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UTILISILNG LASER AND GAMMA SCANNING MODELLING TECHNOLOGY AS A CHARACTERISATION TOOL IN DECOMMISSIONING THE FIRST PRIMARY SEPARATION PLANT AT SELLAFIELD

ABSTRACT

This paper describes the challenges every decommissioning project faces in a complex facility, which is the understanding of the environmental constraints in order to select the best dismantling approach. The challenge posed here is just one cell in a facility at the Sellafield site in Cumbria, UK, known as the shear cell, as it was used to shear reactor fuel. The method adopted to characterise the cell was a system that combined 3D laser scanning, gamma imaging and the NVisage™ modelling system. The paper concludes that this technique when selected for high radiation dose areas can be used successfully to identify key areas of radiation to aid the appropriate decommissioning techniques to be selected. It acts as an excellent means of providing accurate imaging and radiological data which can be used at various stages of a project.

INTRODUCTION

The First Primary Separation Plant to be built at Sellafield was the principal facility that supported the reprocessing of Uranium fuel, and is located within the Sellafield Separation Area. It processed low irradiation uranium metal fuels from 1952 to 1964, when reprocessing was transferred to the second generation Primary Separation Plant.
In the period 1966 to 1969 the South part of the building was modified to process oxide fuel and was known as the Head End Treatment Plant. The building ceased operations in 1973 and was put into a care & maintenance regime between 1973-88, a recovery programme to retrieve head end plant materials and eventual Post Operational Clean Out was implemented prior to the commencement of decommissioning activities in 1990.

The building is a clad, steel-framed, ten storey brick building consisting of an outer annulus, (out-cell areas and services) the core supports the load of the ventilation stack and cell configuration. Cells are constructed of shielded concrete.
It was structured around two identical reprocessing lines that occupied the north and south halves of the building, separated by a dividing wall. Each production line was contained within a Medium Active (MA) cell and two accompanying Highly Active (HA) cells surrounded by the operating annulus of the building. The MA cells extend from the ground floor to the 8th floor.

The exterior walls of the concrete core and some of the interior walls between cells have regularly placed openings which were used for construction access to the internals of the core. They have subsequently been bricked up and finished flush with concrete faces.
The Head End Treatment Plant is situated on the 9th & 10th floors and was constructed on top of the Highly Active South Outer cell. Two dissolver cells were constructed underneath the shear cell, one dissolver in the west cell, two in the east cell.
The shear cell operations were supported by the decontamination cell and maintenance cell which are located on the 10th floor. Separation of these areas is by means of a hydraulically operated shield door. An in-cell crane and manipulator systems allowed modular components to be removed from their location in the shear cell, decontaminated and maintained in the connecting facilities.

Fig. 1. The First Primary Separation Plant

BACKGROUND
Physical Status
The shear cell was the sole point of entry into the process for irradiated fuel. Fuel rods were individually imported into the cell through a gamma gate in the west wall on the 10th floor level. The rods were then sheared into pellets and gravity-fed into dissolver baskets. After dissolution, the insoluble remains in each basket, principally consisting of fuel hulls, were discharged from the cell down two chutes. Separate chutes were provided for zircalloy and stainless steel hulls culminating in two storage vessels. The shear cell remains to be the most challenging prospect for the project team and is the subject matter for this paper.

The shear cell is being investigated as a size reduction facility within the current Primary Separation Plant strategy, providing a waste processing facility for the east dissolvers, and vessels from the Highly Active South Inner cell, the area may also potentially be used to process waste from connected areas.
In order to support this proposed strategy the shear cell would first need decommissioning to be progressed and completed in relation to the overall proposed decommissioning programme for the building.
The shear cell contains the majority of in-cell equipment from operations; the internals associated with the shear pack have been removed and placed in adjacent facilities. Bulky items for example, the dissolver basket, basket tipper, feed envelope, vessels and the shear support and feed column (Fig 2), all remain. The cell is lined with a stainless steel liner which was painted, however this coating is peeling off the walls, creating debris in the bottom of the cell. (Reference 1)

The through wall drives that operated in-cell equipment remain intact. The in-cell crane has not been operated for a number of years; and is housed in the adjacent maintenance cell; a comprehensive survey would have to be completed to assess operability or replacement. The shield door has not been operated for a number of years and will need to be upgraded to modern day standards; this would allow material to be moved from the shear cell to the maintenance cell for eventual size reduction, processing and packaging.
The amount of ILW that is present in the shear cell is estimated to be $68m^3$ of ILW (+ or – 5%). Most of the services (except lighting) supplying the cell have been disconnected and depending on the decommissioning solutions adopted, new supplies would have to be connected. (Reference 1)

Radiological Status

Access is possible into the adjacent maintenance cell in PVC and respirator and working times are in the order of a maximum of 5 hrs with typical dose levels being 120µSv/hr; however the shear cell offers no such access possibilities.
The radiation doses in the shear cell are significantly greater than that of the maintenance cell, background dose has been measured above the shield door at 11.58 mSv/hr (γ) and 18.96 mSv/hr ($\beta\gamma$) using data from a film badge.
With information based on the stainless steel silo, (hulls were sentenced here from the shear process) it is assumed that shear cell dose rates will be a number of magnitudes greater than those measured, due to the likely presence of fuel hull fragments, and accumulated ILW dust/debris.
There have been known spills of radioactive material on the walls of the cell, with a number of hotspots identified, which will be a significant contribution to the overall dose. (Reference 1)

Decommissioning Strategy Summary

The High Active strategy considers a clear area in the shear cell for use as a processing and packaging facility for waste arising from the other cells associated with the Head End Treatment plant. The main objective would therefore be to remove redundant plant, equipment and waste residues from the shear cell leaving an environment suitable to support a Waste Handling Facility. Further, other overarching opportunities, for example, the use of such areas as a demonstrator/learning opportunity for other facilities such as the Thermal Oxide Reprocessing Plant, which is very similar in configuration to the Primary Separation Plant, would be advantageous.

One of the main problems encountered was that plant status and engineering reports were not available, limited characterisation work had been conducted; video surveys, Radscan™ 700™, though it is unclear which aspects of the cell are the major contributors to the dose environment (although eight hotspots are known in the shear cell, it is not certain how these contribute to the overall dose environment). The end point for the shear cell decommissioning project is considered to be an empty cell, with aspects of the cell that deliver the functionality required for future waste processing / disposal remaining in place. All waste from the cell is recovered and transferred to an approved waste store.
A programme of work to recover data, for example, radiological surveys of the cell areas and items within the cell, would allow an improved understanding of the issues inherent to the shear cell in order to identify an appropriate scheme for decommissioning the cells.

If the hotspots were able to be removed or shielded from their current position, what would be the overall radiological condition, and could there be a possibility of reducing levels such that man entries may be made? The project therefore concentrated on the shear cell characterisation. (Reference 1)

Previous results (1998) using Radscan™ 700 in the Shear cell
The Radscan™ was deployed using the then operable in-cell crane, which enabled a number of scanning positions to be used.
The initial measurements carried out at the start of this survey work established that the typical background radiation level at the inspection head was around 400 - 500cps (30-40 μSv/h). When inside the shear cell, and with a 2º collimator fitted, the typical background rose to around 2000cps (6.2mSv/h).

The measurements of surfaces visible from the 6 positions available identified that there were Eight discrete hotspots (Fig 2) of significance when compared with the background levels at each position.
Hotspot number 1, from the plank of wood on the drip tray between dissolver chutes, gave count rates of 52283cps (22.5mSv/h).This was with the inspection head a total of 3.1m away from this hotspot.

Hotspot number 2 originally appeared to be on a collar which is round the base of the upright section of the basket tipper mechanism. Subsequent investigations within the shear cell revealed a rod type object behind the tipper mechanism which gave count rates of 19667cps (9.23mSv/h). This was with the inspection head at a distance of 1.0m from the object.

Hotspot number 3 is present on the substance filling the middle dissolver chute. It gives count rates of 34746 cps (8.61mSv/h) with the inspection head 2.6m away from the top of the chute.

Hotspot number 4 is from the debris in the upper part of the stainless steel storage silo chute. A count rate of 2493cps (685.5μSv/h) was obtained with the inspection head 2.9m away.

Hotspot number 5 is from a hull type object on the floor of the shear cell. A count rate of 67043cps (38.5mSv/h) was obtained with the inspection head 3.2m away.

Hotspot number 6 is from the debris on the drip tray between the dissolver chutes. A count rate of 16610cps (1.91mSv/h) was obtained with the inspection head 3.2m away.

Hotspot number 7 is the debris on a shelf below the entry for the discharge ram. It gives a count rate of 715cps (2.97mSv/h) with the inspection head positioned in the maintenance cell, a total of 12.2m away.

Hotspot number 8 is from debris in the shear machine enclosure and gave a count rate of 41227cps (12.2mSv/h) with the inspection head 2.8m away. (Reference 2)

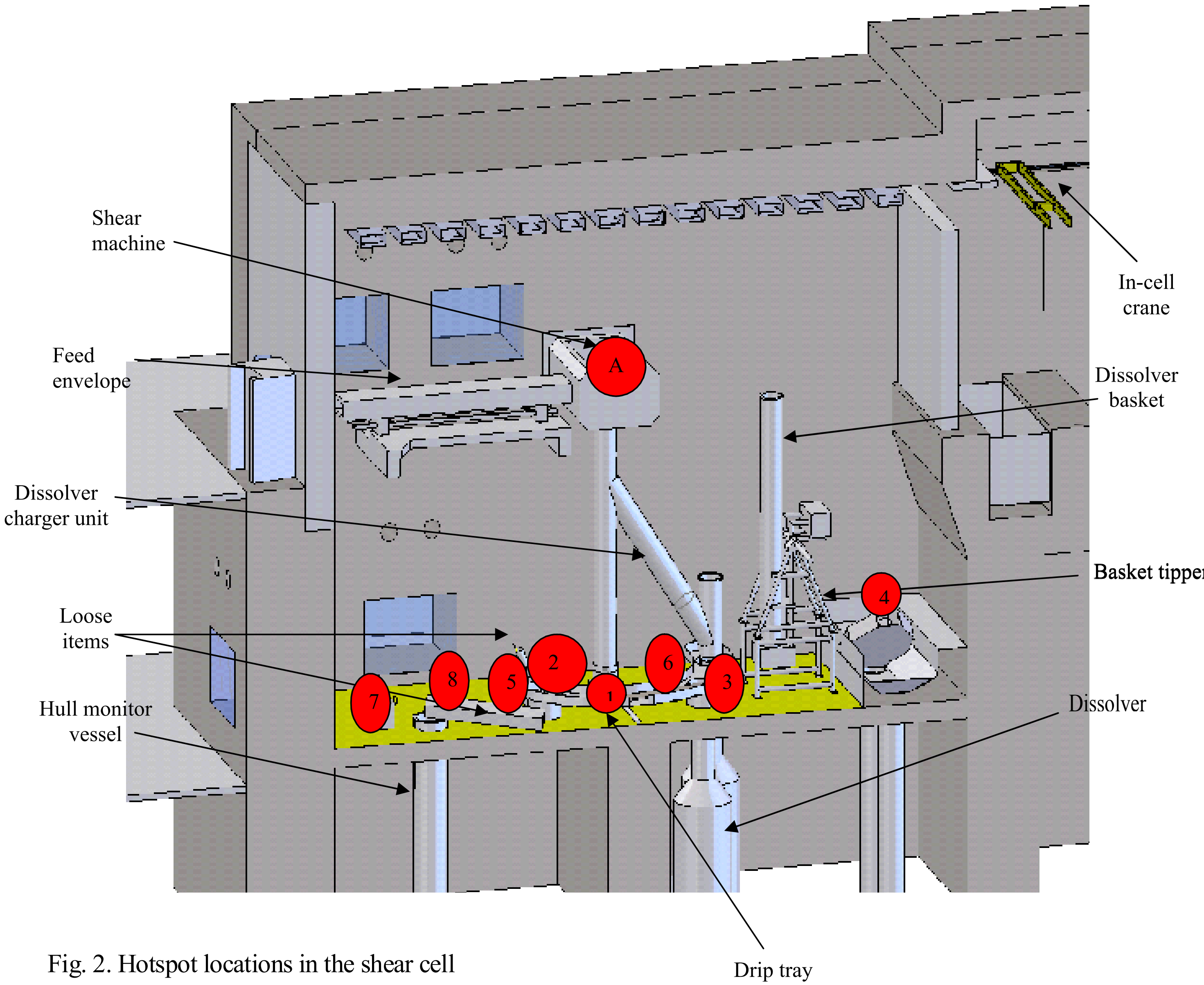

Fig. 2. Hotspot locations in the shear cell

RADIOLOGICAL CHARACTERISATION OF THE SHEAR CELL

Laser Scanning/Gamma scanning and NVisage™ modelling

To progress the characterisation of the shear cell the project engaged REACT Engineering Ltd and Multipass 3D Laser Scans Ltd to carry out Laser scanning using a FARO LS 880 laser scanner, which was used to precisely map the contents of the shear cell.

The data obtained would also be used to create 3D model images of the shear cell integrated with the data from the gamma scanner. Available as built drawings of the shear facility are of poor quality and not always available, using the laser scanner would give the project accurate images of the cell contents. To undertake this analysis the REACT's NVisage™ dose modelling engine was used for radiometric data recovery and to mitigate dose scenarios.

Using this system allows the project to carry out the dose mitigation strategies by interrogating data by shielding/containing the hotspots in other areas of the shear cell and then assessing the remaining ambient dose levels.

FARO LS 880 Laser Scanner
The FARO laser scanner was bought by the Primary Separation Plant (£60k, $96k) so that it could be used on a number of projects and has been an asset in the characterisation work programme for other projects in the building. The cost of hiring is very expensive and having the equipment readily available for deployment in a number of areas has proved invaluable, justifying the high initial cost.

Description
The 3D Laser scanner used for the shear cell survey is a specially modified FARO LS880 large volume scanner. This type of scanner has been developed commercially to record large objects in context with other objects, landscapes and features within a Scene. The scanners record "large volumes" of space are commonly used in Civil Engineering and Architectural applications. The scanner is placed on a firmly fixed vantage point and emits a ranging laser beam outwards through 360 degrees in a flat plane, by means of a central rotating mirror. A ring of individual point measurements are generated at a fixed frequency of 120,000 per second. The rotating mirror is in turn swept slowly around the scene by means of the horizontal turning of the scanner unit. This gives a 360 x 360 degree field of view and generates a cloud of point measurements in a grid form with 20,000 x 10,000 (200 million) points at the ½ density setting, or 10,000 x 5,000 (50 million) points at the ¼ setting.
The base mounting plate of the scanner has been modified to allow it to pass though a 280mm diameter Master Slave Manipulator port. The scanner can be run in any orientation, with range measurement typically accurate to +/- 3mm, and an effective range of the scanner being 0.1 metres up to 70 metres.

Scan Data
Each point recorded is automatically assigned an X, Y and Z coordinate relative to the scanner, together with a reflectivity reading for the surface which has been scanned. Surfaces visible from the scanners point of view are displayed on a computer as either a rectangular fisheye panoramic image, or as a navigable 3D "point cloud" model.

Deployment
By recording a series of scans from different vantage points within the scene, the shadowing caused by the scanners own body, or by objects in the scene can be reduced. Three Master Slave Manipulator ports provided access to the shear cell and using a mechanical extending arm and mounting, several scans were recorded through each port and at various depths into the cell. Scans were also recorded over the top of the gamma shield door. Theses four access routes provided good general coverage of the shear cell.

Processing

Once sufficient scans have been recorded, the scan files are registered together in software to produce a relatively seamless point cloud model of the scene. Perspective, viewing position, and visibility of the point data can all be manipulated to produce greyscale orthographic or perspective views, measurements can also be taken between any of the points in the point cloud model. Further processing of the point cloud Data has allowed the creation of 3D CAD model geometry based on the point cloud data. The CAD models have a high degree of dimensional and positional fidelity to real objects in the shear cell.

3D radiometric models generated from the N-Visage survey were used in conjunction with the point cloud and 3D CAD models to produce graphical and mathematical models of both the physical and radiometric environment within the Cell. (Reference 3)

NVisage™ Gamma Scanning

NVisage™ relies on a geometric model of a facility to interpret a comprehensive set of radiometric data. Several of the objects within the cell, including those already known to be sources, are loose items that have been deposited on the floor of the cell. It was necessary to capture the precise 3D geometry of these items within the plant to enable NVisage™ to model them with sufficient accuracy. An opportunity was therefore exploited to link the radiation survey and modelling with a laser scan of the cell, deploying the NVisage™ scanner at the same time as the laser scanner. The combined data sets provide sufficient information to construct a model of the radiation environment within the cell. REACT's NVisage™ process is a unique plant analysis technique that combines a radiation survey with computer modelling and post processing to derive a model of the radiation environment. This model is then used to predict the evolution of the radiation environment as a result of changes to the plant as decommissioning proceeds. Changes that can be modelled include addition or removal of shields, and the movement, removal or reduction of sources.

The NVisage™ scanner is a compact radiation measurement instrument designed to generate comprehensive NVisage™ data sets from a small number of locations. Its small size enables it to be deployed through penetrations of 127mm diameter and up. Unlike gamma cameras, the scanner has been specifically designed and calibrated so that NVisage™ can calculate the 3D distribution of source material from the data, without suffering 'background' effects. It is this property that enables NVisage™ to access the background radiation levels that would be expected once the large point sources have been removed. The device also has the advantage of high efficiency giving low dwell time, and high dynamic range providing tolerance to high doses, making it well suited to large high dose environments such as the shear cell.

Method

The overhead crane in the shear cell is no longer in service, necessitating an alternative method for deployment of instruments. Limited access is available from the East end of the cell where instruments can be deployed from the adjoining maintenance cell. The maintenance cell has been used as a laser scan location, but it is not suitable as it does not provide a clear view of any of the known source locations.

All other deployments have exploited the use of former Master Slave Manipulator ports. (Reference 4)

These are 280mm nominal diameter penetrations positioned in pairs immediately above each window on each wall. No Master Slave Manipulators are currently fitted and penetrations are shielded with steel and concrete plugs weighting approximately 0.25te each. This survey removed MSM plugs at three locations and a pre-existing deployment arm was mounted on temporary scaffolding in order to deploy first the laser scanner and then the NVisage™ scanner. The locations were on the Western face of the shear cell on the 9th floor (penetration 9/32) and the Southern face of the shear cell on both the 9th and 10th floors (penetrations 9/36 and 10/25 respectively shown in figure 3).

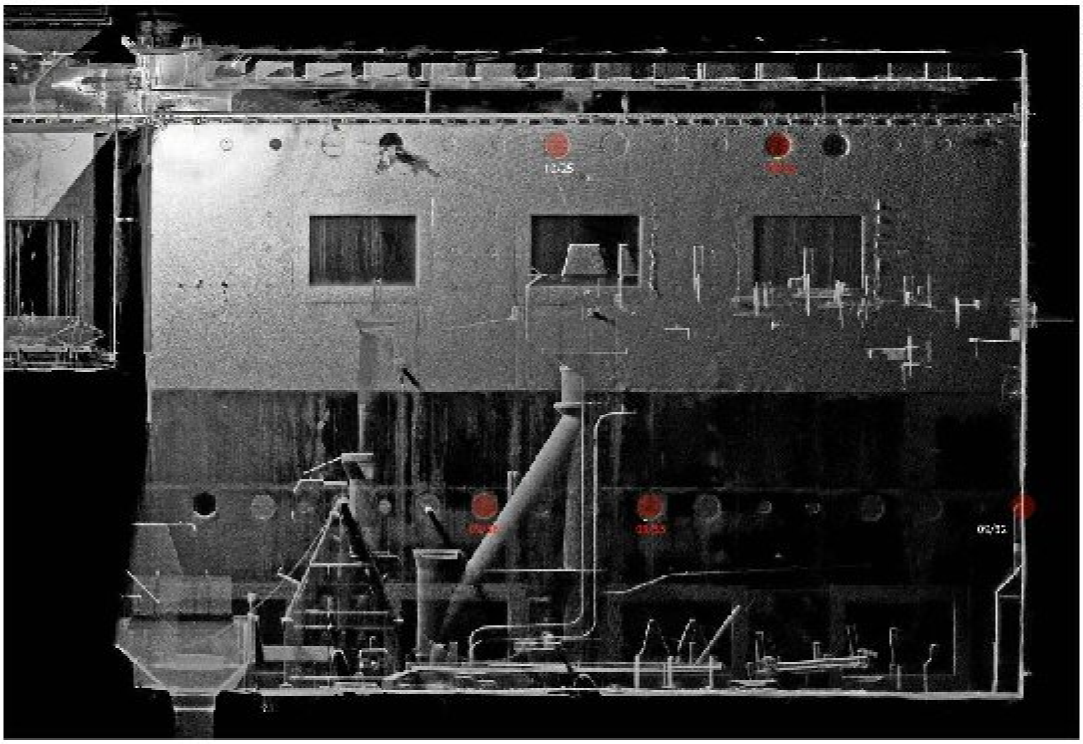

Fig. 3. Penetrations used on the shear cell

Laser Scans

Over 30 individual laser scans, at varying levels of resolution, were completed through the MSM ports used in this survey by Multipass 3D Laser Scans Ltd. The majority of these featured the scanner in an inverted orientation, suspended from its mounting by the deployment arm in order to cast its blind spot on the ceiling of the cell. Scans were also completed with the scanner in an upright orientation in order to obtain a clear view of the cell ceiling. In general scans were taken with the arm extended such that the scanner was just inside the cell, near the centre and towards the far wall in order to give complete coverage of the cell.

Laser scan data consists of the three co-ordinates of a point in space along with the luminescence, or brightness, of that point in space. (Reference 4)

During post processing the data from each scan is positioned relative to the other scans, or "registered", in order to build up a complete data set for the shear cell. The registered data set was itself registered with the pre-existing scans taken from the maintenance cell.

A small number of test scans outside the shear cell were also taken, either at floor level or on the scaffolding erected to remove the MSM plugs and to support the scanner deployment arm. Besides proving the function of the scanner prior to its deployment in the cell the test scans also allow the scans taken in the cell to be positioned within the building envelope.

NVisage™

The NVisage ™ scanner was deployed through the MSM ports as previously described.
The West wall scan was taken at maximum extension into the cell which gave the scanner a clear view of the rod shaped object in a basket, which had previously been identified as a source. The 10^{th} floor South wall scan was taken with the scanner positioned to give a clear view down into the shear machine 'hopper'. The 9^{th} floor South wall scans were positioned to give a clear view of the drip tray and surrounding objects, and to look for any sources that might be obscured behind the dissolver charger unit.

OUTPUT FROM NVisage™

Source Terms

The NVisage™ analysis located the same set of sources that had been identified by the earlier Radscan™ survey. There was some uncertainty following the Radscan™ survey whether the sources were all due to the same isotope; all of the sources identified by the NVisage™ scan were compatible with Cs-137 and this was confirmed by swab analysis.

The principal sources are: (see Figure 2 for the location of these items).

Drip Tray

The main source sits over one of the dissolver covers, at the end of a wooden scaffold board that sits in the drip tray. Other less focussed sources appear near the centre of the drip tray; while these are very much weaker in terms of their concentration, they are also more numerous and make a significant contribution to dose.

Loose Items

At the west end of the drip tray sit several loose items which were left in the cell after Post Operational Clean Out. A rod sitting in a basket was found to be the dominant source; however some activity also appears to be present in the base of the adjacent basket. These items are on a par with the largest source in the drip tray in terms of their dose contribution.

Tipping Machine and Dissolver Basket

The tipping machine has been left with one of the dissolver baskets sitting in it. An extended source is visible on the NVisage™ scan of the basket and tipper, with a concentration maximum where the basket meets the tipper machine. This source may either be due to material held up in the dissolver, or may equally well be contamination on the tipper machine itself. (Reference 4)

Shear Machine

The shear machine was previously found to have contained a source, although the source could not be imaged due to the lack of a stable platform for the Radscan™. A good view of the shear machine was obtained from the 10th floor deployment during this survey. This view found a diffuse hotspot in the area identified by Radscan™. A hotspot in the same location was also visible from the 9th floor, although at a lower magnitude, due to the shielding effect of the shear machine housing. Several other more focussed sources were also visible which were not located by the Radscan™ (fig 2 A). This area of the scan was particularly badly affected by the laser scanner noise; inspection of the raw data suggests that what currently appear to be clusters of point sources will actually resolve into more diffuse single sources once the noise has been removed.

Discussion

The output of this process is a single high resolution 3D model of plant geometry and contaminant distribution. In its current form, this data enables the ability to predict the variation in dose at any of the scanning points as sources are added and removed, moved or shielded. A dose extrapolation away from the scanning points is possible but will have limited accuracy without knowledge of the solid geometry of the plant. (Reference 4)

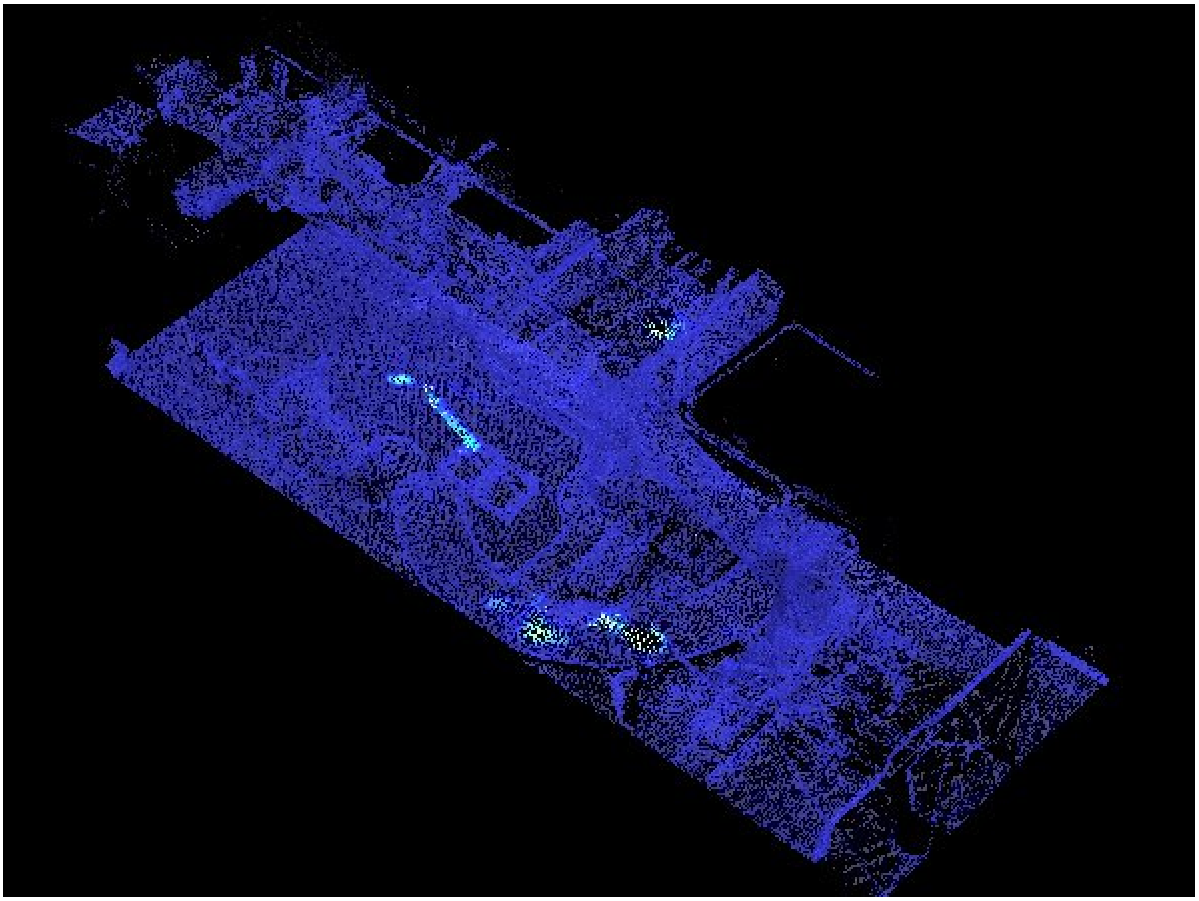

Fig. 4. Showing NVisage™ sources

The ultimate objective of this characterisation work is to determine if it is feasible through a limited number of carefully targeted interventions to enable manual techniques to be used to accelerate and reduce the cost of decommissioning. The overall dose measured at the 9^{th} floor level near the drip tray was 52mSv/hr, indicating that a dose reduction of two orders of magnitude would be sufficient to enable some manual intervention.

Before the feasibility of enabling man access can be determined, potential interventions for reducing the dose from each major source must be identified. These can then be evaluated in the NVisage™ model.

The next stage of the process was to review the N-Visage^{TM} data generated from the initial schedule of work described previously and define the implications in terms of manual/remote decommissioning. This will be used to establish a current datum for the area in relation to how practical manual or semi remote decommissioning operations are and what the key aspects of the dose environment are that are contributing to that conclusion with the following activities.

- Examine the N-Visage^{TM} model to gain an understanding of the likely source terms that exist within the cell.
- Develop generic dose mitigation strategies for the cell. These strategies will be developed as appropriate ways in which the specific source terms might be mitigated rather than considering the practicalities of the engineering requirements for achieving that mitigation.
- Re-run the N-Visage model based upon the dose mitigation scenarios.
- Utilize the output from the N-Visage model to develop a quantitative assessment of the likely impact of the dose mitigation scenarios. (Reference 4)

Results

A number of dose mitigation scenarios were derived based upon the likely source terms and simple approaches utilising shields and relocation of sources to develop an understanding of the effect on the overall dose environment in the cell. The dose mitigation scenarios were based upon engineering judgement and were derived in conjunction with REACT Engineering and the project team. Six scenarios were examined and are described in detail below.

Scenario 1 represented the baseline or current datum, this scenario represents the current arrangement of source terms within the cell without mitigation. The dose field at waist height within the cell showed the contribution of the rod currently in one of the transport baskets and the source terms on the drip tray dominating the overall dose field at waist height at 1Sv/hr.

Scenario 2 involved moving the baskets and rod together with the small fragment of debris on the floor to a new location within the cell. The location is situated in the north east corner of the cell and includes a shielded area behind which the items are placed. The shield is constructed from 100 mm of lead, a thickness that could be achieved by a two layer chevron brick structure.
The N-Visage^{TM} model is able to show the effect upon the dose field by moving the rod and debris fragments to a shielded area with the source terms on the drip tray dominating the overall dose field at waist height giving a dose of 0.85 Sv/hr. (Reference 5)

Scenario 3 is essentially an enhancement of Scenario 2 which involves moving the baskets and rod, the small fragment of debris on the floor and the plank lying on the drip tray to a new location within the cell. The location is situated in the north east corner of the cell and includes a shielded area behind which the items are placed. The shield is constructed from 100 mm of lead.
The dose field at waist height within the cell was based upon this scenario. The model showed the effect upon the dose field of moving the rod, debris fragment and plank to the shielded area with the remaining small source terms on the drip tray now dominating the overall dose field at waist height giving a dose of 0.58 Sv/hr.

Scenario 4 is essentially an enhancement of Scenario 3 which involves moving the baskets and rod, the small fragment of debris on the floor and the plank lying on the drip tray to a new location within the cell. The location is situated in the north east corner of the cell and includes a shielded area behind which the items are placed. The shield is constructed from 100 mm of lead. In addition, to model partial success of this method, it has been assumed that the source terms from the plank and on the drip tray remain in their present location but are shielded by a newly introduced sheet of lead, 50mm thick.

The dose field at waist height within the cell based upon this scenario shows the effect upon the dose field of moving the rod, debris fragment and plank to the shielded area with the effect of the plank plus source terms on the drip tray through the shield now dominating the overall dose field at waist height giving a dose of 0.44 Sv/hr.

Scenario 5 is essentially an enhancement of Scenario 4 which involves moving the baskets and rod, the small fragment of debris on the floor and the plank lying on the drip tray to a new location within the cell. The location is situated in the north east corner of the cell and includes a shielded area behind which the items are placed. The shield is constructed from 100 mm of lead. In addition, to model partial success of this method, it has been assumed that the source terms from the plank and on the drip tray remain in their present location but are shielded by a newly introduced sheet of lead, 50mm thick. The source terms from the shear block are also shielded by placing shields on the underside of the block in an attempt to reduce the contribution to the waist high dose field.
The dose field at waist height within the cell based upon this scenario and shows that there is minimal change from the dose profile derived from Scenario 4 indicating that there is little contribution to waist high dose from the source term identified in the shear block.

Scenario 6 provides a bounding case whereby the source terms above the median value have been reduced mathematically to the median value. In practical terms this would represent the effect of an extensive and systematic clean out campaign of the cell. This scenario has been assessed to show a credible lower threshold that could be expected following a campaign of principal source term removal and decontamination of the remaining surfaces.

The dose field at waist height within the cell based upon this scenario shows that the high dose areas remaining in the cell are concentrated around the drip tray and the mouth of the dissolver. The ambient dose field remains at a relatively high 10 mSv/h although areas towards the shield door and the maintenance cell are under 10 mSv/h. (Reference 5)

CONCLUSION

The programme of work to explore the effect of dose mitigation scenarios in the shear cell in The Primary Separation Plant has been completed. The work utilised the baseline information generated from the recently completed laser and NVisage^{TM} scans and the associated source term distribution model within NVisage^{TM}. Five additional scenarios were analysed in addition to the baseline scenario. The outcome of the analysis showed that the dose field within the cell remained high following mitigation of the principal source terms in the cell. The dose field under these scenarios (2 to 5 above) would preclude man access. These scenarios also represent the programmes of work that would be the most straightforward to implement. However, the analysis from N-Visage^{TM} shows that none of these scenarios would result in general dose levels within the cell that could facilitate manual access.

Scenario 6 was analysed to assess the impact of a sustained clean up campaign following mitigation of the principal source terms. This scenario showed dose levels within the cell of 10mSv/h but hotspots adjacent to the drip tray/tipping mechanism and dissolver mouth have levels in the order of 20 mSv/h. These levels would also preclude man access for any sustained period of time.

The results from Scenario 6 would indicate that there is widespread contamination within the cell which whilst not representing a substantial point source term in itself provides a significant contribution to the overall dose field. The results also show that the area around the shear block, drip tray and dissolver mouth remain the most significant source terms even following a sustained programme of clean up which is consistent with the likely operations carried out in the cell.

The analysis carried out would suggest that the approach to decommissioning of the shear cell should be focused upon a remote methodology, targeting the discrete high source terms initially followed by a more systematic decontamination and clean out campaign. Routine monitoring of the effectiveness of this campaign will provide an indication of when manual access can be gained. (Reference 5)

REFERENCES

1. C. HAMILTON and P. WOOLAGHAN, "Strategy Development for The Shear Cell", E00678/003, REACT Engineering (1998).
2. W. NICHOLSON and A.J. MCCLELLAND, "Radscan™ 700 Survey of Shear Cell, Primary Separation Plant", TR/0601/01/50/004, BNFL Instruments reference (1998).
3. "Primary Separation Plant Laser Scan Survey", (2008).
4. M. MELLOR and T BRENTNALL, "Laser and NVisage™ Scanning report", E00829/400, REACT Engineering (2009).
5. P. WOOLAGHAN and M. MELLOR, "Options Report for Decommissioning of The Shear Cell Based Upon NVisage™ Analyses of Dose Fields", E00912/003, REACT Engineering (2009).

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