South West Water	
Technical Standard	**Wastewater Treatment Sludge Digestion**
Ref : SWW-TS-061 (Issue 4.0) **Issue Date: 24 March 2020** **Status : Issue** **Author: G. Lincoln**	

Wastewater Treatment Sludge Digestion
SWW-TS-061

Author: G. Lincoln
Issue No. 4.0
Status: Issue

Authorised by :I. Lake
Next Review Date: 2022
Ref.: SWW-TS-061

A. INTRODUCTION

I. Purpose

This standard determines the general technical requirements for Sewage Sludge Digestion Plant for use by South West Water.

Sludge digestion refers to Anaerobic Digestion (AD) of municipal sewage sludge. The process consists of a primary mesophilic anaerobic digestion stage, followed by an unheated secondary digestion stage.

Process variants including pre-pasteurisation, acid hydrolysis and thermal hydrolysis (THP) are hereafter collectively referred to as Advanced Anaerobic digestion processes (AAD). Their process specific requirements are not covered by this technical standard.

II. Scope

The Standard shall be applied to the construction of all new anaerobic sludge digestion plant and to the maintenance or upgrading of existing plant

This standard shall be read in conjunction with Wastewater Sludge Treatment TS425.

This standard supersedes existing TS061 (Issue 3) and TS 074 (Issue 2).

III. Responsibilities

This document shall be used by all designers, contractors and consultants who may be designing works or part thereof for South West Water. It is the responsibility of the Contracts Manager and the Project Manager directly responsible for managing a project to ensure that the clauses set herewith are adhered to.

All designers and contractors shall ensure that this standard is applied to all new plant.

Acceptance of any new design shall only be granted on evidence of a reduction of risk to personnel or the environment submitted through a TS-411 variation. Variations may be submitted through the TS-411 SharePoint site.

IV. Enquiries

Technical Standards:
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V. Definitions

The following definitions are used within this Technical Standard:

1. The term 'Purchaser' shall mean the end user or the end user's nominated representative.

2. The term 'approved' shall mean approved by the Purchaser or his nominated representative. Approval shall be obtained in writing.

3. Unless otherwise specified elsewhere (e.g. in a particular specification) the term 'Designer' shall mean the party responsible for the design, construction and works testing.

Glossary of Terms

AD	Anaerobic Digestion
AAD	Advanced Anaerobic Digestion
CH_4	Methane (Biogas monitoring parameter)
CCP	Critical Control Point
H_2S	Hydrogen Sulphide
HACCP	Hazard Analysis and Critical Control Point
IPPC	Integrated Pollution Prevention and Control (EA permit)
LEL	Lower Explosive Limit
PE (p.e.)	Population Equivalent
RAMS	Risk Assessment / Method Statement
VFA	Volatile Fatty Acids (digester monitoring parameter)
WAMITAB	Waste Management Industry Training and Advisory Board

B CONTENTS

C CHANGES TO THIS DOCUMENT

DESCRIPTION OF CHANGE
Issue 2 – reviewed 01 Sep /2010
Issue 3 – Updated and revised including TSAL37 content (Biogas pipework) 12 Mar 2018
Issue 4 – Completely updated and revised to incorporate TS074 (Digester Safety) and include maintenance, commissioning/decommissioning, instrumentation and monitoring requirements.

D CONSULTEES (CURRENT ISSUE)

Engineering	D Curtis, JMcCarey, J Laws, J Russell, S Long
Asset Planning	Will Olsson, T Griffiths, P Gardner, M Price, A Hobbs
Operations	P Kelland, R Howells, S. Jones
Scientific	R Bragg, B Mellors
H&S	A Copland
Maintenance	R Couch, B Swanson

E REFERENCES

REFERENCE	TITLE	LOCATION
TS001	South West Water, Technical Standards Overview	
TS 012	South West Water, Technical Standard - Bolted Sectional Steel Liquid Storage Tanks.	
TS 425	South West Water, Technical Standard – Wastewater Sludge Treatment	
TSAL 37	South West Water, Technical Standard Advisory Leaflet – Biogas handling and pipework	
TS 104	South West Water Technical Standard - Hazardous Area Classification ;Flammable Gas or Vapour Risks	
WIMES 9.01	Combined Heat and Power (CHP) Plant	

F REQUIREMENTS

1. General

1.1 Process Description

Sludge digestion refers to Anaerobic Digestion (AD) of municipal sewage sludge. The process consists of a primary mesophilic anaerobic digestion stage, followed by an unheated secondary digestion stage.
Biogas produced through correct operation of the AD plant may be utilised for process heat requirements through boilers or through combined heat and power (CHP) plant.

1.2 General Requirements

i. The plant shall be fully automatic in operation and capable of operating with a minimum of supervision.

ii. To accommodate holiday periods, the plant shall be designed to operate unattended for a minimum period of four days. With the exception of the digester, spare plant capacity shall be provided where failure of an item of plant would prevent sludge treatment for a period exceeding 24 hours, or sludge digestion requirements being met. Similarly, spare capacity shall be provided should an item of plant be taken out of service for routine planned maintenance and cleaning, to satisfy the above conditions. Wherever practicable, plant shall be fully interchangeable

1.3 Potential Hazards

i. AD facilities are required to contain and manage flammable gas produced by the process. The risk of accidental explosion during normal operation is mitigated by strict adherence to the gas installation standard detailed in section 5 below. **Work on any part of the biogas system shall only be undertaken or supervised by approved contractors.**

ii. The risk of explosion is increased where air is introduced into the gas space, especially where tanks, vessels or gasholders are drained for maintenance. Digester vessels and gasholders may also be damaged if subjected to negative pressure, even where pressure/vacuum valves are fitted. Any work to digestion facilities involving the removal of a digester from service, a change in digester operating level or the reinstatement of a digester shall be approved through the TS411 variation process with signoff by a senior Wastewater Manager (band 5 or above).

iii. Entry to drained digester vessels shall be strictly controlled through the use of Safe Systems Of Work (SSOW) and issue of Permit to Work.

iv. Access to the digester roof should be restricted to authorised personnel only due to zoning in the proximity of the pressure/vacuum relief valve and the risk of falling from height.

2. Design and Construction

2.1 Process Design

i. The primary digester shall meet the following performance process design parameters:

a. The primary digester shall provide an average hydraulic retention of at least 16 days based on effective digester volume (EDV) and typical operating daily feed rates. The minimum hydraulic retention at maximum throughput shall be 12days.

b. The design volatile solids loading shall not exceed 3 kg VS/m^3/day.

c. The minimum volatile solids reduction for a mixed sludge (60:40 Primary: SAS) shall be 45%.

d. The temperature of the sludge in the digester shall be maintained between 35°C and 37°C, with an ambient air temperature equivalent to -20°C in still air when the digester is heated by the combustion of sludge gas alone.

e. In the absence of heating and sludge feed, the digester temperature shall not fall below 34 ±2°C within a 24 hour period with a minimum ambient air temperature of -10°C (including wind chill).

ii. The secondary digestion process shall meet the following performance process design parameters:

a. The minimum hydraulic retention shall be 15 days

b. A minimum of two batch tanks shall be provided.

c. Tanks shall be provided with external (pumped) mixing facilities.

2.2 Sludge Storage

i. Raw sludge covered storage facilities (Balance Tanks) shall be provided prior to sludge screening.

ii. Thickened sludge storage – a minimum of 24h at average digester throughput and 5.5% d.s. shall be provided. The tank(s) shall be provided with external mixers.

2.3 Construction

i. The digester shall be constructed of prefabricated panels manufactured from glass fused steel, with a roof of glass fused steel or other approved material, and comply with South West Water, Technical Standard SWW-TS-012 - Bolted Sectional Vitreous Enamel Coated Steel Liquid Storage Tanks.

ii. Alternatively, concrete may be used, though this is only likely to be cost effective on larger digesters.

iii. Regardless of the materials of construction, advice shall be sought from SWW technical specialist to ensure that suitably resistant coatings are selected for and an approved TS411 variation shall be obtained prior to procurement.

iv. The design operating pressure of the digester shall be 200 mm water gauge (19.6 mbar).

2.4 Dimensions

The digester shall have an aspect ratio height: diameter of 1.0.

2.5 Base

i. The digester shall be founded on a reinforced concrete base slab, designed to accommodate the digester loads at the prevailing ground conditions.

ii. The slab shall have a minimum floor space of 15 degrees towards the central hopper which has a minimum wall slope of 60 degrees.

2.6 Insulation

i. The digester walls and roof shall be externally insulated in accordance with **BS EN ISO 12241** and **BS 5422**.

ii. The digester shall be insulated to maintain a temperature loss of no more than 0.5°C per day in the absence of heating in ambient conditions of -5°C

iii. Insulation shall be in the form of easily removable rectangular GRP encapsulated panels of the same BS colour as is approved for the Tanks. Bolt faces and all edges of the insulation panels shall be covered by GRP.

iv. The rectangular panels shall be no higher than one steel panel height and must have their longer sides running vertically.

v. Individual panels must be able to be removed by one person unassisted, in order to inspect any part of the digester, without having to remove any adjacent panels, (though loosening of adjacent fixing will be permitted).

vi. Fixings must be designed to provide firm positive location for the panel and be robust enough to allow for numerous removal/replacement cycles. Fixings must be simple to remove.

2.7 Fixtures / Fittings

i. All fixtures and fittings shall be of an Approved Certification, appropriate to the environment of the application; and shall be maintainable from a safe environment.

ii. Digesters and gasholders shall each be equipped with two nitrogen purge points, 50mm diameter, valved and plugged. These shall be fitted on opposite side of the digester roof.

iii. External pipework and valves shall be insulated and the valves lockable. All sludge connections to the tank shall have twin isolating valves.

iv. Site drainage shall be provided below each sampling point to allow flushing of the pipework prior to sampling.

2.8 Sludge Outlets

i. All sludge and water pipework shall be flanged.

ii. The outlet of the primary digester shall be via a limpet chamber which gravitates to the secondary digester tanks. The limpet chamber shall be connected to a valved outlet 1m above the digester floor via an external riser pipe. An alternative valved outlet shall also be provided in the sidewall 1m below TWL.

iii. Note, existing limpet chambers may provide a high level outlet at TWL, and a valved outlet 500mm below TWL for scum removal.

iv. The limpet box shall be provided with a high level probe (float switch or fork).

v. A bottom drain of 200 mm diameter shall be provided to allow the removal of sludge and grit. Valves shall be duplicated to prevent accidental draw-down and shall be normally be locked in the closed position

vi. All valves shall be labelled with descriptive text (e.g. scum outlet) and P&ID reference tag.

2.9 Inspection Ports

i. Provision shall be made for two glass inspection ports, each of 500 mm diameter, in the roof of the digester.

ii. Internal glass cleaning mechanisms shall be provided with an external hatch cover for each inspection port.

2.10 Antifoam measures

i. Digester foaming may be a long standing chronic issue or an acute response to factors such as overloading or sludge type. The entry of foam into the gas pipework may cause blockages affecting the operation of the biogas system, and even affect the operation of the pressure relief/vacuum valve.

ii. A spraybar or nozzle shall be provided within the digester headspace directed at the gas takeoff. This shall terminate in a double valved arrangement that allows the connection of high pressure water or final effluent.

iii. If foaming is a known issue, then a dedicated dosing pump and suitable storage for antifoam agent shall be provided.

iv. Foam detection and level measurement are detailed in section 8.

2.11 Access

i. Two access hatches shall be provided through the digester wall at ground level to allow entry. A third access hatch shall be provided in the roof to permit ventilation when the digester is out of service.

ii. A minimum clear opening of 800mm diameter shall be provided at each hatch.

iii. A suitable arrangement of concrete footpaths, steps, walkways and stairways shall be provided to give good access to all parts of the plant for routine and maintenance activities.

iv. Roads

Roads shall have a minimum width of 4.8m.

They shall provide for vehicle access to all large items of plant and sludge delivery and collection points and incorporate adequate turning provision.

An access road shall be provided to allow restricted vehicles into the zoned area(s) for maintenance and removal of plant.

v. Davits and fall arrest posts

Sockets for a mini-lift portable Davit and Sala fall arrest posts shall be provided beside all deep sumps, chambers and tank roof access points to enable personnel and equipment to be lifted in and out easily.

These sockets shall conform to **SWW-TS-550** and be provided with test certificates and each one shall be suitable marked. Refer to TSAL40 for requirement to register equipment subject to stator inspection.

vi. Access Steelwork

Access steelwork, including walkways, platforms, stairs and ladders shall be in accordance with **SWW-TS-550**.

3. Digester Heating

3.1 Heating System

i. The heating system on all new digesters shall be external to the digester. Feed sludge shall be introduced into the system so that it is heated prior to entering the digester.

ii. Boilers serving the heating system shall be capable of operating on biogas or a secondary fuel source (natural gas, LPG or fuel oil). The boilers shall be sized to meet the heating requirements of the digester(s) without input from the CHP. The sizing shall take into account the heat input required to raise the sludge from 5°C to 35°C at maximum sludge throughput[1], plus the heat losse from the digester and pipework at an ambient temperature of -5°C..

iii. Control of the hot water flow to the heat exchanger shall be controlled by measurement of the sludge temperature prior to entering the heat exchanger. The digester temperature signal shall override this control should it go outside selected high and low set points.

3.2 Pumps/Pipework

i. Duty/standby hot water circulating pumps shall be provided together with pipework and individual isolating valves to allow components to be removed.

ii. Pipework shall be fitted with air release valves at high points, drain cocks at low points, non-return valves, and approved double regulating valves.

3.3 Maintenance Features

i. Facilities shall be provided to allow for ease of maintenance by the provision of isolating and drain valves on both the sludge and water sides of the heat exchanger.

iii. An external rodding and cleaning system is to be provided complete with suitable drainage beneath the heat exchanger. If the rodding is above ground level, a suitable access platform must be provided.

3.4 Corrosion Prevention

On completion of the tests for water tightness and flushing of the hot water circuit, the pipework system shall be re-charged with clean water containing a corrosion inhibitor / antifreeze. Frost prevention shall be checked annually, particularly where heat dump radiators are employed.

[1] $Q_s = M_s \cdot C_p (T_2 - T_1)$
Where:
Q_s is heat required to raise temperature from T_1 to T_2 (kW)
M_s is mass flow rate of sludge (kg/s)
C_p is specific heat capacity of sludge (4.19kJ/Kg ^oC)
T_2 is digester operating temperature (35^{o}C)
T_1 is temperature of raw sludge (assume 5°C).

4. Digester Mixing

4.1 Gas mixing systems shall incorporate a set of gas lances sited inside the digester at close to floor level. Digester gas shall be discharged through these lances to mix the digester contents. The lances shall be supplied from a ring main on the top of the digester and shall be equally spaced around the outside of the digester. The lances shall be equipped with valves to allow flushing of the pipes within the digester with high-pressure water or alternatively, nitrogen. The pipes shall extend into the tank to points located at approximately one tenth of the digester radius, as measured from the centre. The pipes shall all protrude into the tank the same distance in order to set up a current, and shall terminate no more than 0.5m above the tank floor. The outlets shall all be positioned on the same level to ensure even gas flow to each.

4.2 Operation of gas mixing lances may be continuous or sequential. Where sequential mixing is employed, each lance shall have its own actuated valve and isolation valve on the tank wall. Inside the tank the mixing pipes will be fixed to the floor by means of suitable clips at 1 m intervals. Pipework internal to the digester shall be rated to a minimum of 16 bar.

4.3 Careful consideration of gas compressor selection shall be made to ensure that there is sufficient capacity to operate the selected number of gas lances simultaneously. Problems have occurred where sequential mixing systems have been replaced with continuously operated systems without a suitable increase in gas compressor output

4.4 External pump mixing systems may be considered only after extensive work to model flow within the digester, and deliver mixing specification as below.

4.5 Any mixing system shall be capable of mixing all the sludge in the Tank within one hour, determined by mixing test below.

4.6 Mixing Test

i. All new or modified digester mixing systems shall be subject to a Lithium Chloride tracer test to demonstrate the mixing performance of the system.

ii. The tracer concentration measured one hour after injection at any point in the digester shall be within 10% of the theoretical completely mixed concentration.

5. Biogas system

Sourced from TSAL 37

5.1 General

AD facilities are required to contain and manage flammable gas produced by the process. The risk of accidental explosion during normal operation is mitigated by strict adherence to the gas installation standard detailed below. Work on any part of the biogas system shall only be undertaken by approved contractors.

5.2 Gas Installation Standard

i. Biogas installation shall be designed, installed and commissioned in accordance with the requirements of the Gas Safety (installation and use) Regulations 1998.
ii. All equipment, apparatus and installation techniques shall be cognisant of, and compliant with the requirements of the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) and ATEX Directives.
iii. Due to the specialist nature of biogas and its specific site requirements, any design and installation of biogas pipework and/or fittings shall be undertaken only by suitably qualified contractors proven to be competent in this field.
iv. Proposals for new or modified biogas pipework shall be reviewed by SWW Technical Performance Team and approved by a SWW approved contractor prior to installation. Refer to TS411 for approved suppliers / contractors.
v. Schematics for biogas pipework shall be maintained by the approved contractor, and amended as modifications are made. Copies of the biogas schematics shall be provided to SWW.

5.3 Routing and Layout

i. Gas for recirculation/mixing shall be drawn from the gasholder

ii. Biogas pipework shall be routed above ground wherever possible.

iii. Underground routes (e.g. road crossings) shall be avoided in order to minimise problems caused by condensation. Where unavoidable, underground routes shall terminate with condensate knock out pots at either end of the section. The gas line shall enter the pot at the same plane so as not to create a low point within the pipe section. This will require the formation of sublevel pits complete with natural drainage points at either end of the section. The gas line shall be installed with a fall to at least one pot so as to be self draining. Note that this method presents a number of difficulties and hence costs, therefore overground routes are likely to prove more cost effective in the long term.

iv. Biogas pipework shall be designed be self draining by providing a minimum fall of 1%, to allow accumulated condensate to be removed by strategically placed condensate pots. The pipeline shall fall in line with the gas flow direction to prevent gas flow holding up the condensate. Where this is not possible the pipe diameter shall be increased by one size.

5.4 Valves

i. Only valves rated for gas use and ATEX certified shall be used. Valve bodies shall be of stainless steel construction. Quarter turn ball valves are preferred.

ii. Isolation points shall be provided at the following locations:

- Digester Outlet
- Gasholder Inlet
- Boiler Inlet
- CHP Inlet(s)
- Condensate Trap Inlet(s)
- Biogas Scrubbing
- Biogas Mixing Inlet Manifold
- Biogas Mixing Outlet Manifold.

iii. Provision shall be made for purge and testing points on either side of each isolation valve,

iv. Slam shut valves (solenoid operated valves energised in the open position) shall be used to isolate the biogas supply to CHP and boiler plant. The valves shall be located external to all buildings and shall close in the event of fire or gas leak detection by any zone of the fire alarm and gas detection system.

v. All actuated valves shall report valve position on SCADA.

5.5 Pressure / Vacuum Relief

i. The digester roof shall be fitted with a pressure and vacuum relief valve (PVRV), or approved equivalent safety device, to vent and relieve excess pressure and vacuum, and to ensure structural damage does not occur in the event of malfunction or incorrect plant operation. Settings and working pressures shall be permanently indicated. PVRV shall be of stainless steel construction for longevity.

ii. Pressure Vacuum relief valves shall be sized on the maximum sludge outflow from the digester assuming drain valves are opened.

iii. The vacuum relief for the PVRV shall be set at -2.5 mbar. The pressure setting shall be set according to the maximum pressure rating of the gasholder bag (see 5.8).

iv. All new installations and digester refurbishments shall incorporate a pair of PVRV's with a cowhorn arrangement controlled by a three way valve that ensures that the digester is always protected.

v. Flame arresters shall not be installed upstream of PVRV's due to the risk of fouling of the flame arrester element interfering with the function of the valve.

5.6 Materials of construction

i. Biogas pipework shall be manufactured in 316 stainless steel in order to resist the effects of corrosion. Note that for underground routing, MDPE is preferred.

ii. MDPE (PE80) pipework may be used for biogas, natural gas or LPG under the following conditions;

- Only yellow MDPE shall be used for conveying methane based gasses to enable correct identification of the pipeline.
- MDPE shall be protected from the effects of UV degradation, and is the preferred material for underground pipework.
- All MDPE pipework shall be assembled with electro fusion welds and shall be assembled by trained personnel with proven competence (this is achieved by formal assessment).

iii. ABS pipework is not permitted.

iv. Ductile Iron pipework is not permitted.

v. Mild steel pipework is no longer permitted.

5.7 Condensate

i. Biogas is saturated with water vapour which on cooling will condense and accumulate. This may obstruct gas flow and also cause damage to any equipment connected to the biogas network. The greatest volumes of condensate will be produced at the compressors since it is here that there is the greatest change in temperature and pressure. The following measures shall be taken to minimise the formation of condensate and to permit its removal:

ii. All biogas pipework should be installed so as to be self draining (see 2. above)

iii. All biogas pipelines and condensate pots/drains shall be insulated to reduce condensate formation and to prevent freezing of drain lines and automatic drains

iv. Condensate pots shall be automatically draining. Preferred arrangement to be confirmed.

5.8 Gas Compressors

i. Gas compressors shall be designed and rated for biogas applications. Due to the potential risk of gas leakage gas compressors shall be sited in the open air, installed on a concrete base, provided with suitable drainage and containment to prevent discharge of lubricants and contaminants to ground.
ii. Gas injection pipework up to the isolation valve at the entry to the digester shall be lagged.
iii. Isolation valves shall be provided on gas draw-off and recirculation pipework. Plugged gas purging points shall be provided on each side of isolation valves.

5.9 Flame Arresters

i. Flame arresters shall be installed upstream of any equipment that consumes biogas as fuel.
ii. Where flame arresters are employed, a differential pressure switch linked to scada shall be installed to provide indication of fouling.

5.10 Gasholders

i. New gasholders shall be biogas specific bag systems. Legacy systems may include floating gasholders, but these have not been installed in recent years due to the lower capital and operating cost of biogas bag systems.

ii. All biogas pipework from the digesters shall be directed to the gasholder and all services (gas compressor, CHP, boiler, flare stack) shall be fed from the gasholder (not directly from the digester).

iii. The maximum pressure rating of the gas bag shall be carefully considered, especially where these are replacing an existing floating gasholder. The digester system operating pressure will be dictated by the lowest pressure of all connected systems, which will typically be the gas bag. Where higher operating pressures are required (e.g. for CHP, boilers or flares) then approved gas boosters shall be employed.

iv. The minimum gasholder volume shall be equivalent to 2 hours storage at maximum predicted gas production (i.e. gas production at maximum design loading). The minimum volume requirement shall not be subject to gas consumption by CHP or boilers.

v. The external materials of the gasholder shall be able to resist wind and snow loading, and shall be resistant to UV degradation.

vi. Duty / standby inflation blowers shall be provided, with an inflation pressure limiting device. A backup pressure relief valve shall also be provided.

vii. Flammable gas detection instruments linked to an alarm shall be installed between the inner and outer membranes.

viii. The internal gasbag volume and pressure shall be monitored and recorded on Scada. A viewing window shall be provided on the exterior membrane to allow visual indication of the internal gasbag condition.

5.11 Combined Heat and Power (CHP) equipment

i. CHP equipment shall comply with the specification and requirements set out in WIMES 9.01. If any conflict arises between WIMES and SWW Technical Standards, these shall be referred to SWW Technical Support Team for advice.

ii. CHP shall be sized according to 105% of the maximum biogas production (i.e. at peak design loading).

iii. The CHP output shall be automatically modulated according to gasholder level, or otherwise controlled to avoid frequent stop / start operation of the CHP.

iv. CHP run hours, energy output, temperature and biogas quality shall be monitored and recorded on Scada. Appropriate data for regulatory reporting, ROCs and energy reporting shall be recorded and reported as required by SWW Energy and Regulatory departments. Refer to Monitoring (section 8).

5.12 Flare Stack

i. A flare stack shall be provided for all digester installations.

ii. Positioning – minimum 10 m from any building and at least 5m from adjacent equipment.

iii. Capacity – at least twice the maximum predicted rate of production (gas production at maximum digester loading)

iv. The biogas flow to the flare stack shall be metered and recorded.

5.13 Gas Contaminant Removal

a. H_2S

i. Hydrogen Sulphide (H_2S) levels in biogas shall be controlled below 400 ppm in order to avoid accelerated corrosion and odour emission.

ii. The Designer shall submit figures for the maximum expected Hydrogen Sulphide (H_2S) levels in the sludge gas, before and after any treatment such as scrubbing. The Designer shall also provide calculations used to obtain such figures and the manufacturer's recommended maximum Hydrogen Sulphide (H_2S) levels for all connected plant.

iii. It shall be the SWW's decision whether or not to install a gas scrubbing plant or provide alternative means or reducing the Hydrogen Sulphide (H_2S) to an acceptable level for the connected plant.

b. Siloxane

i. Where siloxane concentrations exceed 25 mg/m^3, or where CHP capacity of greater than 100 kwh is installed, siloxane removal equipemtn shall be installed.

ii. Siloxane levels shall be controlled below the CHP plant manufacturer's maximum levels, or <10 mg/m^3, whichever is lower.

iii. Where a carbon adsorption process is selected, it shall be sized to require media replacement with a frequency not greater than once in every six month period of operation, at anticipated feed concentrations of siloxane. All siloxane filters shall be provided with the facility to be purged with nitrogen following maintenance.

6. Safety

Sourced from TS071

6.1 Safety Controls

In the event of power failure, high levels, gas leak or any other emergency condition, individual items of plant shall be designed to "fail safe" and alarm out.

The plant shall be designed to shutdown on critical plant failure and initiate an external alarm if an emergency condition is registered.

6.2 Zoning/Hazardous Area

Each site and proposed layout shall be specifically considered to confirm Zoning and Hazardous Area requirements.

Classification - Hazardous area zones shall be defined and classified in accordance with **BS EN 60079-10.**

6.3 Gas Containment

Indoor areas housing equipment containing flammable gas shall be separated from other rooms by gas-tight walls, including gas seals on service ducts.

6.4 Gas Detection

Rooms such as boiler rooms which contain flammable gas and equipment shall be equipped with flammable gas detection in accordance with Clause 5 of this specification.

Automatic Isolation - In the event of failure of the forced ventilation system, the plant shall automatically isolate the electrical equipment in that area and operate the necessary isolating gas valves. An alarm shall be initiated.

6.5 Selection of Electrical Equipment

Electrical equipment shall be selected and installed according to **BS EN 60069-14** depending on the zone it is in.

6.6 Security Fencing

i. Security fencing including all gates shall be provided and installed in accordance with SWW-TS-122.

ii. Security fencing shall be provided around the periphery of any external areas in which explosive gas/air mixtures may be present (i.e. zoned areas). Access through the periphery fence shall be provided by means of gates.

iii. Pedestrian access to zoned area(s) is to be provided by means of two exit points.

6.7 Signs

Hazard warning and statutory required signs shall be provided at all access/exit points to hazardous area(s) and buildings.

6.8 Crash Barriers

All plant containing flammable gas shall be protected from vehicle damage by crash barriers.

6.9 Gas Shut-off Valves

External to all buildings (and Compressor Enclosures), gas lines shall be fitted with fail-safe shut-off valves, de-energised in the event of fire or gas detection.

6.10 Flammable Gas Detection

i. Automatic Detectors

Automatic flammable gas detectors shall be provided to monitor in all enclosed spaces and areas where a hazard could exist, for the particular flammable gases that could be present in that space or area, i.e. propane and/or methane.

ii. Alarm Levels

Gas detectors shall have two levels of alarm. The first alarm at 10% of the lower explosion limit (LEL) of the gas, shall initiate a flashing hazard warning light and an audible warning immediately outside the enclosed space and an alarm condition on the plant control panel.

The second alarm at 25% of the LEL of the gas, shall reinitiate the first alarm level function and completely isolate the electrical equipment in the vicinity of the leak and operate the necessary isolating gas valves. A separate alarm shall be initiated on the control panel for 25% status.

6.11 Toxic Gas Detection

i. Automatic Detectors

Where there is a risk of Toxic gas build up, Automatic Toxic Gas detectors shall be provided to monitor for the Toxic gas present in the enclosed space(s) and area(s) where a hazard could exist.

ii. Alarm Levels

Gas detectors shall alarm at the Threshold Limit Values (TLV) i.e. 10ppm Hydrogen Sulphide level.

This shall initiate a flashing hazard warning light and an audible warning immediately outside the enclosed space and alarm condition on the plant's control panel.

6.12 Fire Precautions

i. Automatic Systems

All buildings and gas compressor enclosures shall be protected by an automatic fire detection and alarm system.

This system shall operate the gas shut-off valves in accordance with the alarm levels (6.10 above).

CHP Engines and Gas Compressors shall be provided with a fire extinguishing system. The system shall automatically operate an inert extinguishing gas within the acoustic enclosure of the engine or compressor.

Notices of the installation of the extinguishing system shall be posted at the point of entry to the building or compartment where the CHP or gas compressor is installed.

6.13 Lightning Protection

Digester(s) and Gas Holder(s) and associated equipment shall be provided with lightning protection equipment in accordance with BS **EN 62305 (relevant parts).**

6.14 Security

i. Materials - the building and external plant shall be designed in such a manner and constructed of such materials, in order to minimise any damage which could be caused by vandals.

ii. Resistance to Unauthorised Access - the building and its relevant components shall be designed to resist entry by potential intruders through doors, windows, roof lights, ventilation grilles and walls.

iii. Alarm System - all buildings shall be provided with an approved forced entry alarm system.

7. Maintenance

Inspection

Digester facilities shall be subject to external inspection annually. The scope of the inspection shall be mainly pipework and system gas integrity, but shall also include sludge pipework, critical alarms, digester structure and heating system.

An internal inspection shall be undertaken every 10 years, requiring the digester to be taken out of service.

Taking a digester in or out of service for maintenance, or any work to the primary digester or associated gas system requires careful planning to avoid the risk of death or injury through explosion, or damage to the digester asset or associated equipment.

The admission of air into a system containing biogas is likely to result in the biogas:air ratio entering the explosive range (5-15% CH_4 in air), creating the risk of gas explosion. Mandatory requirements for digester maintenance work are listed below.

7.1 Mandatory requirements

i. Work to any part of the biogas system shall **only** be undertaken by approved contractors – refer to Section 5.

ii. Maintenance work to the digester involving a change in operating level places the system at risk from implosion. The presence of a pressure/vacuum relief valve is not sufficient to protect the digester from internal vacuum. Any work to digestion facilities involving the removal of a digester from service, a change in digester operating level or the reinstatement of a digester requires formal approval prior to work commencing. This shall typically involve the submission of a detailed RAMS (see7.2-7.3 below) through the TS411 variation process with signoff by a senior Wastewater Manager (band 5 or above) or Technically Competent Manager for the site (TCM as defined by WAMITAB).

iii. All digesters and components of the biogas system shall be fully purged and tested by a SWW-approved biogas contractor prior to being dismantled or brought back into operation. A detailed RAMS shall be prepared prior to purging.

iv. Entry to drained digester vessels shall be strictly controlled through the use of safe systems of work. Ventilation and continuous gas monitoring are prerequisites.

7.2 Digester Decommissioning

Prior to any work commencing, a detailed decommissioning plan shall be prepared based on adoption of the following decommissioning protocol. A RAMS for decommissioning shall be submitted (via TS411 variation procedure) and approved prior to any work being undertaken.

Decommissioning Protocol

This is a generic protocol, site specific variations shall be detailed in the RAMS.

7.2.1 Contingency planning including alternative sludge handling arrangements to be confirmed.

7.2.2 Digester feeding stopped, valves/pumps locked off as appropriate, mixing and heating continues.

7.2.3 Heating stopped, gas mixing continues, digester is allowed to cool to below 20°C.

7.2.4 Digester isolated from gasholder via gas valve, gas mixing to digester stopped.

7.2.5 Purge digester (refer to 7.5) and test to confirm atmosphere is <2.5% methane.

7.2.6 Atmospheric test result / Safety Clearance Certificate issued by approved contractor (see Appendix 1).

7.2.7 Digester roof hatches opened, forced air ventilation as required to provide minimum 5 air changes per hour (ach). Ventilation shall be maintained until digester has been fully drained and cleaned.

7.2.8 Digester drained, lowering level below lower manway. Site specific RAMS required for opening digester door.

7.2.9 Permit to work issued for digester access (covering confined space entry, forced ventilation requirement, personal gas monitoring, emergency planning).

7.3 Digester Commissioning and Handover

Prior to any work commencing, a detailed commissioning plan shall be prepared based on adoption of the following commissioning protocol. A RAMS for digester commissioning shall be submitted (via TS411 variation procedure) and approved prior to any work being undertaken.

Commissioning Protocol

The following protocol is the preferred method of digester startup when sufficient volume of secondary digested sludge is available, either from a paired digester on site or by importing secondary digested sludge by road tanker.

Note this is a generic protocol, site specific variations shall be detailed in the RAMS.

7.3.1 A dry system check of all digester controls, valves and instruments shall be undertaken.

7.3.2 Pipework integrity, pump and valve condition shall be checked. This includes all parts of the feed sludge system, sludge recirculation and digester heating system.

7.3.3 Where any parts of the primary digester tank structure have been disturbed (excluding hatches) then a full hydrostatic pressure test using final effluent shall be undertaken. A full check (wet test) of the sludge recirculation system and the digester level controls shall also be undertaken at this time. The digester shall be drained following testing.

7.3.4 If no biogas is available or may be insufficient for site needs, then the supply of lpg (or alternative fuel) and status of boiler and heating system shall be confirmed.

7.3.5 Confirm arrangements for isolation of non compliant liquid sludge produced during commissioning phase.

7.3.6 Ensure necessary valves for isolation and purging are available and approved purging contractor is booked.

7.3.7 Prepare seed sludge, either from a secondary digester on site, or by importing secondary digested sludge by road tanker. If the latter, ensure sufficient storage is provided on site, as thickened sludge holding tank may be inadequate. To avoid contamination with rag, ensure that tankers are cleaned out prior to filing with seed sludge. A minimum of 70% of the digester volume is required as seed sludge (the remainder being made up with final effluent), though a greater volume of seed sludge will shorten commissioning time and should be utilised if cost effective.

7.3.8 Utilise forced ventilation to ventilate the digester at a minimum rate of 5 ACH. The ventilation shall be ATEX rated and shall be required to operate continuously during the filling operation, therefore redundancy or standby shall be included.

7.3.9 Commence filling the digester with secondary digested sludge. Monitor the displaced air for methane content at 4 hour intervals. If methane concentration exceeds 1% CH_4 in air (or 25% of the LEL), then filling shall stop immediately. The digester shall be filled within a 24 hour period if possible.

7.3.10 Once sludge level in the digester is above the any overflow level or has reached the TWL then filling shall cease.

7.3.11 The digester shall now be nitrogen purged without delay until the atmosphere is less than 5% O_2). Once certification of satisfactory purging has been achieved (see Section 7.5) then the digester shall be sealed. Note that gas lines from the digester may be isolated at this stage - the approved biogas pipework contractor shall confirm the arrangements for opening gas valves that may have been previously isolated.

7.3.12 Start sludge recirculation and heating. Introduce mixing but note this may need to be maintained at a minimal level in order to avoid excessive foaming.

7.3.13 The digester contents shall be gradually heated to the operating temperature. Once temperature of 25°C has been achieved, maintain sufficient heating to increase digester temperature by no more than 1°C per day until 35°C has been achieved

7.3.14 Once digester operating temperature has been achieved, commence sampling programme and analysis (if not already started). See monitoring section 8.8.

7.3.15 Commence feed sludge at 20% of design organic loading[2] (not volumetric) rate. A close watch on digester pH and VFA concentration is required from this point, as is digester level in case of foaming. Biogas quality (% CH_4) is also a useful indicator of process performance.

7.3.16 Process monitoring shall continue whilst feed sludge is gradually increased by 20% per day up to the design maximum[3]. Daily checks on pH, feed %d.s. and CH_4 concentration shall be maintained (see 8.8).

7.3.17 Correct operation of the gasholder shall be confirmed, followed by confirmation of satisfactory flare stack operation (note unable to test until biogas available).

7.3.18 Handover may proceed once stable conditions have been established (see 7.4).

[2] or 0.5 kg VS/m^3 digester capacity per day
[3] or 3 kg VS/m^3 digester capacity per day

7.4 Process stability and handover

7.4.1 Following digester commissioning, the plant may handed over to the client once stable process operation has been achieved.

7.4.2 Stable digester operation may be considered to have been achieved after operation at minimum of 50% of design loading rate under the following conditions for minimum 14 days :

i. Digester temp 35° (±2º)

ii. pH 7.0 ±0.2

iii. VFA <300mg/l

iv. Biogas CH_4 50% ±5%

7.5 Purging

7.5.1 Purging shall only be undertaken by a SWW-approved biogas contractor (listed on TS411 or by prior approval of TS411 variation).

7.5.2 An up to date gas schematic (see 5.2.v) shall be available prior to purging.

7.5.3 Pipework shall be purged in accordance with IGEM standard IGE/UP/1 (current version). This typically requires a minimum of three volume changes for a section of pipework.

7.5.4 Replacement of individual components (e.g. valves, gas compressor, gas booster etc.) may be covered by a generic RAMS. Any work involving multiple components, the digester headspace or the gasholder requires a full RAMS document.

7.5.5 Digester headspace and gasholders are not covered by IGE/UP/1, and shall therefore be purged until the following endpoints are detected in the expelled gas.

i. Purging out of service: <2.5 % CH_4 in air (50% of LEL)
ii. Purging into service: < 5% O_2

7.5.6 Methane or oxygen concentration shall be quantified by a dedicated gas measurement instrument within its calibration period.

7.5.7 Wherever possible, digester purging shall be made through the gas lances in order to break up pockets of biogas within the sludge and minimise the risk of short circuiting across the headspace.

7.5.8 Isolated valves and number and location of spades shall be noted on the certificate of decommissioning or commissioning (as appropriate), as outlined in Appendix 1. This shall be handed to site manager or to the contractor undertaking work on the equipment.

8. Monitoring

8.1 General

i. Data required for regulatory monitoring (i.e. HACCP, IPPC) or performance monitoring shall be captured and stored automatically. This may include (but is not limited to) digester operating temperature, primary and secondary retention time, biogas production rate and CHP output.

ii. Instruments (level, pressure, temperature) and sampling points shall be accessed from ground level, walkways or platforms, not from ladders.

iii. Sludge sampling points shall be provided through the digester walls at diametrically opposed positions, 1.0 m above ground level. Sampling tubes of 50 mm diameter shall extend into the digester and shall have double valves.

8.2 Level

i. Three level measurements are mandatory for digester operation: Digester level, Foam level and Outlet Box level.

ii. Digester level shall be inferred by hydrostatic head measurement. The pressure sensor shall be installed on a spool piece attached to a valve of minimum 100mm diameter.

iii. The position shall be close to the base of the digester for easy access, but any location on the lower half of the digester elevation is permitted. The height of the pressure sensor relative to the digester floor shall be taken into account in the displayed value.

iv. Digester foam level shall be determined by ultrasonic level or radar level detection from the roof of the digester. The probe shall be mounted in a valved arrangement that permits withdrawal of the sensor head without compromising the gas space.

v. High level in the sludge outlet limpet box shall be detected by a simple float or fork level switch. This warns the operator of blockage in the sludge outlet which if not addressed will result in digester high level.

8.3 Pressure

i. Digester pressure shall be measured in the digester headspace or in the gas takeoff pipework.

ii. The pressure of the gas mixing system shall be recorded

iii. The biogas pressure between the gasholder and any system or device utilising biogas shall be measured.

iv. Where a gas bag is employed, gasholder pressure between the inner and outer membranes shall be recorded.

8.4 Temperature

i. Temperature monitoring shall be made at top, middle and bottom of the primary digester. Probes shall be installed in pockets. The output of each probe shall be recorded separately, with the middle probe typically adopted as the CCP.

ii. Temperature of sludge on the inlet and the outlet the heat exchanger shall be monitored.

iii. Temperature of the flow and return legs of water heating system shall be recorded, for both the boiler and the CHP loops.

8.5 Flow

i. Sludge flow instantaneous flow (m^3/h) and cumulative daily volume (m^3/d) shall be recorded (CCP).

ii. Biogas flow (Nm3/h) Biogas flow meters shall be fitted to measure digester gas production from each digester and the biogas consumption of boilers, CHP(s) and flare stacks.

iii. Biogas flow shall be indicated and trended on SCADA with real time and daily cumulative flow.

iv. Water flow (local indication only)

8.6 Biogas Quality

i. A biogas monitoring system shall be installed to allow digester performance to be inferred through gas quality. As a minimum, methane concentration shall be measured but other parameters such as H_2S may also be included

ii. Above 3500 TDS pa, comprehensive gas quality monitoring (CH_4, H_2S, CO_2) shall be installed and maintained.

iii. Less than 3500 TDS pa requires CH_4 monitoring only.

iv. Where siloxane filters are installed, siloxane in biogas shall be monitored on an 6 monthly basis to determine efficacy and media change frequency.

8.7 Sludge Dry Solids

i. Sludge feed %d.s. shall be obtained through online instruments provided for Sludge Boundary monitoring (OFWAT requirement) or installed for polymer optimisation (SWW SD751).

8.8 Sludge Quality Monitoring

i. Routine monitoring of sludge is required to maintain digester performance. Enhanced monitoring is required during the digester commissioning process. Both schedules are laid out in Table 1 below:

Table 1

Parameter	Sludge		Monitoring frequency	
	Feed	Digested	Commissioning	Routine Operation
pH (on site)	✓	✓	Daily	Daily
%d.s.	✓	✓	Daily	Daily
%vm (lab test)	✓	✓	Weekly	Monthly
VFA		✓	Weekly	
Pathogens		✓	Monthly	Monthly
Heavy Metals		✓	Monthly	Monthly

Appendix: Example Decommissioning / Commissioning Certificates

Site Address			
Client			
Engineers Details	Name	GasSafe / OFTEC ID	Date

Gas System Decommissioning Certificate

System/Appliance to be Decommissioned			
Location			
Upstream Isolation Point		Ref.	
Downstream Isolation Point (if applicable)		Ref.	
Isolation Points Locked Off		Isolation Points Identified	
Pipework Spaded		Pipework Capped/Blanked	
Client Walkthrough			

Comments	
System fully decommissioned and safe to be worked on by others	

Engineers Signature		Clients Signature	
Print Name		Print Name	

Site Address			
Client			
Engineers Details	Name	GasSafe / OFTEC ID	Date

Gas System Commissioning Certificate

System/Appliance to be Commissioned			
Location			
Upstream Isolation Point		Ref.	
Downstream Isolation Point (if applicable)		Ref.	
Isolation Points Unlocked		Isolation Points Identified	
Pipework Spades Removed		Pipework Un-Capped/Blanked	
Client Walkthrough			

Comments	
System fully commissioned and is safe for use	

Engineers Signature		Clients Signature	
Print Name		Print Name	