Beckton & Crossness Thermal Hydrolysis Plants

advanced sludge digestion facility (ESDF) powers up at Beckton and Crossness

by Andre Le Roux & Andrew Bowen

Two advanced digestion (AD) plants have been built at Crossness STW, in south-east London, and Beckton STW which lies to the east of the city. They were required to provide additional sludge treatment capacity and better operational flexibility (seasonal sludge generation and maintenance down time) for sludge management at the respective sites. Future increases in sludge production at the sites will be primarily due to population growth in the area requiring increased capacity of the STWs and once complete, the Lee Tunnel will transport greater loads to Beckton. Both Crossness and Beckton STWs are owned and operated by Thames Water Utilities Limited. Beckton STW serves a population of approximately 3.5 million and Crossness STW serves a population of approximately 2 million. At the time of writing, Crossness and Beckton will be the joint sixth largest thermal hydrolysis plants in the world, each potentially treating 36,500 tonnes of dry solids per year (tDS/a) with an installed capacity of 41,975tDS/a.

Beckton STW Raw sludge high energy mixing and storage - Courtesy of Thames Water

Beckton STW boiler house walkways and waste heat flues - Courtesy of Thames Water

Beckton STW Raw sludge feed pipe rack Courtesy of Thames Water

Background

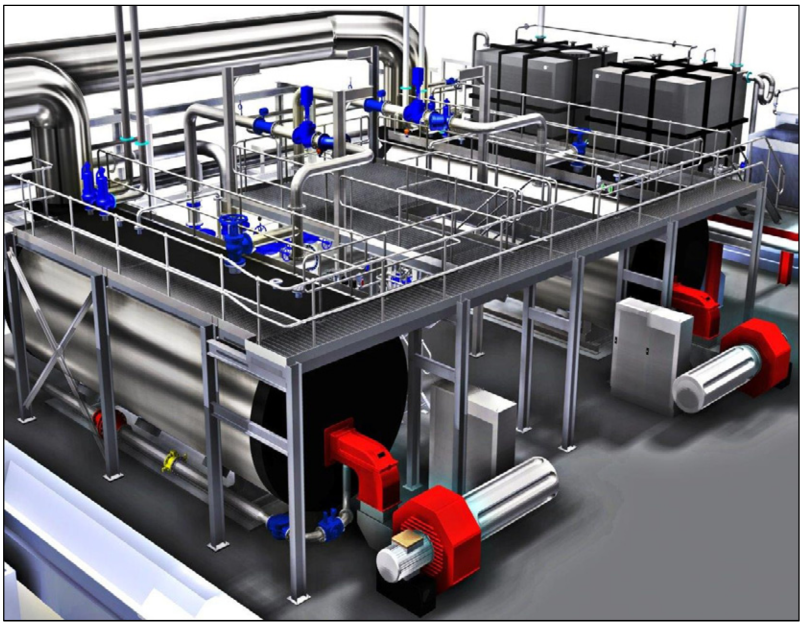
Previously, the bulk of the existing sludge production was treated using the sludge powered generators (SPGs), which incinerate the sludge. However, these SPGs did not have the capacity to incinerate all of the sludge produced and relied on short-term solutions such as lime treatment of the sludge cake to treat the surplus sludge. Lime treatment of the sludge cake produces a lower quality product and a loss of potential renewable energy generation.

Thermal hydrolysis technology pretreats sewage sludge in a two-stage process, combining medium-pressure boiling of sludge followed by a rapid decompression. This sterilizes the sludge and makes it more amenable to anaerobic digestion. Sterilization destroys pathogens in the sludge, which means it exceeds the stringent requirements for its subsequent use in agriculture. Since the first installation in Hamar, Norway in 1996, there are now over 30 AD plants incorporating thermal hydrolysis globally.

THE COMPLETE BOILER HOUSE SOLUTION

Torishima (Europe) Projects Limited [TEP] comprises of proven process, mechanical and electrical engineering teams who have over twenty-years of experience in delivering in the UK Water Sector. Dovetailing with this is a particular expertise in Project Management, installation, commissioning, integration and process optimisation. As a specialist in boiler house and associated process plant installations, we have a fully developed supply chain which has proved its competitiveness over recent awards and certainly offers value against established brands operating in this sector.

A key area of knowledge within the business is in relation to Advanced Anaerobic Digestion [AAD] processes, and in particular Thermal Hydrolysis and Acid Phase/Enzymic Hydrolysis systems.



Current Reference sites:

- Anglian Water
  - Basildon STW
  - Cliff Quay STW
  - Colchester STW
  - Pyewipe STW
- Thames Water
  - Crossness STW
  - Beckton STW
- Wessex Water
  - Trowbridge STW
- Yorkshire Water
  - Blackburn Meadows WWTW
- Severn Trent Water
  - Worksop STW
  - Wanlip STW

The TEP boiler house solution benefits from its partnership with the boiler manufacturer ICI Caldaie. ICI Caldaie Ltd has over 50 years of experience in manufacturing high-efficiency boilers for industrial and commercial use. Designed to the latest European standards the company's product range is more varied and comprehensive than anything else available in the market place. The sector-leading portfolio includes steam, thermal oil and hot water boilers as well as all boiler house ancillaries and safety systems fully compliant with latest legislation. Energy efficiency, reliability and environmental sustainability underpin the ICI Caldaie culture, with a number of innovative design features unique to its range.

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The full-scale commercial application of thermal hydrolysis of sewage sludge at Crossness and Beckton STWs enables the plants to utilise the solids portion of wastewater to produce commercially-valuable products directly from sewage waste; for example electricity and 'class A' biosolid fertilizers.

Beckton & Crossness THPs

Both the Beckton and Crossness plants incorporate thermal hydrolysis technology. The aim of the schemes was to allow refurbishment and continued use of the existing SPGs, with additional sludge treatment capacity provided by the new AD plants. The design throughput of the AD plants was 100tDS/day, with a peak of 115tDS/day.

The AD plants have been designed to accommodate a wide range of feed compositions from 100% primary sludge to 100% secondary activated sludge. The biogas produced from the AD plants is used in the combined heat and power (CHP) engines to generate heat and electricity. Dewatered digested sludge is recycled to land or potentially to the SPGs. All sludge liquors generated during sludge dewatering are treated at the main sewage treatment works.

The core process of the new AD plants is thermal hydrolysis of the sludge prior to digestion. This pre-treatment increases the digestibility of the sludge and plant throughput compared to conventional digesters.

Thermal hydrolysis process

The thermal hydrolysis process comprises two parallel THP streams, with each stream operating independently. Screened and dewatered blended sludge is fed intermittently into the pulper, where it is mixed and homogenised using external progressive cavity type pumps. Waste steam recovered from the reactors and flash tank is returned to the pulper to pre-heat the homogenised sludge.

Homogenised, pre-heated sludge is pumped from the pulper to each reactor, according to the batch sequence. Sludge in the reactors is heated by live steam injected directly via 'sparge' pipes.

The sludge is heated to raise the temperature and pressure to 165˚C and 6 bar respectively, and is then held under these conditions for 30 minutes. The pressure in the reactor vessel is reduced to 2-3 bar, by releasing steam back to the pulper.

The sludge is then discharged to the flash tank, using the pressure remaining in the reactor. The sudden de-pressurisation of the hydrolysed sludge causes cell walls to rupture, thereby increasing sludge digestibility.

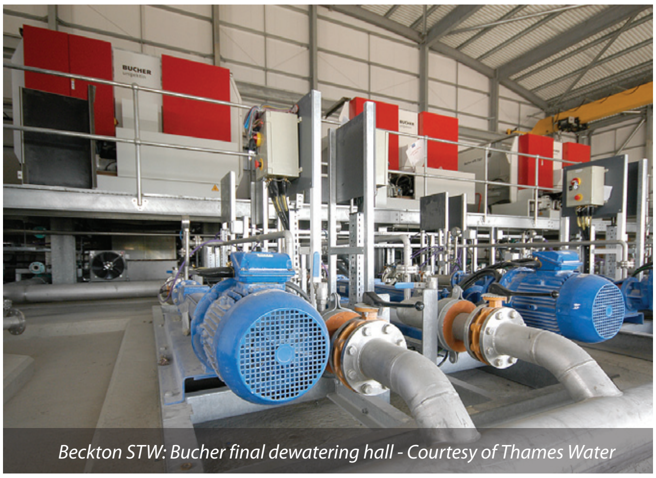
Hot, hydrolysed sludge is discharged from the flash tank and diluted with cold final effluent, to achieve the target %DS for feeding to the digesters. Each THP stream has two duty/standby progressive cavity pumps, which feed sludge forward to a common manifold for feeding 6 (No.) digesters.

Hydrolysed sludge is then fed into 6 (No.) existing primary digesters, which have been refurbished and returned to service. Each digester has an approximate 3,500m^3 working capacity, and a roof-mounted gas holder to provide biogas storage.

A combination of foam traps and condensation traps were installed at the outlet of each gas holder, and one condensate trap was installed at the lowest point of the combined biogas pipeline, just upstream of the biogas boosters. Condensate discharges to the existing foul drainage system.

Digested sludge from the digesters is pumped to post-digestion storage tanks and then dewatered using Bucher presses which produce a high dry solids cake, typically in excess of 40%, which

Beckton STW flue stack sampling platform - Courtesy of Thames Water



Beckton STW: Bucher final dewatering hall - Courtesy of Thames Water

Pre-thickening centrifuges - Courtesy of Thames Water

Beckton STW THP plant and digester with top mounted gasholders Courtesy of Thames Water

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reduces volumes for storage, transport and recycling. Thames Water is the first UK water company to invest in this technology.

Dewatered cake is subsequently stored in a fully enclosed cake storage area within the sludge cake building. All centrate and filtrate generated is treated at the main sewage treatment works.

Biogas is primarily used to supply 3 (No.) CHP engines (duty/assist/assist) to maximise green energy generation. Excess biogas is flared via the waste gas burner.

There are 2 (No.) composite steam boilers which are linked to the CHP engines by exhaust gas flues in order to recover heat from the hot engine gases, thereby reducing the amount of supplementary fuel (natural gas) required. The gas-fired side of each boiler is capable of generating up to 6,000kg/h of steam.

Each boiler has two separate waste heat sections, with one boiler linked to two CHPs and the other to a single CHP. Each waste heat recovery section is sized to generate up to 1,000kg/h of steam.

The biogas treatment and utilisation incorporates the following equipment:

Biogas Boosters: All biogas produced is stored in roof-mounted gas holders. Biogas from the digesters is boosted from 8mbar to 150mbar, via 3 (No.) duty/assist/standby biogas boosters.

Biogas Dehumidifier: Biogas supplied to the CHPs and boilers is dehumidified, to reduce the relative humidity of the biogas to 55% at 10°C. The dehumidification process involves cooling the biogas with a heat exchanger, with water as the cooling medium, and re-heating by a gas-gas heat exchanger, using the heat from the inlet raw biogas. Accumulated condensate is discharged to a collection tank and transferred to the return liquors pumping station.

Siloxane Removal: Due to risk of siloxanes in the biogas, a series of siloxane carbon filters have been installed. The system will operate in a primary/ secondary arrangement with removal of each carbon cartridge for off-site carbon replacement.

CHP Plant: 3 (No.) Edina packaged CHP units with MWM engines have been installed at each AD plant. Each containerised unit comprises the following:

- Gas engine.
- Alternator and all associated ancillaries.
- Exhaust silencers.
- Ground mounted waste heat dump radiator.
- A low-temperature hot water heat recovery circulation system.
- Control room.
- Compartment ventilation system.
- Separate dirty/clean oil storage tank system.

These engines are fuelled by the biogas generated in the digesters and each have the capacity to generate 2MWe. Each unit has an overall efficiency of 84.2% at 100% load, with 42.9% as electrical energy generation and 41.3% as recoverable thermal energy.

The CHP generators produce electricity at 11kV at Crossness and 6.6kV at Beckton, feeding into a new THP HV board. The new board is connected to the existing site HV switch gear through a dual-feed arrangement.

The CHP units' operation is controlled by an automatic generator management system (AGMS), which controls the operating load and number of operating CHPs according to the site HV configuration and the quantity of biogas generated. The AGMS will also control the HV breaker set-up, based on information from the site power management system.

Beckton STW: Bucher units for final sludge dewatering - Courtesy of Thames Water

During average design plant operation, sufficient biogas will be produced to generate 4.2MW of electricity. The number of CHPs in operation and the power output of each engine is therefore determined by the average biogas level in the gas holders. Each self-contained CHP unit is supplied with its own cooling circuit: intercooler circuit and engine cooler system.

Each of these systems is connected to a heat dump radiator, which is sized to be able to reject the maximum amount of heat from the intercooler water circuit (if there is no low-grade heat recovery). High-grade heat from the CHPs exhaust is recovered in the waste heat section of the steam boilers to generate steam for the thermal Hydrolysis plants.

Any additional steam demand by the THP is met by burning natural gas (as supplementary fuel) in the steam boilers. Low-grade heat from the CHPs cooling system is recovered to pre-heat the boiler feed water from 10°C to 70°C. All condensate recovered from the steam header and pipelines – via the steam traps and condensate drains – returns to the boiler water feed tank.

Site electrical demand

The site distribution network operator is UK Power Networks. The AD plants' total site electricity demand includes all the AD plant equipment operating at design load and design sludge feed composition. The peak electricity demand is associated with peak loads through the plant.

The site electrical demand only includes the ESDF and excludes the rest of the sewage treatment works. Power generated from the CHPs is for use on the Crossness and Beckton STWs and any excess will be exported. Electricity to the existing site is metered via two OFGEM certified power meters.

THP Site Electrical Demand Crossness	
Total installed capacity of the Generating Station (TIC)	*6,000kWe*
Declared Net Capacity of the Generating Station (DNC)	*5,794kWe*
Average Parasitic Load of the Generating Station	
• *Biogas Boosters*	*33kWe*
• *Biogas Dehumidifier*	*11kWe*
• *CHP auxiliaries*	*162kWe*
• *TOTAL*	*206kWe*
Total Average AD Plant Electrical Demand	*2,119kWe*
Total Maximum AD Plant Electrical Demand	*2,399kWe*
THP Site Electrical Demand Beckton	
Total installed capacity of the Generating Station (TIC)	*6,000kWe*
Declared Net Capacity of the Generating Station (DNC)	*5,794kWe*
Average Parasitic Load of the Generating Station	
• *Biogas Boosters*	*33kWe*
• *Biogas Dehumidifier*	*11kWe*
• *CHP auxiliaries*	*162kWe*
• *TOTAL*	*206kWe*
Total Average AD Plant Electrical Demand	*2,162kWe*
Total Maximum AD Plant Electrical Demand	*2,450kWe*

Undertakings

The work undertaken to construct and install the THP plants at Crossness and Beckton was carried out by Tamesis, a Joint Venture between Laing O'Rourke and Imtech. Other contractors on the schemes included:

Key Participants	
Thermal Hydrolysis Plant	Cambi
CHPs	Edina
Boiler house	Torishima
Centrifuges	GEA
Final thickening	Bucher
Poly plants	Richard Alan
Thickened sludge storage	Spirac
Gas holders and GCS tanks	Kirk Environmental
Sludge coolers	HRS
Mechanical installation	Merit Merrell JK Fabrication
Steelworks	ECS Billingtons
Cladding	FK Group
MCCs	GPS
HV panels	HSSL
HV installation	IUS
LV installation (Crossness)	Imtech Engineering Services Central
LV installation (Beckton)	Bridges
Systems integration & AGMs	Capula

Civil construction at Crossness started in October 2012, with the mechanical installation commencing in April 2013. Dry commissioning started in February 2014 and wet commissioning started in April 2014. The THP plant was first fired in May 2014, with electricity production planned for August 2014.

At Beckton, the civil construction started October 2012, with the mechanical installation commencing in July 2013. Dry commissioning started in July 2014 and wet commissioning started in August 2014. The THP plant is planned for start-up in September 2014, with electricity production planned for October 2014.

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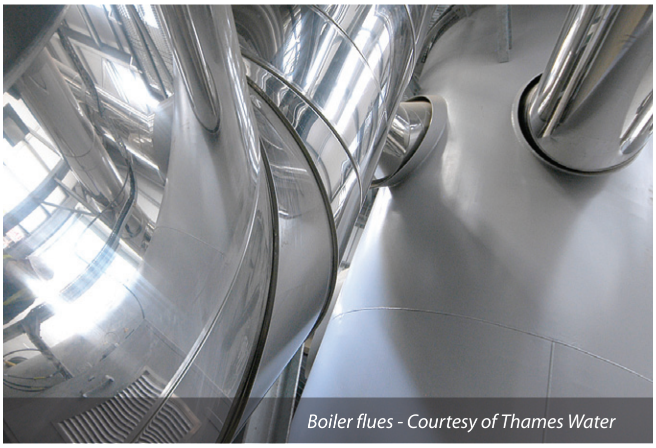

Boiler flues - Courtesy of Thames Water