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Domestic biogas plant—Design, construction and operation—Code of practice

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Foreword

Rwanda Standardsarepreparedby Technical Committees and approved by Rwanda Standards Board (RSB) Board of Directors in accordance with the procedures of RSB, in compliance with Annex 3 of the WTO/TBT agreement on the preparation, adoption and application of standards.

The main task of technical committees is to prepare national standards. Final Draft Rwanda Standards adopted by Technical committees are ratified by RSB Board of Directors members for publication and gazettementas Rwanda Standards.

DRS306 was prepared by a Joint Technical Committee RSB/TC 49, *Renewable energy, RSB/TC 10, Electrical installation and protection against electrical shock* and RSB/TC 50, *Electrical generation, transmission and distribution systems.*

In the preparation of this standard, reference was made to the following standard:

IS 9478:1989 (Reaffirmed 2005) *Family size biogas plant — Code of practice*

The assistance derived from the above source is hereby acknowledged with thanks.

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Committee membership

The following organizations were represented on Joint Technical CommitteeRSB/TC 49, *Renewable energy,* RSB/TC 10,*Electrical installation and protection against electrical shock*andRSB/TC 50, *Electrical generation, transmission and distribution systems* in the preparation of this standard.

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Domestic biogas plant — Design, construction and operation— Code of practice

1 Scope

This Draft Rwanda Standard covers the requirements for the design, construction and operation of a domestic fixed dome biogas plant.

2 Normative references

The followingThe following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenceddocument (including any amendments) applies.

RS EAS 18-1, *Cement — Part 1: Composition, specification and conformity criteria for common cements*

RS EAS 54, *Burnt clay bricks — Specification*

RS 107, *Building sand — Specification*

RS EAS 12, *Potable water — Specification*

3 Terms and definitions

For the purposes of this standard, the following terms and definitions apply.

3.1

biogas plant

plant used to process substrate to produce biogas and sludge consisting of an inlet mixing tank, digester, gaschamber and outlet/sludge tank

3.2

fixed dome biogas plant

closed digester with an immovable, rigid gas chamber and a displacement pit

3.3

collecting tank/inlet tank

chamber where substrate and water are collected, stored and separated from heavy and non-biodegradable materials before feeding them into the digester

3.4

inlet pipe

serves as conveyor of the substrate-water mixture or slurry from the mixing tank to the digester

3.5

digester/biodigester/bio-reactor/anaerobic reactor

any water and air tight container designed for the process of anaerobic microbiological degradation of organic matter into which the slurry is introduced for digestion and methanization

3.6

stirrer/mixer/agitator

manual or mechanical device inside the digester used to stir the slurry

3.7

gas chamber/gas holder

space inside or outside the digester for the collection and storage of biogas

3.8

effluent

residue that comes out at the outlet after the substrate is digested/processed inside the digester

3.9

backfill

layer of compacted soil and gravel to support the digester wall

3.10

substrate

organic material used to produce biogas

3.11

slurry

mixture of substrate and water

3.12

retention time

average period that a given quantity of slurry is retained in the digester for digestion

3.13

methanogens

anaerobic bacteria that act upon organic materials and in the process, produce biogas

3.14

methanization/digestion

various processes that take place among the methanogens, non-methanogens and substrate fed into the digester as inputs

3.15

biogas

mixture of gas (composed of 50 % - 70 % methane and 30 % - 40 % carbon dioxide) produced by methanogenic bacteria

3.16

gas production rate

amount of biogas produced per day per cubic meter of slurry

3.17

loading rate

amount of slurry fed per unit volume of digester capacity per day

3.18

scum

layer of floating material (mainly fibrous) on the slurry

3.19

sludge

settled portion or precipitate of the slurry; a mud-like, semi-solid mass

3.20

outlet pipe

serves as conveyor where the effluent or the slurry is forced out

3.21

filling line

level of slurry when the digesters is at full load

3.22

mesophilic temperature range

temperature range of 20 °C - 40 °C where mesophilic bacteria operate

4 Classification of digesters according to digestion processes

4.1 Thermophilic fermentation

These should be placed where the average ambient temperature in is 30 °C and above.

4.2 Mesophilic fermentation

These should be placed where the average ambient temperature is 20 °C - 30 °C.

4.3 Ambient temperature

These should be placed where the average ambient temperature in is 10 °C - 20 °C.

5 Selection of construction site

5.1 Factors for site selection

Selection of construction sites should be governed by the following main factors:

a) site should facilitate easy construction works;

b) selected site should be such that the construction cost is minimised;

c) selected site should ensure easy operation and maintenance activities like feeding of plant, use of main gas valve, composing and use of slurry, checking of gas leakage, draining condensed water from pipeline; and

d) site should guarantee plant safety.

5.2 Considerations for site selection

Based upon the factors mentioned in 5.1, plant location should be selected based upon the following considerations:

a) for effective functioning of biodigesters, right temperature (20 °C - 35 °C) shall be maintained inside the digester. Damp and cool places should be avoided. Therefore, sunny site should be preferable.

b) area to construct the plant should have even surface;

c) site should be in slightly higher elevation than the surrounding to avoid water logging and also ensure free flow of slurry from overflow outlet to the composting pit;

d) make plant easier to operate and avoid wastage of raw materials, especially the dung, plant should be as close as possible to the cattle shed;

e) mix dung and water, considerable quantity of water shall be required;

f) well or ground water source should be at least 10 m away from the biodigester especially the slurry pit to avoid the ground water pollution;

g) main gas valve which is fitted just above the gas holder should be opened and closed before and after theuse of biogas. Therefore, the plant should be as near to the point of application as possible;

h) edge of plant should be at least 2 m away from the foundation of house or any structure;

i) There should be enough space for compost-pit(s) as these are integral parts of the biodigester;

j) site should be at sufficient distance from trees to avoid damage of biodigester from roots;

k) type of soil should have enough bearing capacity to avoid the possibility of sinking of structure; and

l) when space is a problem, the cattle shed can be constructed on top of the plant after proper backfilling.

6 Pre-requisites for setting up a biogas plant

The following requirements shall be looked into before setting up a biogas plant:

a) individual or the family shall have sufficient source of substrate;

b) sufficient space shall be available for constructing biogas plant and for the location of effluent pits, composting or drying of effluent. This space shall preferably be near the source of substrate andinvariably be close to the place where gas shall be used. As there is no problem of fly breeding or foulodour, the gas plant may be located near the residence; and

c) sufficient quantity of water shall be available for mixing with fresh bio-mass before feeding.

7 Determination of the plant sizes

The sizes of the biogas plant shall depend on the quantity and kind of available biomass and retention time of the material in the biogas system for which the plant is designed as specified in clause 8.

8 Design of biogas plant

8.1 Components of a biogas plant

The biodigester shall have the following six main parts:

a) inlet/mixing chamber for cattle dung fed plant);

b) digester (digestion chamber);

c) gas holder (storage chamber);

d) outlet (displacement chamber);

e) gas conveyance system; and

f) slurry compost pit(s).

8.2 Sizes of biogas plant components

8.2.1 The size of the digester, that is the digester volume (Vd) shall be determined on the basis of the chosen retention time (RT) and the daily substrate input quantity (Sd).

$V_d = S_d \times R_T$ [m^3] = m^3/day × number of days]

where

V_d is in m3;

S_d in m^3/day;

RT in Days;

Biomass/ Organic material in kg and Water in L.

8.2.2 The retention time, in turn, is determined by the chosen/given digesting temperature. For an unheatedbiogas plant, the temperature prevailing in the digester can be assumed as -272.15 °C to +271.15 °C abovethe soil temperature.

Substrate input (S_d) = biomass (B) + water (W) [m^3/d]

The ratio shall be 1:1

8.2.3 The sizes of biogas plant components are shown on Figure A.1 and described in Table A.1.

9 Construction of biogas plant

9.1 Selection of construction materials

9.1.1 Cement

The cement to be used in the plant construction shall comply with the requirements of RS EAS 18-1. It shall be fresh, without lumps and stored in a dry place. Bags of cement should never be stacked directly on the floor or against the walls to protect the cement from absorbing moisture before use.

9.1.2 Sand

Sand for construction purpose shall be clean. Sand containing more than 3 % impurities by volume shall be washed. The quantity of impurities especially mud in the sand can be determined by a simple test using a bottle and clean water. For the test, the bottle shall be half-filled with sand, filled with clean water, and then stirred vigorously. The bottle shall be allowed to sit stationary to allow the sand to settle. The particles of sand will settle first while mud particles will settle last. After 20 min - 25 min, the thickness of the mud layer shall be compared to the sand inside the bottle. The percentage of mud should be less than 3 % of the overall volume. Course and granular sand can be used for concrete work, whereas fine sand complying with the requirements of RS 107 shall be used for plastering work.

9.1.3 Gravel

Individual gravel diameter should not be greater than 25 % of the thickness of the slab where it is used. As the slabs and the top of the dome shall not be greater than 8 cm thick, gravel should not be larger than 2 cm in size. The gravel shall be clean. If it is dirty, it should be washed with clean water.

9.1.4 Water

Water to be used for preparing the mortar for masonry work, concrete work, plastering work, soaking bricks/stones before using them, washing sand and aggregates shall be potable water complying with the requirements of RS EAS 12 to avoid an adverse effect on the strength of the structure.

9.1.5 Bricks

Burnt clay bricks shall comply with the requirements of RS EAS 54. When hitting two bricks together, the sound shall be crisp or clean. They shall be well baked and regular in shape. Before use, bricks shall be soaked for at least 10 m in clean water to prevent them from soaking moisture from the mortar after laid in place.

9.1.6 Cobble stone

Cobble-sized stones of 7.5 cm - 30 cm in diameter should be used for masonry work. They shall be clean and solid.

9.2 Plant layout

The plant layout shall be marked on the ground surface with wooden stakes, rocks, chalk or other materials. To mark the plant, a small peg shall be stuck in the ground at the planned centre of the digester. A cord indicating the radius of the digester shall be attached to the peg. The circumference can be marked by rotating the end of the cord in circular fashion. A suitable arrangement shall then be marked for the inlet tank, inlet-pipe(s), outlet-chamber, compost-pits and gas piping.

9.3 Excavation

9.3.1 The excavation work should only be started after deciding the location of manhole and outlet tank. For safety, the pit walls should be vertical and stepped from the ground surface by one meter away from the centre of the excavation for each meter in depth excavated.

9.3.2 Excavated soil should be placed at least one meter away from the edge of the dig, so it does not fall inside the pit during construction. The pit bottom shall be levelled and the earth shall be untouched.

9.3.3 If the design depth cannot be achieved because of hard rock or high groundwater, the design should be modified to a smaller plant or wider digester or combination of both. The biogas plant should not be constructed at or below the ground water table elevation. The earth base of the excavation shall then be compacted using mechanical or manual tools.

9.4 Construction of digester main chamber

9.4.1 The digester foundation base shall be placed using cobbles and gravel as aggregate then filled with concrete and compacted. The foundation should be 15 cm thick. The upper portion of the foundation shall have a smooth plastered surface to prevent the seepage.

9.4.2 At the centre of the pit, a straight rod or pipe shall be placed in an exact vertical position. The vertical pipe shall be used during the construction as a field-expedient guide to ensure symmetry of the biogas plant. At ground level, a rigid pole, pipe or cord shall be placed horizontally across the diameter of the pit. The vertical pipe shall be secured to the horizontal pipe, pole or cord. After securing, the vertical pipe should be checked to ensure that it is still in the plumb/vertical position.

9.4.3 After the foundation has cured for at least two days, the round wall shall be constructed. The first two rows of bricks shall be positioned side by side so that 23 cm wide base is made. First row shall be placed on a firm, untouched and level foundation. Subsequent rows of bricks shall be positioned on their lengths so that the wall thickness is maintained at 23 cm wide.

9.4.4 The backfilling between wall and pit-side shall be compacted with great care. Backfilling should be done not sooner than 12 h following brick course placement to allow mortar to cure. Earth should be well compacted by adding water and gentle ramming along the circumference of the digester.

NOTE Poor compaction leads to cracks in round-wall and dome.

9.4.5 The cement mortar used can be one part of cement to four parts of sand (1:4) up to one part of cement to six parts of sand (1:6) depending on the quality of the sand. The height of the round-wall is detailed on the drawing in Figure 1 under dimension 'H' as measured from the finished floor. The substrate inlet pipe (and toilet pipe, if installed) shall be placed in position when the round-wall is 30 cm - 36 cm high. To reduce the risk of blockages, the inlet pipe(s) shall be placed as vertical as practically possible.

9.4.6 Exactly to the opposite of the main substrate inlet pipe, a 60-cm wide opening shall be left in the round-wall that serves as a manhole. The digested slurry will flow to the outlet tank through this opening. Additional inlet pipes should be placed as close as possible to the main substrate inlet pipe with a maximum distance of 45° from the inlet-centre-manhole line. When the round-wall has reached the correct height, the inside shall be plastered with a smooth layer of cement mortar with mix of 1:3 cement-sand.

9.5 Construction of dome

9.5.1 When the round wall of the digester is complete, the dome shall then be constructed. Before filling the pit with earth to make the mould for dome, backside of the round wall should be filled with proper compacted back-fill. If this is not done, the pressure of earth for the mould can lead to cracks in the round-wall.

9.5.2 The dome shall be constructed using a mould or cast technique. This can be accomplished by constructing a timber frame then placing the earth-cast top for proper arch design. Once the dome is cast, the timber frame and earth will be removed through the outlet chamber manhole.

9.5.3 Mark on the vertical centre pipe the distance "J" from the finished floor noted on drawing in Figure A.1. The vertical pipe should remain in place as the mould is constructed.

9.5.4 The earth of the mould shall be well compacted. If the earth is further compressed after casting the dome, by its own weight and that of the concrete, it can lead to cracks in the dome. When the earth mould hasthe exact shape of the guide, a thin layer of fine sand shall be spread on the mould-top by gently patting it onthe surface. The sand layer shall prevent the earth from adhering to the cast. The earth used for the mouldshall be damp to prevent dry earth from soaking up water from freshly casted concrete.

9.5.5 Before start of the cast work, sufficient labour and construction materials like sand, gravel, cement and water shall be staged on the site and ready for use. The casting shall be done as quickly as possible andwithout interruptions as this will negatively affect the quality of the cast. A constant, adequate supply ofconcrete (mix: 1 cement, 3 sand, 3 gravel (1:3:3) shall be made for the mason. No concrete older than 30 minshould be used. Special care should be taken to maintain the thickness of the dome while casting, that is thethickness near the outer edge should be greater than the thickness at the centre. For the 4 m3, 6 m3, 8 m3 and10 m3 plant, the thickness at the edge should be 25 cm whereas the thickness in the centre should be 7 cm.Similarly, for 15 m3 and 20 m3 plants, the thickness at the edge should be 25 cm and the thickness in thecentre should be 8 cm and 9 cm respectively.

9.5.6 An alternative to concrete cast construction technique shall be the use of baked clay brick in corbel-arch construction. The compression of the brick and mortar in a spherical shape shall support the dome. Theclay brick dome shall have a near-uniform thickness compared to the cast-concrete dome that thins towardsthe centre. A continuous application of mortar along the sand mould is necessary as the bricks are placed.

The brick dome should be placed continuously and use a mortar mix of (1:4) of cement to sand. Once the bricks for the dome have all been placed, the exterior is covered with (1:3) of cement to sand plaster.

9.5.7 During the casting, the concrete shall be protected against strong sunlight by covering it with wetted burlap, jute bags or straw mats. This protection shall be left in place for at least one week. The day after the casting, the turret shall be made. The turret shall be made with brick, 36 cm square and 50 cm tall. The turret shall be plastered with 1:3 of concrete. Any delays during dome construction can lead to leakage between main gas pipe and dome.

9.5.8 Following completion of the dome, the structure shall be sprinkled with water 3 to 4 times a day during the curing period (up to one week).

9.5.9 After the dome has cured for approximately one week, the timbers and earth of the mould can be removed through the manhole. When all earth is removed, the inside of the dome has to be thoroughly cleaned with a stiff brush and clean water. On the clean surface of the dome interior, the following plaster coats shall be applied to make the dome gas-tight from first to last coats:

a) cement and water wash (1:1);

b) 10 mm layer: one part of cement, two parts of sand (1:2);

c) 5 mm layer: 1:1;

d) cement/acrylic emulsion paint coating: (1.5) parts of paint, 20 parts of cement; and

e) cement/acrylic emulsion paint coating: one part of paint, two parts of cement.

9.5.10 Allow at least 24 h between plaster coats. When a layer of plaster is applied, the work must be executed with great care and without interruptions. The performance of the biogas plant is dependent on the gas tightness of the dome.

9.5.11 For proper insulation during the cold season and as counter weight against the gas pressure inside, minimum top cover of 40 cm compacted earth is required on the dome. If the top cover will be prone to erosion due to wind and rain proper protection with gravel, circular wall, or straw matting should be applied.

9.6 Construction of outlet chamber

9.6.1 The outlet chamber excavation and manhole shall be completed concurrently with the digester vessel and the manhole shall share a common foundation with the digester vessel. The manhole of the outlet chamber should be near the digester wall. The depth of excavation shall be less than the digester vessel measured from the top of digester floor by taking the dimension 'I' minus the thickness of the digester floor shall depend upon construction material used but generally "I" + 13 cm. The earth behind the manhole and under the outlet floor shall be well compacted to prevent cracks in outlet chamber walls.

9.6.2 The inside dimensions of the outlet can be found on the drawing under A, B and D. The overflow level shall be at the top of dimension "D" and top of the outlet chamber walls shall be dimension "D" + 15 cm. Theprescribed dimensions shall be used as they determine the useful capacity of the gasholder. For the samereason the outlet floor and the top of the walls shall be level. The walls shall be vertical and finished with a smooth layer of cement plaster mix: one part of cement, three parts of sand. Outside of the walls shall be supported with sufficient compacted earth up to the overflow level to avoid cracks. The outlet chamber walls should slightly higher elevation than the surrounding ground to reduce chances of surface water entering the outlet during the rainy season.

9.6.3 The concrete slabs for the outlet chamber should be constructed at the same time of dome casting. It should be easy to make the additional concrete at this time and the slabs shall be well cured before they are placed on the outlet. The slabs shall be 8 cm thick with proper reinforcement (re-bar) 3 cm from the bottom side. The number of slabs should be designed that they can be handled by four people without great difficulty. Installing re-bar loop handles on the slabs may be useful for the occasional handling of the slabs.

9.6.4 When preparing the slab casts, a smoothed, clean sand base and lumber shall be used for the frame. Special care shall be taken for the placement of the concrete to prevent small holes that can expose the steel reinforcement to corrosive vapour from the slurry in the outlet chamber which can cause corrosion and ultimately lead to the slab collapse. If holes form in the slab these should be filled with plaster layer. The outlet cover slabs are essential to protect people and animals from falling inside and to avoid excessive evaporation of the slurry in dry season.

9.7 Construction of inlet tank

9.7.1 The inlet tank shall be constructed to mix substrate and water. This can be constructed with or without a mixing device. Installation of a mixing device should be preferable because not only it makes plant operation easier, but it also improves the quality of mix. The installed mixer shall be firmly attached to the structure, easyto operate, effective in the mixing process and the steel parts in contact with the substrate should be galvanized. The top of the structure should not be more than one meter above ground level and both inside and outside of the tank shall be covered with a smooth layer of plaster (Mix: 1:3 of cement, sand). The finished bottom of the inlet tank shall be at least 5 cm above the outlet chamber overflow level. The position of the inlet pipe shall be such that a pole or rod can be inserted through it to the digester vessel without obstructions. This shall allow the operator to clear blockages in the inlet pipe. For the same reason the inlet pipe shall be without bends. Even if a mixing device is not installed, the inlet pit should be round in shape as this is a more economical use of material and easier for hand mixing.

9.7.2 For plants that receive from a toilet, a cleanout valve shall be constructed between the water-trap and digester. The toilet inlet pipe should enter the digester tank no more than 45° from the centreline of the main inlet pipe. Additionally, the toilet pan level should be at least 25 cm above the outlet overflow level.

9.8 Lay-out of pipeline

9.8.1 The gas pipe conveying the gas from the plant to point of user is vulnerable to damages by people, domestic animals and rodents. Therefore, only light quality galvanized iron pipe should be used which shall be, where possible, buried 30 cm below ground level. Fittings in the pipeline shall be sealed with zinc putty, teflon tape or jute and paint. Any other sealing agent, like grease, paint only, soap shall not be used. The use of fittings, especially unions, should be kept to a minimum to reduce the risk of leakage. No fittings should be placed between the main gas valve and the dome gas pipe. The pipe size, inside diameter should be between 10 cm and 20 cm. Pipe size shall be determined by the size of the digester, (amount of gas produced) and amount of gas required in the house.

9.8.2 The biogas generated from the digester is saturated with water vapour. This water vapour can condense on the walls of the pipeline. If the condensate is not removed regularly, it can ultimately clog the pipeline. For this reason, a water drain or trap shall be installed in the pipeline. The position of the water drain should be vertically below the lowest point of the pipeline so that water flows by gravity to the trap. Water shall be removed by opening the drain (Figure B.1). As this has to be done periodically; the drain shall be easily accessible and protected in a well-maintained drain pit.

9.8.3 Neoprene and rubber hose should be used to connect burners to gas pipelines. Other biogas appliances should be mounted and connected to the galvanized iron pipe. As soon as there is gas production, all joints and taps shall be inspected for leakage by applying a thick soap solution and observing for foam movement.

9.9 Compost pits

9.9.1 A minimum of two compost pits shall be dug near to the outlet chamber overflow in such a way that the slurry can run freely into the pits. Enough earth body shall remain. However, at least 1 m, between the pits and the outlet chamber shall be kept to avoid cracking of the chamber walls. The total volume of the compost pits shall be at least equal to the plant volume. The earth excavated from the compost pits should be used for backfilling of the inlet and outlet chamber and for top filling on the dome.

9.9.2 The compost pits can also be filled with agricultural residues and the slurry from the plant for a nitrogen and nutrient rich fertilizer. Compost Pits are utilized by alternating discharge flow allowing the full pit to evaporate and leach into the soil while the other is being filled. Once the pit material desiccates to the consistency of humus, the material could be removed for agricultural application as fertilizer.

9.10 Collecting/mixing tank

9.10.1 Appropriate channels (concrete, PVC pipes, HDPE pipes) shall be provided from the source of substrate to the collecting tank with a minimum slope of 2 %.

9.10.2 The tank should be concreted and a sluice gate should be provided to control or allow the proper mixture of water and manure.

9.10.3 The floor of the mixing tank should be inclined from 8.5% - 17.5 % toward the inlet pipe and it should be elevated at least 0.2 m from the filling line.

9.10.4 A cover made of steel sheet shall be provided to prevent undesired objects

9.11 Inlet pipe

Inlet pipe should be inclined 58 % with the digester wall. It should be sealed at the point of intersection with the digester wall.

9.12 Digester

9.12.1 Digesters should be made of metal, bricks, or reinforced concrete.

9.12.2 For reinforced digester, reinforcement shall be a minimum of 10 mm diameter spaced at 0.15 m (both the curved and the horizontal bars) and the curved bars shall be anchored at the top beam. All reinforcement bars shall be secured and tied together with steel wire.

9.12.3 The concrete walls of the digester shall be reinforced with steel wire mesh before plastering with mortar mixed with sealing compound or water-proofing compound. Plaster shall be applied in three layers (13 mm, 6 mm, and 6 mm thick). Each layer shall be applied continuously and should be finished within one day. All comers of the digester shall be curved.

9.12.4 Floors, beams and foundation shall withstand the maximum load and shall be made of reinforced concrete.

9.12.5 Access to the digester should be through the manhole or through the outlet chamber. If a manhole is used as the access inside the digester, it should be constructed in the centre of the dome and it should be tightly sealed. Manhole cover should be 0.65 m in diameter and 0.125 m thick.

9.13 Agitator

Natural agitation should be performed for small biogas plant. Mechanical agitation should be provided for larger biogas, several times a day for the following reasons:

a) avoid and destroy swimming and sinking layers,

b) improve the activity of bacteria trough release of biogas and provision of fresh nutrients,

c) mix fresh and fermenting substrate in order to inoculate the former, and

d) arrive at an even distribution of temperature thus providing uniform conditions inside the digester.

9.14 Gas chamber

9.14.1 The concrete dome shall be reinforced with screen before plastering with mortar mixed with sealing compound. Plaster shall be applied in three layers (13 mm, 6mm and 6 mm thick). It should be applied continuously and should be finished within one day.

9.14.2 The gas chamber shall be capable of withstanding an internal pressure of 0.15 bar.

9.14.3 The top part of a fixed-dome plant shall be painted with a gas-tight layer (water proofer', latex or synthetic paints).

9.14.4 A weak-ring in the masonry of the digester should be provided to reduce the risk of cracking of the gas chamber. This should be placed between the lower (water-proof) and the upper (gas-proof) part of the hemispherical structure.

9.15 Gas outlet pipe

9.15.1 Gas outlet pipe shall be provided and it shall be connected to outgoing biogas valve.

9.15.2 Ball valves or cock valves should be used. It should also be installed at all gas appliances as shutoff devices.

9.15.3 Sealed T-joints should be connected before and after the main valve to test the digester and the piping system for their gas-tightness separately.

9.15.4 Gas escape valve prepared from three pieces of PVC pipes should be provided, one arm of the T-joint shall be connected from the gas outlet and the other arm shall link to the pipe which goes to the kitchen.

9.15.5 The T-joint is inserted in the bottle and water shall be added to a depth of 40 mm - 50 mm above then lower point of the T. Sides of the bottle should be punched with small holes with a height equal to the desired level of pressure to be maintained.

9.15.6 Piping system connects the biogas plant to the gas appliances or to the gas reservoir. Gas reservoir should be made of plastic or steel. Piping system should be made of steel pipes or PVC pipes.

9.15.7 PVC pipes are susceptible to UV radiation and can easily be damaged; hence, PVC pipes should be placed underground. If the site is located in an area with high intensity of sunlight, steel pipe should be used.

9.15.8 PVC should be laid at least 0.25 m deep underground. It should be placed in a sand bed and be covered with sand or fine earth.

9.15.9 Table B1 shows the recommended pipe diameters depending on the flow-rate of biogas through the pipe and the distance between biogas digester and gas appliances.

9.15.10 If there are turns and bends in the piping system and used for indoors, heavy-duty hose with ply should be used. The minimum diameter should be 13 mm and if used in outdoor, it should be protected from high sunlight exposure.

9.15.11 Piping system should be laid out in a way that allows a free flow of condensation water from moisture saturated biogas back into the digester.

9.15.12 If depressions in the piping system cannot be avoided, water traps shall be installed at the lowestpoint of depressions with a minimum inclination of 1 %.

9.15.13 Flame arrester shall be provided. It should be made of a ball or roll of fine copper wire mesh inserted in the gas line and it should be located near the digester and near to the point of gas use.

9.16 Outlet pipe

9.16.1 Reinforced concrete pipe should be used with a minimum diameter of 200 mm and it should be inclined 58 % with digester wall.

9.16.2 The upper end of the outlet pipe should be level with the bottom of the auxiliary chamber to allow the drawing back of slurry when the pressure decreases.

9.16.3 The outlet pipe shall be sealed.

9.17 Outlet tank

9.17.1 The chamber should be made of concrete with smooth finish. Steel reinforcement may be used.

9.17.2 Overflow should be provided with the height of at least 100 mm lower than the lower surface of the gas chamber. It should flow into farmland of the plant owner or flow into the lagoon for further treatment.

9.17.3 The height of the floor of the chamber from the filling line shall be at least equal to the operating pressure for appliances using biogas or the height should be at least 0.2 m from the filling line plus 15 % freeboard.

9.18 Ground water drainage

9.18.1 If the water seeps from bottom of the excavated pit, blind drain shall be constructed. It should be filled with gravels or chip of tiles, with central sump and take water away manually or by pump.

9.18.2 If water seeps from wall of the excavated earth bank, circular drain outside the location of digester wall shall be constructed to lead water away to sump or some lower places.

9.18.3 In case groundwater is in great quantity, deep wells should be constructed 2 m away from the excavated pit, with a depth 0.8 m - 0.1 m lower than the pit, then pump water away from wells.

9.18.4 In case of too much water and shifting sand sunken barrel shall be used.

10 Production process of biogas

10.1 The required quantity of substrate and water is mixed in the inlet tank and the slurry is discharged to the digester vessel for digestion. The gas produced through methanogenesis bacteria in the digester is collected in the dome.

10.2 The digested slurry flows to the outlet tank through the manhole.

10.3 The slurry then flows through the overflow opening in the outlet tank to the compost pit.

10.4 The gas is supplied from the dome to the point of application through a turret and pipeline.

10.5 When a biogas plant is underfed the gas production will be low; in this case, the pressure of the gas might not be sufficient to fully displace the slurry in the outlet chamber. It is important to design the plant keeping hydrostatic pressure higher at the inlet tank than the outlet tank.

10.6 The hydrostatic pressure from slurry in the inlet and outlet tanks will pressurize the biogas accumulated in the dome. If too much material is fed into the digester and the volume of gas is consumed, the slurry may enter the gas pipe and to the appliances.

10.7 The mix of substrate and water (mixed in inlet or mixing chamber) shall pass through the inlet pipe to the digester. The mixer shall produce gas through digestion process in the digester and the produced gas shall be stored in the gas holder (top of dome).

NOTE In most biogas plants, the mixing ratio for dung (cattle and / or pigs) and water (B:W) is 1:1.

10.8 The digested slurry shall pass out from the digester to outlet tank (displacement chamber) and shall flow out to the compost pits through the overflow opening in the outlet tank. The gas shall then be supplied to the kitchen through the pipe line.

11 Operational requirements of the plant

11.1 Feeding of biodigester

11.1.1 Before operation is started, clean interior digester and after that recheck the installed system to ensure airtight or leakage proof. In addition, all components of the system shall be checked to ensure gastightness.

11.1.2 To ensure durable and sustainable operation of biodigester, the digester shall be fed daily with raw substrate. Fresh material shall be fed daily in the digester to sustain the cooking gas need of the family.

11.1.3 The operator shall ensure that the materials listed below are not fed in the digester as they interruptreaction of bacteria in anaerobic condition. Presence of those materials may cause less biogas production oreven stop production as a whole:

a) soil, sand and stones;

b) branches; and

c) soaps and detergent solution, cleaning chemicals, antiseptic products, paint and rain water.

11.2 Operation of biodigester

11.2.1 At the beginning, if gas cannot be ignited due to the reason that it is not of high quality as it contains a lot of carbonic dioxide resulting from digestion of substrate with oxygen remaining before closing the tank, firstgas should be released from the reservoir, and wait until the next gas comes in which the balloon is refilled.

11.2.2 If biogas doesn't supply sufficiently for cooking, rubber should be employed to tie across the reservoir to increase pressure inside the gas holder. After cooking, attention should be paid to remove rubber from thereservoir so that it can receive new biogas from the plant.11.2.3 If gas holder is seen loose, check the pipelines and gas holder system itself, immediately for fear thatthey are bent or clogged, or control water in the bottle safety valve or at siphon inlets that it could be empty. Ifso, repair shall be done urgently.

11.3 Pumping of substrate

11.3.1 If the amount of substrate requires fast movement, to mix the substrate and when the gravity cannot be used for reasons of topography or substrate characteristics, pumps should be used.

11.3.2 Centrifugal pumps for liquid substrate or rotary pumps for substrate of less than 8 % solid content or positive displacement pumps for substrate with higher solid content may be used.

11.3.3 Pump delivery lines should be made of steel, PVC (rigid), PE (rigid or flexible), or flexible pressuretubing made of reinforced plastic or rubber.

12 Safety considerations

12.1 Visual check

Cracks, gap and tightness of duct in the digester inner wall should be carefully checked using wooden hammer. If vacant sound was heard in a certain area, there is some warping in plastering. Leak trace for wall should be checked by spreading some cement powder over the surface, the wet spot or wet line proves that there is leak hole or leak crack.

12.2 Water-holding mark

12.2.1 There shall be no visible cracks in the digester dome; there shall be no hollow space in the plaster layer.

12.2.2 The digester should be filled with water up to the inlet and outlet pipes level. Allow it to set for 3 h - 5 h until the walls are saturated with water and mark the water level. Set it for overnight, if there is significant drop in water level, it indicates that there are leaks or cracks.

12.3 Air tight method

12.3.1 Fill the digester with water or slurry and observe the drop in level after 24 h. The level shall not drop by more than 10 cm.

12.3.2 After water tightness test, gas test should be followed. Manhole and gas valves should be closed and sealed. Add water through the inlet to increase the air pressure inside the digester up to 0.4 m of water column. Or air may be blown into the digester up to the same pressure. Leave it for 24 h, if the pressure drop is about 10 mm - 20 mm, the digester is gas tight. But if the pressure drop is about 50 mm, the dome is not gas tight.

13 Sludge management

13.1.1 The digested slurry should be either spread on the fields before the beginning of the vegetation period or further conditioned.

13.1.2 The sludge should be channelled to a sludge conditioning facilities where the solid component is separated and sun-dried while the liquid part is aerated to oxidize the toxic component.

Annex A
(informative)

Layout of biogas plant

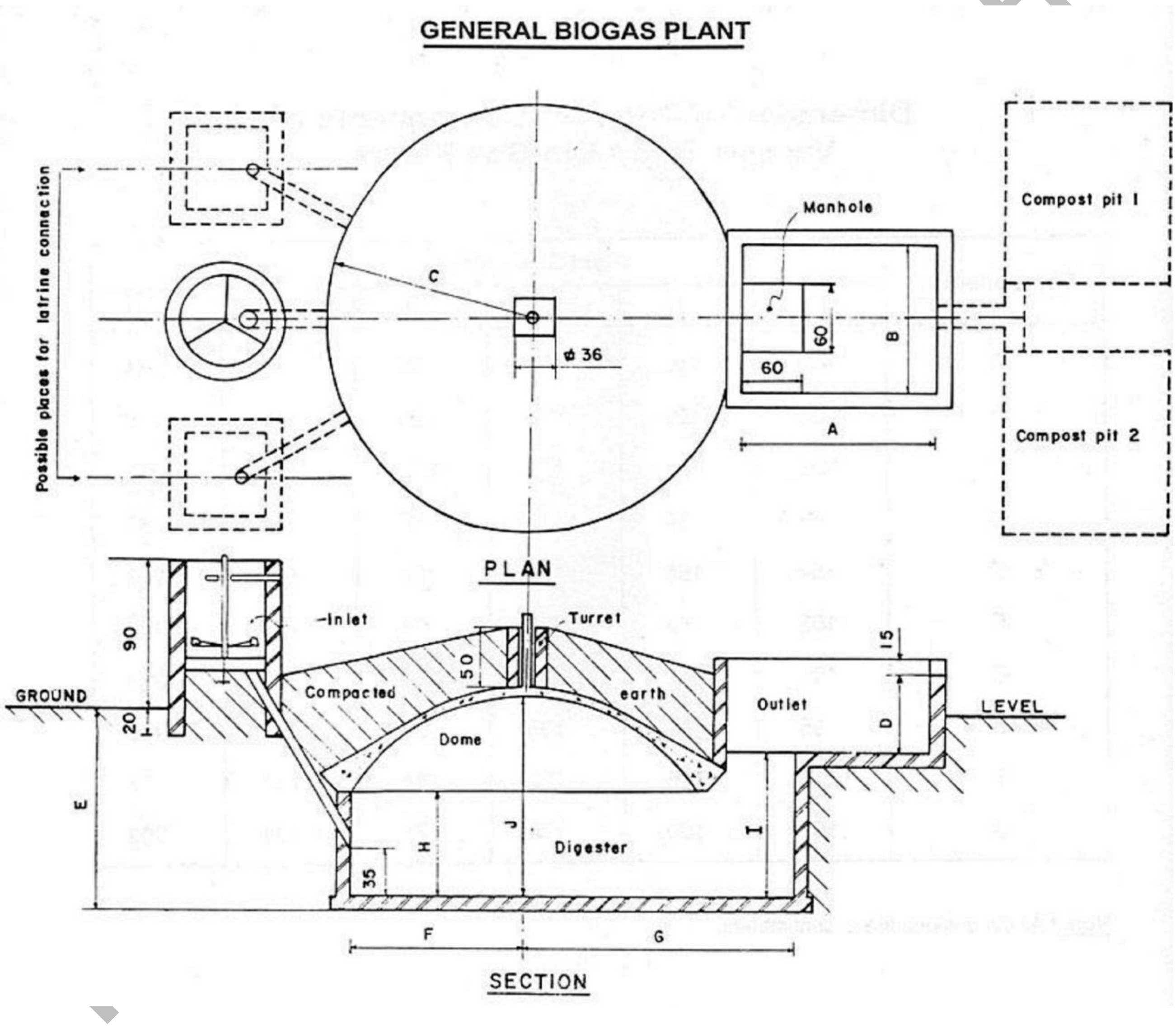


Figure A.1 — Domestic biogas plant design

Table A.1 — Measurement of various sizes of biogas plants

Components of the plant in cm	Plant sizes in m³					
	4	6	8	10	15	20
A	140	150	170	180	248	264
B	120	120	130	125	125	176
C	135	151	170	183	205	233
D	50	60	65	68	84	86
E	154	155	172	168	180	203
F	102	122	135	154	175	199
G	195	211	230	243	265	293
H	86	92	105	94	115	115
I	112	116	127	124	132	137
J	151	110	175	171	193	203

A is the Length of outlet;

B width of outlet;

C radius of pit;

D height of outlet;

E depth of excavation;

F radius of digester;

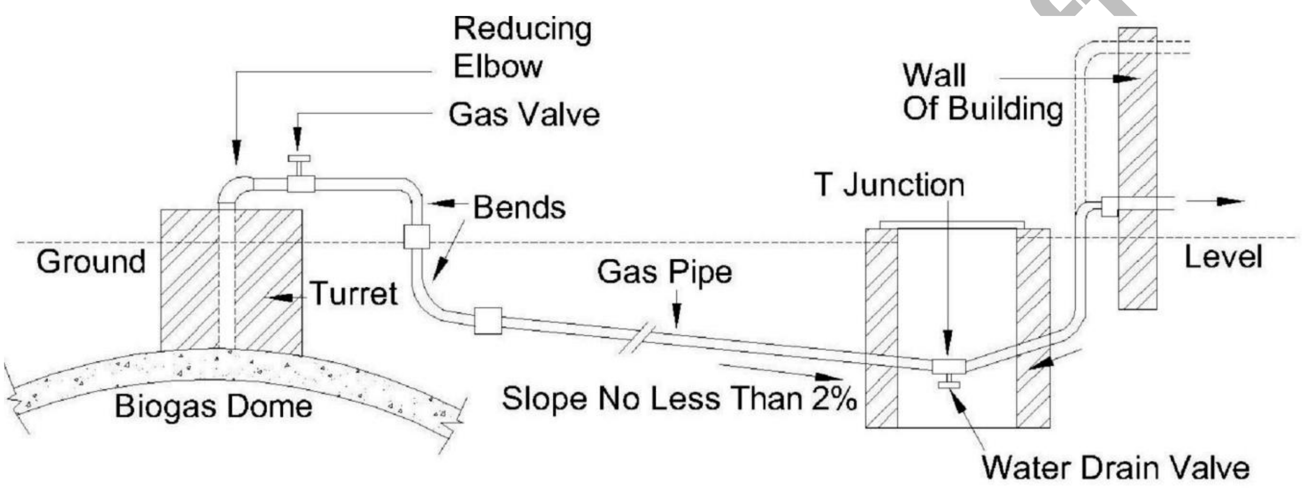
H height of digester wall;

I height of outlet passage;

J inner height of digester and dome.

Annex B
(informative)

Lay-out of pipeline



Pipe size: 10 mm to 20 mm inside diameter

Figure B.1 — Schematic for condensate drain Valve in gas line

Table B.1 — Pipe diameter for different pipe lengths and flow-rate (maximum pressure loss < 5 mbar)

	Galvanised steel pipe (mm)			PVC (m)		
Length(m)	20	60	100	20	60	100
Flow rate (m^3/h)						
0.1	12.7	12.7	12.7	12.7	12.7	12.7
0.2	12.7	12.7	12.7	12.7	12.7	12.7
0.4	12.7	12.7	12.7	12.7	12.7	12.7
0.5	12.7	12.7	12.7	12.7	19.0	12.7
1.0	19.0	19.0	19.0	19.0	19.0	19.0
1.5	19.0	19.0	19.0	25.4	19.0	19.0
2.0	19.0	19.0	25.4	19.0	19.0	25.4

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