Nuclear Communications: A Handbook for Guiding Good Communications Practices at Nuclear Fuel Cycle Facilities

INTERNATIONAL ATOMIC ENERGY AGENCY

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NUCLEAR COMMUNICATIONS:
A HANDBOOK FOR GUIDING GOOD
COMMUNICATION PRACTICES AT
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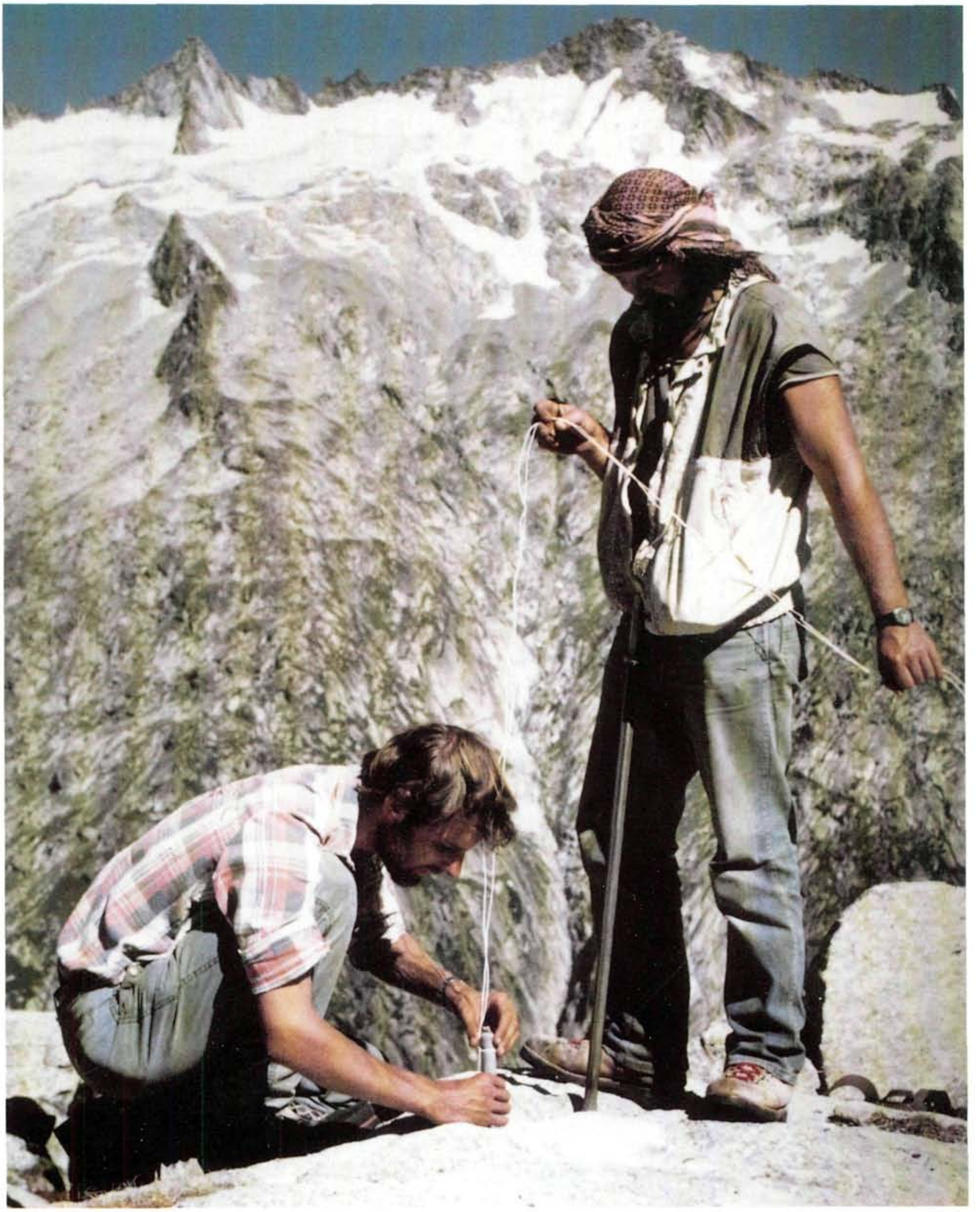
Introduction

This handbook is intended to serve as a guideline in applying good communications practices concerning nuclear fuel cycle facilities. It is based on the premise that communications programmes are as significant and as essential as environmental protection and safety programmes, and should be a major component of day-to-day plant management.

The handbook is designed not only to help in the development, implementation and evaluation of communications initiatives, but also to provide a compact source of information for people involved in plant operation and management. Although it was compiled in order to encourage and facilitate self-reliance, it is also intended to foster a sense of community and to promote the spirit of co-operation and sharing.

The material in this handbook is a composite of the deliberations of a group of technical and communication experts. *(See Appendix III.)* The purpose of the handbook is two-fold: firstly, to identify and address the questions that members of the public may have about different aspects of the nuclear fuel cycle and secondly, to provide some guidelines which may help those who operate nuclear fuel cycle facilities in responding to these questions. The guidelines are by no means comprehensive, since there is no global formula which can be applied to all nations, regions, or localities. There is no universal panacea which transcends all the historical, cultural, sociological, economic and political differences and nuances amongst the various sectors of society. But the contributors believe that at least some of their suggestions and recommendations can be either adopted or adapted by those who must address questions about the nuclear fuel cycle.

Energy, Society and the Environment



Geological investigation in the Swiss Alps. *(Credit: Nagra)*

Electricity Supply and Demand

The economic development of any nation largely depends on how its energy requirements are satisfied. Fuel and power are crucial for scientific and technological progress. As a matter of fact, *per capita* fuel and energy consumption (in particular that of electric power) is one of the basic indicators of this progress. Society's well-being itself hinges on power engineering and energy consumption. For the majority of the world's population the quality of human life is directly related to the level of *per capita* energy availability.

Energy production based on any known technology results in some harm to the environment and to human health. Therefore, the choices between energy sources can be made only on the basis of their comparative risks and benefits, their accessibility and their effectiveness.

A distinction must be made between primary and secondary energy requirements. Primary energy is the energy that is produced and consumed in the form of its natural resources, such as wood, coal, oil, natural gas, wind, natural uranium, solar energy, etc. Secondary energy is produced by converting primary energy into forms convenient for direct use by or distribution to consumers. Electricity and gasoline are examples.

Effective measures for energy conservation adopted in many countries in the mid-1970s to the early 1980s contributed to stabilization of primary energy consumption in most industrialized nations. Nevertheless, electricity consumption has increased even in these countries. This will probably continue since electricity is the most convenient and efficient form of energy delivery. *(See Figure 1.)*

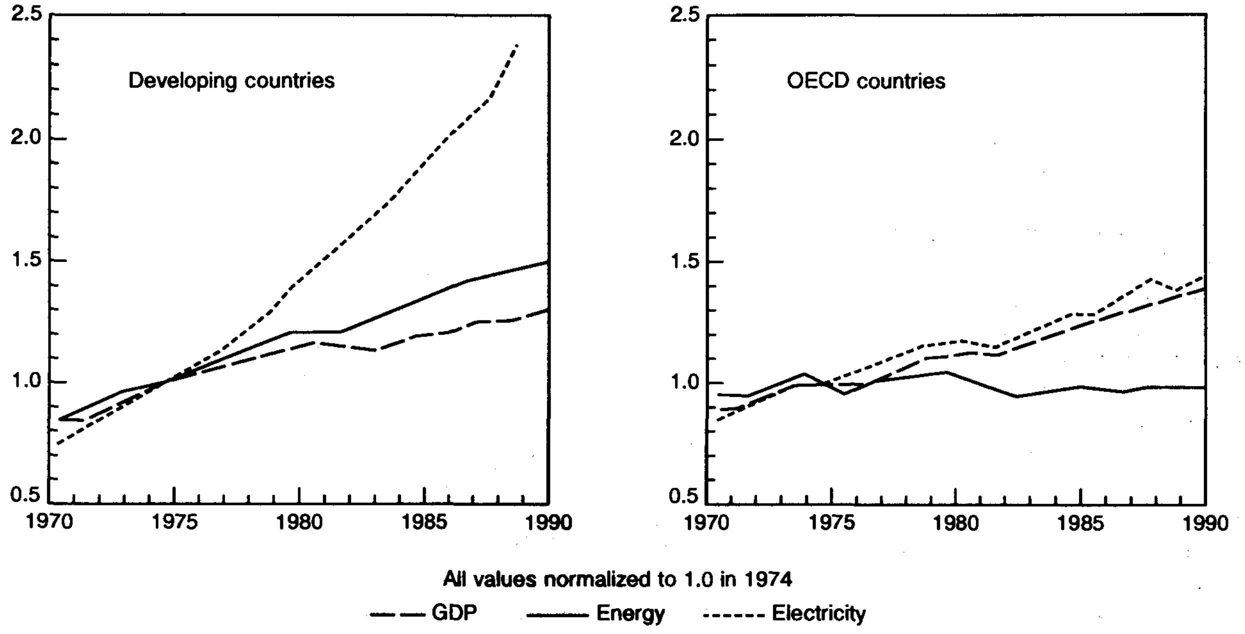
At present energy production and consumption are distributed very unevenly between various countries of the world. About 80% of total world energy is produced and consumed in industrially developed countries with less than 30% of the world population. However, 90% of world population growth in the coming decades is projected to take place in developing countries. These two realities of the modern world, together with the necessity of levelling the differences in the quality of life of the world's population, will lead to new demands for both primary and secondary energy. Therefore all available energy resources will be required and the mix must ensure sustainable development and environmental protection.

When assessing the consequences of using any energy source for human health and the social and physical environment, it is necessary to consider it's "fuel cycle" as a whole: raw material extraction, transportation and processing, the energy generation process itself, and management of the wastes that are produced at all stages of the cycle.

The assessment parameters should include:

- the quantity of fuel to be mined and transported to produce a given amount of electricity;
- the quantity and types of contaminants produced and released into the environment;
- the effects upon workers and the population as a whole;
- types, quantity and toxicity of wastes to be disposed;
- the safety level and the probability of accidents

***Figure 1.* Trends in Gross Domestic Product and in Energy and Electricity Production, 1970-90**



with severe consequences, both immediate and delayed;
- the scale of transport requirements;
- the availability and efficiency of resource use; and
- economic and social considerations.

At present the available energy resources are fossil fuels; nuclear power; and renewable sources including hydro, tidal, biomass, geothermal, solar and wind power. They all have characteristics which affect human health and the natural and social environments.

The use of renewable energy sources, with the exception of hydropower is developing slowly, partly because of their non-uniform geographic distribution, low energy concentration and interruptible nature. For example, in Central Europe the average solar radiation energy on the earth surface is 160 watts per square metre in clear sunny weather for about 2200 hours per year. At the present technological state-of-the-art, a surface area of about 90 square kilometres is required to construct mirrors for a solar plant producing 1000 megawatts of electricity.

Very high capital investments are needed for construction of power plants based on renewable energy sources. Until investments can be decreased and new methods of collecting primary energy developed, we can hardly expect that renewable sources will become ecologically suitable to satisfy the energy requirements of densely populated areas.

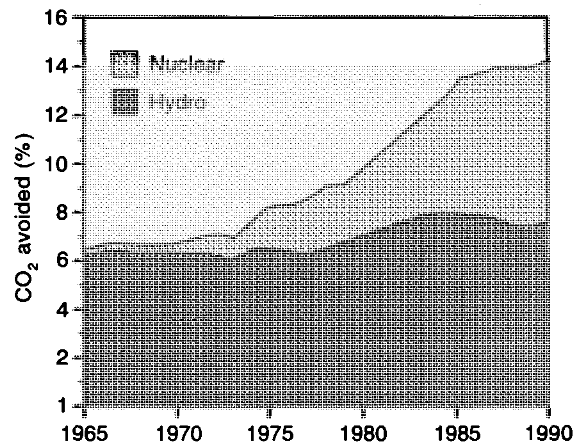
There are few available hydro resources left. Additional hydropower development is limited to geographic regions suitable for creation of large water reservoirs. Such reservoirs can create a lot of damage to the environment, including flooding large land areas and changing regional climatic conditions. In addition, there is a danger of a severe accident as a result of a dam break.

In the early 1990s, the share of hydropower in the total world primary energy production was about 5%. The share of the other renewable sources was smaller. Even asssuming that the use of renewable sources will grow in the near futture, their share of primary energy is not predicted to exceed 6 % in the first decade of the 21st century.

Oil is a convenient energy source and has been the main source of primary energy in many countries. However, there is a clear tendency to limit the use of oil for electricity generation since its supply is limited and it is necessary to conserve it as raw material for the chemical industry and for liquid motor fuel production.

The potential effects of oil extraction, transportation and utilization include leaks of oil from tankers and ocean oil rigs, atmospheric releases of oil residues, sulphur compounds and other impurities, occupational disabilities and fatalities during production, storage and transportation, and accidents caused by fires at oil storage facilities and refineries.

Figure 2. **Percentages of CO_2 Avoided Globally by the Use of Nuclear Energy and Hydropower**



The world resources of natural gas are rather large. However, making it economically available in the regions of consumption is often a problem. Gas transportation using pipelines requires high capital investments and large energy consumption for pumping. In the Commonwealth of Independent States (CIS), the amount of electricity required to pump gas from Siberia is equivalent to the CIS supply of electricity from nuclear power stations, which is about 12% of its total energy production. Just like oil, natural gas is a good chemical and energy raw material and its large-scale burning to produce electricity and heat curtails its other useful applications.

Natural gas can be much less environmentally damaging than oil, but only if significant leakage from pipelines is prevented (since methane is about four times more effective as a greenhouse gas than carbon dioxide). There are also ecological risks from its extraction and accident risks from extraction and transport.

Coal is the only organic fuel whose resources can ensure large-scale availability of electricity in the future. However, its utilization leads to potentially serious ecological and health consequences. They include:

- occupational risk of underground coal-mining;
- hydrological and surface changes related to opencast mining;
- combustion product releases to the atmosphere;
- atmospheric emissions of fly ash, sulphur dioxide, toxic metals, organic carcinogenic substances, and radioactivity.

At present the share of organic fuel (coal, oil, gas, wood, biomass)) in the world's total primary energy consumption ranges from 82% in Western Europe to 97% in Africa and the Middle East. Due to large requirements for liquid motor fuel, the share of oil and gas in the total consumption of primary energy is more than two-thirds in most industrialized

Box 1. **Wastes from Nuclear and Coal-Fired Electricity Generating Plants**

A 1000-megawatt electricity plant operating with a load factor of 75% will produce 6.6 terawatt-hours of electricity per year, which is approximately the electricity demand of Paris.

NUCLEAR PLANT
Annual waste production

- High level waste: 27 tonnes of spent fuel; if reprocessed and vitrified, about 3 cubic metres
- Intermediate level waste: 310 tonnes
- Low-level waste: 460 tonnes
- Some low-level radioactive gases from stacks are without public health significance.
- Tailings from uranium mines and ore processing plants are smaller in volume than corresponding coal mine tailings, per unit of electricity produced.
-

COAL-FIRED PLANT
Annual waste production

- CO_2: 6.5 million tonnes
- SO_2: 44 000 tonnes
- NO_x: 22 000 tonnes
- Ashes: 320 000 tonnes, containing about 400 tonnes of toxic heavy metals such as arsenic, cadmium, mercury and lead

countries. Most industrially developed countries have been making efforts to change the balance of their energy consumption. They are mainly doing this in order to decrease oil and gas consumption for heat and electricity generation and to conserve their resources for non-power applications and motor fuel production. However, some countries have recently been moving towards increased use of gas for electricity generation, because of its short-term economic advantages and the widespread perception that it is environmentally benign.

It should also be noted that the use of any fossil fuel raises an ecological problem that cannot be solved by any cleaning technology. Atmospheric releases of CO_2, which is a combustion product, result in the so-called greenhouse effect that at present is of particular concern since it will affect the global climate. This problem can be solved only by limiting the use of fossil fuel. *(See Figure 2.)*

At present nuclear power is the only alternative to coal for large-scale electricity generation for the majority of regions of the world. Its economic competitiveness has been demonstrated by the experience of many countries.

Inherent features of nuclear fuel are its very high energy content and absence of combustion processes. These features give nuclear power certain economic and environmental advantages. The high energy content leads to a large decrease in the fuel quantity to be extracted, processed and transported, as well as in the amounts of harmful emissions and wastes in the whole cycle. For example a 1000-MWe pressurized water reactor requires annually about 30 tonnes of nuclear fuel, whereas daily requirements of a coal plant of the same power level are more than 10 000 tonnes of coal. Since there is no combustion during electricity generation at a nuclear power plant, there are no CO_2, SO_2, or NO_x emissions. A 1000-MWe nuclear plant also needs only a small construction site of about 30 hectares. *(See Box 1.)*

Even though the gases emitted from coal-fired stations contain more radioactivity during normal operation than nuclear power plants emit, the emission of radiation from nuclear stations after an accident is the major source of public fear of nuclear energy. During normal operation, the radiation introduced by nuclear plants into the environment is only a small fraction of the radiation from natural sources.

Nuclear Energy and its Fuel Cycle

The public's concern over the environmental impact of the nuclear fuel cycle is a deterrent to the relaunching of nuclear power programmes. The worry is not so much about normal plant operations but rather with abnormal situations. There are also concerns about reprocessing, waste management, the economics of the fuel cycle, and the costs of the back end of the fuel cycle, including decommissioning of facilities.

Every human and especially every industrial activity has its effects on and implications for the environment. Such effects and implications result from use of land and encroachment on landscape through artificial structures and buildings; from the use of natural resources such as water; from the production of gaseous and liquid effluents and solid wastes, requiring on-site or off-site disposal; and from the potential release under normal and abnormal operating conditions of hazardous materials. Furthermore, the environment in a socio-political sense is affected by industrial activities through movements and changes of population and the resulting impact on the social and cultural structure, as well as the quality-of-life standards of affected regions, through disturbance by all kinds of traffic and by noise. Last but not least, an important environmental effect is the individual's coming to terms with real or perceived risk resulting from industrial activities.

In balancing benefits and risks, it is virtually meaningless to discuss one source of industrial activity or, in the context of this handbook, one source of energy in isolation. The important question is how does it compare with alternatives. Discussion must aim at helping to choose between available options for an optimal energy mix. Comparison of the economic and especially the environmental aspects of the different options is needed.

Scope and size. One great advantage of nuclear over organic fuels arises from the very high energy density of the fissile atoms and, consequently, the very much smaller quantities of material that are involved in generating the same amount of energy.

Although the number of technical steps needed to produce fuel assemblies and to manage the spent fuel after its use in a reactor is greater and the individual steps more complex than for other fuels, smaller quantities of fuel mean less use of land and resources, less transport, and a very limited number of fuel cycle facilities. There is therefore a considerably reduced risk potential, and much smaller quantities of waste, allowing for unusually high standards in its collection, treatment and disposal relative to the risks from it.

The concentration of fuel cycle activities within a few facilities for each step of the cycle is generally known for such techniques as uranium enrichment or spent fuel reprocessing. Indeed, the worldwide requirements for enriching uranium-235 for light-water reactors is covered at present by only eight plants of industrial scale. Similarly a single reprocessing complex, such as that of La Hague in France, can recover uranium and plutonium from the spent fuel of nuclear power plants with a total capacity of nearly 60 gigawatts (GW), which corresponds to about 20% of the world's total nuclear generating capacity. Much less known is the fact that the uranium mining and milling industry is quite small in terms of total amounts of material moved and in total requirements for manpower, land and resources. The annual quantity of uranium concentrate produced during recent years was extracted from about 80 million tonnes of ore, which is comparable to the material moved by one of the large copper or iron ore mines in the world. The worldwide facilities for fabricating fuel assemblies are larger in number but are relatively small workshops when compared with conventional chemical or mechanical plants.

Thus, the scope and size of an industry can be important measures of its impact on the environment in terms of use of land and resources, transport, demand for labour and the resulting social consequences, as well as in terms of the quantity of effluents and wastes produced. In this respect, the nuclear fuel cycle activities are compatible with the global needs for environmental protection.

Radioactive wastes. However, the impact of nuclear fuel cycle industries on the environment must be judged not only by quantities and size. Special consideration must also be given to the potential consequences of the radioactivity of the material to be processed in the various steps of the cycle. This produces ionizing radiation which, directly or indirectly, changes the electric charges of atoms or molecules and therefore their chemical properties. This might have a significant effect on biological processes and can in certain circumstances damage living organisms. This feature of the nuclear fuel cycle is unique in comparison with other fuel cycles.

These consequences must be guarded against by careful management of nuclear waste to ensure that it is safely contained and properly disposed of, and by prevention of the accidental release of radionuclides, for example because of leakages, breaks in containment or failures of filtering systems, or as a result of fission caused by uncontrolled accumulation of fissile material.

In normal circumstances, the discharge of radiation from nuclear fuel cycle facilities is a small fraction of natural background radiation. The magnitude of the effects of radioactive contamination from uncontrolled dispersion of radionuclides into the environment on people, animals and plants depends on the amount of radioactive substances discharged, as well as the kinds of radionuclides involved. In considering these effects, it is useful to discuss the biological basis on which such impacts are evaluated and the fundamental principles on which appropriate protection measures can be based. From what is known about the physical and chemical properties of radionuclides from their release to the environment through to an observed effect in humans, it is possible to estimate the radiation dose, from both internal and external exposure, and to assess the biological consequences appearing either in the exposed individuals (somatic effects) or their progeny (genetic effects).

In designing and operating nuclear fuel cycle facilities, first priority is given to protection of plant workers, the public and the environment against radiation. The philosophy of radiation protection as laid down by the International Commission on Radiological Protection (ICRP) is based on the following principles, which are strictly applied to nuclear fuel cycle facilities:

- that each source of exposure to radiation be justified in relation to its benefits or those of any available alternative;
- that any necessary exposure be kept as low as reasonably achievable;
- that dose equivalents received do not exceed specific limits; and
- that allowance be made for future development.

Radioactive wastes and effluents are generated during the operation of nearly all nuclear fuel cycle facilities, and must be adequately minimized, contained and disposed of to prevent impacts from their radioactivity. They are highly variable in composition, volume and radioactivity level. In addition, the half-lives of the radionuclides contained vary greatly.

The appropriate treatment (also called conditioning) for wastes depends on the method chosen for their disposal. There are two basic kinds of disposal. One is known as DD — to dilute and disperse the waste in the atmosphere or in water in concentrations harmless to humans and the environment. This method is used, for instance, in combustion processes such as those in oil or coal-fired power plants. The other, known as CC, is to concentrate and confine the wastes, isolating them from the biosphere.

In the nuclear fuel cycle industry, the CC method is used for most of its waste management. The DD method is used only for cleaned waste waters and filtered off-gas which only have traces of radioactivity that are well below the permissible limits. Apart from its high degree of environmental friendliness, this method for nuclear wastes is practicable because only comparatively small amounts of waste arise.

Wastes from mining and milling operations contain only low concentrations of naturally occurring radioactive materials, but they are produced in large volumes (although much smaller than the volumes of waste from mining coal which would generate an equivalent amount of electricity) and are disposed of near the site of origin. The treatment of uranium mill tailings has attracted much interest recently. They contain the bulk of the radioactivity originally present in uranium ore. Special precautions are required to prevent or reduce the dispersion of radionuclides from such tailings, particularly the escape of radon gas into the atmosphere and the leaching of radium into ground and surface waters. Direct exposure of the public is limited through the use of buffer zones around tailing piles.

Wastes arising from uranium conversion, enrichment and fuel fabrication are small and contain only small amounts of naturally radioactive elements. The non-radioactive contaminants, such as fluorides, in the off-gas streams require more attention than the radioactive contaminants. They are of the same nature as contaminants in chemical plants.

Reprocessing and, once available at a technical scale, the conditioning of spent fuel for direct disposal, are the most sensitive parts of the nuclear fuel cycle with respect to waste generation and treatment. In a reprocessing plant, the requirement of safe confinement of the various kinds of waste is taken into account by conditioning the waste as follows:

- During reprocessing, more than 99% of the radioactivity contained in the spent fuel elements is retained in the highly active fission product solutions. These solutions are then concentrated, dried and calcinated in order finally, together with glass-formers, to be melted and thus become homogeneous glass. This melted glass is poured into stainless steel canisters to solidify, and the canisters are welded gas-tight after being cooled down.
- Process chemicals (including water) used in reprocessing are, as far as possible, reused. They have to be purged of radioactive impurities. Thereby, chemical precipitation or concentration gives rise to sludges and concentrates which together with used purification resins make up the medium activity waste. This is mixed with bitumen or concrete and placed into stainless steel containers.
- Medium activity wastes also include the metallic parts of the used fuel elements, such as hull pieces, grid spacers and head and foot pieces. After chopping and dissolution, they are washed and put into stainless steel containers.
- Low-level waste is made up of those items which become contaminated with radioactive substances during operation of a reprocessing plant and cannot be decontaminated and reused. In view of the different final disposal requirements, the wastes are categorized according to containers which hold more or less than 0.1 curie alpha activity per ton of packaged waste.

For many non-radioactive wastes, comprehensive protective measures have often been imposed only after the dangers have first occurred. In contrast, for radioactive wastes there has been established from the very start a comprehensive system of listing, collecting, treating and disposing.

Release of radionuclides due to nuclear plant accidents is the principal other potential cause of environmental impacts from the nuclear fuel cycle industry. The potential risks from nuclear power reactors and the design and other measures to ensure their safety are described in many publications and documents of the IAEA.

The front-end of the nuclear fuel cycle from mining of the uranium ore to fuel assembly fabrication has a fairly low risk potential whereas the back-end with reprocessing, waste conditioning and related transport deserves more attention due to the content of highly active fission products in the spent fuel and wastes.

As large reprocessing plants can each cope with spent fuel from up to 30 large nuclear power plants, it is frequently assumed that risks attached to a reprocessing plant must be the greatest of all nuclear activities and that they must be greater than those of power reactors, as the most often discussed risk reference case.

This assumption is incorrect. The total radioactivity in a reprocessing plant of about 1000 tonnes per year capacity is roughly of the same order as that in a large power reactor. In a reprocessing plant the inventory of radioactivity is distributed among a number of building complexes with areas of several thousand square metres and is contained in a large number of individual containers and vessels. Furthermore, only about 2% to 4% of the total radioactivity occurs in liquid solutions whereas the bulk is safely stored in solid form either as fuel assemblies or solidified wastes at a reprocessing facility.

The decay heat of a 1300-MWe nuclear power plant requiring cooling after shutdown is around 370 MWth. That of a large reprocessing plant is less than 10% of this figure. The energy generation from irradiated materials in the process liquids of the various reprocessing steps is around 1/10 000 of that of a power reactor in operation. As a result, there is no need for most of the process equipment to be cooled. For the few coolant-related components, such as storage ponds for fuel assemblies and the storage tanks for fission product solutions, several ways are available for simple corrective measure.

Other factors to be considered are the temperatures and pressures during operation of a reprocessing plant. Nearly all reprocessing steps are performed at temperatures not exceeding 60°C. At such low temperatures no substantial evaporation and hence contamination can occur, even in the case of leakages. Components working at elevated temperatures, such as dissolvers and vitrification furnaces, have cooling and washing equipment so that low temperatures prevail immediately beyond the respective apparatus. Unlike a power reactor, which is designed to withstand high pressures, a reprocessing plant is operated throughout at atmospheric pressure or even under reduced pressures. Possible leakages within the hot cells of a reprocessing plant therefore do not lead to a breakdown of pipes and vessels. The plants are designed to retain any leaking material by a multi-barrier system of welded process equipment, cell lining and concrete cells.

During operation, a nuclear reactor is kept in a physical state called nuclear criticality. In contrast, reprocessing is performed in a safe sub-critical state. Several measures are available to guarantee subcriticality in a reprocessing plant, such as safe geometry of the equipment, safe concentrations of process material and the use of materials which prevent a chain reaction. Application of one or more of these measures guarantees that a nuclear chain reaction cannot occur in a reprocessing plant. Hypothetical calculations of the result of a chain reaction indicate that energy would only be released during a very short period and would be such that its effects could be retained within the operating cell. Any comparison with a reactor core meltdown is therefore unfounded.

In summary it can be stated that the potential risk from reprocessing plants is substantially lower than the already small risk from nuclear power plants.

Transport of radioactive wastes. For transport of radioactive materials, the basic rule is that consignments should be able to circulate with a minimum of special precautions en route, as is the case for other dangerous goods. The safety of transport should, as far as possible, not rest with the way in which the material is carried by the transport agent, but it should be built into the package itself. This reduces the risk of human errors and simplifies the procedures.

Regulations for the safe transport of radioactive materials were prepared by the IAEA and have now been widely adopted for international and national transport. They were prepared by nuclear specialists and engineers working with experts in the transport of dangerous goods with very wide experience of the sort of unexpected circumstances and accidents that can occur, and in close technical collaboration with the competent international transport organizations such as the Control Office for International Railways and the International Air Transport Association (IATA).

The main objectives of regulations for the safe transport of radioactive material are to:

- limit radiation doses for transport workers, handling workers and members of the general public to acceptable levels under normal conditions of transport;
- limit the risks from accidents to acceptable levels for transport workers, handling workers and members of the general public by limiting the activity content and specific activity of material in different transport packages and consignments;
- provide a uniform set of classification and test requirements for transport packages.

To achieve these aims the same general safety principles as in other activities of the fuel cycle apply: containment; limitation of surface contamination; reduction of external exposure of people through shielding and distance; and avoidance of criticality risks from fissile materials by restricting the amount of material in any one place, its geometric arrangement and the undesired interference of moderators. The required level of protection is attained by appropriate combination of these factors commensurate with the radiological hazards involved.

The Public Perspective

As for all industrial activities, nuclear fuel cycle activities have some impact on the environment and are not free of risks. However, compared to the environmental impacts and risks of other energy sources, nuclear energy comes off very favourably.

In the final analysis, public opinion will determine the fate of nuclear power. If the credibility gap between the industry and the public widens further, nuclear power has only a slim chance of survival, far less of development. Some countries have rejected or abandoned nuclear energy; some have expressed their intent to do so; some have put their plans on hold; some are ambivalent; a few have decided they have little or no alternative to nuclear power. In all cases there is a common denominator: varying degrees of public skepticism. This skepticism is based on several factors, including lack of understanding and knowledge about the availability and potential consequences of different energy sources, lack of trust in government and institutions, distaste for technology in general, fear of anything nuclear, and the spectre of Three Mile Island and Chernobyl. The nuclear debate is neither new nor unique. Much of it is a descendant of historical resistance to change and is part of a much larger social agenda. However, development of nuclear power has come at a time when public opinion is able to affect decision-making to a far greater extent than in the past. It is essential that this greater democratic power is accompanied by the public knowledge necessary for making informed and rational choices.

Despite the prevailing skepticism, there are indications that many people are beginning to re-examine their assumptions about nuclear power. In some countries opinion polls show increased public awareness of the need for additional nuclear capacity to meet growing electricity demand, and increasing reappraisal of nuclear electricity in the light of mounting concern over environmental pollution. From the environmental standpoint the nuclear option should look good, but it has its own environmental Achilles heel — the public perception that nothing can be done with the enduring nuclear wastes to render them harmless. In addition, opinion polls show that some people blame nuclear power for emission of greenhouse gases. Sensible choices cannot be made on the basis of this degree of misinformation. A perspective based on fear is a difficult issue to deal with. But we should not be afraid of fear. We can approach it with serenity, rationality and a careful, considered and consistent outlook. But to do so, we must first acknowledge the fear and talk openly about it. We must also talk about the risks as well as the benefits, recognizing that people have rational as well as irrational fears and respecting their value judgements. We must not promise more than we can deliver. And we must put a human face on nuclear energy.

The public perspective on nuclear energy is influenced by a number of factors:

- Lack of knowledge about risks, benefits and availability of energy sources.
- Alienation of much of the public from technology, from the experts, and from administrative and political systems. This alienation is compounded by the industry speaking to them in technical language that they do not understand. People find it hard to identify with or understand experts who speak a strange language, but can more readily identify with those who use their own concepts, terms, modes of expression and values.
- Perceptions of risk are strongly influenced by historic memory of past incidents, and factors that make the risk particularly memorable distort the perception of that risk. Probabilistic information is not easy to understand.
- People tend to overestimate the risks that are of dramatic or sensational origin, such as nuclear risks, and underestimate the more mundane and prevalent ones, such as road accidents.
- People oppose uncertainty and want to know "exactly what will happen", in order that their anxiety be reduced. People also tend to ignore evidence that contradicts their beliefs.
- The industry's own lack of sensitivity and credibility. The lack of sensitivity includes the need to realize that depersonalized technical information has little emotive impact. The industry has to make an effort to understand the public rather than to expect the public to make an effort to understand the industry. It should distinguish between value judgements and emotional responses. Credibility is impaired by impressions of secrecy and lack of transparency.
- Delayed responses in crisis situations, which create uncertainty and allow rumour to fill the information gap.
- Media that are sometimes biased, sometimes slipshod, and often prone to sensationalism. They tend to oversimplify, emphasize the dramatic aspects of conflict, and focus on disagreement between experts.
- A powerful, organized and dedicated anti-nuclear lobby which generates fear and exaggerates risk.

The overall public perspective on nuclear energy is predicated on a miscellany of perceptions, some positive but many negative. Public opinion polls in some countries indicate a strong recognition of the importance of nuclear power in the future and a realization of its environmental advantages vis-a-vis certain alternatives but at the same time there is a widespread misconception that nuclear power contributes to the greenhouse effect. In some countries and regions nuclear power has a positive image, particularly where there is concrete evidence that it provides reliable and economic electricity, and a high degree of energy independence.

The negative perceptions, however, are strong and pervasive. Among the factors that create nuclear phobia are:

- the fear of radiological hazards and accidents, and particularly the risk of longer-term health effects;
- the belief that nuclear facilities pollute the environment with non-radiological by-products and chemicals;
- the perception that work in a nuclear plant is dangerous and unhealthy, not only for the

employees but also for their families, particularly their children;

- the belief in the vulnerability of nuclear facilities to terrorism and sabotage;
- the mystique of plutonium, and the perception that this forms a direct link between the peaceful and the military applications of nuclear energy;
- the distrust of the secretive scientists, technocrats and large institutions that are thought to represent and symbolize the nuclear community;
- the belief that the risks outweigh the benefits and endanger future generations; and
- the feeling that, even if nuclear power is relatively safe and benign, it is nevertheless uneconomic and unnecessary.

The public fear over nuclear power is deep-rooted and derives from a wide spectrum of motivations and persuasive influences. Nuclear power, despite its environmental advantages, is regarded as part of the "environmental problem". Anxiety about the environment is not a fad. It is increasing every year, to the point where people are prepared to take personal responsibility for it rather than trust governments to protect it. Environmental activism has become mainstream, direct and vocal, and pressure groups are becoming widely recognized as legitimate voices in the environmental debate. It is in that evolving context that the public perspective on nuclear power must be assessed.

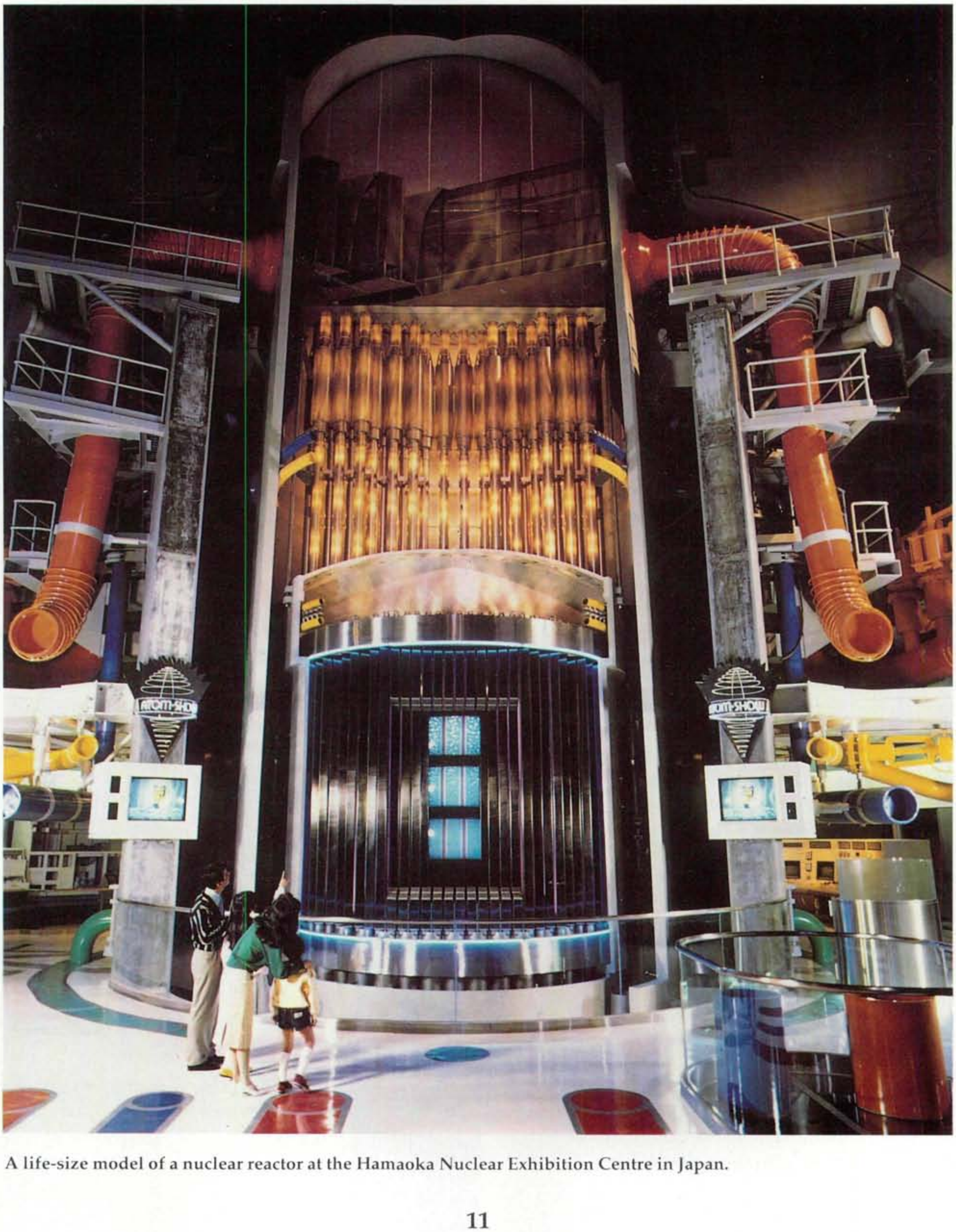
If nuclear energy implies mythical images, industry has some of its own adopted myths to contend with. One is that the "public" is a monolithic body over which you wave a magic wand called "information" and thereby you create awareness and everybody who suspected or hated you now trusts and adores you. It just isn't so. The steps from issue to concern to information to awareness to understanding to contemplating to acceptance are long and steep.

Public relations and public relationships are not synonymous. Building relationships requires more than good two-way communication. It requires understanding and acceptance of how others see things, respecting others' value judgements rather than labelling them as emotional in contrast to rational, balancing emotions with reason, negotiating persuasively without coercion, listening and consulting before decisions are taken, and acting reliably and predictably.

Accommodating public opinion is a necessity of democracy. If public trust is to be fostered, public concerns have to be addressed and answered. Therefore the nuclear industry must listen to its major client, the populace, learn what it wants, and respect its values and aspirations. Public consultation is pivotal to the success or failure of any project. Public consultation implies public participation in the decision-making process. A community has a vested interest in exercising some control over its own future and in assuming that its voice is heard and its opinions respected. Public participation not only allows a flow of two-way communication, but also protects all parties against surprises.

Inside the Sellafield Visitors Centre, United Kingdom. ***(Credit: BNFL)***

Public Communication and Participation



A life-size model of a nuclear reactor at the Hamaoka Nuclear Exhibition Centre in Japan.

Public Participation and Information Needs

Communication is the vital link between nuclear facilities and the public. If people do not know and understand the facts on which optimal energy choice decisions should be based, they cannot make informed decisions on how their own objectives can be met.

It is evident that the nature and extent of the role that the public plays in moulding nuclear policy varies from country to country. In some countries the public has a direct effect on the formulation of public policy. In others the input can be indirect, but not necessarily less influential. There is no question of choosing whether the public will be involved. As the demand for public participation grows, whether it is direct or indirect, the need for communication grows correspondingly. If it is true that citizens will play a significant role in determining the future of nuclear energy and other energy options, their information needs must be met. Information alone may not change opinion significantly, nor assuage all the concerns and fears of the public regarding nuclear power. However, lack of information or information of the wrong kind will on its own, or by allowing anti-nuclear groups to convince with biased and erroneous information, entrench public resistance and hostility which in turn will constrain the nuclear option.

"To know us is to love us" is not an acceptable principle of communication. Information is not a goal in itself, but an instrument for fulfilling other goals, such as affecting attitudes, positions and images. Not only must the public receive the information but they must see the information as credible and relevant to their thoughts and responses about an issue. It is a complex and arduous process.

While it must be recognized that the public has its information needs, it should also be recognized that the public is inundated with information overload and is therefore selective in its reception of information and its reaction to it. The nuclear community must therefore realize that information, like beauty, is in the eye of the beholder. It is useful only if it is responsive and relevant to the needs of the recipient and provided in terms of looking from outside the industry inwards, rather than the reverse.

This means listening to the public in order to know what information it wants and what its actual concerns are. It is not enough to address only what the industry thinks ought to be the public's concern or to provide information which is not central to its concern. For example, it is counter-productive to present and compare only the risks of immediate death when the main worry is long-term health effects. It is also necessary for the nuclear industry to respect and understand the public's value judgements and not to label them dismissively as "emotional factors". It is important to remember that public communication programmes are only part of a dialogue, but nevertheless an important part.

Public communication programmes are the principal currency for the industry to inform the public on issues of cost, benefit, need and risk. For each issue the information needs differ and this must be reflected in the industry's communication programmes. The nuclear community is frequently accused of secrecy and evasion, an allegation which must be avoided at all cost. The antidote is to be "open and honest" and to use communication which is early, simple, candid, consistent, accurate, factual, understandable, continuous, and credible. Communication involves listening as well as telling. It must reflect sensitivity to public needs and concerns, to evolving circumstances and to cultural nuances. It should be proactive rather than reactive, and should be an executive driven routine part of an organization or facility's operation. The language, tone and content are crucial. A valuable guideline to the transmittal of the story is the questions of the newspaper reporter — who? what? where? when? and why?

A clear communications policy is the key to credibility and credibility is earned, not created. It is based on perceptions which give rise to varying levels of confidence. It has been consistently found in opinion research that credibility is the single most powerful persuasive force. Trustworthiness and goodwill are two related, but somewhat different, factors of credibility and they cannot be achieved overnight, since they are not determined by events or issues but by a continuous and conscious process. The concept of credibility is closely tied to concerns for ethics, rationality, responsibility, professionalism and competence. At the end of the day it will be the prolonged absence of a serious accident in a nuclear facility that will make nuclear power acceptable. Without the tangible evidence, public relations and advertising alone cannot build public acceptance. The need therefore is not for information per se, but for genuine communication involving long-term education, sustained relationships, mutual respect, understanding and rapport with the cultural background against which a facility operates or seeks to operate.

The information needs of a nuclear facility may be local, regional or national. In addition there is an international dimension which demands a worldwide network that ensures rapid, consistent and accurate distribution of necessary information.

The audiences are numerous and include:

- Employees and their families
- Local communities
- Local officials/politicians
- Opinion formers, including community activists
- Local doctors, teachers, and other community leaders
- Local media

- Local organizations — women's groups, service clubs, church groups, etc.
- State/regional organizations
- National media
- National governments, politicians, trade unions
- Scientific and professional organizations
- National public
- International public, organizations and media

These groups are not homogeneous, either collectively or individually. They are diverse in interests, age groups, educational background and culture but tend to have two things in common — they want information and they want their opinions known and to have influence. However it must be recognized that information, no matter how desirable or sought after, is neither panacea nor placebo for improving public acceptance of nuclear energy. It is a long-term and difficult process involving complex intellectual issues.

The messages should be personalized whenever possible. They should be continuous and consistent and part of a regular programme of information release and distribution through all available delivery systems. Spokespeople should be trained in media and public presentation techniques. Nuclear news should be handled like any other news.

There is a wide range of channels through which information can be distributed. They include speeches and seminars; publications including brochures, newspapers, education packs, posters; film and video; advertising; letters either to individuals, large mailing lists or to newspapers; visitors centres and other exhibitions and displays; plant tours; meetings and presentations; video text, employee newsletters, etc.

It is important to remember that the media cannot singly or collectively answer all communication needs in all countries or in all circumstances. In many cases they are not affordable, even if otherwise feasible. Nuclear facilities would be well advised to consider which ones might fulfill their own and their publics' information needs. Used proactively rather than reactively, they can be invaluable in filling the information gap that separates the industry from the public.

Terminology

Clear, simple language communicates better than technical jargon, and information should be related to things with which the audience is familiar. A fundamental criterion of information in any communications programme is that it must be tuned to the antenna of the receiver. Some people can absorb it better when written, others when it is presented in pictures or pictograms. Some want detailed information; others prefer a broad, simple picture to detail. Information therefore must be honed to suit the recipient. Since most people think that 10-9 is bigger than 10-8, the nuclear industry has to take a giant leap in simplifying its technical vocabulary into language that is meaningful to the average person. It is not an easy task, but bridging the language gap is key to meeting the information needs. It is up to the provider of the information to do this, not the recipient.

While the professional should have all the data available to give if asked, very few numbers and, if possible, no unfamilar units should be used. It is not the exact numbers that it is important to communicate (although this is not an excuse for inaccuracy), it is the idea that an item is very big, very small, within a certain limit, or its size in relation to something else, that should be conveyed. Comparisons with appropriate familiar items communicate better than lists of numbers or technical data.

Probabilities are generally not understood. In using probabilities the nuclear community is trying to communicate that the relative risk is small in relation to the benefit. Discussion of how small a risk is, on its own without making comparisons, may communicate only that "this is risky". Making comparisons with the risks of other comparable activities communicates better that there are disadvantages to rejecting nuclear power. However, comparisons with unrelated activities such as cigarette smoking have little impact and are usually deemed irrelevant and irritating.

Technical jargon seldom conveys the intended message. If an aircraft manufacturer does not talk about triple redundancy to the public, why should a nuclear plant designer?

Words which have a technical meaning and are also in common use with a somewhat different meaning, particularly if that common meaning is negative or frightening or unsuitable, should not be used. Examples are: poison, cask, morgue, skeleton, coffin, (swimming) pools. These words do not communicate the appropriate message. The speaker and the listener both know the meaning of the word perfectly, but it has a different meaning for each. Another expression which is better avoided for a similar reason is "fast-breeder" which by analogy can be taken to mean very rapid (out of control) plutonium production.

Care may need to be taken with words which translate into misleading words in other languages, such as "spent" = "verbraucht" in German, which means "no further use", or "critical" = "kritisch", which in general usage means "dangerous".

The television reporter's criteria for selecting quotes or "sound bites" provide a good guideline for applying the KISS (keep it short and simple) principle.

A good quote is:

— ***Brief:*** Five to 20 seconds (the average TV clip is 9 seconds long). *"To sum it up, we're against it."*

— ***Self-contained:*** *"Not only is nuclear energy im-*

portant but it will play an increasingly important role in the future."

— Phrased in everyday language, not technical or bureacratic jargon: *"Let me put it this way; we're in the business to stay."*

— One that avoids using words that are in common use in a different, technical sense: *"The reactor went critical this morning."*

— Colourful or metaphorical: *"The key to unlocking the door to our energy future is nuclear power."*

Communication Programmes

The development of any communications programme entails a series of logical steps. The key ones are:

- opinion research;
- the development of a relevant communications programme with stated objectives;
- the implementation and management of that programme, choosing from a variety of options;
- establishing methods of evaluating the programme; and adaptation of the programme based on the feedback from the evaluation exercise, and by necessity as circumstances change.

An aide memoire for this sequence is ROPE: Research, Objectives, Programme, Evaluation.

Each of these stages will be examined in the following pages. In addition the particular needs of certain target audiences will be considered, for example employees, journalists, politicians and institutional organizations such as regulatory authorities.

Each step will be examined in some detail, but of necessity, a full description of these complex subjects is not possible. The intention is to give enough information to act as a guide to the development of a variety of communications programmes, and to act as a check list when developing a programme.

Opinion Research

Except for the dedicated traveller, there is little point embarking on a journey without first establishing why the journey is being made and when it is going to end. Opinion research should be the basis of any comunications programme, identifying the possible routes which can be taken, establishing the obstacles that might lie along the way, and helping to quantify the objectives of the communication exercise. Opinion research will help to evaluate the programme over time.

Though the need for opinion research seems obvious, many programmes have been developed in a variety of industries without the benefit of opinion research. While it is possible to produce an effective programme in this way, a successful programme is more likely to be developed if the opinions of the public are researched and known.

Many forms of opinion research can be considered, but all must be professionally designed and evaluated. It is important that the most appropriate form of research is used, and that a true measure of opinion is reflected in the research findings. The results of poorly designed research are worse than useless — they are invalid and misleading. Sometimes a combination of two or more research methodologies may be appropriate. This is particularly important where a number of different publics need to be considered. For example, the needs of a particularly important, albeit numerically small group such as key politicians or journalists, can be sought using one method of research, while the views of a much larger group, such as the general public, could be established using a different method.

Each situation will require a specific research programme, dependent upon the nature of the plant, the culture of the country or locality in which the plant is located, and the availability of professional opinion research facilities.

The following is intended to give a guide to the advantages and disadvantages of the major forms of opinion research.

Market research surveys can be divided into two broad categories:-

- ***Smaller scale, qualitative surveys*** — the technique is to use group discussions or in-depth individual interviews to assess, possibly in greater depth and in a less structured way, the views of the interviewees. The interpretation is more subjective than in quantitative surveys, but the results can be useful and valid.
- ***Large scale, quantified surveys*** — these involve interviewing large numbers of people (normally 1000 or more) to give a statistically valid sample. The interviewing may be in the interviewee's home or by street interviews, by telephone, or by postal questionnaires.

The format of the questionnaire can vary enormously, from a small number of questions with Yes/No/Don't Know answers, to complex multichoice or open-ended answers using various techniques of questionnaire design.

The selection of the type of research to be used will depend very much on the problem to be addressed, and the funds and time available. A major advantage of quantitative research, which must use a statistically valid sample to produce meaningful results, is that over a period of time, if the survey is repeated often enough, trends can be identified which are often more useful than a one-off result. Such surveys are particularly important during the evaluation stage of a communications programme, as well as in identifying the initial problems that need to be addressed.

Qualitative surveys are particularly useful in small sub-groups of the population, for example, journalists, politicians, opinion formers such as school teachers, where it is difficult to interview a large enough number of people to ensure a statistically valid survey, and where the responses of the interviewees may be more sophisticated than could be accommodated in a formal questionnaire.

These surveys are also useful in assessing particular aspects of a communications programme, such as individual advertisements, where pre-testing of the advertisements through small discussion groups (often called focus groups) is an established method of evaluation. Such pre-testing is particularly valid with sensitive subjects such as nuclear energy, where those developing the advertisements may be too close to the subject. This may result in the advertisement overlooking the real concerns of the wider public outside the industry, or using language that is not easily understood by the target audience. Testing the advertisement with a representative sample of the public can help to avoid costly and embarrassing mistakes, as well as helping to identify more appropriate methods of communication.

The sample. A vital consideration in any research exercise, whether quantitative or qualitative, is identifying the scope of the research in terms of the sample to be selected. This could be either in geographical terms, whether the sample should be chosen on a local, regional, national or even international basis, or in terms of socio-economic subgroups or special interest groups. Samples can be in such a way that while a statistically valid representation of the total population is obtained, the particular views of a special interest group can be "over-sampled", so as to assess the views of that particular group.

For many years socio-economic groups have been based on sub-divisions of the population according to earnings/education, such as A, B, C1, C2, D, E, where A's represent the top "echelon" of society and E's the unemployed and generally less influential sectors of society.

Surveys will invariably classify respondents by age and sex as well as socio-economic group. Attitudes towards nuclear energy often vary enormously according to age, sex, socio-economic group and other factors such as terminal education age/academic qualifications, and these will be important factors in the development of an effective communications programme. Some socio-economic classifications assign to women the classification of their husbands rather than their own; this is misleading.

With subjects such as nuclear energy a more sensitive method may be more appropriate. It is generally recognized that opinions about issues such as nuclear energy are less conditioned by an individual's income, but more by attitudes and lifestyle. A competent research company can give advice on which classification system is most appropriate, and indeed whether a particular research exercise could accommodate more than one form of classification. This is often necessary when the research infrastructure within a particular country is designed around a particular form of classification. For example, while a research survey may be conducted on the basis of an "attitudes and lifestyle" classification, it may still need to be related back to more traditional A-B-C1 classifications if, for example, these are the basis of national newspaper readership figures or TV viewing statistics.

The careful selection of the sample is even more important with numerically small groups such as journalists, politicians, etc. The influence of very small numbers with a particular viewpoint can cause a biased result in small-scale samples, and it is important that the selected sample is carefully screened to avoid distorting the survey results. It is generally unwise to have those with extreme views included in such a sample, particularly when group discussion techniques are used, as those with extreme views will influence the less committed and produce a distorted result.

Selection of survey company. The criteria for selecting an opinion research company depend very much on the use the research will be put to. Those research companies being considered for nuclear industry opinion research will need to be questioned closely on their abilities and experience in sensitive areas of research. Many research companies are capable of carrying out straightforward surveys, but the number able to cope with complex questionnaire construction and sampling is more limited. If it is planned to release the results of surveys in any way, it will be necessary to appoint a research company with an established reputation to give the research results the appropriate acceptance and authority.

In the field of qualitative surveys, the specialist companies are generally smaller, and the success of the survey will depend on the ability of an individual researcher who is able to maintain an objective, balanced view during group discussions and in-depth interviews. As such results are almost always for internal consumption, and used in planning, the reputation of the research organization matters less than in larger quantitative surveys which may be published.

During the selection process of a research company, particularly for larger quantitative surveys, it is normal to approach a number of specialist companies, perhaps three or four, since prices as well as the level of expertise can vary considerably. As the value of quantitative surveys increases over time after the completion of a number of surveys, thus establishing trends, the long term viability of a research company is an important consideration.

Questionnaire design. While the main responsibility for the design of a questionnaire will fall upon the market research company, a number of key factors have to be considered.

If the survey is to be repeated on a regular basis to establish trends, the questionnaire has to be robust enough to last over a period of years. Any change in questions, whether wording or the introduction of new or altered questions, will affect the validity of the trends.

It is unfortunately true that questionnaires can be designed to produce the right answers. It is equally true that this does not help in the development of an appropriate communications programme. The ideal view to take when designing the questionnaire is to think ahead to when the survey results are being analyzed, and assess how useful each question and its answers will be in helping to formulate an effective communications programme. Very often questionnaires seem to be designed in isolation, without thinking of the end result, and most of the questionnaire is taken up by answers which may be of passing interest, but which do not contribute to the overall solution of problems. The result is very often disappointment when the survey is completed. With the benefit of hindsight, those commissioning the survey wonder why they asked a particular question in the first place.

Planning ahead is particularly important if the survey is to be repeated, thereby establishing trends. If the key questions can be identified from the outset, this will produce a far more worthwhile survey.

In designing the questionnaire it is important to try and set the issue being researched in the context of other issues, ideally comparing with alternatives and other industries. Confronting members of the public with a particular set of questions creates an artificial situation as they may be being asked to address questions about which they may not be in the slightest concerned. The process of asking those questions will arouse concern and interest. It is therefore important that the questionnaire design establishes how important the issues are in the first place, by comparison with other social and industrial issues. There should also be a balance between prompted and unpromted answers, again to attempt to establish the real degree of concern amongst the sample. Indeed, it is worth considering a "Don't Care" option in the range of possible answers to the questionnaire as an alternative to "Don't Know" which many respondents are reluctant to select.

For example, it is often said that a relatively small proportion of the population is actively anti-nuclear, and an even smaller proportion is actively pro-nuclear. The size of these minorities will vary from country to country, and indeed from location to location within countries. However, a survey will indicate that a very large proportion of a sample is concerned and actively interested in nuclear matters, purely because the questions have been asked of those interviewed. This is clearly an artificial situation, and judgements have to be made as to the relative importance of different sectors of the population, their degree of concern, and the way in which they might respond to any future communications programme. To some extent, a well thought out questionnaire will establish an accurate view of the true level of concern.

Survey analysis. The analysis of any survey will be conditioned by the type of survey selected. Normally, with a large scale quantitative survey, the research company will provide a basic analysis. However, invariably it is advisable for the commissioning organization to examine the data very carefully, as a whole host of clues to the development of a future communications programme can merge from a detailed examination of the survey data. Very often it will be one or two key questions which provide the routes to be followed in the development of a future communications strategy.

With smaller qualitative surveys, involving group discussions etc, the responsibility for analyzing the survey rests heavily upon the researcher who has conducted the group interviews. The commissioning company will need to question the researcher closely to get further information.

There are of course two directions from which research can be examined:

- To assess the research to try and establish, in a logical manner, an appropriate communications programme.
- Alternatively, it is very often the case that a communications programme is already in existence, or ideas for a new communications programme have been formulated, and the research is being used to check the validity of these programmes. Both approaches are valid ways of using research.

Few organizations live in a perfect world where communications can be developed as an entirely logical process, and it must always be remembered that research is there to *help* develop a relevant communications programme. Intuition and experience are important aspects which should never be overlooked.

Publication of market research results. Whether to publish the results or not is a question that should be asked at the outset, checking with the selected market research company and ensuring that publication is within the market research code of practice in any particular country. It should be remembered that it is unwise to publish selectively. In other words, to publish the results which suit an organization, and ignore those that don't, is full of danger. Most responsible market research companies are rightly jealous of their reputation and integrity, and will insist on seeing how results are to be published to ensure they are a fair reflection of the whole survey.

Very often, however, market research surveys are intended purely as management tools and therefore the question of publication does not arise. However, even if the results are not to be published, an organization should consider how to answer questions about the survey from journalists and other interested parties.

Programme Development

The development of a communications programme will depend upon a number of key factors:

The Issues. These will have been identified or confirmed through opinion research, through newspaper and TV reports, the activities of pressure groups or local organizations, as well as the knowledge and intuition of those developing the communications programme. There may be one key issue, or there may be a series of issues that need to be addressed. The issues may also need to be prioritized, or dealt with in a particular order. It may be concluded, following analysis, that some issues can be profitably addressed by a communications programme. Others may be so difficult to address that consideration should be given to a change of policy so that the issue is avoided or has less impact. In an industry such as nuclear power, where public opinion is a major factor, it is important that trivial issues are not allowed to escalate into crisis dimension. An analysis of the impact of particular operations or developments on public opinion may help to avoid a particular policy ever being followed that would create a major issue.

Resources. The form of a communications programme is dictated by the resources that are available or could be made available. However, if the issues to be addressed are of importance and are capable of being resolved or modified, arguing the need for the appropriate level of resources may the most important part of the development of a communications programme. For example, if public hostility to a particular plant is likely to result in its closure if that hostility cannot be reduced, there is little point spending large sums of money on the development of new manufacturing/processing facilities, while giving few resources to a communications programme which might be the only way of reducing the hostility. Very often in the nuclear industry the impact of public opinion is overlooked, is not correctly assessed, or is not taken seriously enough, and as a result the resources made available for communication or public relations are far smaller than should be the case.

The Target Audience. The size and composition of the target audience for any communications programme will be determined by a combination of research, intuition and experience, the level of public awareness at the time the communications programme is being developed, and the location and type of facility in question.

The programme should take into account possible changes in target audience. These can occur because of changing circumstances, the ever-changing nature of public opinion, the activities of pressure groups, and a whole host of other factors. For example the requirement for public information programmes at all nuclear plants was changed significantly by the Chernobyl accident. Equally the changing level of public awareness resulting from the growth of the environmental movement has had an impact on the development of all communications programmes. The greater openness in society in many countries also has an impact upon nuclear plants and their relationship with the public. The activities of anti-nuclear organizations, either locally or globally, can also have an impact on particular facilities.

It has to be recognized that the target audiences are likely to be constantly changing, and any programme should be flexible enough to cope with this fact.

Target audiences can range from the general public as a whole within a country, or in particular circumstances across national boundaries; all the local population within a defined area; particular sectors of the population defined by socio-economic or attitudinal groups; and particular audiences such as teachers, politicians, journalists, opinion formers or employees. Complex communications programmes will identify the appropriate target audiences, and different aspects of the programme will be developed to reach each of the various target audiences. For example, advertisements which are suitable for some socio-economic groups may be unsuitable for others. Similarly information packs developed for politicians or journalists may be unsuitable for the general public, and vice versa.

What is important is that the characteristics of each part of the target audience is carefully analyzed, and an appropriate programme is developed for all those target audiences considered important. This is a complex business, and will require considerable sensitivity and expertise by those involved. It is also important that methods of measuring the impact of the programme on the various target audiences is established, so that its effectiveness can be evaluated and modified as appropriate.

The Objectives. It is important that certain objectives, quantified wherever possible, are decided upon from the outset as this will have a major impact upon the resources devoted to a communications programme — its scope, the number of target audiences that can be addressed and the ways in which they are addressed. The objectives must be realistic, and timescales should be established so that the progress of the communications programme can be evaluated over time.

In setting objectives, sensitivity as to what is possible and as to the degree to which public opinion can be changed is important. Setting unreasonable objectives will undermine the credibility of any programme.

In setting specific, quantified objectives the large number of factors which can have an impact upon the success of a communications programme must be considered. For example, the objective may be to obtain over a period of, say five years, a stated level of public acceptance (having defined "acceptance"). If some new factor emerges, such as the worldwide development of the environmental movement, it may well be necessary to analyze the movement of public acceptance of other plants of a similar nature in other industries. Attitudes towards all industries may be affected by the worldwide environmental movement. If it can be illustrated that the nuclear plant's communication programme has produced a better result than similar plants in other industries, the programme may be working well, even if the original target for public acceptance has not been reached.

Programme Options

In developing a communications programme, many tools are available. These include advertising, publications, films and videos, exhibitions and visitors centres, educational materials, media relations, speakers panels, special events and others. All can play their part in an effective programme and a combination of techniques will normally be used. The following pages give only a brief introduction to their various merits and disadvantages.

Advertising. The use of advertising is becoming more widespread in the nuclear industry, although the number of organizations using advertising on a large scale is still relatively limited. Advertising has the key advantage of being controllable while also (potentially) having a major impact. It has the major disadvantage of being expensive, and in some countries being subject to restrictions on what can be said, particularly with TV advertising.

The type of advertising selected for a particular programme will depend upon the issues, resources and target audiences identified above. This in turn will determine whether advertisements should be large or small, continuous or one-off, their content and style, and the type of media to be used.

It has to be accepted that advertising can only have a limited role in imparting detailed or scientific information about an industry such as the nuclear industry. It can however be very useful for advertising the availability of other information such as brochures, films or exhibition facilities. It is also an extremely useful medium for conveying an image of openness. Overall, it can be particularly effective in changing opinion due to the large number of people that can be reached through an advertising programme.

It is important, however, that advertisements are thoroughly tested before publication or being broadcast to ensure the message and impact are positive, relevant and understandable. In a complex area of communication such as the nuclear industry, as high a proportion as 90% of advertisements may be rejected during the pre-testing stage. To publish or broadcast advertisements that are less than effective is extremely wasteful, and in terms of impact may be worse than doing nothing.

It is also vital that the advertisements are entirely accurate, and meet in full all legal and regulatory requirements. Advertisements published by the nuclear industry are likely to be attacked and criticized by anti-nuclear groups and any error will be exploited by opponents of the industry.

The main forms of advertising media are as follows:

- *Television.* There is little doubt that television is the single most powerful advertising medium yet developed. It has the capacity for imparting images and a level of impact way above that of other advertising media. It can also reach very large audiences. On the other hand, the messages that can be transmitted are limited as television is relatively weak in imparting detailed information. It is also an expensive medium, with high production and transmission costs. Furthermore, it has the disadvantage of being very strictly controlled in most countries, to the extent that messages about controversial issues such as nuclear power may be restricted, or may not even be allowed. It is however a very useful medium for advertising other forms of information, such as brochures, films, exhibition facilities, site visits, etc, and for imparting an image of openness or community involvement.
- *Radio.* Many of the comments applying to television also apply to radio, except that radio advertising generally has less impact than TV. It is, however, much more economical, particularly when local radio stations near to sites can be used.
- *National Press.* In those countries with an established national press, effective advertising campaigns aimed at the whole population, or specific socio-economic groups can be mounted. More detailed information on nuclear issues can be dealt with more effectively in press advertisements than with TV or radio, and generally the costs are lower. However, an effective national campaign is still relatively expensive, as repetition of the message is very important. Small scale campaigns, with advertisements appearing only a small number of times, are generally unsuccessful. There is also a considerable challenge in making advertisements dealing with issues such as nuclear power stand out against the large number of other advertisements carried by national newspapers. However, if effective advertisements can be designed, there is little doubt that they can have considerable impact.
- *Local Newspapers.* Advertising in newspapers local to a nuclear site can be an effective, economical method of communication. The costs are rarely very high, and the high degree of interest in the locality near a nuclear plant can ensure a wide readership for appropriately designed advertisements. The local nature of such newspapers allows close and careful targeting of the advertisement geographically.

• *Magazines.* These are particularly useful in reaching specific target audiences, such as women, young people, or particular groups through special interest publications. As with national newspapers, it can be difficult to design advertisements which stand out from the many other advertisements in a magazine, but the ability to reach particular target audiences can make magazine advertising effective.

• *Posters.* Posters can be used to impart a simple message, but with controversial issues such as nuclear power, may be subject to vandalism and graffiti which can undermine their effectiveness.

Publications. Brochures and other publications have been the mainstay of nuclear communications programmes for many years. They have considerable advantages in that issues can be dealt with in some depth, while careful design and the use of photographs and diagrams enable an organization to impart relatively technical information in a format that can be understood by the various target audiences.

It is very important that brochures are targeted carefully, and that the scope of a brochure is not too wide. Ideally, a brochure describing a relatively complex process might be in one form for those relatively scientifically qualified, and in a different form for the general public. It is important not to include too many subjects within a single brochure, as the capacity of most target audiences to absorb a very wide range of information is limited.

The quality of design, as well as the text, is crucial if the right image is to be imparted to the reader of a publication. The public will rapidly draw a negative perception of an organization which is incapable of producing well designed and well written publications. Equally, the organization that produces good literature is likely to be more highly regarded.

It is often useful to have copy and design vetted by people outside the organization, to ensure that "typical" members of the target audience are able to understand the contents of a publication. Focus groups are as useful in vetting publications as they are in establishing the potential effectiveness of an advertisement.

Having produced a publication, it is very important that it is effectively distributed. Very often, a publication is produced at considerable expense, but little attention is given to ensuring that it reaches the target audience. The availability of a publication can be an ideal subject for an advertising campaign, while other methods of distributing a brochure should be considered. These include door-to-door distribution, direct mail within specific localities, or distribution at exhibitions and other events.

It is also equally important that brochures should not be over-distributed. It is often the case that visitors to a plant or exhibition leave with a very wide range of publications. Faced with the daunting task of reading these publications, many members of the public will not even begin the task. It is far better to give only the most relevant publications to visitors and other potential readers.

Film and Videos. Films and videos can be extremely effective in conveying relatively complex messages in an entertaining and effective format. It is a form of communication where quality is very important. Audiences have become increasingly used to high quality television programmes, and will judge the quality of an industrial film or video against these standards.

The selection of a professional/video production company is the normal first step, using a comprehensive brief including the objective of producing a film/video, the target audience, method of distribution, and any special requirements such as usage at exhibitions or, possibly, on television. As with publications, it is crucial to consider the method of distribution. A common pitfall of an industrial film/video, which may be of the highest quality, is the failure to ensure that it is distributed widely. If it isn't seen, it is unsuccessful.

With the increasingly wide availability of domestic video recorders, video is becoming the dominant format for distribution. Film is still useful for larger audiences, such as at talks and lectures. As with publications, the availability of films/videos can be an ideal subject for advertisements. Films and videos tend to be expensive to produce and it is therefore important that they reach the widest possible audience. A showing on television is ideal, but other outlets such as at visitors centres or exhibitions, in schools programmes and by a speakers bureau can be extremely useful. Video cassettes, which are now relatively inexpensive to produce in bulk, can be almost as economical per copy as a brochure, and consideration should be given both to free distribution if the message is important enough, or to selling the video cassettes.

Slide Tape. Slide tape presentations are, in effect, a cheap version of films/videos, but they have the additional benefit of being capable of personalization. Individual slides can be changed to suit a particular audience. In addition, sophisticated slide tape programmes, employing a number of slide projectors, can be highly effective and can achieve almost film-like effects. These are particularly useful in major exhibitions or in visitors' centres.

Exhibitions. Exhibitions are a major part of the nuclear industry's communications programmes, ranging from large on-site visitors centres through to off-site exhibitions, travelling expositions and small on or off-site displays explaining a particular aspect of the industry. A brief description of each of the above is as follows:

- *Visitors Centres.* Increasingly, nuclear sites are encouraging visitors. An ideal way to introduce the visitor to the operations of a site is through a Visitors Centre, but it should not be used instead of or in order to restrict visits to the actual facility. Some centres around the world are now attracting

A life-sized model of an advanced gas-cooled reactor at the Sellafield Visitors Centre, United Kingdom.
(Credit: BNFL)

hundreds of thousands of visitors and have become the focal point of a communication programme.

The most effective Visitors Centres employ modern, entertaining audio-visual techniques, working models, computer programmes, interactive video and other displays, as well as a range of printed/panel exhibits and publications to take away. Some of the exhibits at major centres, such as in Japan, or the Sellafield centre in Britain, have full-scale models of nuclear reactors, with working parts to demonstrate how a nuclear reactor operates. Such exhibits are expensive, and have to be well designed to remain reliable over periods of years. However, smaller scale visitors' centres can still be highly effective, if the needs of the visitor have been clearly identified, and appropriate displays and information have been installed.

Research on how people use exhibitions indicates that the modern "consumer", increasingly brought up on television, is relatively unwilling to read traditional exhibition panels containing extensive text and diagrams. Wherever possible, more effective methods of communication, particularly featuring video and other techniques, should be used.

Also in an increasingly sophisticated world visitors expect facilities equal to the best tourist attractions, such as good quality catering, toilet facilities, creches and reception facilities.

Many visitors are left dissatisfied if the ability to visit a nuclear plant is restricted to a Visitors Centre. Ideally a Visitors Centre should be used to introduce the visitor to the site and explain the process carried out there, followed by a more detailed visit of the nuclear site itself. If visitors are to tour nuclear facilities, it is important that consideration is given to various on-site displays, which explain the processes taking place in that area of the plant. On large sites, special buses or coaches, again employing audio visual techniques ranging from on-board videos to a guide equipped with a microphone, can be ideal methods of communication. For new plants viewing galleries can be an integral part of the original design.

The operation of visitors' facilities on this scale is necessarily expensive. However, examples in various parts of the world have shown this to be amongst the most effective methods of communicating what goes on at a particular site, and increasing the level of acceptance through a policy of openness by encouraging visitors and explaining what happens.

The recruitment, selection and training of staff to operate a visitors' centre, and other aspects such as plant tours, are an important consideration. The staff must be able to relate to the public, and while technical competence is important, their personality and ability to communicate is of equal, if not greater, significance. The personality of the visitors' centre staff and tour guides will play as important a part in the impression gained by visitors as almost any other factor. Once selected and trained, it is important to keep such staff highly motivated and constantly aware that a vast majority of visitors will be seeing the Visitors Centre or plant for the first time, even though the tour guide may have conducted a tour on literally thousands of occasions.

Exhibits. In various countries, major exhibition facilities are available where nuclear exhibits can help to explain the complexities of the industry. For example, national science museums are ideal, as these normally attract very large numbers of people in any year.

While exhibits in institutions such as science museums are useful, the scope is generally limited to explaining the history, the development and role of nuclear energy, and the science lying behind the industry, rather than the impact or role of specific nuclear plants. However, the greater understanding that can be derived from a visit to such a museum makes this an ideal contribution to the overall public relations effort of the industry within any country.

In addition there are often major exhibitions organized at which nuclear organizations can exhibit. Again, considerable thought should be given to the design of the exhibition stand, as the initial impact on the visitor to a particular exhibit is often determined by the overall quality of design, as well as the detailed content.

Other exhibitions designed and managed by a particular nuclear utility are as follows:

- *Travelling exhibitions.* These can either be in the form of mobile units such as caravans (often custom built for exhibition use) or easily transportable and erectable displays, often using patented exhibition display systems.

Travelling exhibitions can be used at events like local shows or at venues such as shopping malls, town centres, holiday resorts, or any other location where sufficient numbers of people are likely to be interested in viewing the exhibition.

The display material should be designed to withstand the rigours of travel, and be economical to set up at the various locations. While relatively economic to run, such exhibitions can reach large numbers of people (often measured in hundreds of thousands in a year). They do however require a considerable commitment in terms of experienced, knowledgeable staff to answer questions and debate issues. They are extremely useful in distributing literature, small novelties, souvenirs, and other interesting giveaways.

Occasionally, there are opportunities for unusual travelling exhibitions. For example, a nuclear ship could be used, as in Sweden, with an exhibition built in the ship's hold, and the ship calling at a variety of ports. The imaginative use of such a facility will almost certainly impress the public and media.

- *School exhibitions.* Schools offer an ideal venue for suitably designed exhibitions. Teachers normally welcome exhibits, although it is important that the content of such exhibitions be balanced and is not seen as nuclear industry propaganda. The educational element of the content should be given high priority.

It is important that exhibitions for schools are very carefully designed to meet the needs of the various age groups. In addition, interactive displays should be used where possible, although they have to be extremely robust. Literature, again designed to meet the needs of the age groups concerned, can be distributed. Teaching Packs for the school staff, containing ideas and materials for projects, etc., can be a highly effective method of communication.

- *Plant exhibits.* Whether or not a nuclear plant has a visitors' centre, those visitors who tour the plant will find exhibits along the route, explaining what happens in that particular part of the plant, particularly useful. The processes employed within the nuclear industry are often complex, and anything that simplifies the understanding of the processes is worthwhile.

Open Days. Even if a nuclear plant has no facilities for site tours on a day-by-day basis, the idea of Open Days for employees and those in the locality is worth considering. They help to demonstrate a degree of openness, and a willingness to explain the plant's processes to the local public. There is often a great deal of interest, and careful planning is necessary to ensure that the very large numbers of people that might attend can be accommodated efficiently and comfortably. However, the positive impact achieved can make the expense and effort extremely worthwhile.

Speakers Panels. The concept of speakers panels, consisting of people within the industry who are willing to go out to talk to audiences about the industry, is well established in many countries. It is a relatively cheap and effective way of reaching interested audiences, and the impact is invariably positive. To obtain the most positive benefits, training programmes and regular seminars for speakers to update them on current issues are necessary. Ideally, speakers should also be provided with highly professional speakers aids, such as audio-visual equipment and demonstration materials to illustrate their talk. Speakers panels are particularly effective in supplementing many other aspects of a communications programme. It has to be recognized however that the numbers of people, except within a restricted locality, that can be reached through this method of communication is limited.

In any speakers panel, great care should be taken in the selection of speakers. They must be individuals who can relate to the needs of their audiences, speak in a language non-technical audiences can understand, and have sufficient knowledge over a wide range of subjects to be able to answer questions competently and convincingly. They must also be able to withstand the difficult and intense questioning some members of the public may subject them to, particularly when the audience being addressed is anti-nuclear.

Media Relations. An efficient and effective media relations operation is crucial to any communications programme, particularly in a sensitive area such as nuclear power. Almost inevitably, the operation of a nuclear facility will entail regular contact with the press, whether local, national or international.

A vital requirement in any media relations programme is the ability to respond rapidly and honestly to enquiries during an incident or other newsworthy event. It is important that the media relations aspects of any incident, however serious, are fully considered in advance and that training exercises are carried out regularly to assess the effectiveness of the media relations operation. The reaction and requirements of the media have to be assessed as fully as possible, to ensure that appropriate facilities and staffing are available in the event of an incident. Further thoughts on crisis communications are included in a following section.

However, there are many other aspects of media relations to be considered apart from responding to requests for news and information. The development of a more proactive press relations programme, with regular press releases, briefings, facility tours of the plant, the dissemination of positive news, all play a part in developing a positive image for a nuclear facility.

A detailed press clipping service is essential in operating a press relations programme. Monitoring the media coverage of a nuclear facility will enable the Press Office to respond to newspaper letters and articles and TV and radio reports, correcting any inaccuracies or misinformation where necessary. Monitoring of the "tone" of media reports will also indicate whether changes to a media relations programme need to be considered. Ongoing analysis of media coverage will show trends in attitudes and perceptions.

The maintenance of a supply of good quality colour and black and white photographs, in various formats, will enable visual materials to be distributed to the media, helping to produce a higher quality of visual impact in print and TV reports. It is also worth considering the production of "electronic press materials", for example in the form of video tapes which can be released to TV companies. This will also help ensure that TV coverage of a particular facility is of a high visual quality. These tapes should be maintained to a high standard, and new materials added as new plants and facilities are built.

It is important that media relations are conducted by experienced personnel, ideally with experience in working with the media. The press office must also be able to communicate effectively in non-technical language, while having sufficient knowledge of the plant's operations to be able to interpret its role for the media.

The development of close working relationships with local and other media is a long-term commitment which should be the focal point of media relations activity. Development of positive relationships is important in day-to-day operations, and press coverage is likely to be more positive if there is a mutual respect between the press office of the nuclear facility and the media. This will be particularly beneficial in more difficult situations such as an emergency or crisis, where trust between the press office and media is crucial.

Special Events. The planning of special events to attract positive media coverage, or to solve a particular image or communications problem, should be considered. For example, in the public testing of safety procedures, a classic example was the nuclear transportation flask test in England in 1983, when a train was crashed into a flask. Events such as this, handled well, can produce widespread positive news coverage.

Occasions of commemoration or celebration, such as anniversaries and awards, can also be used to stage special events.

Education. Long-term acceptance of a nuclear facility through greater understanding can be derived from an effective education programme. This has the double benefit of:

- Educating children about the role of nuclear power, and where appropriate, the operation of a local nuclear facility.
- Developing a more positive relationship with teachers, a key opinion forming group.
- By involving itself in the local community and the improvement of educational standards, the nuclear facility will benefit in terms of future recruitment and training of employees.
- Education has both short- and long-term benefits. It is particularly important that the educational materials produced and distributed by nuclear facilities are balanced, contain a distinct educational element, and do not attempt to distort arguments or indulge in propaganda. To do so would simply result in rejection as unsuitable, and attract criticism from teachers, parents and children alike.

Education programmes can embrace a wide variety of materials, such as publications, exhibitions, speakers panels, films and videos etc, but with the material produced specifically with the world of education in mind. In addition, specific educational material dealing with aspects of the school curriculum which are closely associated with the nuclear industry's operations (e.g., physics, chemistry, environmental studies, geography) can be a key constituent of an effective educational programme. These materials can take the form of educational packs, consisting of teacher's study notes, posters, videos, computer disks suitable for use on school equipment, and other items.

Many nuclear visitor centres are geared to school groups, and it is worth considering the needs of schools in the design of visitor centre facilities. Some visitor centres go even further, with the provision of educational study facilities such as lecture theatres or project rooms, manned by specialist staff trained to deal with teachers and pupils.

Educational materials can be made available to schools, either free or charged for. There are many examples within the energy industry, particularly the oil industry, of major long term educational programmes which have proved to be successful, and have been of benefit to both the companies and the education community.

Other educational initiatives which have been productively undertaken include sponsorship of science fairs, educators' seminars, scholarship programmes, job-shadowing and "science academy" ventures in which students work on laboratory projects at nuclear centres while simultaneously earning academic credits.

Special Communication Programmes. As well as the general public, and other groups listed above, special programmes should be considered and developed for particular publics. Examples are:

- *The local community.* At all stages of the life cycle of a nuclear facility, the key group to consider is the local community. From the moment a facility is originally considered through to its eventual decommissioning, it is this group that is most closely involved. All the techniques already discussed, and others listed below, should be considered and as full a programme as possible implemented. The views of the local community will have an impact on almost every other aspect of a communications programme. The local communities' attitudes will be reflected in those of politicians, local government officials, the press, pressure groups, and so on. Ultimately, the local community can decide whether the facility starts or continues to operate, whatever the legal position, if there is a strong enough feeling of opposition. It must be remembered that it is for the industry to make a case to the community for its facility being in that particular community's backyard.

It is probably fair to say that it is the local community and its relationship with the nuclear facility that will determine whether that facility develops successfully or not.

The key requirement is to keep the local population informed. Every method of communication can be considered, and those that are used will depend upon local conditions.

Many industrial facilities maintain formal links with the local community through liaison committees or similar groups, where the operations of the plant are discussed on a regular basis with representatives of the local community. Such representatives are chosen from amongst local politicians, local authorities, members of the emergency services such as the police, fire services, hospitals, members of the regulatory authorities and specialist advisors or experts. Meetings can be open to the public and the press, as the purpose is to disseminate information about the operations of the plant, as well as obtaining the views of the representatives of the local population.

Regular newsletters, distributed either by the liaison committee or by the nuclear facility, can be placed in local libraries etc., distributed to the local press, or distributed to each local household.

- *Local authorities, politicians etc.* As well as through methods such as local liaison committees, it is necessary to establish a close working relationship with influential members of the local population, including elected representatives, local officials, church leaders, and community leaders such as doctors and teachers.

These relationships can be maintained through regular meetings, facility tours of the plant, seminars etc, to explain the operation of the plant, and to discuss particular issues.

Local newsletters are a particularly appropriate way of communicating information to these groups. Positive and negative information, for example information on incidents, can be incorporated in the newsletter which should be published on a regular basis — weekly, monthly, or however frequently is thought suitable, given the newsworthiness of the plant. Copies of newsletters can also be distributed to local libraries and through other appropriate outlets. Another way of disseminating information is to install bulletin boards at venues such as the local post office.

- *Local clubs, organizations etc.* Local organizations often look to major local companies for support for a wide range of activities, and an appropriate programme of such support can be an excellent way of establishing a positive relationship.

- *Employees.* The employees working at a nuclear fuel cycle facility are potentially the best ambassadors for the organization and industry that employs them. They have social contacts with many people in the locality, and are often asked questions about their work and the operation of the plant. Consideration should be given to ways in which information on the plant can be passed to employees so that they can respond to such questions. The very process of communicating with employees will normally produce a more positive, better motivated workforce, which in turn will produce more positive communications with the public.

Specialist employee communications programmes cover a wide range of communication methods ranging from tannoy announcements to internal newspapers, including notice boards, special briefing notes, meetings, discussion groups, operational briefing meetings, electronic bulletins, and so forth.

● *Anti-nuclear groups.* Relationships between nuclear fuel cycle facilities and anti-nuclear groups are often difficult, but on occasions positive relationships can be developed. The degree to which a positive relationship can be established will often depend upon the personality and beliefs of the local representatives of particular pressure groups, and each situation will have to be assessed upon its own merits.

It does have to be accepted that many groups are fundamentally opposed to nuclear energy, and therefore are not seeking a positive relationship. It is important, however, that poor communications should not become a pretext for an even more difficult relationship which can be exploited in the media and elsewhere by the opposing groups.

While it is probably unreasonable to expect a dramatic improvement in relationships with anti-nuclear groups through a communications programme, an effective channel of communication with such groups should be seriously considered in the development of any communications programme.

● *Regulatory authorities.* Most nuclear fuel cycle facilities are governed by at least one regulatory authority, and it is essential that an effective communication link between the facility and the regulatory authorities is established and maintained. Just as the general public, as well as specialist groups such as journalists or politicians, can be influenced by the quality of a communications programme, so regulatory authorities are likely to regard more highly those facilities with effective and reliable methods of communications.

Programme Evaluation

The most accepted method of evaluation of a communications programme is through opinion research, analyzing the results and assessing these against the objectives set. This method becomes increasingly effective as trends in the research findings emerge over a period of time, and those assessing the opinion research become more familiar with the research. Other methods of evaluation are through the reaction of the press and the comments and observations of visitors, while intuition will again play an important role.

As stated in the section on research, evaluation is made all the more easy and effective if the research established at the outset of the programme is robust enough to identify the real issues and effective answers and reliable trend data. It is always necessary to remember that situations continually change. Attitudes are rarely consistent. The public's expectation of information is generally increasing, and new media outlets and methods of communication are becoming available. In the evaluation of a communications programme, such changes and new opportunities must be considered. If not, valuable opportunities may be lost and the validity of the communications programme may be lessened.

Maintaining objectivity during the evaluation stage of an exercise can be difficult. In many cases, those conducting the evaluation exercise were responsible for the introduction and implementation of the original communications programme. They may have had difficulty arguing the case for that programme. If the programme is proving less successful than anticipated, it may be difficult to accept this relative failure. The use of outside consultants, and particularly the selection of opinion researchers who can give useful and objective advice, is often the most effective way to overcome such problems. It should also be accepted by all concerned that the implementation of any communications programme is difficult and complex. It is highly unlikely that any organization will get it right the first time, while changing conditions will ensure that new methods, new target audiences, even new objectives have to be set and the programme developed accordingly.

It is also likely that issues will change over time within different publics. The concerns, for example, of the local community may over the years move in directions that differ from those of the national population. The rapid emergence of the greenhouse effect as an international concern demonstrates the way in which the arguments about energy policies and the relative merits of nuclear power can change within a very short timescale. Equally, an incident at a nuclear facility can change local attitudes. Each of the various publics needs to be evaluated and the communications programme developed for each public.

In some areas such as advertising, there is also a need to keep the communications programme fresh and novel as well as relevant, and this places particular strain on the creative ability of those producing the new materials. Publications, films and videos, etc, also date and can appear old-fashioned, as graphic styles and formats change over time. Distributing old-fashioned, out-dated materials can damage the credibility and reputation of a nuclear facility, and effort and expenditure should be devoted to maintaining standards.

It is difficult to give indications of the length of time various forms of publicity material can be used, but the necessity of changing and updating material should be allowed for in the initial assessment of costs of a communications programme. In some areas, such as Visitors Centres, continual updates will need to be a feature of the exhibit materials, and these can often be expensive to implement.

Box 2. Dealing With the Unexpected: Guidelines for Media Relations

In the event of a crisis, media relations are of paramount importance. The following are some useful guidelines:

1. Do not put out information until an authorized communicator has verified all the facts.

2. Reinforce the idea that there will be a designated spokesperson for all information.

3. All information given should be factual, avoiding guesswork or hypotheses or speculation.

4. Certain types of information should be withheld pending notification of appropriate parties, for example, families of affected employees.

5. Certain kinds of information that might pose legal problems should be handled through proper channels, calling upon legal assistance.

6. All information should be given frankly and honestly.

7. All written information should be reviewed and approved through the agreed channels prior to release.

8. All information should be given in terms that reporters can understand.

The initial statement after an accident or incident can be the most important in terms of a company's credibility. Prepared and approved by the appropriate management, it should include the following information:

- Nature of the accident or incident (who, what, when, where);
- What products, processes or materials were involved;
- Assessment whether the public or the environment are in any danger;
- Regulatory or other authorities that have been notified;
- Response and remediation;
- Extent of damage or injuries; and
- Persons to contact for further information

Many companies caution against giving information which is speculative, gives financial estimates of damage, implies negligence or prematurely assesses the quality of the response to the emergency.

In conclusion, a communications programme is dynamic and should be continually assessed and adapted as conditions change and time passes. What was effective last year may no longer be so. What was considered irrelevant last year may now be the public's number one concern.

Opinion research, media analysis and intuition should point the professional communicator in the right direction. With adequate resources, the programme can then be adapted and developed accordingly.

Dealing With the Unexpected

The organization that is not prepared for a communications crisis is not necessarily the most likely to be confronted with one. It is, however, the least likely to be able to cope with it.

But while crisis communication plans are necessary, on their own they are not sufficient when dealing with the unexpected. An established communications climate which has created a bond of trust and credibility, in times of both rain and sunshine, is the best insurance policy for dealing with the unforeseen event. Since such events may be lurking around the corner, the communication climate should be an integral and well managed part of the entire life cycle of an operation or facility, from the planning stage through to decommissioning.

In the life of any organization or enterprise, situations can arise which create special challenges. They are compounded if preparatory measures have not been taken to deal with such situations, however hypothetical they may appear.

A crisis in any industry is an unplanned and unexpected event which triggers a real, perceived or possible threat to life, health, safety, the environment, financial status or corporate credibility. It normally contains a number of basic elements:

- It comes with little or no warning.
- There is little or no information, especially in the early stages.
- Information is often contradictory, incomplete and constantly changing.
- Communications tools will not function the way they are supposed to.
- There may be physical damage or injuries.
- There is much confusion.
- Murphy's Law will apply — if anything can go wrong it will go wrong.

Despite these characteristics, a crisis does not necessarily mean disaster, especially if it is handled promptly, prudently and properly. Some basic steps can help.

Pre-crisis planning. An organization should attempt to predict the kinds of crisis that could occur and should prepare basic strategies for dealing with them. Spokespersons should be designated and trained, and should regularly be exposed to retraining and simulated exercises. It is open to debate whether a professional communicator should be trained in the technical issues he or she will have to

Box 3: Dealing With the Unexpected: Sample Responses for Emergency Situations

The following are examples of the type of questions that might be asked in emergency situations. Each question has two answers which a spokesperson might give. Which of the two is more appropriate?

Q. What happened?

A1. An unscheduled excursion occurred during a stress analysis experiment in our high temperature loop facility.

A2. A minor explosion took place during a test in which uranium fuel was being heated to abnormally high temperatures.

Q. How did it happen?

A1. I don't wish to speculate. Our investigation has just started and we hope to have preliminary findings by the day after tomorrow.

A2. My guess is that there was a flaw in the fuel cladding but we won't really know until we have examined all the possible causes. There could be a number of reasons for the incident.

Q. When and where did it happen?

A1. It happened in our materials development laboratory at 10:35 this morning.

A2. The accident occurred about 10:30 in one of our laboratories where we subject materials to extreme conditions of temperature and pressure.

Q. Who was involved?

A1. There were four people in the area at the time.

A2. George Smith, the Lab's Chief Metallurgist and three young technicians.

Q. What happened to these people?

A1. One of them, who was close to the explosion, received facial cuts which required several stitches. The others were not hurt but they were taken to the plant clinic for observation.

A2. George received cuts to his face and has been treated. The others were not injured but they were lucky they were at the far end of the room when the fuel sheath ruptured.

Q. How much damage was there?

A1. It is impossible to assess fully at this stage but we know that it was limited to a small area of the materials development laboratory.

A2. We don't really know but it must be at least $100 000. It only affected a small area but there is some expensive equipment there.

Q. What preventative procedures were in effect?

A1. Our standard procedures are (describe).

A2. We have routine procedures but I can't tell you whether they were being followed or not.

Q. How does this affect your operations?

A1. Our operations are continuing normally except for the building where the incident happened. It will not be back in operation until our investigation is complete.

A2. It is not really affecting us at all. What is done in the building where the accident happened is only a very minor part of our operations.

Q. May we speak to someone who witnessed the event?

A1. We will bring witnesses to talk to you as soon as possible

A2. We don't allow our employees to talk to the media.

deal with, or whether a technically competent person should be trained in communications skills. The choice will often depend upon the availability of individual personnel.

The spokesperson is a key individual in crisis communications. A good spokesperson should be credible, articulate, accessible and knowledgeable. Other necessary characteristics are the authority to speak for the company, the ability to explain technical matters in layman's terms, and an understanding of the requirements of the media.

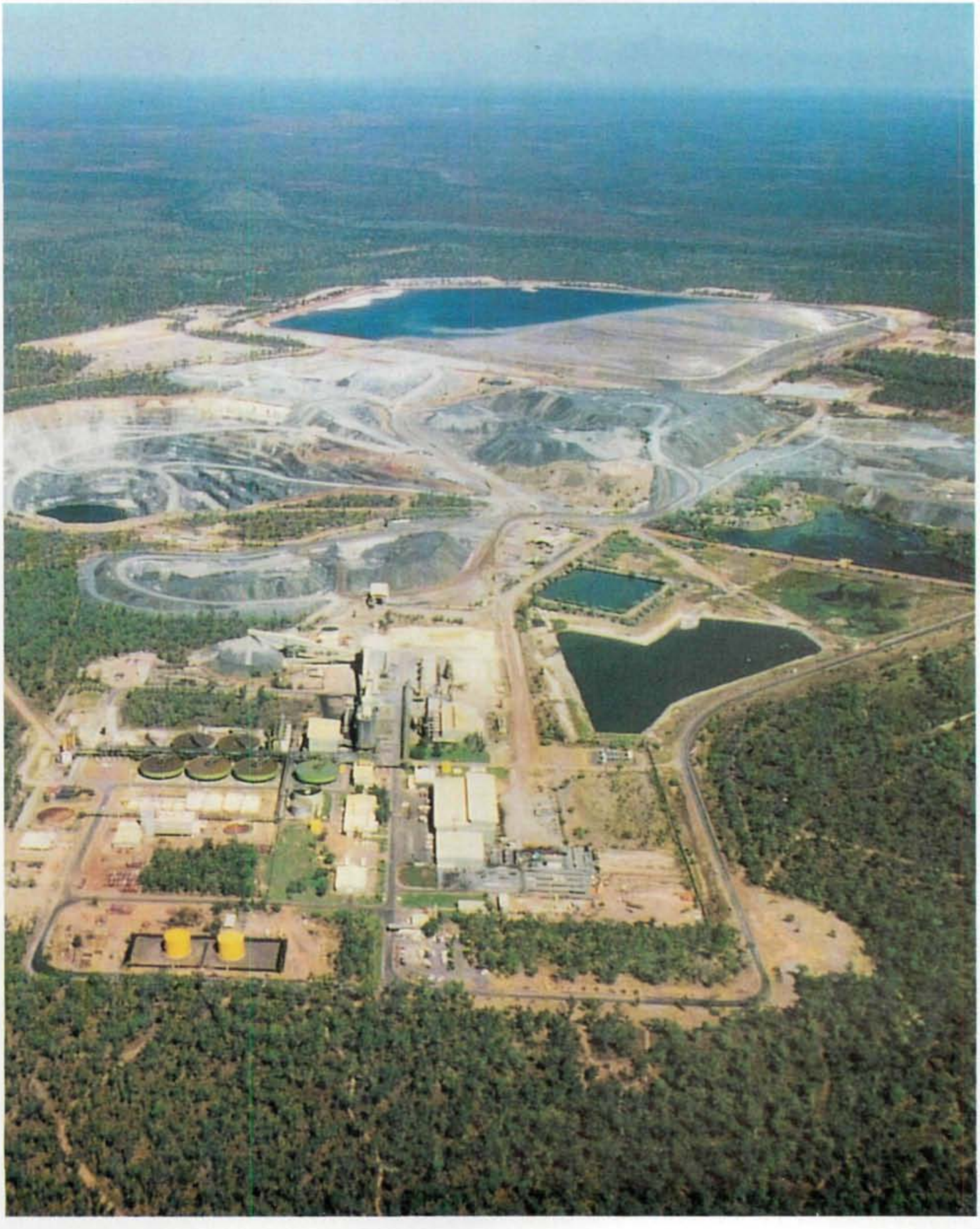
Another component of pre-crisis planning is the preparation of press materials or kits. These might include fact sheets, company and facility description, photos, maps, biographies of key managers, data sheets, company contacts, pamphlets about products and operations, video clips and so on.

Contingency plans. These might include notification of local hospitals and emergency services, notification of families of employees, the role of spokespersons, notification of media, resource requirements such as conference rooms, telephones, press briefing rooms, etc.

It is also important that there has been a long-term development of trust and credibility in communicating with the public, as this will be invaluable in a crisis situation.

The goals of a crisis communications plan are to control communications, to restore order as quickly as possible, and to restore public trust that you have everything under control.

The Nuclear Fuel Cycle and the Environment



The Ranger uranium mining centre in Australia. ***(Credit: ERA)***

Characteristics of Nuclear Power

Nuclear power stations generate electricity from the heat produced when the nuclei of the atoms of heavy material are split. The nuclear reactions that produce the heat take place in a reactor. The heat is then used in a boiler to produce steam to drive turbines.

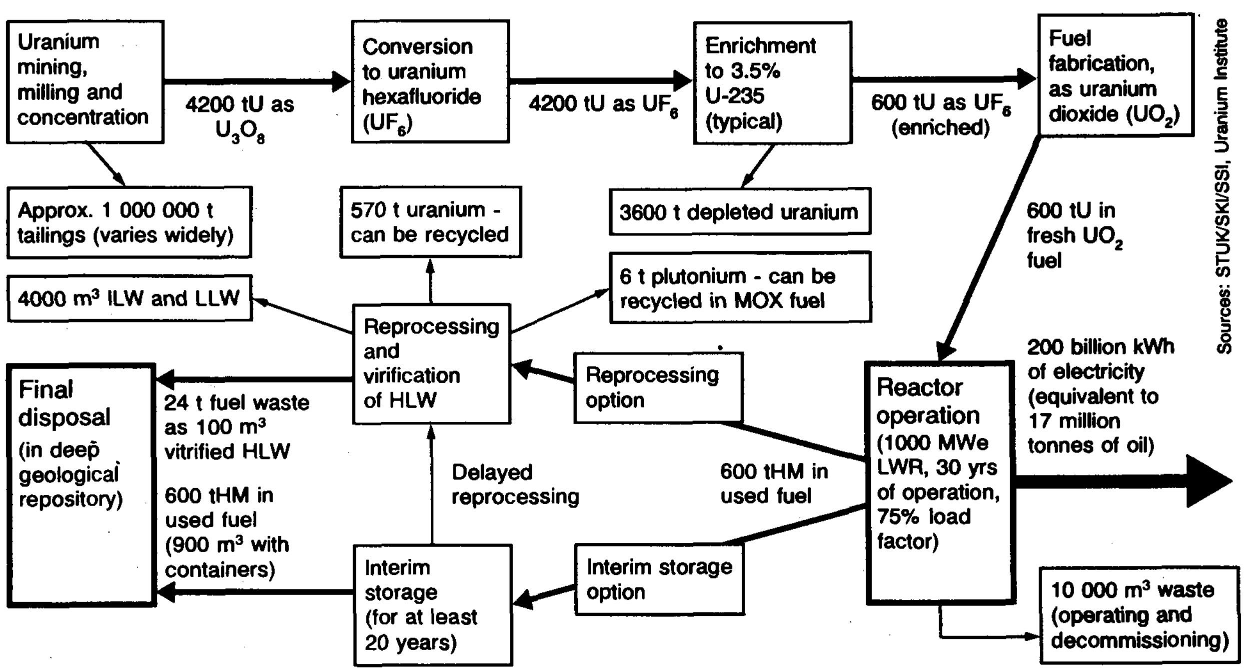
The material used as the fuel in current nuclear power stations is usually uranium. However, other possible fuels such as thorium have been considered. *(See Figure 3 for a description of the material inputs and outputs of a typical light-water reactor.)*

Uranium ore occurs naturally in the earth's crust and is mined by conventional mining techniques. It is then processed into a form suitable for using as fuel in a nuclear reactor. Natural uranium contains two main isotopes, uranium-238 and uranium-235. Only the nuclei of the uranium-235 atoms are readily fissile, i.e. capable of being split, under most conditions, but uranium-235 accounts for only about 0.7% of natural uranium. Therefore, although some reactors use natural uranium as their fuel, most reactors use slightly enriched uranium, in which the proportion of uranium-235 atoms has been artificially increased, or enriched by uranium-235 taken from a further quantity of natural uranium. Consequently, most of the uranium that is mined is enriched after processing and before it is fabricated into fuel elements for loading into a reactor.

Inside the reactor the fuel is irradiated as nuclear fission reactions take place. The uranium-235 atoms when split form lighter elements, known as fission products, some of which are highly radioactive. Some of the uranium-238 atoms are also transformed in the reactor to form heavier elements, also radioactive. The most important of these is plutonium. Plutonium-239, the isotope of plutonium produced in the largest quantity, like uranium-235, is fissile and therefore a potential fuel; indeed some of the plutonium so formed is then subsequently fissioned and releases energy while the fuel remains in the reactor. About one third of the energy released while the uranium fuel is being irradiated comes from the fission of plutonium.

The heat produced by the fission reactions is removed by a cooling agent that passes over the fuel and transfers the heat to the steam circuit which is linked to the turbine. In some types of reactors liquids, such as ordinary (light) water or heavy water, are used as the coolant; in others gases, such as carbon dioxide, are used. The largest number of power reactors currently in operation use light water, and are generically referred to as light-water reactors (LWRs). There are two main types of LWR: the pressurized-water reactor (PWR) and the boiling-water reactor (BWR). But there are also sig-

Figure 3. **Materials Balance for the Nuclear Fuel Cycle of a Typical Reactor**



This chart shows the main material inputs and outputs for the operation of a typical light-water reactor, including the waste produced and electricity generated. The quantities given are approximate, as actual figures will vary from reactor to reactor.

Notes: tU = tonnes uranium tHM = tonnes heavy metal (in used fuel, comprises uranium, plutonium and fission products). Sources: STUK/SKI/SSI, UI nificant numbers of heavy water reactors (HWRs), particularly in Canada, which has developed the Candu HWR, and of gas-cooled reactors, particularly in France and the UK.

When the spent fuel is discharged from the reactor, it contains unconsumed uranium, fission products, plutonium and some other heavy elements. It generates heat, is radioactive and is placed in storage ponds filled with water to cool. When it has cooled sufficiently it is possible to dissolve the spent fuel and chemically process ("reprocess") it in order to extract the unused uranium and plutonium. These materials can then be fabricated into new fuel elements and recycled to the reactor. When new fuel elements are fabricated in this way they contain a mixture of uranium and plutonium, the plutonium providing the main fissile material in the fuel.

Three different types of fuel cycle are commonly identified depending on whether or not the spent fuel is reprocessed and, if it is, to what type of reactor the uranium and plutonium are recycled:

- In the *once-through* fuel cycle* the spent fuel is not reprocessed but kept in storage ponds until it is sent for permanent disposal, for example by conditioning it and burying it underground in a deep geological repository.
- In the *thermal** reactor recycle* the spent fuel is reprocessed and the uranium and plutonium are separated from the fission products. Both the uranium and the plutonium can then be recycled in new fuel elements to reactors of basically the same type as that in which the plutonium is initially produced. (Alternatively, it is possible to recycle only the uranium and to store the plutonium and vice versa.)
- In the *fast*** reactor recycle* the spent fuel is similarly reprocessed and the uranium and plutonium fabricated into new fuel elements. They are, however, recycled to fast reactors (FRs), in which there is a central core of uranium/plutonium fuel surrounded by a blanket of depleted uranium, i.e. uranium from which most of the uranium-235 atoms have been taken during the process of enrichment of other uranium. This depleted uranium therefore consists mostly of uranium-238 atoms, some of which are converted to plutonium during irradiation. By suitable operation, such reactors can produce slightly more plutonium than they consume (hence the name 'breeder'), the precise mode of operation depending on the need for plutonium.

Both thermal and fast reactor recycle necessitate facilities for the storage of separated plutonium until required for recycle and arrangements for the transport of plutonium between sites, in addition to reprocessing and fuel fabrication plants and the facilities for the storage or disposal of wastes. Transport of separated plutonium is not necessary if the reprocessing and fuel fabrication plants are located on the same site.

Overview of Nuclear Fuel Cycle Facilities

Let us consider the separate components of the nuclear fuel cycle (NFC) in brief to understand the main impact of NFC on the environment and other main features of the NFC facilities which attract public attention.

Uranium Mining and Milling

Uranium is very widely distributed in the earth's crust and oceans, but can only be economically recovered where geological processes have locally increased its concentration. Economically workable uranium-bearing ores typically contain less than 0.5% of uranium, and in some cases ores are mined with grades as low as 400 parts per million. On the other hand, some uranium deposits exhibit uranium concentrations of several per cent, though these are not very common.

The minerals containing uranium are mined by conventional open-pit or underground mining methods and the uranium is extracted from the crushed ore in processing plants or mills using chemical methods appropriate to the specific mineral form. These usually extract some 85% to 95% of the uranium present in the ore.

In some cases it is possible to pass chemical solutions through the ore beds and dissolve the uranium from the ore directly. This process is known as solution mining, or *in-situ* leaching. Uranium can also be recovered as a by-product of the extraction of other metals from their minerals, for example copper and gold, and as a by-product of phosphoric acid production from phosphate rocks.

The uranium concentrate produced in the ore processing plant is known as yellowcake and usually contains between 60% and 85% uranium by weight. Depending on its quality the concentrate is sometimes further purified in a refinery near the mine before being shipped in metal containers to a conversion plant.

While uranium is only weakly radioactive, radiological hazards can arise from thorium-230, radium-

* Strictly speaking, this method of operation is not a "cycle" since the unused part of the spent fuel is not recycled.

** A "thermal" reactor is so called because the neutrons that cause fission have been slowed by collision with a light element in the core of the reactor, so that they are in thermal equilibrium with their surroundings (i.e. they are at the same temperature and therefore have a similar kinetic energy, 0.025 eV at room temperature).

*** A "fast" reactor uses high-energy neutrons (above 0.1 MeV) which have not been slowed down in the same way as thermal neutrons).

226, radon-222 and their daughter products, uranium dust and beta or gamma radiation. However, the general procedures for radiation protection associated with uranium mining and milling can prevent potential health problems which arise from:

- the radiotoxicity of various radionuclides in ores;
- the toxicity of other chemical components common to wastes from other mineral extraction operations. The wastes include large volumes of solids and liquids as well as small quantities of airborne contaminants. These must be managed during the operation of the mine/mill to ensure there is no adverse impact on people or the environment. As most of the radioactivity present in the ore is discharged with the mill tailings, there is a continuing need to manage the wastes after uranium mining/milling is completed.

The radon problem is not unique to the uranium industry but occurs in many underground mining operations and has even become a matter of concern in highly insulated conventional buildings where reductions in the levels of ventilation can lead to the accumulation of radon seeping from building materials or from the earth itself.

Conversion

While the ore concentrate is fairly pure, it requires further purification to reach the high standards required for nuclear fuel and this is achieved by dissolving it in nitric acid, filtering and treating the solution with chemical solvents. The product is the compound uranyl nitrate which is more than 99.95% pure.

The uranyl nitrate is reconverted to uranium oxide and this in turn is converted to uranium hexafluoride (UF_6) which is used in the enrichment process. If enrichment is not required, for example for heavy water reactor fuel, then uranium dioxide (UO_2) is produced from the uranyl nitrate and shipped directly to a fuel element fabrication plant. The UF_6 or UO_2 are shipped in metal containers.

Enrichment

Only reactors such as the graphite moderated reactor or the heavy water cooled and moderated reactor are able to function with fuel containing only the natural proportion of uranium-235. Light water cooled and moderated reactors as well as advanced gas cooled reactors contain materials that absorb a greater proportion of the neutrons which are essential to the functioning of fission reactors and this has to be compensated for by increasing the concentration of the uranium-235 isotope in the fuel from the naturally occuring 0.7% to around 3% to 4%. The process in which the concentration of a desired isotope is increased is known as enrichment and is based on the slightly different masses of the uranium isotope's nucleus.

The enrichment techniques available for uranium involve separation in the gas phase and this is the reason for the production and use of readily volatile uranium hexafluoride. This compound has the additional advantage that fluorine has only one isotope so that molecular mass differences are entirely due to differences in the masses of the uranium atoms they contain.

The common methods of separating uranium isotopes depend on small differences in the average speed at which molecules of different masses move. Gaseous diffusion through porous membranes is the most widely used technique but a number of countries use gas centrifuges.

Laser excitation techniques, in which advantage is taken of small differences in the light absorption characteristics of uranium atoms or their compounds, and enrichment through chemical processes are being actively developed in many laboratories.

After passing through the enrichment plant the uranium hexafluoride has been separated into two fractions. The smaller of these is enriched in the uranium-235 isotope and is shipped to the fuel element fabrication plant in simple metal cylinders with suitable precautions to guard against inadvertent criticality.* The larger fraction (enrichment tails) is depleted in uranium-235 and this is stored to await the day when breeder reactors can make use of the uranium-238 it contains or when economic or technical changes make the recovery of some of the residual 0.2% to 0.3% uranium-235 contained in the tails worthwhile.

Fuel Fabrication

The enriched uranium hexafluoride is chemically converted to pure uranium dioxide powder which is then pressed into pellets and fired in a kiln to produce a dense ceramic fuel capable of withstanding high temperatures and retaining gaseous waste products. The fuel pellets are stacked together, then sealed in tubes of zirconium alloy which resists corrosion by water. These loaded tubes, called fuel pins, are put together in a lattice of fixed geometry called a fuel assembly (264 pins per assembly, for the reference PWR reactor). A similar procedure is adopted for unenriched uranium oxide fuel for Candu reactors and for the fuel for advanced gas reactors, although in the latter case stainless steel, which resists corrosion by the carbon dioxide reactor coolant, is used in place of zirconium alloy to contain the fuel pellets.

*If a sufficient quantity of uranium-235 is contained in a small enough volume, a self-sustaining fission chain reaction can occur. It is then said to have gone critical. A non-critical assemblage may in special circumstances become critical however — for example, if it is submerged in water that slows the neutrons down and increases the efficiency of the fission process. This can be avoided easily by keeping the quantities down, spacing them out, or including neutron absorbing materials.

Fuels which are produced from uranium which has come directly from the mine, with or without enrichment, can be fabricated using a process line designed to handle low-energy alpha radiation. This requires adequate ventilation to prevent workers inhaling fine particles of uranium oxide but does not require special shielding or the use of remote handling techniques. Uranium recovered from spent reactor fuel by reprocessing additionally emits beta and gamma radiation and due precautions must be taken at the fabrication plant to ensure that the material is appropriately shielded so as to avoid exposing the workforce to unnecessary radiation.

Uranium fuel assemblies can be shipped to the reactor site without special precautions other that those needed to avoid criticality and to ensure that the assemblies arrive in a clean and undamaged state.

At the Reactor

New fuel arriving at the reactor site produces negligible amounts of heat and is placed in a store designed to contain a sufficient stock to cover the reactor operator's needs and to guard against any short term problems with supply.

From the store the fuel assemblies are transferred to the reactor and placed in the core where they remain for up to three to five years, depending on the selected refuelling schedule.* During this time a proportion of the uranium atoms undergo fission to produce energy and fission products. As a consequence, the discharged fuel is highly radioactive and has to be heavily shielded. A typical discharged PWR fuel assembly gives out hundreds of kilowatts of heat which is produced by the radioactive decay of the fission products within the fuel, and it has therefore to be placed in water where it can be cooled for one to two years, or longer if the capacity exists and the operator so wishes. The water in the storage pond also provides protection from the radiation from the used fuel.

In addition to the spent fuel, a reactor during its normal operation produces some liquid and solid wastes containing low levels of radioactivity.

Interim Storage of Spent Fuel

After the period of cooling in pools at the reactor site the most highly radioactive fission elements will have decayed and the rate of heat production from the spent fuel will have declined. Nevertheless, the fuel assemblies are still highly radioactive and give out considerable quantities of heat (about 5 kilowatts after one year and 1 kilowatts after five years). The spent fuel is therefore loaded into heavily shielded transport containers and shipped to an interim storage facility.

The interim storage can take place at the reactor site in the cooling pools attached to the reactor if these have sufficient capacity, or at away-from-reactor sites, or at the reprocessing site. Therefore interim storage can be seen either as a part of normal reactor operation or as part of the reprocessing operation.

It is only when spent fuel is transported to and stored at away-from-reactor facilities that interim storage appears as a clearly identifiable stage of the fuel cycle and thus with its own costs. A number of different approaches have been developed for interim storage in which the fuel assemblies, either intact or processed to reduce their volume, are stored in cooling ponds or in dry storage.

Disposal of Spent Fuel and Waste

Following conditioning and, in some cases, interim storage for a number of years to allow further reduction of radioactivity and heat generation, spent fuel or solidified blocks containing the high level waste, suitably encased, can be transported to a repository. Here they can be held under supervision and, when considered appropriate, sealed off permanently. It is essential that the spent fuel and high level and long lived alpha wastes from the reprocessing plant are isolated from the biosphere for a very long period of time. The solid matrix in which the highly radioactive wastes are incorporated, the package chosen to contain the spent fuel or these blocks, and the geological formation chosen to isolate the radioactivity from the biosphere are therefore carefully selected to ensure the long term safety of the disposal.

For disposal repositories attention has been concentrated on deep crystalline rock formations such as granite, salt deposits and clay beds. These options, for which most of the required technology is already available, provide the possibility of safe disposal of wastes.

An international collective opinion on safety assessment methodologies for radioactive waste repositories has been developed by the advisory committees of the OECD Nuclear Energy Agency, (the Radioactive Waste Management Committee) and the IAEA (the International Radioactive Waste Advisory Committee).

This opinion has been endorsed by Commission of European Communities (CEC) experts and is a landmark statement regarding the status of scientific evaluation of radioactive waste repositories. The experts stated that safety assessment methods are available today to evaluate adequately the potential long-term radiological impacts of a carefully designed radioactive waste disposal system on humans and the environment. They also considered that the appropriate use of safety assessment methods, coupled with sufficient information from potential disposal sites, can provide the technical basis to determine whether radioactive waste disposal systems would offer to society a satisfactory level of safety for both current and future generations.

*Some reactors, significantly Candu, are refuelled during operation and the used fuel bundles are removed and replaced after being in the reactor for 12 to 18 months.

Specific Issues, Questions and Responses

In many countries having nuclear power programmes, companies have opened Visitors Centres near their nuclear plants or related facilities in the interests of furthering public understanding about energy sources and nuclear power operations. ***(Credits: TEPCO, ESKOM, BNFL, Framatome)***

In this chapter, the issues relating to different fuel cycle facilities are described in greater detail, taking into account their environmental impacts, specific public perceptions and concerns, and appropriate responses and mitigating activities. Communications activities for one part of the fuel cycle may be applicable to other parts. Those mentioned here are indicative and thus not repeated for all segments of the cycle so as to avoid redundancy.

Uranium Exploration

Exploration for minerals creates a period of considerable uncertainty and concern for the local population, particularly for local land owners or custodians of tribal lands. The best asset for a public relations initiative in these circumstances is a local person with a flair for consultation with local people and a keen ear to identify individual and community concerns and gain the support of senior management to deal with them promptly. The questions asked will include:

Who are these people?
What authority do they have?
What are my rights as a landowner or tenant?
Do I have the right to say 'NO' to exploration?
Who do I go to for the settlement of disputes?
Who owns any minerals found?
How long will the exploration programme take?
What are they going to do?
What's in it for me?

Many of these questions will be asked not only by individual landowners/tenants but by the community as a whole. At the same time questions will be asked and concerns expressed about what happens if a viable ore body is discovered. The company's executives and public relations staff should consider these matters *before* the success or failure of the exploration programme is known.

The following public relations activities are suggested:

● ***Before exploration begins:*** Identify the individuals, community groups and special interest groups that are likely to be affected or become involved.

Ensure that they hear about the exploration programme first from the company and not from the media or some other third party.

At first contact provide individuals and groups with a simple document setting out their rights and the exploration company's rights and obligations.

Provide details of the exploration programme, who is involved, what will happen, how long it will take and the area it will cover. A contact name and number should also be given of someone in the company who can promptly and accurately answer questions and has the authority to deal with complaints. Consider the formation of a Community Liaison Group comprising people representing various interests, points of view and fields of expertise. The group should elect its own chairperson, be formed early in the exploration programme and meet regularly. The group is formed primarily to advise the company on the project and will become of critical importance if the exploration programme is successful and leads to the development of a mine and ore processing plant.

● ***During exploration:*** The local community, landowners and special interest groups should be kept up-to-date on developments and on any major activity and should always hear such information first from the company and not some third party.

● ***After exploration:*** Landowners and the community should be informed as soon as possible of the completion of the exploration programme and their tolerance and co-operation acknowledged.

The decision to proceed or not to proceed with mining and/or milling should be communicated as soon as possible. Any outstanding complaints should be promptly resolved and rehabilitation completed.

Uranium Mining and Ore Processing

The present practice in many countries is to prepare an environmental impact statement (EIS) before the development of any mine or construction of an ore processing plant. Even if not required by law an EIS is recommended as the most useful single document to give the public a good understanding of the project and to provide an opportunity for them to express their concerns and have their questions answered.

From the point of view of the company the EIS provides an inventory of the environment before the project begins, against which they can continue to measure the impact of their activities.

From the public's viewpoint the EIS gives in advance a detailed description of the project, its likely impact on the natural environment, its socio-economic impact and likely duration, and provides a proper basis for value judgements necessary for practical decision-making in respect of the project as it proceeds. *(See the examples in Appendix 1.)*

The draft EIS should be open for public and government scrutiny and comment and company response before the Final EIS is prepared and official authority sought to proceed with the project.

It should deal with all likely public concerns and questions before, during and after cessation of the project:

● Before the project, likely questions include:

How long will construction take?
What types of equipment will be used and what will the noise levels be?

What will be the composition of the labour force? How many will be single men?

Will they be housed in the local community or at a construction camp?

Will local goods and services be used and local people employed?

How will the yellowcake be dispatched from the plant and will it be transported through residential areas?

● During the project, likely questions include:

What is being done to control dust and monitor radiation levels?

Is the operation of the mine and/or processing plant matching the standards forecast in the EIS? Are the health and safety standards set by the authorities for plant workers and the public being met or bettered?

Who can I talk to about........?

● After the project, likely questions include:

Is the area going to be completely restored for public use?

Will the plant and buildings left be decontaminated?

Who will be responsible for the site and maintain it after the company has finished mining and/or processing ore?

How long will the closure and rehabilitation take?

Will there be any environmental and radiological surveillance programme after the project is finished?

How will the tailings dam be made safe?

The timing of the public participation programme is crucial to its success. As a general rule earlier is better than later. However, programmes must be designed specifically for each project and must be comprehensive, balanced and accurate. By addressing issues of concern early they can create a better understanding of the project and its objectives thereby improving the company's credibility with the public and helping to reduce opposition. They cannot, however, overcome all opposition.

It is important that public response to the project should be monitored and any public participation programme be modified in order to incorporate people's input. The objectives of monitoring are to identify outstanding issues of concern; to determine public preferences; to identify areas not being covered by the programme; to incorporate public input into the planning process; and to check if the public is receiving and understanding the information.

Public participation activities may include, but not be limited to any of the following:

Printed materials. Brochures, including a brief summary of the project, acknowledgement of the issues and opportunities for people to participate. They can be produced quickly, on a single issue if necessary, and are cheap. Newsletters can be produced at regular intervals to give up-dates about the project and the decision making process.

Public meetings. A public meeting is an open gathering to present information and exchange views. To be successful the meeting must be well advertised, if possible with an independent chairperson and company staff of proven experience. The advantages of public meetings are that information can be provided to a large number of people; the cost is relatively low; they are usually accepted as the most legitimate form of public consultation; the public is familiar with the process and is usually willing to be involved.

The shortcomings are that large attendance can limit the quality of interaction and exchange of ideas; the meetings do not ensure that all views are heard; and a vocal minority may dominate the meeting.

Community liaison groups. A community liaison group comprises people representing various interests, points of view and fields of expertise. Ideally the group should comprise less than 12 people, be formed early in the planning process and meet regularly. The chairperson should be elected by the group itself.

The advantages of public liaison groups are that a small group is best placed to investigate fully all the relevant issues; they improve the company's credibility by demonstrating a willingness to work with the community; members of the group become knowledgeable about the project; they provide a forum for two-way exchange between the company and the public.

Disadvantages are that the group cannot be a decision-making body because it has not had power to make decisions delegated to it by the local community; information does not always get passed on to the rest of the community; and the group may not be representative of the full range and balance of interests.

If community liaison groups are formed they should have a defined lifetime and pre-established, agreed rules of procedure. Also the method used to select members will reflect the credibility of the group. Never try to keep someone off the group.

Presentations to groups. Talks by senior company staff or consultants to the company may be made to community groups such as the Chamber of Commerce, the ratepapers association, conservation groups, parents and citizens associations and service clubs. Typically, such a presentation would be made at the group's regular meeting place and would consist of a short presentation followed by a period of questions and answers.

The advantage of presentations to specific groups include information can be matched to audience needs; groups with an identifiable interest can be targeted and reached; and group members may pass on information to others in the community.

Weaknesses include the possibility of hostile audience reaction; and the fact that without the use of other means of communication presentations of this kind can fail to reach sections of the community.

A presentation to a group provides a useful opportunity to develop a working relationship. A group should not be excluded just because it may not be supportive.

Other Activities. Other activities may include open days for the local community to visit the site and meet senior management; workshops and displays; advertising; news releases and newspaper feature articles; and radio and television interviews.

While not a panacea for all project ills, effective public participation can benefit a company by creating greater community acceptance of a project. By resolving people's concerns during the pre-planning stages the time and costs involved in obtaining necessary project approvals can be significantly reduced. For projects that are already in operation a good working relationship with the local community is every bit as important, particularly in periods of changing public values and environmental standards.

Uranium Conversion

Plants generally have to satisfy environmental impact assessments which deal with a number of factors. Public information professionals should extract relevant data from the plant's specific EIS or safety report.

All conversion processes use hydrofluoric acid (HF). Because of the environmental and health impact of this chemical, all effluent streams must be treated to remove the HF and contaminant uranium.

The waste types resulting from the refining and conversion of uranium concentrates to UF_6 are generally common to all facilities.Waste arises from two sources, waste products originating from the concentrates and waste products originating from the process reagents used. In general, wastes are handled by treatment and recycle or treatment and disposal.

Social, geographical and environmental factors to be taken into consideration include location, population density, geology, seismology, hydrology, meteorology, agricultural and industrial activities, the nature and dimension of the plant site and the local infrastructure.

Plant information staff should have information on the possibilities of, and measures taken to prevent aquifer and water contamination, and on waste from the plant and its disposal. They should have a checklist of all the radiological and chemical emissions, separately for each one, and be able to give information on the spot about what they all are, how much there is of each, and how they are dealt with and where they go.

All the above should be covered for normal operating conditions and also for abnormal operating conditions, including incidents and accidents, whether these are malfunctions in processes or unrelated - for example fires or airplane crashes. Prevention of incidents and mitigation of their consequences to living organisms should be included.

Information should also be available on water consumption; transport impact; noise; dismantling (restoring greenfield site); and on social factors including employment; numbers; skills; duration; health risk and precautions for employees; local availability; effect on local infrastructure; non-nuclear local development; relationship with local authorities; financial impact on local community, for example taxes; impact on property values; security aspects; safeguard measures; enclosure of site; and surveillance measures outside site.

The main cause of concern that is guarded against is chemical toxicity. Others are the possibility of unhealthy and dangerous working conditions, and, in case of recycled uranium, some radiological hazards. The economics of recycled uranium is frequently questioned.

Uranium Enrichment

At present, gaseous diffusion and the centrifuge process are the two principal processes in commercial use for uranium enrichment. Gaseous diffusion represents most of the installed capacity. In both these processes, isotope separation takes advantage of the slight difference in the atomic masses of the uranium-235 and uranium-238 isotopes.

The basic material used in the diffusion or centrifuge process is uranium hexafluoride, UF_6. All the environmental factors dealing with this compound are therefore also related to enrichment facilities.

The possible environmental effects of an enrichment plant due to UF_6 are radiological and chemical depending on the specific characteristics of this material.

The chemical discharges may be essentially hydrogen fluoride (HF), a highly corrosive chemical which is dangerous to human health. It arises from the potential hydrolysis of UF_6. This hydrolysis reaction also produces uranyl fluoride (UO_2F_2) which is the origin of potential radioactivity from uranium enrichment plants.

It is necessary to emphasize that in nearly 50 years of the industrial history of uranium enrichment, there has been no external release of these products, chemical or radioactive, which has caused damage to human beings.

The total energy necessary to supply a big diffusion plant (10 MSWU/a) is about 3000 MWe per annum, equivalent to three nuclear power plants of 1000 MWe at full power.

One concern is derived from another important characteristic of the enrichment processes: the thermodynamic yield is about one-third which means that two-thirds of the total energy applied to the enrichment process must be removed through very powerful cooling systems, with very large cooling towers. The large size of the plants and their very big cooling towers are the cause of most of the public concern about these plants.

Other concerns may be derived from the quantities of natural UF_6 feed to be managed by these facilities and the quantities of wastes or tails coming from the depletion part of the cascades.

Fuel Fabrication

The fabrication of uranium fuel is similar to other chemical processes. The chemical toxicity of uranium is comparable to that of other heavy metals and higher than its radioactive toxicity. So the licensing process and impact assessment can be compared to the usual acceptance procedure for industrial installations The following items are therefore pertinent:

Surroundings: This includes the location, and maps of major population concentrations in the vicinity and nearby installations.

Geology: Subsoil; rock; seismic behaviour described for the public in a historical context. You may say that in the last hundred years the biggest shock was in (date), and did such-and-such amount of damage; for the educated public you might use a known scale (such as the Richter scale).

Hydrology: Ground water table/flows; surface water table/flows.

Meteorology: Winds; inversions.

Local activities: Agriculture and food manufacturing; all other industrial activities; local infrastructure.

Plant itself: Area of site; use of site; size and type of buildings including appearance and density.

At present each fuel assembly consists of zirconium tubes containing UO_2 pellets. Before fabrication of the pellets, uranium which is delivered as UF_6 has to be converted into a stable dioxide (UO_2). After undergoing various treatments, the UO_2 powder is compacted in a press into small cylindrical pellets, which are then sintered and ground. The pellets are then loaded into zirconium tubes and the tube ends are sealed by means of welded plugs.

After successfully passing numerous inspection and testing procedures, the completed fuel assembly is ready for shipment and placement in a nuclear power reactor.

As uranium dioxide is a very heavy stable material, the environmental impacts of such plants are low; nevertheless a number of precautions are taken. The wastes are, as in all nuclear installations, safely stored, treated, and recycled when possible. The discharges to the environment are limited and controlled and have never exceeded in recent years the limits specified in the certificates of authorization.

The transformation of UF_6 into dioxide, the fabrication of uranium dioxide pellets and to a lesser extent, the rods' loading and welding, and the final assembly present some associated risks. These include chemical risk from hydrofluoric acid emission; risks linked with the presence of nuclear material such as contamination, irradiation and criticality; fire, earthquake, flood and sabotage risks; and usual hazards of industrial processes.

The safety of employees is ensured primarily by the design and construction of the plant and by the procedures for its maintenance and operation.

Although the public is not very concerned about uranium fuel fabrication itself, the questions asked relate more to the use of uranium and subsequent generation of wastes than to fabrication. Some companies have been involved in active public information plans. The following is extracted from a presentation by ABB ATOM at PIME'89, the European Nuclear Society's Public Information Materials Exchange conference.

"For more than ten years ABB ATOM Nuclear Fuel Facility in Sweden has gained a lot of public attention. When the nuclear power debate was coming up in the middle of the seventies, the Nuclear Fuel Facility very soon became a spectacular object. It provided a possibility to bring factual information about nuclear power to the public. Today that public interest still exists.

"For ABB ATOM the facility works as a tool of information activities in several ways, as a solid base for ABB ATOM's presentation of nuclear power technology to the public. This is valid especially to satisfy the local school demand for a real life object complementary to the theoretical nuclear technology education.

"Beyond the fact that the Nuclear Fuel Facility is a very effective fuel production plant, it is not too wrong to see it as an important resource for education as well as a tool for improved public relations. The Nuclear Fuel Facility is subject to attention from a lot of various groups in society. Politicians, authorities, journalists and customers all have an interest in how the facility is operated. For that reason it is important for the owner to carry out an impeccable performance.

"Probably the most important part of the public groups are their local representatives, not to forget employees of ABB ATOM. The local interest is mainly concentrated on two things. First, how is the Nuclear Fuel Facility expected to affect the surrounding environment? Second, how will it develop as a significant local employer?

"The information demand of the various groups is very complex. The customers need to know that ABB ATOM can provide qualified technical competence and reliable supplies. In the same way the

Box 4. MOX (Mixed Oxide) Fuel Fabrication

Plutonium, generated during fuel irradiation in reactors, can be separated by reprocessing. Mixed oxide (MOX) fuel fabrication permits the recycling of this plutonium into light water reactors. In the process mostly used in Europe, plutonium dioxide powder is mixed with uranium dioxide powder. In Japan, a process has been developed in which uranium and plutonium nitrates are denitrated together to fabricate MOX. Thus plutonium oxide is not produced separately. The uranium can be natural uranium or depleted uranium, which is plentiful as a byproduct of the enrichment process. The uranium powder has very little radioactivity. The plutonium powder is an alpha emitter, so the process has to be contained for protection. Ageing plutonium may have increasing gamma-radioactivity due to the formation of americium.

The fabrication steps are:

- blending of uranium and plutonium components
- manufacturing of ceramic pellets
- loading and sealing of cladding tubes
- assembly of tubes into bundles

There are MOX fabrication plants in Belgium, Germany, France, Japan and Great Britain.

Like other nuclear fuel fabrication, MOX fabrication *per se* raises few public questions but because plutonium is involved it tends to highlight the perceived association between the civilian and the military applications of nuclear energy.

Here are some of the questions asked about MOX: Does MOX change the operation and safety of nuclear power plants? Can it be used in any plant? Is reprocessing the sole alternative? Is recycling compulsory once plutonium has been separated? Is it the only way to use it?

The use of MOX does not induce important modification in the operation of a nuclear power plant when the amount of recycled fuel assemblies is limited to 20% to 30%.

The fuel assemblies are externally identical and the reactor will operate in a similar way to those using conventional fuel. There is very little difference between fresh or irradiated fuel handling if the correct procedures are followed.

There has been, on the whole, fairly little public concern about the MOX plants. Reactions come more from local authorities seeking reassurance that the local population will have a voice in the process that assesses the environmental impact of the facility.

Questions raised in the past were mainly concerned with the adequacy of the location: proximity of an airport, risk of contamination of the water aquifer, seismic stability, ease of access and safety of increased transport activities of dangerous materials, infrastructure suitability for the evacuation of the population in case of an accident. Most of the present fabrication plants are operated or under construction inside or in the immediate vicinity of existing nuclear research centres. Typically, they are not large buildings. They are not noisy and do not emit smoke, dust or other wastes. Thus, they are fairly acceptable neighbours in that area.

Siting factors

Some of the siting factors to be taken into account and presented to authorities are as follows:

- *Location:* Population density, nearby installations, villages and towns in the area, etc.
- *Geology:* These characteristics are presented to support the environmental impact assessment. Seismic considerations are predominant. Although the Richter scale may now be fairly well known by the public, historical events and their limited impact are the best reassurance.
- *Hydrology:* It must include aquifers, lakes, artificial reservoirs, canals, and other waterways.
- *Meteorology and climatology:* Of the climatic conditions the most important data are wind regimes and inversions. This is connected with the dispersion of plant exhausts both in normal and accidental conditions.
- *Local activities:* A major concern is the potential impact on agriculture and food production. This must be given in a detailed form because of the impact of radioactive releases on food production. In normal operating conditions, drinking the milk from neighbouring cows at a rate of 0.5 litres per day would give doses ten million times below the permitted level, with negligible consequences.Local infrastructure: Roads and access, impact of materials and personnel transport, amenities.
- *The plant itself:* Location, size, numbers employed, potential pollutants are provided to the public during construction and operation.

Environmental factors

Environmental factors requiring special consideration are:

- The public is very concerned about waste reprocessing and storage, wondering what the best solution is, how to make the waste harmless and how it is currently handled. Some people believe MOX would produce more waste both in volume and hazard if recycled many times.
- People tend to believe that plutonium emits very dangerous radiation and that the long-term ef-

fects are not known, particularly for plutonium recycle. They have frequently been told that plutonium is the most toxic substance known to man.

- What could potentially happen in a MOX plant? People hope to be well-protected by a competent authority that could act quickly and efficiently in case of accident and that the plant is designed to resist earthquakes and other natural hazards.
- The population wants assurance on the security of transportation measures, especially against accident and sabotage.
- Since facilities have a finite life, local populations are afraid of what might happen during the dismantling of a plant and what would become of the site afterwards.
- There is a general feeling in the public that nobody knows exactly what the practical consequences are of the use of plutonium, for people and their environment.

The last statement describes the dilemma and difficulty of the public information specialist who attempts to translate technical language into meaningful information in a context of time and toxicity. There is no doubt that plutonium is toxic, but it is certainly not the most toxic material as some people have claimed. It is not even the most dangerous alpha emitter. It should not be absorbed or inhaled. Small amounts that stay in the lungs or are transferred to the blood through wounds, could slowly induce tumours in the lungs, bones or liver that might lead to death after ten years or more. Time is an important factor as it leaves the possibility to act: the absorption of plutonium is easily detected and therapeutic methods have been developed to eliminate this plutonium.

Compared to some fission products, plutonium is far less radioactive. And it is less chemically poisonous than more conventional products like mercury.

Are there special wastes produced due to the decision to recycle plutonium? Reprocessing will create a larger volume of wastes of low and medium range activity but it will reduce the high level waste volume to some 40% of their volume without reprocessing. It is clear that waste does not disappear in this process but instead of having to store spent fuel for ever the wastes can be conditioned, preferably as vitrified glass, or ceramics in the case of long-term high activity fuel residues. Such a process is already applied, for example at Eurochemic in Belgium.

During fabrication operations, there has been a constant reduction in the amount of plutonium-containing wastes produced. Present levels are: in solid wastes, the amount of unrecoverable plutonium is lower than 0.001 of the manufactured quantities; in the liquid wastes, it is even lower — down to 0.0001.

Social factors

Social factors of concern are:

- Human errors are always possible. How far can we trust specialists? The qualification and experience requirements must be very high. And it is perceived that it is dangerous to work in a plutonium plant despite the safety measures that are applied.
- The proximity of a plutonium plant is seen as dangerous for the population and requires expensive investments. Local authorities worry about how their opinion is taken into account when, for example, the infrastructure is put in place for handling potential emergencies.
- Reprocessing is perceived to encourage proliferation. That MOX is a good solution has yet to be proved. Is the present system of controls adequate to the expansion of plutonium related activites? What are the implications for international nuclear relations? These are questions that may arise.
- Experts try to justify economically the recycling of plutonium. Nevertheless a lot of people are against MOX plants, arguing that they are not technically and economically viable. The economic advantages of MOX fuels must be demonstrated.
- Finally, what is the projected scale and structure of the civilian plutonium business in the 1990s?

The expansion of MOX fabrication plants depends upon the amount of plutonium available from civilian reprocessing plants. The quantities of MOX that might be fabricated at the end of the century will be lower than 300 t/year in Europe. This would represent the reloads (30% of MOX per reload) of some 40 light water reactors.

The economical advantages of recycling MOX are specific to the local electicity producers' situation. Factors to consider are the price of uranium and enrichment, the cost of storing used fuel in pools, and the contractual conditions obtaining for reprocessing and storage of separated plutonium.

In terms of nuclear arms proliferation the plutonium is far less accessible in a reactor than in a storage vault. The IAEA is entrusted with the heavy responsibility of surveillance and safeguards all over the world, in cooperation with national regulatory agencies and other organizations.

A typical demonstration of the safeguard system's efficiency is given at the Belgonucleaire MOX fuel plant in Dessel. The plant at Dessel was the first such plant to be put under practical and formal international safeguards. The Belgian Government delegated its control powers to EURATOM which, with the IAEA, forms joint inspection teams. A computer-recorded 24 hours surveillance of any plutonium movement from glove-box to glove-box ensures that a permanent inventory is available at three points. Resident inspectors or frequent inspector teams visit and permanently qualify the inspection and control methods and inventory values.

Commercialisation of nuclear fuels is also governed by the so-called London Guidelines or Nuclear Suppliers Guidelines which set the minimal conditions for exporting fuels.

Physical protection must be ensured. This was the objective of a "Convention on the Physical Protection of Nuclear Materials" signed in 1980, again under the responsibility of the IAEA. These rules define, among other things, three categories of materials and the levels of physical protection to be supplied during international transport and storage. Storage of Category I and Category II must be under "constant surveillance by guards or electronic devices, surrounded by a physical barrier with a limited number of points of entry under appropriate control". For Category I, in addition, "access is restricted to persons whose trustworthiness has been determined, and which is under surveillance by guards who are in close communication with appropriate response force". Plutonium fits into Category I whenever there is more than 2 kg, into II from 500 g to 2 kg, into III under 500 g (III requires storage in an area with controlled access).

The local authorities are also involved in the control of plutonium plants at various stages of construction and operation. A dossier describing the plant and its local possible impacts is published and made accessible to the public. During operation, the town/village "mayor" is involved in the organization of safety and can thus either directly or through regional/national authorities influence the measures to be taken.Workers are constantly under medical surveillance and accidents involving plutonium absorption have been very near to zero, e.g. in Belgium during thirty years of operation of the plutonium fuel refabrication plant. Plutonium can be handled safely if the necessary rules are followed. Two facts are favorable in limiting the risks of absorption: it is dense and nonsoluble in water in the form used. Plutonium is used in the factory essentially in the form of oxide. Its density is then comparable to that of lead. Thus it does not disperse if it escapes from a container by accident; and, in the form of nitrates used during some part of the transformation process, it is only soluble in strongly acid media. Otherwise it precipitates and, in water, immediately forms oxides again.

Plutonium handling is always done in a controlled atmosphere inside glove-boxes. With the increase of recycled plutonium activity, two actions are taken: shielding of some parts of the process and automation. Automation can, among other factors, reduce the amount of dust in the boxes that inevitably deposits on the plexi-glass walls. It is effective in reducing operating personnel exposure, but one must be careful that it does not increase maintenance and service personnel exposure, causing longer down-time due to replacements of parts or change of toolings.

As mentioned earlier, the public is more concerned by the use of plutonium in reactors and by its existence and generation rather than by the fabrication plant itself. The possible military uses of plutonium is a continuing factor in the nuclear debate. The fact that, during the generation of electricity, plutonium is generated in existing reactors and contributes to our primary energy uses is more or less ignored. The debate is dominated by questions about the toxicity of plutonium, the increased risk of proliferation, and the possibility of terrorist action.

To allay such anxieties, logic and rationality are not always sufficient. Images created by the military uses of plutonium have become entrenched. The bombing of Hiroshima and Nagasaki and the apparently careless handling of plutonium at military sites are cudgels that are constantly used to beat the civilian nuclear program over the head.

It is a plausible assumption that some countries or political groups could have attempted, or will attempt, to divert plutonium. Diverting MOX in the fuel cycle is not the easiest and most efficient way to obtain plutonium. The risk that nuclear fuel falls into the wrong hands must not be neglected, but the risk of this happening as a result of civilian nuclear activities is small.

Thus we can conclude, like the Nuclear Control Institute, that "the risks of nuclear terrorism are real and potentially devasting, although its likelihood is still very low".

Safeguards are a positive action. Their implementation by an independent organization under the control of the highest democratic international institutions is essential.

Public concern about plutonium has been associated mainly with fast reactor development and reprocessing. For MOX recycling in thermal reactors, public concern has been expressed essentially by specialized professional and political groups. It centres around risks outweighing benefits, fear of proliferation and terrorist activities, fear of accidents, radiological hazards and toxicity, dangerous and unhealthy work, secrecy of operation, and claims that MOX is uneconomic. An example of public concerns and responses to them is the Melox plant in Marcoule, where concerns of the local population and of political and ecological groups have led to an organized opposition. Cogema has responded by arranging plant visits for employees, press, local policy leaders and other interested parties, and by distributing appropriate printed information.

information demand of the nuclear authorities is very well defined. Rules and regulations clearly point out what is to be followed up. We talk about regulations of environmental impacts from releases of uranium or chemicals to air or water, but we also talk about labour's radiation protection and uranium safeguards. In addition to this, the authorities require administrative information on uranium transportation or information needed to support issuance of necessary import/export licences.

"An ordinary visitors' programme includes a brief oral company presentation together with some basics on nuclear power technology, and guided tours through the workshops of the facility. The tours make it possible for the visitors to have direct contact with the personnel at the facility. As the guides to a great extent are technicians or foremen from the workshops, this contributes to the visitors' confidence. They get an opportunity to meet 'ordinary working people' and are not taken care of only by 'public relations professionals'.

"The employees of the Nuclear Fuel Facility also have another important task in acting as 'ambassadors' for the facility towards the public. That role requires a solid knowledge about the company and the facility operation. For this, and other reasons, ABB ATOM recognizes internal information as a very important task. For several years there has been provided a personnel paper, internal newsletters and regular internal information meetings.

"Occasionally open-house activities have been organized in addition to the regular visitors' service. The employees, their families and their relatives were invited to these very popular activities. There is no doubt about the positive contribution to the public goodwill of the Nuclear Fuel Facility, gained from the open-house activities."

Fuel in Use — Power Reactors

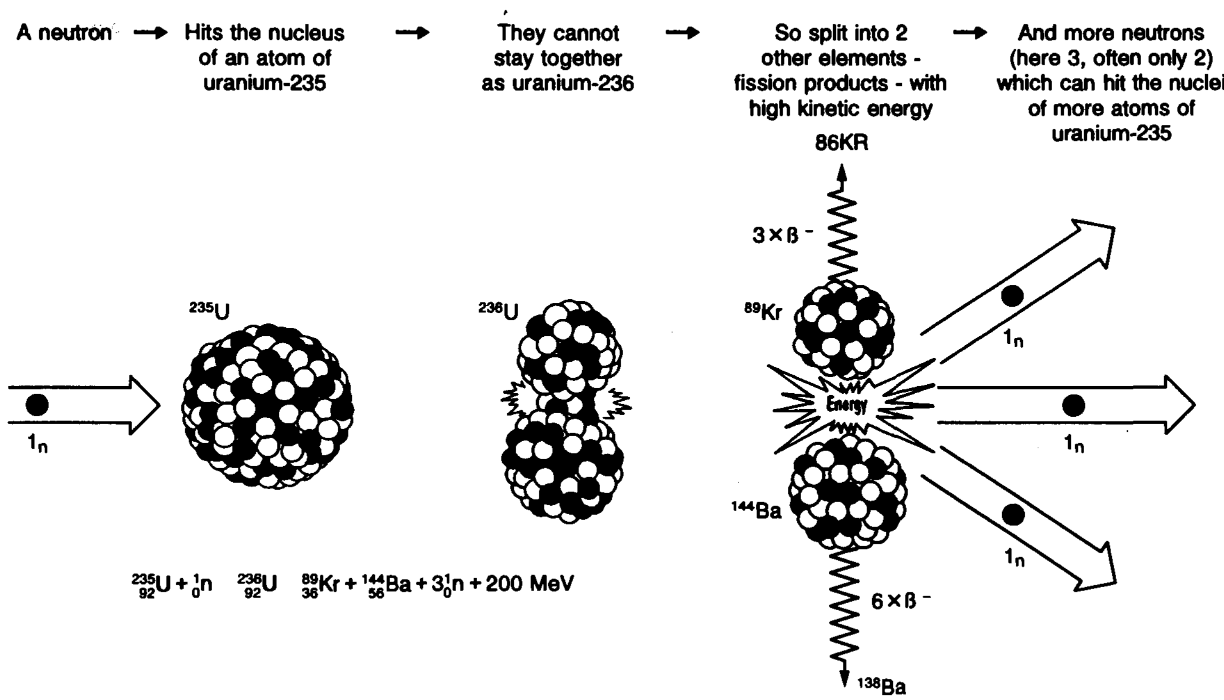
In all nuclear reactors energy is produced within the fuel by a chain reaction of fissions of the nuclei of its atoms. Each fission splits a fuel atom into two new "fission product" atoms and also expels from its nucleus two or three neutrons which cause fission in other atoms. *(See Figure 4.)*

Thermal reactors use materials called moderators to slow the fast neutrons produced by fission so that these neutrons can more easily fission other uranium-235 atoms. Fast reactors use a fast neutron spectrum, i.e. there is no moderator. Thus, they can use plutonium-239 — which captures fast neutrons — as fissile material and they can breed plutonium-239 by neutron capture in uranium-238, which is thus transformed into plutonium-239.

The chain reaction can be controlled by the use of materials incorporated into control rods which can be moved in or out of the core of the reactor to control the reaction rate.

The heat produced by the chain reaction is removed from the reactor core by a liquid or gaseous coolant, which directly or indirectly produces steam to operate the turbine and also prevents the reactor core from getting too hot. The steam is then used in the same way as steam made in a coal, oil or gas fired

Figure 4. **Typical Example of the Fission of Uranium-235 and Radioactive Decay of its Fission Products**



power station: it drives a turbine which powers a generator which produces electricity. In research reactors, the generated heat is dissipated via water coolers. *(See Figure 5 for diagrams of the most common reactors in commercial operation.)*

The safety requirements for nuclear power stations account for a large part of nuclear power station hardware, operating strategy and cost. Precisely how the safety requirements are fulfilled differs for the different types of reactors, but the fundamental safety principles are the same for all nuclear power reactors.

During its licensing procedure, each nuclear installation has to prove that no allowable limit of radioactive release will be exceeded, not only during normal operation, but also under fault or accident conditions. The priority is to prevent failures rather than simply to mitigate their consequences, but the design also has to allow for dealing with failures if, inspite of all precautions, they do happen.

To protect a nuclear power plant several different safety systems are designed and built-in. There are three basic safety features: inherent safety characteristics, passive components/systems and active components/systems. These are used in various combinations.

Inherent safety characteristics make use of the laws of nature to keep the power plant safe. They, therefore, work on their own to maintain the reactor in a safe condition or to return it to one if something goes wrong. An inherent safety characteristic found in most power reactors is the circulation of the coolant by natural convection when the circulating pumps fail to operate. An example of the passive safety systems is the dropping of shutdown control rods in some reactors by gravity alone.

No operating commercial nuclear power plant of current design uses inherent and passive systems alone to control every accident. All need active safety systems as well. These need some activating signal and a power supply or an activating signal combined with a passive execution. Inherent and passive systems are not necessarily superior to active systems. Active systems can control a wider range of parameters efficiently, and their function can be tested unrestrictedly. The safety of nuclear power plants is ensured by a good combination of all three rather than by a choice between them. The most recent reactor designs make extensive use of passive safety features.

In any technical activity, adverse human factors including mistakes or even deliberate errors can never be entirely excluded. However, their effects can be minimized and mitigated by design and quality assurance, control, the self-regulating characteristics of reactors, and automatic safeguards on safety-related operations. These automatic safeguards are similar to those which are applied on underground trains and elevators to prevent them from starting unless all doors are shut. A high degree of automation, particularly of safety-related functions, is necessary to relieve personnel as far as possible from the need to take quick decisions under stress.

Most nuclear power reactors adjust to change in power output automatically and generally these changes are slow. This, together with the application of proven and reliable control equipment, makes their safety virtually independent of manual operation. They are also truly "forgiving" because their design allows time for dealing with all kinds of failure.

There are many basic design safety principles common to all reactor systems. Descriptions of the most important of these — redundancy, diversity and physical separation, and the multiple barrier concept and defence in depth — follow. At all times there must be a correctly working system to fulfill each protection and safety function. The most important design principles to ensure this are:

System Redundancy. More components or subsystems of a safety system than are needed to make it work are provided.

Diversity. Two or more systems based on different design or functional principles are available for the same safety function.

Physical Separation. Components or systems intended to perform the same function are separated physically.

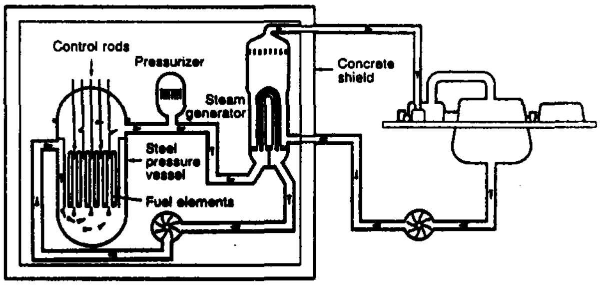
The Fail-Safe Principle. Components or systems are designed to fall automatically into their safest condition if they fail, or if power is lost.

The basic preventive measure against release of radioactive material is very simple in principle: a series of leak-tight barriers is put between the radioactive material and the environment in order to provide a shield against radiation and to contain the radioactive materials.

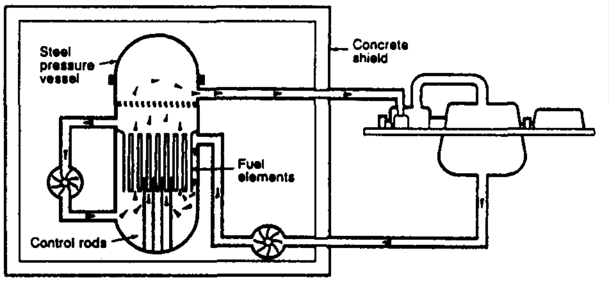
The innermost barrier is the fuel itself. The metallic or ceramic matrix of the fuel retains most of the fission products. The second barrier is the leak-tight and corrosion-resistant cladding of the fuel. The third is formed by the primary pressure-bearing boundary of the reactor coolant system. This can be a heavy steel or concrete vessel or a multitude of tube channels built to withstand high pressure. The coolant system itself may include cleaning and filter systems. Finally, most reactors are also either enclosed by a pressure resistant containment which forms one or two barriers — primary and secondary containment. In some other plants, the last barrier consists of a reactor building (confinement) which can be sealed automatically and vented safely through filters to the environment.

The basic aim in nuclear power plant safety is to maintain the integrity of the multiple barriers. This is assured through the defence in depth approach, which can be characterized by three levels of safety measures: preventive measures, protective measures and mitigative measures.

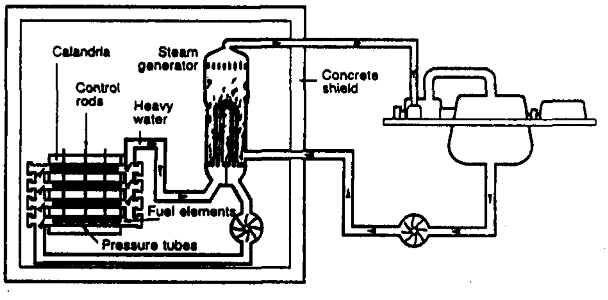
Figure 5. **Diagrams of Types of Nuclear Power Reactors**



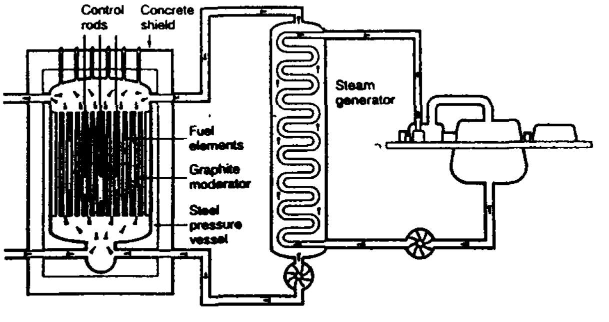
Pressurized water reactor



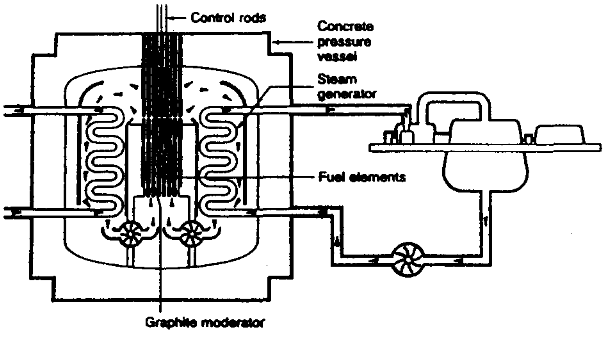
Boiling water reactor



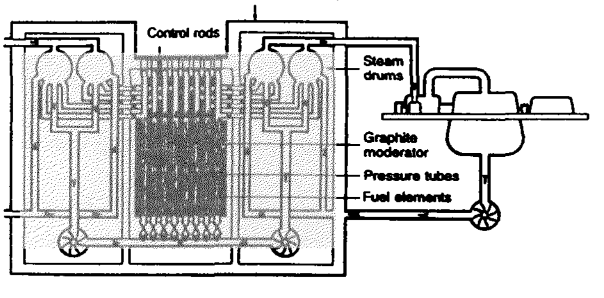
Pressurized heavy water reactor (Candu)



Basic gas cooled reactor (Magnox)



Advanced gas cooled reactor



Boiling light water, graphite moderated reactor (RBMK)

Source: UI, UKAEA

Box 5. Questions About Nuclear Power Plant Operations

As with any major undertaking, the public has questions about the effects of normal reactor operation and the possibility of accidents and their consequences. These should be addressed separately to avoid confusion. Many of the questions about normal operation also apply to consequences of accidents, but the extent and significance of possible effects are very different. For normal operation, there are years of experience and a large body of data to provide answers, but for accidents, because they have been few and each one unique, it is necessary to use estimates.

Questions which may be expressed in relation to normal operations are:

How long will construction last?
How will it affect the environment?
Will it be noisy and disruptive?
What will it look like?
How much space will it take up?
How much water is needed for cooling and what environmental effects will that have?
How is contamination of local water sources prevented?
Does the reactor affect the local climate?
Is food grown nearby safe to eat?
Is there a health risk to people living nearby?
Is there a health risk to workers?
Could material be stolen to make a nuclear bomb?
Is the waste properly dealt with?
What will be done about the plant when operation is over?
Will the area need to be isolated and guarded for decades afterwards?
When will the area be restored for normal use?

Questions which may be asked about accidents include:

Could this reactor have an accident like the one at Chernobyl?
Can a reactor blow up like a nuclear bomb?
Could an earthquake, tidal wave or other natural disaster cause an accident at the reactor?
What is done to stop sabotage or terrorists?
What plans have been made for accident management and protection of the local population, for example by evacuation, distribution of iodine?
How and how quickly would people be informed if there were an accident?
Who decides what information would be given to whom?
Are the local emergency services involved in the emergency plan?

Nuclear safety does not depend only on technical and scientific factors. In an open scientific community, with a free and international exchange of knowledge, experience and feedback from any accidents, it is unlikely that any major harmful aspect of nuclear safety remains unexplored after more than 30 years of development and operating practice. Further, in societies with a clear separation between executive, legislative and judicial powers, it would be difficult to neglect or sacrifice any aspect of nuclear safety to other goals with impunity. Regulatory control provides an independent verification of all safety aspects of the plant. Above all, however, nuclear safety is primarily ensured, not by laws and regulations, but by responsible design and operation.

A nuclear plant has to be designed, constructed, operated and maintained in accordance with the applicable governmental rules and regulations. The licensing procedure and the continuous regulatory control, including radiation monitoring of the plant and environment by independent authorities and experts, occur in accordance with the respective laws.

Almost all the fission products formed during the generation of electricity by a nuclear power plant are retained in the fuel elements. A small fraction can, however, escape into the coolant and add to radionuclides produced by neutron activation of the structure. Most of the radionuclides are removed by gaseous or liquid processing systems. Part of the radioactive material may eventually be released into the environment.

These wastes are minuscule in volume, however, when compared to the wastes from burning fossil fuels, and they can be isolated almost entirely from the biosphere.

Nuclear power plants in normal operation cause very little environmental detriment and are beneficial when they replace plants which would emit CO_2, SO_2, and NO_x. In this respect they would help to reduce acid rain and limit greenhouse gas emissions.

Permissible radiation exposures of the public and of nuclear workers are limited by law. The limits are decided nationally, but follow, or are more stringent than, the recommendations of the International Commission on Radiological Protection (ICRP), which are usually embodied in a country's own national legislation.

The risk specific to nuclear power stations is leakage of radioactive products into the environment if all safety barriers were to fail. Permanent monitoring of the environment is a special task of normal plant operation.

There is no danger of a nuclear power reactor exploding like a nuclear bomb. A bomb requires fuel with more than 50 % uranium-235, whereas reactor fuel has only 3% uranium-235. The configuration of the fuel and the fact that it is immersed in water which slows down neutrons are also among the reasons why a reactor cannot explode like a bomb.

Most of the waste heat in the nuclear fuel cycle (about 93%) is discharged to the environment during reactor operations.

All steam-powered electricity generating plants, whether fossil-fuelled or using uranium, have a common potential problem in their need to release waste heat to the environment. Heat from combustion of fossil fuel or from the fission of uranium in a reactor produces steam at high temperatures and pressure which, in turn, drives a turbine connected to a generator. The 'spent' steam from the turbine is condensed by passing large amounts of cooling-water through condensers. Modern steam turbines operating with conventional fossil-fired boilers attain thermal efficiencies of 37% to 43% but the steam conditions of nuclear plants are such that the turbine efficiency is lower, about 30%. In fossil-fuelled power plants about 10 % of the total heat of the boilers is released to the atmosphere with the flue gases whereas in nuclear power plants essentially all the heat from the core is used to generate steam. Despite their lower turbine efficiency, there is therefore no significant difference in terms of total heat release to the environment between nuclear and fossil-fired plants in producing an equal amount of electricity. However, if once-through cooling is used, a larger amount of unused heat is released to the receiving water from a nuclear power plant than from a fossil-fuelled plant.

Environmental Impact Assessment Studies are done before siting a nuclear power plant to determine thermal effects on aquatic communities such as fish and plankton. Interest is mainly centred on how heated discharge affects metabolism, physiology, growth, reproduction and population dynamics. Again, monitoring the ecosystem continuously is an essential activity at a nuclear power plant.

Experiments carried out with the dual purpose of limiting thermal releases and making use of waste heat discharges have shown positive results. Pilot installations which have already been built adjacent to nuclear power plants, particularly in France at Cadarache, Grenoble, Pierrelatte, St. Laurent-des-Eaux and in Germany are serving as models for systems involving several hundreds of hectares which will be or are already being developed.

Using waste heat in sealed pipes in the soil has advanced crop growth in market-gardening enterprises by one to three months and has doubled the yield of crops such as potatoes and strawberries.

Thermal releases from nuclear power plants should therefore no longer be considered as having exclusively negative effects on the environment. These releases can have a beneficial effect on the local economy, improving plant, animal and fish production and creating areas of permanent plant growth to improve the landscape.

As with any major undertaking the public is concerned about the effects of normal reactor operation and the possibility of accidents and their consequences. These should be addressed separately to avoid confusion. Many of the concerns about normal operation also apply to consequences of accidents, but the extent and significance of possible effects are very different. For normal operation, there are years of experience and a large body of data to provide answers, but for accidents, because they have been few and each one unique, it is necessary to use estimates.

The accidents at Three Mile Island in 1979 and at Chernobyl in 1986 cast long shadows over the nuclear industry and raised public anxiety to unprecedented levels. While no fatalities resulted from the TMI accident, 31 people died as a result of the accident which destroyed the reactor at Chernobyl. There were two immediate deaths from burns and multiple trauma. About 200 people suffered acute radiation sickness, 29 of whom died during the three months following the accident. The debate over the long-term health effects will continue for many years.

Why Chernobyl happened has been discussed in great detail in many publications. The accident or its aftermathwill not be analyzed here except to say that it serves as a constant reminder of the demands upon nuclear communicators to discuss knowledgeably and honestly the technical, social, environmental and institutional aspects of nuclear energy. Nothing in this world is perfectly safe. But in comparison with other methods of generating electricity, or of the risks of doing without it, the dangers of nuclear power are very small. Communicating this is difficult but necessary.

In some countries Public Information Centres have become an integral part of day-to-day nuclear power plant operations. Indeed, in some countries information centres have been built off-site prior to plant construction and on-site at the very start of construction. As mentioned earlier, the role of visitors' centres is greatly enhanced when combined with tours of the plant itself. In Japan a recent innovation has been introduced: public viewing galleries are built into the plant design in order to give visitors a better perspective of the operation.

Public Information Centres range from simple to highly sophisticated. They may include reactor models, interactive displays, video theatres, conference rooms and restaurants. Some have elements of entertainment as well as education and information. Other have meeting facilities that are made available to community organizations. One Information Centre in Japan has a swimming pool as an added attraction for visitors.

A key component of a successful Public Information Centre is the quality of its staff. Well-trained, knowledgeable and people-oriented guides and information officers who can provide the public with quality contact are among the best assets that a nuclear power plant can have.

Interim Storage of Spent Fuel

Interim storage of spent fuel is carried out either at reactor sites or at "away from reactor" sites (AFR). The purpose of interim storage is to lower the radiation level and the heat from the spent fuel.

In a first step after its useful energy producing life in the reactor the then "spent" fuel (sometimes also referred to as "used" fuel or "irradiated" fuel) is removed to a spent fuel storage pool at the reactor site. There it is generally stored under water for several years. This pool is continuously cooled and decontaminated by filters and/or ion exchange resin beds.

As this first step of interim storage of spent fuel is usually closely related to the operation of the reactor it will in most cases be covered by the public communications programme for reactor operation.

Many of the spent fuel storage pools have, however, been re-designed, enlarged and re-licensed to accomodate more spent fuel for longer periods than originally planned. In such cases a special public communications programme may be required.

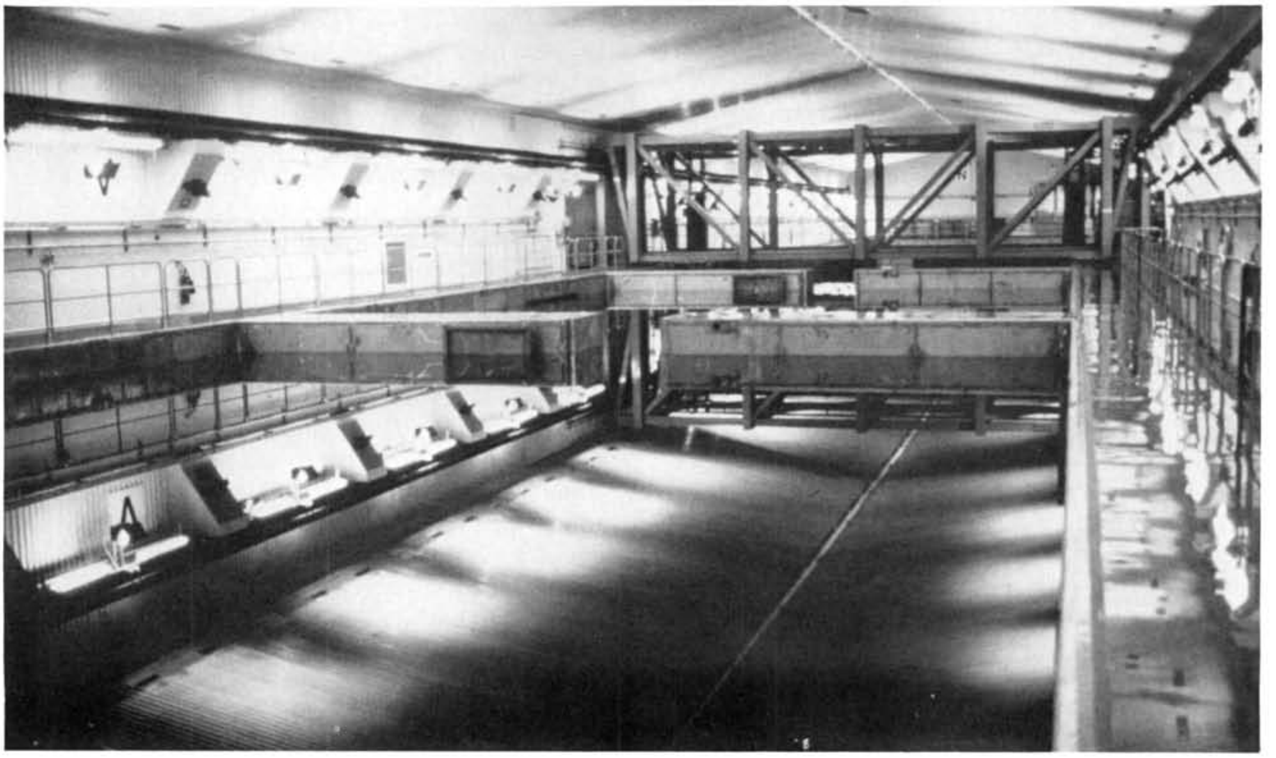
The reason for such modifications has mainly been the increase or burnup of the fuel elements demanding a longer period of cooling before further treatment by reprocessing or conditioning for direct disposal.

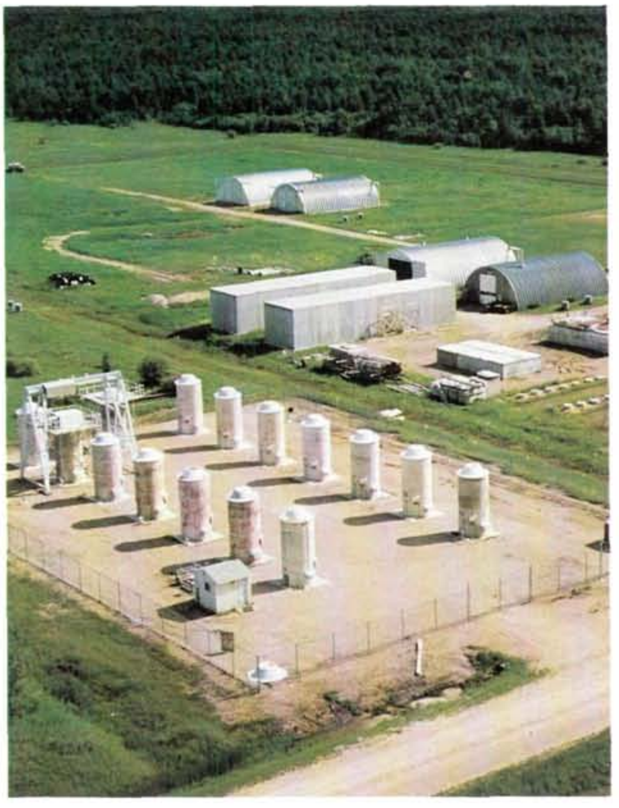
A method of storing spent fuel assemblies in special containers at the reactor site after the fuel has been stored in the storage pool for some years is also technically developed and commercially available. These containers can be constructed of radiation absorbing concrete or of cast iron and some have provisions for forced air cooling or convection air cooling.

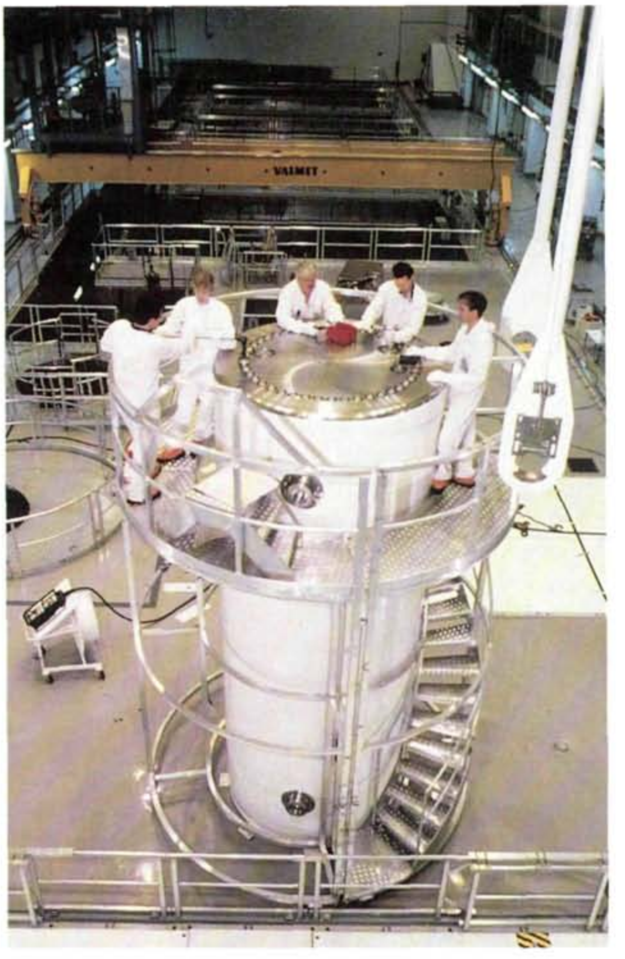
In some countries the spent fuel storage pools at the reactor are large enough to contain all of the spent fuel elements used during the lifetime of the reactor. In other countries this method is not licensable and therefore AFR-storage facilities have had to be built. Such facilities may use water pools with cooling and purification systems or different methods of dry storage in special containers or dry vaults. The licensed storage period may vary from 10 to 50 years, thus giving a significant reduction of heat evolution and of the radiation level. For example a storage period of 40 years brings the radiation level and the heat production of a spent fuel element down to 1/10 of the values appearing after one year of storage in the spent fuel storage pool at the reactor.

All nuclear power plants with light water reactors use water pools for the initial storage of spent fuel elements for periods between at least one year and normally 7 to 10 years. There are some other plants like gas cooled high temperature reactors which contain dry storage facilities for their spent fuel elements.

The pool inside Sweden's spent fuel storage facility known as CLAB.







Above: **An aerial view of a concrete canister storage facility for spent fuel in Canada.** *Right:* **The storage facility for spent fuel at Olkililuto in Finland.** *(Credits: (AECL, TVO)*

AFR storage facilities include: surface water pools at La Hague (France) and THORP (UK); surface water pools at Greifswald (Germany); underground water pools at CLAB (Sweden); dry storage in containers like CASTOR in air cooled storage buildings at Gorleben and Ahaus (Germany); dry storage in concrete canisters (Canada); and dry storage in concrete vaults (USA).

Here are some examples of interim storage facilities for spent fuel:

Sweden. The CLAB facility is situated on the Simpevarp peninsula in Sweden near the Oskarsham nuclear power station with its three reactors. The choice of site provides a number of advantages, for example access to a common harbour, central workshops, etc.

The above-ground complex consists of a number of interconnected buildings. The incoming spent fuel and core components are handled in a reception building. Directly connected with the reception building are buildings for auxiliary systems (cooling and purification of water, waste handling, ventilation, etc.), for service systems (pumps, heat exchangers, etc.) and for the electric power systems.

The actual storage building is located underground in a rock cavern whose ceiling is located 25-30 metres below ground level. The rock cavern is lined with concrete and reinforced with rock bolts. Inside the ceiling is a lining of sheet metal.

The rock cavern is 120 metres long, 21 metres wide and 27 metres high. It contains four storage pools and one smaller central pool connected to a transport channel. Each storage pool contains about 3000 cubic metres of water and can hold 1250 tonnes of spent fuel. The storage section can be expanded in future with additional rock caverns situated parallel to the first one.

The spent fuel is transported from the reception building to the storage building in a fuel elevator. The elevator shaft is connected to the storage pools by a channel. The storage building is also connected to the surface buildings through a shaft containing a personnel elevator, ventilation ducts and electricity and water supply.

The total capacity of the four storage pools is 5000 tonnes of uranium in spent fuel, with one additional pool in reserve. There is an open space below the pools so that they can be inspected for leakage at any time. The receiving capacity of the facility is 300 tonnes per year, equivalent to about 100 transport containers. The operating staff is about 75 persons. The construction costs of the facility were about US $300 million. The operation of CLAB is controlled and monitored primarily from a central control room by means of computerized control systems. In addition, there is local control equipment in the facility.

Box 6. Questions About Spent Fuel Storage

The most common questions concerning environmental effects from construction and operation of spent fuel storage facilities concern the following:

- the site area to be exempted from normal human activity
- possibility to locate the facility in a populated area, isolated area or underground
- radioactive waste treatment
- radioactive releases in air, or into water
- handling of solid or solidified waste
- consequences of natural catastrophes
- contamination in case of minor or larger accidents

In replying to these questions it must be made clear that the employees working in the AFR-facility as well as the public and the environment outside of it are being protected against damage from the radioactive substances in the spent fuel. It is, therefore, important that the fuel assemblies are protected against mechanical and chemical damage so that they are still in good condition for further handling even at the end of the storage period. Such protection is achieved either by handling the fuel assemblies under water or by keeping them in crashproof containers. Moreover, if there is any handling done it is done by remote control.

In pool-type facilities with the fuel covered by four to eight metres of water the radiation level at the surface of the water is so low that the personnel can work without any significant additional protection. The same is valid for dry storage facilities because of the shielding effect of the concrete or steel containers.

Here are some of the social issues that pertain to interim fuel storage:

- The benefits to the local community from construction and operation of the facility; extra road network; extra working places; no pollution from this kind of facility.
- Some drawback to the local community, such as bringing spent fuel from different parts of the country or even from different countries.
- The need to establish a system to provide information to the public in routine and emergency cases, both on a local and countrywide basis.
- The need to obtain information on AFR storage. The information could be provided as follows: contact on specially installed telephones, lectures, discussions, video and films at information centres, information by mail or through local press, radio and TV, visits to AFR facilities, ongoing information on the level of radiation close to the facility,
- The reliable protection of the facility against terrorist activities.
- International safeguards measures.

It is important that the company which runs the AFR storage facility establishes good contacts with local authorities, mass media and the population at an early stage of siting and construction. Public anxiety and fear could be allayed by a well-planned public information campaign run by the company and supported by the authorities. Such an information campaign must include the following activities:

- The development of public information programmes at different stages of the facility: planning, site exploration, construction, commissioning, operation.
- Information on the licensing procedure and regular meetings with the regulatory body at the site.
- Establishment of a Public Information Office (Centre) at or near the facility, or in the adjacent community.
- Establishing regular contacts with local people and politicians, through meetings, newsletters, discussion groups, liaison committees and advisory boards.
- Establishing and maintaining contacts with journalists.

At each stage, answers must be given to the public within the framework of the above information programme to the following questions which are frequently asked. They include:

What is spent fuel?

How dangerous is the spent fuel and for how long?

What is meant by interim storage?

How is it possible to handle spent fuel?

How much spent fuel has been produced up till now?

Can't spent fuel be stored at the reactor sites?

Will foreign spent fuel be accepted for storage in this facility?

What happens if the water (or air) cooling fails?

Can the heat from spent fuel be utilized?

What happens if the transport flasks fall off the lorry (or ship)?

Can the transport flasks explode?

What is done with the transport flasks when they have been emptied?

Can the spent fuel be used for production of nuclear weapons?

Who ensures that the spent fuel is handled in a safe way?

Is it possible for a local municipality to veto the construction of a storage facility for spent fuel?

What is the cost of interim spent fuel storage?

What are the advantages or disadvantanges for the municipality if an interim storage facility is built locally?

Canada. AECL (Atomic Energy of Canada Limited) began developing the dry storage method as an alternative to wet storage at the Whiteshell Laboratories in 1974 and has accumulated a lot of experience of dry spent fuel storage in cylindrical reinforced concrete canisters.

The canister is a thick-walled concrete monolith, containing baskets of fuel bundles in the dry state. The decay heat from the fuel is dissipated to the environment by natural heat transfer. The original canisters are situated in a field on the Whiteshell site.

During subsequent years, concrete canisters were tested to store fuel from Candu reactors. Between 1984 and 1989 all spent fuel generated by AECL's prototype reactors (Gentilly-1, Douglas Point and NPD stations) was safely and economically stored in concrete canisters, as part of the decommissioning activities. Utilities presently operating Candu reactors are also planning to put used fuel into dry storage.

Finland. The designed lifetime of the KPA Finnish AFR storage facility at Olkiluto nuclear power station is 60 years. For an individual fuel element it means 40 years interim storage time. After that time it will be possible to dispose of the spent fuel finally in the bedrock.

It is possible to enlarge the facility so that other core components can also be stored, e.g., control rods, neutron detectors, and so on.

It is possible to make wet fuel transport from TVO-I and TVO-II to the KPA store. Later it will be possible to construct an additional unloading line so that it is possible to transport fuel either wet or dry.

The KPA store conforms with Finnish rules, regulations and laws, and the international standards and regulations are fulfilled as applicable.

Germany. Two dry storage facilities have been built in Germany at Gorleben (Lower Saxony) and Ahaus (North-Rhine/Westphalia). Both are designed after the same principle with a large storage hall, having air inlets spread over the side walls and outlets in the roof so that cooling of the storage area by natural convection is enabled. The storage capacity of each facility is 1500 tonnes of uranium in spent fuel elements, contained in combined transportation/storage containers of cast iron (CASTOR-Containers). Cooling of the containers by natural air convection in the storage hall ensures that the fuel cladding and component temperatures are maintained safely below limits imposed by the licensing conditions. The maximum temperatures of the containers are also kept within the limits given by the IAEA regulations.

The storage facility consists mainly of the different areas for receiving the transport containers, for unloading and inspecting them, and finally for their storage in an upright position. The storage hall and the unloading cell are designed to withstand dynamic loads like earthquakes.

This type of storage facility was chosen because of its inherent safety characteristics which guarantee cooling. Even in the event of the building being hit by an aircraft the containers themselves are safe by design. Moreover, the facility costs are mainly those of the rather expensive containers so that the utilities which own and operate the facilities need to spend only a rather small initial sum for the buildings. Only with filling up of the store do the costs finally increase to match the costs of equivalent water pool storage, which itself has low operational expenses.

A pool-type storage facility for spent fuel elements has been built at Greifswald on the Baltic Sea at the site where four Soviet type VVER reactors were in operation and three other ones under construction. All reactors are, however, shut down since the unification of East and West Germany.

Reprocessing

Spent nuclear fuel contains about 1% of "unburned" uranium-235, more than 90% of the uranium-238 originally present in the fresh fuel, between 0.5% and 1% plutonium, as well as actinides and fission products. The mechanical and chemical processes to recover uranium and plutonium and to separate fission products and actinides are known as "reprocessing" of spent nuclear fuel.

Most industrial countries in the past 20 to 30 years have found themselves in the precarious situation of having to import energy. Energy imports — above all in the most-used form, namely oil — create political dependence and unfavourable balances of payment.

It is prudent and proper that we attach great significance to environmental protection, ecology and the recycling of materials, and that we aspire to the highest conceivable safety for handling and storage of wastes. The source and availability of raw materials and the need for environmental protection have a direct and significant bearing upon the question "Why Reprocessing?"

Whereas fossil fuel is burned up virtually completely in a single combustion process, only a limited amount of the energy content of nuclear fuel in a nuclear power plant is usable during one throughput. The so-called burn-up in today's light water reactors accounts for 3.5% of the uranium at most. Left over are about a quarter of the pre-throughput fissile uranium (uranium-235) and more than a third of the plutonium formed during reactor operation. Altogether, 95.5% uranium and 0.9% plutonium are still contained in the fuel when it has to be taken out of the reactor after use.

To be able to recycle the unused part of the uranium and the plutonium, one must separate them from each other and from the fission products. That separation takes place in the reprocessing of spent nuclear fuel. Recycling is a necessity from the standpoint of the husbanding of resources. That becomes evident when one realises that from a tonne of spent fuel (equivalent to two spent fuel elements from a PWR light-water reactor) uranium and plutonium is recovered with an energy content equivalent to 20 thousand tonnes of crude oil.

A reprocessing plant with a yearly nuclear throughput of 600 tonnes wins back as energy content the equivalent of more than 20 million tonnes of black coal. Both the above comparisons relate to the re-use of the regained uranium and plutonium in light water reactors. The utilization is many times higher in fast reactors.

As well as being a nuclear fuel, plutonium has an extremely long life as a radiotoxic material — so its separation by reprocessing and putting it to use again in a nuclear reactor represent a considerable defusing of the waste question.

Consequently, reprocessing means the harnessing of energy raw materials which one already has, as well as environmentally sound treatment of radioactive waste materials.

Spent fuel from nuclear power plants has been reprocessed in several plants for more than a quarter of a century. Not only is reprocessing technically feasible, but it has withstood long years of testing.

At the present time world prices of uranium are low, so it has been argued that there is no economic benefit to the electricity producer in reprocessing his spent fuel to recover the unused uranium and plutonium. But experience with world oil prices has taught that the price and availability of major fuels can change very markedly over a timespan shorter than that required to plan and build a spent fuel reprocessing plant. That is the prime reason for maintaining a policy of fuel reprocessing and of maintaining the option to introduce fast reactors which will provide the greatest independence from fuel prices in the longer term.

Spent fuel assemblies delivered to a reprocessing plant are first unloaded from the transport casks in order to be put into a storage facility. Stores may range from comparatively small buffer stores, to allow continuous feeding of fuel into the plant, to large capacity stores, providing space for extended interim storage of spent fuel assemblies. The storage facilities in general consist of water pools, provided with cooling and cleaning devices. Fuel assemblies are either being stored in fuel assembly racks or multi-element flasks.

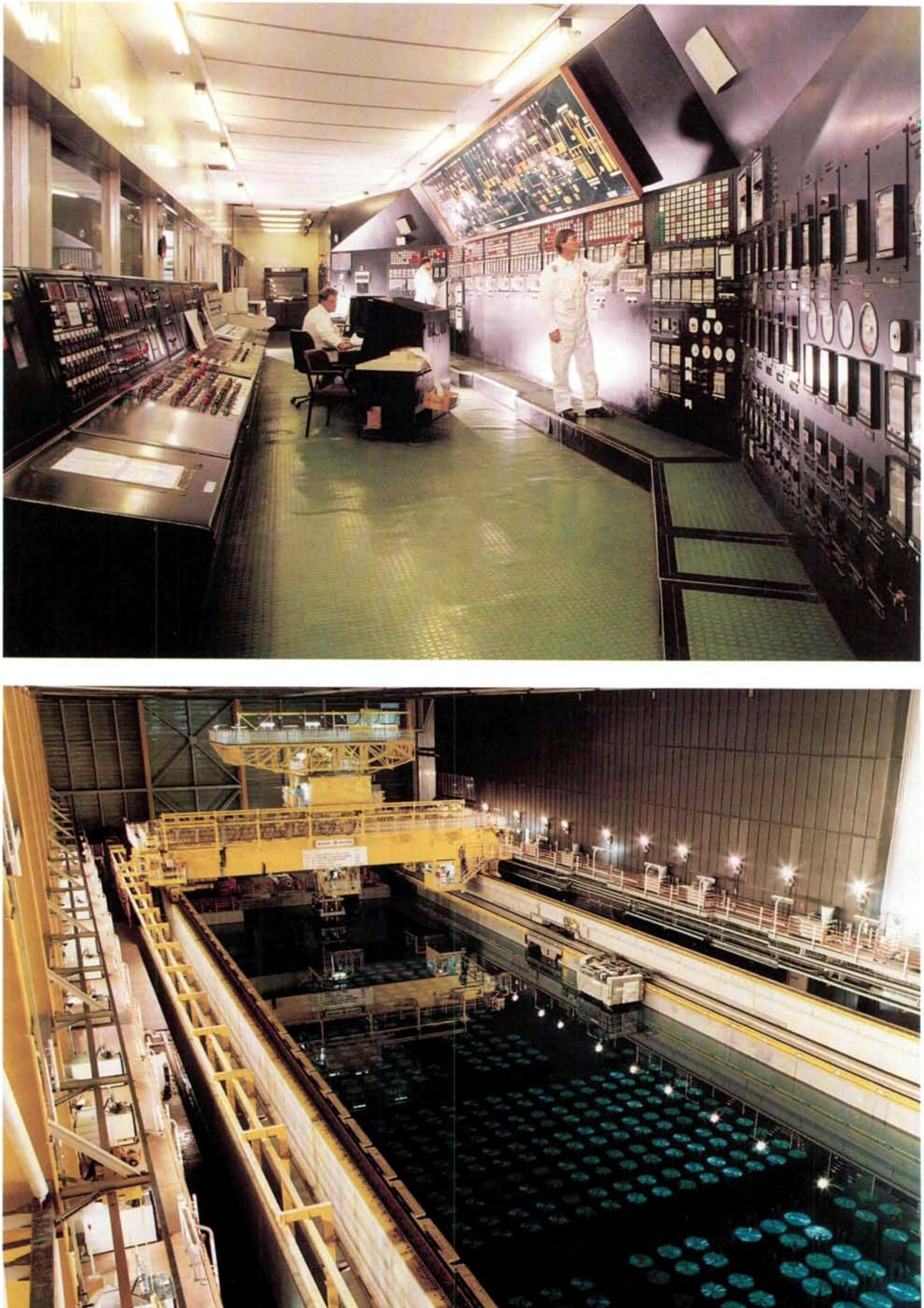
From the storage ponds the spent fuel assemblies are delivered by remotely controlled transport devices into heavily shielded hot cells, where the fuel is prepared for the subsequent chemical extraction process. This part of a reprocessing plant, known as "head end", comprises chopping of the fuel assemblies into short lengths with the aid of shearing machines and the dissolution of spent fuel in nitric acid in specially designed dissolver vessels. After clarification of the resulting liquid from insoluble residues, with either filters or centrifuges, the solution containing uranium, plutonium, other actinides and the fission products is transferred into the chemical part of a reprocessing plant as feed for the extraction process. Uranium and plutonium in the solution are then separated and purified by a solvent extraction technique, known as the "Purex" process. The basis of the process is the selective solubility of uranium and plutonium in tributylphosphate diluted with dodecane and kerosene. Being an organic solvent it can be separated from the aqueous nitric acid feed solution after having been loaded with uranium and/or plutonium. The extraction apparatus used is either pulsed columns or mixer settlers. Several such extractors are combined in an extraction cycle to allow extraction and re-extraction of the fissile material to be recovered. To achieve the specifications set for the recovered uranium and plutonium, up to three cycles in sequence are being used. In the first cycle, uranium and plutonium are co-decontaminated, to remove the highly radioactive fission products, and then separated into uranium and plutonium streams. In the second and, if available in the third cycle, the separated uranium and plutonium streams are further purified and concentrated by Purex solvent extraction technique.

The end products of the extraction are uranylnitrate solutions and plutonium nitrate solutions. Both solutions and mixed solutions are converted into solid oxides either at the reprocessing plant or at conversion facilities adjacent to fuel refabrication plants.

Waste products arise at each stage of reprocessing. These are pretreated where necessary and either recycled or stored for subsequent conditioning into solid waste forms, ready for long-term interim storage and final disposal. The bulk of the radioactivity is contained in the nitric acid fission product solutions, separated in the first extraction cycle. These solutions are concentrated and collected in high integrity stainless steel tanks, provided with redundant cooling systems. After interim storage of about one year, the fission product solutions are solidified by vitrification. The resulting glass is poured into stainless steel canisters, which after lid welding are stored for extended periods, awaiting later disposal. Liquid and solid wastes with medium- or low-level radioactivity are conditioned into solid packages by encapsulation in either cement or bitumen in stainless steel drums or containers.

Process off-gases are scrubbed to remove chemical and radioactive contamination and monitored before discharge to the atmosphere via stacks. Ventilation air is similarly checked before return to the atmosphere. Sewage water to be released contains only very small traces of radioactivity, well below official limits after having been cleaned by evaporation or chemical treatment.

For the public faced with the question of whether to accept a closed nuclear fuel cycle, the most important evaluation criteria are understandably the risks to the environment and population from operation



The control room and spent fuel storage pond at the Sellafield reprocessing plant in the United Kingdom. *(Credit: BNFL)*

Box 7. Questions About Reprocessing Operations

Regarding reprocessing operations, various questions have arisen. The questions, and responses to them, may be summarized as follows:

Concern:

That a greater amount of concentrated radioactivity will be released, because a large quantity of spent fuel will be processed at the plant.

That a serious accident similar to Chernobyl may happen.

Response:

A large amount of spent fuel from nuclear power stations is stored and reprocessed at a reprocessing plant. However, spent fuel is cooled at each nuclear power station site for at least about one year, and in general up to seven and sometimes to ten years before being carried to a reprocessing plant. Since the radioactive intensity is decreased to less than 1/100 by this time, a large amount of radioactivity is not concentrated at the reprocessing plant, unlike that at the nuclear power station.

The potential fire and explosion hazards are extremely small compared with those at ordinary chemical plants which are usually operated at high temperatures, while a reprocessing plant operates mostly at atmospheric pressure and at a temperature of about 100°C. Furthermore, the possibility of an accident is very remote because preventive measures are of course taken. However, in the unlikely event that an accident should occur, it would not have a large effect on the outside facility because the equipment is installed in small chambers which are surrounded by a reinforced concrete wall about one metre thick. This wall is constructed for the purpose of shielding radiation and for containing radioactivity.

Nuclear fission chain reactions are highly unlikely at a reprocessing plant because of the special geometrical design of the equipment, the operation procedures and safety measures. For the same reason there is no possibility of an accident which would have as large an impact on the environment as Chernobyl.

Concern:

That a large amount of radioactivity will be released even at normal operating conditions.

Response:

The radioactivity discharged from a reprocessing plant is kept as low as reasonably achievable (ALARA) by applying the best technology available. Under normal operating conditions, radiation outside the plant does not exceed natural background radiation.

Concern:

That farming, dairy and marine products near the plant will be contaminated.

Response:

Several countries, e.g. England and France, have a nearly 30-year history of reprocessing plant operation. A small amount of radioactive substances attributable to reprocessing plants have been detected in the environment around them. But no detrimental effects on the ecosystems have been observed.

There is negligible influence on human, as well as on agricultural, livestock and fishery products given that the maximum additional radioactivity to which the environment will be subject is estimated to be 0.02-0.03 mSv per year.

Concern:

That no one will buy farming, dairy and marine products. (Even if radioactive contamination is not detected their products will be difficult to sell because of fear spread by rumour-mongers).

That even a small amount of artificial radiation from the reprocessing plant will have a bad effect on the human body, even though the body gets used to and becomes immune to radiation in the natural world.

That leukaemia will prevail due to these reprocessing plants.

Response:

These assertions have always arisen when new nuclear projects were launched all around the world. However, the experience over more than 30 years shows that they are completely unfounded.

Concern:

That recovered plutonium may be abused for production of nuclear weapons.

Response:

All the civilian nuclear activities are limited to peaceful uses. Nuclear substances, such as uranium and plutonium, are strictly accounted for to the gram unit.

The plutonium which is recovered from the spent fuel of a nuclear power plant has a low content of weapon-grade plutonium isotopes.

The facilities are strictly inspected by the International Atomic Energy Agency's inspectors.

For security reasons, the access to the facilities where plutonium is handled is restricted and special security measures are applied.

Concern:

The ground is unstable because of faults, and an earthquake may cause a serious accident.

Response:

The facilities will be designed to withstand the largest imaginable earthquake that could happen in the siting area.

Concern:

An airplane crash may cause a disaster.

Response:

Although airplane crashes on a reprocessing plant have an extremely low probability, further protective measures are taken in the construction of the buildings, which have to be strong enough to contain radioactive material in the unlikely case of an airplane crash.

of a reprocessing plant. Like any large-scale industrial activity, reprocessing is not risk-free. But fanciful scenarios suggesting that reprocessing gives rise to intolerable dangers for health and life are simply not true. Probabilities of safety-relevant incidents occurring are kept very low, and damage from such an incident would be very limited, because of reprocessing's characteristics and management combining design and construction measures into a tight network of safety precautions.

Gaseous, liquid, and solid wastes are generated during the spent fuel reprocessing. They are treated by waste treatment facilities designed and operated to limit radioactive release from the plants to values as low as reasonably achievable. Although the bulk of radioactive materials are kept in the facilities by processing these wastes, small amounts of radioactive materials are discharged into the environment. The concentration and the amount of the discharged radioactivity in the waste are monitored and controlled.

More important than the radiation exposure being kept low by regulations during normal operation is the question of the consequences for the population if there were an accident.

In assessing the safety of the reprocessing plant, certain hypothetical accidents shall be selected and evaluated to confirm that the defence-in-depth concept is properly adopted in the fundamental design philosophy of the plant and evaluated to judge that the isolation of the plant from the general public is adequately established.

A reprocessing plant contains large amounts of radioactive material. Massive release via a serious accident is, however, not possible for several reasons:

- the reprocessing plant's radioactivity is distributed in spaces and parts separate from each other. Only a small proportion of the total amount is in liquid (and therefore in principle easily dispersible) form;
- most of the processes run at low temperatures between 25° and 60°C. Higher temperatures occur only in the dissolver (under 100° C) and in the evaporator (under 130° C) and in the vitrification of the fission products (1000° to 1200°C);
- the reprocessing processes are carried out, in principle, at below atmospheric pressure. Overpressure is used only for a few non-radioactive media such as compressed air and process steam;
- used fuel elements are reprocessed only after at least one year of interim storage. During this period, their radioactivity and decay heat have dropped to less than 1% of what it was when unloaded from the core.

These physical and technological facts mean that reprocessing has an even smaller — substantially smaller — risk of danger than the already low risk at larger nuclear power stations.

As is the case with nuclear power stations, for reprocessing plants experience and accident studies lead to definitions of "design basis accidents", against which precautionary protective measures are planned. First and foremost, these precautions involve measures to prevent occurrence of accidents. Second, preparations are made on the assumption that an accident happens despite the preventive precautions. In such a case, retention and protection devices have to keep radioactive releases below the regulation-stipulated permissible limits.

A fundamental distinction is made between accidents caused by internal, and those by external, factors. Externally the most important factors are natural (earthquakes, floods, lightning) and human (air crash, pressure waves from a chemical explosion, countryside fires, sabotage). The measures taken against these factors are overwhelmingly constructional. The most important plant-internal disruptions are: explosions, fires, leaks, criticality, self heat-up if cooling or power supplies fail, fall of heavy loads.

What kind of measures prevent and mitigate accidents? Here are three examples: explosion of an evaporator for the highly active liquid waste; criticality incidents; and loss of cooling in heat developing solutions.

The cause of the evaporator explosion is a hefty exothermic reaction after the forming of a third phase ("red oil") out of the aqueous fission product solution and organic products, which entered the evaporator. Such reactions occurred several times between 1953 and 1959 in US plants. In one case, this led to destruction of the evaporator. Subsequent investigations showed that such reactions happen only when temperatures exceed 140°-150°C. Hence, the most important measure to prevent explosion of the evaporator is to operate at temperatures below the 140°-150°C level. The medium to heat the evaporator has a maximum temperature of only 130°C. In such conditions, an explosion would only be possible if three events occur simultaneously: entry of organic substances into the evaporator, formation of "red oil", and failure of the evaporator's heat regulator. Even so, it is assumed that an explosion could occur. It is estimated that its force would be equivalent to several kilogrammes of TNT.

Because it cannot be ruled out that the evaporator itself will be destroyed by the explosion, the cell is lined with stainless steel sheeting and the cell sump fitted with a collecting device so that outflowing fission products can be pumped into a reserve tank. The concrete walls prevent large-scale effects outside of the cell. If the evaporator is destroyed, radioactive steam or aerosols can find their way into the cell atmosphere — and will be retained in the cell's ventilation filters. The sets of filters are installed at a distance from the evaporator, so that they cannot be destroyed by pressure waves from an evaporator explosion.

Criticality incidents are of special significance for reprocessing plants, because the fission product solutions involve good moderating systems with relatively small critical mass. Between 1959 and 1970 there were several such accidents. The power generated during the chain reaction evaporates a part of the solvent, leading to fission product dilution interrupting the nuclear excursion and limiting the release of energy.

Occurrence of criticality can, according to the parameter conditions, be prevented by various measures. The principle of "safe geometry" is used especially for extractors and interim tanks — by limiting the dimensions of components. The dimensions are chosen so that criticality safety is guaranteed, independent of the fission product concentration. If the process technological requirements do not allow geometrical constraints, the subcriticality is secured, e.g., by limiting the fissile material concentration in the solutions or through neutron absorbers (boron, cadmium, gadolinium, hafnium), which are distributed either homogeneously in the solutions or heterogeneously in the components.

Despite these precautions, criticality belongs to design basis incidents for today's reprocessing plants — in other words, it is assumed that criticality could occur, causing steam which would carry a part of the chain reaction's fission product releases into the off-gas system. The aerosols involved would be retained by the scrubbers and filters. The gaseous fission products are overwhelmingly short-lived; during the through-flow time in the off-gas system chimney stack they decay so much that they can be released with an effect on the environs that is far below the prescribed limits.

Important social factors are:

• ***Opportunity of employment for local residents.*** Roughly 6000 to 7000 construction workers per day are estimated to be necessary at the peak of construction at the reprocessing plant, up to 50% of whom are generally local residents.

After the reprocessing plant construction has been completed and commercial operation has commenced, about 1000 direct employees in the reprocessing operation will be necessary at the site and 1000 indirect employees of the reprocessing-related companies will also be required. Approximately one half of them will be local residents.

• ***Economic effects due to the investment for the construction of the reprocessing plant.*** As the construction proceeds, demand for construction materials such as ready-mixed concrete, aggregate (cement, gravel, sand), reinforcing bars and steel frame will be increased, and consequently procurement from the local area will be increased. As many local contractors as possible will hopefully be given contracts. As a result, about 20% of the direct investment is expected to be spent on local contracts.

Along with the construction of the reprocessing plant, new enterprises will be created. These are classified into two categories, direct and indirect. Direct ones are those directly related to the reprocessing plant, such as operation of facilities, maintenance, cleaning, landscaping, and security.

Indirect ones are housing and accommodation of employees for construction and plant operation, and use of a commercial district for supply of daily necessities.

Leading manufacturers and many construction companies will join the direct enterprises for construction of the reprocessing plant. So they will provide offices, warehouses and housing accommodation. These manufacturers will maintain offices on the site for maintenance after commercial operation has commenced. As directly related companies, those for guard and security, supplying daily necessities, public information centre, and transportation will be established. As indirectly related businesses, among the required facilities will be hotels, apartment buildings, shopping centres, restaurants, and recreational amenities.

Radioactive Waste Management

Radioactive waste from the nuclear fuel cycle comes in many forms, various sources, and a wide range of levels of radioactivity. The classification and handling of these wastes depend on the form and level of radioactivity they possess.

Radioactive waste is managed to reduce and, if possible, eliminate the potential risk to humans and the environment. *(See Figures 6, 7, and 8.)* Procedural activities are incorporated which minimize handling, treatment, conditioning, packaging, transportation, storage and disposal of radioactive wastes.

When compared on a volume basis with other industrial wastes, radioactive wastes generated by nuclear fuel cycle facilities are significantly smaller, almost to the point of being insignificant by comparison. Another important characteristic is that the associated hazard decreases with time, whereas most heavy metals contained in industrial wastes will remain toxic forever.

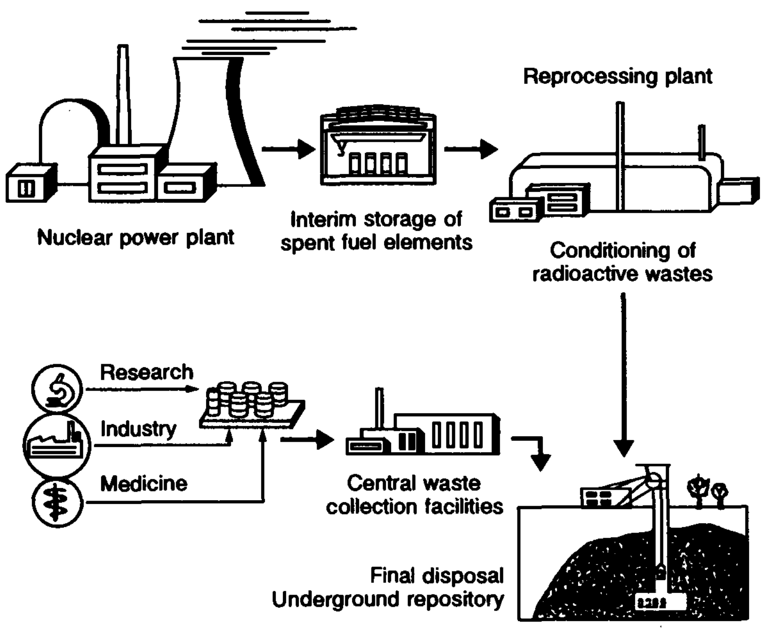
Radioactive wastes are found in all nuclear fuel cycle activities. These wastes are usually categorized by nature and level of activity, heat content and potential hazards. Their quantities largely depend on the amount of fuel processed, the type of nuclear facility involved, and the national strategy for spent fuel management in the particular country.

One classification system in use that is based on the nature of radioactivity distinguishes between:

- **short-lived wastes:** the radioactivity decays to innocuous levels in less than 300 to 500 years, and
- **long-lived wastes:** the radioactivity remains an important issue for thousands of years.

The waste in the second category usually contains large amounts of natural and/or transuranium ele-

Figure 6. **An Approach to Radioactive Waste Management**



Radioactive wastes arise from peaceful uses of nuclear energy in research, industry, medicine, and electricity production. Most wastes containing low levels of radioactivity are processed and disposed of by near-surface burial. High-level radioactive wastes from reprocessing of spent fuel from reactors receive further special handling. Liquid high-level wastes are typically stored in stainless-steel tanks as acid or acidic solutions and sludges. Before final disposal in a geologic repository, liquid high-level waste requires solidification and packaging. Spent fuel that will not be reprocessed is stored underwater in specially constructed pools or in dry storage facilities before conditioning, packaging, and emplacement in a deep geologic repository. The diagram shows a general approach (national practices may vary in some respects).

ments (alpha-bearing radionuclides), which will remain radioactive for a very long time. The waste classified as short-lived contains mainly activation products and some fission products with half-lives not exceeding 30 years.

In another classification system, three waste categories are recognized:

- **high-level waste:** the highly radioactive products which generate heat and require shielding during handling and transportation (spent nuclear fuel, if regarded as a waste, falls into this category as well);
- **intermediate-level waste:** the waste does not generate heat but still requires shielding during handling and transportation; and
- **low-level waste:** the level of radioactivity is such that the waste does not require shielding during normal handling and transportation.

There are four main waste types:

Wastes from nuclear fuel production. In the first stages of the cycle, from uranium mining and milling through enrichment of fuel to the fuel fabrication, only natural radionuclides are contained in the waste. Their low concentrations are dominated by thorium-230, of which the half-life is 80 000 years and which decays to radium-226 with a half-life of 1600 years. The wastes originating from mining and milling are accumulated mainly in tailings which are kept in tailings dams, open piles or impoundments with a solid or water cover. At present, engineered solutions are under development to minimize releases of radium and radon from older tailings.

The waste originating from uranium fuel enrichment and fabrication has a similar composition, but is much smaller in volume by comparison with the waste from the preceding stage.

Reactor wastes. Some of the radioactive wastes generated at nuclear power plants are low in radioactivity and the radionuclides contained therein have a low radiotoxicity and usually a short half-life. However, nuclear reactors are the largest in number among all nuclear facilities and, except for mill tailings, produce the greatest volume of radioactive wastes.

The nature and amount of wastes produced in a nuclear power plant depend on the type of reactor, its specific design features, operating conditions and on the fuel integrity. These radioactive wastes contain activated radionuclides from structural, moderator and coolant materials, activated corrosion products and fission products arising from the fuel. The methods applied for the treatment and conditioning of wastes generated at nuclear power plants now have reached a high degree of effectiveness and reliability and are being further developed to improve safety and economy of the system.

Liquid radioactive wastes generated at nuclear power plants usually contain soluble and insoluble radioactive components, and non-radioactive substances. The main objective of liquid waste treatment methods is to decontaminate aqueous waste to such an extent that the decontaminated bulk volume can be either released to the environment or recycled. Waste concentrate together with wet solids resulting from liquid waste treatment must still be transformed into solid products for further storage

Figure 7. **Schematic of Radioactive Waste Disposal**

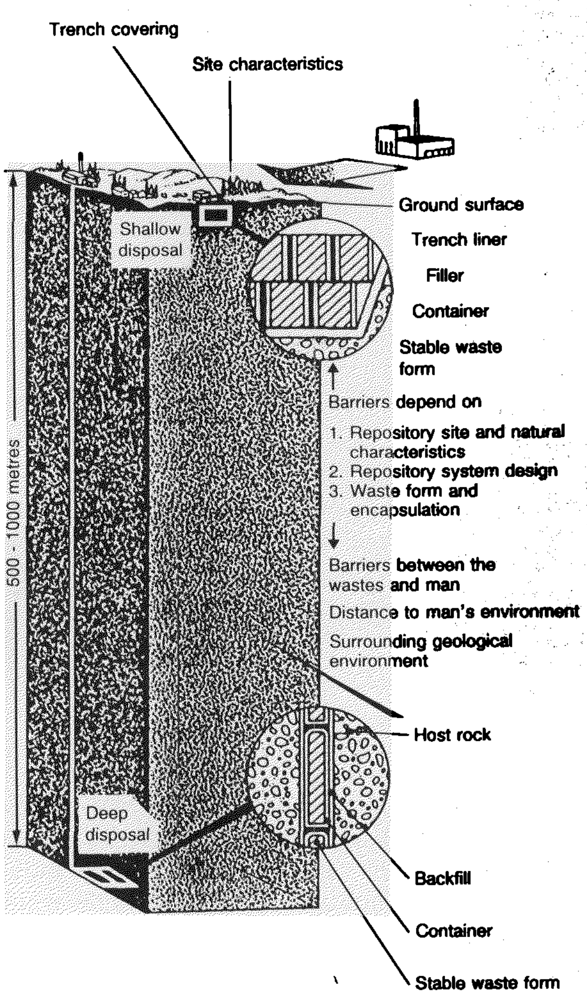
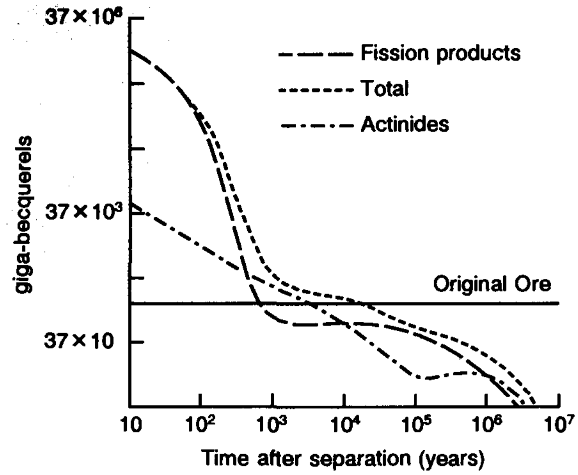


Figure 8. **Radioactivity Levels Over Time**



Above: The radioactivity of high-level waste declines steadily over time, most dramatically over the first hundreds of years. Eventually the radioactivity level will be lower than that of the natural uranium ore from which the spent fuel originally came. The graph shows the levels of radioactivity in waste products for one tonne of fuel and its originating ore bod.

Left: Most types of radioactive waste can be disposed of safely in near-surface disposal facilities, which are built in some countries. Radioactive wastes containing high levels of radioactivity require disposal in deep geologic repositories. Potential repository sites in stable formations are selected after long and careful investigations and safety assessment. To contain the waste, and retard any possible migration of radionuclides from the repository, over long periods of time, a multiple-barrier concept is used when designing the repository system. Multiple-barriers may include the specially designed waste canister/container, buffers, the engineered facility, the natural host rock, and backfill.

and disposal. Immobilization processes involve the conversion of the wastes to chemically and physically stable forms that reduce the potential for migration or dispersion of radionuclides by processes that could occur during further handling and disposal. If possible, waste conditioning should also achieve a volume reduction.

The nature of low-level solid waste at nuclear power plants varies considerably from facility to facility and can include redundant items of the reactor plant, ventilation system filters, floor coverings, contaminated tools, etc. Another source of solid waste is the operation and maintenance activity, giving rise to paper, plastic, rubber, rags, clothing, and small metallic or glass objects. This waste is usually segregated, treated for volume reduction and packaged into suitable containers for storage and final disposal.

Wastes from reprocessing. High-level radioactive waste originates from the reprocessing of spent nuclear fuel. It contains practically the whole spectrum of fission products in high concentrations together with certain amounts of transuranium elements after separation of uranium and plutonium from the fuel. Most of these high-level wastes are stored in underground containers provided with adequate cooling to allow removal of heat and decay of short-lived radionuclides to a level which would facilitate later handling, solidification, transportation and disposal. However, great progress has been made in techniques for solidification of these wastes and, in three countries, vitrification facilities are safely operated on an industrial scale.

Decommissioning wastes. Radioactive wastes from the decommissioning of nuclear facilities include dismantled reactor internals, structural materials, and decontamination solutions. Except for reactor internals, most waste is low-level in nature and its volume is comparable with quantities of wastes generated during the operational lifetime of the facility.

The treatment and conditioning of low and intermediate level wastes which result from various nuclear fuel cycle activities are well established technologies based on chemical and physico- chemical processes, such as ion-exchange, chemical precipitation, evaporation, etc. Concentrated wastes are fur-

Storage of vitrified high-level waste. *(Credit: BNFL)*

ther solidified by cementation or bitumenization. For solid radioactive wastes, incineration or compaction or melting and baling are methods by which most volume reduction is obtained. Subsequently, storage of the conditioned and packaged wastes can be made for different periods of time and in different ways. The common feature of these storage operations is that the waste can be retrieved when desired.

Solidification of high-level wastes is achieved by incorporating them into a glass matrix, thus creating a vitrified solid product having some favourable properties, such as low leachibility, good thermal conductivity and high radiation stability.

Radioactive waste from decommissioning can be handled much like wastes from other nuclear operations. The volume of wastes can be reduced by a variety of methods, using mechanical, thermal or chemical treatments. Compaction, incineration, melting, chemical decontamination, and evaporation of liquids are methods effectively used in worldwide practice.

Disposal of solid or solidified radioactive wastes is the final step of the nuclear fuel cycle which is applied to properly conditioned materials and packages in accordance with the criteria established for the selected disposal system. Only in cases where the radioactivity of wastes is very low may conditioning not be necessary. The major objective of safe disposal is to isolate the waste from humans and their environment during a time adequate for the decay of the contained radionuclides to insignificant levels.

It is recognized that for more than 99% by volume of the radioactive waste originating from the nuclear fuel cycle, safe disposal methods exist, based on engineered designs capable of isolating the radionuclides from the human environment for the whole required period of time. This option encompasses disposal of low- and intermediate-level wastes into both near-surface and geologic type repositories which have been successfully operated for several decades.

For the remainder, i.e. high-level radioactive wastes containing long-lived radionuclides, and for spent fuel, the disposal systems are under development and are expected to be operational in the beginning of the next century. The most currently preferred option is the emplacement of wastes into vaults excavated in deep geologic formations and provided with a multi- barrier system to mitigate the release of nuclides for long time scales. The safety assessments for these systems can demonstrate that the potential hazard for the general public resulting from these releases is sufficiently small to comply with internationally agreed limits of acceptable risks. The uncertainties in prediction modelling are appropriately covered by redundancy in the engineered design of the repository.

Due to the variety of potentially suitable geological media and of many possible designs, disposal systems offer a relatively high degree of flexibility. Small imperfections in one component of the disposal system can be outweighed by implementing some additional barrier in the repository, or by providing more reliable packaging of the waste, and vice versa. For example, corrosion resistant containers for disposal of high-level waste that would last for a time span of at least 1000 years, have already been developed.

Nuclear fuel cycle facilities involve radiological risks to humans and the natural environment and, in addition, considerable changes in terms of both physical and aesthetic quality. The radiological risk includes contamination of the biosphere, i.e. air, land and water, by radionuclides intentionally or accidentally released from the facilities. Controlled releases from these facilities are generally very low and are kept within acceptable limits established by a country's competent authorities. Uncontrolled releases may occur as a result of human error, facility failure, and natural or man-induced events such as flooding, earthquake, explosion, etc. It is therefore important that an assessment is made of the anticipated impact on the environment.

In some countries, legislation has been introduced which makes it mandatory to carry out an environmental assessment. Such assessment should include not only the radiological impacts of radioactive materials potentially released to the biosphere, but also the non-radiological aspects, such as the impact on the local ecology, national parks and other protected areas, communities, landscape, economy, and air and water quality. The impacts associated with radioactive waste management are of a different nature depending on the particular facility and the type of wastes handled.

Major environmental risks arising from the front end of the nuclear fuel cycle are contamination of air by radioactive dust and radon and contamination of water by radium and non-radioactive chemicals during the ore processing. As regards the fuel enrichment and fabrication, chemical and fire risks prevail over the radiological one as the radioactivity of wastes is low and practically all the wastes can easily be recycled.

In normal operation of nuclear reactors and reprocessing plants, some airborne radioactive wastes are generated in either particulate or gaseous form. The most important volatile radionuclides are halogens, noble gases, tritium and radiocarbon. The composition and the amount of radioactivity present in the various airborne waste streams largely depend on the facility type and the release pathway. All gaseous effluents at these facilities are treated before discharge to the atmosphere to remove most of the radioactive components therefrom.

In some low-level liquid waste streams, decontamination by ion-exchange and/or volume reduction by evaporation are usually so effective that the resulting liquids can be discharged to the environment without further treatment.

Most radioactive wastes from decommissioning contain low-level radioactive materials and a smaller amount of waste of higher activity (mainly reactor internals). Taking a nuclear power plant as a whole, the majority of it — some 85% — does not become radioactive at all and can be treated as ordinary industrial waste. In the remainder, where the activity is very low and there is no further use for removed materials, the waste can be released to the biosphere in a manner similar to household garbage.

Among various nuclear facilities, the disposal systems represent a special case. The overlying principle of safe disposal of radioactive wastes is to ensure that humans and the environment will not suffer unacceptable detriments from the disposed wastes at present and in the future. This implies that the individuals as well as the general public have to be protected from any harmful effects of radioactive materials potentially released from the repositories to the environment and, furthermore, that the disposed waste will not present any commitments or constraints to future generations.

To achieve these goals, it is important that the isolation capability of a waste disposal system is maintained for all the required period of time, until the radioactivity of the wastes is within acceptable limits. Thus, the overall disposal system must control the pathways through which risk to humans may arise. The pathway of most concern is, in general, migration of radionuclides through groundwater to the biosphere, where the contaminant can enter into food chains. However, other pathways such as intrusion into the repository site and/or effects of disruptive natural events, also cannot be excluded.

Social factors are of crucial importance in decision-making on radioactive waste management. In the past, these factors have been implicitly taken into account by the regulatory and technical staff in development of various approaches to waste management and, particularly, to waste disposal. Nowadays, more explicit involvement of politicians and the general public in making such decisions seems to be helpful. It is well known that social and economic benefits and compensations (if any) of a radioactive waste facility in some countries are likely to be of greater attraction, especially to communities with depressed local economies.

In most countries, the implementation of nuclear energy is impeded by public concerns about the safety and environmental consequences of electricity production in nuclear power plants. Among these concerns, the question of what to do with nuclear waste is a key issue. In some countries it is the over-riding issue.

Although scientists and engineers are confident that modern technology can ensure the safe disposal of nuclear wastes, the general public is often not so sure. As a result, in many countries the public attitude greatly influences the progress of nuclear energy and, for the near future, it can be expected that this situation will not change. However, adverse public attitude has, in a certain sense, beneficial impact on the development of safe disposal systems thereby advancing and deepening the studies to solve satisfactorily this particular problem.

The fear that the highly radiotoxic and long-lived wastes can cause serious harm to people and the environment has the following three reasons:

- a fundamental apprehension of radioactivity;
- a lack of knowledge about what radioactive waste is;
- a lack of knowledge about behaviour of radioactive substances in nature.

Therefore, many countries have implemented public interaction programmes, the intent of which is to develop the degree of public understanding necessary to achieve implementation of the waste disposal technology. Such programmes encompass activities that range from simply giving information to involving members of the public or special interest groups in the decision-making process. Although national public interaction programmes vary from country to country because of different political and social characteristics, the fundamental principles for achieving public understanding are similar in nature.

The development of an effective public interaction programme is based on applying various communication means to a number of audiences. To achieve understanding from the local public where there is intention to locate a disposal facility, the following media are of major importance: organized visits/tours to nuclear facilities; information meetings; newsletters. Also helpful are news releases, interviews, films, videos, and face to face contacts. Local authorities are best informed through exhibitions, brochures, pamphlets and news magazines.

The main facts that should be known about radioactive wastes and their management can be summarized as follows:

- Amounts are relatively small.
- High-level waste is an extremely small part of the total.
- Radioactivity can be very precisely measured.
- Toxicity of radioactive materials decreases with time and most of it disappears eventually.
- Much is known about the effects of radioactivity on people.
- Safe, proven temporary storage methods for all wastes exist.
- Final disposal facilities exist for short-lived waste.
- Information on techniques is internationally exchanged.
- Only a minor part of nuclear electricity costs is for waste.

The radioactive waste accident that has drawn most media attention is the one that took place near the Kyshtym nuclear weapons complex in the Soviet Union in 1957. A chemical explosion in a high-level waste storage tank led to evacuation of 600 people initially and 10 000 eventually. The area treated as contaminated was about 400 square miles. There were no casualties from the explosion, and medical and epidemiological studies indicate no excess mortality rates or disease among those exposed. Nearly all of the land has been restored for use, mostly as farms.

Spent Fuel Disposal

Though up to now no country in the world has built a facility to dispose of spent fuel, there are several countries which have voted for long-term interim storage and investigated the possibilities of direct disposal of spent fuel elements.

Here are some examples.

- In the United States, spent fuel elements are being put into long-term storage at the individual reactor sites, so it was necessary to extend the capacity of the reactor storage pools by applying compact storage or by establishing container storage areas on site but outside the reactor building. Recently dry storage has been approved at reactor sites.
- In Sweden, spent fuel elements are being collected at the central storage facility of CLAB where they are brought by ship transport. The technology for final storage of such fuel elements in a granite formation is under investigation in the Stripa-mine and the äspö hard rock laboratory. Sweden has announced its plan for a demonstration deep disposal store to hold about 8000 tonnes of fuel encapsulated in copper, at a depth of 500 metres.
- In Germany direct disposal of spent fuel elements has been under theoretical investigation for some time, and containers suitable for such procedures have been developed which can hold several spent fuel elements after being disassembled but without mechanical treatment like cutting or rolling. A small pilot plant for the conditioning of spent fuel elements to prepare them for such final disposal and put them into safe packaging is under construction at the site of an interim store at Gorleben.

Facilities for the conditioning of spent fuel elements for disposal normally are or will be located either close to an interim store for such fuel or to a deep geological repository into which they can be disposed of after conditioning.

In any case the area needed for such a facility may be regarded as small compared to the one needed for nuclear power plants or reprocessing plants: a few hectares should be sufficient.

Final disposal of spent fuel will be carried out deep in the bedrock. Different geological media are being considered for spent fuel isolation, e.g. crystalline rock (granites, etc), clay, tuff and salt formations.

The spent fuel will first be stored for an interim period of 10 to 50 years, during which radiation and heat generation will decrease. After that period, the

Box 8. Questions About Spent Fuel Disposal

Disposal of spent fuel may give rise to questions among the local population, policymakers, and environmental groups. Questions which may be asked will include:

What is spent fuel?

Fuel elements which have been used in a reactor and which are now considered as waste. However, they still contain valuable compounds which may be retrieved either now, by reprocessing, or later, after retrieval of the directly disposed fuel elements.

How dangerous is spent fuel and for how long?

Spent fuel emits dangerous gamma radiation for about 1000 years. It also contains plutonium and other transnuclides which are poisonous and may be dangerous up to 100 000 years or more. As the danger from transnuclides is not gamma but alpha radiation, they are dangerous only if they enter the human body.

Will it be easier to make nuclear weapons from spent fuel after a thousand years?

It will be difficult to retrieve the spent fuel from a deep geological repository. If retrieved, it still has to be reprocessed for recovery of plutonium. This plutonium will not be of weapons grade due to the content of the isotopes plutonium-240 and plutonium-242.

Who controls that the spent fuel is handled in a safe way?

The answer depends upon the specific authorities in a particular country.

Is it possible for the municipality to veto the localization of a final repository of spent fuel?

The answer depends on the country and on its national, regional and local laws.

Are there some advantages for the municipality if a final repository for spent fuel is localized there?

The facility will create jobs and may improve roads, railways and other parts of the infrastructure. In some countries the municipality will receive grants or taxes from the proponent of the project.

How is it possible to know that the containers around the spent fuel will not corrode so that the radioactivity will be taken out?

Corrosion tests have to be performed under conditions such as prevail in a geological repository. The use of natural materials may be preferred as natural analogues of how long such materials have existed in nature may provide complementary evidence.

What happens with the groundwater when we dispose of radioactive waste?

Groundwater is important in geological repositories in hard rock below the water table. Studies of groundwater are important. The movement of groundwater may be very slow, which means that the geological barrier will be effective.

What are the benefits of using bentonite clay or other buffer elements?

Bentonite clay will expand when groundwater enters slowly through cracks. The clay will provide a dense barrier with very low flow of groundwater through it.

Why is copper such a good material for the container around the spent fuel?

In a deep geological storage in hard rock, below the water table, analyses have shown that there is no dissolved oxygen in the water. This means that there will be no corrosion of the copper.

Will it be possible to live on the ground above a final repository if such a facility is at 500 meters depth?

Yes. The radiation will be the natural background only.

Is it possible to use the land near a final repository for agriculture?

Yes. There will of course be controls such as samples from the environment in the same way as near any nuclear facility.

What happen with the final repository if there is an earthquake?

In hard rock the containers will just move with the rock and be protected by the bentonite clay around them. If there is movement in the rock, this will preferably be along old faults which should be avoided when siting the repository.

What happens with the final repository during and after the next ice age?

The next ice-age may cause new cracks down to about 100 metres in granite, but it will not hurt a repository at 500 metres depth or more.

Will it be possible to retrieve the spent fuel from the repository if better technology is developed in the future?

It will be possible before the closure of the repository, difficult after the closure. It may be more difficult in a rock-salt repository because of the plasticity of salt.

Many of these questions will be asked not only by individuals but by the community as a whole. The company's executives and public communications staff should consider these matters *before* an application is made to localize a site for final disposal of spent fuel.

spent fuel will be encapsulated and placed in a disposal facility deep underground. The containers will be made of a corrosion-resistant metal or ceramic which may vary depending on the conditions in the repository. Metals like copper, titanium or steel could be chosen as container material.

The containers containing spent fuel may be surrounded by a buffer material such as bentonite (clay) or rock salt.

Groundwater is the only medium which may transport dissolved radioactive species from a geological repository vault to the biosphere. The characteristics described above mean that there are a number of barriers against spreading of radionuclides from the spent fuel to the biosphere, such as low solubility of the spent fuel in groundwater, corrosion resistance of the container, slow transport of radionuclides through the buffer material, slow transport through the "near-field" which may be engineered by treatment of fractures and slow transport through geological media.

The aim of final disposal of spent fuel is to isolate it from the biosphere during the long period of 100 000 years or more when it is radiotoxic. This means isolation against slow processes such as corrosion, diffusion of oxygen, and movement of ground water, but also against possible events like earthquakes and volcanic activity.

In the search for a site for deep geological disposal of spent fuel, investigations by geological and geophysical methods including deep drilling are usually performed at several sites before one site is chosen for the disposal.

Public Communications Programmes. It will of course be necessary to have public communications programmes in the communities near each site where substantial investigations are performed.

Before a special site is chosen, a broad communications programme must be started in the whole country to explain what such a final repository is and what the environmental impact may be.

When one or more sites are chosen for closer study, it will be necessary to take the following steps:

- identify local and regional politicians, community groups, special interest groups and individuals that are likely to be affected or to become involved;
- make contact with these groups directly, explain the project and answer questions;
- establish an office for communication with the public in the community where a final disposal site may be chosen. This may be a small office but personnel should be available to answer questions;
- distribute by post an information newsletter to all people in the community and to the surrounding communities;
- invite journalists from local and regional media to briefings, when top management will be available for discussions;
- establish regular meetings with an advisory panel or discussion council with local and regional representatives.
- invite regulatory officers to the site to present the project;
- invite geological associations and other scientific and technical clubs to present the project.

There is a wide range of information which can be drawn on to support the work of the public communications staff. This will come from the company's own previous experience or from foreign companies working with disposal of spent fuel, from university researchers in radiation, from international organizations like IAEA and ICRP, and from descriptions of natural analogues such as the "natural" reactors at Oklo in Africa and the highly enriched uranium ore body at Cigar Lake in Canada.

The public communications staff should have close contacts with the technical staff of the company in order to be updated on the progress.

The following is some basic information essential for the public communications staff:

- a detailed profile on the local communities and the surrounding environment;
- database with addresses for distribution of newsletters, etc;
- knowledge of previous nuclear activities in the region;
- copies of technical reports on the project;
- copies of relevant laws/codes of conduct,etc, governing the granting and operation of licenses, legal responsibilities and rights of all concerned.

Transport of Radioactive Materials

Transport is not just the physical movement of a consignment but comprises all operations and conditions associated with and involved in the movement of radioactive material. It includes the design, fabrication and maintenance of packaging, the preparation, consigning, handling, carriage, and storage in transit through to receipt at the final destination. Transport also includes the normal and abnormal conditions that may be encountered in carriage and in storage during transit.

Radioactive materials are considered "dangerous goods". Other examples of dangerous goods are flammable liquids, corrosive materials and poisons.

Radioactive materials are used, created and transported at various stages of the nuclear fuel cycle from mining and milling through conversion, enrichment and fabrication to use at the reactor and subsequent storage and or reprocessing. Worldwide about 50 000 tonnes of uranium concentrates are transported annually. Uranium hexafluoride, enriched uranium hexafluoride, fresh fuel, spent fuel and high-activity waste are also transported. And one should not forget the millions of shipments of radioisotopes that have taken place for medical, agricultural and industrial applications.

Comparing the 50 000 tonnes of uranium shipments to other energy sources, there are shipments of about three billion tonnes of oil each year, and about four billion tonnes of coal. Although materials may be stored or used for long periods at nuclear power plants and other nuclear fuel cycle facilities involving movement on site, at some point they are transported to another facility. Sometimes these facilities are only a few miles away, requiring a single method of transport. Others may involve several methods such as road, rail, air and water, and distances of thousands of miles as with shipments between Europe and Japan. Over the years transport and handling equipment has been developed to control the radioactive materials and to limit worker and public exposure to radioactivity.

The following methods of transportation are used in the transport of radioactive material: road, rail, water (barge or ship), air. There are numerous issues to be considered which are common to all modes of transport: physical security, permits, routing, safety, scheduling, design of package and transport vehicle, cost, insurance, operator training, maintenanance, spare parts, weather, domestic transport, international transport. There are also various types of accident and other potential problems associated with the transport of radioactive material to consider: collision or crash, explosion, fire, human factors, component failure, grounding, rupture, overheating, smoking, theft, sabotage, diversion, misrouting.

In order to be acceptable for worldwide application in all modes of transport, for any radioactive and fissile material, the regulations must reduce the hazards to transport workers and the general public to an acceptably low level, i.e. be "safe".

The following basic requirements must be met to achieve safety:

- effective containment of the material;
- effective control of radiation emitted from the package;
- a subcritical condition for any fissile material, i.e. "criticality" must be prevented; and
- adequate dissipation of any heat generated within the package.

The intention is to ensure that as far as possible each package may be dealt with in the same way as other potentially hazardous goods that are carried by conventional means of transport and handled by workers with no specialized training. To ensure safety, reliability is built into the package design, rather than depend on operational controls.

The underlying philosophy is that as far as possible the consignor should be responsible for ensuring safety during transport. Those who prepare each package for shipment are responsible for ensuring that regulatory requirements are met. This minimizes the contribution required from carriers, and allows consignments of radioactive materials to be transported with a minimum of special handling. Transport industry workers are expected to treat radioactive consignments with care, but with no more care than that accorded to other dangerous goods.

In the regulations, requirements concerning package strength are expressed as performance standards rather than as specifications for design, such as wall thicknesses, details of joints and closures and so on. In other words, the regulations prescribe what must be achieved, rather than how it shall be done.

The inner vessel which contains radioactive material may be protected in various ways against damage which may occur during transport. For example, outer layers of protective packing material may be used. Large flasks of the sort used to transport irradiated nuclear fuel are often fitted with energy absorbing devices to protect them in the event of an accident. Additional shielding may also be necessary to ensure that radiation levels around a package are at acceptable values.

The purpose of these regulations is to establish standards of safety that provide an acceptable level of control of the radiation hazards to persons, property and the environment that are associated with the transport of radioactive material. They apply to the transport of radioactive material and are in addition to those that are an integral part of the means of transport.

Relevant transport regulations for dangerous goods of each of the countries through and into which the material is transported, and the regulations of the relevant transport organizations, apply in addition to these regulations.

In the transportation of radioactive material, accidents and other problems have been few and relatively insignificant with respect to environmental hazards or damage. This has been achieved through preplanning and hard work by all associated with packaging, handling and transportation. In spite of this excellent record, transportation of radioactive material is the most visible and perhaps the most vulnerable part of the management and operation of nuclear fuel cycle facilities, from the point of view of physical protection.

In August 1984, the "Mont Louis", a freighter carrying approximately 350 tonnes of uranium hexafluoride in thirty containers, was involved in a collision in the North Sea off Belgium and sank in about 15 metres of water. The material was carried as a solid in pressure vessels, with a steel wall thickness of 15 mm. Within forty days of the accident, all containers were recovered, intact, from the wreck.

Box 9. Questions About Radioactive Waste Transport

The prime question about the transportation of radioactive material concerns the type of accident that allows the radioactive contents to be released to the environment with subsequent damage or risk of damage to the population. Such accidents may have any number of causes including crash or collision, fire, component failure, and human error.

Responses to these questions may be varied. Questions about an accident that releases radiation may be answered by referring to one or more of the following:

- As for all stages of the nuclear fuel cycle, having the public understand that radiation is a natural phenomenon, and that the main task during transportation is to reduce as much as possible the dose and the period over which it is received.
- Screening videos showing the computer detail work that goes into the production of flasks for the transportation of high-level radioactive material and the subsequent physical testing of the flask (e.g. drop and fire tests, and the more dramatic road and rail crash tests done by Sandia Laboratories and the Central Electricity Generating Board in the UK).
- The use of purpose designed transport, e.g. "Sigyn" — ships, trailors, railroad platforms.
- The number of movements of radioactive materials compared to the number of accidents involving radioactive materials.
- Accidents involving the transportation of other hazardous materials in day to day use.
- An awareness of the wide range of national, regional and international codes covering the transportation of radioactive materials by various means —road, rail, air, and sea.

Considering the present levels of safety in the transport of radioactive material, it is not generally necessary to recommend routing restrictions. However, when such requirements are imposed, consideration is taken of all risks including normal and abnormal risks, both radiological and non-radiological.

Public and worker safety is assured when these regulations are complied with and public confidence is achieved through quality assurance and compliance assurance programmes. Quality assurance involves plans and actions by designers and manufacturers of packagings, and by consignors, carriers and competent authorities to ensure that all requirements applicable to packages and consignment are properly met. Compliance assurance involves reviews, inspections, and other actions aimed at confirming that the requirements of these regulations are met in practice.

Another concern is the possibility of material being sabotaged or hijacked during transportation for purposes of terrorism or diversion. Responses to such concerns are more difficult as public disclosure of some of the protective measures may in practice reduce their effectiveness.

Here we should take into account the obligations of the States and their co-operation and assistance in non-proliferation of nuclear material as well as their responsibility for physical protection of such material. Also, the use of satellite surveillance and other modern methods of communication as well as national and international monitoring systems to track the movement of radioactive materials, particularly high-level radioactive material, both on and off site, could be discussed. However, it is the very nature of high-level radioactive material that makes hijack, sabotage, or diversion extremely improbable events.

Radioactive materials are packaged in different ways depending on the form, quantity and concentration of the radioactive material. All materials must be packaged so that the radiation level will not exceed 10 millisievert per hour at a distance of two metres from the outside surface of either the package or the truck. Thus, a person who is two meters away from the truck for 15 minutes would receive a 2.5 millisievert dose. This is a very small amount of exposure. For comparison, the average person receives about 300 millisievert each year from natural background radiation — cosmic rays, building material, radon in the soil and air and other natural causes.

There have not been fatalities or injuries associated with the release of radioactive materials in any transportation accident.

Upon examination, only one container was found to have developed a leak in a closure valve. However, a small quantity of seawater leaked into this container and blocked the valve with a solid uranium compound.

If the containers had been ruptured and seawater had come in contact with the uranium hexafluoride, there would have been a chemical reaction producing compounds containing uranium and fluorine. There was no danger of explosion.

The reactive products would have soon been so diluted by seawater that they would have been undetectable, as seawater naturally contains both uranium and fluoride. So none of the people involved were contaminated or injured. Other accidents have happened with trucks carrying uranium concentrate, but have only caused very localized contamination which was cleaned up in a few days.

Petrochemicals are a dangerous cargo — they are flammable and can disperse quickly over a wide area when the container is damaged. Probably the worst demonstration of this occurred at the height of the 1978 summer holiday season when a tank truck filled with propylene went off a road alongside a camping site in Spain and exploded, killing 215 people.

The transport of fossil fuels also has its risks. Five major fossil fuel fires in tunnels have occurred since 1949. For example, a tank truck carrying approximately 32 000 litres of petroleum-based fuel collided with other vehicles and burned inside the Caldecott Tunnel in the USA in 1982; seven people lost their lives.

Between 1969 and 1979 there were nineteen accidents as a result of which more than 40 000 tonnes of oil were spilled at sea due to tanker collisions and wrecks. These were surpassed when the Amoco Cadiz ran aground off the coast of France in March 1978, and 220 000 tonnes of oil spilled into the ocean. Now, areas exposed to waves, currents and winds have almost completely recovered, but oil from the Amoco Cadiz still persists in areas protected from the movement of the sea, and there may be long-range effects on the reproduction of marine organisms in the area.

Later high-profile tanker accidents were those of the Exxon Valdez in Alaska in 1989 and the Braer in Scotland in January 1993. The total oil spilled from the two was estimated at 123 000 tonnes.

The transport of explosives also takes its toll.

In 1917 a freighter carrying 2300 tonnes of explosives blew up in the harbour of Halifax, Nova Scotia, killing about 3000 people, injuring 9000 and destroying 6000 homes. In 1944 a ship carrying 1270 tonnes of explosives caught fire and exploded in the harbor of Bombay killing 1250 people. In 1947 in Texas City, USA, a shipload of ammonium nitrate exploded. This caused a chemical plant and another ship to explode, resulting in the death of 576 people; another 2000 were seriously injured. A similar explosion of ammonium nitrate in Brest killed 21 people the same year. In 1956, seven trucks carrying dynamite exploded in Colombia killing 100 people. In 1979 a train accident at Mississauga, near Toronto, Canada, prompted one of the largest peacetime evacuations. About 250 000 people had to leave their homes following the derailment and rupture of tank cars carrying liquid fuels, petrochemicals and chlorine. It is interesting to note that this happened in the same year as the Three Mile Island accident, but received much less media attention.

The transport of radioactive materials, as with all dangerous goods, presents a risk, but because there are stringent and uniform systems of international regulatory control, the risks are much less than those created by the transport of many other goods. More than 100 million packages of radioactive material have been shipped in the last 35 years, and there has been no accident with serious radiological consequences to the public. *(Also see table.)*

Physical Protection. The transport of nuclear material is probably the step in the nuclear fuel cycle most vulnerable to an attempted act of unauthorized removal of nuclear material or sabotage. Therefore it is important that the protection should be designed and built "in depth" and that particular attention should be given to the recovery system. Emergency procedures need to be prepared to effectively handle any possible threat.

Achievement of the objectives of physical protection is assisted by:

- minimizing the total time during which the nuclear material remains in transit;
- minimizing the number and duration of nuclear material transfers, i.e., transfer from one form of transport to another, and from one storage mode to another;
- protecting nuclear material in temporary storage in a manner consistent with the category of that material;

In the United States, a study by the Department of Transportation showed that radioactive material is involved in less than one-half of one percent of all accidents involving shipments of hazardous materials.

Five-year total of hazardous materials accident reports in the United States

Classification	*Percent of total reports*
Flammable liquid	51.27
Corrosive materials	33.33
Poisons, class B	6.32
Flammable compressed gas	2.24
Oxidizing material	2.01
Non-flammable compressed gas	1.67
Miscellaneous and unknown	1.47
Flammable solid	0.57
Radioactive material	0.45
Explosives	0.38
Combustible liquid	0.21
Poisons, class A	0.08
Total	100.00%

- avoiding the use of regular movement schedules;
- requiring predetermination of the trustworthiness of all individuals involved in transport of nuclear material.

The IAEA has developed "Explanatory Material for the IAEA Regulations for the Safe Transport of Radioactive Material" as one of the documents in the Agency's series of Safety Guides.

A spent fuel flask being transported by ship. (Credit: BNFL)

Uranium Exploration and Mining: Examples of Codes of Conduct and Practices

The following two examples are extracted from information prepared in Australia for the draft Environmental Impact Statement for the Jabeluka Ore Body in the Northern Territory, Australia

1. Code of Conduct and Practice for Minerals Exploration Drilling

Introduction

This booklet has been prepared by the Victorian Chamber of Mines as a guide to its member companies on acceptable conduct when carrying out exploration drilling programmes in Victoria. This code of conduct should apply on all types of land holdings in the State, be they Crown Land or Private Land. The members of VCM have agreed to conduct their operations in accordance with the following principles, however the code does not constitute a legal requirement.

General Principles

As with any exploration activity a number of general principles should be adhered to:

- A minerals tenement must be held over the ground and all conditions applied to the tenement observed.
- Liaise closely with landholders, local shire clerks and government bodies who have title to, or responsibility for, the land.
- Minimize damage to improvements, vegetation, crops, land and road foundations.
- Minimize disturbance to landholders and their livestock.
- Rectify as soon as possible any damage that can be reasonably repaired.
- Pay landowners/shires compensation for any agreed damages as soon as possible.
- Leave all drill sites clean and, where practical, cut drill casing below plough level and cap holes.
- Abide by this code of conduct and the "Code of Conduct for Exploration & Mining on Private Land" published by the VCM in April, 1988, and ensure that all members of the drilling crews and their supervisors are aware of required practices and conduct.

Types of Drilling

This code of conduct is relevant to all types of exploration drilling and therefore includes:

- ***Auger Drilling***. Shallow drilling done by hand or a small motorized auger (which can be trailer or land cruiser mounted).
- ***RAB (Rotary Air Blast)***. A small truck mounted rotary air blast drilling method.
- ***Conventional Open Hole Percussion***. Air is pumped down the rod and sample cuttings are returned by being blown out up the outside of the rod.
- ***Reverse Circulation (RC)***. A dual rod system where air is pumped down between the outer and inner rods and the sample is returned up the inside of the inner tube.
- ***Diamond Drilling***. Where diamonds are used as the cutting tool and a solid core of sample is recovered. The cutting face is kept cool using water/mud.

Drilling methods 1) and 2) are only really effective above the water table although both can be done in damp conditions. Methods 1) to 4) use air as the bit-cooling mechanism and therefore have no major problems with water supply or drilling mud contamination. Diamond drilling is the slowest, most expensive and most complex and generally causes the greatest individual drill site preparation. It requires a good supply of water and holding tanks to mix and recover drilling muds/fluids.

Private Landholder Compensation

It is important that before any drilling equipment or personnel arrive on site that compensation agreements have been signed with Private Landholders. Agreement should be reached on matters such as:

- Levels of compensation on the basis of per drill hole or, where there is crop or pasture damage in drill site preparation or by access, on the basis of land area disturbed.
- The area and specific paddocks that are to be used by the drilling crew and equipment.
- The route of travel to drill sites which is the most convenient to the landholder.
- Necessary precautions to reduce fire risk, fire

safety equipment and adherence to fire bans.

- How drill holes will be filled in, plugged or capped once this programme is completed.
- The method of restoration of drill sites and access tracks once the programme is finished.

Items of Particular Concern

There are a number of matters that commonly concern landholder and government officials. The VCM's guidelines to its member companies are:

- ***Responsibility.*** The management and responsibility for the drilling programme rests with the company managing the Mineral Tenement. Its representative (generally the on-site geologists) should make contact with the landholder/government official concerned and discuss all of the following items to ensure complete understanding by all parties (including the driller). The drilling crew should operate under clearly defined instructions at all times.
- ***Access.*** Access roads convenient to all concerned must be established. If the weather is very wet the use of these routes may need modification. Where possible, avoid excessive traffic near farmhouses. Establish whether it is best to stay on established tracks or to spread the vehicle load over the paddock.
- ***Site Preparation.*** Discuss drill site location, especially for diamond drill holes, with those responsible for the area. Avoid damaging trees as much as possible in both access track and drill site establishment. If top soil is removed, it should be carefully stored at a convenient, undisturbed location so it can be returned to the site on restoration.
- ***Fences and Gates.*** Leave all gates open or closed, as found or otherwise according to written instruction from landowner/government official. Do not interfere with any fences without permission.
- ***Dogs and Firearms.*** Firearms should be banned. Dogs should not be taken onto drill sites without permission from landowner.
- ***Fire Precautions.*** All fire bans must be observed and all drilling operations should have adequate fire fighting equipment.
- ***Drilling Fluids.*** Where water is needed for drilling fluid or mud, discuss its access with the landholder or local shire. Ensure that all on-site holding tanks are adequate and well dammed so that drilling fluids cannot spread out over the local area.

If good quality water is found in any drilling hole the landowner/government official should be notified. If brackish water is located similar notification should be made and all precaution should be taken to prevent contamination of the local drainage and soil. Where water flows containing high suspended solids occur, settling pits must be constructed before the water is channelled into the drainage. If settling is slow, discuss with landowner whether floculants or alum can be used to aid settling.

- ***Sampling.*** Samples collected during the drill programme should not be left on site but be removed as soon as possible. At no time should plastic bags containing samples be left on the landholders property without permisiion. Excess sample cuttings around the collar of the hole should at the end of drilling be either returned down the hole or disposed of in a manner not detrimental to local soil and pasture conditions.
- ***Livestock.*** Discuss with landowners all matters relating to disturbance of livestock and their protection from dangers associated with drilling. In some circumstances, such as diamond drilling, it may be necessary to erect temporary fencing to prevent stock access to drilling fluid holding areas.
- ***Capping of Holes.*** Holes should be capped according to the needs of the landholder and the programme. If the area is to be used for crops no steel casing should be used but holes should have PVC cut below the depth of ploughing with a PVC cap. All holes, whether cut off below ground level or not, should be capped to prevent potential water damage.

2. Code of Conduct for Mining — An Approach to Environmental Land Management

Introduction

The members of the Chamber of Mines share community concern over environmental damage and support the concept of sound environmental management. They conduct exploration and mining operations to standards as high or higher than those laid down by the State Government.

The Chamber supports the concept of multiple use. Members of the VCM are committed to conducting mining in Victoria in a manner which has minimal environmental impact, and returns the land for a safe and productive later use.

With regard to care for the environment and rehabilitation of the project area members have agreed to the following guidelines.

General Principles

Members of the VCM will:

- design and construct mineral projects to high professional standards.
- operate mineral projects in an environmentally-responsible manner.
- seek means to facilitate rehabilitation of operating areas by progressive action throughout the project.

- actively review measures introduced for environmental control and rehabilitation, monitor key variables; report significant results, and their meaning, to the relevant authority.
- ensure that their employees and contractors are fully informed of, and understand these corporate objectives.
- demonstrate a corporate commitment to environmental principles, and encourage their employees to have similar commitment.
- closely liaise with State and local government officials responsible for the environment, and site rehabilitation.
- closely liaise with adjacent landholders and the local community, to ensure a mutual understanding of operational and off-site effects.
- operate within the environmental and site rehabilitation conditions applied to the project.

Close liaison with State and local government bodies is essential throughout the project.

The Chamber supports the concept of multiple land use: mining is a temporary occupant of land, which is rehabilitated and then becomes available for other uses. Underground mining enables other land use at surface while mining is in progress.

Where mining competes with other forms of land use there should be a balanced assessment of the best prospective utilisation of that land.

The whole community favours the protection of areas of major scenic, heritage, and scientific value. The industry accepts that there are occasions when the responsible decision is to exclude development in areas of exceptional merit.

Environmental Practice

The Planning Stage. The project manager should:

- consult with all responsible authorities, relevant local community groups, and adjacent landholders before undertaking new projects of significant expansion.
- seek amendments to planning schemes, where warranted.
- prepare public displays and information sheets outlining the plans for mining and rehabilitation, and ensure good communication with local residents.
- nominate a company spokesperson, and facilitate the flow of information about the project.
- investigate alternative methods of mine operation, and alternative sites for ore treatment and products disposal, to identify ways to minimize the potential impact on the social and physical environment.
- design and locate the treatment plant and infrastructure to reduce its visual impact.
- identify potential environmental problems, and incorporate counter-measures in the design. In liaison with the appropriate Government departments, establish relevant monitoring practices and standards.
- undertake preliminary environmental studies immediately, to determine whether an Environmental Effects Statement will be necessary.
- commence baseline environmental studies as soon as possible, and incorporate social issues where necessary.
- design solid waste dumps to minimize runoff, trap any sediment in the runoff, and inhibit erosion.
- incorporate a comprehensive rehabilitation programme in the final design, to achieve a sustainable use, and stable land forms, after mining.
- develop specific fire prevention measures.
- plan and control activities so as to minimize any impact on sites of natural, historical, aboriginal or archaeological significance.

Note: Planning must have in mind an ultimate land use for the operating areas, compatible with the surrounding environment. Where it is impractical to establish end uses at the planning stage, the matter should be regularly reviewed with the relevant bodies during the life of the project.

The Construction Stage. The project manager should:

- ensure that clearing of vegetation is reduced by care in siting, the design of a compact treatment plant and administrative buildings, and close control on the design and use of access roads and industrial space. Existing roads and open space should be incorporated. This will enhance the appearance of the workplace and the visual amenity of the whole area. It may also reduce the cost of both initial landscaping and continuing rehabilitation.
- maintain or develop a vegetation buffer around the project site.
- prevent the undue clearance of isolated stands of significant vegetation: these are often important for habitat reasons.
- conserve all available topsoil during the construction of the mine, for the later rehabilitation of disturbed areas. Stored topsoil should be used within twelve months.
- exercise care to avoid unnecessary disturbance, clearing or grading, this will restrict erosion, and reduce the area requiring regeneration.
- ensure that the initial treatment, and subsequent management of cleared areas, including disused roads and tracks, facilitates the regrowth of species indigenous to the area, unless alternative land uses are planned.
- carefully plan traffic requirements for the construction and operating stages; place limitations on the number of access roads/tracks, using ex-

isting access wherever possible.

- stabilize built-up earthworks, and commence the rehabilitation of the resultant slopes using indigenous grasses or shrubs.
- establish a water management and drainage scheme, particularly in areas subject to excessive runoff, or periodic flooding.
- make provision for the containment of spillage.
- when close to residential areas, confine surface construction to working hours acceptable to the local community, and minimize the generation of dust and noise.
- continue to liaise with the responsible authorities and relevant local groups on environmental and planning matters, and keep them fully informed of progress.

The Operating Stage. The project manager should:

- have regard to the social environment, as well as the invested capital, in setting appropriate working hours.
- seek to achieve progressive rehabilitation during the operation.
- monitor the success of the reclamation programme, and modify, if warranted.
- monitor and report key environmental variables, according to the programme established during the planning stage.
- give particular attention to the water management programme for the entire site, including clarification and treatment, where necessary.
- ensure that the dewatering of mine workings, and any discharge beyond the site, complies with the policy objectives expressed in the State Environmental Protection Policy.
- incorporate any drainage from stockpiles or waste dumps in the overall water management programme, contained or treated where necessary.
- store chemically-active waste products (e.g. sulphide-bearing material) separately, to inhibit degradation of the environment.
- place solid waste (including tailings) when stored at surface, so as to meet the requirements of the statutory authorities. For surface storage, the design should enable recontouring and/or rehabilitation to the end use intended at the completion of the project.
- continue investigation of the most appropriate means of re-use of areas used for tailings storages, leached heaps and waste rock stockpiles, and/or their revegetation.
- maintain a public relations programme, and arrange regular public inspection of the project.

Rehabilitation

Members of the VCM are committed to ongoing rehabilitation of their operating areas, and the timely rehabilitation of those areas — fully in accordance with State government conditions.

The Rehabilitation Stage. Rehabilitation plans should be specific and detailed, so as to be used as a measure of performance.

- Remove all rubbish, plant, equipment, construction materials and structures from the site unless alternative arrangements have been made with land manager or landowner.
- Dispose of all hazardous material in an environmentally acceptable way.
- Reshape the land having regard to surrounding topography, pre-existing drainage lines, and the final use of the site.
- Spread the stockpiled subsoil then topsoil over all exposed areas.
- Reseed and replant vegetation, using endemic species where native vegetation is to be re-established. Always seek the advice of experts on the most suitable species and the best techniques for ensuring their survival.
- Control weeds and vermin using environmentally acceptable methods.
- Engineering works or surface cover may be required to control erosion.
- Ensure that waste material including tailings, is not left in a state that may lead to contamination of the environment.
- Continue maintenance of the site until a self-sustaining cover of vegetation can be ensured and the surface is stabilized against erosion.

Organizing Communication for a New Facility: A Case Study

This case study is an excerpt from a presentation to the IAEA Public Information Forum, 11 September 1991, by Mary Boyd, Manager of Public Outreach Services, Duke Engineering and Services Inc., USA.

If you are fortunate enough to have played a role in siting a nuclear-related facility, or are planning to play such a role, the most important principle to remember is that you are affecting people and people must be communicated with in a respectful manner. This is not surprising or original advice to knowledgeable communicators but I hope that the immediacy of my experience in this regard will be relevant to you.

Louisiana Energy Services, or L-E-S for short, will build our nation's first privately owned uranium enrichment facility. It will be the first commercial use of centrifuge technology for enrichment in the USA. It is the first application to the US Nuclear Regulatory Commission for a license for a major nuclear-related facility in almost 20 years. It will be the first facility to benefit from one-step licensing legislation, which was passed by the US Congress just last fall for facilities that process uranium hexafluoride, and finally, it will be the first nuclear-related facility in Northern Louisiana.

Here is some background information. The purpose of our project is to provide an additional source of domestic enrichment for US nuclear utilities. As you know, enrichment is one of several steps in making nuclear fuel. At the Clairborne Enrichment Center, we will use thousands and thousands of centrifuges to physically separate uranium-235 from uranium-238, concentrating the lighter uranium-235 to the 3% to 4% level needed for commercial nuclear power plants. In the USA, enrichment represents about 40% of the total cost of new nuclear fuel, so the savings that companies make by securing enrichment from Louisiana Energy Services will help hold down the cost of nuclear power. Our plant will be able to serve the needs of about 15% of the nation's currently existing nuclear power plants. In addition, the centrifuge technology uses only 1/50th of the electric energy required at the US Department of Energy's two gaseous diffusion enrichment plants.

The Clairborne Enrichment Center will be an extremely clean operation. Through heating and cooling, uranium hexafluoride, which is the material we process, goes from solid to gas back to solid. All we will do is physically separate lighter uranium from heavier uranium inside the centrifuges, which contain rotors spinning more than a thousand times a second. The function is almost entirely performed at less than atmospheric pressure. There are no high temperatures or pressures. There are no chemical conversions. There is no nuclear fissioning.

Does this mean, then, that there is no controversy about the plant?

No, that is not the case. We went into this project with our eyes wide open, and we knew anything associated with the nuclear industry had the potential for controversy and concern. Most importantly, however, we knew from our previous experiences that public acceptance could be achieved if the information were disseminated properly, if the licensing period was used advantageously and if we paid attention to local politics and culture.

Louisiana Energy Services is a limited partnership consisting of URENCO, the European Enrichment Consortium that operated centrifuge enrichment facilities in the United Kingdom, The Netherlands and Germany; Fluor Daniel, an internationally-known engineering and construction firm; and three utilities — Duke Power, Northern States Power and Louisiana Power & Light, which operate 11 nuclear power plants.

Our plant is expected to cost about $800 million. It will require about 400 workers during construction and about 180 during operation. We filed our 15-volume license application in January of this year. We expect to receive our license and start construction in early 1993, with initial cascades (that is a group of centrifuges) in production by late 1995. We will eventually pay about $6 to $8 million a year in property taxes and we plan to hire the majority of the employees from the surrounding region.

Our project was announced with much fanfare on 9 June 1989, by US Senator J. Bennett Johnston of Louisiana, Chairman of the Senate Energy and Natural Resources Committee. His interest in our project came about the same time we were beginning to look for a site. In order to maintain their reliability, our centrifuge machines, some of whose European counterparts have been spinning continuously for more than 16 years, require being sited where the possibility of a damaging earthquake is very low. In a parallel development, Senator Johnston's national focus as Senate Energy Committee Chair and as a proponent of a more businesslike uranium enrichment enterprise understandably turned inward to Louisiana when he learned how clean and safe the centrifuge facilities were and what good neighbours they were in their communities. So thanks to mother nature, who blessed Northern Louisiana with the suitable geology, to Senator Johnston's interest and to Louisiana Power & Light, our project came to call Louisiana home.

The economy of Claiborne is strongly based on oil and gas and has fluctuated with the ups and downs of that energy industry. When we announced our project in 1989, unemployment was about 13% to 14%. Now, thankfully, it is about half that. Claiborne Parish is a rural area — 18 000 people in 720 square miles. The people are bright, caring and strongly tied to their local area. The nearest large urban area is Shreveport, which is about 50 miles away. There are no nuclear plants nearby. The only taste of nuclear these residents had had was back in 1987 when there was speculation about siting a low-level waste disposal facility there. They did not want it and they filled the local high school football stadium to tell the Governor that much.

But a lot of the people who were opposed then are supporters of our facility today. I should like to think communications has had something to do with that.

By the time of our announcement, we had narrowed our site search to Claiborne Parish but not yet to a specific property. That took several more months. We used this time to familiarize residents with our project through a series of meetings throughout the parish. As they got to know us, we got to know them, along with their level of support or concern. Though a few individuals were openly hostile, our reception was overwhelmingly positive.

People were willing to listen and learn, so that when the first salvo from a Washington anti-nuclear group was fired, it had the accuracy of a "Scud" missile. It underestimated the intellectual strength of its target and was intercepted by a "Patriot" in the form of a discerning local newspaper editor — with a little help from us.

An organization called Public Citizen, a Washington-based Anti-Nuclear Group, issued to the Claiborne parish newspaper material that attempted to compare our proposed facility to the U.S. Department of Energy's enrichment plants, which use a different technology and have had their share of environmental problems. We had recognized that this attempt would be made, and we were prepared. Our initial education efforts in the parish were critical in preventing the spread of this misinformation.

When we finally determined the most technically appropriate site in late 1989, we went door to door in the immediate area with information and materials. We received a variety of responses from "That's good news" — How many jobs will you have?" to "What is it — will it cause cancer?" to a shrug of the shoulders.

Final site selection gave impetus to the small group that had already expressed opposition to our project, and it has filed as an intervenor in the licensing process. Another Washington anti-nuke group is assisting them financially, which is understandable. After all, if the LES Project succeeds, it will help hold down the cost of nuclear power today and make it a stronger choice for meeting our country's long-term energy needs tomorrow, so no wonder the group feels threatened!

As part of our information programme, we took to the extreme a tool that has served us well in this business. By that I mean the plant tour. Since there are no facilities like ours yet in the USA, we took two groups from the Parish to see two of the centrifuge enrichment facilities that are located close together in The Netherlands and Germany. We provided plant tours and the opportunity to meet with employees and a variety of local officials and residents. We also built in some unstructured time so the visitors could do interviews in the towns where these plants are located. We prepared a videotape from the first trip so others in the parish could share in the experience.

Last summer, we sponsored a trip by 20 residents to the Westinghouse Fuel Fabrication Facility in South Carolina and to Duke Power's Oconee Nuclear Station and "World of Energy Visitor Center". The purpose of this trip was to show the two parts of the fuel cycle after enrichment — fuel fabrication and use of that fuel in the reactor. Far more importantly, at Oconee we wanted these folks to find out what it was like to have a nuclear facility in their community. So we arranged to have a number of local officials available — a county council representative, emergency planning officials, a merchant, a manufacturer, an education official, a real estate agent, a hospital administrator — to answer any questions about Oconee or about having Duke Power as a citizen in their community. The visitors were also free to stop and talk with anyone in the community they wanted to — we just provided rental cars and said "Go". This was an extremely successful effort. As a matter of fact, the participants joked that they were going to go back to Claiborne parish and say they no longer wanted an enrichment plant — they wanted a nuclear plant instead! We repeated the Oconee portion of this trip for another group this summer, and it was equally successful.

Other activities we have undertaken include:

- Inviting educators selected by the school board supervisor to attend our summer teacher workshops on energy that we sponsor at Duke Power Company.
- Providing a tour of Duke Power's Environmental Laboratories where Louisiana visitors could see samples of Claiborne parish water that were being analyzed for information needed for our Environmental Report.

- Memberships in important statewide or regional organizations, such as the Louisiana Association of Business & Industry and The Southern Growth Policies Board.
- Opening an Information Office in Clairborne parish with visually appealing exhibits and a knowledgeable local resident as a community relations representative.
- Starting a newsletter that goes to every household in the parish.

In summary, we have attempted to demonstrate the technical credibility of the process we will use at our plant and the technical competence of the companies involved; to make information about the project easily accessible; and to use and adapt public outreach techniques that have worked well at Duke Power over the years.

Have we been successful?

The most frequent question we get at our office is "When will the jobs be available?" — Those far outweigh questions about the safety of the plant.

The day after we filed our license application, a group of parish leaders sent a telegram to the chairman of the Nuclear Regulatory Commission urging timely review of our application because of their belief in the safety of the plant and their eagerness for the jobs it will bring to Claiborne Parish.

This summer, the NRC held a public meeting to get comments on environmental issues that should be covered in the Government's Environmental Impact Statement it must write on our project. At this meeting, the majority of folks in attendance were plant supporters. Most of the speakers in favour of the plant were people who had taken tours of the enrichment facilities or nuclear plant and could discuss knowledgeably the environmental issues they wanted the NRC to address. They are a core of support that is extremely effective.

So, we believe we are well on the way to establishing LES as a good long-term corporate citizen in the parish and to creating a climate that will permit state and federal regulators to make timely decisions on a technical, rather than a politically reactive, basis.

APPENDIX III

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In response to needs expressed by Member States, the IAEA convened a Consultants Group in 1989 to address questions that members of the public may have about nuclear fuel cycle facilities. The Group initiated the publication of a handbook focusing on ways of dealing with the important issues of public information and communication as a preliminary step in assisting the staff of nuclear fuel cycle facilities to apply the principles of building good public relationships to their communication programmes.

The Consultants Group, under the chairmanship initially of Robert Cartwright (United Kingdom) and subsequently of John Macpherson (Canada), was amplified by an Advisory Group. The handbook is the product of the joint effort of the group members and of its Scientific Secretary, J. L. Rojas, and I. G. Ritchie of the IAEA Division of Nuclear Fuel Cycle and Waste Management. They were helped during their deliberations by Mr. J. L. Zhu, then the Director of the IAEA Division of Nuclear Fuel Cycle and Waste Management and various staff members. The ongoing encouragement of Mr. David Kyd, Director of the IAEA Division of Public Information, and Rita Scott, then a member of the Division, was also appreciated, as was the help of members of the Division of Nuclear Power. Appreciation is further expressed to all the participants and their Member States for the valuable contributions, and to others who provided useful ideas and materials.

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