The Design and Construction of a Modular, Transportable, Liquid Effluent Treatment Plant for Use in a NPP Undergoing Decommissioning – 14562

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ABSTRACT

A UK Nuclear Power Station which has ceased electricity generation is currently in the Care and Maintenance (C&M) preparations phase of decommissioning. The existing active effluent treatment plant needs replacing and a new treatment plant is required to treat liquid waste from a solid waste dissolution process. This paper describes the development of a new Treatment Plant to manage existing and new effluent waste streams including those from the solid dissolution process.

In decommissioning, treatment plants are often typically required infrequently and for relatively short periods of time. Also their functionality requirements can change throughout the various phases of decommissioning. Therefore a cost effective, modular and flexible plant design was required with isolation and bypass arrangements to accommodate only the required treatment operations during the various C&M and decommissioning phases.   The plant must also be capable of operating as a continuous or batch process to suit the requirements at any given time.

A robust and proven solution for a modular and flexible plant is the use of standard ISO containers to accommodate the plant and equipment and this approach has been adopted for the treatment plant.   This permits better space utilization and reduces the commissioning and maintenance burdens as the modular equipment is supplied in a “ready to operate” state. Also it substantially reduces capital costs in terms of installed hardware and infrastructure and because it is transportable facilitates increased resource sharing between nuclear sites and final decommissioning of the treatment plant itself. The plant has been fully constructed and tested off-site before being transported to the NPP, which reduces installation and commissioning time and costs. The plant consists of a suite of Active Liquid Processing Units, which are capable of effective solids separation and removal of radioactivity with a broad envelope of characteristics and isotopes, to meet the legislative requirements and guidance to exclude all entrained solids, gases and non-aqueous liquids and to minimise radioactive discharges. This provides a discharge route for radioactive aqueous waste generated on the site during decommissioning into the local estuary. The units include the following: chemical dosing, pre-filtration unit, ultra filtration, automated control, instrumentation, ion exchange unit, auxiliary tank skid, and spares. The functionality and features of the various processing units are descried in the paper along with the challenges of meeting the required functionality and performance of both the individual and integrated units.

INTRODUCTION

A UK Nuclear Power Station which has ceased electricity generation is currently preparing to enter the Care and Maintenance (C&M) phase of the decommissioning process. As part of the decommissioning and deplanting activities, two requirements for treatment of liquid effluent were identified. Firstly, the treatment of the effluent output from a solid waste dissolution process and secondly, the treatment of active liquid wastes arising across the dormant site.

The solid waste dissolution plant was to be a new build, with a projected service life of approximately five years. Consequently the treatment plant for the effluent from the solids dissolution plant was to have a matching service life, after which it would be decommissioned for storage or reassignment.

The existing site active effluent treatment plant was deemed beyond economical repair; however the site required the facility to treat effluents arising for a further fifteen years. A new plant was specified.

During the decommissioning cycle of a NPP, it is required to process, decontaminate and prepare for safe storage or disposal, a variety of materials. These requirements are often transient and infrequent. The nature of the decommissioning process dictates a degree of flexibility in terms of input specifications and operational use constraints of all process plant and equipment to be used during the decommissioning.

Modular Liquid Effluent Treatment Plant during final assembly

MODULAR DESIGN PHILOSOPHY

JFN proposed a modular solution to the requirement, as this approach delivers multiple advantages, including:

1. Rapid realization and delivery compared to fixed plant installation.
2. Minimizes site infrastructure requirement and disruption.
3. Integration of best available technology and use of commercially available items where available/applicable.
4. De risks the design process.
5. Full assembly, testing and inactive commissioning can be completed in the factory.
6. Shortest possible installation and commissioning programme at site.
7. De risks site based activities.
8. Simplified opportunities to develop/augment plant should operational requirements dictate.
9. Simplified decommissioning by process and/or module.
10. Opportunity to redeploy.

1. **Rapid realization and delivery**. The grouping and installation of the necessary process elements into ISO container based modules removes the requirement for costly and lengthy civil constructions at the NPP site. It may also simplify any planning constraints. This is particularly advantageous if the user requirement is in response to an emergency or is a short term activity. The modular approach allows the detail design phase to be delivered by multiple teams working concurrently, an essential precursor being the identification of the module interfaces. If required, modules can be fabricated, assembled and pre tested at differing locations/sub-contractors and relocated to final assembly/testing site at the appropriate time.

Skid Mounted Micro Filter being craned into position

2. **Minimizes NPP site infrastructure requirements**. The use of ISO container packages reduces site requirements to adequate space for plant and it's safe operation, the provision of necessary services such as electrical power, water supply, drainage (for surface water collection and treatment) and safe access for delivery of any process chemicals, removal of any solid waste for external disposal/storage. There is no requirement for construction of permanent buildings and the attendant cost and project complexity. This advantage in cost, time and space is enjoyed both at the beginning, during and end of the plant's life cycle.

3. **Integration of best available technology and commercially available items**. Modularization and containerization allow bespoke application of best available technologies (BAT) and Commercial Off The Shelf (COTS) items to be easily integrated into the overall process solution in a compact and cost effective manner. The integration of COTs items significantly reduces technical and commercial risks whilst the use of BAT allows optimal plant performance to be delivered. In addition, this approach assists in future proofing the plant, in that it is possible to isolate and redesign, modify or replace an individual module without disrupting the total installation.

A Container Lid being trial fitted

4. **De-risks the design process**. The risks inherent in the design phase of the project are significantly reduced by the modular approach allowing the use of a combination of JFN staff and supplier resources. This combination allows expert knowledge from a specialist supplier of each required process element to be amalgamated with JFN's established expertise to produce a fit for purpose design without the risk and cost of "reinventing the wheel".

5. **Full assembly, testing and inactive commissioning at the factory**. The completed modules are fully assembled and interconnected into final configuration at a JFN site. The plant is then tested and demonstrated to the client. During this Factory Acceptance process (FAT) the plant is fully exercised in all operation modes, which has the advantage of allowing the client to update their requirements prior to delivery to the NPP site. Any modifications required can then be addressed at JFN's site with a minimum of delay when compared to the difficulties that working within a licensed nuclear facility can impose. Full

commissioning using appropriate simulants follows the FAT, allowing process to be proven inactively. Again, any resulting changes can be made with minimum impact. This attribute of the modular approach significantly de-risks the project as the plant can be demonstrated to be fit for purpose and compliant to the specification before delivery to site. Any revisions to the client requirements and specifications can be adopted using the JFN factory facilities without the added complications and programme extension that inevitably arise from carrying out such works at the NPP site.

6. **Shortest possible installation and commissioning programme at site**. The high degree of plant function and compliance to requirement that has been demonstrated to the client prior to delivery to the NPP site means that the on–site activities can be minimized. The delivery to site of the containerized modules, their positioning, interconnection and connection to pre prepared services can be programmed to be measured in days – a true "plug and play". The reassembled plant is then put through a compact decommissioning programme prior to preparation for "Active Commissioning".

7. **De-risks site based activities.** With a conventional, civils based plant, any modifications or developments are subject to the often rigorous and arduous site procedures which add to programme duration and cost. With the factory tested modular approach the risk to the programme duration and cost of NPP site based activities are reduced because of the degree of offsite factory testing and qualification that is made possible by this modular, containerized approach, thus significantly reducing the risk of requiring on site works.

8. **Simplified opportunities to develop/augment plant** should operational requirements dictate. Given the nature of the overall NPP decommissioning process, it is possible that the process may be required to accommodate operational aspects unforeseen when the specification was originally conceived. The modular nature of the JFN solution lends itself to development as new modules can be added with the minimum of disruption to the existing plant. This flexibility is at best, difficult to deliver with a fixed installation.

Final Monitoring & Delay Tank being dispatched to client site

9. **Simplified decommissioning by process and/or module**. At the end of the plant's service life, it will be decontaminated prior to decommissioning and dismantling/storage. This can be approached module by module or by process. In this example, the process stream treating active effluents arising across the site is expected to remain in service at least ten years after the stream processing the FED dissolution waste has completed its duties. The partial decommissioning and dismantling required can be achieved with a minimum disruption to the operation of the remaining process. The dismantling and safe disposal of the module structures and components is also simplified compared to a fixed installation. Consider the radiological shielding, traditionally provided by significant thicknesses and volumes of concrete which become contaminated, requiring specialist and costly demolition and disposal techniques. In the modular design, contamination is contained by the ISO container's relatively small volume of steel, whilst shielding is strategically located outside the containment. Thus the shielding material, mainly steel, are isolated from the most contaminated aspects of the plant and, after minimal decontamination can be recycled conventionally.

10. **Opportunity to redeploy**. The modularity of the design realization delivers the opportunity to relocate the equipment within the specifying NPP as the decontamination lifecycle progresses to take advantage of site geography opportunities or to redeploy the plant to other NPP sites after appropriate decontamination and preparation for transport. Thus the economic and ecological justifications for such projects are more appealing.

Top Mounted Motorised Valves for ease of maintenance

TECHNOLOGIES UTILISED

The plant consists of two discrete process streams, one to treat the effluent output from a solid waste dissolution process and a second to treat active liquid wastes arising across the dormant site. The purpose of both streams is to isolate and prepare for safe containment dissolved and suspended heavy metals and radionuclides whilst producing a liquid effluent conforming to the NPP discharge authorization limits.

Solids Dissolution Process

The solids dissolution process liquid waste stream consists of the following key processing units:

a) Receipt and buffer tanks to accommodate varying incoming flows, transfer pumps are integrated into tank lids ease of access.
b) Reaction tanks incorporating acid and alkali dosing sets to allow automatic pH adjustment, polyelectrolyte dosing sets for the production of a floc, agitators and transfer pumps. The supernatant liquor is passed to the micro filter stage. The floc is passed via specialist pumps to a sludge holding tank.
c) Skid mounted microfiltration for removal of suspended solids down to 0.5. A close coupled Cleaning in Place (CIP) set is integrated for removal of entrained solids. The CIP waste is passed back to the buffer tanks.

Solid Waste Handling area during assembly

Skid Mounted Filtration plant in its iso-container

d) Granulated Activated Carbon (GAC) column for removal any fine material passing through the Ultra filtration unit, the GAC is particularly effective for removing organics (e.g. oils). It also protects the following Ion Exchange media from blinding by deposition.
e) Ion Exchange columns, two in number, arranged in series, charged with ion selective resins to remove residual activity. Effluent leaving the iX columns is monitored for compliance before entering a sentencing tank for final monitoring before disposal.
f) Sludge holding/Filter press feed tank. The floc is temporarily stored to accommodate process flow variances before being fed to a filter press. The GAC and iX medias are periodically replaced by new, the exhausted medias being passed to the sludge settling system for dewatering via the filter press. The replacement of GAC and iX medias is a periodic maintenance procedure and conducted separately to the normal processing of dissolution wastes.
g) Filter press. A press is used to dewater the floc sludge, to reduce activate waste volumes requiring storage. The supernate from the press is passé back to the front end buffer tanks for reprocessing. The solids from the press are discharged by gravity into a proprietary Temporary Transport Container (TTC) for onward transport for storage.

FED Solids Settling Tank

Ion Exchange Skid

Active Liquid Waste Stream

The active liquid waste stream consists of the following key processing units:

a) Receipt and buffer tanks to accommodate varying incoming flows, these tanks are equipped with acid and alkali dosing sets to allow automatic pH adjustment and transfer pumps.
b) Skid mounted microfiltration and ultra-filtration units, for removal of suspended solids down to 0.5micron. Both units have close coupled Cleaning in Place (CIP) sets for

removal of entrained solids. The CIP waste is routed to a Solids Settling tank.

c) Granulated Activated Carbon (GAC) column for removal any fine material passing through the Ultra filtration unit, the GAC is particularly effective for removing organics (e.g. oils). It also protects the following Ion Exchange media from blinding by deposition.
d) Ion Exchange columns, two number, arranged in series, charged with ion selective resins to remove residual activity. Effluent leaving the iX columns is monitored for compliance before entering a sentencing tank for final monitoring before disposal.
e) Solids Settling. Solids removed by the filtration stages CIP systems are passed to a settling tank periodically, in time the supernatant liquor is drawn off for recycling to the front end of the process whilst the settled solids are discharged by gravity into suitable containers for storage. The GAC and iX medias are periodically replaced by new, the exhausted medias are passed to the settling system for disposal.

MOSAIK® container transfer bogie undergoing FAT tests inside and outside the container

SUMMARY

The modular approach offers many advantages when compared to a conventional fixed, on site construction based proposal. The modular concept is particularly applicable to unforeseen site challenges where quick deployment is desirable or when design change is demanded. The design, build and testing within a factory environment give rapid progression to delivery and commissioning, engendering ownership and commitment from all stakeholders. The advantages of test and client acceptance prior to delivery to site should not be underestimated as key factors in reducing project durations, particularly in the on-site and final commissioning phases.

This modular approach is not limited to liquid waste challenges; it can equally well be applied to such diverse requirements such as site change rooms, decontamination suites and temporary ventilation systems.