World Nuclear Association Annual Symposium
5-7 September 2001 - London

Long-term storage of radioactive waste – a regulatory view

Sheila Hutchison, Frances Taylor

Introduction

In 1998 the UK Government upheld the Cumbrian County Council's refusal to grant planning permission for an underground rock characterisation facility near Sellafield, which was intended to be the precursor for a deep repository. That decision has effectively delayed the availability of any future disposal facility for intermediate level waste (ILW), and made it clear that it will be many decades before a disposal route, or other long-term management option, is available for ILW and high level waste (HLW). An alternative approach favours long-term storage and retrievability of radioactive waste rather than deep disposal. This was one of the main conclusions to emerge from a recent Citizens' Panel Consensus Conference [1] that addressed the topic of radioactive waste management.

NII wished to evaluate the impact of the above decision on the safe management of radioactive waste in the UK, and carried out a review of the current situation, the findings of which were published in 1999 [2]. The review showed that although there was no immediate safety issue, there is a need for nuclear operators to develop strategies that will ensure that radioactive wastes are stored safely for much longer periods than previously envisaged. It also highlighted the considerable accumulations of legacy wastes. The review revealed that, if an operating repository is not available within the next 15 to 20 years, up to 20 new stores would be required for the radioactive waste currently accumulated. If the delay extends beyond 50 years then a programme of store replacement or refurbishment will be required and, possibly, provision for the handling and repackaging of wastes.

Hence the management of radioactive wastes in the foreseeable future will require its long-term storage pending development of a final management solution. NII expectation is that for planning purposes, time-scales of at least 50 years for a repository to become available and a further 50 years for emplacement of wastes should be used. This would be followed by a further period while the decision is made to close the repository and leads to a storage period in excess of 100 years. NII has been developing guidance for its inspectors in the areas of radioactive waste management and decommissioning which sets the regulatory framework for assessing the adequacy of nuclear operators' arrangements in the light of the current circumstances. This paper draws together aspects of the guidance [3] and other material [4, 5, 6] that has been presented in public fora.

Regulatory Background

The main legislation covering the safety of workers and the general public at nuclear installations, in the UK, is the Health and Safety at Work Act 1974 (HSWA74) and associated statutory provisions, which include the Nuclear Installations Act 1965 (as amended, NIA65). Under NIA65, no site may be used for installing or operating any nuclear installation unless a site licence has been granted by the Health and Safety Executive (HSE). NII is that part of HSE responsible for administering this licensing function. NII aims to secure the maintenance and improvement of standards of safety at licensed nuclear installations, including the protection of workers and members of the public from ionising radiation. In regulating radioactive waste management and other activities in accordance with statutory powers, NII should ensure consistency with UK Government policy [7].

NIA65 requires a site licence to be issued before prescribed activities may be undertaken. NII may attach such conditions to the site licence as it may think fit with respect to the handling, treatment and disposal of nuclear matter, or as may appear to NII to be necessary or desirable in the interests of safety. It is largely through this route that NII achieves its regulatory aims. There are 36 conditions attached to a licence; these are essentially non-prescriptive and generally require the nuclear operator to make and implement adequate arrangements to address safety and waste management issues. The non-prescriptive nature of the licence conditions enables a continuous and flexible form of regulation, which can be applied throughout the life-cycle of a nuclear installation.

Licence conditions related to radioactive waste management require the operator to make arrangements to:

- control the introduction and storage of nuclear matter (nuclear matter being fuel, radioactive materials and waste);
- ensure that the production rate of radioactive waste is minimised, and that it is accumulated under suitable arrangements, with adequate records;
- dispose of radioactive waste, in accordance with an appropriate authorisation, if so directed at the discretion of NII; and
- control and contain radioactive material and waste, so far as is reasonably practicable, to prevent leaks, to detect and report unauthorised leakage, to ensure that waste arisings are minimised and properly contained and that appropriate use is made of available disposal routes.

A further fundamental requirement of the nuclear site licence is for nuclear operators to produce safety cases for all operations which may affect safety, and this includes radioactive waste management.

NII continuously reviews its regulatory approach, including the adequacy of the site licence conditions, and will respond to developments and changing circumstances, both national and international.

The disposal of radioactive waste and discharge of radioactive material in airborne and liquid discharges from any facility, including nuclear licensed sites, is regulated, under powers derived from the Radioactive Substances Act 1993, by the Environment Agency (EA) in England and Wales and the Scottish Environment Protection Agency (SEPA) in Scotland. All other aspects of radioactive waste management on nuclear licensed sites, including its generation, accumulation, treatment and storage, are regulated by NII under the licence and other regulations made under HSWA74. The vast majority of radioactive waste in storage in the UK is located at nuclear licensed sites. Close liaison is maintained between NII and the two environment agencies, through interdepartmental agreements, with the aim of ensuring that waste management aspects are regulated in an effective and consistent manner.

UK Government policy on radioactive waste management was reviewed in 1994/95 and the conclusions of that review were set out in "Review of Radioactive Waste Management Policy, Final Conclusions (Cmnd 2919)" [7]. Two basic principles of UK Government policy that are relevant to the context of this paper are the concepts of sustainable development and storing radioactive waste in accordance with passive safety. The future national strategy for radioactive waste management is under review. The most recent UK Government statement is given in its response [8] to a report by the House of Lords Select Committee on Science and Technology on this subject [9]. The UK Government has made clear that it wishes to "take account of the Committee's views and undertake wide consultation before announcing how it wishes to proceed". The UK Government and devolved administrations in Scotland and Wales plan to publish a wide-ranging consultation paper to "discuss the processes that would be involved in the various management options for radioactive waste, rather than the relative merits of the options themselves" in the near future.

The licensing regime is goal setting rather than prescriptive and therefore NII does not generally issue guidance to the nuclear industry on its expectations. However it has published the Safety Assessment Principles [10] used by its inspectors in assessing licensees' proposals. It also issues more detailed guidance to its Inspectors. Over the last few years HSE has been developing and consolidating its guidance on radioactive waste management and decommissioning taking account of government policy. NII realised that this was a topic of wide interest so it discussed the draft guidance with interested organisations and presented papers at conferences [11, 12, 13, 14] on its emerging thinking. This was found to be a very useful exercise. The work is now complete and the guidance [3] has been placed on the Nuclear Safety Directorate section of the HSE website (http://www.hse.gov.uk/nsd/nsdhome.htm). The guidance identifies NII's four fundamental expectations for the management of radioactive material on nuclear licensed sites:

- the production of radioactive waste should be avoided and minimised;
- radioactive material should be managed and stored safely in a responsible manner, i.e. controlled and contained;
- full use should be made of existing routes for the disposal of radioactive waste; and
- remaining radioactive material should be promptly put into a passively safe state for storage pending future disposal or other long term solution.

The guidance will be reviewed regularly in the light of experience with its use.

This paper will concentrate on NII's expectations of how nuclear operators can demonstrate safe storage of ILW.

Passive Safety

Of particular relevance to long-term storage of wastes is one of NII's fundamental expectations that, so far as is reasonably practicable, radioactive materials and radioactive waste should be stored according to the principles of passive safety [4]. The more hazardous the waste (for example HLW) and the more mobile its form, the greater the safety benefit from passively safe storage and the sooner this should be achieved. Only when this is not reasonably practicable, should potentially mobile wastes be accumulated in a raw state for significant periods.

Passive safety, which is an element of UK Government policy, requires the radioactive wastes and materials to be immobilised in a form that is physically and chemically stable and stored in a manner that minimises the need for control and safety systems, maintenance, monitoring and human intervention. Wherever possible it should be packaged in a form that is suitable for both long-term storage and ultimately for disposal. Nirex is the UK organisation that provides advice and maintains specifications for the packaging of radioactive waste, and it issues letters of comfort to nuclear operators for those waste forms that it considers consistent with future disposal requirements.

In some cases there may be a conflict between processing waste now to achieve passive safety and the foreclosure of future options, such as disposal. In such cases an operator will be expected to demonstrate an appropriate balance has been achieved between current and future safety requirements, and in some cases the need for short-term safety improvements may be overriding. However, NII believes that in the majority of cases it should be possible to place radioactive waste in a passive safe state that can also be shown to be acceptable for final disposal. Where decisions may impact on the final disposal the environment agencies also have a regulatory interest.

Passive safe storage of radioactive materials and radioactive waste is most appropriately achieved by providing multiple physical barriers to the release of radioactivity to the environment. The physical barriers include the form of the waste or material itself, the material used for encapsulation, the waste container and the storage building or structure, each of which should be designed to provide effective containment and prevent leakage.

As stated earlier, in its strictest sense, passive safety requires that safety is assured without dependence on active systems, maintenance, monitoring or human intervention. However, with respect to the long-term storage of radioactive waste, assurance will be required that deterioration is not occurring and in some circumstances it may be necessary or advantageous for active systems to be in place to control the environment in which waste is stored.

Factors to be Considered for Long-term Storage

Passive safety is best achieved through the provision of multiple physical barriers against the release of radioactivity into the environment. In the following paragraphs some of the

important factors to achieve this containment, namely wasteform, container and store design, are discussed and the need for the adequacy of arrangements to be demonstrated through a safety case.

Safety Cases

The nuclear site licence requires nuclear operators to produce safety cases for all operations that may affect safety. This includes the long-term storage of radioactive waste. This should address all phases in the life of a storage facility, including construction, commissioning, operation and decommissioning. NII expects safety cases to be made on the basis that arrangements are consistent with modern standards, which are represented by sound engineering principles and current best practice. Furthermore it should demonstrate that the risks from the operations have been reduced as low as reasonably practicable (ALARP).

If new facilities are to be designed and constructed then they are expected to be fully consistent with modern standards. However, in some cases operators may choose to use or modify existing facilities for the storage of wastes. Justification of the safety of older plant will require careful consideration of the current and future condition of the plant and the intended use. The standard approach is to establish the shortfalls against modern standards and investigate what safety improvements are reasonably practicable. A particular concern is that old or deteriorating facilities that fail to meet current standards will fall further behind in the future.

Nuclear operators should carry out routine verification that the safety case remains consistent with each facility and its operation, and in addition the licence conditions require them to carry out more comprehensive periodic safety reviews, typically every 10 years. These reviews are intended to consider operational history, provide a comparison with modern safety standards and justify any differences or concerns.

Containment

For the safe storage of ILW the primary consideration is to ensure that the radioactive waste is immobile and is contained in order to minimise the potential for dispersal. The waste should therefore be in a form that is physically and chemically stable and should also be resistant to any significant deterioration over the storage period. The waste should be characterised to provide information for any future handling.

Certain raw radioactive wastes may be in a form for which the radioactivity is already immobile and therefore meet the requirements for passive safety without the need for processing. Such cases will require to be demonstrated, but examples could include robust metallic components.

In many cases, the raw radioactive material or radioactive waste will require conditioning to place it into a passively safe form to immobilise the radioactivity. Typical waste forms that fall into this category are gases, liquids, wet solids, slurries, sludges, powders and particulate material. The conditioning processes that are typically used for immobilisation of liquids and solids are encapsulation in cement or vitrification.

Other raw radioactive wastes may be in a form for which some intermediate processing may be required prior to conversion into a passive safe form. For example, highly

reactive or corrosive substances should be neutralised or made less reactive by chemical processes. In the few cases where a raw radioactive waste is not suitable for processing, then these wastes should be identified and an acceptable alternative strategy for their future management developed.

For some of the heat generating wastes corrosion could lead to volumetric growth of the waste form and, where it is a close fit within the primary container, internal pressure could ultimately result in failure of the containment. It must be demonstrated that there has been sufficient research and development to show that the possible extent of corrosion is understood, that suitable operating parameters have been derived, and that there is an adequacy of engineering provision e.g. store cooling to control these parameters. It is particularly important to recognise the need for validation of analytical models against experiments that replicate as closely as possible the expected plant conditions, although it is unlikely that experiments or development trials will be able to replicate the range of anticipated plant conditions. For example, there will never be sufficient lead in times to run representative ageing tests. Claims against extrapolated data need to be adequately justified within the safety case.

Experience has shown that long-term bulk storage of radioactive materials can be problematic and this leads to an expectation that future long-term storage will be in discrete containers. Containers may have to be moved for logistic or inspection reasons and so they will need to be sufficiently robust to allow such movements during the intended storage period. These considerations result in simple expectations:

- containers should be designed for the intended purpose;
- container material should be selected for its resistance to degradation;
- multiple containment barriers should be provided;
- containers should be manufactured to an appropriate quality; and
- containers should be designed to allow the movement, if required, of the radioactive wastes either for inspection purposes or between stores.

Each container should be clearly identified and its position and contents recorded for retrieval purposes. It should be possible to retrieve any container for inspection or transfer within a reasonable timescale, e.g. one week.

The final physical barrier to the release of radioactivity to the environment is the storage building or structure. However, in aiming to achieve passive safety the most significant barriers are first and foremost the waste form itself, and secondly the waste container. This means that in some cases, the role of the storage building or structure may be limited to providing environmental protection, radiation shielding and presenting a secure boundary against unauthorised intrusion or interference and entry of wildlife.

The nuclear operator should be able to demonstrate that the design of the storage building or structure is fit for purpose, taking account of the expected time required for passive safe storage, the hazards posed by the stored wastes as well as any external hazards i.e. the design should be proportionate to the defined purpose of the building and to the risks.

Some operators propose to use existing structures, modified in some cases, for future long-term storage. In these cases, it should be demonstrated that, so far as is reasonably practicable, the structure meets current standards and is safe for the projected period of storage. Where a building is designed for a shorter life with the intention of periodic refurbishment, justification should be provided that the waste can be stored safely while the refurbishment is carried out.

The storage building will need to provide sufficient protection to the stored wastes so as to optimise the life of the packages and to facilitate safe transfer to the final disposal facility (or to a further storage facility) at the appropriate time. This may necessitate control and monitoring of the environment of the storage building (temperature, relative humidity and constituents of the atmosphere) and also of the surface temperature of the waste packages in order to minimise corrosion rates. This may be particularly important on near coastal sites where chloride levels in the atmosphere are relatively high. Such environmental control cannot be achieved by purely passive means and it may be necessary to adopt a forced ventilation system with control of relative humidity and a filtered inlet to remove atmospheric contaminants such as salts. This is an example of where there may be a need for an active system as opposed to a passive system. Current experience is that such systems are very reliable, simple, long lived and easily maintained.

One of the foreseeable mechanisms for the mobilisation of radioactivity in waste is the ingress and action of water in a store. Potential sources of water ingress are groundwater, rainwater, flooding and condensation. The possibility of stagnant water being in contact with the containers, coupled with the air in the store possibly being salt laden, as many stores are likely to be near the sea, could lead to corrosion resulting in failure of the lifting integrity of even stainless steel containers. An effective means of reducing potential water ingress is to site the storage building above ground level. If a building is below ground level then it is best positioned above the local water table. In general, NII expects that the design of a storage building will include facilities to monitor for water ingress and the means to remove the water.

Other monitoring systems and alarms may be needed to provide detection of build up of flammable gases, fires and unauthorised intrusion. A radiation monitoring system would provide the ability to detect radioactivity in liquid or gaseous forms in the event of damaged/deteriorated packages. The panels and electronics associated with the monitoring system should be situated in an area of the building suitable for personnel access or external to the building. The need for surveillance and inspection of the waste packages and of the building to ensure safety should be minimised. It would, however, be good practice to provide periodic surveillance and inspection to confirm that the condition of the waste and its storage are not deteriorating. The building design should include provision for routine inspection, including access to all the packages by remote or manual means depending on the radiation levels, and the ability to retrieve packages for inspection and remedial action. There may be benefit to be gained from including the facility for members of the public to view the waste for reassurance purposes.

The design of the building should facilitate the retrieval of all waste packages either for inspection, possible remedial treatment or further storage elsewhere, and for disposal at the end of the period of passive safe storage or at an earlier time should radioactive waste management strategies change. Inevitably when retrieval has to be considered after a

considerable time of storage, there will be a need to demonstrate that the storage regime will permit this.

Waste handling equipment may not need to be continuously available, but should be capable of being returned to service when needed and should be maintainable within an area suitable for personnel access either inside or external to the building. Depending on the radiation levels associated with the waste packages, remote or manual handling techniques will be necessary. The possibility of degradation of handling equipment needs to be considered during the design and safety case preparation stage for a store. It may be possible to remove the crane used during store filling from the storage environment, both when it is between store loading campaigns and at end of filling. However, it is also necessary to consider the integrity of any container lifting point or stillage that may be used for transfer and storing of containers.

Records

It is clear that the records required to support the safe management of radioactive wastes during long-term storage and ultimately final disposal will need to be accumulated and retained for a long time. As a result, consideration needs to be given to the content of such records and the form in which they are kept. The nuclear operator should hold the records until the responsibility for the wastes and materials has been passed to another body such as the operator of a disposal facility.

NII expectations with respect to the preservation of nuclear operators' records can be summarised as:

- records should contain all the information that may be required in the future;
- records should be accessible to those who will consult them; and
- records should be assembled and maintained in a secure form.

The following list provides some guidance on what NII expects to see recorded:

- characteristics of the radioactive waste and radioactive materials including the radionuclide inventory, volume, radiological classification, physical and chemical form;
- waste origin and location in store;
- development and specification of conditioning recipes;
- development and specification of packages;
- details of packaging;
- store design and construction;
- inspection, maintenance and test results;
- records of all waste disposals;
- quality records; and
- safety case records.

The fundamental requirement is that records should be maintained in a secure and accessible form for as long as the information could be of value in the future. Even if future generations suspect the validity of the records they should provide a means for verification of package and store design. The need for long-term storage prior to disposal means that the projected storage period for many records associated with radioactive

waste management may be considerable. Therefore the means of preservation of the records during this time and the retrieval of the information also needs to be considered and should take account of legal requirements (i.e. suitability for use in legal proceedings), ageing, fire, flood and potential obsolescence of the retrieval system.

Comparison with International Practice

During development of its guidance on radioactive waste management NII commissioned two projects [15] to review ILW storage practices in the UK and overseas (Belgium, France, Netherlands and Switzerland). The findings from these projects showed that although facilities are designed in accordance with local regulatory requirements there is commonality with NII guidance. For example environmental conditions are managed to control, to prevent or minimise corrosion of packages; waste package surveillance is undertaken; waste packages can be retrieved within an acceptable timescale.

Summary and Conclusions

The UK regulatory system provides a flexible framework within which nuclear operators must demonstrate that operations are being undertaken in a safe manner and in accordance with the ALARP principle. By making its guidance to inspectors on radioactive waste management freely available, NII has made clear to nuclear operators its expectations for the long-term storage of ILW in the UK. The intent behind these expectations is to have ILW stored in a passively safe form that can be monitored to detect deterioration in a facility that is fit for purpose. In the event that deterioration is detected or a disposal route becomes available the waste should be readily retrievable for further conditioning or transport.

REFERENCES

[1] UK National Consensus Conference on Radioactive Waste Management, 21-24 May 1999, ISBN 0-948729-317 (also see www.ukceed.org).

[2] HM Nuclear Installations Inspectorate, Intermediate Level Radioactive Waste Storage in the UK: A Review, HSE Books.

[3] HMNII, Guidance for Inspectors on Management of Radioactive Materials and Radioactive Waste on Nuclear Licensed Sites, (http://www.hse.gov.uk/nsd/).

[4] L Williams, D Mason, S Blakeway and C Snaith, A regulatory view of the long term passively safe storage of radioactive waste in the UK, Proceedings of an international conference on Safety of Radioactive Waste Management, IAEA Cordoba, 13-17 March 2000.

[5] W Seddon, Engineering Considerations Associated with Plant used for Storage of Intermediate Level Waste – A Regulator' s View, IMechE RadWaste 2000, October 2000.

[6] D Turton, I McNair, Safe Storage of Radioactive Materials in the 21st Century – A Regulatory View, INucE Containment 2000, May 2000.

[7] Cmnd 2919, Review of Radioactive Waste Management Policy Final Conclusions, London HMSO 1995.

[8] The Government Response to the House of Lords Select Committee Report on the Management of Nuclear Waste, DETR, October 1999.

[9] Management of Nuclear Waste, House of Lords Select Committee on Science and Technology, London HMSO 1999.

[10] Health and Safety Executive, Safety Assessment Principles for Nuclear Plants, HSE Books 1998, ISBN 0-11-882043-5.

[11] DM Watson, Decommissioning in the UK, a Regulatory Perspective, poster presentation to WM ' 99 Conference (Abstract No. 892), Tucson, February 1999.

[12] DJ Mason, Regulatory Aspects of Decommissioning in the UK, a paper presented at a Joint NEA/IAEA/EC Workshop on the regulatory aspects of decommissioning, Rome, May 1999.

[13] DJ Mason and CE Temple, Regulatory Aspects of Decommissioning, IBC 6th International Conference on Decommissioning of Nuclear Facilities, London, June 1999.

[14] FE Taylor, The Regulation of Shutdown Licensed Facilities in the UK, IBC 7th International Conference on Decommissioning, London, October 2000.

[15] SM Wickham, TW Hicks, DN Simister, AG Davies, Long-Term Surface Storage of ILW, INucE Containment 2000, May 2000.