Changing the Rules on Fuel Export at Sellafield's First Fuel Storage Pond -12065

Derek Carlisle, Sellafield Ltd, Sellafield, Cumbria , UK

ABSTRACT

The Pile Fuel Storage Pond (PFSP) was built in 1949/50 to receive, store and de-can fuel and isotopes from the Windscale Piles. Following closure of the Piles in 1957, plant operations were scaled down until fuel processing eventually ceased in 1962. The facility has held an inventory of metal fuel both from the Piles and from other programmes since that time. The pond is currently undergoing remediation and removal of the fuel is a key step in that process, unfortunately the fuel export infrastructure on the plant is no longer functional and due to the size and limited lifting capability, the plant is not compatible with today's large volume heavy export flasks.

The baseline scheme for the plant is to package fuel into a small capacity flask and transfer it to another facility for treatment and repackaging into a flask compatible with other facilities on site. Due to programme priorities the repackaging facility is not available to do this work for several years causing a delay to the work. In an effort accelerate the programme the Metal Fuel Pilot Project (MFPP) was initiated to challenge the norms for fuel transfer and develop a new methodology for transferring the fuel.

In developing a transfer scheme the team had to overcome challenges associated with unknown fuel condition, transfers outside of bulk containment, pyrophoricity and oxidisation hazards as well as developing remote control and recovery systems for equipment not designed for this purpose. A combination of novel engineering and enhanced operational controls were developed which resulted in the successful export of the first fuel to leave the Pile Fuel Storage Pond in over 40 years. The learning from the pilot project is now being considered by the main project team to see how the new methodology can be applied to the full inventory of the pond.

INTRODUCTION

The Pile Fuel Storage Pond (PFSP) at Sellafield was built and commissioned between the late 1940s and early 1950s as a storage and cooling facility for irradiated fuel and isotopes from the two Windscale Pile reactors. The pond was linked via submerged water ducts to each reactor, where fuel and isotopes were discharged into skips for transfer along the duct to the pond. In the pond the fuel was cooled then decanned underwater prior to export for reprocessing. [1]

The plant operated successfully until it was taken out of operation in 1962 when the First Magnox Fuel Storage Pond took over fuel storage and decanning operations on the site. The pond was then used for storage of miscellaneous Intermediate Level Waste (ILW) and fuel from the UK's Nuclear Programme for which no defined disposal route was available. By the mid 1970s the import of waste ceased and the plant, with its inventory, was placed into a passive care and maintenance regime.

By the mid 1990s, driven by the age of the facility and concern over the potential challenge to dispose of the various wastes and fuels being stored, the plant operator initiated a programme of work to remediate the facility. This programme is split into a number of key phases targeted at sustained reduction in the hazard associated with the pond, these include:

Pond Preparation

Before any remediation work could start the condition of the pond had to be transformed from a passive store to a plant capable of complex retrieval operations. This work included plant and equipment upgrades, removal of redundant structures and the provision of a effluent treatment plant for removing particulate and dissolved activity from the pond water.

Canned Fuel Retrieval

Removal of canned fuel, including oxide and carbide fuels, is the highest priority within the programme. Handling and export equipment required to remove the canned fuel from the pond has been provided and treatment routes developed utilising existing site facilities to allow the fuel to be reprocessed or conditioned for long term storage.

Sludge Retrieval

In excess of 300 m^3 of sludge has accumulated in the pond over many years and is made up of debris arising from fuel and metallic corrosion, wind blown debris and bio-organic materials.

The Sludge Retrieval Project has provided the equipment necessary to retrieve the sludge, including skip washer and tipper machines for clearing sludge from the pond skips, equipment for clearing sludge from the pond floor and bays, along with an ‘in pond’ corral for interim storage of retrieved sludge.

Two further projects are providing new plant processing routes, which will initially store and eventually passivate the sludge.

Metal Fuel Retrieval

Metal Fuel from early Windscale Pile operations and various other sources is stored within the pond; the fuel varies considerably in both form and condition. A retrieval project is planned which will provide fuel handling, conditioning, sentencing and export equipment required to remove the metal fuel from the pond for export to on site facilities for interim storage and disposal.

Solid Waste Retrieval

A final retrieval project will provide methods for handling, retrieval, packaging and export of the remaining solid Intermediate Level Waste within the pond. This includes residual metal fuel pieces, fuel cladding (Magnox, aluminium and zircaloy), isotope cartridges, reactor furniture, and miscellaneous activated and contaminated items. Each of the waste streams requires conditioning to allow it to be and disposed of via one of the site treatment plants.

Pond Dewatering and Dismantling

Delivery of the above projects will allow operations to progressively remove the radiological inventory, thereby reducing the hazard/risk posed by the plant. This will then allow subsequent dewatering of the pond and dismantling of the structure.

A graphical illustration the programme structure is shown in figure 1.

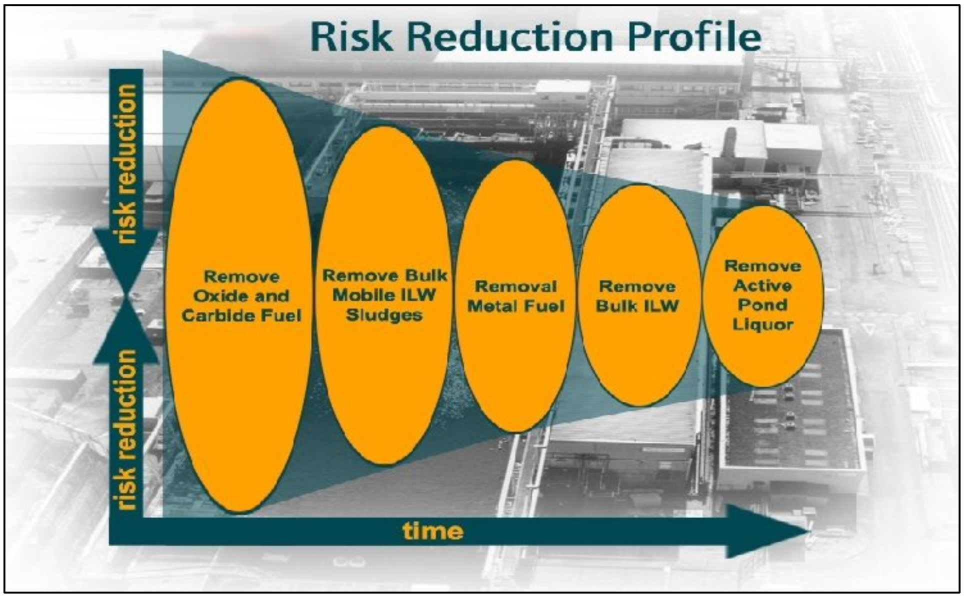

Figure 1. Graphical Representation of PFSP Remediation Strategy

Significant progress has been made in delivery of this strategy with retrieval and treatment capability brought into service for the canned fuel and sludge streams, the programme therefore switched attention to the metal fuel stream.

The facility has held an inventory of metal fuel both from the early operations of the Windscale Piles and from other programmes since operations ceased in 1962. The removal of the fuel is a key step in the remediation process, unfortunately the fuel export infrastructure on the plant is no longer functional and due to the size and limited lifting capability in the plant, it is incompatible with today’s large volume heavy export flasks.

The baseline scheme for the plant is to package fuel into a small capacity flask and transfer it to another facility for treatment and repackaging into a flask compatible with other facilities on site. However, due to programme priorities, the repackaging facility is not available to do this work for several years causing a delay to the work.

In an effort to avoid this delay the Programme Manager challenged a small team to look for a way to export fuel without using the intermediate plant and hence challenge the normal practices associated with fuel export from the plant. From this challenge the Metal Fuel Pilot Project (MFPP) was born.

METAL FUEL PILOT PROJECT

The Metal Fuel Pilot Project was specifically set up to challenge the norms associated with how fuel is transferred both within and between plants on the Sellafield Site. By doing this the project would develop a scheme to transfer metal fuel directly from Pile Fuel Storage Pond to the Sellafield Site Fuel Handling Plant (FHP) without utilising intermediate plants. To do this novel methods would have to be found to provide the functionality usually provided by the intermediate plant, namely inspection, conditioning and repackaging of the fuel.

The baseline scheme for export of metal fuel from the pond was to load a 12t flask underwater in the pond; this flask can be handled by the PFSP building crane. The 12t flask would then be transferred to a fuel inspection facility where the fuel would be inspected and conditioned, within concrete containment cells, before being transferred into a skip suitable for storage at the Fuel Handling Plant (FHP). This skip would then be transferred to FHP in a 50t standard fuel transport flask, which is compatible with the receipt equipment at that plant.

As the modifications required to allow either the donor or receipt plant to receive a direct transfer using only the 12t or 50t fuel flask were prohibitively complex, the project took on the challenge of loading the 50t fuel flask at PFSP without the protection offered by underwater flask loading and transfer. To do this the fuel would have to be inspected and conditioned for export within the pond itself before being consolidated and transported through the plant without the use of the massively shielded flasks or concrete cells usually associated with such work.

To enable the transfer a number of challenges had to be addressed, this included unknown condition of the fuel, reliability of inventory data, development of remote operations capability for normal plant equipment, dose control and the development of a safety case based upon enhanced operator control rather than engineered protection. But perhaps the biggest challenge faced by the project was to break down the resistance to changes from the norm for this type of work, and to build confidence that the plant could carry out this type of work to exemplary standards.

Fuel condition, handling and sentencing

The metal fuel stored within the pond had not been handled for over 40 years and while inventory records from the 1950s, 60s and 70s were available little evidence to corroborate the accuracy of the records existed. From the known sources and age of the fuel it could be inferred that it was likely that activity levels would could make the desired export methodology tolerable. However, many of the hazard management strategies were dependant on both this data being underpinned and the condition of the fuel being acceptable; this was also essential allow robust inventory management at the receipt plant.

The only other data available to confirm inventory records and make any judgement on fuel condition was from remote camera surveys of the material but these were badly limited in detail due to the thick layer of pond sludge also present within the fuel skips.

Figure 2. Typical images from fuel skip surveys

These limitations in the inventory characterisation meant that before the fuel could be exported each piece had to be washed, picked up, identified and inspected prior to being placed in a purpose built export skip in which the fuel would be transferred to FHP.

The first step in this process was to identify skips within the pond most likely to contain fuel suitable for export, this was done by review of the historic records [2]. Favourable skips were then washed in the skip washer provided as part of the sludge retrieval project to remove the sludge from the fuel. The skip wash machine uses a hydraulic suspension process to clear sludge from the skips and collect it in an ‘in pond’ corral. This process removed most of the sludge from the fuel and allowed the plant operators to identify and pick up the individual fuel bars before transferring them to a sorting table; however, in some cases additional cycles of skip washing was required to clear sludge from boxes and other internal containers.. This identification and sorting operation had to be achieved deep under the surface of the pond utilising cameras and long handled tools. To increase the difficulty of the task, very little experience of handling or identifying this fuel was available due to its age, and there was significant uncertainty about whether the physical condition of the fuel would have deteriorated to such an extent it could not be handled.

Significant effort was invested to provide guidance to the plant operators to allow them to identify fuel within the skips utilising in pond cameras; using this guidance the team was able to identify and segregate the fuel from the other pond inventory. Detailed inspection of the fuel on the sorting table found it to be in remarkably good condition with very little evidence of corrosion. The status of the fuel inventory was also found to be reasonably consistent with the archive records and radiation data from the fuel was also generally consistent with the expected levels. This data substantiated the assumptions made in developing the export methodology and confirmed the fuel was suitable for export.

Figure 3. Fuel on the sorting table

Once retrieved and sentenced by the operators the fuel identification and consolidation data was extensively peer reviewed both inside and outside of the programme for acceptability. This data became the basis for control of inventory transfer as the project proceeded.

Hazard identification, assessment and safety case development.

From its earliest inception the MFPP was intended to challenge the norms for retrievals projects delivery in general and safety case generation in particular. A traditional approach to the project would have required the development of engineered protection systems for all of the hazards associated with the work. Given the scale of the likely modifications required to achieve this, the opportunity to accelerate metal fuel export would be lost if this approach was taken. The project team were therefore challenged to develop a safety case base upon enhanced operational controls rather than engineering protection. After some initial consideration the team concluded that it should be possible to export an unshielded skip of fuel directly from the pond to a prepared transport flask.

The first significant hurdle in doing this was to gain agreement to the radiological justification for the work, known as the ALARP (As Low as Reasonably Practicable) Case. As a nuclear plant operator there is a need to prove that any work undertaken follows the principles of ALARP i.e. risks and dose is managed to be As Low as Reasonably Practicable. While it is clearly important that the pond is emptied, it was difficult to prove that there is any significant additional risk in holding the fuel in the pond until the baseline route became available. Therefore, if the accelerated route has a higher risk than the baseline route, it is not clear that the ALARP principle is met. The breakthrough for the project came when the ALARP case was widened to include the benefits to the programme overall both in terms of potentially releasing other work and in exploring novel ways of progressing decommissioning work. Once these benefits were clearly stated it became clear that if the project could demonstrate the risk from the work were relatively low the case could be made.

The two key hazards associated with the work were identified as radiation dose to the operator performing the transfer, and the potential dose uptake due to fuel fire or rapid oxidisation, that was associated with a number of fault scenarios [3]. The first of these hazards could clearly be managed using the principles of enhanced operators controls, through the provision of remote operating stations, good human factors based training and strictly enforced exclusion zones. The applicability of operator controls to the second hazard was less clear.

Initial technical work ruled out the possibility of a fuel fire; however a number of fault sequences were identified which could lead to the rapid oxidisation event particularly during fuel transfer. [4] When the team analysed these events it became clear that there is no strong body of evidence supporting either the progression of the fault or the potential consequences. The team considered that it was highly likely that due to this lack of evidence it was possible that many of the traditional assessment methods were highly pessimistic. The project team therefore began to try and underpin a more realistic assessment to support the ALARP case. As this work developed it became evident that significant, time consuming, research and development work would be necessary. Pursuing this strategy therefore did not align with the project strategy as, in addition to the time required to develop a new understanding, the team concluded that attempting to build a new type of safety case based upon new underpinning data was probably unrealistic.

The project went back to the key drivers for the project which were to open up a new route out of the building and concluded that the objective could be met by using a traditional approach with some pragmatic creative application. Utilising the previous approach to fault progression and consequence assessment the team defined the maximum transfer inventory which would ensure that even in the worst case the consequences to the public would be negligible. This meant that provided dose to the worker was managed the principles of the ALARP case could be met. While this decision meant that the skip would not be fully loaded on the transfer, the inventory would still be significant, the route would be proven and fuel could be consolidated into the skip at later date in the receipt plant. On this basis a safety case based on restricted inventory and enhanced controls was generated and approved by the plant regulators.

Plant preparation

The scheme for exporting the fuel was to take the skip loaded with fuel out of the pond, using the 12t crane controlled from a remote location. The skip would then be lowered down the building hoistwell into a cuboid fuel flask parked in a prepared area. The cuboid flask would then be remotely lidded using the 12t crane after which personnel would allowed to enter the area, secure the lid and monitor the flask.

The first task was to modify the building to accept the flask. The increase in flask sizes since the PFSP last operated meant that, as well as the flask being beyond the capacity of the building crane, the hoistwell was also not large enough to accept the flask trailer. A series of civil modifications to demolish an internal blockwork wall and alter escape and access routes were undertaken to allow the trailer to be parked in the hoistwell and position the flask on the centreline of the skip export route. Further work was required to physically protect the building structure during delivery of the flask, this was essential to avoid new fault conditions on the plant.

Figure 4. Flask delivery to PFSP

The next series of modifications were aimed at upgrading the plant 12t crane to make it suitable for remote operation. The crane is a standard overhead travelling crane which is normally operated by a local pendant and maintaining a line of sight to the load. For the Metal Fuel Pilot Project the key safety principle for managing dose to the operator would be to operate the crane from a remote location. In order to allow remote operation the operator was provided with a remote operating station with an extensive camera system to allow the operator a full range of views of the transit route for the skip; a range of guides and dowels were also provided to help locate the skip and lid.

Along with preparing the plant for remote operation systems also had to be implemented to recover the crane and load in the event of a crane failure. This was more of a challenge as the crane was designed on the basis that it would be carrying inventory in shielded flasks and in the event of a breakdown the maintainer would be able to get onto the crane and affect a repair. This maintenance philosophy is clearly not appropriate if an unshielded load were to be suspended from the crane. The solution to the problem was the provision of remote long travel recovery system based on simple wire rope winches which could be used to pull back a failed crane from a remote location. A shielded location was also provided, from which the hoist brake could be lifted and the load lowered off. These simple systems could then be used to recover a suspended load to either the pond or the flask in the event of a crane failure.

The final series of modifications was the removal of handrails and other obstructions from the transit path for the skip to make the transfer as simple as possible. Figure 5 shows the plant prepared for transfer including the 12t crane and part of the camera system.

Figure 5. Plant ready for transfer

Team preparation

The final and most important element of the preparation work was ensuring the team were ready to execute the transfer. As the safety case for the work was based on enhanced operational controls, it was essential that the operators understood the constraints they were working in and could demonstrate high levels of competence. A programme of training, operational and emergency rehearsals, readiness reviews and inspections was planned out and executed for the work.

The first stage in building operator confidence was to enable a series of trial runs of the skip export operation, to do this the project provided a recently refurbished fuel flask which was free from contamination and could be left open for long periods and an identical fuel skip to the one to be used for fuel export. Multiple repetitions of the flask de-liding, skip loading and flask liding operations were carried out and adjustment of the cameras, crane markers and other operator aids made until the operation could be carried out with a high level of consistency. The same approach was then followed for the emergency arrangements with extensive rehearsal of dropped load, crane breakdown and misaligned load scenarios.

Figure 6. Dummy skip during transfer trials

These operations were documented in detailed method statements and emergency instructions which defined how the operations were to be carried out and provided a link back to the safety case for the work.

Once the operations team were confident they were ready to carry out the transfer a series of readiness reviews and inspections were carried for both by internal and external assurance and regulatory bodies. Once complete the plant was declared ready to export the fuel.

Active transfer

On 24th September 2011 the first skip of fuel was exported from PFSP for 47 years; the operation to transfer the fuel from the pond to the flask and to lid the flask was carried out without incident and took just 67 minutes and the fuel was transferred to the receipt plant two days later. The fuel is now securely stored in the more modern containment of the Sellafield Site Fuel Handling Plant where it will remain until a final disposal route for fuel is agreed for the site.

CONCLUSIONS

The Metal Fuel Pilot Project has succeeded in meeting its headline objective of undertaking the first fuel export from the plant in over 40 years, however more importantly it has challenged the “rules” for fuel handling and waste retrievals on the Sellafield Site. The development and implementation of a safety case based on enhanced operational controls rather than engineered protection enabled the project to get to the point of retrieving material much more quickly than would have normally been expected.

For the PFSP plant in particular the pilot project has opened up another export route from the plant to the massively shielded flasks normally used on site. In turn this opens up options for not only future fuel exports but also for some of the Intermediate Level Waste inventory also held in the pond. The learning from the pilot project is now being considered by the main project team and it is possible that a large proportion of the remaining metal fuel inventory will be exported in a similar way.

REFERENCES

1. Carlisle, D (2010) Decommissioning Sellafield’s First Fuel Storage Pond - WM2010 Conference, Phoenix, AZ, March 7 - 11, 2010, 10070
2. Payne, P (1998). An Assessment of the PFSP Metal Fuel Inventory, PG/REP/X0060, Technical Report, Sellafield Ltd (Not Published)
3. Sewell,P (2011), Metal Fuel Pilot Project (MFPP): Preparation for Export and Export of Magnox Skip, RP_LPSERP-015_SAFE_00027, Technical Report, Sellafield Ltd (Not Published)
4. Jackson, W (2011). PFSP MFPP Pyrophoric Material Hazard management Strategy, RP_LPSERP-015_PROC_00011, Technical Report, Sellafield Ltd (Not Published)

GLOSSARY

ALARP	As Low As Reasonably Practicable
FHP	Fuel Handling Plant
PFSP	Pile Fuel Storage Pond
MFPP	Metal Fuel Pilot Project