear power plant (KKW)
   
   Reactor type: AEG-BWR
   
   Capacity: 640 MWe (net)
   
   Start-up: 1975

   Owned and operated by PreussenElektra (PE).

Since then, KKS has produced about 80 billion kwhs; KWW about 50 billion. Some years ago, KKS was reconstructed in order to deliver steam for a nearby salt factory. Both plants had to undergo various structural changes to implement changing safety requirements. Electricity generating costs of both plants are low in comparison to those of plants more recently connected to the grid.

The nuclear power programme in northern Germany has developed since the early seventies and now generates about 70 per cent to 80 per cent of all electricity. Northern Germany therefore belongs to those European regions having a very high share of nuclear energy in the electricity supply system. The complete list of nuclear plants is as follows:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Type</th>
<th>MWe</th>
<th>Commercial operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stade</td>
<td>PWR</td>
<td>640 MWe (net)</td>
<td>1972</td>
</tr>
<tr>
<td>Würgassen</td>
<td>BWR</td>
<td>640 MWe (net)</td>
<td>1975</td>
</tr>
<tr>
<td>Brunsbüttel</td>
<td>BWR</td>
<td>771 MWe (net)</td>
<td>1976</td>
</tr>
<tr>
<td>Unterweser</td>
<td>PWR</td>
<td>1230 MWe (net)</td>
<td>1979</td>
</tr>
<tr>
<td>Krümmel</td>
<td>BWR</td>
<td>1260 MWe (net)</td>
<td>1984</td>
</tr>
<tr>
<td>Grohnde</td>
<td>PWR</td>
<td>1300 MWe (net)</td>
<td>1985</td>
</tr>
<tr>
<td>Brokdorf</td>
<td>PWR</td>
<td>1335 MWe (net)</td>
<td>1986</td>
</tr>
</tbody>
</table>

Stade, Brunsbüttel, Krümmel and Brokdorf are jointly owned by PreussenElektra and HEW, while Grohnde is a joint venture of PreussenElektra and other partners. All BWRs except Würgassen are operated by HEW, the PWRs by PreussenElektra. The development of PreussenElektra’s nuclear capacity can be seen in graph N° 1.

The increasing importance of nuclear power in the PreussenElektra grid can clearly be seen in graph N° 2, which also demonstrates the structural changes in primary energy supply since 1972. HEW underwent a very similar development.

A nuclear power programme which is carefully constructed step by step, as in northern Germany, requires close co-operation in outage planning. At KKS, both utilities have practised this since the plant began operation. All outages and revisions are performed within a specific time schedule, taking into consideration requirements of both grids. The outage planning of PreussenElektra’s nuclear capacity can be seen in graph N° 3, which also indicates the yearly time dependance of PreussenElektra’s grid load.

Jointly owned nuclear facilities can also help ease the management and high cost of replacement power during unplanned shutdowns. Both companies are operating their power plants — fossil, hydropower and nuclear — by centralised load dispatchers; in both grids, nuclear power is operated in the base load for economic reasons.
Nevertheless, in the PreussenElektra grid, load reductions may be necessary, particularly during weekends or holidays, and they have become a routine mode of operation.

Both companies have become increasingly involved in nuclear fuel management since the early seventies. Activities started by taking full responsibility for the purchase of natural uranium and enrichment services for all nuclear plants, including first cores and reloads. Today, they normally undertake the complete contractual responsibility for supply services including natural uranium, conversion and enrichment.

HEW started in-core fuel management activities in the mid-seventies by co-operating with a Norwegian group using computer programme systems developed in the Norwegian Institute for Nuclear Energy. HEW is still using this system to perform operational studies, cost calculations, etc. The company eventually intends to take over full responsibility for in-core fuel management, including licensing procedures. PreussenElektra started in-core fuel management activities in the early eighties. Since then, in-house activities have gradually been expanded and this company now has full responsibility for one PWR (Unterweser), including licensing requirements. The intent is to supply in-house, in-core fuel management for all nuclear power plants for obvious reasons: confidential commercial data are involved, and the interests of the operating company and fuel manufacturers are often contrary. Nevertheless, PreussenElektra and the main fuel manufacturer, Siemens (KWU), are performing common fuel cycle optimisation calculations using the Siemens (KWU) programme system. Cycle-length studies demonstrated the 12-month cycle to be advantageous compared to an 18-month cycle. At PreussenElektra, one physicist is responsible for the in-core fuel management of each nuclear plant.

Beginning in the early eighties, German utilities decided to fund a mixed-oxide (MOX)-fuel qualification programme, together with ALKEM, the German plutonium fabrication company. In 1984 four MOX-fuel assemblies were loaded for the first time into the Unterweser PWR. These four assemblies have performed well since then. MOX-fuel is also being tested in Grohnde. Operating licenses for all PWRs except KKS include the permit to load MOX-fuel. A standardised fuel assembly version is used, which fits all the large PWRs. In the long run, it is intended to recycle the full amount of plutonium produced.

On the BWR side, MOX-fuel operating permits are being prepared, although the licensing procedures are still in progress.

After conditioning, low-level operational wastes are now stored at the plants or in storage halls. All waste is being conditioned so as to be acceptable at the forthcoming Konrad depository.

Nuclear fuel reprocessing is the standard route to close the fuel cycle, and contracts exist with French and British reprocessing companies. After the start-up of the Wackersdorf reprocessing plant in the second half of the nineties, reprocessing will increasingly be done in the German plant.

By connecting Brokdorf to the grid, the nuclear power programme for northern Germany is completed. No additional nuclear capacity is under construction, no further expansion is presently considered. Long-term operating licenses exist for all units. Nevertheless, severe accident mitigation measures are going to be implemented at all plants as part of a backfitting programme and most of the work has already been done. Through this backfitting programme, the nuclear capacity of northern Germany will be well equipped for the rest of the century.

Has the nuclear power programme in northern Germany been a success? The answer is clearly yes! Looking at the original aims:

- to become independent in primary energy use in power production and
- to improve the price of electricity compared to other parts of Germany,

there is good reason to be satisfied. As for the price development, PreussenElektra has continuously improved the situation in comparison to the Federal Republic average as can be concluded from graph No 4. Company prices have remained unchanged since 1982. Almost the same can be reported for HEW. There is no doubt that electricity prices, once disadvantageous from an industrial viewpoint, have become a credit point in northern Germany.

Finally, the environmental aspect should be mentioned. In this respect, nuclear energy has improved the situation dramatically. Graph No 5 demonstrates a decrease in the emission of sulphur dioxide, which is mostly
due to the use of nuclear power. Only a small percentage of the decrease in emissions is due to desulphurisation measures. Nearly the same is true for the emission of carbon dioxide. Graph No 6 demonstrates the CO\textsubscript{2} emissions replaced by nuclear energy in the PreussenElektra grid system. It is well known that man-made CO\textsubscript{2} emissions play an important role in long-term global atmospheric effects leading to increased average temperatures. Nuclear energy in the industrialised countries is considered to be the most effective countermeasure available at present in the electricity-producing industry.

Nuclear energy in northern Germany is a fine example of how a power production system has been successfully restructured in twenty years' time. Energy independence, economic and environmental aspects have improved remarkably. Nuclear electricity generation has played an increasingly important role as can be seen from graph No 7. In particular, attention should be drawn to the economic situation: the whole north of Germany has benefitted from this. We shall therefore continue to improve our operations and we shall keep the nuclear option open for the future.
The outlook for commercial nuclear power plants

Rémy Carle

The nuclear energy scene today is astonishing. Whereas nuclear power plants throughout the world are operating smoothly and meet 15 per cent of total electricity consumption, a prevailing mood of pessimism poses a serious threat to this form of energy. The constructors’ order books are thinning. Several countries express misgivings about nuclear power plants, and some have even decided to abandon them. Just a few are doggedly pursuing their course. This situation is all the more paradoxical since the arguments for developing the nuclear sector in the first place still apply today, and indeed, new ones have been added. Ultimately, the nuclear industry remains essential for balancing resources; it has economic advantages; properly controlled, it does not entail any truly serious hazard to man; and finally, it is the least polluting source of energy. It is already the energy of the present and will certainly be that of the future.

It is true that, after a period of crisis due to shortages, energy supplies have once again become plentiful. In the long term, however, nothing has changed concerning reserves which can be easily mobilised at affordable prices. What is meant by “affordable prices”? The level reached by oil prices at the end of 1988 is obviously cyclical and temporary. Any country basing its long-term energy policy on this level alone would be extremely unwise. Such low crude oil prices no longer cover the operating costs of most producers and indeed the strongest contenders should not overlook this basic arithmetical rule: to obtain the same level of earnings, if the sales price is divided by two or three, the sales volume must be multiplied by the same factor. And this applies just to earnings, not even to profits or royalties. How long can a country continue to undersell its reserves so as to eliminate its competitors?

Even allowing for sudden swings in price levels during the next decade, the overall trend will move relentlessly upwards. At world level, oil reserves are not about to be depleted as long as the right price is paid. The same applies to natural gas, which requires very heavy investment, possible only above a certain price level. Hydropower resources located close to consumption centres are already largely harnessed and the remaining potential is much less easy to exploit.

It is often stated that coal reserves, which are vast compared with current requirements, are sufficient to cover all requirements for centuries. The market for this heavy and bulky raw material, which is difficult to transport as well as to use, has so far not shown the expansion announced by its promoters. It also requires a minimum price level. Although the Middle East — for oil — and Australia or South Africa — for coal — will continue to enjoy cheap resources for a long time, they cannot alone meet the entire world requirements.

Demographic forecasts show that the world population will double in less than one generation. While energy demand in industrial countries has stabilized, new energy needs will arise, especially in developing countries. They will first be met through traditional energy sources, such as wood, coal and oil, which are the only feasible ones in the economic and social context of these countries. To give some idea of the scale involved, China consumes almost one billion tonnes of coal per year.

Consequently, both environmental pollution through sulphur and nitrogen oxides and the more recently discovered hazard of carbon dioxide, which have already reached worrying proportions, are likely to become more acute in future.

Our world is not infinite and its capacity to absorb harmful products is limited. The decay of forestland, which can be partly correlated to acid rain, has alarmed the public. Admittedly steps have been taken to reduce emissions, but the processes available are expensive, and although efficient, leave a substantial share of the initial emissions untouched. The accumulation of carbon dioxide is even more worrying, but can it be prevented? The impact of a steady increase in the atmospheric concentration of carbon dioxide has still not been fully assessed. Climatic effects occur through complex thermal exchanges and there are natural control mechanisms in existence. However carbon dioxide is obviously building up. Since the beginning of the industrial era, world consumption of fossil fuels has totalled the equivalent of 300 to 400 billion tonnes of oil and as much again is likely to be consumed in the next 40 years. Meanwhile, the carbon dioxide level in the atmosphere has risen from 0.023 to 0.034 per cent. If the greenhouse effect we suspect today really does exist, it is high time to act. We cannot, of course, stop using fossil

Mr. Rémy Carle is the Deputy Director General of Electricité de France.
fuels from one day to the next. Each country will have to find the best mix of energy sources within its own geographical, economic, social and human capacities. In this mix, nuclear energy will become steadily more prominent, especially in major industrialised countries, which are in the best position to use it on a massive scale under good safety conditions.

Today, emotional fears about nuclear accidents and the apparent glut of inexpensive energy resources are enticing us away from nuclear energy. All those who agree with this view, argue that it is unreasonable to run any risk, however small, when low-cost energy resources are so plentiful. But what does this actually mean? Out of fear of a highly hypothetical accident, we would be accepting the certainty of pollution with wide ranging and long-term impacts which are just as dangerous. The general public now seems to be coming round to the idea that each God-given day, an all-pervading and irreversible peril is being created through the use of oil, and above all, coal. Assuming a reversal of attitudes, perhaps those who generate electricity will be able to turn back to nuclear energy once the general public and the authorities have perceived the facts. At any rate, this should lead us to the conclusion that there is no perfect solution to energy problems, there are only imperfect ones, each requiring multiple precautions and controls and, among them, the nuclear solution with all the modern technology which contributed to its development, is one of the best.

For another few years, perhaps only a few countries (France, Japan, USSR, South Korea) will order new units. I am confident, however, that by the end of the century, the trend will be reversed and, in light of the benefits of nuclear energy, programmes will be revived even before it becomes necessary to replace existing reactors.

Pressurised Water Reactors (PWRs) and, to a lesser extent, Boiling Water Reactors (BWRs), account for most of the plants in operation or under construction throughout the world today. These reactor systems are well tried and the operating experience accumulated over 4 000 reactor-years ensures that they will continue to be the most frequently constructed and used reactors for a long time. In all likelihood, until fast breeder reactors become operational, pressurised water reactors and boiling water reactors will conquer all their competitors, with the possible exception of CANDU reactors. What is the point of "inventing" new reactor systems merely in order to circumvent public opposition? The industrial development of any new system is very expensive, and new power plants would have to demonstrate considerable advantages to overcome this handicap. Intrinsically safe small reactors are totally unrealistic — a figment of the imagination based on the slogan "small is beautiful", which has never been verified in the nuclear sector and was discarded everywhere else a long time ago. Designed on paper, they will not win over the public but they may well weaken the trust placed in other reactor systems.

Pressurised Water Reactors (PWRs) account for two-thirds of the nuclear reactors worldwide. Almost all French nuclear power plants are equipped with PWRs, like the St. Alban power station shown here.
This does not mean to say that technology will remain rigidly entrenched in the current thinking. Many advances are possible which are being investigated now and will be applied in due course when the necessary tests to demonstrate technical and economic reliability are completed. In addition to improved equipment, the optimisation of nuclear fuel should be the primary goal of these advances: improved assemblies, better core management methods, longer periods of use between refuelling operations with higher enrichment levels, consumption of plutonium in the form of plutonium oxide mixed with uranium, use of reprocessed uranium. Core design might even be modified. No change of reactor systems is envisaged but advantage may be taken of the undermoderation properties of pressurised water reactors, and the relative shares of water and neutron absorber may even be modified during fuel cycles to briefly encourage the formation of plutonium, which could then be consumed without extraction through fuel reprocessing. Devised almost 30 years ago, this technique might advance, provided the savings in raw material uranium compensate for the cost of additional technological requirements. Through such improvements, uranium resources could be used more effectively, thus reducing the cost of nuclear electricity.

**WORLD NUCLEAR POWER PLANT SITUATIONS**

*as of 1st January 1988*  
(Source ELECNUC)

<table>
<thead>
<tr>
<th>Reactor System</th>
<th>Installed Reactors</th>
<th>Reactors under construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Capacity GWe</td>
</tr>
<tr>
<td>PWR including VVER</td>
<td>255</td>
<td>185</td>
</tr>
<tr>
<td>BWR</td>
<td>86</td>
<td>70</td>
</tr>
<tr>
<td>Total LWR</td>
<td>311</td>
<td>255</td>
</tr>
<tr>
<td>Total all reactor systems</td>
<td>422</td>
<td>304</td>
</tr>
</tbody>
</table>

The reactor of the future, due by the middle of the next century, is still the sodium-cooled fast breeder reactor. Current low energy prices and cheap uranium resources have, for the present, postponed the development of these reactors. I feel the main uncertainty is not whether they will be adopted in future but when and how fast they will replace other systems. Demonstrating the technical and economic qualities of a new reactor system is a lengthy challenge, and all major nuclear countries therefore acted wisely in starting to develop fast breeder reactors a few years ago. We must continue our efforts to meet the challenge of the next century. What is at stake is too extensive for one country alone to handle. Several European countries have worked together to build the demonstration reactor Superphenix. This joint work must be pursued to the final stages in terms of R&D as well as defining a European fast breeder project to be launched during the next decade. Japan, the USSR and the United States are working along the same lines. Perhaps one day, all countries will pool their efforts, making fast breeder technology truly international so as to meet worldwide needs and ambitions.

Disenchantment in the wake of Chernobyl and lower oil prices should not put us off. We are merely on the brink of nuclear reactor development. Although now faced with paralysing opposition in many countries, those who generate electricity must not give up. Through optimum operation of their power plants, they must demonstrate that nuclear technology is reliable and safe and convince public opinion that this development must be pursued. Furthermore, there is no other way to overcome the inescapable shortage of low-cost energy sources and of abating worldwide pollution. To give up now would be a mistake and would also harm our descendants. Tomorrow, belief in the future of the use of nuclear energy for civilian purposes and its role in electricity generation will be self-evident, but today it is vital.
Can International Co-operation Play a Major Role in the Development of Nuclear Energy?

Pierre Strohl

From the outset, international co-operation has been instrumental in the development of nuclear energy. The international organisations set up 30 years ago to promote the growth of this new technology are still active to this day. Governments entrust them with important tasks and, regardless of their own views on the share of nuclear electricity generation in energy policy, all countries acknowledge that co-operation is essential and must be further strengthened. While the future role of international co-operation in nuclear energy development is therefore hardly called into question, its conditions and content have considerably evolved over the years. Constant adjustment is needed as nuclear programmes evolve in order to meet current and longer term requirements of governments.

In the nuclear field, international co-operation began in a climate of optimism based on the expectation of rapid growth in nuclear technology in industrial countries, seemingly essential for meeting energy supplies. European countries were also aware that the first stage in nuclear research and development could only succeed if they pooled the technical, human and financial resources at their disposal. Consequently, the main objective of the European Nuclear Energy Agency* was to set up joint enterprises for constructing different reactor prototypes and experimental fuel cycle facilities. Euratom’s objective was “to establish the conditions necessary to the formation and growth of the nuclear industries” in the European Community. The establishment of the International Atomic Energy Agency (AIEA) reflected not only the decision to set up an international system for monitoring the peaceful uses of nuclear energy but also the desire to share this technology with developing countries.

In fact, contrary to expectations, industrialisation did not proceed very quickly, and, in any case, nuclear electricity generation was not urgently required to meet energy needs. Multilateral co-operation did not therefore give the expected impetus to the direction and progress of research and development. On the other hand, it enabled a larger number of countries to take advantage of the results of this work. During the industrialisation stage, the direct contribution to technological development by international organisations gradually diminished and was replaced by industrial co-operation, often conducted through bilateral agreements.

Later, environmental policies caused international organisations to look more closely at their activities in reactor safety, radiation protection, radioactive waste management and regulation. The Three Mile Island and Chernobyl accidents and the concern shown by the general public about radioactive waste disposal reinforced this tendency. These problems now figure prominently in their programmes. This turn of events and the hardening of policies concerning the non-proliferation of atomic weapons reflect a marked reversal in international co-operation priorities, the emphasis now being placed on controlling nuclear energy risks rather than promoting nuclear development. Are intergovernmental nuclear organisations thus relegated to the role of policing nuclear energy?

This question calls for several important comments concerning the future. Although the international organisations we have just mentioned were set up in order to promote nuclear development, right from the start they were also responsible for contributing to radiation protection and accident prevention. In the 1960s, they drew up radiation protection standards, organised co-operation between those responsible for nuclear safety and paved the way for the harmonization of regulations. At the national level, nuclear activities were regulated by very strict licensing and control systems before the first reactors even began to operate. In fact, the very existence of specific risks connected with the use of radioactive substances and fission energy facilitated the drafting and implementation of special regulations. In short, requirements concerning the protection of public health and the environment against radiation and radioactive contamination had to be incorporated into the nuclear development process as a prior condition for this development.

This is, no doubt, why the recommendations of the recent report on the World Commission on Environment and Development (Brundtland report), which concern the problems to be solved in the nuclear energy field, do not propose any radically new objectives for the current programmes, whether at the national or international level. More generally, the approach followed in the implementation of nuclear programmes seems to be in line with the concept, proposed in the report, of “sustainable development”, i.e. taking into account long-term requirements to preserve the environment and natural resources for future generations. The very low level of pollution by nuclear installations, the methods used for the disposal of long-lived radioactive waste and the fast breeder reactor projects provide concrete examples of this concept.

Mr. Pierre Strohl is the Deputy Director General of the NEA.

* In 1972, it became the OECD Nuclear Energy Agency when non-European countries joined.
One of the virtues of international organisations is precisely that their action leads to concomitant progress in industrial development and in safety and radiation protection standards through continuous exchange of experience, especially that concerning any inadequacies or errors in the application of quality criteria. In this context, both for countries with nuclear electricity programmes and for the others, international co-operation therefore represents an acknowledgement of the fact that priority must be given to the search for a high level of safety and of the obligations to this effect between States.

As with most other industrial sectors, the future of the nuclear industry will depend on its ability to continue to integrate scientific and technological advances. For instance, technological innovations are likely to play a major role during the next few decades in the viability and competitiveness of the different energy sources. In this connection, the nuclear industry may have a leading edge precisely because international co-operation is well-established in this field. It should also be noted that technological advances relating to proven reactors, advanced reactor systems, small reactors or fuel cycle installations cover both industrial performance and safety. In other words, international nuclear organisations must monitor technological development very closely in order to propose co-operation programmes enabling their Member countries to take advantage of the progress made under the best possible conditions. This is the approach to be followed at the OECD Nuclear Energy Agency which groups industrialised countries producing over 80 per cent of the world nuclear electricity output, including those with the most advanced programmes. The progress of technology in the OECD area will therefore have a marked impact on the nuclear industry's growth potential, even outside the OECD area. Furthermore, the role which NEA might play in the current system of nuclear co-operation alongside the universal vocation of IAEA and the policies pursued within the European Community can be seen more clearly.

While emphasizing the expected advantages of co-operation programmes in technological development, it must nevertheless be borne in mind that national energy policies differ as to the future contribution of nuclear energy and at the same time, that priority given to environmental protection is shared by all countries. The outlook for co-operation will depend on whether it is possible to maintain a harmonious balance between the requirements and objectives of participating countries. This is particularly difficult to achieve at a time when national policies for the development of nuclear energy are being pursued in different, or at any rate uncertain, directions.

It is definitely not up to international organisations to decide for each country its prospects for nuclear growth. However, on the basis of current decisions and national projects, it is likely that nuclear electricity programmes will move forward or be maintained in quite a few countries, especially those with more advanced programmes. Outside OECD and Eastern Europe, nuclear energy is likely to grow in several new industrialised countries. Finally, many

The Halden Reactor, one of the earliest NEA international projects, focusses today on nuclear fuel performance analysis and man-machine communications systems.
developing countries continue to take an interest in nuclear technology. With an economic outlook of long-lasting expansion, any energy strategy based on the assumption of a general decline of the nuclear industry is therefore highly likely to be misguided. Accordingly, an unduly conservative attitude to nuclear technology and regulation would not be suitable for meeting the requirements of modernisation and quality in power plants already planned. It would no doubt also have a negative impact on international co-operation.

The essential priority in international co-operation during the next few years will be the promotion of improvement at all levels: technological innovations to increase economic performance, practices and procedures facilitating operational reliability and safety, regulatory policy, obligations of operators and governments in the event of an accident, etc. Such an approach would eliminate the often false contraposition of international activities connected with technological development against those aimed at controlling the nuclear risk. Studies, research and development projects and negotiations to be undertaken by international organisations should be directed towards the pursuit of the progress likely to be jointly achieved, and this would be in the best interest of all countries, regardless of their own policies. This interest is easy to define and, indeed, extends beyond the nuclear field: have available diversified energy production sources which ensure long-term environmental protection, are economically competitive, and guarantee the security of supplies.