A full scale energy comparison of municipal sludge dewatering using Volute disc press versus a typical centrifuge at Davyhulme WwTW

Executive Summary

Evergreen Water Solutions (EWS) and United Utilities (UU) worked collaboratively to successfully apply for grant funding through the IEEA programme for Volute dewatering technology. The aim of the project was to pilot test the Volute technology at full scale on a United Utilities site to demonstrate the significant energy savings compared to a typical centrifuge. This case study summarises the trial performance of the FS 402 VOLUTE™ as a raw and digested sludge dewatering press compared to existing centrifuges at the Davyhulme wastewater treatment works.

The Volute full scale trial was targeting 70% energy efficiency using Volute compared to centrifuges along with additional process advantages to United Utilities. Volute demonstrated a "like for like" 84% energy saving compared to the onsite centrifuges. The direct dewatering of secondary sludge to reduce nutrient levels (phosphorus) was also pilot tested on the site as part of the final trial. The lowering of nutrient levels entering the receiving water courses is a priority for UU. The objective was to direct dewater primary and digested sludge to over 25% dry solids.

Additional energy saving pilot trials were completed on the Davyhulme site to test the feasibility of Volute to maintain a 14% sludge cake for the thermal hydrolase process (CAMBI plant) on site to reduce the number of process steps of dewatering and rewetting the sludge cake for THP process.

Centrifuges are the preferred dewatering technology for many UK water companies. Volute is a technology in competition with centrifuges, belt presses and screw presses, to process liquid sludge and produce sludge cake.

The Industrial Energy Efficiency Accelerator (IEEA)

The IEEA programme supports the development of innovative technologies that will help industry reduce energy consumption and cut carbon emissions. It focuses on innovations with large potential cross-sector energy and carbon reduction impact - either new technologies or established technologies applied to new sectors. Over £15 million in public and private funding has been committed to develop solutions through partnerships between technology developers and industrial companies willing to test technologies on-site. The programme is funded by the UK government (BEIS) and managed by the Carbon Trust, with support from Jacobs.

Figure 1 The United Utilities' Davyhulme wastewater treatment facility

Volute has shown over 80% reduction in power when compared to centrifuge technology and consumes up to ten (10) times less water than a belt press. The Volute can be applied to multiple industries including meat processing, food and beverage industries, chemical sludge, dissolved air flotation (DAF) process in abattoirs, biological and anaerobic digested (AD) sludge. We hope the results of the Volute trial will encourage other UK companies to consider Volute as a low energy alternative to centrifuges.

The site

The selected site for the trial was Davyhulme Wastewater Treatment Works (WwTW) in Manchester, the North West's biggest wastewater treatment facility. The sewage sludge is produced as a by-product of wastewater treatment, and within United Utilities 185,000 tonnes of sewage sludge is treated annually. UU spend up to £7m per annum on power treating biosolids. The project was designed to test treatment of raw sewage sludge pre-anaerobic digestion and post anaerobic digestion. The anaerobic digestion process on site was Cambi thermal hydrolyse.

Innovation in municipal sludge dewatering with Volute Disc Press

The Volute disc press is a single stage process made up of three zones: Flocculation, Thickening and Dewatering. The Volute process was selected for the pilot at Davyhulme because of its ultra-low energy requirement to dewater biosolids. Biosolids sludge dewatering is a key part of recycling the biosolids safely in a municipal wastewater treatment process. The dewatered digestate from the biosolids process can be used as a soil conditioner and recycled back to the land through local farmers; the rest goes to the UU incinerator facility. After the sludge is dosed with the correct polymer it is pumped to an integrated flocculation tank pre-Volute cylinder which causes the sludge to flocculate and create flocs. The separated liquid is gravity fed to the Volute cylinder where the clean filtrate passes through the moving rings and the flocculated solids remain in the cylinder. The thickened sludge travels through the thickening section of the Volute cylinder by the action of the moving V-screw where its reaches approx. 10% dry solids. The V-screw is tapered in design in the dewatering section of the Volute cylinder and presses the sludge against the moving rings and the fixed end plate to create pressure on the sludge cake. The low shear and high pressure within the cylinder dehydrate the liquid sludge to a sludge cake up to >30% Dry Solids. The Volute V-screw rotates at 2.5 rpm making the Volute extremely energy efficient and low maintenance for the plant operators.

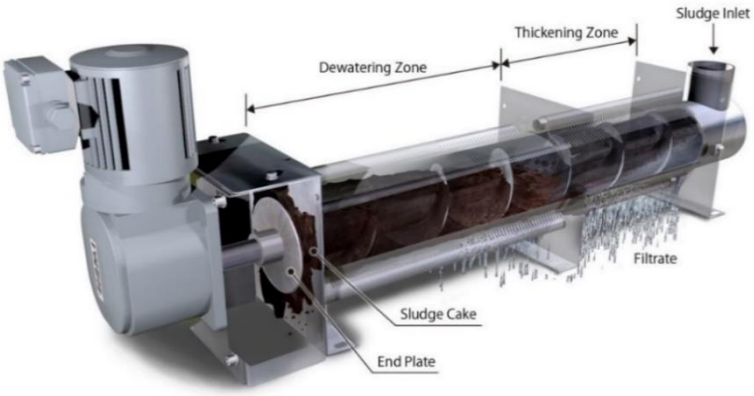

Figure 2 Schema of the Volute

Figure 3 Solid's separation process using Volute disc press with polymer

The Volute process offers the end user several significant advantages over other dewatering technology including flocculation, thickening and dewatering in a single stage. The very low power consumption and low wash water requirements make it suitable for small remote treatment sites that have limited power available and minimal operator attendance. The Volute can be operated unmanned and can be designed for wastewater plants as small as 500 population equivalents (PE) or 2kg of Dry Solids/hrs. The volute will also have a significant carbon saving during the construction phase of any dewatering projects as no reinforced concrete floor or sound enclosures are required for installation. The volute has a compact footprint so civil construction is minimum of 1.5m² footprint.

The Volute has an operating speed of 2.5rpm therefore vibrations are negligible compared to centrifuge technology at 3,000rpm. The centrifuge operating at 3,000rpm also creates additional odour and noise in the process room therefore an odour control system may be required with a centrifuge installation.

IEEA support was essential to take Volute to a full-scale trial plant to complete “side by side” comparison using the same sludge feed to both Centrifuges and Volute. The IEEA funding allowed EWS to design and build a 40ft ISO shipping container into a “plug and play” dewatering plant room to meet the United Utility PLC asset standards. The Volute container was delivered, installed and process commissioned by EWS at Davyhulme WwTW. Due to the commercial support from the IEEA, EWS were able to have a permanent project engineering team and an EWS site technician on site to operate the Volute.

The IEEA funding contributed towards the cost of monitoring the on-site centrifuge’s power consumption using Centrica power clips and the Volute power consumption was monitored within the main Volute panel. We calculated the throughput in terms of kg/DS/kW hrs. We also completed an extensive sampling program on the sludge feed, filtrate quality and sludge cake dry solids with the results collected by an accredited lab, and additional analysis was undertaken by a UU accredited lab and shared with IEEA and EWS.

The Demonstration

Existing Dewatering Process

The dewatering process at Davyhulme utilised multiple centrifuges to thicken the sludge to 28 - 32% dry solids or to the required consistency for land spreading. The centrifuge typically rotates at circa 3,000 rpm to separate solids from liquids, which requires significant electrical power typically up to 50 kWh per/tonne of solids processed. As opposed to the Volute which rotates at circa 2.5rpm and therefore power consumption is circa 4 kWh per tonne of solids processed. There are four centrifuges pre Cambi THP for the raw sludge with a design capacity of 1.6 tonne/DS/hrs and two centrifuges post Cambi THP for the digested sludge with a design capacity of 2.0 tonne/DS/hrs.

The key aims and objectives of the demonstration are shown in Table 1. The primary aim was to demonstrate a 70% reduction in electricity usage associated with the dewatering process at Davyhulme utilising Volute as opposed to the existing centrifuges.

Table 1 The key success criteria of the trial and the assessment metrics associated with each objective

Criteria	Current benchmark criteria	Success Criterion
Energy consumption per tonne of treated solids (kWh/tDS)	*Existing centrifuge results*	*15 kWh/tDS (70% better than the existing units)*
Liquor quality and lower treatment costs	*Compare against existing liquors (suspended solids and chemical oxygen demand)*	*Expect liquors to improvement on existing but needs accelerator to support demonstration of this.*

Design and Build of the Volute plant

As this was the first Volute FS400 series installation in the UK, we recommended and carried out multiple polymers jar testing to select the best polymers. The Volute FS400 pilot installations allowed process dimensioning and operational cost modelling for United Utilities for future projects. A number of site visits were required pre-installation to finalise detailed design and integration of the Volute into Davyhulme STW.

The Volute installation required a package plant Volute ISO container, a sludge buffer tank to feed the Volute with post digested sludge and GMS access steel work to access the ISO container and sludge cake screw conveyor for filling the onsite skip.

The project was divided into multiple stages including design, installation and mechanical and electrical commissioning and process commissioning. The manufacture of the Volute FS 400 multi disc press was completed by Amcon Europe in the Czech Republic and the ISO container design and manufacture was completed in the UK. The project "design and build" was managed by EWS' Project Engineers and the Volute trial was operated by EWS's Process Technicians.

The 3D design modelling was completed inhouse by the EWS design team and we employed specialist mechanical fabricators to modify the ISO container so it would be a suitable plant/process room. The ISO container was designed to separate the MCC/control panel room from the plant room with partitions and separate pedestrian doors. The ISO container roof was also modified with a retractable sliding roof for future maintenance requirements of the Volute. The service interval for the volute is 10,000 continuous operational hours for the moving rings and 30,000 hrs for the cylinder V screw. The Volute was also equipped with multiple size pumps so we could test the Volute at different flow rates up to 60m^3 per/hour with variable % dry solids (DS) sludge concentrations and different sludge sources on site. The sludge sources tested were raw sludge (primary and secondary mix), post AD sludge and RAS/SAS (return activated sludge). The Volute ISO containerised plant was installed on the biosolids resources centre in Manchester for United Utilities.

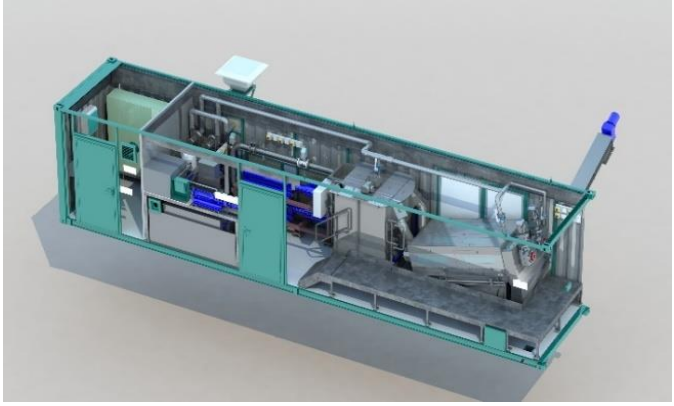

Figure 4 Container 3D Design approved by United Utilities

Figure 5 Volute 40ft ISO Container Design for Davyhulme STC project

Process Description

A process flow diagram (PFD) of the equipment is provided in Figure 6. The feed pumps transfer sludge from the sludge buffer tank to the flocculation tank, whilst polymer is added directly to the flocculation tank via the polymer emulsion dosing pump as part of the polymer make up system. The polymer make-up system mixes liquid polymer with potable water to create a polymer emulsion of a specified concentration, as defined via the polymer make-up system local control panel. The process calculation is then inputted into the HMI (human machine interface) of the main Volute panel for process calculations of polymer usage and optimization of the dewatering process.

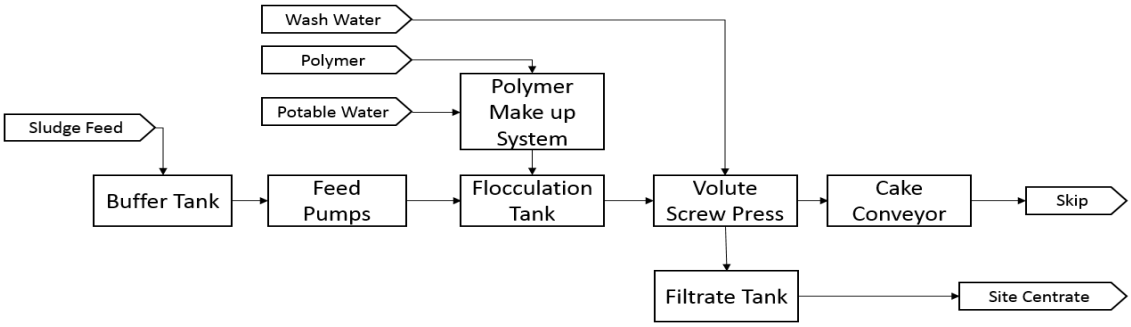

Figure 6 Process flow diagram of the Volute and other required process equipment at Davyhulme WwTW

The flocculation tank agitator runs continuously to ensure the sludge and polymer emulsion is sufficiently mixed to form flocs. The flocculated sludge then overflows into the cylindrical volute disc press unit. Sludge is first thickened within the thickening zone, whereby water is drained by gravity through the moving rings. The sludge progresses through the unit towards the dewatering zone with progressively narrowing gaps between the fixed and moving rings. Thus, in the dewatering zone, water is mechanically forced out of the sludge by the increased pressure inside the cylinder. The dehydrated sludge cake created by the volute press is discharged from the outlet into a cake transfer conveyor, which removes the sludge cake from the Volute for disposal. The filtrate created by the volute press is drained into the filtrate sump located below the Volute cylinder, before being drained out into the external filtrate pumping station.

Volute Energy Monitoring

United Utilities installed power consumption monitored on the centrifuges using Centrica power clips to record the power consumption and also the tonnes/DS/hrs were recorded by an inline dry solids reader for TSS and an inline flow meter. The energy usage from both pieces of plant was then converted to kW used per/tonne of Dry Solids. This made a direct comparison of the centrifuge and the Volute energy consumption and dewatering capacity. The Volute power consumption was monitored within main control panel of the volute ISO container. Evergreen and United Utilities site technician took daily grab and composite samples of the filtrate to confirm the filtrate was below 1,000 mg/L of TSS and sludge cake for % dry solids was above 30% dry solids. The filtrate and sludge cake results in this report were tested on-site by a UU accredited laboratory and independently tested by an external accredited laboratory.

Volute Energy Result

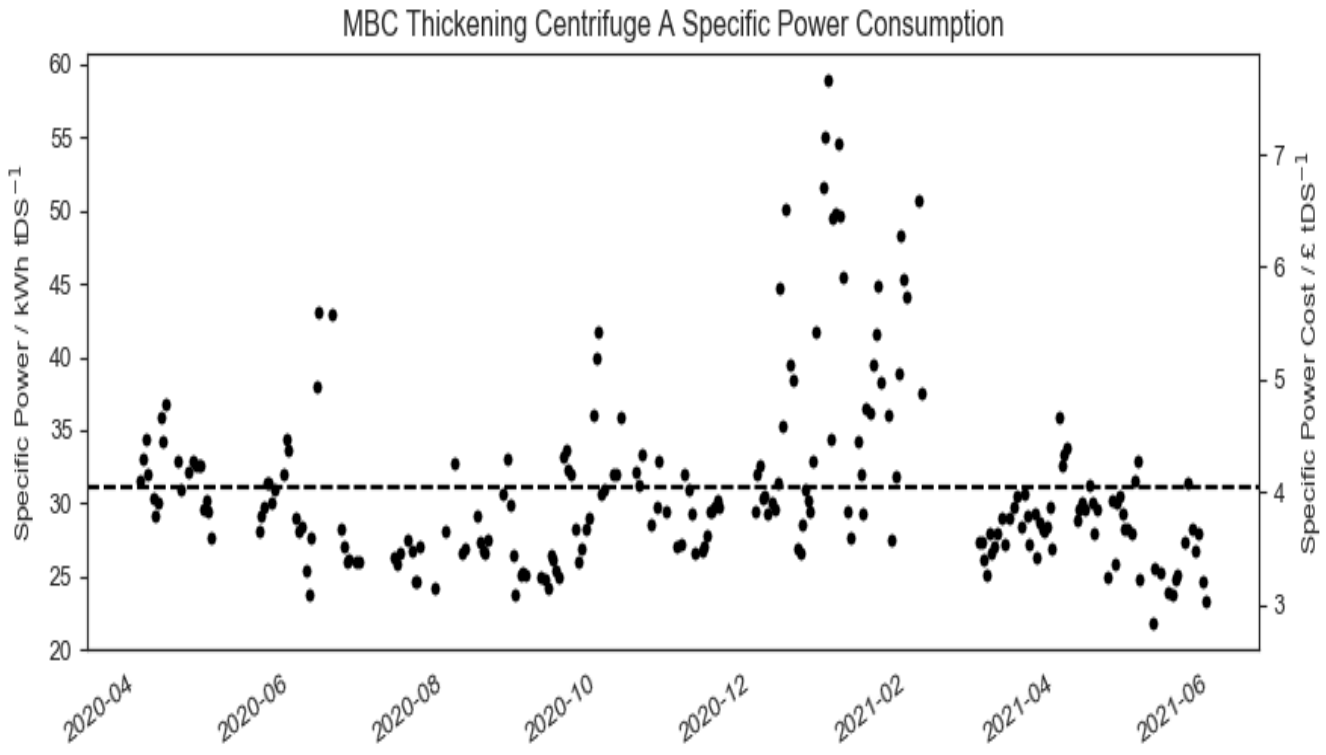

Figure 7 MBC Thickening Centrifuge at specific power consumption

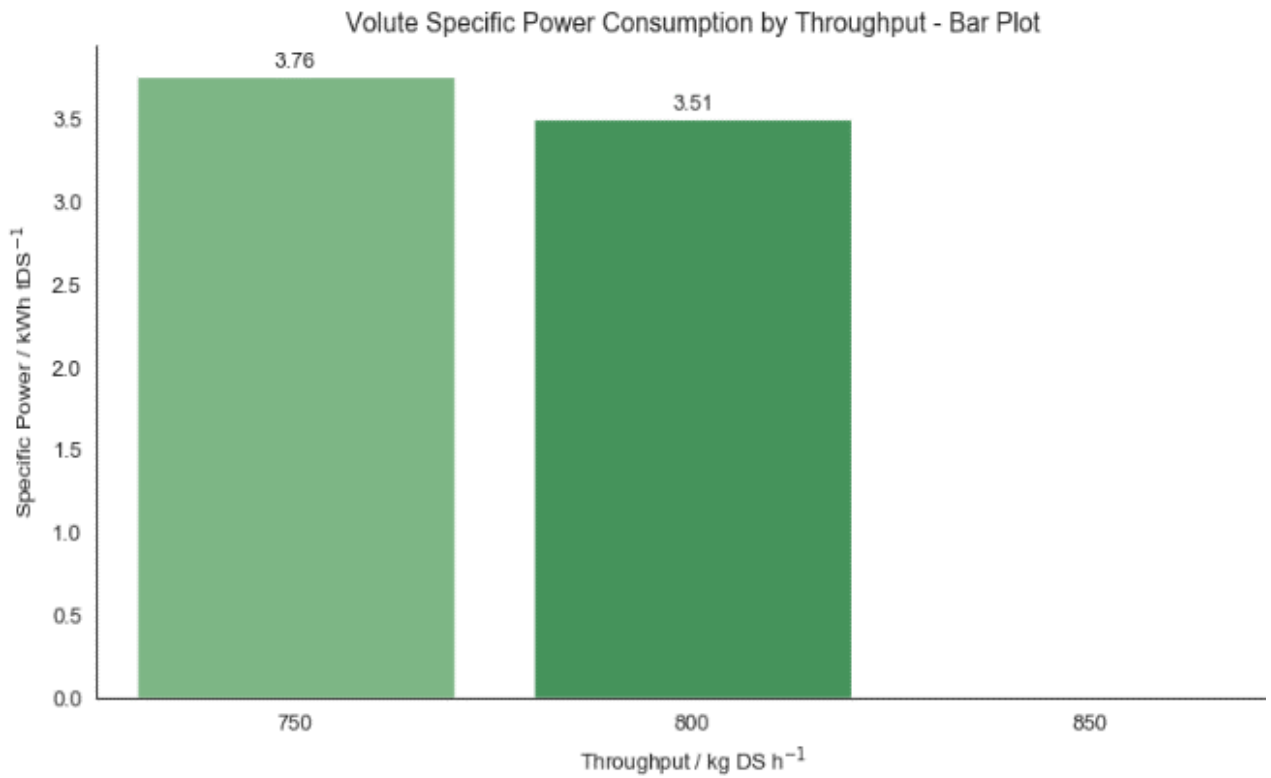

Figure 8 Volute specific power consumption by throughput

Volute Energy Savings

Table 2 Comparison specific energy consumptions

Plant Item	Specific Energy Consumption (kWh / tDS)
Davyhulme dewatering centrifuges	31.1
Volute at 800kg dry solids per hour	3.51
Volute at 750kg dry solids per hour	3.76

Dewatering centrifuge polymer consumption average ~5.67 kg/tDS, Volute polymer consumption over test period ranged from 3.0 to 5.0 kg/tDS.

The Volute has significant potential to save the UK municipal water industry up to 84% of the energy usage in the wastewater sludge dewatering market. The Volute is suitable for dewatering low concentration (0.3% DS) drinking water Alum sludge to a stackable sludge cake of >18% DS meeting the DWI standards.

There is also growth potential for this technology in the food and beverage sector. Other markets for Volute include distillery's, pharmaceutical and oil processing.

Lessons Learned

- Having a design and specification agreed in advance with the client is paramount to allow procurement to occur on time.
- Constant communications channels with the client and weekly project review meetings have helped with the cooperation of the client's engineering staff on site.
- Good site planning has enabled for the installation and site integration work to be carried out seamlessly through good communication with the site engineers, and providing installation programmes and a commissioning plan.
- As the project was delivered in an ISO 40ft container there were many design challenges to overcome due to space constraints. An agreed level of compromise was given by both parties on the access and ingress to process plant and equipment installed and the level of redundancy of equipment installed.
- The standardisation of local control panels and PLC automation for the volute process would have made the design of the control panels less time consuming.

Since the completion of the volute Davyhulme pilot test work, we have commenced volute pilot work for full scale volute projects with Yorkshire Water, Severn Trent, Anglian Water and Welsh Water.

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