Radiological Protection and Dose Uptake in the Thermal Oxide Reprocessing Plant (Thorp)

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INTRODUCTION

BNFL's Thermal Oxide reprocessing plant (Thorp) reprocesses uranium oxide fuel assemblies which have been irradiated in thermal reactors in the UK and overseas. Plans for the plant were first announced in 1974, following the shutdown of a precursor facility in 1973. The application for planning permission was submitted in 1977, and permission to construct the plant was given later that year. Thorp essentially consists of two parts - the Head End and Chemical Separation facilities. The license to commence active commissioning of the Head End facility was granted in early 1994, followed later that year by that for the Chemical Separation facility. The Consent to Operate Thorp was obtained in August 1997.

PLANT DESIGN

The Thorp design relies primarily on biological shielding in the form of bulk concrete for the protection of personnel from radiation exposure. Shielding assessments for Thorp are based on reference case fuel, and it was further assumed that vessels and pipework were full of active liquor. The potential for plateout of activity in vessels and pipework was also identified as a potential source of radiation exposure.

As part of the shielding design analysis, parameters such as occupancy, normal operations and maintenance tasks were assessed in each area, and a radiological classification of the plant was undertaken. Target dose rates, associated with a radiation classification identifier R1 – R5 (increasing radiological significance) were assigned to each area of the plant and the shielding designed against these targets.

Table 1 Radiological Classification of Areas - Radiation

Classification	Maximum permissible radiation levels (µSv/hr)	New Plant Design Targets (µSv/hr)
R1	2.5	0.25
R2	7.5	1
R3	100	7.5
R4	ALARP	ALARP
R5	ALARP	ALARP

During commissioning, the radiological integrity of the shielding was extensively checked at strategic points throughout the plant, and re-checked as the burnup of the fuel feedstock increased. All commissioning data confirmed that doserates in R2 operating areas met the target level of 1µSv/hr, ie well below the maximum permissible levels.

Routine checks are undertaken in all operating areas and, to date, the vast majority of operating areas are still within 1µSv/hr, and no R2 operating area has exceeded 7.5uSv/hr as a result of routine operations. The radiation classification of an area is reviewed periodically by the area Radiation Protection Adviser (RPA) based on results of routine monitoring surveys and operational experience of the area.

The design of Thorp also aimed to reduce radiation exposure and occupancy times in potential high dose areas, by the use of remote control, remote manipulators, remote reading of instruments, and gamma interlocks.

Processes requiring operator intervention have been eliminated as far as practicable by the introduction of such measures as the installation of ejection systems, automatic liquor sampling, pneumatic transfer of samples to areas for analysis and remote filter changing within the filter caves.

CONTAMINATION CONTROL

In the same way that Thorp is subject to a radiological classification of areas from an external radiation point of view, there is also a contamination equivalent (C1 – C5).

Table 2 Radiological Classification of Areas – Contamination.

Classification	Occasional Surface Contamination (Bq/cm^2)		New Plant Targets (Bq/cm^2)	
	Alpha	Beta	Alpha	Beta
C1	<0.4	<4	0.004	0.4
C2	<4	<40	0.004	0.4
C3	4	40	ALARP	ALARP
C4	40	400	ALARP	ALARP
C5	>40	>400	ALARP	ALARP

The radiation and contamination classifications of an area are carried out independently of each other, against such criteria as expected and potential radiation and contamination levels in an area,occupancy time in an area, work to be undertaken in an area and so on. The system allows a degree of flexibility with area classifications being made more or less restrictive following consultation with the RPA.

There are examples where a review of classification of an area has resulted in it being regraded based on operational knowledge of an area. For example the Thorp UO3 store was originally a C2 R3 area, but has since been regraded to a C1 R3 area. This, whilst still a controlled area, has resulted in a relaxation of the contamination controls originally deemed necessary for the area, whilst still retaining the required levels of safety.

The contamination control philosophy of Thorp is based on controlling contamination to such an extent that the normal operating areas must not exceed limits that are two orders of magnitude more restrictive than traditional non active area limits (alpha).

Contamination is controlled at the source of arising both by engineering methods such as gloveboxes and the ventilation systems, and the use of secondary containment,good working practices and monitoring arrangements to prevent the spread of contamination.

The Thorp ventilation system facilitates this by cascading air from C1, ie clean areas, through to C5 areas. From here, it is filtered, monitored and discharged thus helping to control the spread of contamination around the plant.

Located around the plant at all operational/maintenance (C2/C3) interfaces are a series of sub changerooms. These sub-changerooms are an essential part of contamination control. Personnel are required to change their footwear and wear additional protective clothing dependant on the radiological nature of the task, prior to crossing the C2/C3 barrier, and they must be monitored free of contamination on undressing, prior to crossing back into the C2 area. It is at this interface that the spread of contamination around the plant is controlled most effectively

Thorp is subject to an extensive programme of contamination surveys, the frequency of which is determined by parameters such as the type of work carried out in the area and occupancy. The survey schedule has been reviewed several times since commissioning using the above parameters and operational experience gained about an area resulting in some areas being monitored less frequently, and some more frequently.

To date the vast majority of contamination surveys have been below the relevant action level. Less than 5% of all surveys undertaken in the last 5 years have exceeded this action level, primarily in known contamination areas, i.e. maintenance areas and subchangerooms. This indicates that contamination is not migrating into the operating areas, and that the contamination control arrangements are working effectively.

PREPARATION OF THE WORKFORCE

The Thorp plant, designed to the highest radiological standards, and installed with state of the art technology, was to be commissioned and subsequently operated by a workforce who, in some cases, had never previously worked in the nuclear industry. One of the major challenges facing the Thorp management was how to give this workforce the technical skills and safety knowledge to commission and operate the plant safely.

There was also a need to provide them with the necessary behavioural skills to empower a large number of individuals to act as a single co operative team within a working culture that promoted safety as the number one priority.

Each individual had a role specification developed through hierarchical task analysis, and which included relevant extracts from safety legislation, the plant safety case, advice from human factors experts and external best practice. All personnel were then given generic Thorp wide training, which included, for example, emergency instruction briefings and then specific training, which included radiation protection training, that addressed their job specific competence requirements.All individuals were then assessed and deemed competent prior to working unsupervised.

Individuals undergo periodic refresher training and reassessment in all aspects of training including radiation protection.

OPERATIONAL EXPERIENCE

The Thorp workforce have encountered several minor engineering issues during operations, however they have also demonstrated the ability to tackle complex issues safely. During 1998/99 the Head End Plant encountered problems with erosion and blocking of lines that transfer fuel cladding. Modifications needed to be made to an area of plant where there was no routine access, and the radiological conditions were extremely challenging. Doses for this task were very well managed, with a total collective dose of less than 10 mSv recorded for the entire operation. Approximately 100 different people made in excess of 550 cell entries during the duration of the work, equating to an average whole body dose of approximately 0.1mSv per person.

Table 3 Occupational Exposure in the Head End facility 1995 – 1999

Year	Highest dose (mSv)	Average dose (mSv)
1995	1.2	0.27
1996	1.6	0.57
1997	1.3	0.33
1998	1.3	0.33
1999	<1.2*	0.37*

* = forecast at time of writing

Table 3 shows that there has been no discernible increase in doses received in the Head End facility arising from work in this area. This is attributed in no small part to engineering, operations and radiation protection personnel working closely together to establish the best practical way to undertake individual tasks. All options are explored to keep dose uptake ALARA, and all aspects of the chosen task are then planned and rehearsed prior to the actual work being undertaken. Practical radiation readings enabled doses to be estimated and necessary controls to be put in place. Regular reviews of the process enabled learning to be shared, methodologies to be improved,and contingency arrangements to be introduced if necessary.

OCCUPATIONAL EXPOSURE

Thorp is designed so as to restrict the maximum individual whole body dose to less than 15mSv/yr, and the work group average dose to less than 5mSv/yr. These figures can be compared with a legal dose limit of 50 mSv in legislation at the time. Whole body doses in Thorp are received almost entirely as a result of external radiation exposure. The effect of internal exposure is minimal due to the design and operation of the plant, ie ventilation, containment, subchangeroom procedures etc (covered previously). Internal exposure is not routinely assessed on Thorp, but there are routine campaigns to confirm that exposure patterns are as expected.

The routine whole body dosemeter currently used is the film badge. During commissioning, the strategy was that these dosimeters should be issued on a monthly basis, but as operational experience has been gained, the issue period has been extended to a quarterly basis for 70% of the Thorp workforce. New developments in dosimetry are currently being evaluated to further improve dose control.

Table 4 Occupational Radiation Exposure from the Start of Operation (All Thorp)

Year	Average Dose (mSv)	Highest Dose (mSv)
Design Target	5	15
1995	0.3	1.2
1996	0.6	3.9
1997	0.4	2.7
1998	0.4	2.4
1999	0.4*	1.5*

* = forecast exposure

Table 4 gives the dose uptake for the whole of the Thorp facility for each year since commercial operation was commenced. All exposures are well below the design standards, and it can be seen that, as the plant faces more challenges in terms of throughput and intrusive maintenance, there is no subsequent increase observed in dose. It is, however, imperative that we avoid complacency and, even at these very low exposure levels, dose control remains a key priority.

CAMPAIGNS

All components of dose are monitored to confirm that they are within expected limits, and hence whether they should be routinely assessed, via campaign programmes covering all areas.

Campaign	Dosimeter
Neutron Exposure	PADC – Poly Allyl Di Glcol Carbonate
Extremity exposure	TLD - Thermo luminescent Dosimeter
Internal Exposure	PAS – Personal Air Sampler

To date, there has been no need for personnel working in Thorp plant to have these components routinely assessed.

ENVIRONMENTAL DISCHARGES

AERIAL DISCHARGES

All discharges have been well within the Thorp stack authorised limits and design targets. Emissions of particulates have been less than 1% of the limits, and those of volatile species, for example,Kr_{85}, I_{129}, C_{14} and H_3 have also all been well within relevant limits. The discharges of I_{129} and H_3 were, however, above the expected flowsheet figures, and so there are plans to reduce these discharges still further where practicable . Significant improvements in the discharges of H_3 were made in 1998 for example, and further improvements should be evident from 1999 figures.

LIQUID DISCHARGES

There are no specific limits that apply to Thorp effluents, which are largely treated by downstream plants. Sea discharges are, however, very small compared to the site limit and the maximum calculated dose impact from these streams in total was approximately 3μSv in 1997. The most significant contributor has been Co_{60}, which exceeded flowsheet expectations on specific occasions. Again, there are plans to reduce these discharges, as well as use modelling techniques to predict when discharge peaks will occur.

CONCLUSION

Up until the end of 1999, Thorp has reprocessed approximately 2500te of spent fuel, with average doses being in the region of 0.5 mSv. It can therefore be demonstrated that the generic radiation protection arrangements employed on Thorp, including plant design, engineering controls, training, culture and working practices have been responsible for the extremely low dose uptake of the workforce. The plant is well designed, both in terms of reducing dose uptake and ensuring that contamination remains at the point of origin, which in turn ensures that routine access areas remain clean.

Aerial discharges are well within all relevant limits, as are liquid discharges. Work is, however, ongoing to reduce these to levels even further to ensure that they remain as low as reasonably achievable.

The engineered design of Thorp, together with the radiological protection systems and the continued development of a strong safety and operations culture will, therefore, successfully support the future safe operation of Thorp.