Farmer's Friend Biodigester Model Construction Manual

National Biodigester Programme Cambodia

November 2005

Updated December 2006

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1. Introduction

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 bio-slurry 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 will provide the knowledge on methods for selecting appropriate size and site for construction as well as steps of construction works related to the Farmer's Friend (2005) model of biodigester.

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:

- 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 necessary information on benefits of biodigester to the users and motivate them for biodigester installation
- 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
- 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

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

3. Sizes of Biodigester

Farmer's Friend Biodigesters are fixed dome design plants. 4, 6, 8 and 10 m3 biodigesters of Farmer's Friend Biodigester models are eligible for obtaining subsidy from the Government of Cambodia under the National Biodigester Programme. No other sizes and designs will be eligible to receive subsidy under the programme. The following table presents some facts about these 4 sizes biogas plants.

Table- 1: 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 days*

4. Components of a Biodigester

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 Farmer's Friend Biodigester 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. Gas Tap
12. Gas Stove with rubber hose pipe
13. Gas Lamp (Optional)
14. Slurry pit(s)

5. Selection of Plant Size

The size and dimensions of the biodigesters have been decided based upon 40 days retention time and 50% gas storage. This means that the fresh feeding fed into the digester should remain inside it for at least 40 days before it comes out through outlet. Likewise, the plant should be able to store 50% 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 pig 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 (dung or pig manure).

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, 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 also passes 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 problem in operation. **The important point 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 or pigs then only the size is determined by the gas demand which is usually taken to be 0.33 cum gas per person per day.**

6. 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 and mortar 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 it. 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 Farmer’s Friend 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 (moisture) 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 Cambodian standard. Light quality Galvanised Iron pipe is best suited for this purpose; however, high quality PVC pie could also be used. The pipe should be of half inch diameter. For length of more than …m, 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. The weight of 100 pieces of each GI fitting should be 13 kg, 9 kg and 6 kg for tee, elbow and socket respectively.

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.

7. 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/pig manure, plant must be as close as possible to the cattle shed or pig sty.
- To mix dung and water or flush pig 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.

8. Construction of Biodigester

When suitable sites and construction materials and appliances to meet the quality standards are selected, the construction work of biodigester has to be started. The following are the steps in constructing biodigester:

- Lay-out of plant and digging of the pit
- Fixing the curvature and laying of the foundation
- Construction of a central masonry block and collar
- Construction of the foundation of manhole
- Fixing of radius and constructing the bottom part of digester and manhole
- Installation of inlet pipes
- Plastering of the outside of the digester wall
- Construction of the arch portion above the manhole
- Construction of the remaining part of digester
- Plastering of the remaining part of the outside of the digester
- Backfilling the empty spaces outside the digester wall
- Constructing gas holder
- Installation of scaffolding, construction of top of gas holder and fixing of main gas pipe
- Constructing Inlet and outlet chambers
- Constructing outlet covers
- Plastering of the dome (outside and inside)
- Installation of pipeline, fittings and appliances
- Testing for leakages
- Filling the plant with feeding
- Constructing slurry pit(s)
- Filling the top of dome and sides of outlet tank with earth
- Cleaning the site

The construction methods have been described in the following sections.

8.1 Lay out of Biodigester and Digging of Pit

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)
- Select the outer diameter of the pit (digester diameter plus wall thickness) as shown in the drawing 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 inner breadth of outlet plus wall thickness on either side of this tangent.
- 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.

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 as shown in the drawing, the work of fixing curvature at the bottom has to be considered while digging
- 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.
- A rope or chord with length equal to inner radius of digester as shown in the drawing plus length needed to tie it with a pole and a wedge at each end is taken and tied at the pole exactly at the centre. A wedge is tied in the other side of the rope. The length from the pole to the wedge should be equal to inner radius of digester plus plaster thickness.
- With the help of this rope/chord, decide the depth of digging and the shape of curvature. Never dig more than the depth as indicated in the drawing. If done so, earth has to be compacted firmly in this area to fill it.
- 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.

8.2 Concreting in Foundation and Construction of Central Pillar

Next step after digging of pit and fixing of curvature is the construction of concrete foundation. The concrete course must rest in unmoved natural soil strata. If the soil is loose, the pit bottom must be properly compacted before constructing concrete foundation of digester pit. The following points should be carefully followed while constructing the foundation:

- Fix the centre of curvature and insert a pipe or stick
- Clear soil from the surface. If the surface is loose, ram the earth in the bottom with rammers. While ramming, ensure that the curvature is always maintained.
- Prepare cement concrete mix with 1cement, 2 sand and 4 aggregate (1:2:4) with proper water cement ratio. The size of aggregate should be less than 20 cm.
- Start concreting from the centre. At first, lay concrete in the centre at an area approximately 50 cm diameter. Take out the pipe or pole placed in the centre while concreting. Always take the minimum depth of concreting to be 7.5 cm (3”). If the soil has lesser bearing capacity this thickness can be increased to 10 cm (4”).
- Once the concreting is done at the central part, construct a central masonry pillar. The height of pillar should be as shown in the drawing. Fix a nail (7 to 10 cm long) in the centre of the pillar at the top.
- Place concrete in four sides of the pillar to prepare a guide layer. The breadth of such guide layer could be 15 to 20 cm. It look like star in the centre once this layer is prepared

- Lay concrete in the areas between these guide layers and compact it properly to avoid voids in it.
- Special care has to be given to fix the concrete collar at which the brick wall for digester rests. The breadth of concrete collar has to be 15 cm (6”). The radius of the collar has to be outer radius of digester wall plus 10 cm to allow space for plastering. This radius has to be fixed with the help of the centre pillar.
- Take a bamboo stick of 1.5 to 2 cm diameter with length more than outer radius of digester wall as given in the drawing. Insert a nail (7.5 cm) exactly at a distance equal to outer radius of digester wall plus 3 cm from one end in the bamboo. Make a groove in the other side which acts as guiding support. The depth of groove should be fixed in such a way that the length between the end of groove and the nail is maintained to be outer radius of digester wall plus 1.5 cm. This bamboo is called the ‘guiding bamboo’ or sometimes ‘master bamboo’.
- With the help of the central pillar and the guiding bamboo, fix the radius of collar and lay concrete accordingly. The thickness of the collar should be 10 cm (4”).
- Lay concrete for the foundation of manhole while making this collar. The length and breadth of concreting should be 60 cm plus wall thickness in two sides plus plastering in two sides (60+7.5+7.5+1.5+1.5 cm). The foundation of the manhole looks like the extended portion of the collar.
- Do not pour concrete from the ground level, carry it to the bottom and pour it from a height not more than 30 cm.
- Allow the concrete to set before starting construction of digester wall (at least one full day).

8.3 Construction of Digester and Gas-holder

After a day of constructing foundation, construction of digester wall has to be started. The central masonry pillar and the guide pole 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.
- Fix the radius of wall at the collar with the help of guiding bamboo. Place the first brick with the help of guiding bamboo and the nail inserted in it. Go on placing the bricks in circle with the help of this bamboo. Construct the brick wall from one direction only, either clockwise or counter clockwise. The brick base should be maintained inside while constructing the wall.

- 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 pig manure or 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.

- When the height of wall reaches equal to height of manhole as shown in the drawing, arch for manhole has to be constructed with the help of framework. Bricks should be placed in either side as support and a horizontal plank should be placed above the brick support. To maintain a dome shape, soil has to be placed above the plank at the desired shape. Brick has to be laid on edge maintaining the inner curvature of wall with the help of guiding bamboo.

- The outer wall has to be flushed with cement-water slurry before starting the fresh layer in each day. **There is no need of plastering of outer wall**.
- When the height of manhole wall reaches to the bottom of outlet floor, the construction of manhole should be stopped. The top of wall at this level will support the base for outlet tank.
- When the height of the wall is in such position that the guiding bamboo makes 45 degree angle with the horizontal, 'S' hooks has to be used. One end of the hook is used to firmly support the brick and the other end houses a counterweight. This counterweight stops bricks from dropping inside by virtue of its own loan before being set. Bricks or sand bags can be used as counterweights. About 100 hooks and counterweights have to be prepared so that each brick in the one layer is supported by one of the hooks.

- When construction of wall reaches in the stage that the diameter of the top hole is about 50-60 cm, it is difficult to construct wall with brick and counterweights. To construct this portion, scaffoldings are provided from the bottom inside the digester, to support the wooden planks as frameworks. Soil in the shape of top of dome is prepared as mould for laying bricks in this part. Sand is sprinkled in this mould before laying brick and compacting with mortar.

- Main gas pipe has to be fitted in the centre of the dome while constructing this part of gas holder. 60 cm long GI pipe of 3.5 cm diameter with reducing elbow (3.5 cm to 1.5 cm) in one end is used as main gas pipe. The other end of the pipe consists of welded MS rods 3 numbers of 10 cm long and 8 mm dia to ensure firm stability of the pipe. This end is properly fixed and concreted in the dome.

- Once the construction of brick work and fixation of main gas pipe completes, the outside of the dome should be flushed with cement water slurry using a broom or brush. This Plain cement flush (1 cement: 3 to 5 water by volume) should be well sprinkled on the surface to close any cavities left while constructing brick dome.

8.4 Plastering of Digester and Gas-holder

The scaffolding prepared to fix the central top portion of the gas holder can be removed after two days. After removing the scaffoldings, the surface has to be cleaned with scrubbing with water and iron brush. The entire surface of the brick wall has to be cleaned before starting the plastering. The outside of the gas holder too has to be well scrubbed and cleaned. After cleaning the following layers of plastering works have to be applied to make the gas holder perfectly gas-tight.

Outside:

- Scrubbing and scratching
- 1 Layer of Plain cement-water flush (1 cement: 3 to 5 water by volume)

Inside:

- Scrubbing and scratching
- 5 layers of dome treatment works:
  - Layer-1: Plain cement-water flush (1 part cement and 3-5 parts of water)
  - Layer-2: 10 mm thick plastering with cement sand mortar (1 part of cement and 3 parts of sand)
  - Layer-3: 3-5 mm thick cement cement-sand punning (1part of cement and 1 part of sand)
  - Layer-4: Plastering with cement and acrylic emulsion paint mix (1 part paint and 12 parts cement) 3 mm thick
  - Layer-5: Painting with thick layer of cement- acrylic emulsion paint (1 part of paint and two parts of cement)

A plaster coat must be at least one day old before applying the next layer. 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.

8.5 Construction of Turret, Manhole and Outlet Tank

Turret is constructed to protect the dome-gas pipe. The construction of turret has to be done when the plaster applied in the outer surface of the gas holder sets well. The turret could be square or circular in shape. The size of square should be 20 cm. If it is circular the diameter should be 20 cm. The height of turret should be 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 concreting (inner depth+1.2+7.5 cm) form the ground level. When excavated at this depth, the level 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. 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 floor of the outlet should is depth of outlet tank plus concrete thickness (7.5 cm).
- Once the excavation is completed lay concrete on the properly rammed surface. The ratio of mix should be 1:2:4 (cement:sand:aggregate). The concrete surface should be levelled and smooth. In this surface, once the concrete is set, outlet walls have to be constructed. In place of concrete, brick soling followed by thick plaster can be used for floor of outlet. The inner-dimensions of outlet should be as shown in drawing (length and breadth). While fixing the

dimensions allow 2.5 cm for plastering (two sides). Lay a first layer of mortar (1 cement to 3 sand) and start constructing wall. Place bricks in the four corners of the tank wall which will ease the construction. The walls have to be vertical and finished with a smooth layer of cement plaster (1 cement to 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 plaster in the outer portion of the walls.**


- The overflow level in outlet wall should be at least 10 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 floor for outlet. 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 7.5 thick with proper reinforcement of 2 to 2.5 cm from the bottom. The slab must 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	53	3	8	10
6	125	58	3	8	12
8	135	64	3	8	13.5
10	145	68	3	8	15

For all slabs:

Thickness	: 6 to 7.5 cm (2.5 to 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

8.6 Construction of Inlet

After the completion of the construction of outlet tank, inlet is constructed. If the feeding material is cattle dung then a inlet tank is constructed. This tank is constructed to mix dung and water and make the required paste with solid content about 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. 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, one day should be allowed to set the mortar properly. Then both inside and outside of the tank is plastered 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 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.

8.7 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 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 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 if the users prefer it. The pipe has to be cut in pieces as per the requirement by the hexa-blade. When the required sized pipes are cut and fittings are decided, the work of pipe laying and jointing could be started.
- Fittings in the pipelines must be sealed with good quality sealing agent and Teflon tape. In the case of GI pipe and with good quality adhesive and Teflon tape in the case of PVC pipe should be used. 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.

- 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 places. 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 dome with greatest care.
- As soon as there is gas production, the joints and taps must be checked for leakage by applying a thick soap solution. If there is leakage, the foam will either move or break. If so happens, the joints must be sealed properly. The general layout of the pipeline arrangement has been shown in the following sketch.

8.8 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 compost pits must be at least equal to volume of the plant. The depth of the compost pits must not exceed more than 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

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.

9. Finishing Works and Instructions to Users

The sites should be cleaned and cleared after the construction works. 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 to 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 have 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

10. 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 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.

Bill of Quantities for Biodigester Capacity 4, 6, 8 and 10 m^3 – HRT 40 days

SN	Item	Unit	Unit Cost USD	4m^3		6m^3		8m^3		10m^3	
				Quantity	Total Cost $	Quantity	Total Cost $	Quantity	Total Cost $	Quantity	Total Cost $
I	**Construction Materials**										
1	Solid Brick	piece	0.04	2000.0	80.0	2400.0	96.0	2800.0	112.0	3200.0	128.0
2	Cement	bag	4.00	14.0	56.0	18.0	72.0	22.0	88.0	26.0	104.0
3	Gravel 1x2	m^3	18.00	0.5	9.0	0.8	13.5	0.9	16.2	1.2	20.7
4	Coarse sand	m^3	8.00	0.4	3.2	0.6	4.8	0.8	6.4	1.0	8.0
5	Fine sand	m^3	10.00	1.1	11.0	1.2	12.0	1.3	13.0	1.4	14..0
6	Inlet PVC pipe 10cm Ø	piece	4.00	2.0	8.0	2.0	8.0	2.0	8.0	2.0	8.0
7	Iron bars ø 6	kg	0.70	10.0	7.0	12.0	8.4	14.0	9.8	15.0	10.5
8	Binding wire	kg	0.90	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
9	Acrylic emulsion paint	Litre	3.00	1.0	3.0	1.2	3.6	1.3	3.9	1.5	4.5
			Subtotal 1		**177.7**		**218.8**		**257.8**		**298.2**
II	**Appliances /Accessories**										
10	G.I, Gas outlet pipe Ø 0.5", 0.6 m length	piece	5.00	1.0	5.0	1.0	5.0	1.0	5.0	1.0	5.0
11	GI nipple, Ø 0.5"	piece	0.35	1.0	0.4	1.0	0.4	1.0	0.4	1.0	0.4
12	Main gas valve Ø 0.5"	piece	1.70	1.0	1.7	1.0	1.7	1.0	1.7	1.0	1.7
13	Male-female socket Ø 0.5"	piece	0.45	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5
14	PVC 90^o elbow	piece	0.12	4.0	0.5	4.0	0.5	4.0	0.5	4.0	0.5
15	Tee Ø 0.5" (aluminium thread inside)	piece	0.40	1.0	0.4	1.0	0.4	1.0	0.4	1.0	0.4
16	Glue for PVC connection	bottle	0.70	1.0	0.7	1.0	0.7	1.0	0.7	1.0	0.7
17	Water drain	piece	4.00	1.0	4.0	1.0	4.0	1.0	4.0	1.0	4.0
18	Gas tap	piece	6.00	1.0	6.0	1.0	6.0	2.0	12.0	2.0	12.0
	Teflon tape	piece	0.30	1.0	0.3	1.0	0.3	1.0	0.3	1.0	0.3
20	Liquid gasket rubber	bottle	1.40	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.7
21	PVC pipe Ø 0.5	metre	1.30	10.0	13.0	10.0	13.0	10.0	13.0	10.0	13.0
	Gas hose pipe Ø 0.5"	metre	0.40	1.0	0.4	1.0	0.4	2.0	0.8	2.0	0.8
23	Stoves single burner	piece	13.00	1.0	13.0	1.0	13.0	2.0	26.0	2.0	26.0
	Lamp	piece	6.5	1.0	6.5	1.0	6.5	1.0	6.5	1.0	6.5
			Subtotal-II		**52.9**		**52.9**		**53.5**		**53.5**
III	**Labours**										
25	Skilled Labour	No.	4.00	10.0	40.0	11.0	44.0	13.0	52.0	15.0	60.0
	Unskilled Labour	No.	1.50	10.0	15.0	11.0	16.5	13.0	19.5	15.0	22.5
27	Excavation of soil	cu.m	1.50	8.0	12.0	9.0	13.5	9.0	13.5	10.0	15.0
			Subtotal III		**67.00**		**74.00**		**85.00**		**97.50**
			Total		**297**		**345**		**395**		**408**
	Total (Including guarantee and after sales services)				**322**		**375**		**430**		**488**