Effective Occupational Radiation Controls at a UK Nuclear Recycling Plant.

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INTRODUCTION.

The Sellafield Site of BNFL is situated on the West Coast of England in the County of Cumbria. It is a large site and contains many and varied nuclear plants dating from the early 1950s up to the late 1990s. The main activities undertaken are: -

- Surveillance of redundant plant
- Decommissioning of redundant plant
- Receipt, storage and reprocessing of Magnox Fuel
- Receipt storage and reprocessing of Oxide Fuel
- Manufacture of Mixed Oxide Fuel
- Operation of four Magnox Reactors
- Services to the above areas
- Construction of new Magnox and Oxide facilities

Each of these activities contains a variety of different safety issues and experience. The site currently employs about 6600 people on operations on plant whose design and operational life dates from the 1950's to the present day and which can be expected to continue operating well into the next century. In addition there are some 2800 Contractors employed on work involving radiation exposure. These facilities therefore present a vast spectrum of radiation environments, which reflect the progress in regulatory, design and operating standards.

DESIGN STANDARDS

The Magnox Fuel Reprocessing Plant was designed in the early '60s on the basis of a maximum permissible "wallpaper" doserate of 25 μSv/hr, using pessimistic assumptions on fuel throughput and type, with the intention of limiting the maximum plant exposure to less than 50 mSv per person per year (the long term operational statutory limit at that time).

A review of Safety Standards in the late 1970's, which took account of ICRP thinking, aimed to develop a comprehensive and long lasting set of design criteria for new plants, primarily the Thermal Oxide Reprocessing Plant (Thorp). That review resulted in the design criteria summarised summarised below :

- Average Whole Body Exposure — less than 5 mSv/year
- Maximum Whole Body Exposure — less than 15 mSv/year
- Extremity Exposure — less than 300 mSv/year
- Internal Exposure — should be negligible
- The plant design should also be subject to an ALARP assessment

Because application of these design criteria required the determination of representative data for the associated modelling work, it followed that a very thorough understanding of both plant operational manning philosophy and plant radiation doserates was needed. Although they tend to be somewhat somewhat crude and conservative devices, the actual doserates that have been encountered have been less than the design criteria in practice. For example the original Magnox Receipt, Storage and Decanning Plant (B30), the design of which preceded these design criteria, was replaced in 1986 by the Fuel Handling Plant (B311). This facility now handles all the Magnox Fuel arriving at Sellafield, and the reduction in the radiation exposure of the operators is significant, as can be seen from the following table. :

Average Exposure (mSv/yr)		
	B30	**B311**
Process Personnel	22.5	0.7
Maintenance	11.9	0.8

These improvements in radiation exposure were the result of detailed involvement of existing plant operators in new plant design, and a thorough examination of the processes of radiation exposure.

OPERATIONAL EXPOSURE LIMITS AND TARGETS

Whilst Criteria for Design of new plants were being formulated and accepted, operators had to continue to process fuel in plants designed twenty years earlier. Therefore, the operating exposure criteria are necessarily significantly different from design criteria. Until the 1970's, operators were permitted to receive up to 30 mSv per quarter (subject to a limit 5(N-18) where N is the age in years), but in the mid 1970's, in advance of legislation, BNFL introduced a firm annual limit of 50 mSv per year, this being entirely external exposure, (i.e. it was assumed that received internal exposure was not significant in relation to body burdens).

This approach continued in force until 1986 when the Ionising Radiations Regulations, 1985 were introduced in the UK. At this point, Internal Committed Exposure had to be added to External Exposure to satisfy what had become a legal occupational dose limit of 50 mSv per year. This had a significant impact on site operations and required, amongst other things, the establishment of a Personal Air Sampling Service, which initially provided 600,000 PAS's per year, but has since reduced to less than 300,000 per year.

The next change in BNFL’s operating exposure criteria occurred at the beginning of 1988 with the introduction of a dose restriction level of 30 mSv per year (internal committed exposure plus external exposure). This was followed two years later with a further reduction of this internal restriction to 20 mSv per year, coupled with a target of less than 75 mSv in 5 years. In 1991, the Company limit was retained at 20 mSv, but a Sellafield Site Dose Restriction Level of 15 mSv was introduced.

OPERATING EXPOSURE LIMITS/RESTRICTIONS AT SELLAFIELD :

Prior to 1977	30 mSv/quarter, 5(N-18)
1977	50 mSv/year External
1986	50 mSv/year External & Internal
1988	30 mSv/year External & Internal
1990	20 mSv/year External & Internal and 75 mSv over 5 years
1991	15 mSv/year External & Internal and 75 mSv over 5 years

RADIATION EXPOSURE RESULTS

External average and collective exposures are shown in Figures 1 and 2, and show a halving of collective dose and a quartering of average doses since the 1970's. The number of people exceeding 10 and 15 mSv per year is shown in Fig 3. This data demonstrates the commitment that BNFL has to reducing radiation exposure to levels that are ALARP. From 1991 to 1997 only a handful (~5 in each year) exceeded 15 mSv, and no-one exceeded 15 mSv in 1998 or 1999. 1998 (the last year with full data available) saw the lowest radiation exposure since the site began operating.

The radiation exposure averages for employees working on the Calder Hall Nuclear Power Station over the past few years is shown in Figure 4, and demonstrates that even with a plant that has been operating for more than 40 years, there is still room for improving radiation exposure.

The Nuclear Plants at Sellafield cover a wide range of ages and the radiation exposure of each broadly reflect its age. Figure 5 shows the collective exposures on a range of activities over the past few years. As can be seen the largest collective exposure is to Contractor Employees, although their average exposure is well less than the site average. The largest collective dose is otherwise received by decommissioning workers. Average exposures at Sellafield also vary significantly, according to the age of the plants or the nature of the work :

Sellafield Activity	Average annual exposure in mSv
Magnox Reactor Operation	4.7
Magnox Reprocessing Plant Operation	1.9
Thorp Reprocessing Plant Operation	0.6
Waste Management Services	0.8
Decommissioning Operations	4.1
Site Services	1.0
Contractors	1.0

CONTRACTOR EXPOSURES

Extensive use is made of non-BNFL employees – Contractors – in all parts of the Sellafield Site.

Approximately 2,800 contractors are currently employed on radiation exposure work. They have exactly the same limits and controls applied to their exposure as to BNFL employees, and are not used for short term high exposure work any more than a BNFL employee is. In order to ensure that Contractors are not used for short-term high exposure work a Management System has been introduced which ensures that individuals will continue to be available for work throughout the year. This "Stargate" approach sets automatic management controls on the exposures of Contractors at the end of each quarter of the year. The average exposure to Contractors in 1998 was 1 mSv.

RADIATION REDUCTION METHODOLOGY

In the mid 1970's the objective of reducing radiation exposure became more important, and independent specialist teams were established to thoroughly probe the operation methodology of a plant and identified specific radiation reduction strategies. These strategies fell into 6 broad categories.

*	Engineering changes	- Ventilation and containment - Shielding - Remote operation
*	Dose awareness and control	- Personal Alarmed Digital Dosemeters - Job doses - Budgeting using IT solutions
*	Job Efficiency	- Operational changes - Minimum personnel to do task
*	Work Reduction	- Stopping unnecessary jobs - Changing scope
*	Rotation/Job sharing	- Last resort - Could increase collective dose
*	New Plant	- Expensive but effective!

The above strategies are applied according to the needs of the particular tasks, but an overarching Management System – referred to as the ALARP Process is common to all. As Low As Reasonably Practicable means applying a structured approach to radiation reduction using appropriate experts and techniques. The process is:

- Systematic
- Visible and auditable
- Uses quantified data and tools
- Involves knowledgeable and skilled people
- Includes monitoring and review

An ALARP Process is normally in four stages

1. Assess global options for dose reduction and prepare preliminary estimates.
2. Divide Project into sub-tasks and apply reduction techniques to each. Calculate a dose budget for each stage.
3. Monitor and review work as it takes place and record doses for sub-tasks.
4. Aggregate sub-task doses, feed back and compare with predictions, and review.

A key ingredient to the successes of radiation exposure reductions and control at Sellafield is not the "engineering solutions", but rather the softer issues of dose awareness, involvement, individual commitment and feed back. In common with improvements in other safety fields, our success owes a lot to Human Factor type influences.

BEHAVIOURAL SAFETY PROCESS.

In BNFL we have introduced a behavioural safety programme to increase our employees understanding and awareness of the safety issues that are around them. People have been trained to observe people's behaviour and the observed have been trained to support the observers!! These training courses are primarily aimed at conventional safety improvements, but are equally effective for radiation protection. Thus we are achieving an increasingly aware population who are individually committed and more ready to improve their radiation exposure patterns by working with others. Coupled with the Management Systems, structured and systematic analysis of dose reduction techniques using experts and experienced people, we have been able to sustain a continuing reduction in average radiation exposures.

As the average exposures have reduced and the skills of radiation reduction firmly entrenched, an increasing emphasis is being placed on obtaining more work per mSv – dose effectiveness – thus allowing more efficient use of employees and keeping the collective exposures low. This is particularly evidenced on the Calder Hall nuclear power station where average and collective doses are now lower than they have ever been, in spite of increasing age.

EXAMPLE OF SUCCESSFUL HIGH RADIATION WORK

The Magnox Reprocessing Plant has been operating since 1964 and is expected to continue operating until at least 2010. During this period there have been, or are planned to be, a number of significant improvements to the plant. One particularly large refurbishment operation which has taken 19 years, cost about £96M and the original collective dose estimate was 23 manSv. This required special radiological controls on job planning and execution. The project is virtually complete with all active connections made and inactive commissioning successfully complete. Access to the plant is sealed and active commissioning successful. The final collective radiation exposure is about 11 manSv, half the original estimate.

RADSCAN

A new tool in regular use at Sellafield is the Radscan, a device which superimposes a visual image of a work area with a gamma image of the same work area, thus enabling sensible decisions to be made on decommissioning and shielding without costing radiation exposure doing the surveys. The Radscan has been used in plants undergoing decommissioning, old plants carrying out major refurbishment and new plants carrying out maintenance – all to great success. The Radscan is manufactured by a BNFL Group Company, BNFL Instruments Ltd.

NEW STATUTORY REGULATIONS

On January 1st 2000, the Ionising Radiations Regulations 1999 came into force, which set out revised Dose Limits for employees. The change was from 50mSv per year to a primary limit of 20 mSv per year. This has caused no difficulty at Sellafield, or elsewhere in BNFL since we had implemented a dose strategy some years earlier which is effectively at least as stringent than 20 mSv per year. We have, however, amended our Event Reporting Limits to reflect the reduction.

THE FUTURE FOR RADIATION EXPOSURE AT SELLAFIELD

Operating Plant Radiation exposures are likely to remain fairly static, with minor improvements, obtained using the strategies outlined above, being partially countered by the ageing of the plant, though radiation increases due to ageing has not been a significant feature in plants designed in the last twenty years. Radiation exposures during decommissioning operations though are thought to increase both for collective and average exposures.

The techniques for maintaining the successful radiation reduction achievements will remain largely as they are now, but with an increasing emphasis on Information Technology and human factors type methods. Further large reductions in radiation exposure will only arise from plant closure and completion of decommissioning work. Whilst there has been much success in decommissioning plants at Sellafield, there remain many more to complete. Increasing emphasis will be on work efficiency – obtaining more work per mSv, and not simply on dose reductions.