Modified GGC Model Biogas Plant for Rwanda-2007

Construction Manual

National Domestic Biogas Programme

Rwanda

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1. Purpose of this Manual

A biodigester is a structure constructed under the ground, made with cement, brick/stone, sand and pipes & appliances to decompose organic material and produce biogas- to supplement conventional fuel sources; and bioslurry- to apply as organic manure in the farms. By feeding the recommended amount of cattle dung/pig manure and water every day in the digester, clean gas is produced. This fuel is used mainly for cooking and lighting purposes where as the digested slurry is used in vegetable gardens and agricultural fields.

The success or failure of any biodigester depends mainly upon the appropriateness of the design, suitability of site for construction and quality of construction works including quality of construction materials and workmanship involved during construction. This booklet highlights the methods for selecting appropriate size and site for construction as well as steps of construction works related to the Modified GGC Model of Biogas Plant -2007, for Rwanda.

This manual is prepared to assist the masons to successfully carry out their anticipated roles in constructing quality biodigesters.

2. Responsibilities of a Mason

The mason's role is vital in successful installation of biodigesters. The following are some of the major responsibilities of a mason:

- Provide necessary information on benefits of biodigester to the users and motivate them for biodigester installation
- Select proper size of bio-digester based upon the availability of feeding materials
- Ensure that the quality standards of construction materials and appliances are properly complied with.
- Follow strictly the design and drawing as provided to them during construction of bio-digesters.
- Comply with the Construction Manuals while installing the biodigesters.
- Provide the users with minimum requirement of knowledge and skill to operate various components of bio-digester
- Ensure timely completion of the work
- Report progress and difficulties, if any, to supervisors regularly
- Ensure the involvement of trained mason for the construction – do not allow untrained masons to take lead responsibly in constructing biodigester
- Work as extension worker and promoter of the technology in their areas of influences
- Provide regular follow-up and after-sales services to the users to ensure trouble-free functioning of completed plants

3. Components of a Biogas Plant

There are 6 main parts of the biodigester: inlet (mixing chamber) for cattle dung fed plant and maturation pond for pig manure, digester (digestion chamber), gas holder (storage chamber), outlet (displacement chamber) and gas conveyance system and slurry compost pit(s). The mix of dung and water (mixed in inlet or mixing chamber) or pig pig manure flushed from stable passes through the inlet pipe to the digester. The mixer produces gas through digestion process in the digester and the produced gas is stored in the gas holder (top of dome). The digested slurry passes out from digester to outlet tank (displacement chamber) and flows out to the compost pits through overflow opening in the outlet tank. The gas is then supplied to the kitchen through the pipe line. The modified GGC Model Biogas Plant generally consists in detail of:

1. Inlet (Mixing Tank)
2. Inlet Pipe(s) separate for cattle dung/pig manure and latrine
3. Digester
4. Gas Holder (dome)
5. Manhole
6. Outlet (Displacement Chamber) and overflow opening
7. Main Gas Pipe and Turret
8. Main Gas Valve
9. Pipeline
10. Water Outlet (Water Trap or Drain)
11. Pressure Gauge
12. Gas Tap
13. Gas Stove with rubber hose pipe
14. Gas Lamp (Optional)
15. Slurry pit(s)

4. Steps for the Installation of a Biogas Plant

A mason has to carry out the following activities in sequential order while installing biogas plant in farmer's premises:

- Selection of correct size of biodigester
- Selection of construction site
- Collection of construction materials that meet the quality standards
- Lay-out of plant
- Digging of the pit (Excavation)
- Fixing the diameter and laying of collar (base layer for brick work) for digester and manhole walls
- Construction of digester walls and manhole
- Installation of inlet pipes
- Backfilling the empty spaces outside the digester wall

- Construction of the top of manhole (usually called as beam)
- Construction of gas holder (preparation of mould, concreting, fixing of dome gas pipe)
- Constructing Inlet chamber
- Constructing outlet chamber and outlet covers
- Plastering of the inside of dome
- Construction of turret
- Installation of pipeline, fittings and appliances
- Testing for leakages
- Filling the plant with feeding
- Construction of slurry pit(s)
- Filling the top of dome and sides of outlet tank with earth
- Cleaning the site
- Orienting the users on simple operation and maintenance activities

These steps have been descried in detail in the following sections.

4.1 Selection of Correct Size of Biogas Plant

Modified GGC Biogas Plant is fixed dome design plants. 4, 6, 8 and 10 m3 biodigesters of Modified GGC Biogas Plant models are eligible for obtaining subsidy from the Government of Rwanda under the National Domestic Biogas Programme (NDBP). No other sizes and designs will be eligible to receive subsidy under the programme. The following table shows some basic information related to different sizes of the biodigester being introduced.

Quantity of Feeding Required

SN	Capacity of plant (M3) *	Daily gas production (M3)	Fresh dung required every day ** (Kg)	Water required every day (litre)
1	4	0.8 - 1.6	20-40	20-40
2	6	1.6 - 2.4	40-60	40-60
3	8	2.4 - 3.2	60-80	60-80
4	10	3.2 - 4.0	80-100	80-100

* *Capacity of plant means the volume of digester and gas storage dome*

** *Average retention time: 40 day*

The size and dimensions of the biodigesters have been decided based upon 50 days retention time and 60% gas storage. This means that the fresh feeding fed into the digester should remain inside it for at least 50 days before it comes out through outlet. Likewise, the plant should be able to store 60% the gas produced in 24 hours. Therefore the size of the biodigester has to be selected based upon the daily available quantity of feeding materials.

Before deciding the size of biodigester to be installed, all the dung available from cattle or the swine manure has to be collected to know how much feeding material is available every day. The following table shows the capacity of biodigesters to be decided based upon the availability of feeding material (mainly cattle dung).

Quantity of feeding material available daily (kg)	Recommended Size of Plant (cum)	Quantity of Fuel wood saved per day (kg)
20-40	4	4 to 8
41-60	6	8 to 12
61-80	8	12 to 16
More than 80	10	16 to 20

If the plant is not fed properly as per the requirement, gas production will be less than the theoretical expectation. If gas production is less, the gas collected in the gasholder will not have sufficient pressure to push the digested slurry to the outlet. In such case, the slurry level will be raised and reach to the gas holder instead of flowing to outlet. When the main gas valve is opened in this situation, the slurry may pass to the pipeline together with the gas. Therefore, if there is not enough quantity of feeding material available as per the prescribed rate, bigger size of biodigester should not be installed. Underfed and bigger plants will just increase the cost of installation and also create problems in operation. The important points to be considered while deciding the size of biodigester is that the basis for selecting size is the availability of dung not the family size or gas demand. If the farmer has higher number cattle then only the size is determined by the gas demand which is usually taken to be 0.33-0.40 cum gas per person per day.

4.2 Selection of Construction Site

Selection of construction sites are mainly governed by the following factors:

- The site should facilitate easy construction works.
- The selected site should be such that the construction cost is minimised.
- The 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 etc.
- The site should guarantee plant safety

Based upon the above mentioned factors, it is recommended to select plant location based upon the following considerations. Please note that it will not be possible to meet all the requirements as stated below, however, it should be ensured that as many as possible points are considers.

- For effective functioning of biodigesters, right temperature (20-35°C) has to be maintained inside the digester. Therefore it is better to avoid damp and cool place – Sunny site is preferable.
- The area to construct plant should have even surface.
- The site should be in slightly higher elevation than the surrounding. This helps in avoiding water logging. This also ensures free flow of slurry from overflow outlet to the composting pit.
- To make plant easier to operate and avoid wastage of raw materials, especially the dung/swine manure, plant must be as close as possible to the cattle shed or pig sty.

- To mix dung and water or flush swine manure to the digester, considerable quantity of water is required. If water source is far, the burden of fetching water becomes more. However, the well or ground water source should be at least 10 meter away from the biodigester especially the slurry pit to avoid the ground water pollution.
- If longer gas pipe is used the cost will be increased as the conveyance system becomes costly. Furthermore, longer pipeline increases the risk of gas leakage. The main gas valve which is fitted just above the gas holder should be opened and closed before and after the use of biogas. Therefore the plant should be as near to the point of application as possible.
- The edge of plant should be at least 2 meter away from the foundation of house or any structure.
- There should be enough space for compost-pit(s) as these are integral parts of the biodigester.
- The site should be at sufficient distance from trees to avoid damage of bio-digester from roots.
- Type of soil should have enough bearing capacity to avoid the possibility of sinking of structure.
- When space is a problem, the pig-sty can be constructed on top of the plant after proper backfilling.

4.3 Collection of Construction Materials and Appliances

If the construction materials to be used for the construction of biodigester are not of good quality, the biodigester will not function properly even if the design is correct and workmanship involved in construction is excellent. The plant will never be of high quality if inferior quality of construction materials is used. In order to select these materials of best quality, required quality standards and specifications of these materials are briefly described below:

Cement

Cement should be high quality Portland cement from a brand with a good reputation. It must be fresh, free from lumps and stored in dry place. Cement with lumps should be used for construction. Bags of cement should not be stacked directly on the floor or against the walls. Wooden planks have to be placed on the floor to protect cement from dampness. Cement bags should be stalked at least 20 cm away from any walls.

Sand

Sand should be clean and should not contain soil or other materials. Dirty sand will have very negative effect on the strength of the structure. If sand contains more than 3% impurities, it must be washed. The quantity of impurities especially the mud, in the sand can be determined by a simple ‘bottle test’. A small quantity of sand is put into a transparent bottle and water is poured into it. The bottle is shacked vigorously for a while. The bottle is then left stationary to allow the sand particles to settle down. The particles of sand are heavier than that of silt and clay, so it settles faster where as the mud particles settle slower. After 30 minutes, the layer of mud verses sand inside the bottle is measured without shaking the bottle. If the depth of mud is more than 3% of the total depth, than it can be concluded that the sand contains too much mud. If this happens, the sand should be washed

before use. Coarse and granular sand are best for concreting, however, fine sand has to be used for plastering works.

Gravels
Size of gravel should not be very big neither very small. It should not be bigger than 25% of the thickness of the concrete product where it is used. The thickness of concrete layer in the foundation and that of outlet slabs is not more than 7.5 cm (3”), therefore the maximum size of gravels should be 2 cm or ¼ size of the size of thickness of concrete layer. Gravel should be clean, hard and of angular shape. If it is dirty, it has to be washed properly before use.

Water
Water is mainly required for making the cement mortar for masonry works, concreting works and plastering. It is also used to soak bricks before using. Besides, it is required for cleaning or washing construction materials if they are dirty. The water from ponds or cannel may be dirty so it is better not to use it. Dirty water will have an adverse effect on the strength of structure. Water from water tap or well or any other sources that supply clean water has to be used.

Bricks
Brick plays a very important role in construction especially for Modified GGC model of biodigesters. Bricks should be of high quality (no.1), usually the best quality available in the local market. The bricks should be well burnt, straight, regular in shape & sizes and should not have cracks or broken-parts. High quality bricks make a clear metallic sound when hitting them to each other. Such bricks should be able to bear a pressure of 120 Kg per square centimetre. Before use, bricks must be soaked for few minutes in clean water. Wet brick will not absorb water from the mortar which is needed for setting properly.

Acrylic Emulsion Paint
It is used to make the gas holder (dome) of biodigester air-tight. Paint of this type should meet quality standard and they must be approved from concerned quality control authority.

Mild Steel Bars
MS bars are used to construct the covers of outlet tank and water drain chamber. It should meet the engineering standard generally adopted. For plants of 4, 6 and 8 cum, MS rods of 8 mm diameter and for plant of 10 cum capacity 10 mm diameter is recommended. MS bar should be free from heavy rust.

Main Gas Pipe
Gas stored in the gas holder is conveyed to the pipeline through this pipe which is placed in the topmost portion of the dome. The joint of reduction elbow with this pipe should be perfect and gas tight otherwise gas leakage from this joint can not be stopped easily. Therefore it is recommended that the reduction elbow has to be fitted in a workshop to ensure perfect air-tightness of the joint. The gas pipe should be properly galvanised and approved by concerned quality control authority. This pipe should be made up of light quality iron and MS rod has to be welded at one end to embed it with the concrete during installation. The length of this pipe should be at least 60 cm.

Main gas valve
It controls the flow of biogas in the pipeline from the gas holder. It is opened when gas is to be used and closed after each use. If substandard quality of main gas valve is used, there is always risk of gas leakage. This valve should be of high quality and approved by the concerned quality control authorities.

Pipes and fittings
The pipe to be used to convey gas from gas holder to the point of application should conform to quality specification as per the standard of Rwanda. Light quality Galvanised Iron pipe is best suited for this purpose; however, high quality PVC pipe could also be used. The pipe should be of at least half inch diameter. For length of more than 60 m (30 m if two burners are to be used at a time), ¾" diameter pipe has to be used. If GI pipe is to be used, a six meter pipe should weigh at least 6 kg. The fittings used in the pipeline of a biogas plants are socket, elbow, tee and nipples. These fitting should meet the required quality standards.

Water Outlet
It drains the water condensed inside the pipeline when biogas comes in contact with the cool pipe. This is an important component of biogas plant and therefore, its quality should carefully be controlled. It should be easy to operate and threads in it should be perfect. It should be ensured that the hole in the screw nut is bored properly and is located at the right place. The thickness of the nylon washer has to be 4mm and either a 4 cm long handle pin or a properly knurled opener should be used. This appliance should be approved by the concerned authorities.

Gas Tap
Gas tap is used for regulating flow of gas to the gas stove. Care should be taken to install gas tap of high quality. It has been often complained by the users that this taps are becoming problematic with gas leakage through them. It is important that the 'o' ring is placed properly and is greased thoroughly and regularly. The gas tap should not be too tight or loose to operate. The taps to be used in biodigesters should be approved by concerned quality control authority.

Rubber Hose Pipe
It is used to convey gas from the gas tap to the stove. This pipe should be made up of high quality neoprene rubber and should not develop cracks when folded. It should have 15 mm outer and 9 mm inner diameters. The minimum wall thickness of the pipe should be 2.5 mm.

Gas Stove
Gas stoves can be found with single and double burners. In general a single burner gas stove used for household purpose consumes 350 to 400 litre of gas per hour. The efficiency of gas stove is very important for the successful functioning of the biodigester. The stove should be of good quality and strong enough to firmly rest in ground. The primary air intake should be easily adjustable and the holes should be properly placed. The jet and pipe leading to the burner should be straight and aligned properly. The holes in the burner cap should be evenly spread across it.

Gas Lamp

Gas lamp is another important appliances used in biodigesters. Often users complain about the malfunctioning of these lamps. These lamps should be of high quality with efficiency more than 60%. Usually, a biogas lamp consumes 150 to 175 litres of biogas per hour. Lamps to be used in biodigesters have to be approved by the concerned quality control authority.

Gas Pressure Gauge

U-shaped pressure gauge (manometer) made up-of a transparent plastic or glass tube and filled with coloured water or a clock-type digital or analogue pressure meter has to be installed in the conveyance system to monitor the pressure of gas. Whatever may be the type this device should best among those available in the local market and should meet set quality standards, if any.

Mixing Device

This device is used to prepare good quality water-dung solution in the inlet tank when cattle dung is used as feeding material. Usually for household biogas digesters, vertical mixing devices are installed. The device should be of good quality, as per the design, and the mixing blades have to be well galvanised. The blade should be properly aligned for the effective mixing.

4.4 Proper Construction of Biogas Plant

4.4.1 Plant Layout

Construction works of biodigester starts with the process of layout works. This is the activity carried out to mark the dimensions of plant in the ground to start the digging work. For this purpose, first a small peg has to be stuck in the ground at the centre spot of the digester. Then the following steps should be followed:

- Level the ground and determine the centre line of the digester, outlet tank and inlet pit (generally called as hart-line)
- Decide the reference level. It is better to assume the levelled ground level as the reference level. The top of the dome (outer) should exactly be in this level.
- Select the outer radius of the pit (digester diameter plus wall thickness plus space for a footing projection of at least 10 cm) as shown in the drawing under dimension ‘Rp’ and mark it in the rope or chord.
- Insert a stick or wooden peg in the levelled ground at the centre of the proposed digester pit. With the help of this pole and chord prepared earlier, make a circle, which indicates the area to dig.
- From the centre point where the central line meets with the perimeter line, draw a tangent and measure a length equal to half of the breadth of outlet plus wall thickness (for outlet chamber) and half of the size of manhole (30cm) plus wall thickness for manhole, on either side of this tangent. Mark the manhole ensuring that the inner size is 60 cm x 60 cm.
- Draw horizontal parallel lines from the points in either side in the tangent, which will meet the dome. From the centre point where the central line meets with the perimeter line, measure the length of outlet plus wall thickness to decide the outer dimension of outlet.

- Check the size diagonally to ensure that the corners are exactly at 90 degrees.
- Use coloured powder to mark the dimensions.
- Decide the location of slurry pits while laying out plant digester and outlet.

4.4.2 Digging of Pit

After completion of lay-out work, the work for digging of pit has to be started. Tools like, crow-bar, picks, spade, shovel and basket should be available at the site. The following points have to be followed to dig the pit.

- Digging should be done as per the dimensions fixed during layout
- As far as practical the cutting in ground should be vertical, however, if the soil is cohesion-less and angle of repose needs more slope cutting, scaffolding may be needed. If the water table is high and digging to the required depth is difficult, a deeper pit has to be constructed near the digester pit. Water accumulated in the digester pit has to be drain to this pit through underground pipes. Water should be pumped from this pit.
- Once the depth of digging is equal to the dimension 'Dp' as shown in the drawing, the work of levelling and ramming the base has to be done. The pit bottom must be levelled and the earth must be untouched.
- Always ensure that the excavated earth is deposited at least 2 m away from the pit in each side to ease the construction works.
- Be careful to avoid accident while digging near the sides as soil may collapse.
- Dig the foundation for the manhole (first step of outlet tank) along with the foundation for digester as per the dimensions in the drawing during the layout.
- Now horizontal poles have to be placed in the ground level crossing each other at 90 degree in the centre. Ensure that the poles rest at levelled ground.
- If because of hard rock or under ground water, the right depth can not be achieved, the pit has to be made as deep as possible, while after completion of the structure some protective measure have to be constructed so that the walls of outlet and dome is supported well from outside

4.4.3 Construction of Digester

After the completion of digging of pit, construction of digester wall has to be started. The central wooden pole and the guide chord have to be used in this case. The following points should be followed while constructing digester and gas holder.

- Soak the brick in water for about 10-15 minutes before use.
- Prepare mortar for brick wall construction in the ratio of 1 part cement to 3 parts sand.
- At the centre of the pit, a straight rod or pipe (the 0.5" GI gas pipe) must be placed in an exact vertical position. At ground-level, a heavy pole or pipe has to be placed horizontally on the centre of the pit. The vertical pipe can now be secured to the horizontal pipe or pole. After securing, the vertical pipe has again to be checked whether it is still in the right position. Now, fix the radius of

wall at the floor with the help of a string or chord attached to the vertical pole or pipe. The length of this string or chord can be found on the drawing under the dimension 'Rd'. 1.2 cm has to be added to this length to allow space for plastering. Every brick or stone which is laid in the round-wall has to be exactly Rd+l.2 cm away from the vertical pipe. After deciding the radius of digester, a circle has to be drawn to decide the inner circumference of the round wall. Now, the base of round wall (the collar) is constructed. The collar is a thick layer of mortar 2.5-3 cm placed on the untouched earth in the floor of the excavated pit along the circle.

- Place the first brick with the help of guiding string. Go on placing the bricks in circle with the help of this string. Construct the brick wall from one direction only, either clockwise or counter clockwise. The face of brick wall should be maintained inside while constructing the wall. The first row of bricks must be positioned on their sides so that a **4.5"** high, **9"** wide base is made. It is essential that first row is placed on a firm, untouched and levelled soil. The next rows of bricks can be positioned on their lengths so that the wall thickness becomes 4.5". It is not necessary to make pillars in the wall but the backfilling between wall and pit-side must be compacted with great care. This backfilling has to be done in the morning before starting the construction work. Earth should be well compacted by adding water and gentle ramming all along the circumference of the digester. Poor compaction will lead to cracks in round-wall and dome.
- If stone is used for the construction of round wall, the wall should rest against the pit-side as it is difficult to have proper backfilling because of the irregular shape of the outside of the stone wall. The cement mortar used can be 1 cement-3 sand to 1 cement-4 sand depending on the quality of the sand.
- While laying bricks ensure that the space (joints) between them is filled with mortar, properly compacted. The thickness of mortar joint should at least be 10 mm. However it should not exceed 15 mm. Ensure that the mortar joints in two adjacent brick layer never fall in vertical line.
- When the height of round wall reaches 30 cm, place 2 inlet pipes (one for conveying cattle dung and the other for human excreta from toilet). These pipes should drain exactly at the opposite side of the manhole opening. The slope of these pipes should at least be 45° with the ground level. Ensure that the lengths of inlet pipes are sufficient enough to construct the floor of inlet at least 15 cm in higher elevation than the level of slurry overflow at the outlet wall.
- The height of the round-wall can be found on the drawing under dimension 'Hc' when measured from the finished floor. The dung inlet pipe and toilet pipe must be placed in position when the round-wall is 30 to 35 cm high. To reduce the risk of blockages, the inlet pipe(s) must be placed as vertically as practically possible.
- Exactly to the opposite of the dung inlet pipe, a 60 cm wide opening must be left in the round-wall which acts as manhole. The digested slurry also flows out to the outlet tank through this opening. The inlet pipe from the latrine should be placed as close as possible with the dung inlet pipe with a maximum distance of 45 degrees from the dung inlet on the dang inlet-centres-manhole line (hart line).
- Now the digester floor has to be constructed. For this, a flat soling of broken bricks or stones should be done in the compacted floor. After properly ramming the stone layer, a thick layer of plaster in cement mortar (1:4) has to be applied and finished properly..

- When the round-wall has reached the correct height, the inside must be plastered with a smooth layer of cement mortar with a mix of 1 cement - 3 sand.

4.4.4 Construction of Gas Holder (Dome)

When the construction works of round, wall as described above, is completed than the spherical (dome-shaped) gas holder has to be constructed. The gas holder is constructed with plain cement concrete with the help of an earthen mould prepared by filling excavated earth. Before filling the pit with earth to make the mould for the dome, backside of the round wall should be filled with proper compacted earth-back-filling. If this is not done, the pressure of the earth for the mould can lead to cracks in the round-wall. On the vertical centre pipe which is used for constructing round wall, a mark has to be made at a distance 'H'all, as given in the drawing, from the finished floor. Now soil has to be filled in the finished digester up to the marked height. Once the earth filling is completed, the vertical pipe can be removed by pulling it upwards. It has to be replaced by a shorter 0.5" dia. pipe, approx. 0.5 metres length, in the earth exactly at the same spot. Now the template should be used to make the shape of the dome. The top of the round wall must be clean when the template is in use. The template can be checked by making sure the top is horizontal and the side exactly vertical. Furthermore, the part of the template that touches the round-wall must be in the same position all over the round wall. It is important that the earthen mould is 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. The earth used for the mould has to be damp to prevent dry earth from soaking up water from freshly casted concrete

When the earth mould has the exact shape of the template, a thin layer of fine sand has to be spread on the mould-top by gently patting it on the surface. Any excess sand or soil that falls on the round-wall has to be removed. Before starting the casting work enough manpower and construction materials like sand, gravel, cement and water has to be collected on the site. The casting has to be done as quickly as possible and without interruptions in between. Such interruption will negatively affect the quality of the cast. A constant, adequate supply of concrete (mix: 1 cement, 3 sand, 3 gravel) must be made for the mason. No concrete older than 30 minutes should be used.

Special care should be taken to maintain the thickness of dome while casting, i.e. the thickness in and near the edges should be more than the thickness in the centre. For 4 and 6 m3 plants, the thickness in the edge should be 15 cm where as the thickness in the centre should be 7 cm. Similarly, for 8 & 10 m3 plants, the thickness in the edge should be 20 cm where as the thickness in the centre should be 7 cm. For 15 & 20 m3 plants, the thickness in the centre should be 8 & 9 cm respectively and the thickness in the age should be 25 cm. The small pipe on the top of the mould must be left in place till the main gas pipe is installed. This is to make sure that the main gas pipe is exactly in the centre.

Already during the casting, the concrete has to be protected against strong sun-light by covering it with jute bags or straw mats. This protection has to be left in place for at least one week. Also from the day after the casting onwards, the dome has to be sprinkled with water 3 to 4 times a day which is known as curing.

4.4.5 Plastering of Digester and Gas Holder

Gas-tightness of the gas-holder is very important for the effective functioning of any biodigester. If the gas stored in the gas-holder escapes through the minute pores, the users will not be able to get gas at the point of application. The whole investment will therefore be wasted if gas holder is not made perfectly gas-tight.

After approximately one week, depending on the temperature the earth of the mould can be removed through the manhole. When all earth is removed, the surface of the gas holder has to be cleaned with scrubbing with water and iron brush. The entire surface of the concrete dome has to be cleaned before starting the plastering. After cleaning, the following layers of plastering works have to be applied to make the gas holder perfectly gas-tight.

- Scrubbing and scratching (chiselling)
- 5 layers of dome treatment works:
    - Layer-1: Plain cement-water flush (1 part cement and 3-5 parts of water), applied with the help of broom
    - Layer-2: 10 mm thick plastering with cement sand mortar (1 part of cement and 3 parts of sand) applied with plastering trowel
    - Layer-3: 3-5 mm thick cement cement-sand punning (1part of cement and 2 parts of sand) with plastering trowel
    - Layer-4: Plastering with cement and acrylic emulsion paint mix (1 part paint and 10 parts cement) 3 mm thick applied with plastering trowel
    - Layer-5: Painting with thick layer of cement- acrylic emulsion paint (1 part of paint and two parts of cement) applied with painting brush (10 cm wide)

A plaster coat must be well set before applying the next layer. Interval of one day for the third and fourth coat is good for gas-tightness. While applying the plaster layers, the work must be executed with the greatest care and without interruption in between. Each layer has to be smooth and fine. Curing has to be properly done in each surface before applying another layer. The well functioning of the plant is very much depending upon the gas tightness of the dome and hence, the work of plastering each layer has to be done very carefully and as per the set quality standards.

4.4.6 Construction of Turret, Manhole and Outlet tank

Turret is constructed to protect the dome-gas pipe. The day after the casting, the turret must be made. Any delays can lead to leakage between main gas pipe and dome. The construction of turret has to be done when the plaster applied in the outer surface of the gas holder sets well. The size of the turret should be decided based upon the size of stone and brick. It could be square or circular in shape. The size of square should be at least 20 cm. If it is circular the diameter should be 20 cm. The height of turret should be at least 40 cm.

To construct the outlet tank which is also called as displacement chamber, excavation has to be done just behind the manhole. It is important to accurately comply with the dimensions of the tank as they

determine the useful capacity of the gas holder. The following steps should be followed while constructing this tank.

- The depth of exaction should be inner depth of outlet plus the thickness of plaster plus thickness of flooring (Ho+1.2+7.5 cm) form the ground level. When excavated at this depth, the top level of flooring would exactly reach at the top of manhole. The earth in the base of outlet, behind the manhole has to be well compacted otherwise cracks will appear in the outlet floor later on. The inside dimension of outlet chamber can be found on the drawing under length, breadth and depth (Lo, B0 and Ho). The length and breadth of digging should be the inner dimension plus wall thickness plus plaster layer. Ensure that the distance from the floor of the manhole to finished floor of the outlet is equal to height 'Hop' in the drawing.
- Once the excavation is completed, compact the floor and lay broken stones or brick bats (broken bricks) on the floor. After properly compacting the stone or brick floor, lay a thick layer of course cement-sand mortar (1:4). The finished surface should be levelled and smooth. In this surface, once the mortar is set, outlet walls have to be constructed. The inner-dimensions of outlet should be as shown in drawing (Lo and Bo). While fixing the dimensions allow at least 1.2 cm for plastering (in each side). Lay a first layer of mortar (1 cement: 3 sand) and start constructing wall. First, place bricks in the four corners of the tank wall and fix a rope to guide the brick work by tying it with the bricks in either side. The walls have to be vertical and finished with a smooth layer of cement plaster (1 cement: 3 sand). The outer part of the wall has to be compacted well to avoid cracks due to slurry pressure from inside. There is no need of plastering the outside of the outlet tank walls.
- The overflow level in outlet wall should be at least 5 cm in higher elevation than the natural ground level. This is done to avoid the surface run-off from the surrounding areas to enter into the outlet, especially in the rainy season.
- It is better to orient outlet in such a manner that the length is parallel to the hart-line. If there is limitations of land than it can be done in the other way. Always construct the overflow in the longer wall.
- The cover slab for outlet should be casted during the concreting of gas-holder. The slab could be casted on levelled ground as per the dimensions given for different capacity of plants. Special care has to be given to compact the concrete mix while casting slab as small holes left behind will expose the steel reinforcement to corrosive vapour coming from the slurry in the outlet tank. This vapour will lead to corrosion of reinforcement and in longer run the slab may ultimately collapse. Even if some holes are created, these should be closed with a layer of plaster. The slab should be cured daily for at least 5 days before it is placed into its location. The slab must be more than 5.5 cm thick with proper reinforcement of 2 cm from the bottom. The slab must be of size that could be handled by 3-4 people without great difficulty. The outlet cover slabs are very essential to protect people especially the children and animal from falling inside. Furthermore it stops the rainwater entering into the digester and also helps in avoiding excessive vaporisation of slurry in the dry and hot season.

The dimensions of outlet slabs are shown in the following table.

Plant size in M3	Slab size in cm		No. of slabs	Diameter of MS rod	Weight of steel to be procured in kg
	Length	Breadth			
4	115	52	3	8	10
6	125	62	3	8	12
8	145	65	3	8	13.5
10	155	68	3	8	15

For all slabs:

Thickness : 5 to 7.5 cm (2-3")

Cover (bottom) : 2-2.5 cm (1")

Spacing of rods places longitudinally : 15 cm (6")

Spacing of rods in cross section : 30 cm (12")

Concrete ratio : 1 part cement, 2 parts sand and 4 parts aggregate

Curing period : At least 5 days

4.4.7 Construction of Inlet Tank

Usually inlet is constructed after the completion of the construction of outlet tank; however, it can be constructed simultaneously. If the feeding material is cattle dung, then an inlet tank is constructed. This tank is constructed to mix dung and water and make the required paste with solid content about 8-10% in the mix. For plant to feed pig manure, a collection channel and maturation chamber has to be constructed. The following are some of the facts that need to be considered while constructing inlet tank to feed cattle dung into the digester.

- The foundation of the inlet pit should be places in well rammed, hard and levelled surface.
- In this rammed surface first of all the rectangular base of inlet tank is constructed. The height of the base should be decided in such a manner that the floor of inlet tank is at least 15 cm above the outlet overflow level.
- Once the base is constructed, the circular portion of inlet tank has to be constructed where the dung and water is mixed. Prior to the commencement of construction of round wall for the inlet, provisions should be made in the base to house the mixing devise if mixing devise is to be installed. Installation of mixing devise is preferable not only from easy operation point of view but also to improve the quality of mix. To fix the mixing device in position, a pivot should be placed at the centre of the base of inlet. Then the floor of inlet tank is made. In this finished surface, a circular mark with the help of a thread or chord is made of 30 cm radius to decide the inner circumference of the tank.
- The round wall of inlet tank now should be constructed with the brick placed in circular fashion following the mark already made. When the height of circular pit reaches to 45 cm, iron bracket should be fixed to tighten the mixing device, if it is to be installed. The mixing device should be firmly attached to the structure, easy to operate, effective in mixing process and rust-proof. The steel parts in contact with the slurry need to be galvanised properly.

- The height of inlet from the ground level including the base is recommend to be 90 cm, however in no case it should be more than 100 cm.
- Once the round wall is constructed, enough time should be allowed to set the mortar properly. Then both inside and outside of the tank is plastered with cement mortar (1 part of cement to 3 parts of sand).
- The bottom of the tank must be at least 15 cm above the overflow level in the outlet wall.
- The position of the inlet pipe in the floor must be such that a pole or rod could be entered through it without obstructions if any de-blocking is needed. If the inlet pipe is not positioned properly, the inlet walls have to be dismantled to insert rod or pole through it.
- In case of toilet attachment to the plant, it is better to construct pan without siphon or trap as the pan with siphon needs more water to drain the excreta which may result more water inside the digester affecting the hydraulic retention time and total solids in the slurry. It is also not possible de-block the pipe if siphon is placed. The inlet pipe from the toilet should not discharge farther than 45° from the hart-line. Additionally the pan level of toilet should at least be 15 cm above the overflow level in the outlet walls.

4.4.8 Fitting of Pipeline and Appliances

The biogas produced in the digester and stored in the gas holder is conveyed through pipeline. If the laying and jointing of pipe is not done properly, the produced gas could not be conveyed effectively to the point of application. The following steps should be followed while laying pipes and installing appliances:

- Prior to starting laying of pipe, the best possible alignment from the biogas plant to the point of application (kitchen) has to be decided. As far as possible, such route should be the shortest one and with the minimum risk of damage to the pipeline due to external factors.
- When proper alignment is selected digging of trench has to be started. The slope of trench should be gentle and appropriate so that the laying of pipe therein could be done with required slope.
- First of all the gas valve has to be fitted in position. Attention should be given not to have any fittings rather than a pipe-nipple between the main gas pipe fitted in the dome and the main gas valve to avoid the risk of gas leakage.
- Prior to the laying of pipeline, the length of pipe and required quantity of fittings should be decided in good advance. The pipe has to be cut in pieces as per the requirement by the hexa-blade. The threads in pipe have to be made skilfully in the case of GI pipes. To make threads in pipes, vice and die-sets have to be used in a proper way. The pipe has to be secured in the vice and die-set should be used properly to make the threads. Oil has to be added as lubricant to ease the cutting process. This also helps in making the threads perfectly sharp. When the threads are made and fittings are decided, the work of pipe laying and jointing could be started. However, best quality PVC pipe could also be used to minimise the cost. The joint between two pieces of PVC pipes should be properly sealed with sealing agents. Fittings in the pipelines must be sealed with zinc putty, Teflon tape or jute and paint in case of GI and best quality liquid rubber gasket in case of PVC pipes. Any other sealing agents such as grease, paint only, soap, clay etc. must not

be used. To reduce the risk of leakage, the use of fittings should be kept to a necessary minimum. Unions should not be used. Before joining the pipes, one has to ensure that the pipe is not blocked with soil or other materials from inside. A powerful blow of air from one end to other can in this regard.

- The pipeline conveying biogas from the plant to point of application is vulnerable to damages by people, domestic animals and rodents and hence, suitable measures have to be adopted for its protection. It is therefore recommended to use galvanised iron (GI) pipes and bury them to a minimum of 30 cm in the ground. However, best quality PVC pipe could also be used as mentioned earlier.
- The biogas conveyed from the gas holder is saturated with water vapours. This water condenses when it comes in contact with the walls of the pipe. If this condensed water is not drained regularly, it will ultimately clog the pipeline. Hence, a water outlet to drain the water has to be fitted in the pipeline. The position of water drain should be vertically below the lowest point in the pipeline so that water will flow automatically by gravity to the outlet. Water should be drained periodically and therefore the location of water outlet should be conveniently placed. The outlet should be protected well in a chamber (30 cm length, 30 cm breadth and 50 cm deep). The cover for this chamber has to be casted during the period of slab casting for outlet tank.
- When the laying of pipe is done correctly from dome to the kitchen, the next step is to fit the gas stoves and lamps. After positioning gas taps correctly, neoprene rubber hose pipe has to be used to join gas tap and gas stove. No other pipe than the approved neoprene rubber hose pipe of the best quality has to be used for this purpose.
- As per the requirement of the user, gas lamps have to be fitted. The assembling of different parts of the gas lamp has to be assembled with greatest care. The location of lamp should be such that is safe (reasonable far for ceiling and other parts that may catch fire easily; less windy place) and comfortable for operation. The battery-driven started should be installed out of reach of children.
- Now the pressure gauge has to be installed. U-shaped pressure gauge (manometer) made up-of a transparent plastic or glass tube and filled with colored water or a clock-type digital or analog pressure meter has to be installed. In case of manometer, one end of U pressure gauge is joined to the gas pipeline and the other end is attached to an empty bottle exposed to the atmosphere. When the gas pressure in the digester is zero, the surface of colored water in two branches of pressure gauge is leveled in the middle of the water column. When biogas enters the pressure gauge, the colored water level in closed branch drops down, whereas the water level in other branch increases. A difference between levels of these two colored water columns shows the gas pressure in cm of water columns. Pressure gauge is also a safety valve to prevent gas overflow. When gas pressure in the digester surpasses the designed value, the water in the one branch of pressure gauge is pressed into the bottle and the gas escapes outside. When the gas pressure in the digester drops to the normal level, the water stored in the bottle will flow back into the pressure gauge. Clock-type pressure meter is easy to install and read. It can be directly fitted in the gas pipeline with a tee junction. A gas pressure gauge has to be fixed near the point of application of the gas.
- As soon as there is gas production, the joints and valves (taps) must be checked for leakage by applying a thick soap-water solution. If there is leakage, the foam applied in the joints will either move or break. If so happens, the joints must be sealed properly.

4.4.9 Construction of Compost Pits

Compost pits are integral part of the biodigester; no plant is complete without them. A minimum of two composting pits should be constructed near the outlet overflow in such a manner that the slurry can flow easily into the pit. However, at least 100 cm space should be left between outlet wall and compost pit to avoid cracking of the wall of outlet tank. These two pits should be used alternately to fill slurry coming out of digester. The total volume of two compost pits must be at least equal to volume of the plant. The depth of the compost pits must not exceed 1 metre and the distance between the two compost pits must not be more than 50 cm. The length and width at the top must be more than of the bottom and 10 cm mud has to be added on all sides to raise the height from the ground level to avoid rain water enter the compost pits. The following table illustrates the detail dimensions of compost pits for different plant capacities.

Plant size in m3	**Minimum dimensions of pit in cm**			**Number of pits**	**Total minimum volume of pits in m3**
	Length	**Breadth**	**Depth**		
4	200	100	100	2	4
6	200	150	100	2	6
8	200	200	100	2	8
10	250	200	100	2	10

However, the dimensions in most cases will be governed by the availability of land. Keeping the volume and height constant, length and breadth of pit could be decided as per the site conditions.

To make potent and easy-to-use fertiliser, the compost pits should be filled with agricultural residues together with slurry from the plant. It is recommended to construct a shade above the pits to avoid direct sun light. This shade could be used for growing vegetables with vines

5. Finishing Works and Instructions to Users

Once the construction works are completed, the sites should be cleaned and cleared properly. The remains of construction materials have to be dumped properly in disposal areas. The top of the dome has to be filled with soil which acts as an insulation to protect the plant. The outside portion of outlet walls and base of the inlet should be filled with soil and compacted. Proper drainage system should be constructed to avoid rain water entering into the biodigester.

After the completion of the entire construction work the mason has to provide proper orientation to the users on plant operation and minor maintenance. Importance of daily feeding as per required quantity, operation of different appliances, major points to be remembered while operating the plants etc. should be explained to the users before leaving the construction site. Information on the following aspects of operational activities has to be given to the users:

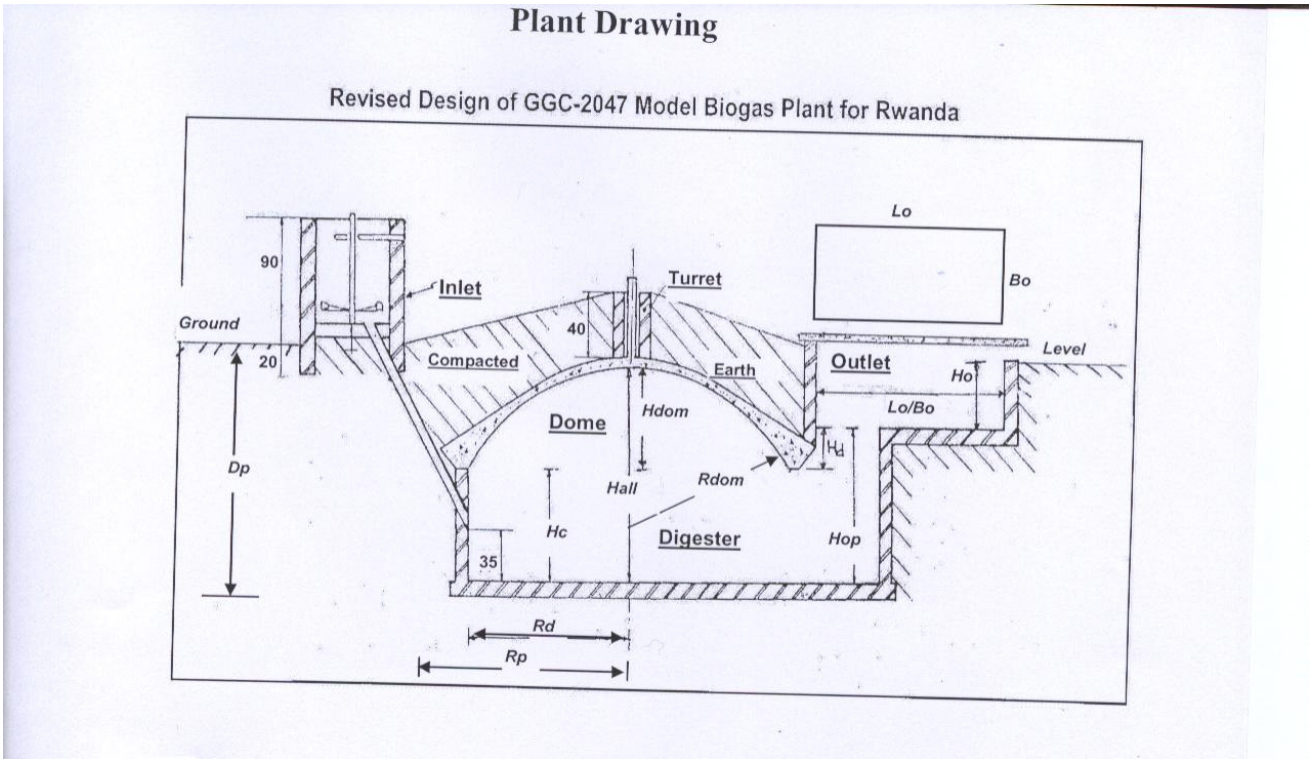
- Initial Filling of Plant

- Daily feeding of Plant
- Use of Main valve
- Checking leakages
- Use of Water drain
- Cleaning of outlet
- Composting/ maintaining compost pits
- Oiling of gas tap
- Cleaning of gas stove
- Cleaning of gas lamp
- Breaking of scum layer
- Reading of pressure gauge and adjusting of gas flow as per the reading

6. Conclusion

If the concerned mason/plumber strictly follows the instruction as described in this construction manual, during the construction phase, the biodigester will function properly with anticipated efficiency. The owner will get the return of his/her investment. This will encourage his/her relatives and neighbours to install biodigesters. However, if the biodigester function poorly, nobody will be motivated to install it. Poor quality plant will harm the reputation of biogas technology and will have serious negative effect on promotion and extension. The masons therefore, should be well aware that good quality plant will help increasing the rate of installation with the demonstration effect which ultimately benefits himself, the farmer and the country as a whole.

Annex:1



Dimensions of Different Components

Components	Symbol	Dimension per size in cm			
		4 m^3	6 m^3	8 m^3	10 m^3
Length of Outlet	Lo	150	180	190	200
Breadth of Outlet	Bo	110	120	140	150
Height of outlet	Ho	45	50	55	60
Radius of digester	Rd	100	120	135	145
Radius of pit	Rp	125	145	160	170
Height of digester wall	Hc	95	100	105	110
Depth of pit (excavation)	Dp	175	185	195	205
Height of Dome	Hdom	65	70	75	80
Radious of curvature of dome	Rdom	109	138	159	171
Inner height of digester and dome	Hall	160	170	180	190
Height of maximum slurry displacement	Hd	27	28	30	32
Height of outlet passage	Hop	122	128	135	142

Annex-2: Bill of Quantities and Cost for Biodigester Capacity 4, 6, 8 and 10 m^3

SN	Item	Unit	Unit Cost USD	4m^3		6m^3		8m^3		10m^3	
				Quantity	Total Cost USD	Quantity	Total Cost USD	Quantity	Total Cost USD	Quantity	Total Cost USD
I	**Construction Materials**										
1	Stones	m^3	**21.8**	3	65.4	3.5	76.3	4.0	87.2	5.0	109.0
2	Cement – 50 kg bag	bag	**14.5**	13	188.5	17.0	246.5	21.0	304.5	25.0	362.5
3	Gravel 1x2	m^3	**21.8**	1.1	24.0	1.2	26.2	1.3	28.3	1.4	30.5
4	Coarse sand	m^3	**18.2**	0.9	16.4	1.0	18.2	1.1	20.0	1.2	21.8
5	Fine sand	m^3	**18.2**	1.1	20.0	1.2	21.8	1.3	23.7	1.4	25.5
6	Inlet PVC pipe 10cm dia, length 2m	piece	**3**	2	6.0	2.0	6.0	2.0	6.0	2.0	6.0
7	Iron bars ø 6 mm	Kg	**1.5**	10	15.0	12.0	18.0	14.0	21.0	17.0	25.5
8	Binding wire	kg	**1.9**	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0
9	Acrylic emulsion paint	Lit	4	1	4.0	1.0	4.0	1.0	4.0	1.5	6.0
				Subtotal 1	**340.2**		**418.0**		**495.7**		**587.8**
II	**Accessories**										
10	G.I, Gas outlet pipe Ø 0.5", 6m length	pcs	**2**	1	2	1	2	1	2	1	2
11	GI nipple, Ø 0.5" for connecting main gas pipe and main gas valve	pcs	**0.4**	1	0.4	1	0.4	1	0.4	1	0.4
12	Main gas valve (Ballvalve Ø 0.5")	pcs	**4.6**	1	4.6	1	4.6	1	4.6	1	4.6
13	Male-female socket Ø 0.5", PVC with aluminum thread, for connecting main gas valve and gas pipeline (PVC)	pcs	**3.6**	1	3.6	1	3.6	1	3.6	1	3.6
14	PVC 90º elbow	pcs	**0.4**	4	1.6	4	1.6	4	1.6	4	1.6
15	T-socket Ø0.5" for water trap (aluminum thread inside)	pcs	**3.7**	1	3.7	1	3.7	1	3.7	1	3.7
16	Glue for PVC connection	kg	**12.7**	0.3	3.2	0.3	3.2	0.3	3.2	0.3	3.2
17	Water drain	pcs	**10**	1	10	1	10	1	10	1	10
18	Gas tap	pcs	**4.6**	1	4.6	1	4.6	2	9.2	2	9.2
19	Teflon tape	pcs	**0.4**	1	0.4	1	0.4	1	0.4	1	0.4
21	PVC pipe Ø 0.5"	m	**0.2**	10	2	10	2	10	2	10	2
22	Gas rubber hose pipe Ø 0.5" and 2 clamps	m	**2**	1	2	1	2	2	4	2	4
23	Stoves - single burner	pcs	**15**	1	15	1	15	2	30	2	30
24	Lamp	pcs	**10**	1	10	1	10	1	10	1	10
25	Pressure Manometer	pcs	**5**	1	5	1	5	1	5	1	5
				Subtotal-II	**68.1**		**68.1**		**89.7**		**89.7**
III	**Labours**										
26	Skilled Labour	No.	**8.2**	9	73.8	10	82	11	90.2	12	98.4
27	Unskilled Labour	No.	**1.8**	20	36	25	45	30	54	35	63
				Subtotal III	**109.8**		**127**		**144.2**		**161.4**
				Total	**518.1**		**613.0**		**729.5**		**838.9**
	Overhead, Guarantee and After-sales Services(15%)				77.7		92.0		109.4		125.8
	Total Cost of Installation				**595.8**		**705.0**		**839.0**		**964.7**

Note: If brick is used in place of stone, the quantities needed in number are:

4 cum plant: 1400, 6 cum plant: 1700, 8 cum plant: 2000, and 10 cum plant: 2400.