Accelerating the Decommissioning of the Sellafield Pile Fuel Storage Pond Using Innovative Remote Tooling Developed with the Supply Chain -16437

David Birks*, Thomas Lacey*, James Cruickshank**, Mark Donnelly**
Shannon Callahan ***
*Sellafield Ltd, Sellafield, Cumbria, UK
** James Fisher Nuclear Ltd, Unit 14, Bridge End Industrial Estate, Egremont, UK
*** James Fisher Technologies Ltd, Longmont, CO 80505, USA

ABSTRACT

The Pile Fuel Storage Pond (PFSP) at Sellafield and adjoining decanning building provided the storage, cooling and decanning facility for used fuel and isotopes from the two Windscale reactors and later some Magnox fuel from the Calder Hall reactors. Operations ceased in the 1970s and the facilities are now undergoing a programme of accelerated decommissioning. The pond is a sub-divided outdoor storage pond containing skips of irradiated fuel and miscellaneous waste items and the building contains a series of sub-ponds, known as bays, connected underwater to the main pond. The radiation environment and access limitations necessitate the use of remote technology for the decommissioning programme.

This paper describes the philosophy and approach and the technology and equipment adopted for the removal and export of key plant equipment and waste items from within the PFSP. In order to progress the project cost effectively and speedily, the Sellafield project team looked for partners in the supply chain with the required experience, expertise and facilities to supply and test "commercial off-the-shelf" (COTS) or modified proprietary equipment. This COTS approach minimised the need for multiple, expensive and lengthy design and manufacturing tasks associated with bespoke equipment. Sellafield partnered with specialist remote handling contractor, James Fisher Nuclear, and the respective project teams worked closely together at every stage of the project from qualifying requirements, identifying potential solutions, through to development, testing, training and final deployment. Optioneering of potential solutions involved early "proof of principle" trials in JFN rig hall facilities, utilising existing equipment and plant mock-ups, along with other equipment manufactured in-house. Together the project teams selected the best solution to take forward, adopting a practical and trials based approach, which allowed rapid and cost effective modification of the solution throughout the project with minimal impact on the programme. When the final solution was validated, plant operators then gained familiarity and training on the equipment so they could execute the work efficiently on plant and so minimise their dose uptake.

The removal of a Large Decanner is described in detail. This was a significant obstruction to the emptying, modification and re-use of the bay and a key milestone in the clean-up of the PFSP. The decanners are large and heavy pieces of equipment which weigh 6.5t each and approximately 6.5m long. Their removal was further complicated by limited equipment and man access, radiological contamination from decanning fuel, challenging material properties, unknown equipment condition and complex lifting requirements. Sellafield Ltd and JFN project teams worked closely together to rapidly develop, trial and deploy a succession of adapted "commercial off-the-shelf" (COTS) tools whilst addressing emerging challenges and completing the overall task on time and budget. The Sellafield and JFN project and design teams provided an underwater: wheel stop removal tool; towing trolley; grinder on a carbon fibre pole, chute cutting 600mm circular saw and hydraulic 6t winch. The suite of tools will be reused on the remaining decanners in the PFSP and First Generation Magnox Fuel Storage Pond (FGMSP) giving cost and programme savings. Each of the tools can also be used, and some have already been, for other tasks in the bay retrievals such as the size reduction of support frames, large steel sections and chemical decanner preparatory works. The "learning from experience" acquired during the project was shared by the Sellafield project with other decommissioning projects across the site.

INTRODUCTION

The Pile Fuel Storage Pond (PFSP) and adjoining decanning building provided the storage, cooling and decanning facility for used fuel and isotopes from the two Windscale reactors and later some Magnox fuel from the Calder Hall reactors. Operations ceased in the 1970s and the facilities are now undergoing a programme of accelerated decommissioning. The pond is a sub-divided outdoor storage pond containing skips of irradiated fuel and miscellaneous waste items and the building contains a series of sub-ponds, known as bays, connected underwater to the main pond. [1]

Decommissioning of the PFSP facility requires the retrieval and export of a variety of canned and metal fuels, ILW sludge and ILW/LLW solids. Work on the removal of fuels from the pond is largely completed, with all fuel expected to be exported by early 2016. ILW sludge is currently being cleared from the pond and bay floors and a new drum filling and export facility is in the final stages of build, with sludge exports due to commence in early 2016. The ILW solid wastes, in the form of residual fuel pieces; fuel cladding; isotope cartridges; and miscellaneous activated items, are currently being characterised and consolidated, primarily using a fleet of Remotely Operated Underwater Vehicles, but also using other retrievals equipment and methods. Within the decanning building there are 12 bays containing a variety of experimental and production equipment that was used when the facility was originally operational. A large amount of this equipment has already been removed as LLW, with some of the more challenging items which are all located underwater still remaining.

At the onset of the decanning building retrievals work it was recognised that each item of equipment to be removed from the bays would present its own challenges. The building and available infrastructure itself provided many physical constraints to removing the equipment. Also, the various items of equipment to be removed came in many shapes and forms, and in some cases the locations of the equipment within the bays restricted access to the work face or prohibited access for lifting using the available overhead cranes. The decommissioning challenges presented by the PFSP have been described in a previous WM conference paper. [2]

The project identified that a range of tooling and techniques would need to be provided to enable the equipment to be safely removed. To achieve the accelerated timescales for decommissioning the facility, a new philosophy and approach was required. In order to progress the project cost effectively and speedily, the Sellafield project team looked for partners in the supply chain with the required experience, expertise and facilities to supply and test "commercial off-the-shelf" (COTS) or modified proprietary equipment. This COTS approach minimised the need for multiple, expensive and lengthy design and manufacturing tasks associated with bespoke equipment. Sellafield partnered with specialist remote handling contractor, James Fisher Nuclear (JFN), and the respective project teams worked closely together at every stage of the project from qualifying requirements, identifying potential solutions, through to development, testing, training and final deployment. Optioneering of potential solutions often involved early "proof of principle" trials in the JFN rig hall facilities, utilising existing equipment and plant mock-ups, along with other equipment manufactured in-house. Together the project teams selected the best solution to take forward, adopting a practical and trials based approach, which allowed rapid and cost effective modification of the solution throughout the project with minimal impact on the programme. When the final solution was validated, plant operators then gained familiarity and training on the equipment so they could execute the work efficiently on plant and so minimise their dose uptake.

This approach was aligned to the Sellafield Ltd company strategic objectives in that it supports the accelerated risk and hazard reduction of the PFSP which is one of the oldest nuclear facilities on site. This was achieved by the use of innovative, fit-for-purpose technical methods and management practices that balanced the risks of necessary retrieval operations with the longer term risk of inaction or delayed retrievals. It also made best use of supply chain partners; using the right company and people, with the skills, knowledge and abilities to achieve the required end result.

Twenty-four months into this working arrangement, Sellafield Ltd and JFN have successfully developed numerous items of equipment that have been deployed on plant to support the retrieval of equipment from both the pond and the bays. One of the tasks was the removal of a Large Decanner weighing 6.5t and approximately

6.5m long. This required the development of various items of cutting equipment to disconnect and free the decanner from its support framework and equipment to laterally move the decanner within reach of overhead cranage to allow deployment of a specialist machine to cut the decanner in half, and also for lifting and export of the two cut sections. Fig. 1 below illustrates the original position of the large decanner on its support framework. During removal operations, unexpected conditions were encountered which had not been detailed in the original design drawings from 60 years ago, or observed from the more recent SONAR and underwater camera surveys that had been carried out. These unexpected conditions meant that the removal methods needed to be reviewed and in some cases additional retrievals equipment was identified that had to be quickly developed to ensure the overall task was completed on time. Having successfully completed the export of the Large Decanner in July 2015, work has commenced on retrieving a further decanner from the PFSP. The same equipment, methods and learning will also be considered for removal of similar decanners from the Sellafield First Generation Magnox Storage Pond.

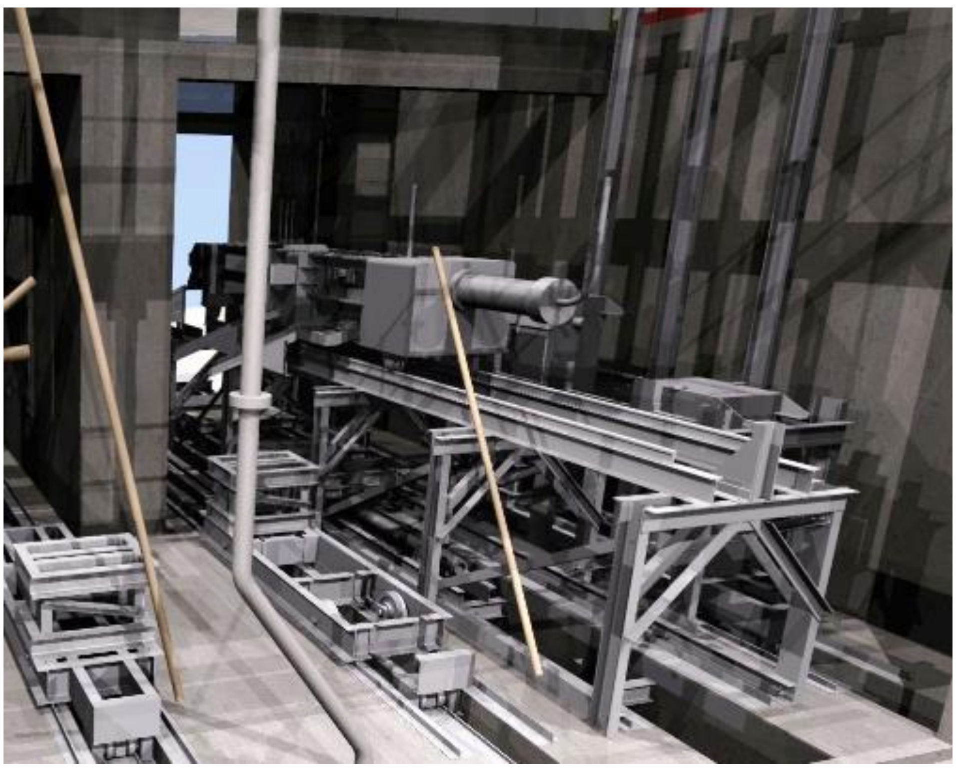


Fig. 1. Large Decanner

The following Case Study describes in detail the joint development work for the tooling for removal of the decanners.

CASE STUDY

Initially, Sellafield Ltd approached JFN to devise a method of traversing the large decanner along its rails into the Decanner Bay, such that size reduction operations of the decanner could be undertaken. This case study outlines the collaborative approach taken by Sellafield Ltd and JFN to develop various solutions to achieve this goal of transferring the decanner. This includes the engineering challenges encountered along the way, and how these were resolved efficiently to enable repositioning of the decanner in the most timely and cost effective manner. The case study focuses on the main tooling developed for this task, which includes:

- Wheel Block Removal Tool
- Decanner Puller
- Long Reach Grinder Tool
- Towing Trolley
- Hydraulic Winch

A strategy employed throughout the project was to utilise Commercial Off The Shelf (COTS) equipment where possible in order to help minimise design time and costs, and to enable working solutions to be trialled and developed at the early stages of concept design. This case study shall demonstrate how this was achieved, with the range of tooling developed within short timeframes, to enable the decanner to be traversed along its rails ready for size reduction operations.

Wheel Block Removal Tool

The original task for this project was to develop a tool capable of removing the South wheel block from the decanner rail. This wheel block had been identified by Sellafield Ltd through camera inspections, and it was highlighted that this obstruction needed to be removed before the decanner could be traversed along its rails. The wheel block is a steel clamp secured to the rails, located adjacent to the wheel of the decanner, as illustrated in Fig. 2.

In order to remove this wheel block, Sellafield Ltd considered a previously supplied tool by JFN that could be operated underwater and was capable of cutting through steel. The tool comprised an off-the-shelf hydraulic reciprocating saw secured to a bespoke mounting bracket that could be remotely deployed and operated. It was suggested that this proven design be utilised for the basis of the wheel block removal tool.

Working together, Sellafield Ltd and JFN developed the tool through designing the bespoke bracket to which the COTS saw would be mounted. The bracket incorporated a hydraulic clamp to enable the tool to be secured to the decanner rail frame, providing a stable position for the reciprocating saw to pivot through the wheel block. The saw was pivoted using a wire rope attached to a manual hoist via a pulley arrangement, thus enabling control of the saw movement remotely. The Wheel Block Removal Tool design is illustrated in Fig. 3.

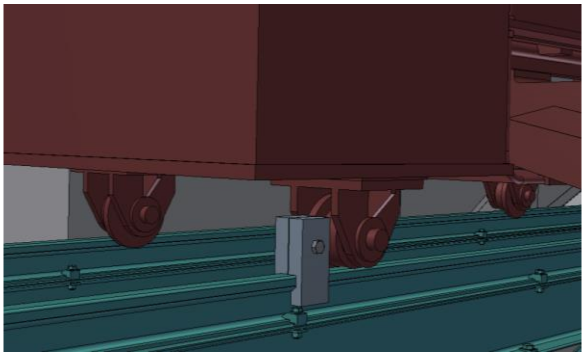


Fig. 2. Decanner Wheel Block

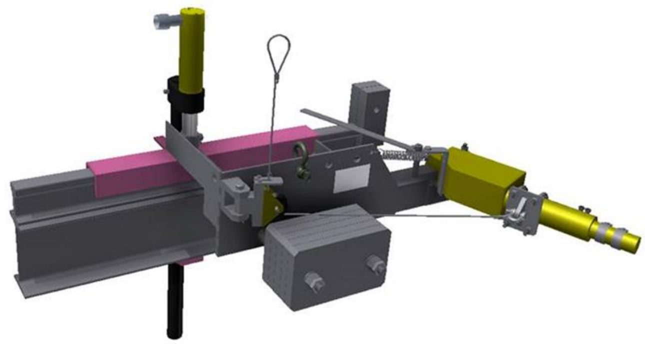


Fig. 3. Wheel Block Removal Tool

Since the tool was based on proven, off-the-shelf equipment, there was little doubt that the saw would function as intended; however, in order to ensure the equipment could be deployed and operated remotely, trials were conducted to prove the equipment was fit for purpose.

For the trials, a mock-up test rig was constructed based on the dimensions from the early drawings and subsequent 3D model. This mock-up included replica decanner rails to which a representative wheel block was secured. A wooden framework of the South end of the decanner was fixed to the decanner rail frame in order to replicate the spatial restrictions of the on-site decanner, as shown in Fig. 4.

Fig. 4. Wheel Block Removal Tool Trial

Fig. 5. Wheel Block Removal in PFSP

The trials were conducted at JFN's Rig Hall facility in Egremont, Cumbria. As this is in close proximity to the Sellafield site, the operators were able to attend and assist with the trials, which was considered invaluable in developing their experience of the equipment in a non-active environment prior to conducting operations on-site. The trials covered the tool deployment, cutting operation and removal of the tool, providing confidence to the team that the equipment would complete the task, with the operators being familiar with all phases of operation. Following the trials, the equipment was delivered to site and used successfully to cut through the South wheel block to detach it from the decanner rail frame. Fig. 5 shows the tool being used underwater within the Sellafield Pile Fuel Storage Pond to remove this wheel block from the rail.

Decanner Puller

Having removed the South wheel block, the next step was to develop a device that would enable the decanner to be traversed along its support rails. Working closely with the Sellafield Ltd engineering team, and after reviewing 3D CAD models and underwater video footage and images, JFN produced an initial conceptual design for a pulley system, as shown in Fig. 6. By using a manual chain hoist suspended from the building crane hook that could connect to the decanner via a wire rope and pulley system, it would be possible to raise the manual hoist to pull the decanner horizontally into the bay. To achieve this, the pulley system would need to be positioned near the bay side wall and an attachment point would need to be identified on the decanner in order to pull the machine into the bay.

With this concept in mind, JFN reviewed the 3D model of the bay and developed a suitable design that would integrate with the decanner and surrounding structure. The system used a pulley wheel attached to a hook that could be deployed into the bay and secured to the decanner rail support frame, which acted as a fixed pulling point. A puller frame was proposed that would be deployed onto a secure and stable position on the decanner. A steel rope attached to the puller frame, was routed around the pulley wheel, and connected to a manual hoist suspended from the building crane hook via a load cell. The intention being that by raising the manual chain hoist the steel cable would become tensioned, pulling the decanner. The load applied could thus be monitored on the load cell to ensure the Working Load Limit (WLL) would not be exceeded.

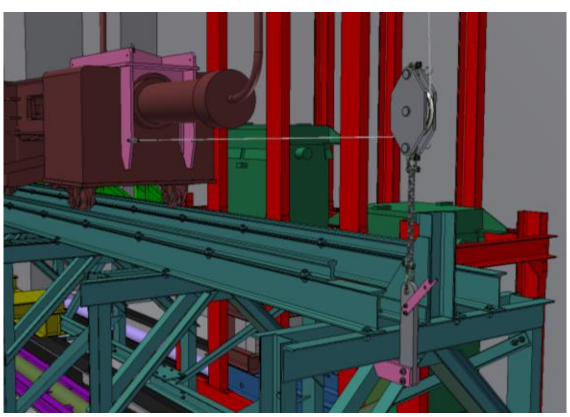


Fig. 6. Decanner Pulley System Concept

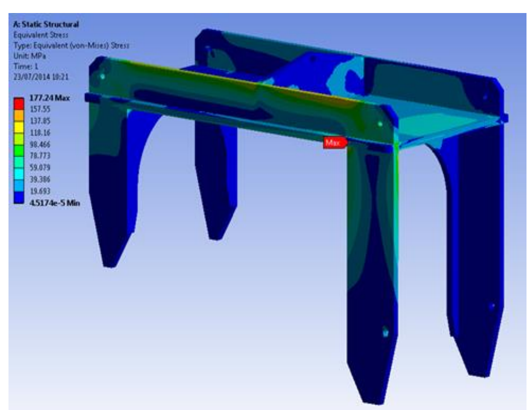


Fig. 7. FEA of Decanner Puller Frame

As a worst case scenario, in which the decanner wheels were seized and the decanner had to be skidded along the rails, it was estimated that a maximum pull force of 2t would be required. Calculations were therefore undertaken to develop a system capable of applying a load of up to 2t. Finite Element Analysis of the system, as illustrated in Fig. 7, was carried out to substantiate the equipment for this required pull force.

At this stage it was agreed by Sellafield Ltd and JFN to create a mock-up of the decanner, which could be supported on the previously constructed replica decanner rails, in order to undertake trials of the equipment. Upon assembly of the test rig and manufacture of the equipment, trials were conducted within JFN's Rig Hall facility in Egremont. The Sellafield Ltd operators attended the trials to assist in and execute the operation of the system, which was beneficial for developing the operators' experience before conducting operations on-site. The trial set-up is illustrated in Fig. 8.

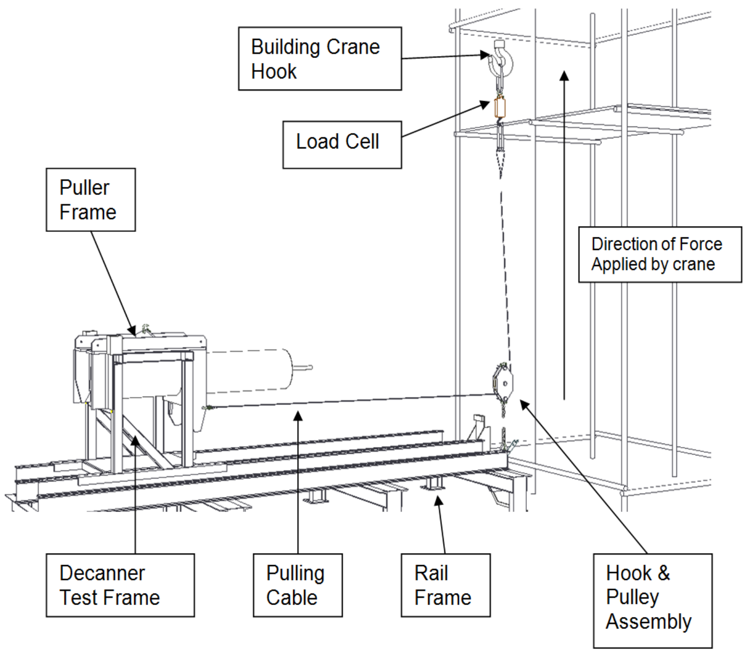


Fig. 8. Decanner Puller Trial Set-up

The trials were successful and proved the system to be capable of moving the mock-up decanner up to a WLL of 2t.

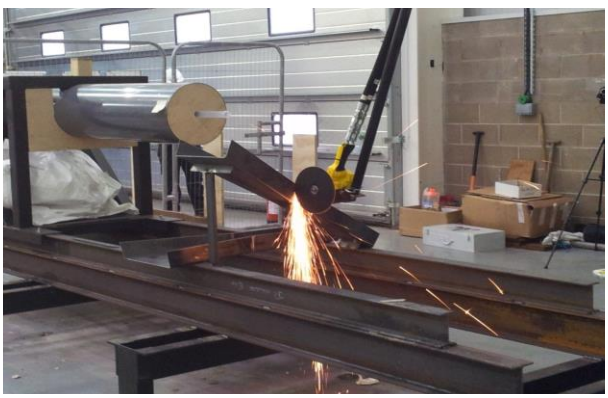
The equipment and the remaining documentation were prepared for final delivery to site. Sellafield Ltd deployed the equipment, and conducted operations to transfer the decanner to the decanner bay; however, it was discovered that the decanner would not traverse along the rails, even when the maximum load of 2t was applied.

This prompted more intrusive camera inspections to be undertaken by the Sellafield Ltd operators, who soon discovered an additional wheel block had been clamped onto the decanner rails. In addition to this, it was also identified that the decanner was restrained in position by the decanner chutes, which had been welded between the decanner machine and the surrounding steelwork structure within the pond. These restraints affecting movement of the decanner were not detailed on the original drawings of the decanner or surrounding steelwork. These modifications were in fact implemented when the equipment was originally installed, with relatively little information recorded of these details.

The team therefore next considered how the chutes could be detached from the decanner. Working together, JFN and Sellafield Ltd teams proposed and trialled a number of methods to detach the chutes. These included a hydraulic cropping tool deployed by means of a buoyancy bag, a wire noose to attempt to break the welds and a COTS grinder, deployed via a long reach pole.

Long Reach Grinder Tool

From the preliminary trials, the grinding option proved the most promising, and was therefore taken forward and developed further. The preliminary trials involved securing the COTS grinder to a 6m long deployment pole, and attempting to cut through steel fabrications that represented the chute geometry and inclination within the ponds. Fig. 9 below shows one of the early trials that was undertaken as a "proof of principle" test.



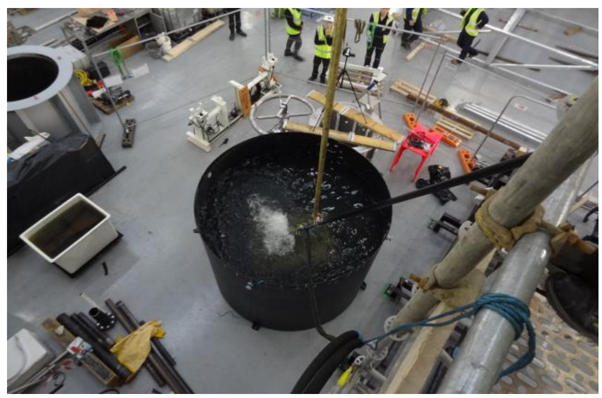


Fig. 9. Preliminary Grinder Trials

Fig. 10. Underwater Cutting Disc Trials

From these trials, it was observed that the grinder was capable of cutting through the chute mock-ups in a dry environment; however, further trialling of the tool underwater highlighted that water drag affected the rotational speed of the grinding disc, with less successful cuts being achieved. In addition to this, it was discovered during the on-site camera surveys that the actual decanner chutes differed in geometry from the early manufacturing drawings. Due to these factors, it was apparent that an alternative cutting disc, both in size and composition, would be required to undertake the cuts successfully on site.

This led to a phase of testing the grinder underwater using a variety of different cutting discs. This was undertaken within a test tank at the JFN rig hall, where the hub of the grinder was also adapted to accommodate discs suitable for use with alternative cutting machines. Fig. 10 illustrates the set-up under which these trials were carried out.

It was proven during these trials that the most effective disc for cutting the chutes underwater was a 24” (~600mm) Tungsten Carbide Tipped (TCT) disc. The necessary modifications were therefore made to the COTS grinder to accommodate this size disc, whilst the deployment pole design was underway to develop a tool suited for its application on site.

The developed tooling solution therefore comprised a 24” TCT cutting disc secured to a COTS grinder that could be installed and operated via a 6m long deployment pole. In order to provide stability during the cutting operations, the tool utilised existing plant steelwork located above the pond water, to which it could be clamped and pivoted around. A spring loaded mechanism that clamped to the steelwork was also incorporated into the tool design, which enabled axial movement along the deployment pole. This allowed the tool to be deployed in a cutting arc, whilst simultaneously being pushed into the cut. The design of the long reach grinder tool is illustrated in Fig. 11.

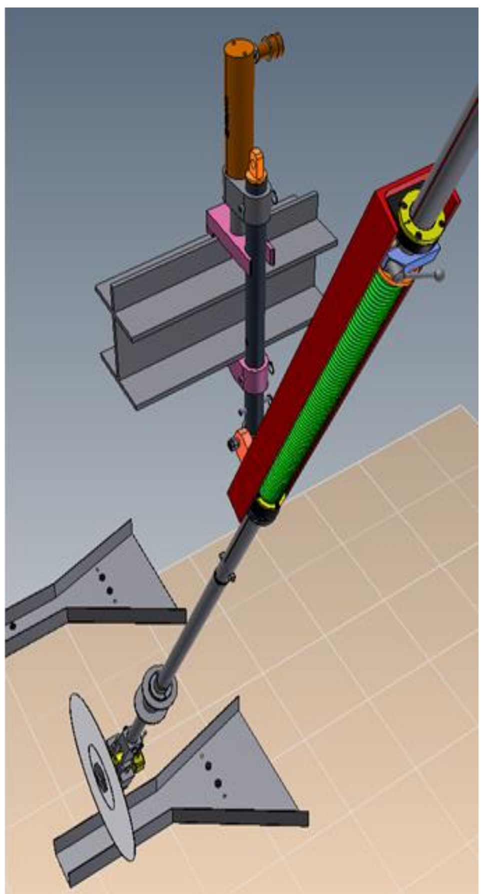


Fig. 11. Long Reach Grinder Tool Design

Further trials were then undertaken using the developed design, both to test its operation, as well as to provide the operators with valuable off-site training in the use of the tool. These trials are illustrated in Fig. 12.

Fig. 12 Long Reach Grinder Tool Trials

Fig. 13. Chute Cutting in PFSP

The tool proved extremely successful on plant, and all chutes were detached from the decanner. The tool being used to cut one of the chutes within the pond is shown in Fig. 13. Since cutting the decanner chutes, the tool has also been used to cut a range of items within the ponds to assist with size reduction and decommissioning operations.

Towing Trolley

The additional wheel block that remained secured to the decanner rails was found to be inaccessible beneath a decanner chute, and therefore could not be cut free using the wheel block removal tool. It was therefore proposed that since the wheel block could not be removed, the decanner would need to be lifted over the obstruction, which led to the development of the decanner towing trolley.

Since it was possible to access the South end of the decanner with the 12t building crane, the decision was made to raise this end to a sufficient height that would enable the decanner wheel restrained by the inaccessible wheel block to clear this obstruction. To avoid applying a lateral load to the building crane, it was necessary to rest the South end of the decanner on a support frame, to which the pulling load could be applied using the decanner puller arrangement, thus towing the decanner over the inaccessible wheel block.

Sellafield and JFN worked collaboratively on developing a towing trolley, as shown in Fig. 14, which could be deployed into the pond to locate onto the decanner rails.

Fig. 14. Decanner Towing Trolley

Since the building crane was required to lift the end of decanner, the trolley needed to be deployed and manoeuvred into position beneath the decanner using the two auxiliary runway hoists. The towing trolley was also required to support the partial weight of the decanner that would be resting on it, estimated to be 5000kg. The towing trolley was successfully deployed on site, with the South end of the decanner lifted onto it as illustrated in Fig. 15.

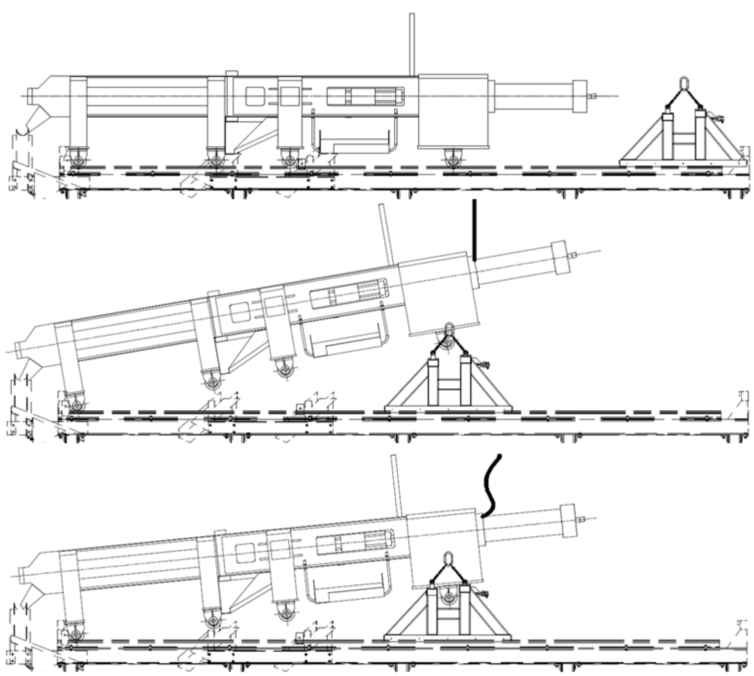


Fig. 15. Decanner Supported on Towing Trolley

Hydraulic Winch

Having cut through the chutes and deployed the towing trolley, the decanner was no longer restrained, and was now free to be traversed along the rails. The original puller frame was designed for this purpose; however, concerns were raised as to the actual pull force that may be required to move the decanner, taking into consideration the cutting operations that had recently been undertaken. For example, debris on the rails from cutting of the wheel blocks, or snagging of the chutes between the ground edges, as well as the additional frictional resistance of the towing trolley on the rails, could increase the necessary pull force to traverse the decanner.

Although the puller frame was designed to apply a load of up to 2t, it was felt that a back-up plan should be considered, should this force not be adequate to move the decanner. An alternative solution was therefore proposed by the Sellafield team that would enable a greater pull force to be applied to the decanner. This involved the use of a COTS hydraulic winch, which could apply a force of up to 6t.

Since this pull force greatly exceeded the 2t load previously considered, the initial task involved assessing the decanner rail structure to determine the maximum load that could be applied. JFN therefore carried out this assessment through undertaking Finite Element Analysis of the rail structure to determine the maximum permissible loading, as well as suitable reaction points on the structure for the winch frame to engage with. An example of this analysis is illustrated in Fig. 16.

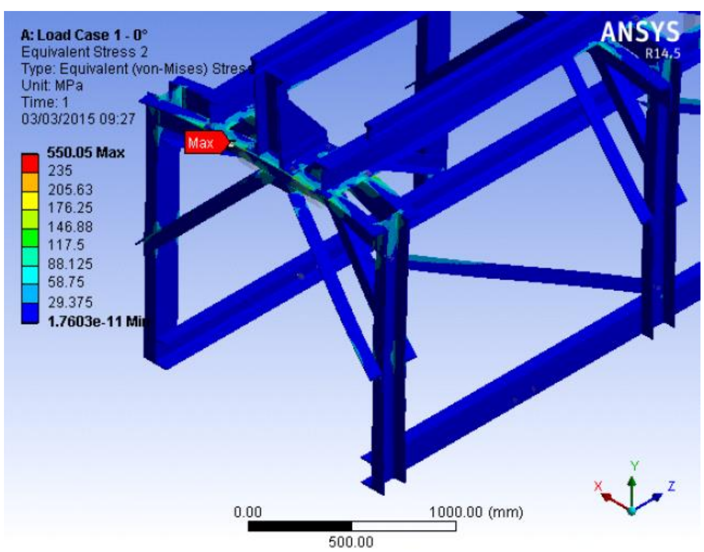


Fig. 16. Substantiation of Decanner Rail Structure

On undertaking this assessment, a suitable bracket was developed to which the COTS winch could be secured, allowing the load to be applied through the rail structure appropriately. The design of the winch bracket also needed to take into consideration features to enable remote deployment and operation of the winch.

Following the development of the winch system, the items were procured and manufactured within a very short timeframe in order to meet the project requirements. An as indication of the efficiency of this project, the time from concept design through to manufacture and trials was within a 3 week duration. The trials were again conducted within the JFN rig hall and helped to provide operator training in the use of the equipment. Photographs from the trials showing the tooling deployment and operation are shown in Fig. 17 and Fig. 18.

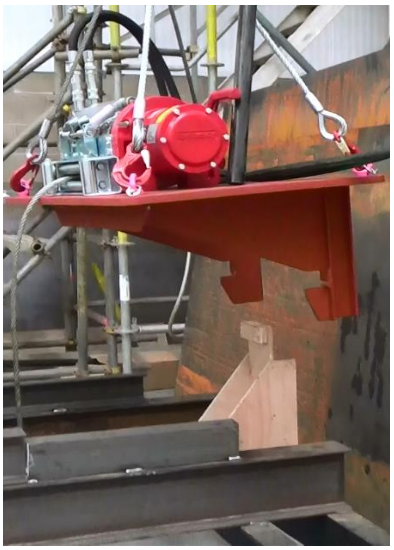


Fig. 17. Hydraulic Winch Deployment

Fig. 18. Hydraulic Winch Operation

Following the operator trials and familiarisation, the winch was successfully deployed on site, and the decanner finally traversed along the rails into a position to allow size reduction operations to be undertaken in July 2015. Once the decanner had been size reduced, it was then removed from the pond, as illustrated in Fig. 19, before being packaged and transferred to the waste store.

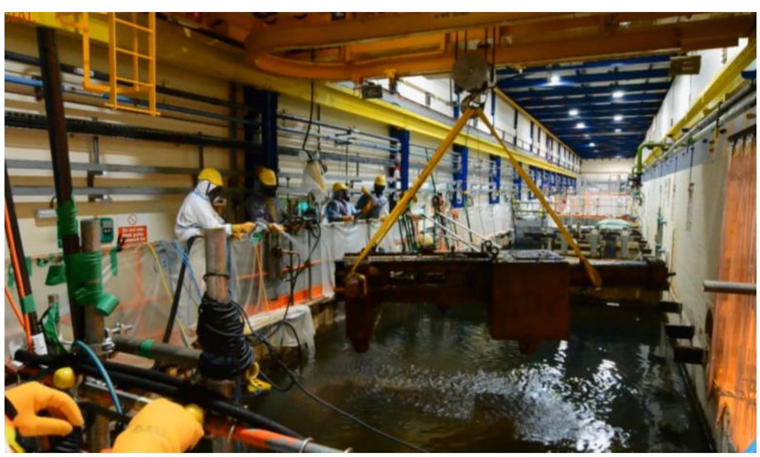


Fig. 19. Removal of Cut Section of Large Decanner from PFSP

CONCLUSIONS

The collaborative approach to working with the supply chain in the development and application of fit for purpose decommissioning equipment has been successfully demonstrated. This has been achieved by use of a supply chain partner with full testing capabilities, together with the use of the right people with the right skills at the right time.

Each time a new task was identified, the team searched for readily available COTS equipment and tooling that could be adapted or modified to suit the application. To confirm suitability of such equipment, "proof of principle" trials were quickly carried out and this provided the confidence required to progress with the development of the final tools to be deployed on plant.

Wherever possible, COTS equipment and tooling that had already been successfully used on plant was used where other similar applications were encountered. This approach minimised the amount of support equipment required on plant; such as hydraulic power units and control equipment.

The use of plant mock-ups was effective in carrying out trials in order to validate the suitability of the final tooling and equipment. All trials were attended by the actual operators that would be carrying out the work on plant and this gave them the opportunity to become familiar with the deployment and use of equipment to ensure that time spent on plant in an active environment was minimised.

As the tasks progressed on plant, the need for the team to be adaptive to changing or unexpected conditions was essential. In some cases additional equipment requirements were identified and this equipment had to be quickly developed to ensure the overall task was completed on time.

By applying the use of fit for purpose equipment and tools it was demonstrated that decommissioning can be achieved in much shorter timescales than the more traditional approach of using bespoke engineered solutions. The learning gained from the removal of the Large Decanner has since been shared within the Sellafield community. The same equipment and methods will be used for removal of a second machine from the PFSP and will also be considered for similar decanners from the Sellafield First Generation Magnox Storage Pond.

REFERENCES

1. Sellafield web-site http://www.sellafieldsites.com/2015/07/sellafield-gives-up-its-cold-war-secrets/
2. David Forsythe, Sellafield Ltd, The Complex Challenges of Risk and Hazard Reduction for a Legacy Fuel Pond at Sellafield UK Waste Management (WM) Conference, WM Symposia, 2010, Phoenix, AZ. 10197