# The Application of HSE's Safety Assessment Principles for Nuclear Plants for Minimising Exposure to Internal Radiations

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**Abstract**

In the UK, the Health and Safety Executive (HSE) regulates activities on nuclear licensed sites by means of conditions attached to site licences which are used, inter alia, to minimise internal exposure to nuclear workers. Legal requirements reflecting the need to minimise exposure for Category A workers are set out in the Health and Safety at Work etc Act 1974 (ref 1) and the Ionising Radiations Regulations 1985 (ref 2) which implement the European Council Directives 80/836 and 84/467. As part of the regulatory process HSE has published its revised Safety Assessment Principles (SAPs) in 1992 - principally for its own internal use. The SAPs are essentially a set of goals, including both deterministic and probabilistic principles, which provide a framework to be used by nuclear inspectors when forming a view on the adequacy of operators' safety cases.

This paper describes the assessment process through which the adequacy of licensees' safety cases in relation to internal radiation exposure is judged by nuclear inspectors. In forming our view on adequacy, a number of indicators of best practice are used including our own Safety Assessment Principles and other published guidance. Particular attention is given to ensuring that the plant design is robust by ensuring that sufficient barriers are in place between radioactive materials and areas where workers or the public may be present. Our interpretation of relevant SAPs will be discussed with reference to recent examples of modern plant design which we have found acceptable.

HSE's guidance places particular emphasis on the need for the provision of sound engineering design in preference to reliance on operational control in order to minimise the potential for releasing radioactive particulates which may give rise to internal exposure. As part of the assessment procedure for new plants, inspectors would expect to examine aspects including containment, ventilation, plant-layout, maintenance, occupancy and instrumentation for monitoring airborne activity levels. As a regulator, HSE recognises that a proper balance needs to be achieved between the cost of a proposed activity and safety targets - the paper provides an insight into the factors which are given particular attention as part of HSE's assessment process. Our experience has shown that the UK approach offers a number of benefits to both regulators and operators including flexibility, transparency and consistency.

**UK regulatory structure**

The operators of nuclear plants in the UK are subject to the requirements of the Health and Safety at Work etc Act (1974) which lays down general duties on employers. Under this Act, the UK has made the Ionising Radiations Regulations 1985 for regulating the risks from ionising radiations, which implement the EC Directives 80/836 and 84/467. In 1993 the European Commission followed up the changed standards in ICRP 60 by publishing proposals for a revised BSS directive. The revised Directive was adopted on 13 May 1996 and designated as Directive 96/29/Euratom. The UK is currently in the final stages of implementing this and other EC Directives and it is likely that a revised set of UK Ionising Radiations Regulations will be implemented in the near future. Specific guidance on the regulations is also published in the form of an Approved Code of Practice (ref 3) and other requirements for dosimetry procedures associated internal radiations has also been written and published in the UK (ref 4 and 5).

Site operators of nuclear plant are subject to additional legal requirements and must comply with the Nuclear Installations Act 1965 (as amended). Under this Act, apart from certain exceptions, no site may be used for the purpose of installing or operating any nuclear installation unless a licence has been granted by the Health and Safety Executive (HSE). Attached to the nuclear site licence are a set of standard licence conditions which cover a wide range of activities such as construction, commissioning, operation, decommissioning, emergency arrangements etc. A common factor to many of these operations is the need for the operators to produce an adequate safety case - this is specified in Licence Conditions (LC) 14, 15 and 23. HSE judges the acceptability or adequacy of these cases - including arrangements for minimising exposure to internal radiations - by taking many factors into account including a comparison against published guidance (ref 6, 7, 8 & 9). In particular the Safety Assessment Principles for Nuclear Plant (ref 7) have been developed for internal use to assist nuclear inspectors in the assessment of licensees' safety cases. Table 1 below summaries the principles most relevant to limiting internal exposure.

**Safety case assessment**

The process adopted by the Nuclear Installations Inspectorate (NII) which is that part of HSE which is charged with enforcing safety legislation on licensed nuclear sites, involves NII in making regulatory decisions which require a safety case and supporting evidence to be submitted by the licensee for consideration and assessment, by the NII. The Inspectorate needs to adopt a consistent and uniform approach to the assessment process; to this end it is necessary to provide a framework which can be used as a reference for the technical judgements that the assessors have to make. The NII's safety assessment principles (SAPs) form such a framework.

In carrying out an assessment, NII assessors need to judge the extent to which the safety submission shows that the design of the plant is in conformity with the principles. Not all of the principles are relevant to every plant, but the extent to which the relevant principles are met will be an important factor in any decision on judging the adequacy of proposals from operators for installation of plant and equipment or modification to existing systems. UK law requires the plant to be as safe as reasonably practicable. The engineering principles in particular represent the NII's view of good practice and we would not expect modern plants to have difficulty in satisfying the majority of them.

**Table 1:** Summary of NII Safety Assessment Principles relevant to minimising exposure to internal radiations

| **TOPIC** | **RELATED PRINCIPLE** |
|---|---|
| **<u>Fundamental Principles</u>** | |
| Individual Exposure Limits | P11 |
| Group Exposure Limits | P13 |
| Risk targets | P43 |
| ALARP | P2 |
| **<u>Engineering Principles</u>** | |
| Robust Engineering | P104, P110, P112 |
| Diversity / Redundancy | P68 |
| Least Operator Reliance | P61, P62 |
| Containment | P222-P238 |
| Ventilation | P239-P242 |
| Plant-Layout | P106, P109 |
| Maintenance | P97-P101 |
| Occupancy | P106 |
| Instrumentation | P105, P113 |

**Fundamental assessment principles**

HSE has identified five fundamental safety principles which underpin the more detailed engineering principles. These are incorporated into UK legislation and are derived from the recommendations of ICRP. The fundamental principles are applicable to all radiological hazards including the minimisation of internal exposure. The key points addressed as fundamental principles are the need to comply with statutory dose limits, to keep all exposures as low as reasonably practicable, to take all reasonable precautions to prevent accidents and to minimise the consequences of any accident.

**Indicators of best practice for internal exposure**

a)<u>Targets for loose activity</u>.

The demonstration of adequacy for plant design in respect of internal dose may be based upon selected key performance indicators. The following levels of surface contamination may be taken as examples of good modern practice in the UK and as a starting point for regulatory decision making.

- Average loose surface contamination to be less than 0.1% of inactive area limit for alpha activity - (typically 0.4Bq $cm^{-2}$) giving a target value of 0.4 mBq $cm^{-2}$, and less than 0.5% of inactive limit for beta activity (typically 4.0 Bq $cm^{-2}$) giving a target value of 20 mBq $cm^{-2}$.

- Average airborne contamination to be less than 0.02% ALI alpha, and less than 0.01% ALI beta, where 1 ALI is the amount of activity necessary to be inhaled in a working year (2000 hrs using standard man data from ICRP 30 but in some local applications this is reduced to 1200 hrs) to give a dose equivalent of 50mSv.

b) Internal assessed dose

We would expect operators in modern nuclear plants receive internal doses of much less than 5mSv. This is a level which is less than 10% of the statutory dose limit and is a threshold below which systematic dose assessment is not required. Our experience in the UK of the most modern plants is annual internal dose due to chronic exposure to radioactive materials is less than 1% (ie 0.5mSv) the statutory dose limit of 50mSv.

c) ALARP

NII's regulation of nuclear activities examines the principles of ALARP in many aspects of nuclear plant activities. This is formally incorporated into UK legislation in Regulation 6 of IRR85. As regulators we normally expect formal ALARP statements to justify the practicality of operations as part of the safety submission.

**Engineering features (minimisation of internal exposure)**

Robust Engineering

Nuclear inspectors expect to see high standards of engineering in the design and operation of plant and equipment containing radioactive materials. In order to minimise internal exposure we would expect licensees to give particular attention to the construction of vessels and plant items in order to minimise accidental releases of radioactive materials perhaps as a result of venting, over-pressurisation, leakage due to incompatible materials being used, over-filling, corrosion or process chemistry difficulties. As part of HSE's assessment of the adequacy of safety cases, it is expected that licensees undertake sufficient research, perhaps by undertaking pilot plant trials, to ensure that the final design is robust against a range of possible faults - for example the variable flow characteristics of plutonium oxide powders. This stems from a requirement in Section 6(2) of the Health and Safety at Work etc Act 1974 (1).

Diversity and Redundancy

NII's Safety Assessment Principles recognise that best practice in nuclear plant operations should incorporate elements of diversity and redundancy and defence in depth. In other words, failure of a single item or loss of part of a protection system should not lead to unacceptable intakes of radioactive materials. Opportunities exist in many places for incorporating the principles of diversity and redundancy, for example, a) in the use of multiple layers of containment around potential sources of airborne activity perhaps using different materials and methods of sealing, b) in the methods used to monitor airborne radioactive particles and providing early warning, perhaps using equipment provided by different manufacturers and/or using different radioactive decay characteristics.

Least Operator Reliance

HSE's preference is for operators of nuclear plant to make arrangements which always remove the worker away from the hazard. In many cases this can be achieved simply by good design and prior planning. In cases where this cannot be done, HSE looks for a justification of why this is not possible and the operator's assessment of the practicability of different methods - perhaps by use of remote technology or alternative processes. As a last resort as regulators we recognise that Personal Protective Equipment (PPE) needs to be used in special cases. This has intrinsic hazards for intakes of radioactive materials and we pay particular attention to the choice of PPE, training of operators, the supervision of activities and the review of activities by local management.

Containment Philosophy

The engineering design of a facility should take account of the need to minimise releases of airborne radioactive material and to provide containment of liquors and solids. Under normal operating conditions vessels and tanks which are intrinsically associated with primary processes would be expected to provide first line primary containment for liquors, solids and aerosols. In the event of process fault conditions where simultaneous leakage of radioactive material and failure of ventilation may occur secondary defensive barriers should be provided. These often take the form of concrete cells, double skinned vessels or building cladding. Operators would be expected to choose appropriate combinations to ensure high standards of integrity depending on the type of process equipment, process materials, the range of credible faults identified by the safety case and the predicted consequences to either workers or members of the public.

Ideal containment for radioactive material would be a sealed box which in principle might be applicable for the ultimate disposal of waste. However, in normal industrial applications where access to containment areas is required, breaks in the primary and secondary containment are inevitable. The safety case should consider each such case on its own merits in order to determine if other engineered solutions are practicable, perhaps based on alternative technologies. Penetrations into primary containment should be protected from areas of high worker occupancy by secondary or even tertiary layers of protection which may in themselves have further penetrations. This leads naturally to a design having several layered levels of protection - often known as the multi-barriered approach. The operators' arrangements would be expected to include a demonstration that design targets relating to standards of containment have been successfully met during construction and active commissioning and then later during routine operation. This requirement for on-going surveillance may in itself require additional design features. These aspects are addressed in HSE's SAPs P222-P238.

Ventilation Systems

The design intent of ventilation systems should be to provide an acceptable environment for employees, to minimise the airborne release of radioactive material, to control airborne activity levels inside occupied plant areas to a level consistent with internal exposure targets and to minimise aerial releases to the environment. A primary objective is therefore to design the ventilation system so that the air flow in the plant is directed from areas with low activity to areas of potentially higher activity in order to minimise the spread of activity throughout the plant and to prevent any back diffusion into occupied work areas.

The plant safety case would be expected to provide details of:

(i) building ventilation (number of air changes; heating, cooling and filtration of input air supply; distribution; extract and filtration of exhaust air);

(ii) Cell ventilation - details of primary and secondary HEPA filtration including availability of standby arrangements for maintenance and/or failure;

(iii) Cabinet ventilation - details of depression standards, primary and secondary HEPA filtration.

(iv) Vessel ventilation - details of depression standards, primary and secondary HEPA filtration.

(v) Other - some areas such as laboratories may require specific filtration arrangements over and above these needs for clean area offices and corridors.

Current UK best practice requirements is specified in ref 10 (AECP 1054 1989)

The installation, commissioning and design of the ventilation system should demonstrate the system is properly balanced (ie input rate matches extract rate), the specified number of air changes are being provided and that there are no 'dead spots' in this individual process or cells.

Plant-Layout

The lay-out of the plant is important in minimising internal exposure. Particular attention should be given to the proximity of areas of high occupancy (offices, corridors) and emergency reception areas to plant areas having potential radioactive contamination. Attention should also be given as part of the safety case to routes within plant which may be used for transporting radioactive materials.

Maintenance

In order to operate a nuclear facility efficiently and effectively the process may rely on discrete items of plant and equipment which are significant in safety terms and which may present a radiological hazards when failure occurs. Typical example might be pumps, valves, instrumentation, motors etc. The safety case should identify items of plant needing maintenance and where practicable the design incorporate redundancy, diversity and segregation, and also should be based on modular units minimising the likelihood of spread of radioactive contamination. Other passive design features incorporated into the maintenance function might be the lack of moving parts, examination of vessel internals for structural examination, use of long life electrical components and the identification of maintenance internals based upon a risk based analysis.

Occupancy

The design aim should be to remove the worker from the hazard by providing appropriate engineered barriers which are highly reliable. The use of appropriate technology, remote operation and maintenance should provide an operating system where human intrusion is minimised. The safety case should include a demonstration that these aspects have been considered and optimised with respect to intakes of radionuclides. The use of personal protective equipment as a substitute for poor plant design is not accepted in the UK for new plant designs.

In some areas it is necessary to account for worker occupancy as part of a regime of internal dosimetry assessment. This is normally based on individual occupancy in discrete plant areas or zones when combined with the results of personal air samples. Sometimes, but less often, worker group averages are used in conjunction with personal air sample results. Another variation accepted in the UK to combine either individual or group occupancy with environmental static air samplers. In this latter case experience has shown that it becomes more difficult to demonstrate the adequacy of the assessment process against possible changes in airborne concentration with time and space within the assessment period and location. Further details are given in reference 5.

Instrumentation

Control and instrumentation are important parts in the radiological performance and design of modern nuclear plant. These systems should be provided to ensure the safe control of plant systems, adequate monitoring of the plant environment and provide early warning of fault conditions. Alpha, beta and gamma monitoring instruments should be provided where appropriate depending on the process and plant conditions. The number, type and location of instruments should be specified in the plant safety case. An important aspect of the surveillance process should be the extensive use of alarms to denote any deviation from the accepted norm and to record information for later review and analysis. Radiological information should be available to operators in the control room or local control point and should be based on hardwired systems and which incorporate features of reliability, diversity and redundancy. In some circumstances radiological instrumentation may also provide a trip function, such as the shutting down of ventilation components.

In the assessment of internal dose we have found from our regulatory experience that it is necessary to give particular attention to the number and siting of plant static air samples in order to give a reliable indication of the atmosphere representative of the workers breathing zone.

Statistical Analysis of Data

In 1987 HSE established a UK computerised Central Index of Dose Information (CIDI) in order to receive and process annual dose summaries. CIDI receives data from record-keeping Approved Dosimetry Services for most UK classified workers and undertakes a statistical analysis of these data for different occupational categories. The database provides HSE with intelligence on the performance of dose reduction measures being used within the UK nuclear industry and confirms that total annual whole body doses are generally in decline, although CIDI not specifically identify contribution from internal exposure. Further details on the operation of CIDI are in reference 11. A recent analysis (ref 12) by BNFL for workers at Sellafield reflects this downward trend also which is partly attributable to reduction in internal exposure.

Application in UK Plant Design

Two recent examples where NII's Safety Assessment Principles for minimisation of internal exposure to radioactive materials have guided NII assessment are the Oxide Fuels Complex at the BNFL Springfields site (ref 13) and the THORP plant at BNFL Sellafield (refs 14, 15 and 16). In each example, the operators recognised that it was not cost effective to modify existing plant to meet new standards of radiological protection and at the same time meet commercial programme commitments. The new plant designs were therefore developed which incorporate many features of best practices such as multi-barriered containment, plant monitoring systems, modern ventilation, high standards of containment.

## Conclusions

The UK regulatory approach which is based upon a non-prescriptive goal setting licensing system offers a number of potential benefits to both regulators and operators. Such factors include flexibility, transparency and consistency. Statistical analysis of the results of reported annual whole body exposure and the internal dose component since the introduction of IRR85 have shown substantial reductions which we believe has resulted in improved health and safety of workers and increased confidence in the regulatory system. The views expressed in this paper are those of the author and not necessarily the Health and Safety Executive.

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