

## **THE DESIGN, CONSTRUCTION AND COMMISSIONING OF A TRANSPORTABLE RADIOACTIVE SLUDGE DEWATERING UNIT (TRSDU)**

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### **ABSTRACT**

Active mobile wastes have been produced and are now stored on Power Station, Reprocessing and Military Nuclear Sites. Typically these are fine colloidal precipitates, sludges, resins, sand and coarser grits, frequently mixed together. There is a need to retrieve and process these mobile wastes as storage tanks fill and, increasingly, as facility decommissioning is undertaken. Retrieval results in dilute slurries that need to be dewatered before final treatment (immobilisation in a cement matrix in the UK). Elsewhere a polymer matrix or drying to solids would be used.

The conventional approach is to build a dedicated facility at each location. However, an alternative and more cost-effective solution is to use mobile dewatering and cementation plant, visiting each site for typically a year.

The challenge was to devise, develop and construct a Transportable Sludge Dewatering Unit (TRSDU) that meets stringent transport, dose, contamination, throughput, and reliability constraints. The solidification plant is (TILWSP) based on an established design.

This paper discusses the design and construction of the TRSDU, undertaken through a turnkey contract awarded to NUKEM Nuclear Ltd (NUKEM) by BNFL Magnox Generation.

The concept process selection, development, detail design component testing construction of the TRSDU are complete. The process plant has been commissioned and final demonstration of the equipment is well advanced. The active plant is housed in a single ISO style container with three additional ISO containers for Services, Control and Storage.

### **INTRODUCTION**

The paper outlines the technical and economic benefits of the TRSDU and describe concept and design development, detail design, construction, and inactive commissioning / operation.

## BENEFITS

### Plant Costs:

|                                     |       |
|-------------------------------------|-------|
| Fixed Plant Cost – Ten Sites @ \$8M | \$80M |
|-------------------------------------|-------|

|                   |       |
|-------------------|-------|
| Mobile Plant Cost | \$17M |
|-------------------|-------|

(Development Cost \$1M, Capital Cost (TRSDU & TILWSP) \$7M,

Site Costs (10 sites) @ \$0.8M + Decommissioning \$0.5M)

|         |              |
|---------|--------------|
| Benefit | <u>\$63M</u> |
|---------|--------------|

### Waste Disposal Costs

|            |       |
|------------|-------|
| With TRSDU | \$10M |
|------------|-------|

|               |              |
|---------------|--------------|
| Without TRSDU | <u>\$40M</u> |
|---------------|--------------|

|         |              |
|---------|--------------|
| Benefit | <u>\$30M</u> |
|---------|--------------|

|                                              |              |
|----------------------------------------------|--------------|
| Total Benefit (plant and waste cost savings) | <u>\$93M</u> |
|----------------------------------------------|--------------|

## TECHNICAL

- The crossflow filtration system treats mixed sludges from sub micro to 5mm particle size containing up to 50 wt% solids with fluid viscosities in excess of 450 cps.
- Robust, low/maintenance free pumps are used for dewatering and fluidic pumps for sludge transfers.
- On and offline filter conditioning facilities are incorporated to maintain filtration performance.
- The processing is controlled automatically through a P.L.C. and S.C.A.D.A. system using operator initiated sequences.
- The active process equipment is housed in a single ISO style freight container which has been rated as an IAEA IP2 package. Control and auxiliary equipment is housed in three ISO IP2 containers.

## CHALLENGES

### Process Concepts

An extended assessment and test programme of dewatering technologies was undertaken. The range of materials to be processed, as well as the radiological, space management and transport issues were assessed in detail. Crossflow filtration using heavy gauge, large bore tubular sintered stainless steel filters was identified as the only cost effective process capable of dealing with the range of feeds and meeting the site effluent limits for the water separated from the sludges. Mott Corporation of Hartford Connecticut supplied the cross flow filters for the final tests and the process plant.

The cementation package selected is a 'Large Liner' which optimises the storage volume for the product. Thus, dewatered sludge is to be delivered in 1.7m<sup>3</sup> (approx) batches within a narrow concentration band to ensure product quality and minimise waste costs. These constraints necessitate a relatively large batch processing system with accurate measurement and adjustment of the sludge concentration.

## Wastes and Product

The retrieved sludges consist of Magnox corrosion products, primarily hydrated magnesium hydroxide, mixed with varying types and amounts of filter aids (dicalite, slate dust, filter bed sands) and contaminants (sand, graphite, oil, rust and other debris). These waste will be transferred to the TRSDU at variable concentrations, typically below 5wt% and concentrated by crossflow filtration to products up to 50wt% and 450 cpoise, to meet stringent cement solidification formulation requirements.

## Filter Conditioning

Additional features were incorporated into the design from the development programme for on line and off line filter conditioning. The manufacture's on line backpulsing concept was extensively modified and developed during design so that a sealed system suitable for a nuclear application was eventually installed without loss of efficiency. The filter chemical cleaning and filter precoating systems were also incorporated into the design, without increasing the container volumes.

## **EQUIPMENT**

The challenge of abrasive, high viscosity self compacting sludges in combination with onerous radiological requirements was met by a combination of rigorous equipment selection, development and testing. Simulant testing was carried out on all major components, valves and instruments.

## Sludge Pumping

The key safety and reliability issue is to be able to empty the plant for routine maintenance or fault recovery. Fluidic pumping was chosen for sludge transfers as it combines the highest intrinsic reliability (no moving parts) with excellent sludge pumping capability and very low active ventilation arising. Testing confirmed that the provision of a high integrity line flushing system is the key feature in this plant emptying system.

The sludge dewatering and sludge transfer pumps need to be capable of maintenance and blockage free operation with these viscous and abrasive slurries, some of which display rapid setting and compaction. Resuspension and pumping systems suitable for use after long setting times (eg extended power loss) proved to be a continuous problem at pilot scale which NUKEM solved through development in parallel with detailed design. Fluidic Reverse Flow Diverters (RFD's) were proved for sludge transfers and an abrasive and corrosive resistant centrifugal pump was sourced by investigating parallel applications in heavy industry. The development, installation and demonstration of effective handling systems for these difficult sludges is a major achievement.

## **TRANSPORT AND SPACE MANAGEMENT**

### Containers

The active process plant requires shielding, typically 750mm thick concrete, dependent on the waste activity. The weight would make the process container unsuitable for transport. A cost effective solution was developed. This proved to be an unshielded transportable process module

in an ISO container. This is a massive all stainless steel construction fully compliant with IAEA transport regulations and tested and certified by Lloyds. Similar containers to the same standards have been constructed and tested for housing the control system, the inactive services and feeds and for transporting loose components (piping, cabling, ventilation plant). The process container has removable panels in the roof and walls to permit access for maintenance and removal of equipment.

3-D “solid” CAD modelling has been used throughout to optimise the conflicting space and weight requirements. See Figs. 1 and 2.

The internals of the process container and process equipment have in situ decontamination and emptying features and are finished such that the radioactive transport contamination and inventory requirements can be met. As the container is fully enclosed, cooling systems are provided for sludge dewatering to ensure cemented sludge product quality and for the container to avoid overheating of components. The containers are compliant with IAEA requirements and have been designed and structurally tested to obtain Lloyds Approvals.

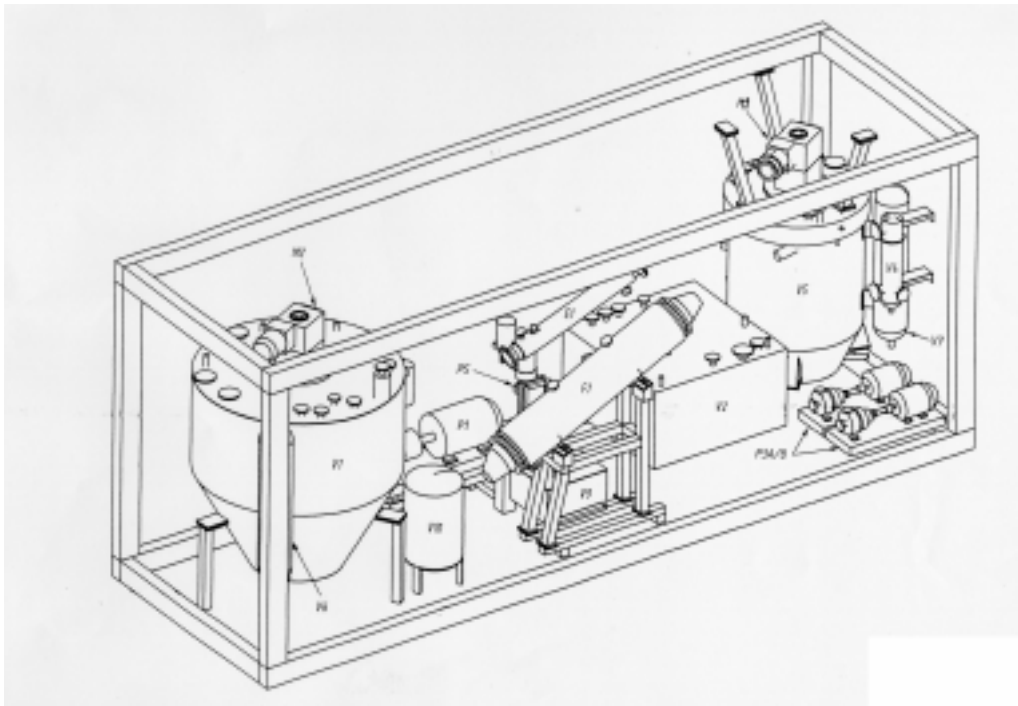


**Fig 1. Process Module-Plant Items**

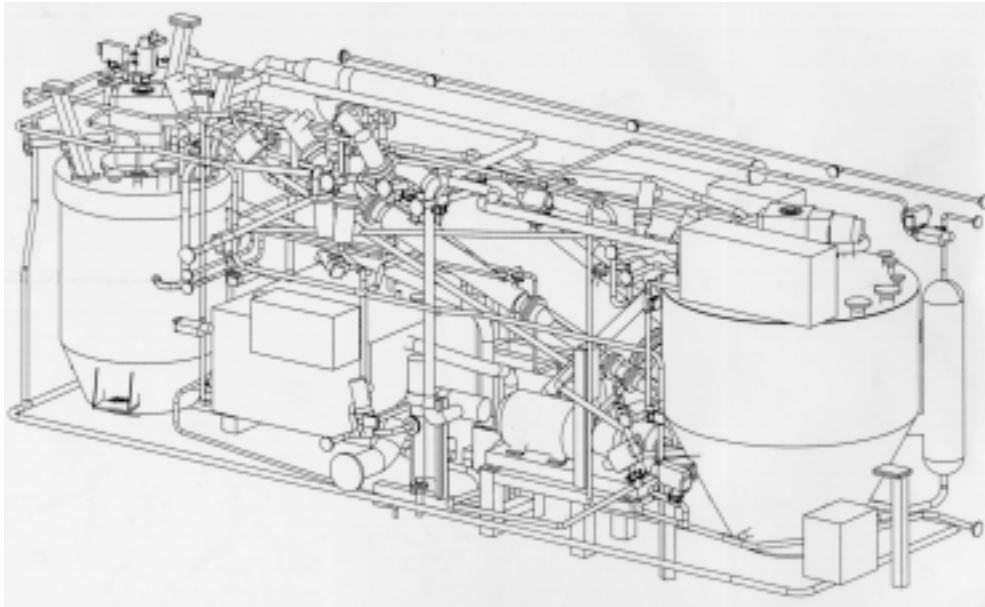


**Fig 2 Module - Equipment, Piping, Vent**

## PROCESS DESCRIPTION

### Outline

The dewatering process concept is shown in Figure 3. The plant receives dilute slurries from the TILSWP and removes excess water by crossflow filtration. The concentrated sludge is transferred into a large liner in the solidification module for cement immobilisation, whilst permeate from the cross flow filters is discharged to the site/station Active Effluent Treatment Plant (AETP) for further treatment and disposal as appropriate.

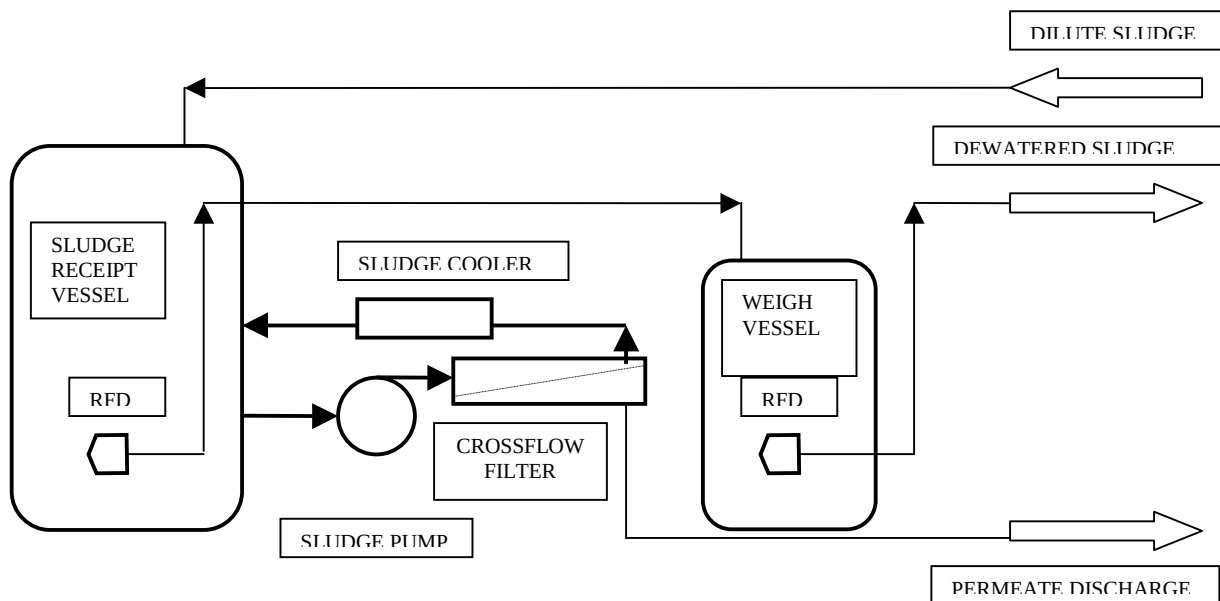


**Figure 3 - Basic Flow Scheme**

### Sludge Retrieval

Sludge is recovered hydraulically from the station and this dilute sludge is pumped to the 5m<sup>3</sup> sludge receipt vessel. Some preliminary settlement of coarse material may be undertaken in TILWSP.

### Dewatering

Sludge is pumped from the receipt vessel via a centrifugal pump, through the crossflow filter and returns to the vessel via a cooler. If the sludge temperature exceeds 35°C the cement sludge block may crack during curing. The filter permeate is collected and discharged to the site effluent system. It can also be used for tank and line flushing to minimise effluent production. The sludge volume reduces as permeate is removed and further batches of dilute sludge are transferred into the receipt vessel until sufficient thickened sludge has been accumulated for producing one large liner. The thickened sludge is then transferred to the weigh vessel where the solids concentration is assessed accurately and adjusted before transfer to the large liner.

The centrifugal sludge dewatering pump has a variable speed drive and is constructed specifically for operation with high concentrations of abrasive solids in corrosive conditions. The crossflow filter has 79 x 2.28 metre long 20mm diameter heavy duty sintered stainless steel tubes. The crossflow filter tube bundle has been designed such that it can be replaced as a unit. Sludge is transferred using reverse flow diverters (RFD). These are exceptionally reliable, have no moving contact parts and have very low activity pick into the motive air. They are capable of pumping slurries up to 50% solids.

Provision has been made for on line automated cleaning of the filter by rapidly reversing the permeate flow (backpulsing) and for automated off line chemical cleaning of the crossflow filter for control of longer term biological chemical particulate or fouling. The chemical cleaning system can also be used to decontaminate all the active process equipment. There are facilities for preconditioning the filter after chemical cleaning to reduce short term fouling.

The shielding and safety aspects were covered by a full shielding assessment and safety reports dealing with all operating and transport safety aspects were prepared.

### **CONTROL**

The semi batch process is completely automated and fully interfaced with the waste retrieval, waste solidification and site effluent systems. Operating control is achieved through a sophisticated PLC SCADA system using an extensive suite of plant mimics and operating sequences which address approximately 150 inputs and 120 outputs. Full product processing and condition trending is provided.

Separate independent hardwired shut down and plant emptying systems are installed. These limit plant operations to a safe envelope and ensure safe shutdown and recoverable conditions in the event of an emergency.

The key parameter of sludge concentration is monitored continuously by a PLC algorithm as well as by installed instruments and it is confirmed by load cell vessel weight level measurements before discharge for cementation.

A conventional plant mimic screen, pointing device (mouse) and alarm console are the main operator interfaces. Two closed circuit T.V. cameras allow the operator to view the contents of the sludge vessels.

## **PROJECT**

The project successfully integrated a process development programme, which is still ongoing, with a turnkey, fixed price design and build contract which NUKEM are completing ahead of schedule and to cost.

The ongoing process development was accommodated by using sophisticated design tools (process simulation, 3-D CAD tools, computerised design calculations) to establish an appropriate envelope for processing and equipment parameters.

This was used “back to back” with the control, container and process equipment construction contractors on an ongoing basis to ensure a final “fit” without rework. This activity was supported by NUKEM in depth HAZOP and design review procedures and rigorous attention to detail and to document control, QA, validation and inspection. The investment in ensuring that information and requirements are effectively communicated and recorded, both to and from all suppliers and subcontractors, and the extensive use of sophisticated design and project management tools coupled with the ability to identify, acknowledge and solve problems ongoing have resulted in a successful, properly managed project.

NUKEM produced full staged generic site safety reports, site specific safety reports and a staged safety case with the accompanying HAZOP, reliability studies, dose and conventional safety assessments. These have also been interactively integrated into the designs and specifications on an ongoing basis to control cost and programme impact.

## **ACKNOWLEDGMENT**

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