



BV Dairy AD Plant

Operating Techniques



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1. Introduction to Anaerobic Digestion

This section will provide a brief introduction to the process of anaerobic digestion and will identify the common indicators of digester failure.

Anaerobic digestion is the breakdown of biological material by micro-organisms under anaerobic conditions. A number of different bacteria work together, transforming biological material into biogas. There are three main steps in this process:

Hydrolysis

This is the initial stage of anaerobic digestion; it is the breakdown of the larger compounds (i.e. proteins, carbo-hydrates, fats) into smaller compounds (i.e. amino-acids, simple sugars, fatty acids). Failure of this stage can be shown by an accumulation of solids, due to the failure of solid breakdown and, by a decline in the methane yield.

Acidogenesis

The smaller molecules produced by the hydrolysis stage are converted in this stage to mainly acid products: this is known as fermentation. The acids that are produced are known as Volatile Fatty Acids (VFAs); these still have the potential for future breakdown.

Acetogenesis

The third stage of anaerobic digestion is acetogenesis. Here, simple molecules created through the acidogenesis phase are further digested by acetogens to produce largely acetic acid, as well as carbon dioxide and hydrogen.

Methanogenesis

The acetate produced in the acidogenesis stage will be used in this stage by methane-producing bacteria resulting in the production of methane. This stage is the most sensitive of the process; a failure in this stage will be highlighted by an accumulation of VFA's and this is often the first sign of digester failure.

Anaerobic digestion relies on a number of different groups of bacteria all of which can be inhibited if there are unfavourable conditions within the digester. The success of anaerobic digestion is dependent on the successful performance of all four stages to ensure that complete breakdown can occur without any intermediates, such as VFAs, accumulating. To ensure that the process of anaerobic digestion is performing correctly and no inhibition is taking place it is important that the parameters listed in the laboratory timetable are measured frequently. This will recognise any imbalances in the process as early as possible to avoid failure and/or reduction in gas yield. Any significant changes in the measurements, especially COD and VFA, must be carefully monitored.

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If a decline in methane, quantity and quality, is observed or/and an increase in the VFA's to concentrations greater than 500 mg l⁻¹, feeding to the digester should be reduced or stopped all together to avoid digester failure.

The table below provides some information on the different parameters and their recommended optimal levels.

Parameter	Optimal levels
pH	A neutral pH of 7 is the optimal for the methane-producing bacteria. If the pH is lower/higher a reduced methane yield can be observed
Volatile Fatty Acids	The concentration of VFA's should remain below 500 mg l ⁻¹ ; higher concentrations can result in digester failure. VFA's are made of a number of different acids including propionic which can exert toxicity onto the digester. Individual acids cannot be measured on site but samples can be analysed at the University of Southampton.
Ammonical-nitrogen (NH ₄ -N)	Concentrations of 50-200 mg l ⁻¹ can be beneficial to the digestion process and concentrations up to 1000 mg l ⁻¹ do not have any adverse effects on the system. Concentrations of over 1500 mg l ⁻¹ can be inhibitory to the system
Temperature	The target for the digester's temperature is 30°C; this should be carefully monitored and maintained: a decline in the temperature can lead to a reduction in the methane yield – if working properly, and all other parameters are on target, our digester can withstand temperatures as low as 20°C, however always aim for a minimum of 25°C.
Chemical Oxygen Demand (COD)	This must be carefully monitored as an increase in COD could be indicating an imbalance in the system: the COD entering the digester via the feed may not be breaking down therefore accumulating within the digester. A high COD may also be highlighting an elevated level of VFAs. If COD continues to increase the level of feed should be reduced and monitored to see if the level declines



2. Operating techniques of the BV Dairy digester

This section will detail the actual process that is followed at the AD site. Figure 1 shows the layout of the site and Figure 2 shows a schematic block process flow diagram of the whole process. The design capacity of the plant is 202T/day.

The process can be separated in to several sections as described below.

1. Waste pre-assessment

All waste feedstock into the AD plant is sourced from the adjacent BV Dairy operated factory. The factory manufactures soft cheeses, yogurts and clotted cream on a 24/7, 364 day per annum operation.

The raw material for the manufacturing process is milk sourced from local farms. All milk deliveries are tested and certified as being pesticide free by a third party laboratory. In addition heavy metals, Veterinary Medicines Multi-Residue Screen 1 and Raw milk Aflatoxin levels are also tested by a third party laboratory. Controls and sampling at this stage prevents these contaminants passing through the manufacturing process into the waste streams and subsequently the AD plant.

Feedstock comprises two fractions, permeate and trade effluent separately collected within tanks at the factory:

- Permeate – A by-product of the soft cheese process with a high COD value.
- Trade – A composite effluent from the drains in the factory, containing washings from the floor of the factory and excess product and raw materials from the Cleaning in Place (CIP) process. Timed composite samples of Trade are taken over a 24 hour period and tested for COD and pH.

2. Waste acceptance

The permeate and trade are transferred separately by automatic pumps from the factory through sealed underground pipework to the AD plant equalisation tanks, one for each waste type.

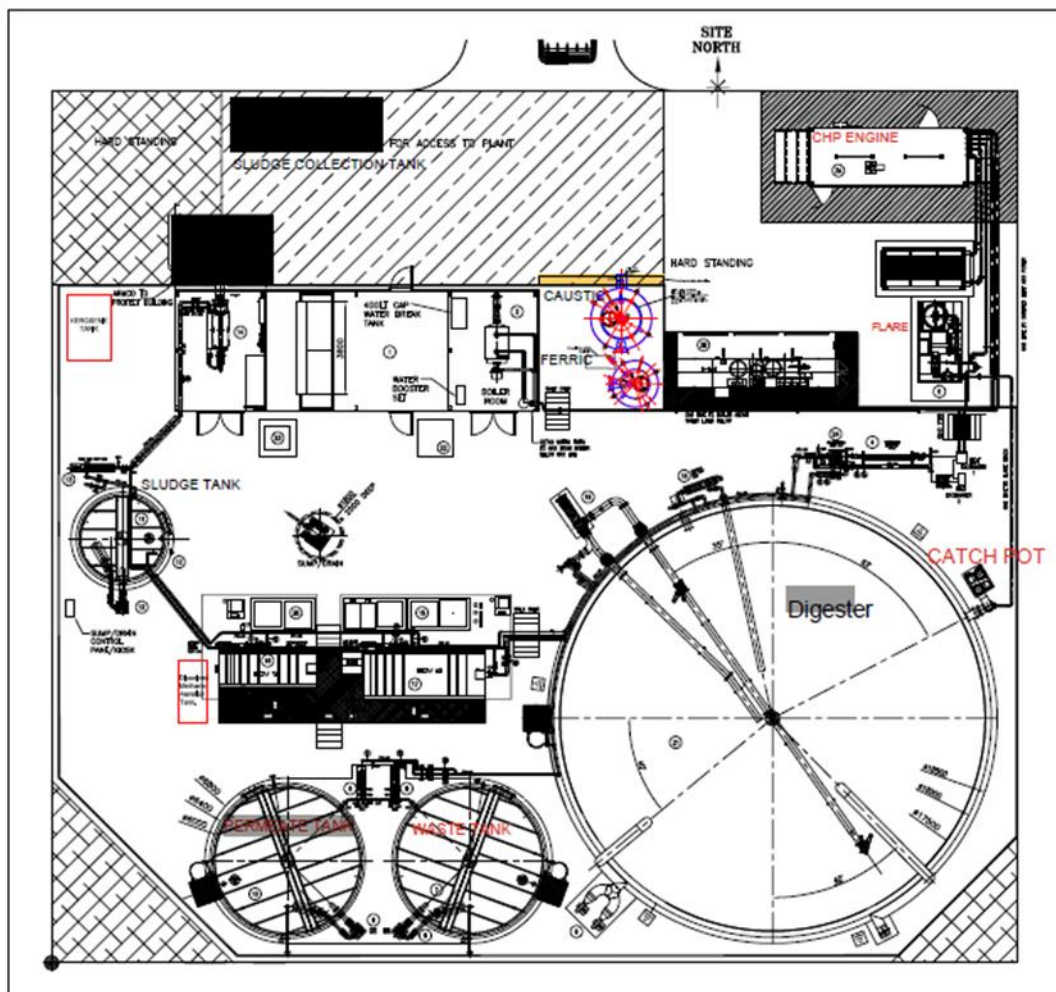
3. Equalisation tanks

These equalisation tanks are used as storage and to balance the flow of the two feed sources, into the digester. Both have a capacity of 150 m³. The height of the contents of both tanks are measured continuously by pressure sensors within the tanks with recordings sent back to the SCADA control panel and management system which automatically controls the AD plant. Automatic cut-offs in the PCL control system are in place to prevent tank overfilling.

Each tank is constructed from steel and has been assessed to conform to ISO 28765 & BS7543 :2003. Above ground pipework is lagged to prevent loss of heat between the tanks and the digester, thus saving on energy required to maintain the digester temperature as the incoming effluent does not lose heat during transfer.

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Figure 1, site layout



4. Digester

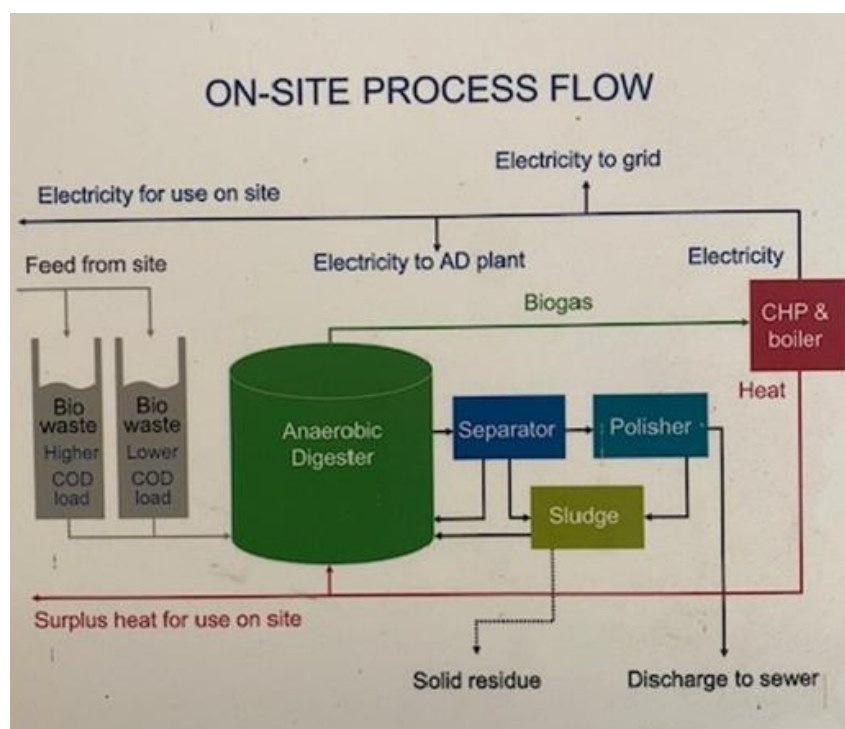
The digester is a simple continuously stirred insulated tank that has a working volume of 1000 m³ with a 200 m³ gas space. The digestate height is monitored by a pressure sensor with the measurement recorded by the SCADA control panel. Automatic cut-offs in the PCL control system are in place to prevent tank overflowing. In addition to the digestate height, the temperature and pH within the digester are continuously measured. If the pH level falls below specific parameters the PCL control system will automatically dose caustic into the digester to raise the pH to above the limit value.

The digester tank is constructed from concrete and has been assessed to conform to BS 8110 & BS 8007. Above ground pipework is lagged to prevent loss of heat between the tanks and the digester, thus saving on energy required to maintain the digester temperature as the incoming effluent does not lose heat during transfer. Heat to the digester is provided via a heat exchanger attached to the CHP unit. This ensures the digester is maintained at optimum

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temperature for biological reaction, whilst saving on the use of fossil fuels required should the boiler be used.

Figure 2, Process flow diagram



5. Cavitation Air Floatation Thickener (CAFT)

This process is now converted to Dissolved Air Floatation (DAF), whereby the mechanical stirring action has been replaced by a high pressure , low volume aerator in the base of the tank to provide microbubbles to bring the solids to the surface.

The effluent from the digester is pumped via the thickener feed to CAFT. MC2265 cationic polymer is injected into the line and secondly the AE27 anionic polymer is injected before entering CAFT to create solid separation. When the digestate and blended polymer enters CAFT, DAF water is introduced to create flocculation and floatation. The aim of this is to return the solids to the digester and to send treated effluent forward to the next stge. This will maximise the biomass retention within the digester. If the solids level within the digester has reached the upper limit, the solids can be diverted to the sludge tank to be removed from site via third party haulier.

6. Flocculator

Treated effluent travels from CAFT to the Flocculator during which ferric chloride is dosed to create Phosphate separation. The flocculator has a large paddle which stirs the treated effluent to mix the ferric chloride and treated effluent. The treated effluent then travels to CAFP where further AE27 anionic polymer is injected to bind the separated Phosphate to create a floc

7. Cavitation Air Floatation Polisher (CAFP)

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This process is now converted to Dissolved Air Floatation (DAF), whereby the mechanical stirring action has been replaced by a high pressure , low volume aerator in the base of the tank to provide microbubbles to bring the solids to the surface.

The liquid fraction from CAFT will enter CAFP via the Flocculator to facilitate solid separation in CAFP. The separated solids from the CAFP now enter the sludge tank, while the liquid fraction will enter the Dissolved Methane removal system.

8. Dissolved Methane removal system

This system has been adapted to the CAFT and introduced into an additional aeration tank adjacent to CAFP. The system comprises a series of aeration disks installed after CAFP that are designed to disturb post-separated liquid to facilitate the release of any dissolved methane in solution within the effluent. Effluent from this tank then passes to the sump to be pumped to sewer. This stage is important as it stops the dissolved methane being transferred into sewer pipes and holding tanks, thus removing the potential to be subsequently released and cause an explosive atmosphere down stream of BV Dairy.

9. Sludge Storage Tank

The sludge from CAFT or CAFP can be pumped into this tank and will be stored until a collection is arranged. We use a third party tanker company to collect the digestate. Due to the small size of the sludge tank there is an additional sludge holding tank which is filled prior to scheduled collections. The additional tank has capacity for a full tanker load. It is essential this tank is filled no more than 24 hours prior to collection due to the fact that there is no mixing system on the tank. Consequently storage longer than 24 hours will cause the sludge to separate out and cause problems whilst trying to load into the tanker.

10. Catch Pot

The catch pot is a secondary safety device connected to the digester tank. In the event that there is more gas produced within the digester than being used by the gas engine or flare, the catch pot will allow the gas to escape to atmosphere, relieving pressure, rather than the dome becoming damaged or rupture. Upon activation of the catch pot, sensors within it will stop both trade and permeate feeds and PLC system will automatically alert site personnel.

11. Flare

The ground flare is a primary safety device with a nominal capacity of 135 m³/hr. Its function is to burn any excess gas that is not used by the CHP unit due to either breakdown, maintenance, insufficient gas or low methane content. The flare unit contains the pump used to supply the CHP engine and also the flare. The flare ignites automatically upon sensing that the gas dome level is above 80% of its maximum capacity. Activation of the flare prevents the gas volume within the digester reaching a critical level as determined by the PLC control system. Should the gas volume exceed this critical level for any reason, the liquid within the catch pot will be pushed out and gas released into the atmosphere.

12. CHP Unit

The CHP unit comprises an internal combustion engine converted to run on biogas connected to a generator and a heat exchanger taking heat from the exhaust. The engine has a rated

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thermal input of 0.6MW Thermal. The primary function is to generate electricity for use in the factory, saving approximately 15-20% of the factory's electricity use from the national grid, thereby reducing the carbon footprint of the factory. As a by-product, the excess heat captured from the engine is used to keep the biomass in the digester warm, again saving on fossil fuel usage that would be required if the boiler had to be used.

13. Raw Material usage

The operation of the AD Plant requires a number of proprietary substances to ensure that the optimum conditions are maintained within the digester and also to facilitate the removal and separation of digestate from the liquid effluent. Table 1 contains these raw materials and their uses.

Table 1 – Raw materials.

Description of raw material and composition	Maximum amount (tonnes)	Annual throughput (tonnes each year)	Description of the use of the raw material including any main hazards (include safety data sheets)
Water	N/A	5,500	Polymer dilution distributed from the sparge arm to prevent foam build-up.
Sodium Hydroxide (Caustic 32%)	2.7	1	pH balance within the digester.
AE27 Anionic polymer	1.2	6	Flocculant for use in CAF T and P
C33 Cationic polymer	2.7	19	Flocculant for use in CAF T
Ferric Chloride	2.7	17	Used to reduce H ₂ S in the digester.
ANTIPREX	1.0	1	Prevents the build-up of struvite.
Kerosene	3.0	14	Fuel for boiler to heat digester.

14. Secondary Containment

The whole AD plant and associated activities including the digester, storage tanks, CHP unit, and offices are contained within a sunken impermeable concrete and HDPE lined base and 2m high side walls. This secondary containment has been assessed against the CIRIA 736 standard and was found to be appropriate for the risk presented, however 3 minor remedial elements were itemised which are currently being addressed to bring up to a satisfactory standard.

15. Monitoring and emission controls

In addition to the monitoring undertaken in the factory and within the AD Plant as described above additional monitoring is performed at the AD plant.

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Daily samples are tested for COD and pH for the digestate, Trade and Permeate and treated effluent sent to sewer. In addition Total phosphates are sampled daily from the treated effluent in accordance with the site's discharge consent. Gas composition is also sampled for methane, carbon dioxide and hydrogen sulphate.

The AD Plant system is designed to be enclosed therefore reducing the number of emission points. As previously stated all delivery, transfer and treatments are undertaken in sealed pipework and tanks.

Monitoring of gas leaks from pipework and the CHP system are undertaken on a six monthly basis using a Optical Gas Imaging (OGI) Camera.

Daily odour monitoring using the site Odour Management Plan and visual inspections are undertaken to determine if any fugitive emissions are occurring other than at the nominated emission points.

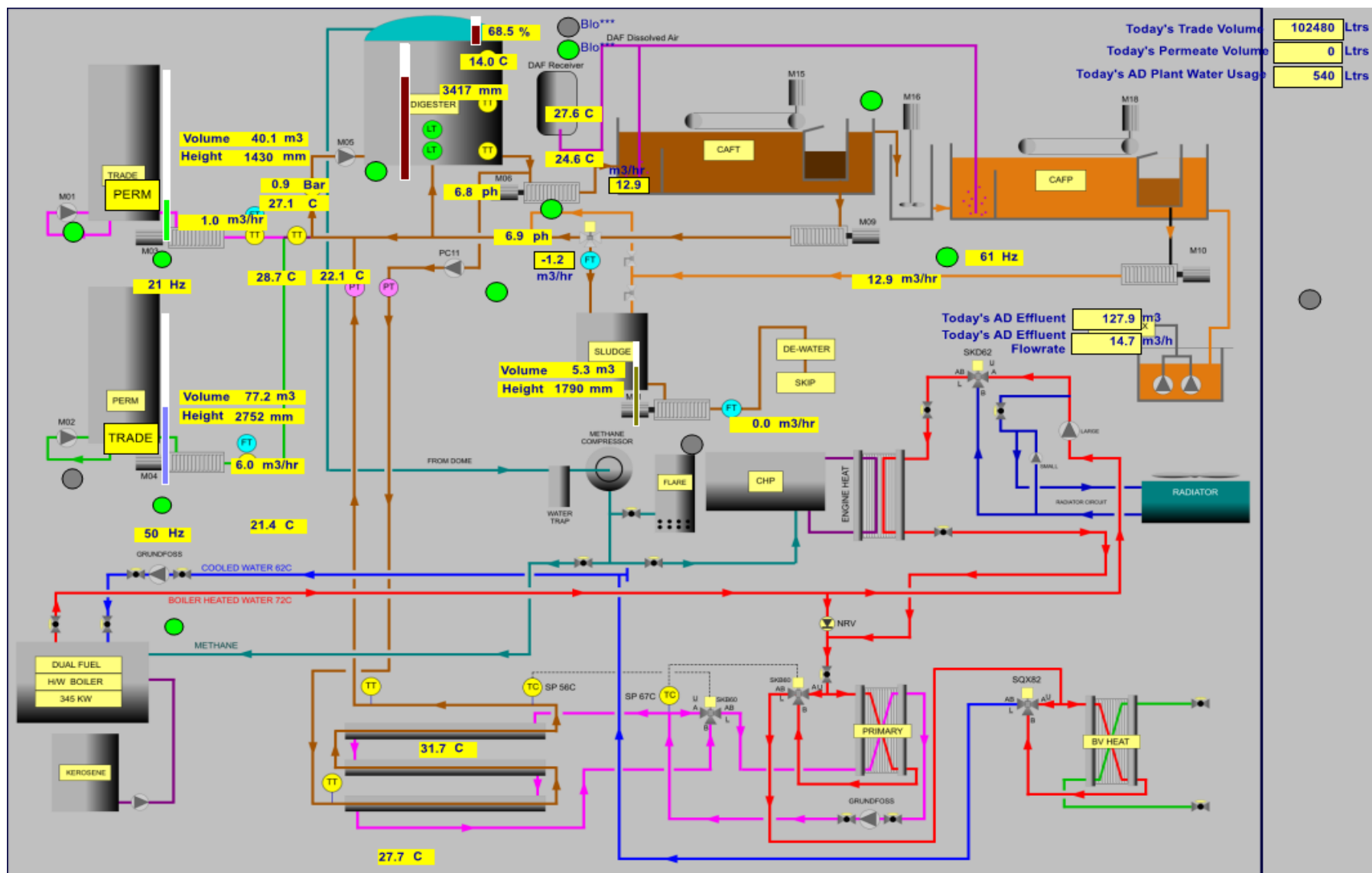
In accordance with the permit, annual monitoring of the engine stack is undertaken for the determinants in Table 2

Table 2 Point source emissions to air				
Emission point reference and location	Source	Parameter	Quantity	Unit
Generator Exhaust before heat exchanger.	Generator Exhaust	Oxides of Nitrogen	500	mg/Nm ³
	Generator Exhaust	Carbon Monoxide	1400	mg/Nm ³
	Generator Exhaust	Sulphur Dioxide	350	mg/Nm ³
	Generator Exhaust	Total volatile organic compounds including methane	1000	mg/Nm ³
	Generator Exhaust	Non-methane volatile organic compounds	75	mg/Nm ³
	Generator Exhaust	Temperature	>200	°C
Gas Flare	Gas Flare	Oxides of Nitrogen	150	mg/Nm ³
	Gas Flare	Carbon Monoxide	50	mg/Nm ³
	Gas Flare	Total volatile organic compounds including methane	10	mg/Nm ³

The following page shows a snap shot of the AD plant mimic screen from the SCADA system. This image will give you an idea of pipe runs, pressure sensors, flow meters, tank levels etc.

Please note that the dissolved methane removal system is not shown due to being a new system.

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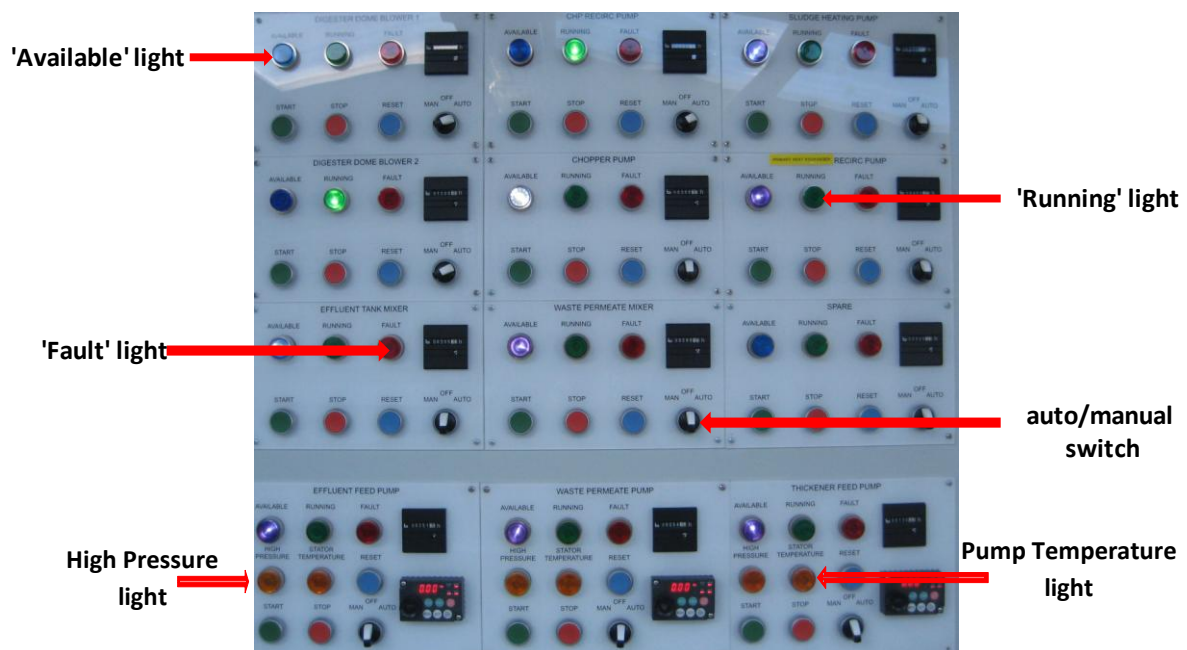


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3. Introduction to the control panel

The AD plant is partially automated and is controlled by the control panel and the Programmable Logical Controller (PLC) screen located in the Control Room. The digester can be run either in manual or automatic operation. Automatic should be selected as controls are in place to protect the plant from unintentional failure, i.e. tanks running dry or overflowing, heating systems getting to hot or cold. Manual should only be used in an emergency or to override. The system should run in Automatic unless there is a significant reason and the item that is running in hand is monitored and not left unattended.

Automatic control



- All of the switches should be turned to 'auto'
- There are five indicating lights which should be monitored:
 - **Fault:** An error has occurred with the pump/mixer
 - **Available:** The pump/mixer is not on but when it is required it is available. This light will be on in the case when that specific pump is not required (i.e. Permeate pump will show available when there is not enough permeate in the storage tank to run).
 - **High Pressure:** A feed Pump has exceeded the set pressure, line blockage or valve closed.
 - **Stator Temperature:** Pump is working harder than it should, line blockage, pump failing.
 - **'Running':** Pump/mixer is running

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The automatic running of the digester can be controlled from the PLC screen located next to the control panel. From this screen the following adjustments can be made:

Rate of feed

The rate of the feed is controlled by two factors: the height of the digester and the height of the feed in the equalisation tank.

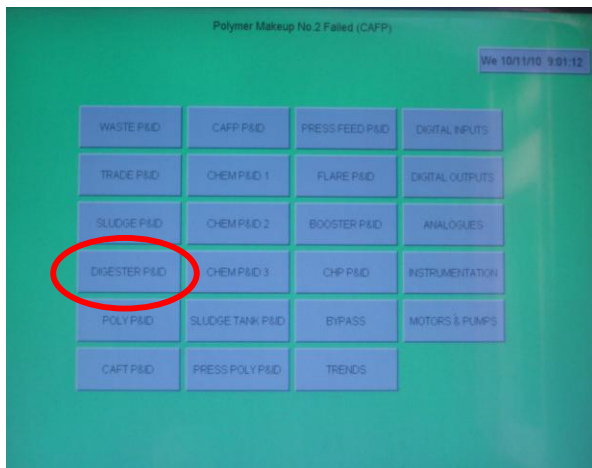
Equalisation tank

The pumping of the feed will stop once the height in the tank falls below a given value, which can be adjusted by:

1. Select 'Trade P&ID' from the main screen
2. Select 'Trade set up'
3. From the set up screen select 'Level Lo Stop trade effluent pump'.
4. Enter the new height and press enter
5. Repeat this for the permeate by selecting 'Waste P&ID'

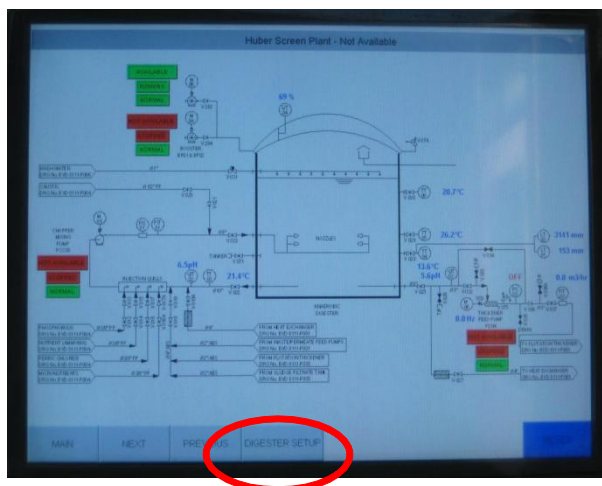
Digester height

Feeding of the digester can be controlled by the height of the digester, which can be adjusted via the PLC screen. When the digester exceeds that specified, the pumping of the feed will stop and will not start until the height falls. To adjust the height:

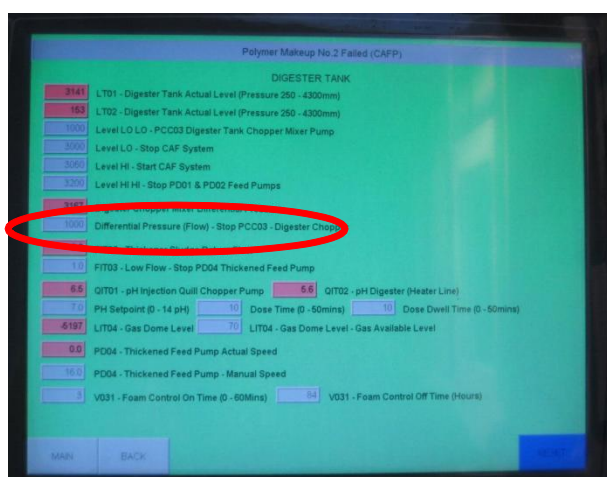


- 1 From the main screen select 'digester P&ID'

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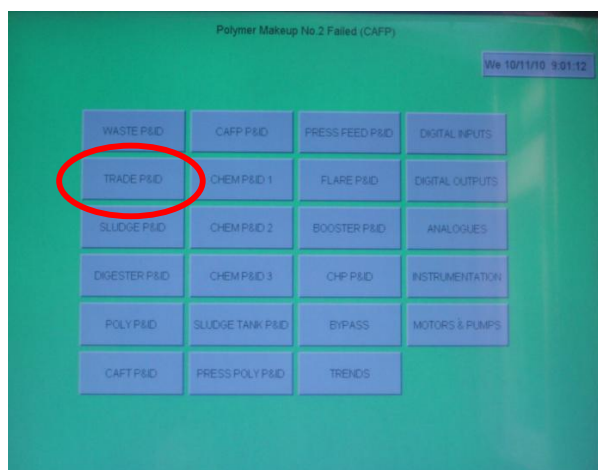


- 2 From the digester screen, select '**digester set up**'



- 3 From the digester set-up screen select '**level HI HI -stop feed pumps**' to increase or lower the height (in mm)

The amount of feed entering the digester can be altered by adjusting the feed pumps by:



- 1 From the main screen select 'trade P & ID' to display a diagram of the two feed storage tanks

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1. Select 'trade set up' at the bottom of the screen
2. From the set up screen the speed of the pump (in Hz) can be altered by selecting 'Trade-effluent pump actual speed' and entering the new pump speed.
3. Repeat this process for permeate but select 'waste P & ID' from the main menu

Running of the CAF system

The CAF system will be controlled by two factors, the height of the digester and the height of the sludge in the sludge storage tank.

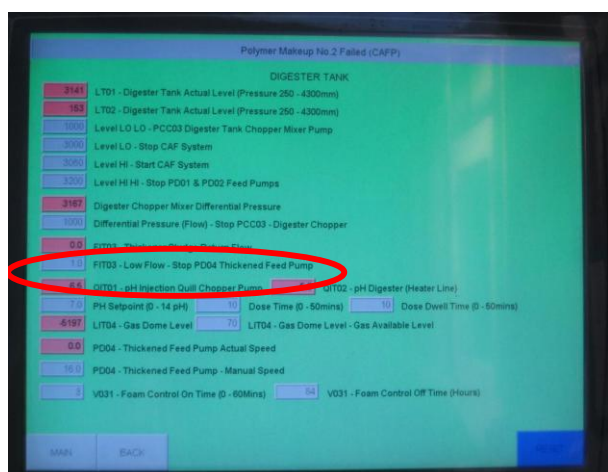
Sludge tank

Separated digestate from the CAFs can either go back to the digester or be sent to the sludge tank. The valve arrangement allows you to send from either just CAF P or from both CAF T and P (see sludge tank filling SOP document BVD 8.12.18 for full details). The fill height can be changed via the setpoint, when the fill set point is achieved the CAFs will stop to prevent overfilling / overflow providing the CAF is running in auto.

Digester height

This is adjustable and can be altered by following the below instructions.

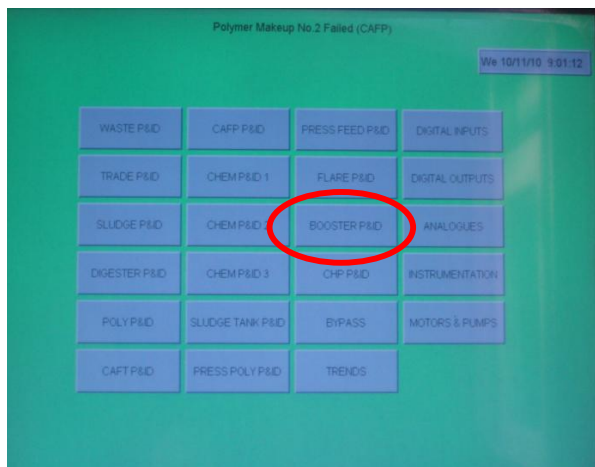
1. Follow instructions under 'pumping of feed' for 'digester height'



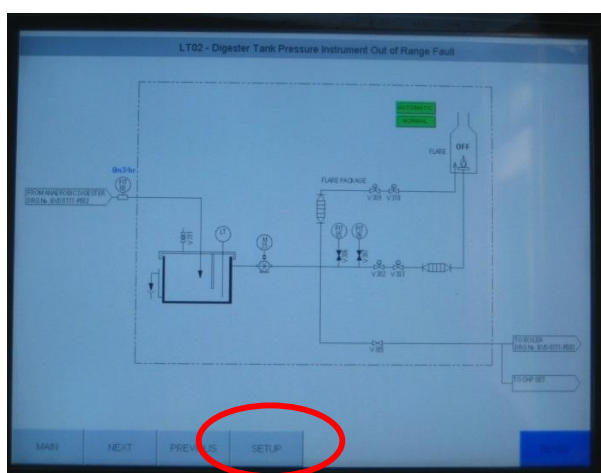
2. From the digester set up screen select the 'level LO –stop CAF' or/and 'level HI- start CAF system' to adjust the height (in mm)

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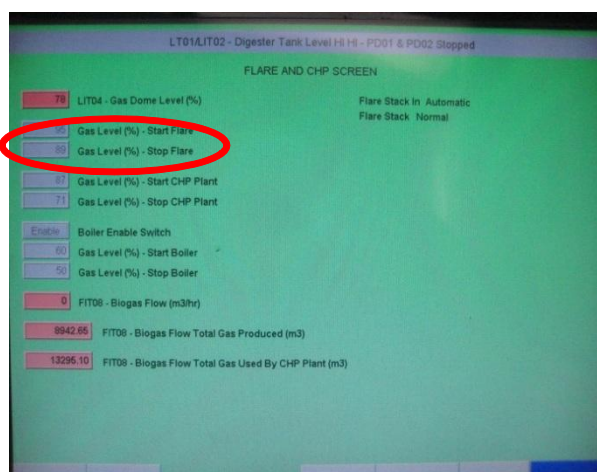
Running of the flare and CHP unit



- 1 From the main screen select 'flare P & ID' to display a diagram of the flare

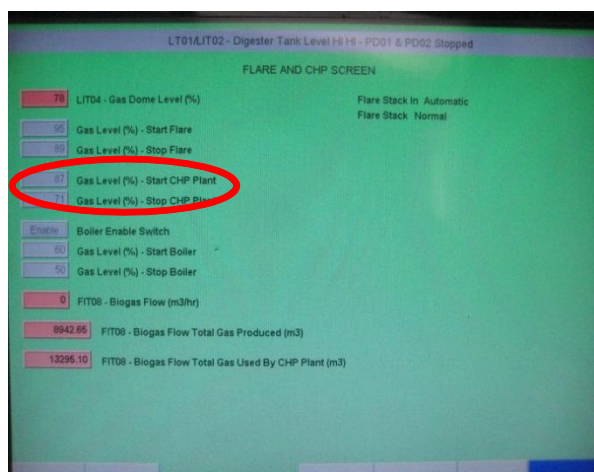


- 2 Select 'set-up' at the bottom of the screen



- 3 To adjust the start of the flare select 'Gas level (%) - start flare' and adjust the value
- 4 To adjust when the flare stops, select 'Gas level (%) - stop flare' and adjust the value

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- 5 To adjust the start of the CHP select 'Gas level (%) -start CHP plant' and adjust the value
- 6 To adjust when the CHP stops, select 'Gas level (%) -stop CHP plant' and adjust the value

4. Running of the AD plant

Daily checks

The following information should be checked on a daily basis by manual checks at the AD plant. The

1. All pumps/mixers are working, especially the polymer dosing
2. Any leakage from tanks, CAFs and pipework, any leaks should be reported to your line manager immediately.
3. Visual check of the CAF system, if the CAF doesn't look right and there is sludge carry over you will need to investigate. This will involve checking polymer IBC levels, checking polymer make up systems and if there is no resolve a jar test may need to be carried out to confirm polymer dose rates are correct (BVD 8.12.17).
4. Flow of the effluent / trade and permeate pump.
5. Digester height, temperature, pH and flow to the CAFT
6. Complete daily laboratory tests (refer to laboratory daily timetable)

Critical limits

The suggested limits of the vital parameters are given in Table 2; this acts as a general guideline.

Table 2: Parameter limits

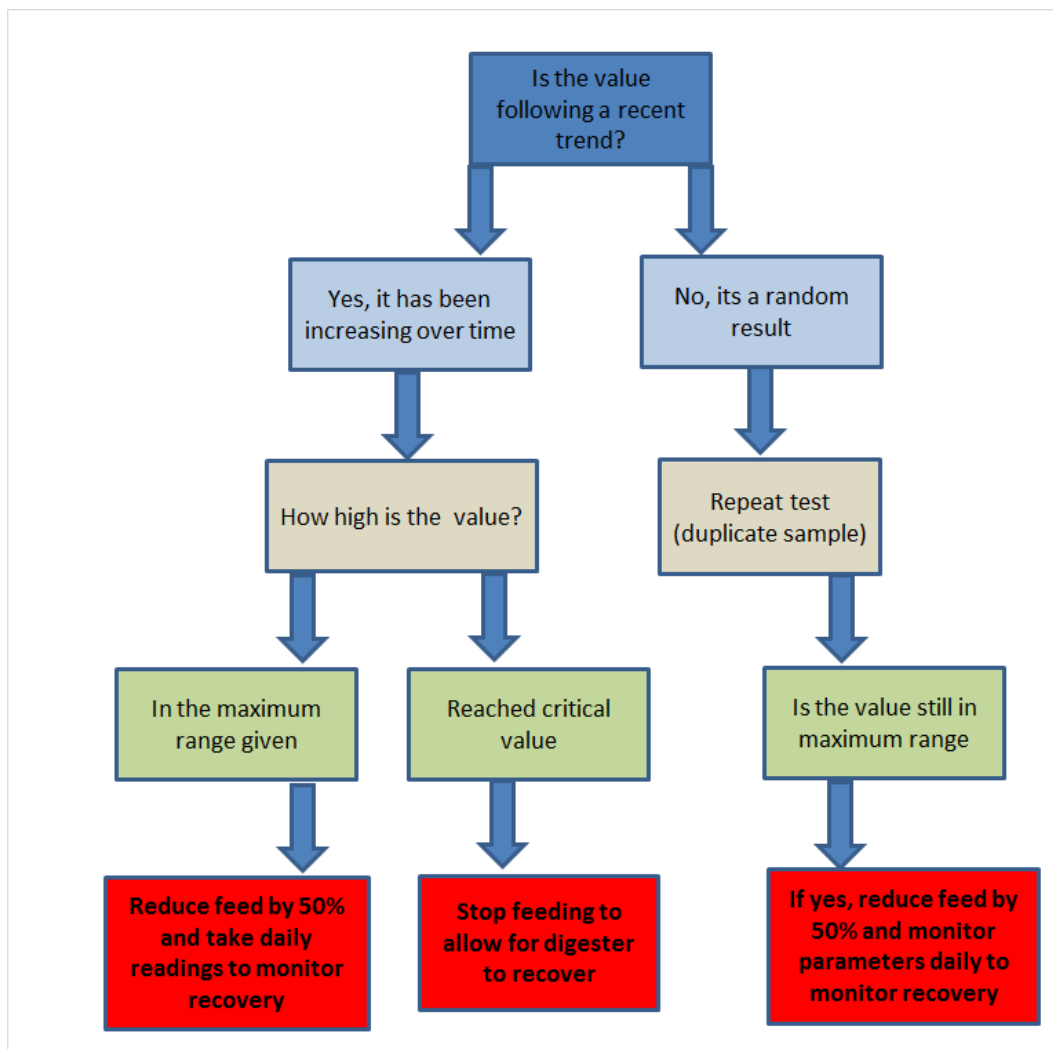
Parameter	Minimum Value	Optimal Value	Maximum Range	Critical range (reduce/stop feeding)
pH	6.8	6.8-7.2	7.25	Below 6.7 or above 7.4
Volatile Fatty Acids	n/a	0-300 mg l ⁻¹	300-500 mg l ⁻¹	>500 mg l ⁻¹
Ammonical-nitrogen (NH ₄ -N)	50 mg l ⁻¹	50-200 mg l ⁻¹	200-1000 mg l ⁻¹	>1000 mg l ⁻¹
Chemical Oxygen Demand (COD)	0 mg l ⁻¹	0-400 mg l ⁻¹	500-800 mg l ⁻¹	>800 mg l ⁻¹
Methane	56%	60-68%	n/a	<55%

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Solids %	1.8%	2%	2.2%	<1.5% or >2.6%
H2S ppm	n/a	<200ppm	500ppm	Check Ferric dosing

Instructions in the case of digester failure

In the case of a value falling outside the optimal range follow the below flow diagram for the appropriate course of action:



If the **feed has to be reduced** follow the below steps:

If parameters fall back into the optimal load within 1-2 days or evidence of reduction is shown:

- Increase feed by 10% and continue at this feed level for 1-2 weeks with careful monitoring.
- If stability in the optimal range remains, increase the load by 10% and run for a further 1-2 weeks to ensure stability.
- If stability continues increase feed by 20% and leave at this load for 3-4 weeks

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If no improvement to the parameters occurs with 1-2 days or if the parameters reach the critical value stop feed to allow digester to recover.

5. Trouble shooting guide

This guide is examples of issues that have happened in the past and what the resolve was at that time, there may be something else that has failed but this guide will give you a starting point to investigate. Not all solutions are shown as there may be other problems causing the issue. If you are unsure about something or something doesn't seem correct consult with either the AD plant engineer or Technical for advice.

Trade tank feed volume lower than expected, at full speed the flow rate should be around 7.2m ³	• NRV Partially blocked, remove and check. • Rotor or stator or both worn, Replace.
Permeate tank feed volume lower than expected, at full speed the flow rate should be around 2.1m ³	• NRV Partially blocked, remove and check. • Rotor or stator or both worn, Replace.
Digester foaming / overflowed via gas line / catch pot.	• Check for any large / sudden changes to digester feed stock (particularly a high increase in COD and volume of feed into digester). • Check anti foam device is running / working. (currently undergoing maintenance).
Digester feed erratic, feed pumps stop start due to digester height reaching setpoint value.	• Potentially a build up of gas in the line which houses the level pressure sensor. a build up of gas in this line can give a false reading of the digester height. Remove sensor and flush though / check line.
Digestate COD is above critical limit	• We have found that running the digester at a height of above 3400 allows a crust to form where the digestate doesn't mix properly. Due to this we aim to run the digester at a height of 3200. Periodically (every other month) reduce this level to 2800 to encourage better mixing within the digester.

Chopper pump starts up but trips out after a few seconds.	Check the line pressure sensor, if this value is less than 0.3 bar when the chopper pump is running the pump will trip out. A rough guide is when the pump is off (static pressure) the value should be 0.1 bar per meter head pressure from the digester, then when the pump is running it should give another 1 bar pressure. So with the chopper pump running and a digester height of 3 meters you should see a value of 1.3 bar.
Sludge heating system Delta T is low.	- Sludge H/E requires cleaning. - Heat source off, check CHP is running, Check boiler is running.
Sludge heating system Delta T is ok or higher than expected, However the digester is not gaining / maintaining heat.	- Extreme cold weather can influence this. Put the boiler into original mode to run all the time during this period. - Low flow rate through the sludge H/E, work the gate valve that feeds the sludge H/E system and Thickener pump, Check the NRV is clear just after the sludge heating pump.
Prominent Poly make up system not running even though the last chamber is empty.	Check the level probes in the last chamber, sometimes there is a build-up on the probes and they require a clean.



By signing this document, I agree that I have read, understood and will comply with all health and safety points raised and will adhere to all instructions within this version of the S.O.P.

Print Name Trainer	Duration	Type of training +	Trainee signature	Trainee print name	Date

+ Key

FT = First training

PC = Procedure change

R = Refresher

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