Innovative Approach to the Management of Waste Arising from the Decommissioning of a Redundant Plutonium Processing Facility – 17081

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ABSTRACT

There are a number of redundant plutonium processing facilities located at Sellafield, in the North West of England within the United Kingdom (UK).

Over past decades several decommissioning strategies have been deployed to clean up these redundant facilities. Whilst there have been many successes previously reported, there remain many challenges. Some of these challenges have recently been addressed through a new approach which introduces a number of innovations.

The new approach seeks to significantly reduce risks to both decommissioning personnel and the environment by minimising the extent of physical ‘hands on’ decommissioning activities and by simplifying the waste production process.

A large bagless transfer system has been engineered to allow the transfer of whole gloveboxes into crates. This leads to a significant reduction in hazardous ‘hands on’ work in a highly contaminated environment. The crates are consigned directly to interim storage on the Sellafield site.

These hazard minimisation activities have only been made possible through the development and implementation of a new approach to criticality safety assessment.

This new approach has recently completed active commissioning with the first waste being safely exported in June 2016.

INTRODUCTION

Located in the North West of England, within the United Kingdom, the Sellafield site comprises a range of facilities associated with the nuclear fuel cycle. These facilities include reactors, reactor fuel manufacture, irradiated fuel storage, irradiated fuel reprocessing and the storage of irradiated fuel reprocessing by-products. Many of the Sellafield site facilities were designed and commissioned during the 1950s/60s and are no longer in operation.

Amongst the facilities, there are a number associated with plutonium processing. Some of these were dismantled during the 1950s/60s in order to enable upgraded facilities to be installed. Small items of dismantled equipment were drummed, and larger pieces of equipment were placed into storage crates. These waste materials, referred to as Plutonium Contaminated Materials (PCM), were placed in storage awaiting the development of PCM waste treatment and disposal routes. During this time many hundreds of PCM crates were accumulated, as well as several tens of thousands of 200 litre (55 US gallon) drums of PCM waste.

During the 1970s/80s business plans were developed to fund the provision of PCM waste treatment and disposal routes. This work culminated in the provision of the Waste Treatment Complex (WTC), commissioned in the 1990s. 200 litre (55 US gallon) raw waste drums are fed into WTC which are then high force super-compacted into ‘pucks’ and cement grout encapsulated, typically 5 or 6 at a time, within a 500 litre (132 US gallon) stainless steel drum [1].

At the same time (late 1980s), a separate Decommissioning business unit was established to undertake the necessary investment to enable redundant facilities to be decommissioned and their hazards removed. During the 1980s and 1990s a variety of projects were instigated to develop decommissioning techniques and demonstrate their effectiveness across a wide range of plutonium contaminated facility environments.

A key constraint to the decommissioning techniques being developed during this period was the need to produce a waste form compatible with WTC. As a result, decommissioning technique development focussed on methods for size reducing waste items to dimensions suitable to fit within a 200 litre (55 US gallon) drum. A variety of techniques were developed ranging from simple manual cold cutting techniques to remote specialist cutting and waste handling methods.

The decommissioning techniques developed were successful to varying degrees. By the late 1990s/early 2000s it was found, by the ongoing plutonium decommissioning projects, that the use of largely ‘hands on’ techniques was the most successful (i.e. reliable and predictable) approach.

However, during the 2000s, a small number of incidents occurred where decommissioning personnel received radiation exposure, providing a clear reminder of the dangers associated with ‘hands on’ plutonium decommissioning activities.

As a result, existing safety management arrangements were reassessed and a more conservative approach was adopted for selecting decommissioning techniques which minimised decommissioning workers hazards exposure. It is within this context that it was determined that a new approach would be taken to the completion of an ongoing plutonium facility decommissioning project.

Finishing Line Decommissioning Project

Early Progress

The Finishing Line was operated from the 1960s to 1980s following which it was subject to limited Post Operational Clean Out (POCO). The line comprised a range of process stages, within 16 glove boxes, which received and converted plutonium chemical solutions (Fig. 1). Throughout the period of its operation, the area housing the Finishing Line facilities had become highly contaminated (>2.4×10^5 Bq/cm^2 loose alpha surface contamination widespread) such that it had become a C5[1] cell with all work within it conducted in air fed suits.

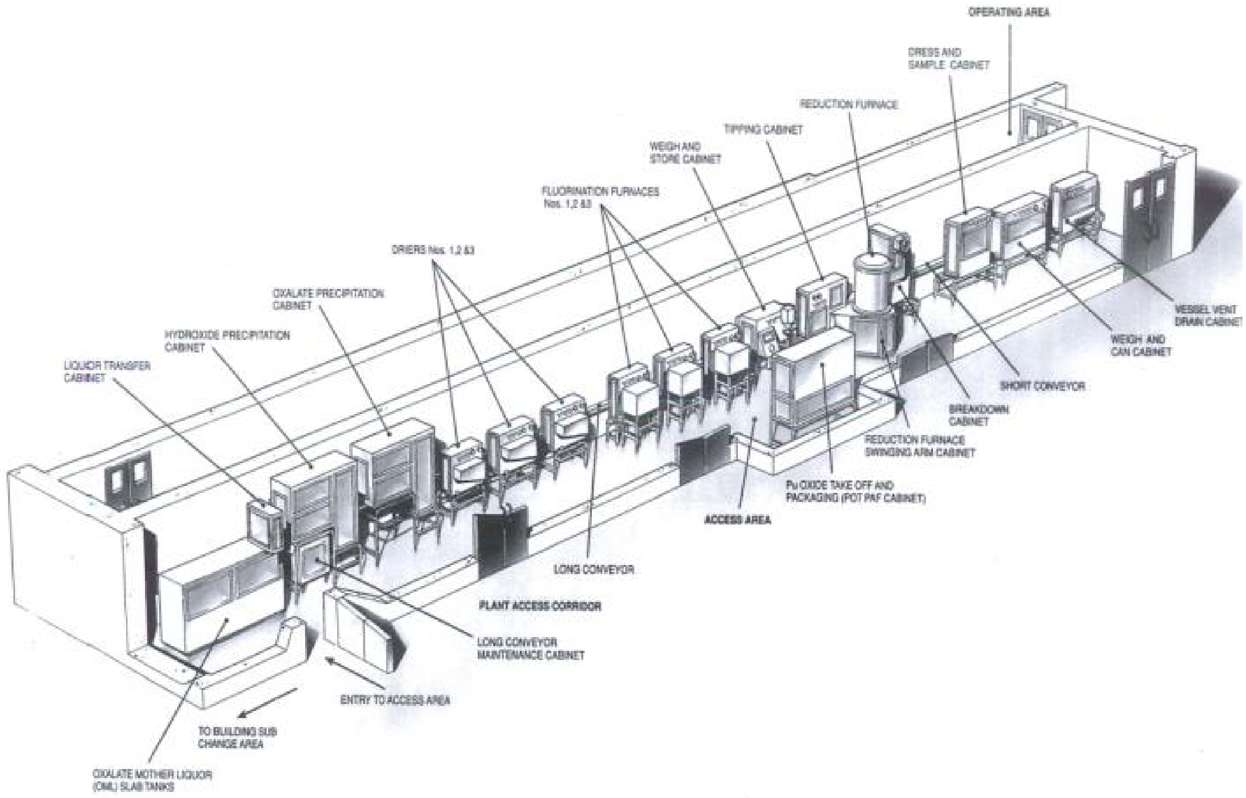

Fig. 1 – Layout of Finishing Line prior to decommissioning

In the early 1990s the Finishing Line Decommissioning Project was established: the project was split between decommissioning the ‘dry’ end of the facility first (10

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[1] *C’n’ is the designation system used at Sellafield to indicate areas of differing contamination levels and can range from C0 to C5 (lowest to highest)*

gloveboxes), before moving on to the ‘wet’ end (6 gloveboxes). This staged approach reflected the need to address different challenges between the ‘dry’ and ‘wet’ ends and also enabled learning from the early ‘dry’ end work to be built into the later approaches.

The approach to the ‘dry’ end was to disconnect and transfer whole gloveboxes (containing their plant and equipment) to a newly constructed central size reduction area within the Finishing Line facility. There, the gloveboxes would be size reduced to drum sized pieces using manually deployed plasma (and other) cutting techniques.

This work was progressed well between 1996 and the mid-2000s, with 7 gloveboxes (out of the 16) being decommissioned before the project was paused due to revised priorities.

New Approach

In order to complete decommissioning of the remaining 9 gloveboxes, and following the decision to adopt a new approach to the Finishing Line Decommissioning Project, a detailed optioneering process was undertaken involving a wide group of stakeholders. The purpose of this optioneering was to identify and understand the various constraints that influenced the approach to be selected.

This review identified that the previous approach (intensive ‘hands on’ size reduction) was dominated by the driver to place waste into 200 litre (55 US gallon) drums.

It was recognised that the highly contaminated working environment surrounding the Finishing Line facilities meant that there was only limited opportunity to eliminate, reduce or control radiological hazards whilst undertaking the decommissioning activities. As a consequence, the optioneering identified that a two stage approach should be considered: (1) removing and containing the remaining glovebox suite in large pieces (so far as physical dimensions would practically allow) and (2) transferring the contained glovebox pieces to storage to await treatment in future facilities designed specifically for their treatment.

In order to implement such an approach, new equipment would be required to enable the large glovebox pieces to be retrieved from within the C5 cell and transferred to portable containers without loss of containment. Additionally, a new approach to assessing criticality safety would need to be taken.

The principle of such a two stage approach was accepted by the Waste Management Department (responsible for PCM waste storage and treatment). An initial concern was that receiving crated waste that did not have a final treatment or disposal route was not appropriate. However, when this was considered against the constraints faced by the decommissioning workers within the Finishing Line environment and, also, the fact that there were already some 600+ crated large PCM waste items in storage awaiting future treatment, the addition of the 20-30 crates produced from the Finishing Line was judged not be significant and, as such, this approach was considered ALARP (As Low As Reasonably Practicable). It would also be the case that the Finishing Line crates would be very well characterised (compared to earlier PCM crates) reducing the scope of further work to support their future treatment and disposal.

Development of 'Whole Glovebox' Removal Technology

In order to realise the aim of minimal size reduction, a number of systems were designed to allow gloveboxes to be exported in as complete a state as possible. These systems were:

- Handling frame (Fig. 2) to allow lifting of gloveboxes using existing features
- Trolleys to allow movement of whole gloveboxes (or large parts thereof) through the facility
- Export facility (Fig. 3), forming the C5 containment boundary, to allow bagless transfer of gloveboxes without breaking containment
- Crate liner (Fig. 3), docking directly onto the export facility, to receive items posted out from the C5 cell area and allow transfer through the building
- Outer crate container allowing safe transport and storage of the package. This was later removed from the process (see 'Simplification of Crate Arrangements' below).

Fig. 2 – Trial of cabinet handling frame

The crate export facility (Fig. 3) provides a large bagless transfer system (door size 1.2m x 1.5m approx) and incorporates a series of interlocks to prevent the door to the C5 cell being opened without a crate liner present. The design, in conjunction with the docking procedure, ensures that only a small, decontaminable area (0.1m² approx) is exposed to both C5 and C2 environments.

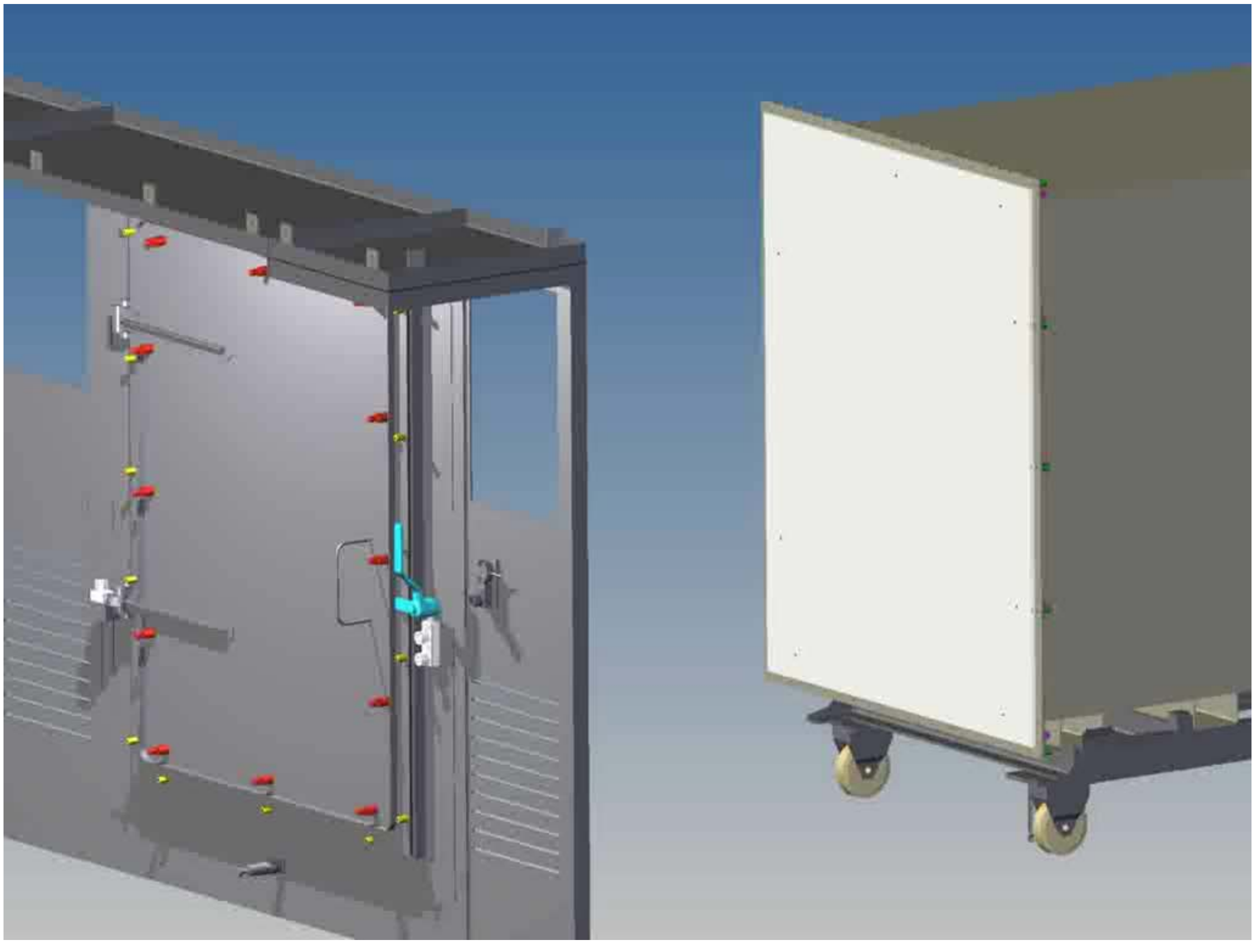

Fig. 3 – Schematic of crate export facility and crate liner

The crate liner was made as large as possible whilst still being able to fit through the building. This meant that the first 6 (of the remaining 9) gloveboxes would be able to be exported whole; the last 3 would require varying degrees of size reduction as they were much larger. Fig. 4 shows the movement of the glovebox through the facility and onward to waste stores.

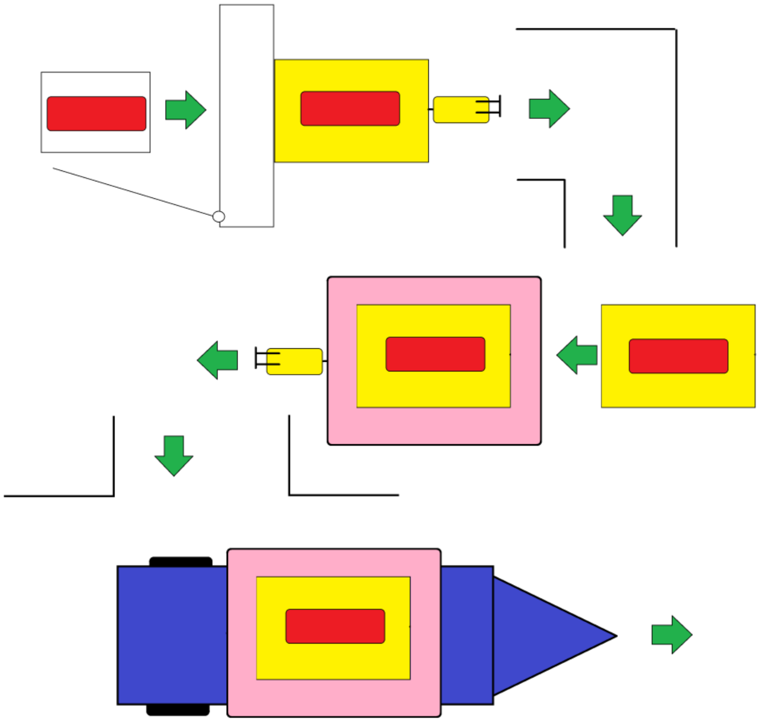

Fig. 4 – Movement of a glovebox from C5 cell to waste stores

In Fig. 4, the isolated glovebox (red) is moved on a trolley within the C5 cell area to the export facility at the C5/C2 boundary and placed into a crate liner (yellow). A powered tug is used to move the liner through the building. The liner is loaded into an outer crate container (pink) using a forklift. The outer crate container is moved outside the building boundary and loaded via forklift onto a bespoke road trailer (blue) for onward transport to waste stores.

Many items of equipment, such as the handling frame, required a precise knowledge of glovebox parameters which was not available from existing documentation. A laser survey of Finishing Line was therefore undertaken to capture all dimensional information with the minimum of ‘hands on’ intervention.

With support from the supply chain, development of size reduction equipment was undertaken with both diamond wire and plasma cutting tools (Fig. 5) being developed. This equipment was designed so that it would operate on ‘semi-remote’ principles, i.e. the item could be set up by an operator who would then retire to a safe distance while the operation was carried out. This option provides much of the benefit of fully remote technology at a fraction of the cost and lead time.

Fig. 5 – Trials of semi-remote plasma cutting system (R)

Criticality Safety

A significant obstacle to the removal of whole gloveboxes is the demonstration of criticality safety. For large items of installed plant, the traditional approach taken at Sellafield has been to use in-situ portable neutron and gamma measurement equipment to estimate the inventory of fissile material present.

The physically constrained space and restricted access within the Finishing Line facility, together with the highly contaminated working environment, would make the deployment of such equipment particularly challenging and likely to lead to large pessimistic uncertainties for the measured values. These pessimisms would lead to the requirement for more extensive size reduction than would be required from dimensional constraints alone.

It was therefore decided that the use of an alternative approach should be investigated, referred to as the 'Low Criticality Risk' method. If successful, adoption of this method would remove the need for the use of measurement equipment to estimate fissile inventory.

Development of Low Criticality Risk Methodology

Fissile mass has traditionally been used to determine the criticality risk for PCM waste items as this is measurable using assay. This has led to a three tier classification (Low, Intermediate and High) for PCM waste items at the Sellafield site.

Depending on how a PCM Waste item is classified affects how it is handled, transported and stored. Specifically, the classification defines spacing requirements and whether or not PCM Waste items may be stacked during storage.

Fissile mass is only one of a number of parameters that affect the behaviour of a fissile system and generally provides only a crude indication of criticality risk. A result of only using fissile mass data is that a bounding approach is usually taken in the assessment of criticality risk. In this case, the other parameters relevant to criticality, such as moderators, reflectors, neutron absorbers, geometry, density, enrichment and physical form, are assumed to be at, or close to, optimised values. In reality the combination of the optimised conditions corresponding to the minimum critical mass is highly unlikely within a PCM waste item. In the absence of these highly optimised conditions, the fissile mass required for criticality increases sharply.

A PCM Waste item can be classified as having 'Low Criticality Risk' if it can be demonstrated that it will not present an unacceptable risk of criticality, even under large deviations of the factors that are relevant to criticality control from the conditions that are judged to exist or potentially arise within the actual PCM Waste item being considered.

The practical consequences of classifying a PCM Waste item as having a 'Low Criticality Risk' are that (1) no Criticality Incident Detection system will be required during transportation or storage, and (2) that only the normal handling, transport and storage spacing requirements for a 'Low' classification PCM Waste item will apply.

To support the implementation of the ‘Low Criticality Risk’ method a systematic procedural approach was developed. This provides step-by-step guidelines to both those wishing to apply the method and provides a framework for the criticality assessors responsible for confirming that the ‘Low Criticality Risk’ method had been correctly implemented.

As a departure from the traditional approach to criticality assessment, the ‘Low Criticality Risk’ method was subject to independent review within the criticality assessment capability prior to being approved for implementation through the management safety arrangements of both the Decommissioning and Waste Management Departments. The revised approach was recognised as having a major benefit for future plutonium facility decommissioning challenges.

Table I illustrates part of the step-by-step guidelines used to gather information to aid characterising the Finishing Line Gloveboxes as ‘Low Criticality Risk’.

TABLE I – Information gathering steps for ‘Low Criticality Risk’ methodology

Options for Gathering Characterisation Information	
a)	Information concerning any materials processed by this equipment during plant operations along with typical inventories and/or flowsheet values.
b)	Details of operations undertaken to clean out gloveboxes etc.
c)	Any equipment history, if relevant. For example, known leaks within a glovebox or cell, any powder spillages, any clean-up operations undertaken within a glovebox, etc.
d)	Have any process items already been removed from the plant?
e)	Photographs and/or drawings of item(s).
f)	Use of criticality computer modelling techniques.
g)	Non-destructive radiographic/radiometric techniques (for example X-Ray, liquor detection, other techniques)
h)	Radiation survey.
i)	Intrusive survey/sampling.

Options a) to f) inclusive were all used in the ‘Low Criticality Risk’ justification for the first of the Finishing Line gloveboxes.

Once the Finishing Line glovebox had been disconnected and removed from its station and final accessible residue recovered, the package of characterisation information was reviewed. The review was carried out by representatives of the decommissioning project team, the Decommissioning Department criticality assessor and the Waste Management Department criticality assessor. The review confirmed that the package of characterisation information was adequate to underpin the justification that this Finishing Line glovebox was a ‘Low Criticality Risk’. Once it had been assigned this classification, PCM operating procedures allowed it to be handled and stored no differently to a traditional ‘Low’ PCM waste item.

Learning from Initial Progress

Commissioning of the new equipment and procedures was completed during late 2015, and following receipt of regulatory permission, active commissioning commenced in 2016 with the first crated glove box removed from Finishing Line and transferred to PCM storage in June 2016.

Two particular areas of learning arose from these initial commissioning stages:

Simplification of Crate Containment Arrangements

The original crate containment design allowed for the use of an initial 'liner' container into which the gloveboxes would be retrieved from the C5 cell. Once loaded, this liner would be placed into an outer crate container.

During finalisation and approval of the planned waste receipt and storage arrangements it was realised that the inner liner could, by itself, provide satisfactory containment for future waste storage. Fig. 6 illustrates the improved arrangement.

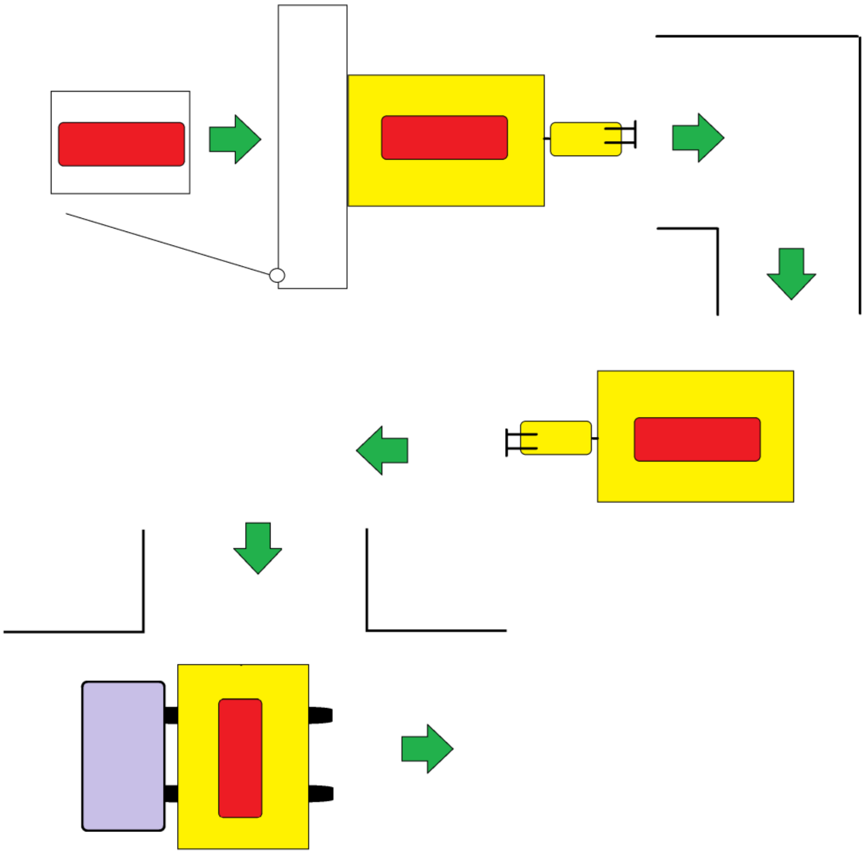

Fig. 6 – Revised package movement scheme following outer crate container elimination (see Fig. 4 for color key)

Rather than an outer crate container and bespoke road trailer (see Fig. 4), the revised approach uses a forklift to collect the package at the building boundary and transfer it to a standard PCM waste transport vehicle.

Although making this change to the containment approach required additional design substantiation and safety assessment work, the benefits were much-simplified waste handling and a substantial cost saving in terms of removing the capital cost of the outer crate containers and the bespoke road trailer.

More importantly, removing the outer container substantially reduced the size of the waste package, so reducing the demand for storage capacity and also the volume of waste that would need to be managed when the crate was treated in the future.

Control of Contamination on Crate Sealing Face

During export of the first crate, more contamination than expected was detected on the seal faces of the crate liner adjacent to the export facility. This was cleaned down but a small amount of fixed contamination remained.

It is believed that this contamination had migrated from the C5 cell due to a number of factors:

- Length of time the crate liner had been docked (approx. 8 months)
- Number of door opening/closing operations that had been performed (several in support of commissioning)
- Force applied to the seal boundary by operators positioning items in the crate liner (items had been placed in and then retrieved in support of commissioning)

It was considered that these factors were unique to the commissioning environment; ordinarily a crate liner would be docked for a matter of hours and the door only opened and closed once. Nonetheless, to prevent recurrence of the contamination issue, a number of improvements were made both to the equipment and the export process.

Additionally the contaminated seal face on the first liner was covered with a bespoke metal overpack which used existing features to create a secondary seal.

CONCLUSION

A revised approach has been developed for the decommissioning of the Finishing Line facility, with the first whole glovebox recently successfully removed.

The revised approach minimises the requirement for intensive ‘hands on’ techniques, so significantly reducing the dangers to the decommissioning personnel involved.

The application of the ‘Low Criticality Risk’ method has demonstrated that a simpler and less pessimistic approach to managing criticality safety can be successfully used, with the resulting crated gloveboxes being very well characterised and with their remaining fissile inventory hazard minimised.

This approach will make their future treatment considerably simpler than the other crated PCM wastes already in storage.

REFERENCES

[1] PCM Treatment and Storage, Sellafield Ltd, http://www.sellafieldsites.com/solution/risk-hazard-reduction/pcm-treatment-and-storage/, accessed 07 November 2016.