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*भारतीय मानक* **मसौदा**

**बायोगैस (बोयोमिथेन) प्लांट का डिजाइन, निर्माण, संस्थापन और प्रचालन – रीति संहिता**

[ आईएस 9478 का तीसरा पुनरीक्षण ]

**Draft** *Indian Standard*

**DESIGN, CONSTRUCTION, INSTALLATION AND OPERATION OF BIOGAS (BIOMETHANE) PLANT – CODE OF PRACTICE**

[ *Third Revision* of IS 9478 ]

ICS 75.160.40

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| **Renewable Energy Sources Sectional Committee, MED 04** | **Last date for receipt of comments is 25 December 2022** |

## FOREWORD

(*Formal clause to be added later*)

Biogas plants are gaining lot of importance due to scarcity of conventional form of energy. This standard lays down the essential requirements and gives guidance for the design and construction of biogas plant.

Biogas plant mainly consists of a digester, gas storage unit, inlet and outlet assembly, mixing chamber and gas distribution pipelines.

This standard was first formulated in 1980 and was subsequently revised in 1986 and 1989, with the title 'Family size bio - Gas plant - Code of practice'. The standard covered the family sized biogas plants upto 10 $m^3$ per day capacity. This have been revised with a view to include larger capacities biogas plants namely small sized (upto 25 $m^3$ per day), medium sized (25 to 2500 $m^3$ per day) and large sized (more than 2500 $m^3$ per day) biogas plants.

This standard is intended to help the purchaser to select and design the capacities of biogas plant for his/her requirements of biogas.

This standard specifies the general guidelines for design, construction, installation and operation of small, medium and large sized biogas (biomethane) plants. This standard includes the classification of biogas plants on the basis of daily biogas production, included and excluded feedstocks for plant, plant performance parameters, different designs materials for digesters and gas holders, and their construction.

The digestate manure from the biogas plant, also known as the fermented/digested solid and liquid manure (organic fertilizer), which means substances made up of one or more unprocessed materials of a biological nature (plant/animal) and may include unprocessed mineral materials that have been altered through microbiological decomposition process. Digested solid and liquid manure (organic fertilizer) can be upgraded/fortified for its use in different crops. Some of the upgraded/fortified digested slurry/manure includes, Phosphate Rich Organic Manure, Potassium Rich Organic Manure, etc. The digestate manure from the biogas plant may be used as an organic fertilizer for agriculture purposes as per Annex H. In the formulation of table 10, assistance has been drawn from Fertilizer Control Order (FCO) 1985.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*Second Revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

**Draft** *Indian Standard*

# DESIGN, CONSTRUCTION, INSTALLATION AND OPERATION OF BIOGAS (BIOMETHANE) PLANT – CODE OF PRACTICE

[ *Third Revision* of IS 9478 ]

## 1 SCOPE

This standard specifies the requirements for design, construction, installation and operation of small, medium and large sized biogas (biomethane) plants. It includes the classification of biogas plants on the basis of daily biogas production, included and excluded feedstocks for plant, plant performance parameters, different designs and materials for digesters and gas holders.

## 2 REFERENCES

The standards mentioned in Annex A contain provisions which through their reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards in Annex A.

## 3 TERMINOLOGY

For the purpose of this standard, the definitions are given below:

**3.1 Anaerobic Digester Mixing** — There are three types of mixing: biogas mixing, impeller mixing and slurry mixing.

**3.1.1** *Biogas Mixing* — This is novel and simple digester turbulence mechanism to break foam, froth and some materials inside the digester without any mechanical moving part inside the digester.

**3.1.2** *Impeller Mixing* — This is expensive digester mixing, mechanical device need not be used for digester mixing until the high organic loading rate digester is designed for production**.**

**3.1.3** *Slurry Mixing* — This is the method of recirculation of digesting material from top to the bottom and from bottom to the top.

**3.2 Anaerobic Digestion** — A biological conversion of biodegradable materials by microorganisms in the absence of oxygen creating two main products: biogas and digestate. An example of anaerobic digestion is the biological conversion of the biodegradable parts of biomass sources, but also fossil biodegradable sources.

**3.3 Bio-CNG/CBG** — Bio-CNG/CBG is a compressed biomethane having similar capabilities as that of compressed natural gas (CNG).

**3.4 Biogas** — This gas produced by anaerobic digestion of organic matter, it comprises of methane ($CH_4$) as the main component (50-70 percent), and carbon dioxide ($CO_2$) (30-40 percent) with varying quantities of $H_2S$, moisture and some other gases in trace quantities

**3.5 Biogas Meter** — Biogas meter is used for measuring quantity of biogas generated by biogas plants of different capacities.

**3.6 Biogas Installation** — Installation including its pipelines, pipes and accessories for anaerobic digestion of biomass and waste, upgrading of biogas, liquefaction of biogas, storage of biogas (in raw, gas or liquid form), storage of $CO_2$, storage of auxiliaries, storage of biomass and digestate.

**3.7 Biogas Pipeline** — System of pipework for transportation of biogas or biomethane with all associated equipment and stations up to the point of delivery and outside the biogas installation. This pipework is mainly below ground, but includes also above ground parts.

**3.8 Biogas Storage** — Buffer, gas holder, tank, vessel, bag or similar to store biogas. The biogas storage can be an integral part of the digester.

**3.9 Biomass** — Material of biological origin excluding material embedded in geological formations and/or transformed to fossilized material. Biomass is organic material that is plant based or animal based, including, but not limited to dedicated energy crops, agricultural crops and trees, food, feed and fibre crop residues, aquatic plants, algae, forestry and wood residues, organic agricultural, animal and processing by-products, agricultural, municipal and industrial organic waste and residues whether or not in landfills, sludge, waste water, and other non-fossil organic matter.

**3.10 Biomass Pipeline/Digestate Pipeline** — System of pipework for transportation of liquid biomass or digestate with all associated equipment and up to the point of delivery.

**3.11 Biomass Pretreatment** — Treatment of biomass with chemical, physical, thermal and biological methods in order to increase methane production when the biomass is digested or gasified.

**3.12 Biomethane** — Methane rich gas with the properties similar to natural gas derived from biogas produced by anaerobic digestion or gasification by upgrading. Sometimes, the term ‘upgraded biogas’ is also used instead of the term ‘biomethane’.

**3.13 Capacity** — Capacity of the biogas plant is the total amount of feedstock or biogas that can be contained or produced respectively.

**3.14 Compressed Biomethane (CBM)** — Biomethane used as a fuel for vehicles or for other purposes, typically compressed up to 20 MPa in the gaseous state.

**3.15 Cooking Biogas** — The kitchen sized micro level biogas plant produces the raw biogas which is directly used for cooking purposes in domestic stoves with and without purification is called cooking biogas.

**3.16 Digestate/Effluent/Compost** — Remaining effluent from the anaerobic digestion process including solid fraction and liquid fraction. It is the digested slurry coming from outlet. This is a rich source of plant nutrients and used as a manure (organic fertilizer). It is also used as inoculum/starter for hastening the process of composting of other organic material.

**3.16 Digester** — This is also known as fermentation tank and is generally embedded partly or fully in the ground. It can be cylindrical or other suitable shape and size, and made of suitable construction materials. It holds the slurry within it for digestion for a recommended retention period.

**3.17 Dry Matter** — Remaining part of biomass or digestate after drying the moisture content.

**3.18 Gasholder** — It is a storage tank for biogas. The gas outlet is at the top of gas holder. The gas holder may be a integral part of the digester design or placed separately.

**3.19 Hydraulic Retention Time (HRT)** — Hydraulic retention time is a measure of the average duration of time that feedstock remains in the digester. It is estimated by dividing the volume of the reactor by daily or hourly volumetric feed rate). It is expressed in time (days or hours).

**3.20 Inlet** — It is for feeding the mixture of biomass and water to the digesters.

**3.21 Inlet Feed Slurry** — It is a mixture of biomass and water in the right proportion which is fed to the digesters.

**3.22 Mixing Tank/Feed Preparation Tank** — This is a tank in which the input feed is mixed with water or liquid digestate recirculate, prior to feeding into the digester through the inlet.

**3.23 Municipal solid waste (MSW)** — The organic and inorganic solid wastes together arise out of municipalities with/without segregation.

**3.24 Organic Dry Matter (Volatile Matter Upon Loss on Ignition)** — Part of biomass or feed slurry or digester content or digestate derived from total dry matter containing carbon and originating from living materials [sample = moisture + dry matter, dry matter = volatile matter (organic) + fixed matter (inorganic/ash)]. Instead of organic dry matter, the term 'total volatile solids' is also used.

**3.25 Organic Loading Rate of Digester (OLR)** — Amount of volatile organic dry matter entering the anaerobic digester over time, measured in kilograms per cubic metre of digester volume per day ($kg/m^3$ per day). The organic load gives an indication of the capacity of the digester whether it's a low rate, standard rate or high rate digester. It provides information on nutrient supply levels of the microorganisms involved, overload or undersupply of the system as well as resulting technical and process control measures to be taken. The organic load describes the efficiency of the anaerobic digester.

**3.26 Organic Fraction of Municipal Solid Waste (OFMSW)** — Out of the total municipal solid waste the organic portion alone is called as OFMSW, which consists of biodegradable (VS) and non-biodegradable organic solid waste.

**3.27 Digester Outlet or Drain** — It is for taking out the digested portion of the slurry.

**3.28 Raw Biogas** — Biogas directly derived from the digester which is not conditioned, cleaned, dried or purified.

**3.29 Substrate** — Part of the biomass which is biodegradable and converted by microorganisms and/or enzymes as catalyst into biogas and fermented manure (organic fertilizer).

**3.30 Total Solids (TS)** — Total solids include both the suspended solids and the dissolved solids which are obtained by separating the solid and liquid phase by drying. It is generally denoted in percentage of feedstock.

**3.31 Transportation of Biogas** — Activity intended to transport biogas from one place to another through pipelines and/or cylinders/cascades in order to supply biogas to distribution systems or for utilization by industrial and domestic consumers.

**3.32 Two Stage Biodigester** — Two digesters are used in series, where the first digester is used for acidification and second for methanogenesis.

**3.33 Volatile Solid (VS)** — Volatile solid is the amount of volatile matter lost after the ignition of pre-dried biomass sample at 550$^{o}$C for four hours. It is expressed in percent of TS.

## 4 CLASSIFICATION OF BIOGAS PLANTS

Biogas plants are classified in Table 1 on the basis of the total biogas production per day from the plant.

**Table 1 Classification of Biogas Plants**
( *Clause* 4 )

| **Sl No.** | **Classification** | **Biogas Production (in m$^3$/ day)** |
|---|---|---|
| (1) | (2) | (3) |
| i) | Small scale | 1 - 25 |
| ii) | Medium scale | 25 - 2 500 |
| iii) | Large scale | > 2 500 |

NOTES
**1** Small scale biogas plants for largely urban and semi- urban areas for digesting domestic organic kitchen and garden waste can be less than 1 m$^3$/day biogas production also; and
**2** The sizes are indicated primarily by the daily gas production levels.

## 5 FEEDSTOCKS

**5.1** Feedstock is broadly identified as:

a) Organic waste from animals;

b) Biodegradable solid and liquid organic waste from industries including sugar mills and food processing industries crop residues and suitable stubbles;
c) Organic/biodegradable fraction of municipal solid waste; and
d) Domestic sewage.

**5.2** Specifications of feedstock to be used in the biogas plant are categorised as:

a) Included feedstock;
b) Excluded feedstock; and

**5.3 Included Feedstocks**

Annex B shows the type of feedstocks considered for biogas plants along with organic loading rate, hydraulic retention time, volatile solid removal and biogas yield according to plant size.

**5.4 Excluded Feedstocks**

The following feedstocks shall not be included in the biogas plants:

a) Fossil fuels and products and by-products made from them;
b) Woody biomass;
c) Paper;
d) Cardboard;
e) Pasteboard;
f) Harbour sludge and other water body sludges and sediments;
g) Plastics;
h) Metals; and
j) Biomedical/Pathogenic waste.

**5.5 Characteristics of Input Feed-Stocks**

Characteristics of input feedstock shall comply with parameters such as C:N ratio, total solids, volatile solids and particle size as prescribed in the Table 2. For sampling and analysis of biomass refer Annex G.

**Table 2 Input Feedstock Parameters/Specifications**
( *Clause* 5.5 )

| **Sl No.** | **Parameters** | **Range** |
|---|---|---|
| (1) | (2) | (3) |
| i) | C:N ratio | 15-30:1 |
| ii) | Total solids (percent) for wet digestion | 5 to 15 |
| iii) | Total solids (percent) for dry digestion | > 15 |

| | | |
|---|---|---|
| iv) | Volatile solids (percent) | > 60 |
| v) | Particle size | Small < 5 mm;<br>Medium 5-15 mm; and<br>Large > 15 mm. |

NOTES
**1** C is organic carbon; and
2 **For < 15 C:N ratio, two-stage bio-digester is recommended.**

## 6 PLANT PERFORMANCE PARAMETERS

Biogas plant performance shall be defined with the parameters such as feedstock characteristics, temperature, organic loading rate, pH, biogas yield, and hydraulic retention time (HRT). Annex B shows the minimum acceptable limit for organic loading rate, hydraulic retention time, volatile solid removal and biogas yield according to plant size. Anaerobic digestion process in the biogas plant shall comply with the requirements as mentioned in the Table 3.

**Table 3 Digester Performance Parameters**
( *Clause* 6 )

| **Sl No.** | **Parameter** | **Range** |
|---|---|---|
| (1) | (2) | (3) |
| i) | Temperature (°C) | Mesophilic process: 20 to 40<br>Thermophilic process: 45 to 60 |
| ii) | pH | 6.8-7.5 |
| iii) | FOS-TAC ratio | 0.3-0.4<br>Recommended for biogas plants of capacity 500 $m^3$ per day or above<br>(*see* Annex C) |

## 7 DESIGN AND CONSTRUCTION

### 7.1 Different Designs of Biogas Plants

The different plant designs for anaerobic digestion for different plant sizes shall be considered as shown in Table 4. A brief about the following different designs of biogas plants is given at Annex F.

**Table 4 Different Designs of Biogas Plant**
( *Clause* 7.1 )

| **Sl No.** | **Small-scale** | **Medium-scale** | **Large-scale** |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| i) | Continuous Stirred Tank Reactor (CSTR) type digesters (horizontal/vertical design) | Up-flow anaerobic sludge blanket (UASB) | Up-flow anaerobic sludge blanket (UASB) |
| ii) | Floating-drum plant with a | Continuous Stirred Tank | Continuous Stirred Tank |

| | | | |
|---|---|---|---|
| | cylindrical digester (KVIC model) | Reactor (CSTR) | Reactor (CSTR) |
| iii) | Floating-drum plant with a hemisphere digester (Pragati model) | External Circulation Sludge Bed (ECSB) | External Circulation Sludge Bed (ECSB) |
| iv) | Floating-drum plant made of angular steel and plastic foil (Ganesh model) | Plug flow reactor | Plug flow reactor |
| v) | Floating-drum plant made of pre-fabricated reinforced concrete compound units | Biogas Induced Mixing Arrangement (BIMA) digester | Biogas Induced Mixing Arrangement (BIMA) digester |
| vi) | Floating-drum plant made of fibre-glass reinforced polyester | High rate solid digesters | High rate solid digesters |
| vii) | — | Fixed film reactor | Fixed film reactor |
| viii) | Fixed-dome plant with a brick reinforced, moulded dome (Janata model) (6 $m^3$ to 25 $m^3$ per day) | Fixed-dome plant with a brick reinforced, moulded dome (Modified PAU Janata model) (upto 500 $m^3$/day) | — |
| ix) | Fixed-dome plant with a hemisphere digester (Deenbandhu model) (upto 6 $m^3$ per day) | Floating films reactors | Floating films reactors |
| x) | Bag type digesters | — | — |

In general biogas plant mainly consists of a digester, gas storage unit, inlet and outlet assembly, mixing chamber and gas distribution pipelines, a typical diagram of biogas plant is shown in Fig. 1 below:

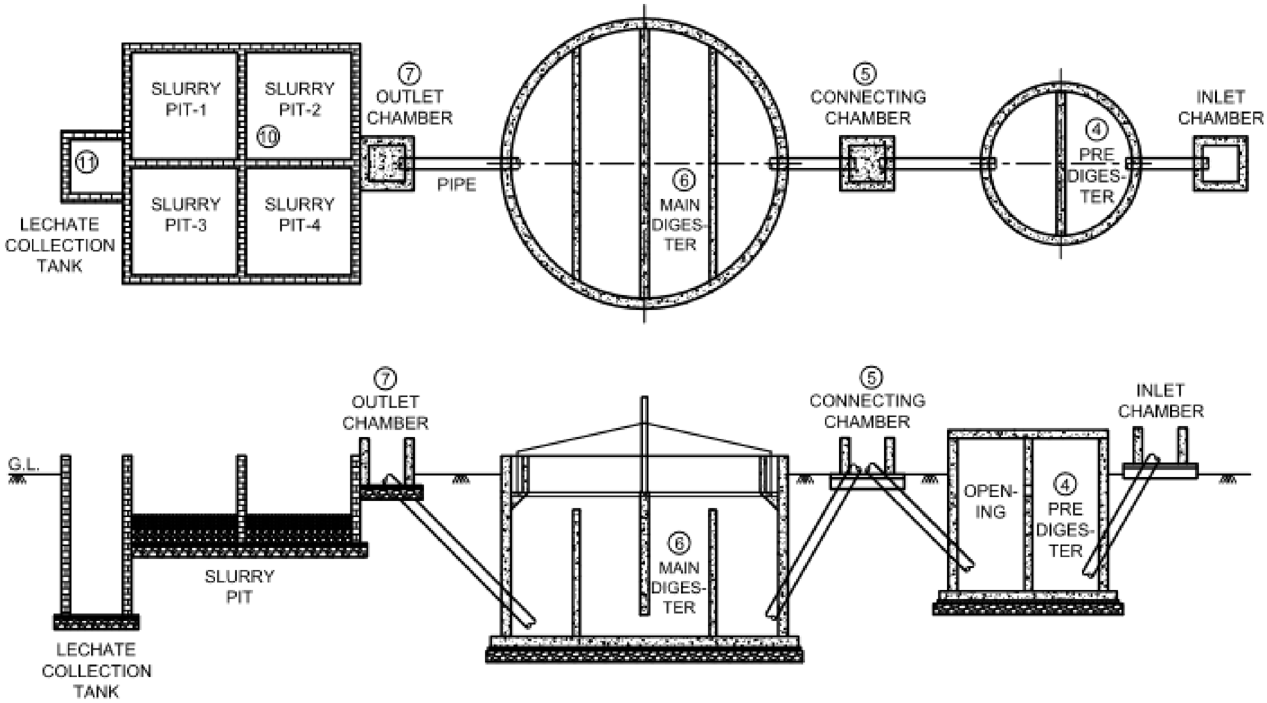


**FIG. 1 CROSS SECTIONAL VIEW OF A BIOGAS PLANT**

## 7.2 Material for Construction

This section covers the requirements of construction material used for construction of biogas digester, biogas holder, pipes and fittings. For construction of any structure refer Annex D also.

**7.2.1** *Digester*

The digester for small-scale plants may be made from bricks, membranes(neoprene rubber, flexible PVC, flexible HDPE)/High density polyethylene (HDPE)/ferro-cement/mild steel/stainless steel/fibre reinforced plastic (FRP), flexi/bag type biogas plants made up of Linear Low Density Polyethylene (LLDPE)/High quality poly-propylene sheet/PVC lined polyester double UV coated fabric, etc., having water and gas leak proof design and fabrication, with ultraviolet protection and desired strength for minimum life of 10 years. The digester for medium and large scale plants may be made from bricks/ reinforced concrete cement/mild steel/stainless steel. For reference the relevant Indian Standards for construction of digester using different materials are given in Table 5.

**Table 5 Material for Construction of Digester**
( *Clause* 7.2.1 )

| Sl No. | Material | Relevant Indian Standard |
|---|---|---|
| (1) | (2) | (3) |
| i) | Masonry | IS 1905 |
| ii) | Reinforced concrete | IS 456 |

| | | |
|---|---|---|
| | cement (RCC) | |
| iii) | Steel | IS 800 |
| iv) | High density polyethylene (HDPE) | IS 2508 |
| v) | Linear low density polyethylene (LLDPE) | IS 2508 |
| vi) | Ferro cement | - |
| vii) | Glass Fibre reinforced plastic (FRP) | IS 12866 |
| viii) | High quality poly-propylene sheet | - |
| ix) | PVC lined polyster double UV coated fabric | IS 7016 (all parts) |
| x) | Polyethylene with Polypropylene/EPDM (Ethylene Propylene Dine Monomer) as outer layer (Bag type digester) | - |

**7.2.2** *Gas Holder*

Gas holder/dome for small, medium and large scale plants may be made from brick masonry and gas leak proof with suitable material. Appropriate corrosion allowance (thickness/coating) to be provided for gas holders made up of Steel. Methane permeability should be upto 200 $cm^3$ per $m^2$ per day at 1 bar absolute pressure as per ISO 15105. For reference the relevant standards for construction of gas holder using different materials are given in Table 6.

**Table 6 Material for Construction of Gas Holder**
( *Clause* 7.2.2 )

| **Sl No.** | **Material** | **Relevant Indian Standard** |
|---|---|---|
| (1) | (2) | (3) |
| i) | Glass fibre reinforced polyester resin with steel frame | IS 12986 (Part 1) |
| ii) | Brick Masonry (upto 80 $m^3$ per day) | IS 1905 |
| iii) | PVC lined polyester double UV coated fabric > 1 000 gsm | IS 7016 (all parts) |
| iv) | Steel | IS 800 |

Calculation of gas holder volume:

Total expected gas production from each Digester = X $m^3$/day
Per hour biogas production from each digester = X/24 $m^3$/hr.
Recommended duration of storage for Biogas = 3 hours (Y)
Required volume of gas holder for each digester = (X/24) × Y $m^3$
Supplied volume of gas holder = 1.10 times required volume

NOTE — Recommended duration of storage for raw biogas is to be minimum 5 hours based on the flow rate of the biogas upgradation system.

**7.2.2.1** *Membrane based gas holder*

The membrane based biogas holder shall not chemically react to mediums such as slurry and biogas, temperature and aging. Membrane material shall be defined in terms of tensile strength, gas diffusivity, temperature resistance (membrane will remain intact in the stipulated range mentioned) surface resistance, fire resistance, UV-resistance. The membrane shall comply with the specifications as given in Table 7.

**Table 7 Specifications for Membrane Based Biogas Holder**
( *Clause* 7.2.2.1 )

| Sl No. | Particulars | Specifications |
|---|---|---|
| (1) | (2) | (3) |
| i) | Tensile strength | Min 3 000 Newton/5 cm as per ISO 1421 |
| ii) | Gas diffusivity | Upto 200 $cm^3$ per $m^2$ per day at 1 bar absolute pressure |
| iii) | Temperature resistance | - 30°C — +70°C |
| iv) | Surface resistance | less than $3 \times 10^9$ Ohm |
| v) | Bleeder resistance | less than $3 \times 10^8$ Ohm |
| vi) | UV resistance | UV content of total solar radiation = 5.4 kWh per $m^2$ per day for designed/projected life |
| vii) | Flame resistance | 100 mm per min (at biogas flash point temperature) |
| viii) | Maximum operating Pressure | 50 mm Water Column (WC) — Set point for pressure release valve |

**7.2.2.2** In case of double membrane based biogas holder, it shall be as per table 7 above, and the following specifications shall also be followed:

a) The biogas produced by anaerobic digestion inside the digester is collected from digester mounted single/double membrane biogas holder installed on each digester;
b) The membrane should be microbiologically resistant as per the geo-synthetic method for determining microbiological resistance by soil burial test as per the appropriate Indian Standard;
c) Digester mounted double membrane biogas holder shall be made up of PVC coated polyester fabric; and
d) The external and internal membrane shall be protected against Ultra Violet light, treated with fungicide, and flame retardant according to appropriate Indian Standard.

NOTE — The minimum material strength shall be further dependent on the project specific requirements dictating the required material strength as appropriate for the results of the static design calculations for the inflated structure.

**7.2.3** *Pipes and Fittings*

**7.2.3.1** The pipes carrying biogas shall be either made of SS304 or above (to be used for carrying raw biogas), polyethylene as per IS 14333, HDPE as per IS 4984, polypropylene, polycarbonate, etc. The pipes shall be corrosion resistant to the feedstock and biogas. The pipes shall be distinct for feedstock and biogas and shall be coded with canary yellow as per IS 2379.

**7.2.3.2** Within the plant, before purification unit the pipes and fittings are to be of stainless steel, after the purification of the biogas, it may be transported using pipes and fittings being used for natural gas as per IS 15663 (Part 1). However, small biogas plant, may also use HDPE, CPVC pipes and fittings instead of stainless steel. All piping material shall have appropriate corrosion allowance and UV tolerance for designed life of minimum 15 years.

### 7.3 Feedstock Storage

**7.3.1** *Solid Feedstocks*

The feedstock storage yard may be equipped with leachate storage facility made of RCC floor as per IS 456 and a leachate collection tank, designed for different feedstocks. The yard shall be properly covered from three sides walls and roof can be a flexible cover. However, small biogas plants, may use leak proof brick structure as per IS 1905 for the storage of feedstock. It should be ensured that there is no release of foul odours from the feedstock storage facility, and protected from rodents, flies and other scavenging animals.

**7.3.2** *Liquid Feedstocks*

The feedstock/slurry may be stored in appropriate leakproof tanks before adding it to the digester, as applicable.

## 8 ELECTRO–MECHANICAL WORK

All electro – mechanical works like valves, gates, pipes and fittings, instrumentations, lightings, wiring, etc. shall be as per Annex E.

## 9 SPECIFICATION OF OUTPUT

### 9.1 Biogas (Biomethane)

The requirements of biogas (biomethane) for use in automotive application, piped network and cylinder applications shall comply with and tested in accordance with IS 16087.

## ANNEX A
( *Clause* 2 )

## LIST OF STANDARDS REFERRED

| *IS/ISO No.* | *Title* |
|---|---|
| 456 : 2000 | Plain and reinforced concrete — Code of practice (*fourth revision*) |
| 800 : 2007 | General construction in steel — Code of practice (*third revision*) |
| 875 (Part 1) : 1987 | Code of practice for design loads (other than earthquake) for buildings and structures: Part 1 Dead loads — Unit weights of building materials and stored materials (*second revision*) |
| 1079 : 2017 | Hot rolled carbon steel sheet, plate and strip — Specification (*seventh revision*) |
| 1161 : 2014 | Steel tubes for structural purposes — Specification (*fifth revision*) |
| 1905 : 1987 | Code of practice for structural use of unreinforced masonry (*third revision*) |
| 2062 : 2011 | Hot rolled medium and high tensile structural steel — Specification (*seventh revision*) |
| 2379 : 1990 | Pipelines — Identification — Colour code (*first revision*) |
| 2508 : 2016 | Polyethylene films and sheets — Specification (*third revision*) |
| 3370 (Part 1) : 2021 | Concrete structures for retaining aqueous liquids — Code of practice: Part 1 General requirements (*second revision*) |
| 3370 (Part 2) : 2021 | Concrete structures for retaining aqueous liquids — Code of practice: Part 2 Plain and reinforced concrete structures (*second revision*) |
| 4923 : 2017 | Hollow steel sections for structural use — Specification (*third revision*) |
| 4984 : 2016 | Polyethylene pipes for water supply — Specification (*fifth revision*) |
| 5312 (Part 1) : 2004 | Swing check type reflux (non-return) valves for water works purposes — Specification: Part 1 Single door pattern (*second revision*) |
| 5312 (Part 2) : 2013 | Swing check type reflux (non-return) valves for water works purpose — Specification: Part 2 Multi — door pattern (*first revision*) |
| 6092 (Part 1) : 1985 | Methods of sampling and test for fertilizers: Part 1 Sampling (*first revision*) |
| 6092 (Part 2/Sec 1) : 2004 | Methods of sampling and test for fertilizers: Part 2 Determination of nitrogen: Sec 1 Introduction (*second revision*) |
| 6092 (Part 2/Sec 2) : 2004 | Methods of sampling and test for fertilizers: Part 2 Determination of nitrogen: Sec 2 Test methods not covered under dual number standards (*second revision*) |
| IS 6092 (Part 2/Sec 3) : 2004/ISO 4176 | Methods of sampling and test for fertilizers: Part 2 Determination of nitrogen: Sec 3 Nitrate nitrogen content — Nitron gravimetric method |
| IS 6092 (Part 2/Sec 4) : 2004/ISO 5314 | Methods of sampling and test for fertilizers: Part 2 Determination of nitrogen: Sec 4 Ammoniacal nitrogen content — Titrimetric method after distillation |
| 6092 (Part 2/Sec 5) : 2004/ISO 5315 | Methods of sampling and test for fertilizers: Part 2 Determination of nitrogen: Sec 5 Total nitrogen content — Titrimetric method after distillation |
| 6092 (Part 3/Sec 1) : 2004 | Methods of sampling and test for fertilizers: Part 3 Determination of phosphorus: Sec 1 Introduction (*second revision*) |

| | |
|---|---|
| 6092 (Part 3/Sec 2) : 2004 | Methods of sampling and test for fertilizers: Part 3 Determination of phosphorus: Sec 2 Test methods not covered under dual number standards (*second revision*) |
| IS 6092 (Part 3/Sec 3) : 2004/ ISO 5316 | Methods of sampling and test for fertilizers: Part 3 Determination of phosphorus: Sec 3 Extraction of water — soluble phosphates |
| IS 6092 (Part 3/Sec 4) : 2004/ISO 6598 | Methods of sampling and test for fertilizers: Part 3 Determination of phosphorus: Sec 4 Quinoline phosphomolybdate gravimetric method |
| IS 6092 (Part 3/Sec 5) : 2004/ISO 7497 | Methods of sampling and test for fertilizers: Part 3 Determination of phosphorus: Sec 5 Extraction of phosphates soluble in mineral acids |
| 6092 (Part 4) : 1985 | Methods of sampling and test for fertilizers: Part 4 Determination of potassium (*first revision*) |
| 6092 (Part 5) : 1985 | Methods of sampling and test for fertilizers: Part 5 Determination of secondary elements and micronutrients (*first revision*) |
| 6092 (Part 6) : 1985 | Methods of sampling and test for fertilizers: Part 6 Determination of moisture and impurities (*first revision*) |
| 6940 : 1982 | Methods of test for pesticides and their formulations (*first revision*) |
| IS 7016 (Part 1/Sec 1) : 2022 ISO 2286-1:2016 | Methods of test for rubber or plastics coated fabrics: Part 1 Determination of roll characteristics Section 1 Methods for determination of length, width and net mass (*third revision*) |
| IS 7016 (Part 1/Sec 2) : 2019 ISO 2286-2 : 2016 | Methods of test for coated and treated fabrics: Part 1 Determination of roll characteristics Section 2 Methods for determination of total mass per unit area, mass per unit area of coating and mass per unit area of substrate (*second revision*) |
| IS 7016 (Part 1/Sec 3) : 2019 ISO 2286-3 : 2016 | Methods of test for coated and treated fabrics: Part 1 Determination of roll characteristics Section 3 Method for determination of thickness (*second revision*) |
| IS 7016 (Part 2) : 2022 ISO 1421:2016 | Methods of test for rubber or plastics coated fabrics: Part 2 Determination of tensile strength and elongation at break (*third revision*) |
| IS 7016 (Part 3/Sec 1) : 2022 ISO 4674-1:2016 | Methods of test for rubber or plastics coated fabrics: Part 3 Determination of tear resistance Section 1 Constant rate of tear methods (*third revision*) |
| IS 7016 (Part 3/Sec 2) : 2017 ISO 4674-2:1998 | Methods of test for coated and treated fabrics: Part 3 Determination of tear resistance Section 2 Ballistic pendulum method (*second revision*) |
| IS 7016 (Part 4) : 2003 ISO 7854 | Methods of test for coated and treated fabrics: Part 4 Rubber — or plastics — Coated fabrics — Determination of resistance to damage by flexing (*second revision*) |
| IS 7016 (Part 5) : 2019 ISO 2411:2017 | Methods of test for coated and treated fabrics: Part 5 Rubber — or plastics — Coated fabrics — Determination of coating adhesion (*third revision*) |
| IS 7016 (Part 6/Sec 1) : 2016 ISO 3303-1 : 2012 | Methods of test for coated and treated fabrics: Part 6 Determination of bursting strength Section 1 Steel — Ball method (*second revision*) |
| IS 7016 (Part 6/Sec 2) : 2018 ISO 3303-2:2012 | Methods of test for coated and treated fabrics: Part 6 Determination of bursting strength Section 2 Hydraulic method (*second revision*) |

| | |
|---|---|
| IS 7016 (Part 7) : 2009<br>ISO 1420 | Methods of test for coated and treated fabrics: Part 7 Rubber — or plastics — Coated fabrics — Determination of resistance to penetration by water (*second revision*) |
| IS 7016 (Part 8) : 1975 | Methods of test for coated and treated fabrics: Part 8 Accelerated ageing |
| IS 7016 (Part 9) : 2003<br>ISO 5978 | Methods of test for coated and treated fabrics: Part 9 Rubber — or plastics — Coated fabrics — Determination of blocking resistance (*second revision*) |
| IS 7016 (Part 10) : 1997<br>ISO 4675 | Methods of test for coated and treated fabrics: Part 10 Rubber — or plastics — Coated fabrics — Low Temperature bend test (*first revision*) |
| IS 7016 (Part 11) : 1987 | Methods of test for coated and treated fabrics: Part 11 Determination of flexibility — Flat loop method |
| IS 7016 (Part 12) : 1987 | Methods of test for coated and treated fabrics: Part 12 Determination of tack — Tear resistance |
| IS 7016 (Part 13) : 2003<br>ISO 5473 | Methods of test for coated and treated fabrics: Part 13 Rubber — or plastics — Coated fabrics — Determination of crush resistance (*first revision*) |
| IS 7016 (Part 14) : 2003<br>ISO 4646 | Methods of test for coated and treated fabrics: Part 14 Rubber — or plastics — Coated fabrics — Low temperature impact test (*first revision*) |
| IS 7016 (Part 15) : 2019<br>ISO 5470-1 : 2016 | Methods of test for coated and treated fabrics: Part 15 Determination of abrasion resistance using taber abrader |
| 8329 : 2000 | Centrifugally cast (spun) ductile iron pressure pipes for water, gas and sewage — Specification (*third revision*) |
| 8749 : 2002 | Biogas stove — Specification (*second revision*) |
| 8935: 1985 | Specification for electric solenoid operated actuators (*first revision*) |
| 9334: 1986 | Specification for electric motor operated actuators (*first revision*) |
| 9523 : 2000 | Ductile iron fittings for pressure pipes for water, gas and sewage — Specification (*first revision*) |
| 9890 : 1981 | Specification for general purpose ball valves |
| IS/ISO 10434 : 2020/<br>ISO 10434:2020 | Steel gate valves flanged and butt — welded ends for petroleum petrochemicals and allied industries |
| 12866 : 2021 | Plastic translucent sheets made from thermo-setting polyester resin glass fibre reinforced — Specification |
| 12986 (Part 1) : 1990 | Biogas plants — Glass fibre reinforced polyester resin gas holders — Specification: Part 1 with steel frame |
| 13095 : 2020 | Butterfly valves for general purposes (*first revision*) |
| 13349 : 1992 | Cast iron single faced thimble mounted sluice gates |
| IS 14333 : 2022 | Polyethylene pipes for sewerage and industrial chemicals and effluent — Specification (*first revision*) |
| IS 15045 (Part 1) : 2021/ISO 5599-1 : 2001 | Pneumatic fluid power — Five — port directional control valves: Part 1 Mounting interface surfaces without electrical connector (*first revision*) |
| IS 15045 (Part 2) : 2021/ ISO 5599- | Pneumatic fluid power — Five — port directional control valves: Part 2 Mounting interface surfaces with optional electrical connector (*first* |

| | |
|---|---|
| 2:2001 | *revision*) |
| IS 15045 (Part 3) : 2001<br>ISO 5599-3:1990 | Pneumatic fluid power — Five port directional control valves: Part 3 Code system for communication of valve functions |
| ISO 15105 : 2007 | Plastics — Film and sheeting — Determination of gas-transmission rate — Part 1: Differential-pressure methods |
| 15663 (Part 1) : 2006 | Design and installation of natural gas pipelines — Code of Practice: Part 1 Laying of pipelines |
| 15778 : 2007 | Chlorinated polyvinyl chloride (CPVC) pipes for potable hot and cold water distribution supplies – Specification |
| 16087 : 2016 | Biogas (biomethane) — Specification (*first revision*) |
| IS/ISO 17292 : 2015 | Metal ball valves for petroleum petrochemical and allied industries (*first revision*) |
| 17875 : 2022 | Stainless steel seamless pipes and tubes for general service |
| 17876 : 2022 | Stainless steel welded pipes and tubes for general service |
| IS/ISO 22109 : 2020 | Industrial valves — Gearbox for valves |

## ANNEX B

( *Clause* 5.3 and 6 )

### Table 8 Type of Feedstocks Considered for Biogas Plants Along with Organic Loading Rate, Hydraulic Retention Time, Volatile Solid Removal and Biogas Yield According to Plant Size

| **Sl No.** | | **Small-Scale Biogas Plant** | | | | | **Medium-Scale Biogas Plant** | | | | | **Large-Scale Biogas Plant** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Types of Waste** | **OLR** (kg VS/$m^3$ digester liquid volume/ day) | **HRT** (day) | **VS removed** (percent) | **Specific biogas produced** ($m^3$/ kg VS removed) | **Min. biogas produced** ($m^3$/tonne solid waste) | **OLR** (kg VS/$m^3$ digester liquid volume /day) | **HRT** (day) | **VS removed** (percent) | **Specific biogas produced** ($m^3$/ kg VS removed) | **Min. biogas produced** ($m^3$/tonne VS) | **OLR** (kg VS/$m^3$ digester liquid volume /day) | **HRT** (day) | **VS removed** (percent) | **Specific biogas produced** ($m^3$/ kg VS removed) | **Biogas produced** ($m^3$/tonne VS) |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
| i) | Poultry Waste + Seed | 1.75 | 40 | 44 | 0.6 | 50 | 2 | 35 | 44 | 0.7 | 60 | 2 | 35 | 44 | 0.7 | 70 |
| ii) | Municipal Solid Waste + Seed | 2.2 | 30 | 75 | 0.5 | 70 | 2.7 | 30 | 75 | 0.5 | 75 | 3 | 30 | 75 | 0.5 | 80 |
| iii) | Food Waste + Seed | 2 | 30 | 70 | 0.55 | 90 | 2.5 | 30 | 70 | 0.55 | 90 | 3 | 30 | 70 | 0.55 | 95 |
| iv) | Vegetable Waste + Seed | 2.2 | 30 | 75 | 0.6 | 80 | 2.7 | 30 | 75 | 0.65 | 85 | 3.3 | 30 | 75 | 0.65 | 95 |
| v) | Slaughter house Waste + Seed | 2.0-3.0 | 20 | 55 | 0.7 | 70 | 3.0 | 30 | 60 | 0.7 | 70 | 4.10-6.10 | 25 | 60 | 0.8 | 65 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| vi) | Agricultural Waste + Rice Straw + Seed | 1.4 | 35 | 53 | 0.33 | 60 | 1.7 | 35 | 53 | 0.33 | 70 | 2 | 30 | 53 | 0.33 | 70 |
| vii) | Kitchen Waste + Seed | 2.2 | 30 | 75 | 0.5 | 70 | 2.7 | 30 | 75 | 0.5 | 80 | 3.3 | 30 | 75 | 0.5 | 70 |
| viii) | Cattle dung [DAP, Milch, Grazed (on grass /straw dominant diet)] | 2 | 40 | 28 | 0.23 | 30 | 2 | 40 | 28 | 0.23 | 35 | 2.29 | 35 | 28 | 0.23 | 35 |
| ix) | Sewage Sludge (no pretreatment) | - | - | - | - | - | 0.8 | 25 | 60 | 0.23 | 35 | 0.8 | 25 | 60 | 0.23 | 35 |

NOTES

**1** Seed/ Inoculum: active biodigester slurry, STP sludge, fresh cow dung or recirculated slurry or water (microbial inoculum);
**2** OLR varies from high rate to low rate to standard rate anaerobic digester high rate 4-8, standard rate 2-4, low rate 1-2, HRT also varies as less than 15 days high rate, 15-25 days standard rate, and more than 25 days low rate digester;
**3** The data shown above is at minimum side; and
**4** The units and parameter above are recommended for optimum performance, however improved performance is desirable.
**5** For reference it may be assumed that for a family of 4 persons, 1 $m^3$ per day of biogas is required for cooking purpose.

## ANNEX C
( *Clause* 6 )

## ASSESSMENT OF FOS/TAC RATIOS

| **Sl No.** | **FOS/TAC Ratios** | **Assessment** |
|---|---|---|
| (1) | (2) | (3) |
| i) | > 0.6 | Highly excessive biomass input, stop adding biomass. |
| ii) | 0.5–0.6 | Excessive biomass input, add less biomass. |
| iii) | 0.4–0.5 | Plant is heavily loaded, monitor the plant more closely. |
| iv) | 0.3–0.4 | Biogas production at a maximum, keep biomass input constant. |
| v) | 0.2–0.3 | Biomass input is too low, slowly increase the biomass input. |
| vi) | < 0.2 | Biomass input is far too low, rapidly increase the biomass input. |

## ANNEX D
( *Clause* 7.2 )

## REQUIREMENTS FOR DESIGN IN CIVIL CONSTRUCTION

### D-1 GENERAL

This may include design and construction of feed storage area, feed handling system (pre-processing), digester feed chamber, anaerobic digester, digested slurry storage and processing for organic digestate manure, biogas storage system, purification and bottling unit/$CO_2$ extraction and processing unit/electricity generation unit, water storage tank, fire fighting system, etc. (as applicable).All these works required to deliver the civil structures complete in all respects including water retaining structures, gas leak proof construction of digester and gas holder (leakage testing), structural steel works, finishing works like handrailings, floorings, plastering, painting of civil and steel structures, roof water proofing, rain water pipes, plumbing and sanitary pipes and fittings (wherever applicable).

### D-2 CIVIL AND STRUCTURAL DESIGN

#### D-2.1 Structural Design

**D-2.1.1** *Reinforced Cement Concrete (RCC) Structure*

All Reinforced Cement Concrete (RCC) structures shall be constructed as per IS 456 and the following:

a) Foundations of structures are assumed to be offering fixed support; and
b) The column above RCC Wall shall be assumed as pinned over RCC wall so that no moment is transferred to the RCC wall below.

**D-2.1.2** *Liquid Retaining Structure*

All liquid retaining structures made up of concrete shall be as per IS 3370 (Part 1), IS 3370 (Part 2) and the following:

a) F.O.S. against uplift shall be 1.25 and against sliding it shall be 1.5.

**D-2.1.3** *Steel Structure*

Fabrication and erection of all the steel structures shall be as per IS 800. Plates and different section used in structures shall be as per following:

| *IS No.* | *Title* |
|---|---|
| IS 2062 | Hot rolled sections and plates |
| IS 1079 | Cold formed light gauge sections |
| IS 1161 | Tubular sections |
| IS 4923 | Hollow sections (rectangular or square) |

#### D-2.2 Loads

**D-2.2.1** *Dead Loads*

Dead loads include the weight of all permanent construction including walls, floors roofs, partitions, staircase and fixed service equipment and other equipment including their contents. Dead Loads for design shall be in accordance with IS 875 (part 1).

**D-2.2.2** *Liquid & Soil Loads*

Tanks below ground shall be subjected to surcharge and lateral pressure due to soil. Following load cases shall be considered for the design of Liquid Retaining Structures (LRS):

a) For wall-water inside tank full upto top of wall and no soil acting outside;
b) For raft-inside tank full;
c) Inside tank empty with soil and surcharge pressure of 1.0 MT/m$^2$ shall be considered on wall where ever required;
d) For two compartments -One shall be treated full up to top of wall and the other empty;
e) The following soil pressure co-efficient shall be considered for calculating lateral loads:
    1) For Free cantilever wall the earth pressure coefficient shall be 0.33 for rest it shall be 0.5 i.e. earth pressure co efficient at rest;
    2) For circular structure and propped wall earth pressure coefficient shall be 0.5; and
f) Ground water table if any shall be considered in the design of structures.

**D-2.2.3** *Live Loads*

The following minimum loads shall be considered in the design of structures:

a) Live loads on roofs = 150 kg/m$^2$;
b) Pump house operating floor = 1 050 kg/m$^2$;
c) Maintenance/Storage/Air blower floor = 750 kg/m$^2$;
d) Suspended switch gear, battery room = 1 000 kg/m$^2$;
e) Stairs, walkway & landing = 500 kg/m$^2$; and
f) Surcharge = 1 000 kg/m$^2$.

**D-2.2.4** *Temperature Loads & Construction Joints*

Temperature load shall be considered half of 2/3 of difference between maximum and minimum temperature. The construction joints in Buildings and Tank structures shall be provided as per relevant standard/engineering practices.

**D-2.2.5** *Impact & Vibratory Loads*

Structures subjected to impact or vibratory loads shall be considered as 2.5 times the weight of vibratory equipment like pumps, motor, blower, compressor etc.

**ANNEX E**
( *Clause* 8 )

**GENERAL REQUIREMENTS FOR ELECTRO-MECHANICAL WORKS SPECIFICALLY FOR MEDIUM AND LARGE SCALE PLANTS**

## E-1 GENERAL

This specifies the general requirements related to electro-mechanical works to be carried out. Material and design of all the equipments, valves, gates, electrical instruments etc. shall be suitable for the duty requirement to ensure minimum design life of 15 years as per relevant Indian Standards. However, the following minimum requirements need to be adhered to:

## E-2 MECHANICAL WORKS

Various parts and components required for mechanical works of biogas plants are given below, however, level of automation to be decided based on the biogas plant capacity:

### E-2.1 Valves

a) All automatic valves may be electrically or electro-pneumatically actuated. Pneumatic valves shall have 5 way acting solenoids and the requisite air pressure depending on the valve specifications as per IS 15045 (all parts);
b) Medium (2 000 $m^3$ per day biogas and above) and large size plants: Entire plant/operations may be automated at desired level;
c) All valves of 500 mm diameter and above, and valves in discharge of pumps/blowers irrespective of size shall be electrically actuated as per IS 9334 and IS 8935;
d) Valves up to and including 200 mm diameter can be wafer/lugged wafer type. All valves above 200 mm diameter shall be double flanged;
e) All valves shall be provided with a dismantling joint for ease of maintenance. Dismantling joint can be common between two adjacent valves;
f) All valves 250 mm diameter and above shall be gear based as per IS/ISO 22109;
g) All valves shall be as per the requirements and of the same size as line size;
h) Valves in water line shall be butterfly type, valves in sludge lines shall be knife gate valves and valves in chemical lines shall be ball valves;
j) NRVs shall be either swing check or dual plate check valves as per IS 5312 (all parts);
k) All valves shall be of PN10 pressure rating or at least 2 times the working pressure, whichever is higher;
m) All NRVs shall be double flanged. Ball valves shall be socketed or flanged type (in case of non-metallic) and flanged (in case of metallic); and
n) All butterfly valves shall be as per IS 13095, gate valves shall be as per IS/ISO 10434 and ball valves shall be as per IS 9890 and IS/ISO 17292.

### E-2.2 Gates

a) Automatic gates shall be electrically actuated and not pneumatic actuated as per IS 9334 and IS 8935;
b) All gates of 1 000 mm × 1 000 mm size and above shall be automatic and electrically actuated;

c) All gates shall be thimble mounted as per IS 13349;
d) Gates shall be in cast iron construction with SS shaft; and
e) As involves entire plant/operations shall be automated, operable through central operating system. All gates required to be automatic to achieve this purpose.

**E-2.3 Actuators**

Electric actuators shall be as per IS 9334 and IS 8935.

**E-2.4 Pipes and Fittings for Different Plant Utility**

a) All process lines including sludge lines shall be HDPE pipelines as per IS 4984 of PN10 rating or Class K9 ductile iron pipelines as per IS 8329. All ductile iron pipe fittings shall conform to IS 9523 of pressure rating PN10 or 2 times the working pressure, whichever is higher;
b) Chemical, Process water and drinking water pipelines shall be CPVC pipelines as per IS 15778,10 $kg/cm^2$ pressure rating or 2 times the working pressure, whichever is higher or SS304, Schedule 20 as per IS 17875 and IS 17876;
c) Air pipe shall be SS304, Schedule 20 as per IS 17875 and IS 17876 or thickness as required for pressure 2 times the working pressure, whichever is higher;
d) All buried pipes shall be laid on beddings as required to suit site conditions after levelling and compaction to minimum 90 percent proctor density. All over ground pipework shall be suitably supported over pipe racks/structural steel supports and anchored to tanks/buildings/structures suitably facilitating easy replacements during maintenance as relevant Indian Standard; and
e) All pipework shall be suitably colour banded for the conveying fluid and direction of flow marked with appropriate colour as per IS 2379.

**E-2.5 Hoist and Cranes**

For medium and large size biogas plants according to requirements and local conditions, lifting equipment (hoists or cranes) shall be provided in all locations requiring lifting and shifting of material for operation and maintenance of plant.

**E-2.6 Hardware**

All hardware like nuts, bolts, washers, flanges, etc., shall be suitable to meet the duty requirement, however components in contact with raw biogas shall be minimum SS304 or non corrosive materials for components use for raw biogas.

**E-3 ELECTRICAL AND INSTRUMENTATION SYSTEMS**

Electrical & Instrumentation systems for medium and large sized biogas plants shall be designed as per the relevant Indian Standards as applicable. Level of automation may be decided based on the biogas plant capacity.

**ANNEX F**

( *Clause* 7.1 )

**DIFFERENT TYPES OF DIGESTERS USED IN BIOGAS PLANTS**

**F-1 CONTINUOUS STIRRED TANK RECTOR (CSTR) TYPE DIGESTERS (HORIZONTAL/ VERTICAL DESIGN)**

CSTR digester consists of continuous stirred tank reactor where continuous mixing of effluent and biomass take place with the help of central and lateral agitators. The essential feature of that the wash out of the active anaerobic bacterial biomass from the reactor is controlled by a sludge separator recycle system. The basic idea underlying the anaerobic contact process is that:

a) Provide contact between the active biomass and feed;
b) Utilize the digester volume effectively;
c) Prevent stratification and temperature gradient; and
d) Minimize the formation of scum layer and the deposition of sludge solids.

**F-1.1 CSTR Digester Process**

a) Raw effluent is collected in a buffer tank and maintains the temperature around 38$^o$C to 42$^o$C. Some quantity of treated spent wash (Digester outlet) also mixed in buffer tank to raise the pH;
b) From buffer tank raw spent wash feeded at top in a center shaft of digester;
c) There will be one central agitator and two to five numbers of lateral agitators are available to make uniform distribution of biomass and substrate for uniform degradation;
d) The effluent travels to the bottom and contact with active anaerobic culture in the reactor by the rotation of central agitator and lateral agitators;
e) The re-circulated sludge also mixed with raw effluent in a central shaft of the digester;
f) The treated spent wash collected through overflow pipe and passed through degassing tower for removal of dissolved gases to achieve better settling of sludge in further process;
g) Biogas collected at the top of the digester and will be stored in gasholder. Biogas from the biogas holder will be compressed and sent to boiler for burning; and
h) Biogas also used for gas engine to generate the power, here $H_2S$ shall be removed from the biogas before using the gas engine.

**F-2 UP-FLOW ANAEROBIC SLUDGE BED (UASB)**

UASB reactor is based on the so-called three-phase separator, which enables the reactor to separate gas, water and sludge mixtures under high turbulence conditions. This allows for compact, cheaper designs. The reactor has multiple gas hoods for the separation of biogas. As a result the extremely large gas/water interfaces greatly reduce turbulence, making relatively high loading rates of 10–15 kg/m$^3$ per day possible. Separation in the UASB reactor requires only 1.0 meter of height, which prevents flotation effects and, consequently, floating layers. Generally, during the treatment of UASB reactor, the substrate passes through an expanded sludge bed which containing a high concentration of biomass first. After that, the remaining part of substrate passes through a less dense biomass which named the sludge blanket. The influent is pumped to the UASB reactor from bottom of it by Peristaltic pump. The influent move upwards and get contact with the biomass in sludge bed, then continue to move upwards and the rest substrates act with the biomass again in the sludge blanket which has a less concentration of biomass compared with the sludge bed below. The volume of sludge blanket must be sufficient to conduct the further treatment to wastewater by-passed from the lower layer of sludge bed by channeling. At the same time, it will help to ensure a stable effluent quality. A3 phases (Gas-Liquid-Solid or GLS) separator located above the sludge blanket to separate the solid particles from the mixture (gas, liquid, and solid) after treatment and hence allowing liquid and gas to leave the UASB reactor. After the treated wastewater will be collected by the effluent collection system via number of launders distributed over entire area discharging, to main launder provided at periphery of the reactor and the biogases generated will be collected as the valuable fuel or for deposal.

**F-3 FLOATING DRUM PLANT WITH A CYLINDRICAL DIGESTER (KVIC MODEL)**

This type of plant has an underground well-shaped digester having inlet and outlet connections through pipes located at its bottom on either side of a partition wall. An inverted drum (gas holder) made of mild steel is placed in the digester which rests on the wedge shaped support and the guide frame at the level of the partition wall and moves up and down along a guide pipe with the accumulation and use of gas. The weight of the drum applies pressure on the gas to make it flow through the pipelines to the points of use. The gasholder alone is the costliest component which accounts for about 40 percent of the total installation cost of biogas plant. It also needs to be painted regularly for protecting it against corrosion. These plants can be of any size to cater the needs of the users.

**F-4 FLOATING DRUM PLANT WITH A HEMISPHERE DIGESTER (PRAGATI MODEL)**

In Pragati Design Biogas Plant the depth of pit is less than KVIC biogas plant. It is cheaper floating drum biogas plant. It can be constructed in hilly area and high water table areas.
The digester of Pragati design plant start from the foundation in dome shape thereby reducing the constructional area, for same digester volume, thus reducing the cost of construction of the plant. The wall thickness of digester is kept 75 mm only. Dome shape construction takes place upto a collar base, where a central guide frame is provided. The digester wall above guide frame is constructed in cylindrical shape.

**F-5 FLOATING DRUM PLANT MADE UP OF ANGULAR STEEL AND PLASTIC FOIL (GANESH MODEL)**

It is basically a KVIC plant constructed with bamboo and polythene sheet. The digester is made of an angle iron frame, bamboo and polythene sheet. The KVIC gas holder and guide frame are used in this design also. The cost of this plant is 70 percent of KVIC plant.

**F-6 FLOATING DRUM PLANT MADE OF FIBRE GLASS REINFORCED POLYESTER**

This type of digester, which is widely used on a household scale, uses fiberglass so it is more efficient in handling and changing the biogas site. This digester consists of one part that functions as a digester and gas storage, each mixed in one chamber without insulation. Digester from fiberglass material is very efficient because it is very impermeable, lightweight and strong. If there is a leak, it is easily repaired or reshaped as before, and the more efficient is that the digester can be moved at any time if the farmer does not use it anymore. The main advantage of fiberglass digester is its ease of implementation and handling, low investment costs and more environmentally friendly.

**F-7 PLUG FLOW REACTOR**

Plug, or tubular, flow reactors consist of a hollow pipe or tube through which reactants flow. The plug flow reactor can be in the form of a tube wrapped around an acrylic mold that is encased in a tank. Water at a controlled temperature is circulated through the tank to maintain a constant reactant temperature. Plug flow reactors, also known as tubular reactors, consist of a cylindrical pipe with openings on each end for reactants and products to flow through. Plug flow reactors are usually operated at steady-state. Reactants are continually consumed as they flow down the length of the reactor. Plug flow reactors may be configured as one long tube or a number of shorter tubes. They range in diameter from a few centimeters to several meters. The choice of diameter is based on construction cost, pumping cost, the desired residence time, and heat transfer needs. Typically, long small diameter tubes are used with high reaction rates, and larger diameter tubes are used with slow reaction rates.

**F-8 EXTERNAL CIRCULATION SLUDGE BED (ECSB)**

High-rate anaerobic digestion system that uses granular biomass to treat wastewater. This technology is ideal for urban areas and facilities with limited space availability. Wastewater with high concentrations of soluble organics can be easily treated in the compact ECSB system, making this technology an ideal choice for breweries, beverage plants, biofuel processors, or the pulp and paper industry. It can be constructed from various materials such as steel, concrete, or fibre/glass-reinforced plastic (FRP/GRP). This technology continuously meet discharge requirements and eliminate wastewater surcharges, Convert organic waste to recoverable green energy (heat and power), Pressurized system design eliminates odour emissions and sealed headspace, eliminating the potential for tank corrosion.

**F-9 BIOGAS INDUCED MIXING ARRANGEMENT (BIMA) DIGESTER**

The biogas-BIMA-Digester System (Biogas-Induced-Mixing-Arrangement) is the ‘Original’ among the self-mixing hydraulic digester systems. It doesn’t require any mechanical equipment such as agitator, circulation pumps or gas injection for mixing the digester. The 2-chamber system uses the produced biogas to create a level difference in the chambers and in this way builds up a mixing pressure of up to 500 mbar. The turbulent mixing occurs against the biogas production in intervals of 4-10 times a day. The system is extremely low-maintenance and has lower operational costs than conventional systems. Ideal applications of this system are high solid sludge and waste, such as in the sewage sludge treatment, treatment of organic solid wastewater, manure, organic household and industrial waste, etc.

**F-10 FIXED-DOME PLANT WITH A BRICK REINFORCED, MOULDED DOME (JANTA MODEL, 6 $m^3$ TO 25 $m^3$ per day)**

The main feature of the fixed-dome biogas plant or Janta Model Biogas Plant is that the digester and the gas holder are integrated parts of brick masonry structure. The digester is made of a shallow well having a dome-shaped roof on it. The inlet and outlet tanks are connected with the digester through large chutes which are called displacement chambers. The gas pipe is fitted on the crown of the masonry dome and there is an opening on the outlet wall of the outlet displacement chamber for the discharge of spent digested slurry. The size of this plant is limited to 25 $m^3$ per day.

**F-11 FIXED-DOME PLANT WITH A HEMISPHERE DIGESTER (DEENBANDHU MODEL, UPTO 6 $m^3$/day)**

The world Deenbandhu means ‘friend of the poor’. This plant is designed on the principle that the surface area of biogas plants is reduced (minimised) to reduce their installation cost without sacrificing the efficiency of the plant. The design consists of segments of two spheres of different diameters, joined at their bases. The structure thus formed, acts as the digester, as fermentation chamber, as well as the gas storage chamber. The higher compressive strength of the brick masonry and concrete makes it preferable to go in for a structure which could always be kept under compression. A spherical structure loaded from the convex side will be under compression and therefore, the internal load will not have any residual effect on the structure. The digester is connected with the inlet pipe and the outlet tank. The upper part above the normal slurry level of the outlet tank is designed to accommodate the slurry to be displaced out of the digester with the generation and accumulation of biogas and is called outlet displacement chamber. The size of these plants is recommended up to 6 $m^3$ per day.

## F-12 FIXED-DOME PLANT WITH A BRICK REINFORCED, MOULDED DOME (MODIFIED PAU JANTA MODEL, UPTO 500 $m^3$/day)

Fixed-dome plant with a brick reinforced, moulded dome or modified PAU Janta Model Biogas Plant is a large capacity biogas plant developed to cater to the needs of dairy farmers. This essentially, is a 'Janta' design but of a higher capacity. The gas-holder is hemispherical in shape and is structurally safe and crack-resistant. The construction of this type of plant is easy and is not very different from the method for the Deenbandhu Biogas Plant. This plant can be constructed with around 50-60 percent cost as compared to the cost of other conventional floating drum type (KVIC) biogas plant. The biogas plant is an all brick masonry structure. Reinforced cement concrete is not used for construction of either the digester or the dome of the plant. The design is suitable for all regions of the country. The plant may be designed for any rated capacity from 20 to 500 $m^3$/day for the hydraulic retention period of 40 days or more depending upon Total Solid Concentration (TSC) of the influent slurry. Normally cattle dung mixed with equal quantity of water is used as feed for the plant having TSC of 9 to 10 percent. The plant may also work satisfactorily for higher TSC of upto 12 percent. This means water consumption may be cut by upto 50 percent depending upon season and physical status of the cattle dung used at the time of feeding. Maintenance requirements of this plant are far lesser than the floating drum biogas plants.

## F-13 FLOATING-DRUM PLANT MADE OF PRE-FABRICATED REINFORCED CONCRETE COMPOUND UNITS

The ferro-cement type of construction can be applied either as a self supporting shell or an earth-pit lining. The vessel is usually cylindrical. Very small plants (volume under 6 $m^3$) can be prefabricated. As in the case of a fixed-dome plant, the ferro-cement gas holder requires special sealing measures (proven reliability with cemented on aluminium foil).

## F-14 FIXED FILM REACTOR

Fixed-film Activated Sludge (AESFAS) Technology/Package provides for additional biomass within a wastewater treatment facility in order to meet more stringent effluent parameters or increased loadings without the direct need for additional tank capacity. Industry practice for upgrading wastewater treatment plants usually focuses on increasing the bioreactor volume to provide the additional bacterial population required to meet the system kinetic needs. However, designers often encounter clarifier solids loading limitations that put an upper limit on the amount of biomass that can be carried in the suspended growth system. AESFAS systems such as MBBR allow for the additional bacterial population to exist on a fixed surface, thereby eliminating the need to increase the suspended growth population. AESFAS systems add the benefits of Fixed Film systems into the suspended growth Activated Sludge process. Activated Sludge has process flexibility and provides a high degree of treatment. Fixed Film processes are inherently stable and resistant to organic and hydraulic shock loadings. Placing Fixed Film media into Activated Sludge basins combines the advantages of both of these approaches.

## F-15 FLOATING FILMS REACTORS

The Moving Bed Biofilm Reactor or MBBR process is based on the aerobic biofilm principle and utilizes the advantages of activated sludge and other biofilm systems without being restrained by their disadvantages. The basis of the process is the biofilm carrier elements that are made from polyethylene. The elements provide a large protected surface area for the biofilm and optimal conditions for the bacteria culture to grow and thrive. The biofilm that is created around each carrier element protects the bacterial cultures from operating excursions to yield a very robust system for those industrial facilities loaded with process fluctuations. The biofilm also provides a more stable 'home' for the bacteria to grow, so there is less space required compared to other biological systems and far less controls. Essentially nutrient levels and DO levels are the only control points for the system. MBBRs can be designed for new facilities to remove BOD/COD from wastewater streams or for Nitrogen removal. Existing activated sludge plants can be upgraded to achieve nitrogen and removal or higher BOD/COD capacity (up to 500 percent increases have been obtained). The reliability and ease of operation has provided satisfaction to over 350 customers worldwide.

## F-16 BAG TYPE DIGESTERS

A balloon plant consists of a plastic or rubber digester bag, in the upper part of which the gas is stored. The inlet and outlet are attached direct to the skin of the balloon. When the gas space is full, the plant works like a fixed-dome plant i.e., the balloon is not inflated; it is not very elastic. The fermentation slurry is agitated slightly by the movement of the balloon skin. This is favourable to the digestion process. Even difficult feed materials, such as water hyacinths, can be used in a balloon plant. The balloon material must be UV-resistant. The advantages of this biogas plants are its low cost, ease of transportation, low construction (important if the water table is high), high digester temperatures, uncomplicated cleaning, emptying and maintenance. The disadvantages of this biogas plants are its short life (about five years), easily damaged. Balloon plants can be recommended wherever the balloon skin is not likely to be damaged and where the temperature is even and high. One variant of the balloon plant is the channel-type digester with folia and sunshade.

## F-17 HIGH RATE SOLID DIGESTERS

Anaerobic Digestion systems can be operated at a wide range of TS contents depending on the feedstock total solids (TS) content and process design. Anaerobic Digestion for high strength wastewater can be carried out at a very low TS content (< 1.0 percent) using high-rate anaerobic reactors, such as an anaerobic biofilter, UASB, or expanded/fluidized bed reactor. For slurry feedstocks, such as sewage sludge, animal manure, and liquid food waste, Anaerobic Digestion systems are usually designed to operate at low TS contents (< 15 percent) and are referred to as liquid Anaerobic Digestion systems. Another type of Anaerobic Digestion that operates at TS contents higher than 15 percent and digests solid organic wastes, such as the organic fraction of municipal solid waste (OFMSW) and crop residues, is defined as solid-state Anaerobic Digestion. High TS contents will reduce the mass transfer rate in Anaerobic Digestion and result in a retarded reaction rate and slow diffusion of intermediate products and inhibitors. The changes of volumetric reaction rate of lignocellulosic biomass in Anaerobic Digestion increase with TS content due to the increase of organic loading but then decrease at TS of around 20 percent, due to the slow mass transfer and accumulation of inhibitors.

## ANNEX G
( *Clause* 5.5 )

## SAMPLING AND ANALYSIS

### G-1 FEEDSTOCK

For feedstock following parameters may be analysed as per the relevant Indian Standard:

a) Total Solids;
b) Volatile Solids;
c) Compositional analysis;
d) C:N Ratio; and
e) Bio Chemical Methane Potential (BMP).

### G-2 PRODUCT/PROCESS

During the operation of biogas plant following parameters may be analysed:

a) PH value;
b) FOS-TAC Ratio;
c) Biogas Yield; and
d) Biogas Analysis.

### G-3 ANALYSIS OF DIGESTED SLURRY

Digested slurry may be analyzed for all parameters using standard test methods as prescribed in Table 9 below:

**Table 9 Testing Parameters for Analysis of Digested Slurry**
( *Clause* G-3 )

| Sl No. | Parameters | Method of test |
|---|---|---|
| (1) | (2) | (3) |
| i) | Sampling | IS 6092 (Part 1) |
| ii) | Moisture, percent (wb) | IS 6092 (Part 6) |
| iii) | Colour | — |
| iv) | Odour | — |
| v) | Particle size | — |
| vi) | Bulk density, g/cm$^3$ | IS 6940 |
| vii) | Total organic carbon, percent (wb) | — |
| viii) | Total nitrogen (as N), percent (wb) | IS 6092 (Part 2/Sec 1 to 5) |
| ix) | Total phosphate (as $P_2O_5$), percent (wb) | IS 6092 (Part 3/Sec 1 to 5) |
| x) | Total potassium (as $K_2O$), percent (wb) | IS 6092 (Part 4) |
| xi) | Micronutrients | IS 6092 (Part 5) |

## ANNEX H
( *Foreword* )

## RECOMMENDED APPLICATIONS OF FINAL PRODUCT AND BY-PRODUCTS

### H-1 COOKING

Biogas may be supplied to households for use in Biogas cookstove for cooking purpose, biogas cookstove shall be as per IS 8749.

### H-2 ELECTRICITY GENERATION FROM BIOGAS (BIOMETHANE)

Biogas (Biomethane) may be used for the generation of electricity using CNG engines. 100 percent biogas engines may also be used for conversion of biogas into electricity as per the relevant Indian Standard.

### H-3 DIGESTATE AS ORGANIC FERTILISER

Organic fertilizer is a by-product of the digestion process and produced in solid and/or liquid form, from the digester. This prescribed composition of the solid organic fertilizer for digestate of biogas (biomethane) plants shall comply for the solid and liquid organic fertilizers produced from the biogas digester as prescribed in Table 10 below, for further packaging and sales as the case may be.

**Table 10 Specification of Organic Fertilizer**
( *Clause* H-3 )

| Sl No. | Parameters | Solid organic fertilizer | Liquid organic fertilizer |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| i) | Moisture percent by weight | 30-40 percent | 90-97 percent |
| ii) | Particle size | Minimum 90 percent material should pass through 4.0 mm IS sieve | Minimum 90 percent material should pass through 4.0 mm IS sieve |
| iii) | Total organic carbon, percent by weight, minimum | 14 | 14 |
| iv) | NPK Nutrients — Total N, $P_2O_5$ and $K_2O$ nutrient should not be less than (for upgraded digestate based organic fertilizer the nos. for $P_2O_5$ and $K_2O$ to be given PROMs) | 1.2 percent | 1.2 percent |
| v) | C:N ratio | < 20 | < 20 |
| vi) | pH | 6.5-8.0 | 6.5-8.0 |
| vii) | Conductivity (as ds/m), not more than | 4.0 | 4.0 |
| viii) | Pathogens | Nil | Nil |
| ix) | Heavy metal content, mg/l, maximum | | |
| x) | Arsenic (As) | 10 | 10 |
| xi) | Cadmium (Cd) | 5 | 5 |

| | | | |
|---|---|---|---|
| xii) | Chromium (Cr) | 50 | 50 |
| xiii) | Copper (Cu) | 300 | 300 |
| xiv) | Mercury (Hg) | 0.15 | 0.15 |
| xv) | Nickel (Ni) | 50 | 50 |
| xvi) | Lead (Pb) | 100 | 100 |
| xvii) | Zinc (Zn) | 1 000 | 1 000 |

NOTES

**1** Bio-$CO_2$ utilization: Bio-$CO_2$ separated from purification of biogas can be used in green house chambers for plant growth – dry ice (food grade), fumigation in grain storage, liquefaction, $CO_2$ sequestration for algae growth, fire extinguishers, and chemical synthesis;

**2** Liquid organic fertilizer can also be upgraded or amended with additional stable organic matter to improve quality; and

**3** Solid and Liquid digestate may be upgraded to make.

a) PROM (Potassium and Phosphate rich organic manure); and
b) Microbial inoculent enriched solid/liquid biofertilizer.

Digestate slurry from biogas plant may be separated through de-watering machines into two, soild and liquid fraction, both the fractions have been notified in FCO. Standards prescribed in FCO are barest minimum and generally achieved without any intervention. In case of Solid fraction (also known as fermented organic manure), moisture is to be maintained below 30-35 percent, as high moisture contents lead to higher microbial activity in storage and may end up losing organic carbon during storage. Liquid manure may be used as it is. Liquid manure is high volume and extremely low in nutrients, generally used in bulk quantities in nearby agricultural fields.

Value addition of fermented organic manure (solid fraction):

a) Phosphate Rich Organic Manure (PROM) – This can be prepared by mixing solid manure fraction with fine powder of rock phosphate to obtain final product with minimum of 8 percent $P_2O_5$ and 10 percent of organic carbon. Ratio of each ingredient can be worked out after analysis of all ingredients and standardizing to achieve the desired value.
b) Organic manure containing 3 percent nutrients - This can be done by adding small quantity of caster or neem cake and/or rock phosphate to comply to the total NPK requirement at 3 percent.