Radiological Protection Arrangements for Decommissioning the Complex Nuclear Site at Dounreay

Peter Thompson, Lesley Mclean, Tim Watkin and Simon White
Dounreay Site Restoration Limited, Dounreay, Caithness, KW14 7TZ, UK.

The Dounreay site is situated on the north coast of Scotland, mainland United Kingdom, and is operated under contract to the UK's Nuclear Decommissioning Authority (NDA) by Dounreay Site Restoration Limited (DSRL). DSRL is a wholly-owned subsidiary of the Babcock International Group. Following a recent competition it will shortly become wholly-owned by a partnership between Babcock International Group, CH2M Hill and URS Holdings (UK) Ltd. Dounreay was instrumental in fast breeder reactor research and fuel reprocessing plant development. The site's business is now one of safe decommissioning and remediation.

To support the timely and financially constrained safe decommissioning, processes and personnel need to be focussed on achieving the business objective. DSRL also requires an independent assurance function. DSRL has embedded some of the assurance function and 'projectised' staff to support project delivery to achieve the business objective.

This paper discusses the evolution of the current arrangements and the expectations for the future, including a review of challenges and successes. The paper also describes some of the decommissioning projects that have benefited from the proactive support and the enhanced controls that have evolved over recent years.

The paper concludes with a review of the lessons learnt during the evolution.

KEYWORDS: Dounreay; Decommissioning; Site restoration; Lesson.

Introduction

The Dounreay site is situated on the north coast of Scotland in the United Kingdom. It was instrumental in the United Kingdom's fast breeder research and fuel reprocessing plant development from the 1950's, but the work programme on the site has changed, and is now one of safe decommissioning and site restoration. Dounreay Site Restoration Limited (DSRL) is the site licence company, operating under contract to the Nuclear Decommissioning Authority (NDA), responsible for the closure programme at Dounreay and is currently a wholly-owned subsidiary of the Babcock International Group. Following a recent competition it will shortly become wholly-owned by a partnership between Babcock International Group, CH2M Hill and URS Holdings (UK) Ltd.

The site is large and houses a number of complex and unique plants, including fast reactors, a materials test reactor, metallurgical laboratories (housing fume cupboards, glove-boxes and shielded cells), novel fuel reprocessing plants and waste storage facilities. Following four decades of research, decommissioning this legacy is a major undertaking. Dounreay is now a site of decommissioning, demolition, waste management and construction, with the intention of returning the site to as far as is feasible, its original condition. The experimental nature of many of its redundant facilities means the clean-up and demolition requires innovative thinking, as well as care and detailed attention as work progresses. There are many publications about Dounreay and more information is available on the Dounreay Site Restoration Limited's web pages www.dounreay.com.

Radiation Protection Arrangements

DSRL has an integrated safety management system that details many documents specific to and related to radiation protection that are implemented throughout its processes. This enables consistent radiation protection practices to be adopted across the complex site. This system implements the United Kingdom's best and good practice in radiation protection as well as innovative approaches, some of which are discussed later in this paper and in reference 1.

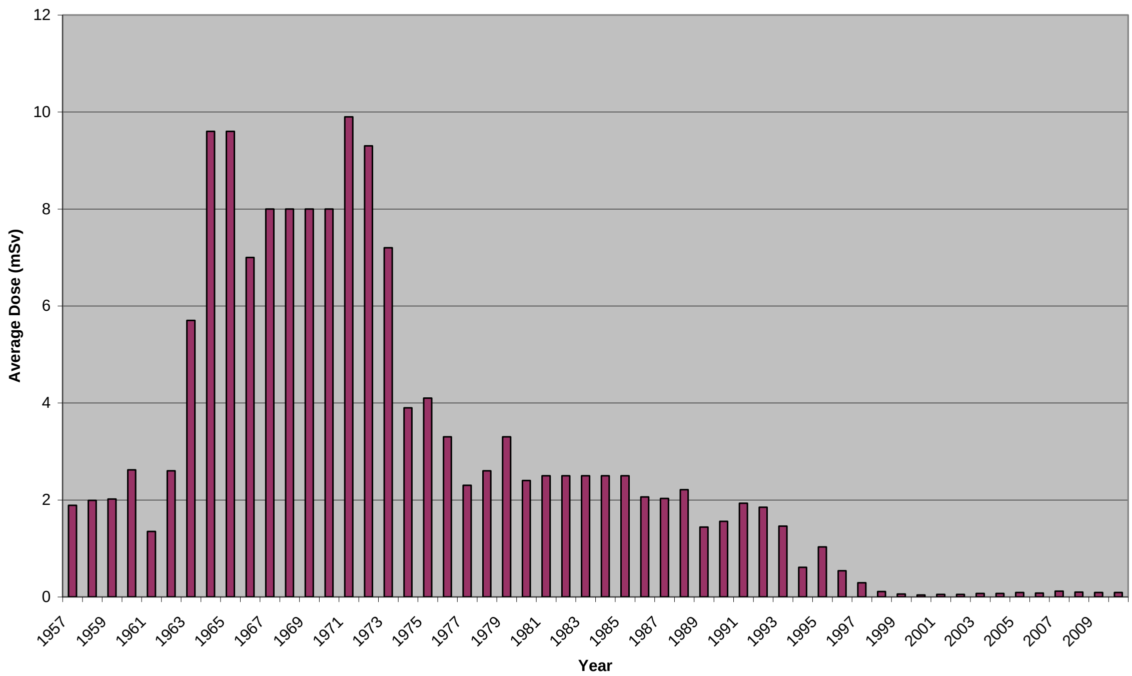
The Health Physicists at Dounreay have been under the day-to-day management of project areas since 2006. To support consistency and professional standards, an independent link to the sites Health Physics Authority (akin to the Head of Profession on certain other United Kingdom nuclear sites) has been maintained. A similar arrangement is in place for a number of delivery focussed support services on the site, such as Industrial Safety Advisers, Environment Advisers, etc.

Since 2008 dedicated Health Physics Surveyors have been in one of two teams, supporting either Reactors Decommissioning or the remainder of the site, including fuel cycle plants and waste processing facilities. This has helped ensure that the Health Physics Surveyors maintain familiarity and competence in the areas they support.

The above arrangements with Health Physicists and Health Physics Surveyors have allowed a team focussed ethos to be engendered to support safe decommissioning.

Experience has clearly identified and demonstrated the benefit of the provision of timely radiation protection advice from conception and through safe delivery of projects. This is now the DSRL way of working and has ensured appropriate and relevant advice is provided at a time that enables relatively easy adoption of pragmatic radiation protection. There is clear correlation of reduction in dose accrual with the adoption of dose reduction initiatives at Dounreay[1] over the last twelve years at least. Figure 1 shows the average effective doses accrued at Dounreay through its life and that even with the significant amount of decommissioning work currently ongoing at Dounreay, doses are being well controlled with the maximum annual dose last year being 4.03 mSv and the average 0.10 mSv.

Figure 1: Average effective doses accrued at Dounreay through its life



Due to the remoteness of Dounreay and the national and international limited pool of competent radiation protection advisers[2]&[3], DSRL has identified a need to ensure that it has a suitable Health Physicist development programme in place, that develops personnel from the start and throughout their Health Physics careers. This approach has been very successful and has enabled the site to maintain an appropriately sized and competent team with an age demographic supportive of the sites lifetime plan.

DSRL is both an active participant and lead in cross industry radiation protection (and other subject) collaboration. We frequently talk, meet and bench mark with our counterparts across the United Kingdom's Nuclear Industry and to a slightly lesser degree internationally. A significant collaboration is within the Industry Radiological Protection Coordination Group (IRPCG) that DSRL chairs. This group produces a number of documents detailing good practice and guidance that DSRL implement, which can be found on the IRPCG web page (www.irpcg.org).

Technical meetings

DSRL's Health Physicists meet at least on a weekly basis to discuss operations, programme, regulatory, legislative and good practice as applicable to safe project delivery. On a quarterly basis, a formally minuted, more detailed technical forum is held to discuss and develop DSRL's radiation protection policy and protocols.

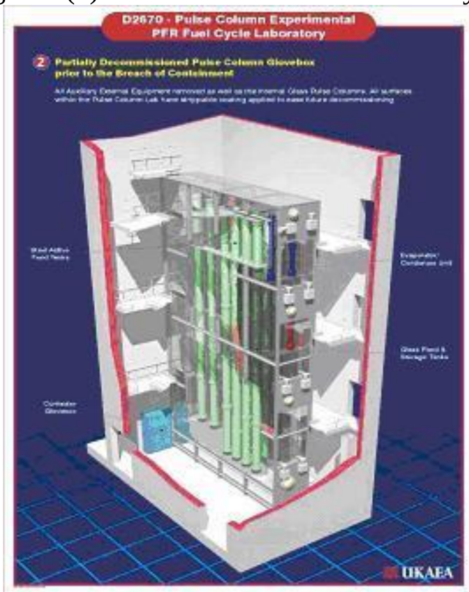
3. Recent Decommissioning successes at Dounreay

The Pulsed Column Laboratory

The Pulsed Column Laboratory (PCL) was built for full scale reprocessing flow sheet trials, using pulsed column technology (figure 2(a)), which was a more efficient solvent extraction process and a replacement for "mixer settler" solvent extraction technology. The laboratory housed a large sectional glass pulsed column rig inside a glovebox with dimensions of 11.5 metres (high) by 6.5 metres (wide) and 1.2 metres (deep) which extended up four floor levels within the building (Figure 2(b)).

Figure 2(a) Pulsed Columns

Figure 2(b) The Pulsed Column Laboratory



During the early stages of the decommissioning work in the PCL there were a number of low level intakes of radioactive material identified following the provision of nose blow samples. The contamination in the nose blow samples was not accompanied by significant surface contamination or airborne activity monitoring results.

A thorough investigation into the intakes highlighted that the contaminant was likely to be of very small particle size (sub micron) and that this was proving to be a significant challenge to the containment and ventilation system that had been installed for the decommissioning work. A recovery programme was instigated and novel techniques, as well as "tried and tested" radiological protection controls were implemented to control and contain the highly mobile plutonium contaminant through to final decommissioning of the glovebox.

There is a detailed discussion of the radiation protection aspects of the decommissioning and the evaluation and implementation of novel, as well as "tried and tested" radiological protection controls within plutonium contaminated environments in reference 4.
The work to remove the PCL Glovebox and decontaminate the laboratory was completed in March 2010 (Figure 3), removing a significant hazard by employing innovative techniques to enable the safe decommissioning of the largest glovebox on the Dounreay Site.

Figure 3. The PCL Laboratory showing the Glovebox decommissioned

Decommissioning of D1200 Redundant Laboratories

The D1200 Laboratory facility was commissioned in the late 1950s to provide general analytical services, including metallurgical analysis work in support of fuel experiments in DMTR, DFR and PFR. This metallurgical analysis work ceased with the end of the UK's Fast Reactor programme and the laboratories performing this function were placed under care and maintenance in 1993.

This facility still provides chemical analysis in support of the environmental discharge monitoring program, calibration facilities for Non Destructive Assay (NDA) equipment and other radiometric and periphery work. The redundant laboratories house various facilities ranging from fume cupboards to shielded cells. The decommissioning strategy for the redundant laboratories is based on the removal of redundant plant and equipment to leave the rooms free from contamination. Figures 4(a) and 4(b) show some of the progress that has been made in one of the laboratories.

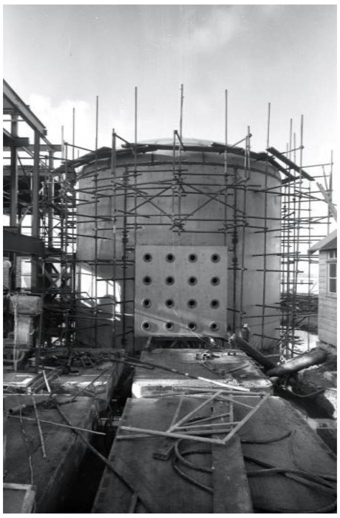
Figure 4(a) Cells in place

Figure 4(b) Cells nearly demolished

Criticality Test Facility Decommissioning

The Criticality Test Facility (figures 5(a) and 5(b)) was built in the late 1950s to provide data on solid and liquid plutonium criticalities in support of reprocessing plant design and development. The building housed a heavily-shielded cell, 7 metres high by 8 metres wide, in which experiments were carried out on solid and liquid-bearing plutonium. The criticality cell, known as cell 4, housed the two plutonium experimental rigs known as PUMA and PANTHER.

Figure 5(a) The Criticality Cell during construction **Figure 5(b) The Criticality Test Facility**



By 1994 most of the plutonium inventory process vessels had been decommissioned. The work after this involved the removal of the highly contaminated criticality test cell and decontamination of the building structure before demolition to "brown field" status.

This started in 1999 and involved carefully planned pressurised suit entries into the plutonium contaminated criticality cell. Unfortunately the cell contained a large amount of historical waste that had been left over from previous decommissioning work. This waste was successfully size reduced, packaged and sentenced to the appropriate waste route. The cell's internal structure (approximately 300m^2) was decontaminated using the "sponge jet" technique. This successfully reduced the steel liner from Intermediate Level Waste (ILW) to Low Level Waste (LLW). Further detail on the work to decommission the facility is detailed in reference 4
The work culminated in a complete radiological survey of the building which included conventional health physics monitoring, plutonium X-ray monitoring and sampling of the building structure before the building was declassified and freed for demolition. Demolition was completed using conventional techniques (figure 6(a)).

The completion of this challenging project removed a significant liability from the site (figure 6(b)) and was a significant success story for the Dounreay site.

Figure 6(a) Demolition of the Criticality **Figure 6(b) The completed project**
Test Facility

D1202 Material test Reactor Fuel Fabrication Plant

The Material Test Reactor fuel fabrication plant (figure 7(a)) had been operational since the mid 1950s, and its’ decommissioning, and demolition (figure 7(b)) was completed recently.

Figure 7(a) Operations in fuel fabrication

Figure 7(b) Demolition of fuel fabrication plant plant

D1207 Decontamination facility

D1207 was the sites original decontamination facility. There was significant chemical and radiological contamination of the building fabric due to historical operations in the facility. Prior to demolition (figure 8(a)) a team removed the redundant ventilation extract ducting and other services from the building and decontaminated every surface (figure 8(b)) of the building, including large areas of the contaminated floor. At the time of writing the facility is expected to be completely demolished by the end of March 2012.

Figure 8(a) D1207 Prior to demolition

Figure 8(b) Decommissioning team removing services

D1203 Uranium recovery and billet production facility progress

D1203 was a uranium recovery facility. The 'amber' area was a highly contaminated facility, within D1203 which housed equipment to dissolve uranium in acid to recover the reusable material and remove the waste products. Figure 9(a) shows decommissioning work in progress utilising a Brokk for semi –remote demolition work) Before any clean-up work could start, the ventilation system had to be upgraded. Redundant glove boxes and solvent extraction plant were stripped out, cleaned up and size reduced. Four-inch thick slab tanks that once held radioactive liquid were removed, and the team employed semi remotely-operated Brokk demolition robot to help them knock down the thirty-two reinforced concrete plinths that separated the tanks. Approximately 130 tonnes of concrete rubble was sentenced as low level waste. Figure 9(b) shows the decommissioning team in the cleaned-up amber area.

Figure 9(a) Decommissioning work in

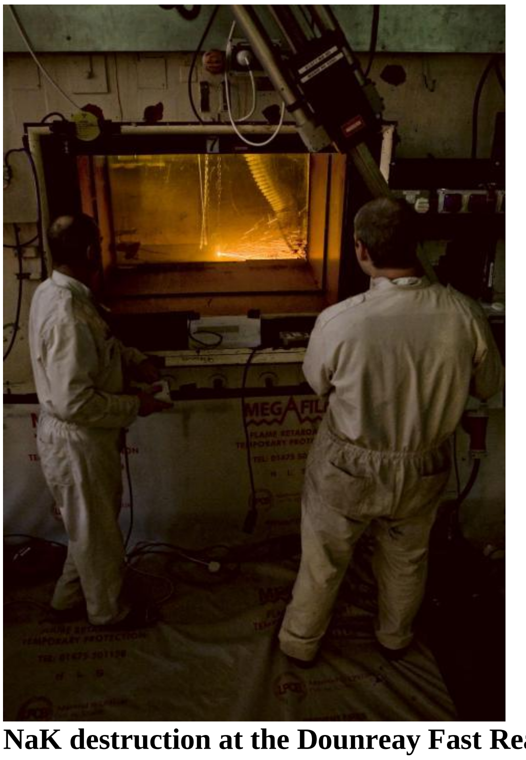
Figure 9(b) The decommissioning team in the Progress cleaned-up amber area

Progress at D1217 Post Irradiation Examination facility

D1217 was a Post Irradiation Examination facility which examined irradiated fuel and other fissile materials from research reactors at Dounreay, elsewhere in the UK and abroad. It played a major role supporting the reactor operations at Dounreay. An extensive period of remote decontamination was required to reduce the radiation levels in the facility's cell suite. As part of this novel remote plasma cutting (figure 10(a)) and scabbling were being used as an integral part of the cell decommissioning. Reduction in radiation levels has now reached a stage where controlled man–entry to the cell and redundant equipment removal (figure 10(b)) is now possible.

Figure 10(a) Plasma cutting in D1217

Figure 10(b) Equipment removal from cells



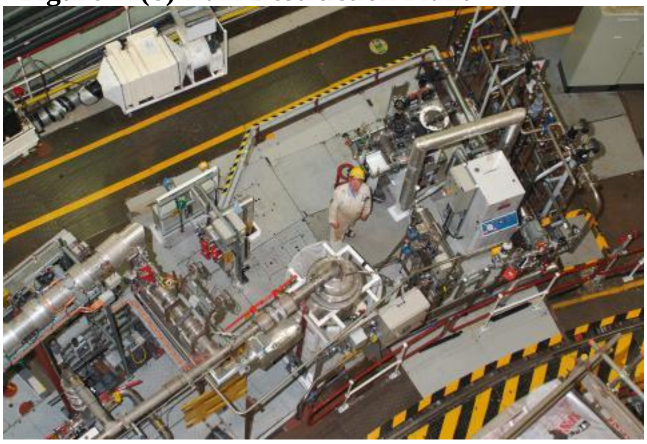
NaK destruction at the Dounreay Fast Reactor (DFR)

The alloy of sodium and potassium (NaK) was used as coolant in the DFR (figure 11(a)). Its safe destruction is one of the Nuclear Decommissioning Authority's highst priorities. At the time of writing the total destroyed to date is more than 161,000 litres of NaK. The site is on course to complete the destruction of the estimated 6300 litres still remaining by the end of March 2012.

The liquid metal is lifted in batches from inside the reactor and its six miles of cooling pipes. The NaK is processed through a purpose-built chemical plant to neutralise the alkalinity and extract the caesium contamination via ion exchange (figure 11(b)), leaving a salty water that can be discharged.

Figure 11(a) Dounreay Fast Reactor

Figure 11(b) NaK Destruction Plant



4. Radiation protection improvements and evolution

From the 1990s onwards there has been a steady advancement in the development of a coherent radiological protection philosophy involving engineered controls and safe systems of work. This process has encompassed the ever evolving best practice and industry standards in all areas of radiological protection and plant design with the explicit intention of legal compliance and dose minimisation, including:

- The late 1990s saw the commencement of an ongoing campaign to reduce the number and size of areas designated as "Controlled Contamination Moderate" areas where historical fixed and loose contamination had previously been tolerated. In some facilities chronic exposure to airborne activity had been associated with these areas.
- Following recommendations made in the Safety Audit of Dounreay in 1998[5] the number of in-house operational Health Physicists were increased to support both operations and decommissioning from early planning through to completion. This has resulted in quality radiological protection advice being "built in" to the projects methodology and documentation.
- Another outcome of the Safety Audit of 1998[5] was an ongoing disposal programme for legacy waste and redundant equipment. This has significantly reduced the radiological inventory in plant general areas and greatly reduced the potential for exposure.
- The introduction of Dounreay Codes of Practice in 1999 has had a significant impact on radiological protection standards. These codes of practice address the design and construction of temporary containments, the use of air fed suits, personal monitoring, safe use of gloveboxes and fumecupboards and the selection and use of mobile filtration units. This has greatly influenced the standard of control achieved when breaking containment in both routine and decommissioning operations where the operators are often further protected by the wearing of air fed suits. The introduction of these Codes of Practice was supplemented by extensive training and, where appropriate, assessment of the individual. Where assessment has been carried out this is formally recorded and subject to periodic refresher training.

- Quantitative respirator fit testing of all individuals required to wear full face respirators was introduced in 1999 and 2000[6]. This now means that all operators are aware of the size of face piece they require and how to don and remove it.
- General refresher training to all site personnel working in controlled areas commenced in 1999. The training addressed personal monitoring, risk assessment, safe working with glovebox and fumecupboard and other topics.
- During 1999 – early 2000s the site focused strongly on improving the application of the hierarchy of controls. This was manifest in the following areas of improvement.
    - Upgrade to modern standards and incorporation of good practice of various facilities ventilation systems. This has provided better dynamic containment and improved filtration of discharges.
    - Introduction of better designed modular containment systems for use in breaking containment and decommissioning plant.
    - Increased use of remote and semi-remote handling techniques.
    - A focused effort to remove fixed surface contamination commenced and this was supplemented by the creation of a database for recording residual activity that will be available to decommissioning projects at a later date.
    - The year 2000 saw the development and introduction of the risk assessed method statement. This brought the findings of the risk assessment and identification of controls together with the step by step method on how the work was to be executed. This gave the opportunity for specific controls to be identified against the relevant step in the method statement thus incorporating the radiological protection advice into the work pack.
    - Around 2003 the electronic Dounreay Modification Report (DMR) was introduced to replace the paper based Safety Assessed Modification (SAM). The main improvement here was the DMR, unlike the SAM, ensures that all the appropriate stakeholders are consulted in the development of the modification.
    - In 2006 a zero tolerance to the presence of loose contamination was adopted for high occupancy areas. This ensured that there is minimal risk of an intake or personal contamination to operators in their normal day-to-day working environment. Following the detection of a breakdown in controls an investigation is carried out to identify the failure and initiate corrective action.
    - A one piece single use air fed suit was introduced for the decommissioning of a plutonium research facility. This suit, with an internal respirator, afforded greater protection during the undress stage thus reducing the potential for an intake. It has become the basis for a new design being introduced this year as a site standard.
    - With decommissioning operations increasing the disposal of air fed suits after a single use in preference to laundering and re-use became site policy in 2008. The risk of residual low level contamination remaining on the inside of the suit after laundering was acknowledged as a risk to the next wearer. This could have lead to a chronic low level internal exposure through out a busy decommissioning plan over many years.
    - In the last six years work has taken place on profiling the interior of containment access ways in order to reduce turbulent eddies and hence reduce the risk of back flow at interfaces. To date it has been very successful and will continue to be extended to all areas of site where it is deemed to be applicable.

Improvements in External dose control

All personnel working in radiological designated areas at Dounreay wear a passive dosemeter that is used to measure personal dose for an individual's legal dose record. These dosemeters, however, only provide a retrospective measure of dose received by an individual and give no indication of the instantaneous dose or dose rates that an individual has/is being exposed to. Therefore, personnel entering areas with elevated dose rates wear, in addition to their legal dosimetry, a dosemeter capable of measuring instantaneous dose and dose rates in order to optimise the dose received. DSRL use an electronic dosemeter that can instantaneous measure Hp(10) and Hp(0.07) doses and dose rates.

When coupled with a transmitter it is possible to remotely monitor an individual's instantaneous dose and the dose rate that they are being exposed to via a receiver and then a laptop computer, with appropriate software. The unit used by DSRL is the Thermo Fisher Scientific Mark 2 Electronic Personal Dosemeter (EPD), that can be coupled to a transmitter (figure 12) that sends a signal via a receiver to a laptop computer running the Thermo Fisher Scientific ViewPoint software (figure 13). The electronic dosemeter and transmitter units are relatively small, light and thus do not adversely affect the operator's dexterity, except in the most restrictive of environments. The electronic dosemeters can also be attached to wrists and ankles, as well as to the chest. This is useful in situations where the extremities could be exposed to elevated local beta dose rates.

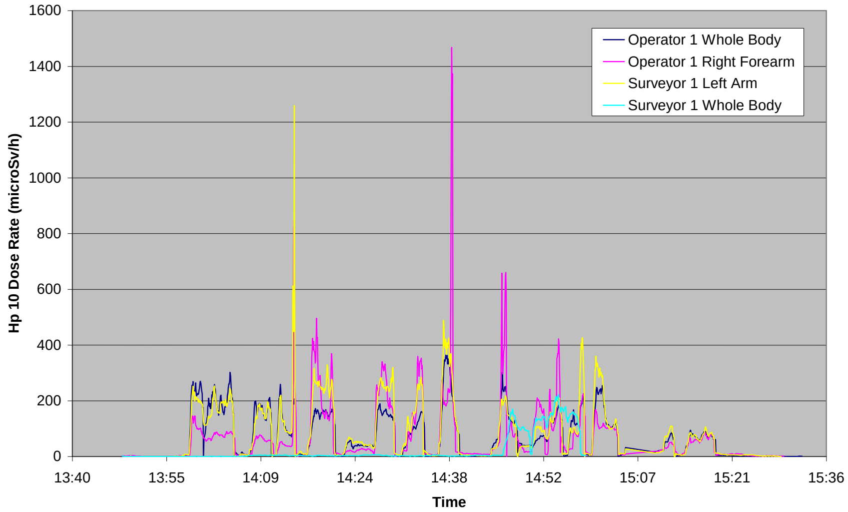
The electronic dosemeter and transmitter units are used at Dounreay to great effect in a number of situations, for example, clean up and recovery of a cell and equipment following a raffinate spill within an engineered containment.

Figure 12 EPD and Teleadapter personal transmitter

Figure 13 Teletrak laptop & antenna

The data generated by the software can be exported in to a spreadsheet package for further manipulation. Figure 14 shows an example plot of dose rate against time for personnel.

Figure 14 Graph of Hp(10) Dose Rate against time for personnel



The benefits of using remote readout dosimetry include:

- Quick and simple to set up and deploy.
- As the dosemeter is small and lightweight, it can be easily manoeuvred into areas of interest.
- Real time results relayed to the laptop are easy to read and interpret, rather than trying to remotely read and manipulate a relatively heavy radiation monitor whilst wearing respiratory protection.
- Health Physics Surveyors do not have to physically access an area and therefore restricts dose to the operator.
- Graphical representation of data points which is easy to interpret and quickly assess gamma and beta dose rates in the area.
- Elevated dose rate areas, that is ‘spikes’ are highlighted, where efforts could be concentrated prior to man access to reduce the dose rate in these area.
- Dose and dose rate alarms can be set for whole body, skin dose and dose rates providing more effective control of dose constraints and task management.
- Multiple users/operators can be tracked using the system.
- Multiple dosemeters can be worn on different areas of the body and the data relayed.
- The system can be used within shielded enclosures, with sufficient repeaters.

The use of a remote readout dosimetry system enables doses to be continuously monitored and reviewed, to support improved working practices to restrict doses to ALARP.

Pressurised Suits – lessons learned and improvements

Irrespective of the engineered controls and safeguards put in place, there is still the potential to require the use of Personal Protective Equipment (PPE) to ensure that the residual radiological risk is tolerable. In the context of decommissioning significant radiological hazard plants with loose radioactive material, this could well mean the use of Air Fed Suits that supply air remotely through a hose to a person contained within a hermetically sealed body suit.

At Dounreay, this was traditionally supported by a two-piece suit that was sealed at the waist, as shown during decommissioning work in figures 15(a) and 15(b).

Figures 15(a) and 15(b) A two-piece Air Fed Suit being worn during decommissioning activities

In common with other nuclear sites, it was acknowledged that an operative in an Air Fed Suit was most at risk during the suit removal process and specifically when all forms of Respiratory Protective Equipment (RPE) are absent. The suit also posed the following challenges:

- The tape applied to provide a seal between the top and bottom halves of the suit is not appropriate in a plutonium contaminated environment.
- The tape applied around gloves is not appropriate in a plutonium environment, and also inhibits air circulation to hands and leads to profuse sweating.
- The top half of the suit is awkward to remove in tight spaces and caused large disturbance of air in undressing area, that could potentially cause migration of contamination if there had been a break down in control.

To reduce this risk, so far as reasonably practicable, an evolution was proposed that entailed a one piece suit with an internal, initially air fed and subsequently filtered, respirator (figures 16(a) and 16(b)). The new Air Fed Suit offers the following advantages:

- 'In built' full face respirator to provide protection on removal of suit.
- Simple one piece design, restricting folds and creases that can trap contamination.
- Semi rigid cuffs allow air circulation to hands.
- Easier to remove, with a large zip across the shoulder area.
- Easier to remove in tight spaces and less disturbance of air on removal.
- This new Air Fed Suit, excluding the internal full face respirator, is of a use once design so that:
- The risk of error when monitoring the Air Fed Suit for plutonium contamination and the dose consequences for failing to detect the contamination (with potentially significant internal doses) is no longer an issue.
- The large resource required to monitor, wash and maintain reusable Air Fed Suits is removed.
- Reduced handling of potentially contaminated items, with the risk of spreading contamination and the associated intakes during the suit monitoring, washing etc. are removed.
- Has user confidence and 'buy in', as they were involved with its development from conception.

Figures 16(a) and 16(b) The Dounreay single use one piece Air Fed Suit with on built respirator

The single use one piece Air Fed Suit has been very successful in use and Dounreay is currently implementing a similar suit, incorporating lessons learnt, to become the site's Air Fed Suit for the future.

This new suit will be:

- Have thinner versions available, but robust, to optimise the waste disposal aspects.
- Be constructed by different manufacturers, to reduce risks with supply.
- Offer the benefits of the current single use one-piece suit.
- Developed with significant user input.

References

[1] David Spencer, Simon White and Timothy Watkin, The Effect of Radiological Protection Policies and Work Programme on Radiological Measurements at the Dounreay Site. 13th International Congress of the International Radiation Protection Association (IRPA).

[2] Department of Trade and Industry, Managing the Nuclear Legacy - A strategy for action, DTI, London (2002), http://www.berr.gov.uk/files/file29300.pdf.

[3] Peter Thompson and Simon White, Gearing up 'radiation protection' to meet the Nuclear Decommissioning Authority challenge, Proceedings of the Seventh International Symposium of the Society for Radiological Protection (2005)

[4] Simon White and Peter Thompson, The safe decommissioning of two plutonium contaminated facilities at Dounreay, European Third European IRPA Congress 2010.

[5] The Safety Audit of Dounreay 1998, http://www.hse.gov.uk/nuclear/dounreay.pdf, (HSE Books, 1998).

[6] S Calder, The introduction of Quantitative Respirator fit testing at The UKAEA Dounreay Site, International Society for Respiratory Protection 2002.