Dose Reduction Techniques Employed During Cell Line Decommissioning

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ABSTRACT

A facility originally consisting of a fully ventilated, massively shielded cell line containing eight glass fibre containment boxes and a single steel entry/exit box was used to process, encapsulate and package Caesium 137. The contamination generated during operations gave rise to dose rates of many Svh^{-1} within the cells such that operator doses became untenable and the facility was shut down. It remained this way for approximately 6 years when decommissioning operations commenced. By this time the facility infrastructure has suffered a great deal of degradation. The project involved using robotic techniques to remove cell contents, cut up the cells, post out the waste and decontaminate until dose rates had been reduced to allow man entry. Initial manual decontamination was carried out by operatives wearing pressurised suits where dose to individual operators was managed in live time by the use of remote tele-dosimetry. During this phase dose estimates were carried out and compared with actual dose received such that using these tools it was possible to minimise the doses received by planning, and increased operator awareness of high dose rate areas.

INTRODUCTION

RWE NUKEM Limited accepted on a turnkey basis a contract to decommission a Caesium-137 sealed source production facility. The facility consisted of eight glass re-enforced fibre containment boxes (GRP) and a single fabricated steel material entry/exit box (see Figure 1). Up to 175 mm of lead shielding was provided along the working face of the facility to minimise operator dose uptake. When the plant was operational materials and equipment inside the cell line were manipulated with tongs that passed through the front working face. Each cell was connected to its immediate neighbour by a 275 mm diameter tunnel that was used for inter box transfers. The boxes were supported on a steel and concrete plinth.

The cell line was used to manufacture encapsulated ^{137}Cs pellets for 13 years. The caesium was supplied either as a solution, a powder or in pellet form and subjected to various processes including wet chemistry before conversion into small ceramic sources. The sources were then encapsulated in stainless steel capsules and shipped to customers. The finished capsules could be as small as 4 mm diameter and 8 mm long containing 75GBq of activity. The pellets were smaller, 2mm diameter and 2mm long. Given the need to manipulate the in cell equipment using tongs alone, spillage of capsules, pellets and liquid stock was a significant possibility. Spilt materials were difficult to recover and could pass into areas that were difficult to see and reach with the tongs.

When manufacturing ceased in 1990, the facility was put on a programme of care and maintenance and the shielded cells used for the temporary storage of the remaining waste. With the passage of time the high radiation dose rates caused the fibreglass and Perspex used in the construction of the inner cells and the plastic ventilation system to deteriorate.

RWE NUKEM Limited was invited to undertake an Option Study in 1993 to determine the optimum strategy for the future management of the facility.

OPTION STUDY

An option study was carried out to identify the most safe and cost effective manner to decommission the facility. At the time the Option Study was carried out the following facts were clear.

- A ‘mirror image’ facility was located alongside the concrete wall shown in Figure 1. This other facility was operational, and the need to keep this plant operational would constrain the lay out and size of any equipment provided to facilitate the decommissioning.
- There was a large volume of caesium-contaminated (~ 18.5 TBq) waste and part finished sources inside the facility. Accessible (using existing facility remote handling tools) contact dose rates were of the order of 30 Sv/h (γ). Beta/gamma dose rates were approximately 20 times higher.
- The associated radiation levels had damaged the facility local ventilation system and the box containment.
- The radiation levels inside the maintenance corridor were ~ 5 Sv/h such that man entry was impossible and consequently it was impossible to repair the ventilation system.

- The radiation had also damaged the internal seals on the tongs and crazed the viewing panels on the boxes. This made it impossible to use the tongs to manipulate the waste and made it difficult to see into many of the boxes.
- Although small access ports existed in three of the cells their size and the high radiation levels precluded their use for waste removal operations.
- Whilst the "plug" door was effective as a shield door it could not be used as a means of access during the initial decommissioning operations.

Four options were considered for the facility:

1. Carrying out the minimum work necessary to enable an appropriate care and maintenance regime to be instituted. This was rejected primarily because it merely deferred the problem rather than dealing with it;
2. To refurbish the existing equipment and then to undertake early post operational clean out but delay final (remote) dismantling of the facility. Again this was rejected as an incomplete solution.
3. To refurbish the existing equipment and then use it to undertake the clean out and to follow this by completing the waste removal and the dismantling of the facility using advanced remote handling techniques. The use of existing equipment would have meant long term close contact with the cell face where the work area radiation dose rates were highest. Also it was anticipated that frequent gaiter changes would be required. The existing and anticipated contamination levels were such that dose rates to the hands would be in the order of 100s $mSvh^{-1}$ giving rise to unacceptable extremity doses;
4. To undertake post operational clean out and the dismantling of the facility using advanced remote handling techniques.

The study concluded that the most practical option that would achieve the desired objective with minimal lifetime costs was option 4.

The overall objective was to decommission the facility in a safe and cost effective manner. The physical endpoint was the complete removal of the facility leaving only the decontaminated areas that form part of the building structure. The target radiological endpoint was that any remaining contamination was firmly bonded to the remaining structure and that levels did not exceed 40 $Bqcm^{-2}$.

DECOMMISSIONING STRATEGY

The project was split into three phases:

1. Pre-works. This involved installation of engineering controls to facilitate the use of the Tele-Robotic System (TRS) and to remove waste from the facility;
2. Remote Phase. This consisted of using the TRS to remove all the loose waste items from within the cells, Size reduce the boxes and dispose, and decontaminate all accessible surfaces such that man-entry was possible;
3. Manual Phase. This consisted of personnel entering the maintenance corridor to remove any remaining contamination such that final access to the area could be made without the need for Personal Protective Equipment (PPE).

For each phase of the operations, method statements and collective dose estimates were prepared. During the execution of the works radiation and contamination monitoring was carried out to ensure that environmental conditions remained as expected. Whole body and extremity personnel doses were measured by a combination of Optically Stimulated Luminescent dosemeters (OSL), Thermo Luminescent Dosemeters (TLD) and electronic Personal Indicating Dosemeters (PID). At the end of each phase a report was produced summarising the operations that actually took place, the reason for any deviations from the original plan, and the actual doses received by the operators. A key milestone in the project was the decision of when to change from the remote phase to the manual phase. Early thoughts on specifying a target dose rate / contamination level were rejected primarily because it was not possible at this stage to determine how successful the TRS would be at reducing the dose rates. Therefore it was agreed with the client that there was little to be gained in defining conditions at which manual operations would start. However in making the decision two factors were paramount:

- Personnel would not be accessing these areas while dose rates were at 'lethal levels';
- RWE NUKEM Company dose limits (which are lower than the UK legal limits) must not be exceeded.

The decision would be a judgement as to whether it was ALARP to continue using the TRS i.e. a point would be reached when the continued use of the TRS did not achieve any significant reduction in dose rate.

PRE-WORKS

The pre-works consisted of the following:

- Installation of a new ventilation system (NVS). The existing system could not be adequately maintained due to the high radiation levels and therefore was not capable of maintaining the flow rates required;
- Replacement of the maintenance corridor shield plug with a sliding shield door;
- Construction of a shielded maintenance bay (MB). This was constructed in order to maintain the TRS in the event of failure and to provide a 'low' radiation background environment for storage of the TRS when not in use. A low background storage environment was key in prolonging the life of the TRS as it reduced the level of radiation damage. In turn this reduces operator dose as less frequent maintenance / repair operations are undertaken;
- A specialised Waste Posting Facility (WPF) to allow the waste (which was packaged in 2.2 litre 'paint cans') to be measured for activity assessment and removed from the facility into heavily shielded flasks;
- A containment around the entire facility including the area where operators would be working. The purpose of this was to prevent / limit the spread of any contamination thus not affecting adjacent operational facilities.

The predominant activities involving personnel exposure were NVS and shield door installation. The dose rate at the connection point of the NVS to the facility was 2 Svh^{-1}. It involved removing a posting port shield plug and connecting a vent pipe onto the aperture. The radiation emanating from the aperture was collimated and the vent system was mounted on a mobile framework containing lead shielding. The shielding reduced the general area dose rates during the installation process and also during operations. However physical connection of the pipe to the port could only be done manually which meant that the operators hands/arms would be exposed to very high dose rates. To minimise the operator's exposure extended tooling was used and a 'mock up' of the NVS – connection system was constructed so that the operator was able to practice the connection technique. This optimised the method and therefore minimised the time taken to carry out this operation and the dose received. The dose estimates were 1.5 mSv whole body and 10 mSv extremity. Actual dose received was 138 µSv whole body and 2 mSv extremity.

The installation of the new shield door was carried out to enable access to the corridor by the TRS. This involved removing the shield plug whilst at the same time sliding the shield door into position. The main concern here was not the exposure of the operators (as they were able to stand out of the way of the radiation beam), but to personnel outside and in nearby buildings. Therefore to reduce the risk of public exposure this operation was carried out in silent hours and traffic management employed to ensure no one entered the projected beam path.

In summary the estimated dose for all pre-work operations was 9.5 manmSv. Actual collective dose received was 5.5 manmSv.

REMOTE PHASE

This phase of decommissioning focused on the use of the TRS to:

- Remove all the debris;
- Cut up and dispose of all the boxes;
- Decontaminate all accessible surfaces using vacuum and scabbling techniques;
- Carry out radiation monitoring as required.

Also included within this phase was the removal of the TRS in order for the manual phase to start.

The control desk was situated ~ 3 m from the front of the shielded cells. The dose rate in this area averaged 2.5 μSvh^{-1}. Space restrictions meant that the desk could not be located further away nor was it practicable to provide a shielded enclosure. Thus from merely operating the TRS an individual could expect to receive ~ 5mSv a year. The issues with respect to personnel doses were those factors which lead to an increase in the ambient radiation levels, an increase in the time taken to complete the project, and the number of TRS maintenance operations that had to be carried out.

For this phase of the work the original estimated collective dose was 35 manmSv. Actual dose received was 132 manmSv. Subsequent reviews during operations meant that this final figure did not come as a surprise. The predominant reason for the increased exposure was that the duration of the project increased from the 11 months originally planned to 4 years. The main reasons for the increase in time were:

- The amount of activity present in the facility was 8 times higher than originally stated. Radiation surveys using the TRS also showed levels ~ 3 times higher than given in the original survey. Although this did not affect the volume of waste produced it did give rise to higher than anticipated dose rates from the shielded waste packages dispatched from the Waste Posting Facility;
- The TRS was not very efficient at cutting up boxes etc when compared to a person carrying out similar operations. The TRS performed adequately when the piece being cut was firmly fixed to the facility structure etc, but loose pieces could not be held firmly enough such that cutting speed had to be reduced.
- Maintenance Bay general area dose rates were restricted to 1 $mSvh^{-1}$. This meant that the TRS was switched from decommissioning operations to MB decontamination operations whenever the radiation levels exceeded this threshold. This was not an infrequent occurrence especially as the activity inventory was much higher than anticipated, and thus significantly contributed to the extended project duration. This restriction was a condition of the Safety Case, as it would be a mistake to allow contamination to build up to such an extent that we risked not being able to maintain the TRS;
- Problems with the TRS itself mainly revolved around the umbilical cable. Due to the space restrictions a cable drum of the appropriate diameter could not be used to feed and withdraw the umbilical as the TRS moved up and down the maintenance corridor. A ‘concertina’ arrangement was employed such that the cable was neatly folded back in on itself when ‘stored’. Although successful as a means of storing and withdrawing the umbilical as required, the folds in the cable always occurred at the same points. This lead to cumulative stress weaknesses that resulted in cable failures.
- Build-up of contamination on the NVS filters lead to an increase in ambient radiation levels in spite of filter shielding having been installed. The NVS had a pre-filter which was located within the facility and two main filters external to the facility which were heavily shielded. It transpired that the pre-filter had to be changed on a frequent basis. This was done using the TRS and therefore extended the project duration as it was involved in maintenance activities rather than decommissioning. A contact dose rate change threshold of 500 μSvh^{-1} was placed on the external filters. This was done to keep ambient working area dose rates down to those levels measured during the planning stages of the project.
- Discovery of a transfer tunnel between this facility and the adjacent operational facility at the box 1 location i.e. it spanned the maintenance corridor thus blocking access for the TRS. This had to be removed and the hole through the concrete dividing wall into the adjacent facility sealed. This was a significant unplanned operation leading to an increase in the project duration;
- The need to undertake more extensive de-contamination of the concrete plinths as the contamination had penetrated deeper into the concrete than anticipated.

It was apparent that although the TRS was the only practicable method for dealing with the waste, and that there were TRS failures which meant operators entering the MB to facilitate repairs, it was the low ambient dose rate coupled with the time taken in completing this project that was the major contributor to personnel doses. A way of reducing the time had to be found. It was also anticipated that an umbilical cable replacement operation would have to be carried out within the year. It was estimated that this would ‘cost’ ~10 manmSv.

It was decided to re-furbish the cell-face tongs so that they could be used in assisting the TRS. Although the existing gaiters had perished the fitting of new external gaiters enabled them to be used without ‘pumping’ contamination into the work area. It was also a relatively quick operation such that extremity doses for the pre-works and remote phases were less than 35 mSv. Refurbishing and using the tongs was so successful that it reduced the anticipated project duration by 6 months. The anticipated dose saving was 5 manmSv. If the dose to the umbilical replacement operation is included then this dose saving increases to 15 manmSv. However operators working at the cell face were exposed to higher dose rates than just working at the TRS control desk alone. Collective doses received during this stage of operations was ~ 4 manmSv giving a net potential dose saving of 11 manmSv.

In hindsight had this approach been taken earlier on then the dose savings would have been greater.

TRS REMOVAL

As already indicated it was not felt prudent to specify a dose rate threshold at which the project would enter the manual phase of operations. However a point was reached where all visible debris had been removed, all the cell boxes had been size reduced and removed, vacuuming of all accessible surfaces had been carried out, and scabbling of concrete surfaces where contamination had penetrated had taken place. The ambient dose rates in the maintenance corridor were 1 - 3 $mSvh^{-1}$. Further scabbling and vacuuming was not having any significant effect on reducing this dose rate further. The operating area ambient dose rates were still at the same level therefore it was then decided that it was not ALARP to continue use of the TRS but to move into the manual phase of this project.

Before this could be completed the TRS had to be removed from the facility. Prior to its removal it was used to gain more information to help plan the manual phase operations. This essentially consisted of the following:

- A gamma radiation survey in order to locate the remaining contamination and radiation hotspots;
- The TRS was then used to place lead shielding over the predominant hotspots. This reduced localised radiation levels but did not have any significant effect on the ambient radiation dose rates within the maintenance corridor.

Having completed all TRS operations it was withdrawn into the maintenance bay for manual decontamination and removal. As maintenance operations throughout the project kept the general dose rates to below 1$mSvh^{-1}$ the lead wall forming part of the MB was taken down to half its height. The MB was lined internally on one side with Perspex which had glove/tong ports built in. Although general area dose rates were < 1 $mSvh^{-1}$ there were contact dose rates in excess of 10 $mSvh^{-1}$ on the floor and other locations within the MB. All accessible surfaces were cleaned using vacuum equipment however little success was gained in reducing the ambient levels by removal of hotspots.

Finally a manual entry was made where it was possible to vacuum the entire MB floor which reduced the dose rates to ~ 0.5 $mSvh^{-1}$. However it was not until the umbilical, cable engine and ancillary components were removed that dose rates dropped to < 100 μSvh^{-1}.

MANUAL PHASE

Project Endpoints

During the planning for the manual phase it became apparent that the initial radiological endpoint of 40 $Bqcm^{-2}$ fixed contamination was unlikely to be achieved. Therefore it was agreed with the client that the following would be more appropriate:

- Non fixed contamination levels when averaged over 1000 cm^2 would not exceed 4 $Bqcm^{-2}$;
- Fixed contamination levels when averaged over 1000 cm^2 would not exceed 40 $Bqcm^{-2}$;
- Airborne contamination levels would not exceed 0.05 DAC;
- Gamma radiation levels at 10 cm from any surface would not exceed 2.5 μSvh^{-1}.

It was also agreed that if during the course of the project the conditions were such that it was not reasonably practicable to achieve the above then a further review with the client would take place.

Operations Planning

Given the information yielded by the gamma radiation survey and the experience gained in the TRS removal it was strongly felt that an initial manual entry would be sufficient to dramatically reduce the ambient dose rates in the corridor. This was because it would be possible for powerful vacuum equipment to be applied in areas inaccessible by the TRS and in a more aggressive manner than the TRS itself could have employed. Before this was done the work area had to be modified to allow manual entry i.e. a modular containment system ‘tunnel’ was attached to the MB. A contamination control change barrier was installed with sufficient room on the ‘dirty’ side for monitoring, decontamination, and undress operations. Operators entered the area wearing a compressed airline fed suit and two layers of disposable plastic ‘oversuits’.

Air sampling within the facility was carried out by fitting a sample head to a tube which was in turn fed through a penetration to a sample pump. Analysis showed that airborne levels were many 1000’s of DAC’s (~ 10^6 Bqm^{-3}

^{137}Cs), and that damp smears taken over an area ~ $1m^2$ had $mSvh^{-1}$ dose rates in contact with them. It was decided not to take many air or smear samples as this created source storage and disposal issues.

Operators were already being routinely Whole Body Monitored to assess internal doses. External doses were assessed as already described with the addition of a remote tele-dosimetry system. Each operator was issued with a PID that enabled dose and dose rate to be displayed as well as transmitted to a control desk. It was therefore possible to obtain a continual update of operator doses as it was being received. Although the operators themselves could see the information on the dosemeters they were wearing this was not easy and affected the efficiency of the tasks they were trying to carry out. The operations controller not only monitored air supply and operator condition, but was also able to monitor their doses. If an operator was picking up dose at a higher rate than his colleague the controller was able to instruct them to swap tasks thus ensuring that no one person received significantly more dose than his colleagues. It was also easy to monitor dose uptake with work progress such that if the dose being received on a particular task was significantly greater than anticipated then operations could be stopped while a review took place. This ranged from a complete cessation of operations i.e. operators withdrew from the facility and undressed, to a partial cessation where operators moved to a low dose rate area while the task was discussed with the project engineer and radiation protection adviser. An example of this was where grit blasting operations did not reduce dose rates in cell 7 as expected. The operation was suspended and the operator advised to change tooling. This had no affect and therefore operations ceased completely and a review carried out. In the end the steel lining plate had to be size reduced and removed as discussed later.

It was at this point that a gamma camera became available and was deployed by opening the shield door and a view along the corridor was obtained. This helped to confirm the radiation survey previously carried out by the TRS.

Operations Performed

The initial entry took 30 minutes to complete. In that time ambient maintenance corridor dose rates were reduced from 1- 3 $mSvh^{-1}$ to < 0.5 $mSvh^{-1}$. The collective dose received by the operators was 0.8 manmSv.

During the manual phase the following operations were carried out:

- Vacuuming of all surfaces;
- Removal of fittings (e.g. lights), floor coverings, and any other removable items serving as contamination traps;
- Scabbling of concrete surfaces;
- Grit blasting;
- Size reduction and removal of steel lining plates that were laid on top of the concrete plinths that supported each cell box. It was not possible for the TRS to size reduce these due to their thickness (25 mm). Size reduction was carried out by ‘stitch drilling’ each plate into handleable sizes. Instead of using the operator to manually drill each hole it was possible to set up the drill (Rotabroach) such that once started, the operator could retire to a low dose rate area until it had finished. Given the number of holes that had to be drilled this turned out to be quite an effective dose reduction technique, and was also less stressful for the pressurised suit operator.

Once the above had been carried out a gamma camera was again utilised and set up to view each cell area as well as the maintenance corridor. This was quicker and incurred less dose to the operator than a manual survey using collimated radiation probes. As a result of the camera’s ability to visualise the remaining contamination it was used after every entry to determine the success of the operations carried out and assisted in planning the following day’s activities.

Again in hindsight if the Gamma Camera had also been used on the MB during TRS removal operations, it would have been possible to see the areas of contamination requiring removal. This would have lead to the decision to make a manual entry much earlier. This in turn would have reduced the time operators spent standing by a half shielded Perspex wall.

As operations continued the dose rates continued to fall until ambient levels of between 50 – 100 μSvh^{-1} were reached.

Revision of Radiological Endpoints

It became apparent that the original endpoints would not be achievable without significant further scabbling due to the extensive migration of ^{137}Cs into the concrete . This was estimated to take several months and the dose penalty would be significant (~ 150 manmSv). A further consideration was that continued scabbling would compromise the structural integrity of this facility and adjacent operational facilities. Therefore the endpoints were revised where there was no alteration to the non fixed and airborne contamination requirements, but the fixed contamination and surface radiation endpoints were replaced by a single requirement to reduce the ambient radiation levels to less than 7.5 μSvh^{-1} i.e. reduce the regulatory radiological designation from Controlled to a Supervised area, and to reduce hotspot dose rates at 5 cm to 30 μSvh^{-1} or less. The client agreed in that final removal of all contamination was best left until the adjacent operational facilities were to be decommissioned as at this stage more aggressive methods could be employed.

Final Operations

The approach adopted was to have a final attempt at contamination removal followed by a sealing in of any remaining contamination. In conjunction with this shielding would be applied (e.g. successive layers of 2mm thick lead sheets) to 'hotspot' areas in order to meet the dose rate endpoints.

The method employed for the final decontamination stage was three applications of a strippable coating to all surfaces followed by a single removal of the coating by peeling it away from the surface thus bringing the contamination with it. Depending upon the surface this achieved up to a factor of 10 reduction in remaining contamination levels i.e. rough surfaces gave the best results as the coating was able to penetrate into the surface matrix and 'grip' the contamination such that when the coating was lifted it was removed. For smooth surfaces it was less effective as any easily removable contamination had already been lifted using the techniques already employed. It was felt that there was little to be gained by repeating this operation as it was likely that any contamination not removed initially by this process would not be removed by a second attempt. Remaining contamination was therefore sealed in by application of two tie down coatings.

Operations carried out to complete the project were:

- Place shielding around the remaining 7 hotspots;
- Removal of the Waste Posting Facility;
- Dismantle the lead shielding covering the maintenance bay and the cell faces. The major hazard was trapped contamination between each lead brick and so operations were closely controlled using ventilated PVC tenting and vacuuming of every brick;
- Dismantling of the containment system installed during the pre-works.

As indicated the predominant hazard to personnel was the liberation of trapped contamination. However the problem of low ambient radiation levels remained, but was now restricted to close proximity to the cell face rather than over the entire work area. It was also now apparent that when working in the MB a significant source of the ambient radiation level was due to shine from the adjacent operational facility. The only practicable dose reduction measure here was to complete operations as soon as possible and to continue to eliminate unnecessary / non productive time spent in the area.

Final Conditions

The final radiological conditions achieved were:

- Non fixed surface contamination levels were < 0.13 $Bqcm^{-2}$ and averaged 0.006 $Bqcm^{-2}$;
- Maximum airborne contamination detected over an 8 hour period whilst work was in progress was $3.6x10^{-5}$ DAC;
- General radiation levels of 6.9 μSvh^{-1} with a maximum in one area of 13 μSvh^{-1}. Maximum contact dose rate was 35 μSvh^{-1} with the average being 17 μSvh^{-1}.

Manual Phase Doses

For this phase of the work the original estimated collective dose was 28 manmSv. Actual dose received was 55 manmSv. Again the continual monitoring and reviews taking place during this phase meant that the final figure, although approximately twice the original estimate, was anticipated and justifiable. As indicated above, even

though the initial dose reduction operations in this phase were successful, the predominant reason for the dose increase was the time taken to remove contamination that had migrated much deeper into the concrete than expected i.e. scabbling depths reached 100 mm in places.

SUMMARY OF DOSES RECEIVED AND DOSE REDUCTION METHODS

Over the four operational years that it took to complete this project a total of ~150 TBq of ^{137}Cs had been removed and contact dose rates reduced by a factor of 10^6. The total whole body collective dose received was 187 manmSv. Average whole body dose in a year was less than 4.5 mSv with a maximum of 5.09 mSv being recorded by a single individual.

Extremity collective doses over the same period was 188 manmSv with the average being 18 mSv and the maximum recorded in a single year was 35 mSv.

Whole Body Monitoring showed that although ^{137}Cs intakes had occurred the levels were such that dose assessments were not deemed necessary by the Approved Dosimetry Service i.e. < 0.1% of the ALI.

The predominant dose reduction measures employed were:

- Plant mock up and practice of technique;
- Use of a Tele-Robotic System;
- Refurbishment of facility remote handling equipment (tongs) to aid the TRS;
- Shielding of filter housings;
- Frequent filter changes;
- Use of Gamma Cameras;
- Use of tele-dosimetry;
- Quick, short duration manual vacuuming;
- Strippable coatings.

Given all the above, the importance of operator training and supervision needs to be stressed. There were occasions where experienced operators prolonged their time in low – medium dose rate areas and had to be reminded to move out of the area. There were instances where trained but inexperienced personnel became contaminated through not appreciating likely contamination traps and undress / monitoring procedures.

CONCLUSION

This project is typical of many decommissioning projects where the initial plan has to undergo significant modification to deal with the reality of the conditions encountered. Although the basic strategy of TRS operations was unchanged, the events that transpired re-enforces the fact that continual monitoring and feedback are required. It also needs to be documented such that this process is demonstrable. Therefore even though the initial dose budgets for this project were exceeded by significant margins, this documentation process has allowed us to demonstrate to the client, and to the regulator, that the actual doses incurred in achieving the final project objectives were justified.

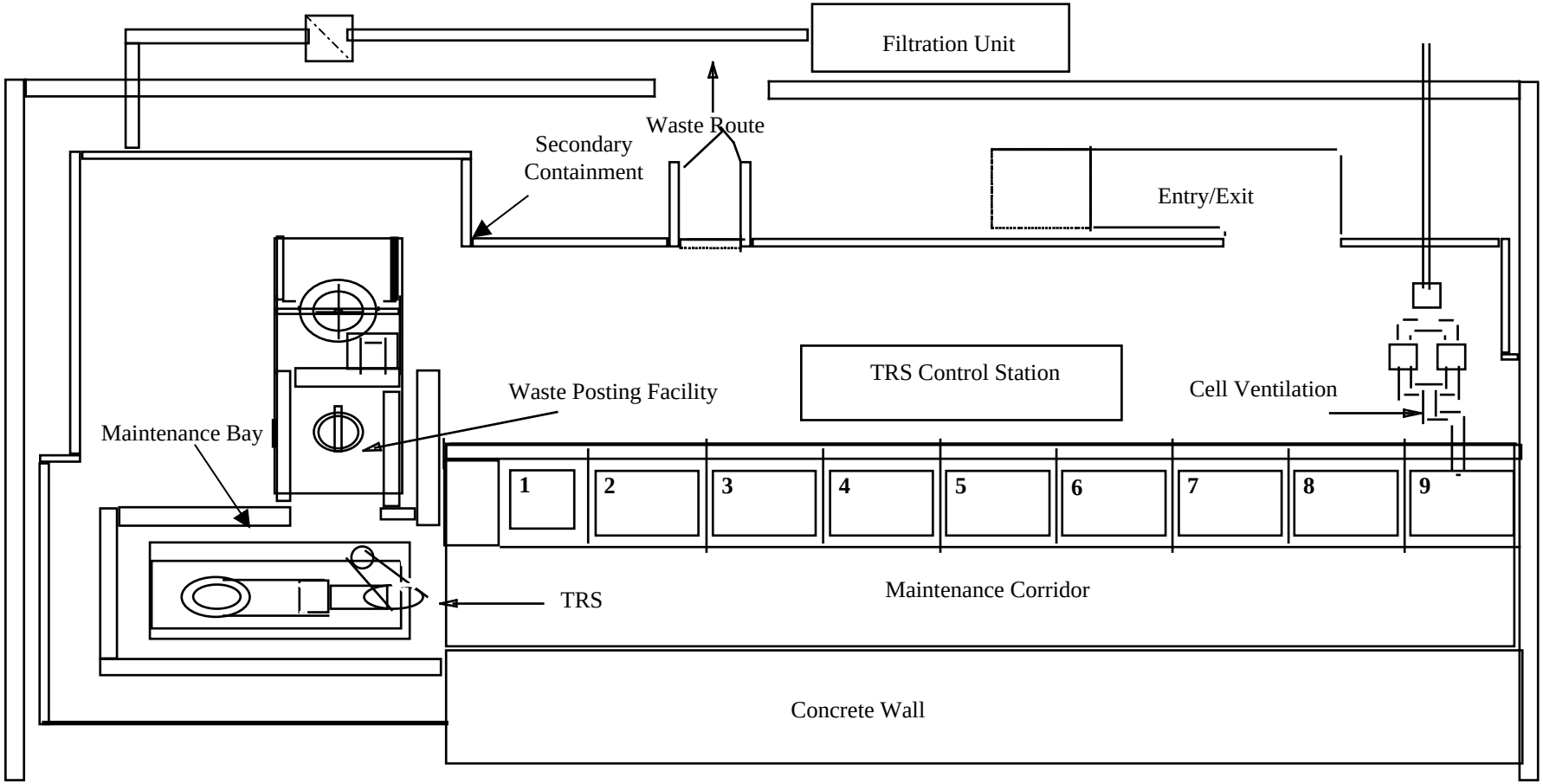

Figure 1 Plan of the facility during the robotic decommissioning phase