Cardiff & Afan Advanced Digestion Plants

Dŵr Cymru Welsh Water delivers AD plants early, and moves towards power self-sufficiency in wastewater treatment

by Barry Oliver

With the escalating cost of energy, one of the key emerging trends is the need for wastewater treatment works (WwTW) to become power self-sufficient. Dŵr Cymru Welsh Water (DCWW) has recognised this, and as part of the company's move towards greater sustainability, it has invested in a £70 million programme of Advanced Digestion plants. DCWW's sludge strategy for AMP5 moves away from energy intensive thermal drying and lime stabilization to Advanced Digestion, with a programme to process 75% of its sludge production across four key sludge treatment centres. It has already achieved power self-sufficient service at Eign (Hereford), and is in the final commissioning stages with two schemes in South Wales, at Cardiff and Afan, where continuous renewable generation of 6.5MW is anticipated.

Cardiff WwTW Advanced Digestion Plant *Courtesy of Dŵr Cymru Welsh Water*

The development and delivery of Advanced Digestion plants at both Cardiff and Afan WwTWs is at the core of this strategy. These sites alone will process 50,000tDS/y using Cambi Thermal Hydrolysis plants and new digesters. This sustainable approach to sludge treatment has been encouraged and supported by Welsh Assembly Government, Regulators, local planning departments and local communities.

Design, construction and delivery

Full construction and delivery of the Cardiff and Afan schemes was required by April 2011 to maximise the Renewables Obligation Certificate (ROC) benefits, and minimise costs to customers. Imtech Process was selected for the delivery of the process and M&E engineering work, working collaboratively with Morgan Sindall, the civil design and construction partner.

A full technical and commercial assessment of available technologies was undertaken with DCWW. The most economic solution for these applications was Cambi Thermal Hydrolysis, due to the very high levels of secondary sludges. The Thermal Hydrolysis option was selected for Cardiff and Afan schemes for the following reasons:

- Best overall economic solution relative to DCWW objectives
- Proven technology experience at the required scale
- Proven delivery capacity and capability
- Process flexibility for various sludge types and quantities
- Proven treatment of SAS
- Process proven on sludge trials
- Higher VM destruction
- Reduced volumes of sludge to agriculture
- Good operational integration with the existing plants

Afan WwTW Advanced Digestion Plant — *Courtesy of Dŵr Cymru Welsh Water*

An integrated design team worked closely with key suppliers and operations teams on both the Cardiff and Afan projects,standardising design wherever possible. The project team was co-located on-site at the earliest opportunity. Detailed design activity schedules were developed, integrated with procurement activities and programmed to ensure timely delivery.

A challenging design and delivery programme was developed with the stretch target of completing both projects six months early. This was achieved through active management including a proactive approach to risk management developing risk mitigation plans wherever required and fully resourcing the project to allow effective acceleration of key technology packages during off-site manufacture. This included factory construction, pre-assembly and testing of both Cambi plants before disassembly and transport to site, allowing mechanical installation to be completed within one week of delivery. The key technology suppliers were incentivised to achieve the accelerated project programme with a focus on right first time, to meet the continuous challenges of best practice, time, cost and risk management, with the primary focus on safe delivery.

The key dates associated with delivery of this programme were:

Date	Status
December 2008	Planning approval
January 2009	Formal agreement of target cost
March 2009	Start on site
May 2009	Construction of major civil structures including the digesters (following enabling works)
January 2010	M&E installation commenced
April 2010	Digesters at both sites completed
July 2010	Start up of Steam Boilers
August 2010	• Initial proving of Cambi • Early start-up of the CHP units using natural gas • Early G59 testing and connection agreements • Early completion of PM5 facilities allowed remote automatic operation of the steam plant.

Process description

The design load for the sludge treatment process is 30,700 TDS/annum. For advanced digestion, the thermal hydrolysis stage is separated from the rest of the digestion process in order to maximise biogas production and to optimise power generation. The sludge from advanced digestion is an enhanced treated product with an E. coli count less than 100 cfu/g DS.

Indigenous and imported sludges

At Cardiff WwTW, the indigenous sludge is SAS, which is pumped from the SBR basins to the Raw SAS tank (capacity 1,200m^3). The existing mixing system in this tank uses coarse bubble aeration. 4 (No.) rotary lobe sludge transfer pumps withdraw the sludge from the Raw SAS tank, and feed it to 4 (No.) pressurised sludge screens. All indigenous sludge is screened to 5mm.

The screened sludge is then dewatered using existing centrifuges and typically has dry solids concentration of 19% w/w. This indigenous sludge cake is then transferred from the indigenous cake silos to the 2 (No.) Thermal Hydrolysis Plant (THP) cake feed silos.

Imported sludge cake is discharged from tankers into 2 (No.) hoppers. If necessary (in order to facilitate cake pumping), heated disinfected final effluent shall be used to dilute the imported sludge cake. Progressive cavity pumps are used to transfer imported sludge cake to the 2 (No.) THP feed silos.

The 2 (No.) THP feed silos (400m^3 capacity each) store indigenous and imported sludge cake. The sludge discharged from the THP feed silos, is diluted using heated disinfected final effluent to achieve the target dry solids concentration for the THP feed (16.5% ± 2% w/w).

Thermal hydrolysis

The hydrolysis stage is used to solubilise much of the solids organic material, including rupturing biological cells to release their contents. This increases the digestibility of the sludge, allowing a higher conversion of volatile matter and giving increased sludge stabilisation.

The thermal hydrolysis plant has a maximum capacity of 668m^3/d at a dry solids content of 17% w/w, equivalent to 39,000 TDS/annum. The thermal hydrolysis plant has 2 (No.) parallel streams, each stream comprising 1 (No.) pulper (capacity 36m^3), 3 (No.) hydrolysis

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Afan WwTW Advanced Digestion Plant

Courtesy of Dŵr Cymru Welsh Water

reactors (capacity 12m^3 each), and 1 (No.) flashtank (capacity 36m^3). There is also 1 (No.) foul gas skid which serves both thermal hydrolysis streams.

Mesophilic anaerobic digestion

The digestion process comprises 2 (No.) digesters, each of 7,500m^3 capacity, with gently sloping floors and fixed roofs. At the design load, and assuming that the digester feed sludge has a dry solids content of 9% w/w, the retention time in each digester is approximately 16 days. Each digester has 4 (No.) mixing pumps mounted external to the tank. The installed pumping capacity is sufficient to turn over the entire contents of each digester in half an hour.

Biogas storage, distribution and use

Biogas collects beneath the fixed roofs of the digesters, and is transferred to 2 (No.) double-membrane gas holders with a total capacity of 4,000m^3. The gas holders ensure that variations in biogas production do not affect the performance of the CHP engines.

Biogas is the primary source of fuel for the 3 (No.) CHP engines, and this can also be burnt in the 3 (No.) boilers. The CHP engines can each generate up to 1.5MW of electrical energy, and 1.65MW of useable heat energy. The boilers each can produce up to 4,000kg/hr of steam at 12 bar, each boiler comprising a fired side (3,000kg/hr steam output) and a waste heat side (1,000kg/hr steam output).

The hot exhaust gases from each CHP engine are directed to the waste heat side of the associated composite steam boiler, where heat is recovered in order to generate steam for the thermal hydrolysis process. Additional heat for steam generation is provided by burning supplementary natural gas as required.

Digested sludge dewatering

Sludge is pumped from the digested sludge storage tank to the sludge dewatering stage. This dewatering stage comprises 3 (No.) belt presses. Prior to dewatering, the sludge is conditioned with polymer. The powder polymer is made down to a 0.1% w/w solution using disinfected final effluent.

The dewatered cake from the belt presses is discharged into 3 (No.) cake bays from where it is transferred to a short term (up to 14 day) storage area. After storage, dewatered sludge typically 25%-30% w/w is hauled off site by lorry and spread on agricultural land.

Commissioning strategy

The commissioning strategy for the Cardiff and Afan Advanced Digestion plants benefitted from the lessons learnt at other full scale plants. The steam boiler plant was initially proved using natural gas, allowing the Cambi Thermal Hydrolysis plant to be tested and proved using water. Similarly, high efficiency CHP units were initially operated using natural gas in order to prove the system components prior to full system integration. Special tests were planned to allow early commissioning of high risk areas such as sludge cake handling, dilution and pumping plant, including the proving of innovative instrumentation and control facilities.

A particular risk associated with similar plants has been process start up. Issues have included severe foaming of the digesters on start up and delays to allow process acclimatisation and the onset of reliable gas production. In order to minimise this risk, a series of bench scale tests were carried out in order to identify the optimum seeding plan and start up rate. The final agreed digester start up plan was to transport digested sludge cake from the Cambi advanced digestion plant at Cotton Valley, Milton Keynes down to Cardiff, dilute it with water, and add sodium carbonate to increase alkalinity. Start-up of the digesters proceeded, as planned, right first time and without incident at either Cardiff or Afan.

CHP units were quickly operated on biogas and full ROC accreditation was achieved within the first month of process commissioning. The ramp up rate was particularly impressive, allowing the first drier stream to be taken out of service within two weeks of starting the Cambi plant, and the complete drier installation was taken out of service within one month.

Operational savings

During the development and detailed design of the Cardiff and Afan AD plant the operational and maintenance costs of the existing sludge treatment plants were monitored and the O&M costs of the new treatment facility was reviewed and agreed with the local operational team, supported by information from our specialist suppliers, and actual cost data from other full scale plants. The forecast operational savings are approximately £7 million/year.

Carbon savings

Carbon modelling of the existing thermal drying plant and the new advanced digestion plant has been undertaken, including fuel and power requirements and emissions associated with transport

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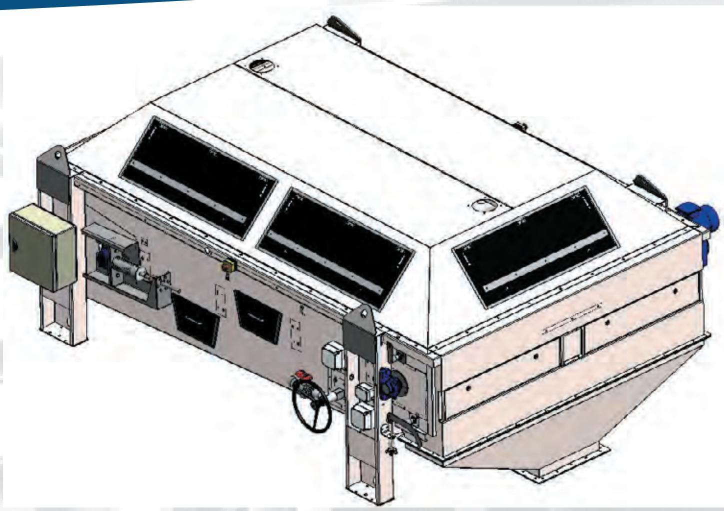

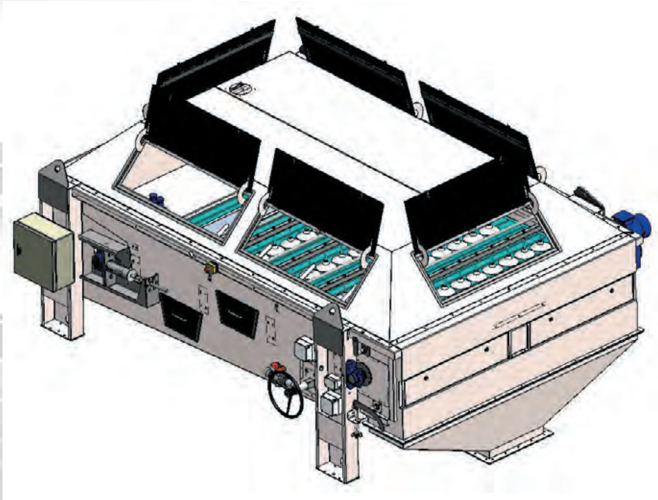

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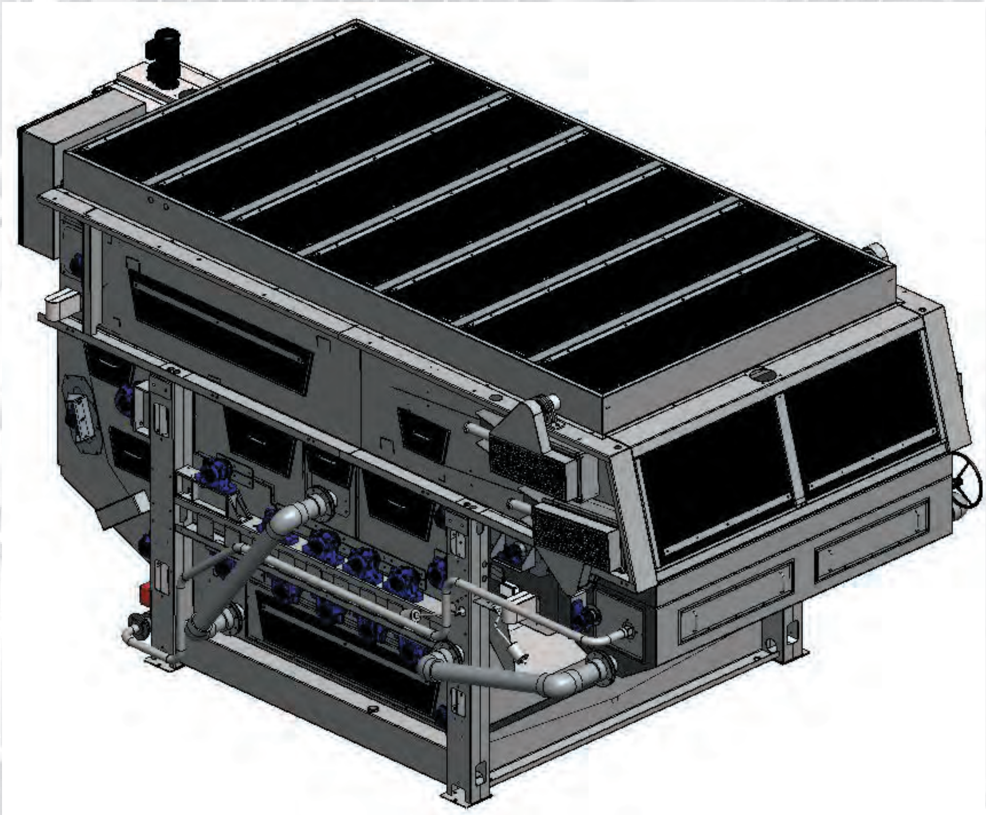

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Heat exchangers downstream of the Cambi Thermal Hydrolysis Plant that control the sludge temperature entering the digesters and return low temperature hot water back to the boilers - Courtesy of Dŵr Cymru Welsh Water

operations. The carbon benefits of the advanced digestion plant include significantly reduced natural gas usage, reduced power consumption and renewable power generation. Overall, the operational carbon saving from advanced digestion at both Cardiff and Afan is 35,000 tonnes of CO_2 equivalent per annum, which represents an operational carbon saving for Welsh Water of 15%.

Towards power self sufficient service

While achieving power self sufficient wastewater service has been achieved at Afan and Eign, achieving power self sufficient service at Cardiff is particularly challenging due to high power requirements to lift the sewage into the inlet works, for aeration of the SBRs and pump transfer of final effluent to sea. Although the performance of the existing SBRs has been optimised to minimise the power required for aeration, the average power use is approximately 100MWh/d which exceeds the expected power output from the Advanced Digestion plant.

Further optimisation of the overall works will continue in order to drive towards power self sufficient service. Improvements under consideration include importing additional sludge cake, and providing settlement upstream of the SBRs.

Conclusion

The strategic development and implementation of the Advanced Digestion programme has been an excellent example of purposeful collaborative working with the delivery of both the Cardiff and Afan projects safely, within a challenging time-scale, and right first time, through learning from previous experience at other sites.

Detailed design and delivery of the projects has progressed smoothly through Dŵr Cymru Welsh Water's capital delivery partners; Imtech Process and Morgan Sindall. Both the Cardiff and Afan Advanced Digestion projects have been designed, constructed, and commissioned within two years of formal contract award in January 2009.

The projects have been delivered ahead of programme, within budget and will generate more than 4.5MW of renewable power, reduce operating costs by over £7m/annum, and reduce DCWW's operational carbon footprint by approximately 15%.

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Afan WwTW Advanced Digestion Plant - Courtesy of Dŵr Cymru Welsh Water