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RWANDA UTILITIES REGULATORY AGENCY

TECHNICAL GUIDELINES FOR CONSTRUCTION OF DOMESTIC FIXED DOME BIOGAS PLANTS

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1. PURPOSE OF THE DOCUMENT

These guidelines highlight the methods for selecting appropriate size and site for construction of the fixed dome biogas plant models in Rwanda. This document is prepared to assist the biogas plant operators to successfully carry out their anticipated roles in constructing good-quality biogas plants.

These guidelines include design and construction material quantities for the fixed-dome biogas plant models of 4, 6, 8 and 10 cubic meters capacity. Design and size of a biogas plant other than those mentioned above is feasible and a skilled technical supervisor (NDBP) should be consulted for deviations from the provided designs.

2. INTRODUCTION

A fixed dome Biogas plant is an airtight underground tank in which organic materials mixed with water are digested/ fermented through anaerobic bacteria action in the purpose of generating biogas fuel. The treated waste is a nutrient-rich, nitrogen-rich fertilizer while the biogas is a flammable gas composed of Methane (component which burns), Carbon dioxide, Hydrogen, Nitrogen and Hydrogen Sulfide. The main components are Methane and Carbon dioxide other gases are in form of traces.

Biogas plants are a preferred alternative to burning dried animal dung as a fuel and can be used for the treatment of human waste.

Other feedstock which can be used includes plant material, non-meat or grease food-wastes, and most types of animal dung. Over a million biogas plants have been constructed in the developing world for treatment of organic wastes, alternative energy supply to direct burning in the home, and overall improvement of human health and the environment. Many factors for selection of feedstock and site location must be researched before deciding to install a biogas plant

Successful construction of the biogas plant requires a proper design and adherence to follow correct construction methods. The success or failure of any biogas plant primarily depends upon the quality of construction work.

The advantages of the fixed dome plant include the simplicity of design, few moving parts, low cost to construct and maintenance. The disadvantages when compared to a floating-dome digester are

primarily the inability to store gas for use on demand; gas from the fixed dome digester must be used as generated or expelled to avoid damaging the digester

3. RESPONSIBILITIES OF A BIOGAS PLANT CONSTRUCTOR

The role of biogas plant constructor is vital in successful installation of biodigesters. The following are some of the major responsibilities of a biogas plant constructor:

- Provide necessary information on benefits of biodigester to the users and motivate them for bio-digester 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 biodigesters.
- Comply with the Construction Manuals while installing the biodigesters.
- Provide and maintain 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
- 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

4. DETERMINING PLANT SIZE & AVERAGE DAILY FEEDSTOCK

The size of the biogas plant depends on the quantity, quality & kind of available biomass, average daily feed stock and expected hydraulic retention time of the material in the biogas system. The following points should be considered.

4.1 Sizing the digester

- The size of the digester, i.e. the digester volume **V_d**, is determined on the basis of the chosen retention time **RT** and the daily substrate input quantity **S_d**.

$$V_d = S_d \times RT \text{ [m}^3\text{ = m}^3\text{/day} \times \text{number of days]}$$

Where V_d is in m^3 ;

S_d in m^3/day or L/day ;

RT in Days;

Biomass/ Organic material in kg and

Water in L

- The retention time, in turn, is determined by the chosen/given digesting temperature. For an unheated biogas plant, the temperature prevailing in the digester can be assumed as 1-2 degree Kelvin above the soil temperature. For a plant of simple design, the retention time should amount to at least 35 days.
- Substrate input (**S_d**) = biomass (**B**) + water (**W**) [m^3/d]
- In most biogas plants, the mixing ratio for dung (cattle and / or pigs) and water (**$B:W$**) amounts to 1:1

4.2 Average daily feedstock

- Generally, 24 to 40 kilograms of feedstock complimented with 24 to 40 liters of water per day with a hydraulic retention time of 40 days will require a 4-cubic meter plant;
- Table 4.2.1 below gives some relevant data about the six different sizes of biogas plants presented in these guidelines.

Plant Size (m^3)	Daily Feedstock (kilogram)	Daily Water (liters)
4	24 - 40	24 - 40
6	40 - 60	40 - 60
8	60 - 80	60 - 80
10	80 - 100	80 - 100

Table 4.2.1 Plant size & average daily feedstock

Note: Plant size is the sum of digester volume and gas storage based on a hydraulic retention time of 40 days

5 DESIGN OF BIOGAS PLANT

5.1 Main components of the biogas plant

The biogas plants detailed in these guidelines consist of:

- Inlet Tank;
- Digester Vessel;
- Dome;
- Outlet Chamber; and
- Compost Pits.
- Inlet tank/Mixing chamber;
- Digester vessel/ Tank body;
- Outlet chamber/ Expansion chamber/
Compensating chamber;

5.2 Production of biogas

- The required quantity of feedstock and water is mixed in the inlet tank and the slurry is discharged to the digester vessel for digestion. The gas produced through methanogenesis bacteria in the digester is collected in the dome. The digested slurry flows to the outlet tank through the manhole. The slurry then flows through the overflow opening in the outlet tank to the compost pit. The gas is supplied from the dome to the point of application through a turret and pipeline;
- When a biogas plant is underfed the gas production will be low; in this case, the pressure of the gas might not be sufficient to fully displace the slurry in the outlet chamber. It is important to design the plant keeping hydrostatic pressure higher at the inlet tank than the outlet tank. The hydrostatic pressure from slurry in the inlet and outlet tanks will pressurize the biogas accumulated in the dome. If too much material is fed into the digester and the volume of gas is consumed, the slurry may enter the gas pipe and to the appliances;

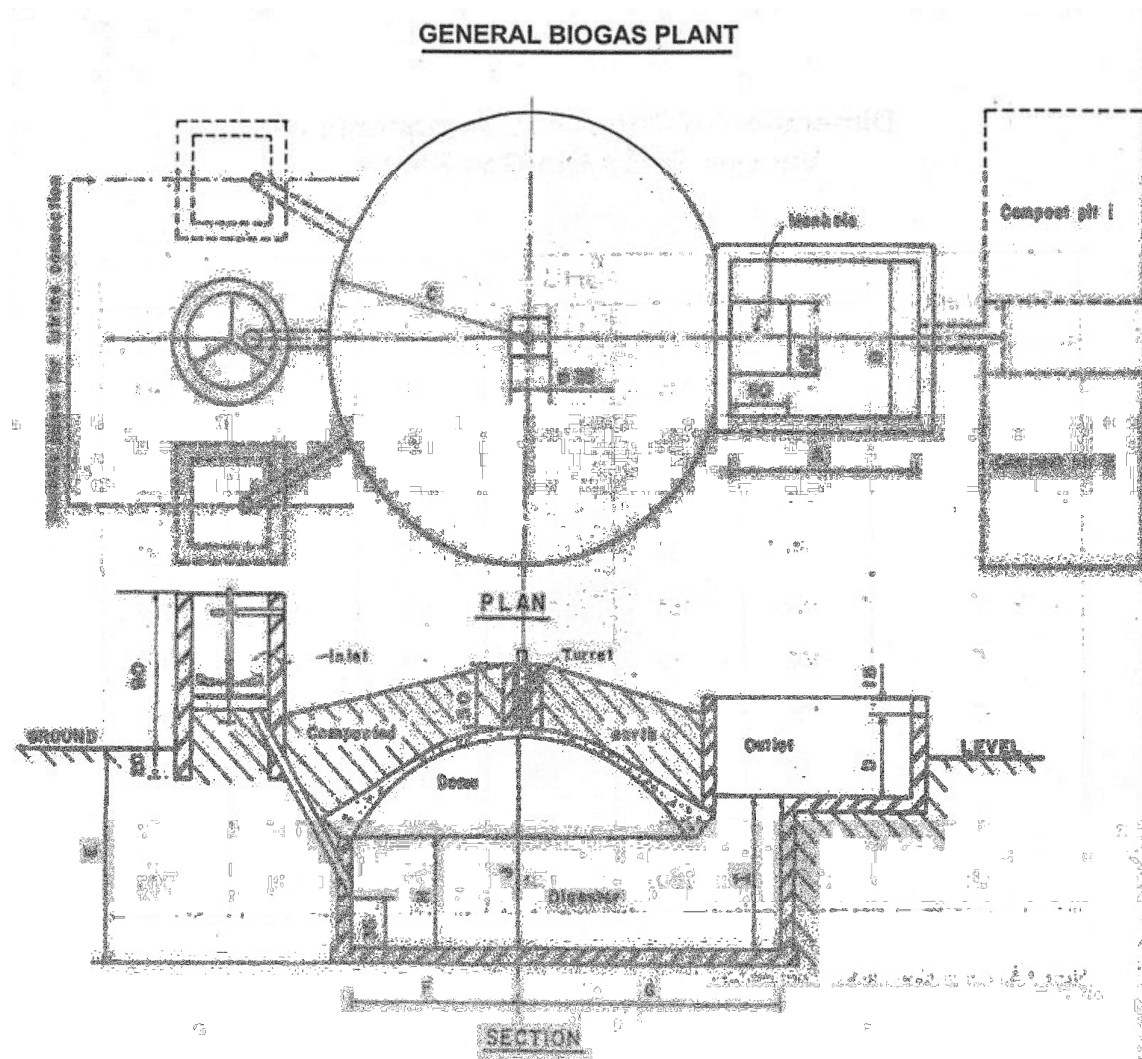


Figure5. 2.1: General biogas Plant Design

Components	Plant size (m ³)			
	4	6	8	10
A	140	160	170	190
B	120	130	140	160
C	140	160	175	200
D	50	55	60	62
E	160	170	180	190
F	110	130	145	155
G	203	219	140	252
H	80	85	90	95
I	105	110	115	123
J	145	155	165	175

Table 5.2.1: Dimensions for the Various Plant Sizes

Note: All dimensions are in centimeters (cm)Where:

A is the Length of outlet

B: Breadth of outlet

C: Radius of Pit

D: Height of outlet

E: Dept of Excavation

F: Radius of Digester

H: Height of Digester wall

I: Height of outlet passage and

J: Inner Height of Digester and Dome

6 CONSTRUCTION OF BIOGAS PLANT

6.1 Selection of construction materials

- If the materials used in the plant construction such as cement, sand, aggregate etc. are not of good quality, the quality of the plant will be poor even if the design and workmanship are excellent;
- Domestic fixed dome biogas plant should be constructed by Stones round wall and outlet, Dome with plain Concrete and slabs with reinforced concrete, inlet with either stones or bricks
- A brief description regarding the specifications for some of the construction materials is provided below to assist with selection of the best quality materials

Items	Unit	Size of bio digester			
Building materials		4m ³	6m ³	8m ³	10m ³
Stones	m ³	4.0	6.0	8.0	10.0
Gravel 20mm diameter maximum	m ³	1.5	2.0	3.0	4.0
Clean coarse sand	m ³	1.5	2.0	3.0	4.0
Clean fine sand	m ³	1.5	2.0	3.0	4.0
Portland Cement	bags	15.0	18.0	20.0	22.0
Acrylic emulsion paint	kg	2.0	3.0	4.0	5.0
Gas Turret pipe with 1 1/4-1/2 reducer	pcs	1.0	1.0	1.0	1.0
Steel rods 8mm	pcs	4.0	4.0	5.0	6.0
Binding wire	kg	0.5	0.5	0.5	0.5
Galvanized wire	kg	0.5	0.5	0.5	0.5
PVC pipe 110 mm, PN 4	pcs	1.0	1.0	1.0	1.0
PVC pipes 20 mm, PN 16	pcs	7.0	7.0	7.0	7.0

PVC elbow 20mm	pcs	7.0	7.0	7.0	7.0
PVC tee 20 mm	pcs	4.0	4.0	4.0	4.0
PVC socket 20 mm	pcs	3.0	3.0	4.0	4.0
PVC Adapter nipple ½	pcs	4.0	4.0	4.0	4.0
PVC Adapter socket ½	pcs	1.0	1.0	1.0	1.0
Tangit Glue	kg	0.25	0.25	0.25	0.25
Galvanized Nipple 1/2"	pcs	5.0	5.0	5.0	5.0
Galvanized Union	pcs	1.0	1.0	1.0	1.0
Galvanised Plug 1/2"	pcs	1.0	1.0	1.0	1.0
Gas hose pipe	m	2.50	2.50	2.50	2.50
Hosepipe Nipple	pcs	3.0	5.0	5.0	6.0
Hosepipe clamp	pcs	6.0	6.0	6.0	6.0
Gas valve 1/2"	pcs	4	4	4	4
Biogas lamp	pcs	0	1	1	2
Biogas stove	pcs	1	1	2	2
Pressure gauge	pcs	1	1	1	1
Teflon tapes	pcs	2	3	3	3
Galvanized elbow	pcs	2	2	2	2
Wood screws	pcs	10	10	10	10
Screw holders 8 mm	pcs	10	10	10	10
Wall clamps 1/2"	pcs	5	5	5	5
Mixing device	pcs	1	1	1	1

Table6.1.1. Biogas Plant Construction Materials

6.1.1 Cement

The cement to use in the plant construction must be of high quality Portland cement from a brand with a known reputation. It must be fresh, without lumps and stored in a dry place. Bags of cement should never be stacked directly on the floor or against the walls to protect the cement from absorbing moisture before use.

6.1.2 Sand

- Sand for construction purpose must be clean. Dirty sand has a very negative effect on the strength of the structure;
- If the sand contains 3% or more impurities by volume, it must be washed. The quantity of impurities especially mud in the sand can be determined by a simple test using a bottle and clean water. For the test, the bottle is half-filled with sand, filled with clean water, and then stirred vigorously. Allow the bottle to sit stationary to allow the sand to settle. The particles of sand will settle first while mud particles will settle last. After 20-25 minutes, compare the thickness of the mud layer to the sand inside the bottle are; the percent of mud should be less than 3% of the overall volume. Coarse and granular sand can be used for concrete work however fine sand is necessary for plastering work.

6.1.3 Gravel

Gravel size should not be too big or too small. Individual gravel diameter should not be greater than 25% of the thickness of concrete product where it is used. As the slabs and the top of the dome are not greater than 7 cm thick, gravel should not be larger than 2 cm in size. Furthermore, the gravel must be clean. If it is dirty, it should be washed with clean water.

6.1.4 Water

Water is mainly used for preparing the mortar for masonry, concrete and plastering work. It is also used to soak bricks/stones before using them. Water is also used for washing sand and aggregates. It is advised not to use water from ponds and irrigation canals for these purposes, as it is usually too dirty. Dirty water has an adverse effect the strength of the structure; hence, water to be used must be clean.

6.1.5 Bricks

Bricks must be of the best quality locally available. When hitting two bricks together, the sound must be crisp or clean. They must be well baked and regular in shape. Before use, bricks must be soaked for few minutes in clean water. This will prevent the bricks from soaking moisture from the mortar after being laid in place.

6.1.6 Cobblestones

If cobble-sized stones; 7.5-30 cm (3-12") in diameter are used for masonry work, they must be clean, solid and of good quality. Cobblestones should be washed if they are dirty.

6.2 Selection of construction site

The following points should be kept in mind when deciding on a site for biogas plant construction. Please note that it will not be possible to meet all the requirements as stated below, however, it should be ensured that as many points as possible are considered:

- the site should facilitate easy construction works;
- the selected site should be such that the construction cost is minimized;
- the selected site should ensure easy operation and maintenance activities like feeding of the plant, use of the main gas valve, composting and use of slurry, checking of gas leakages, draining condensed water from the pipeline, etc.;
- the site should guarantee plant safety;
- for proper function of the plant, the optimal temperature has to be maintained in the digester. Therefore, a sunny site should be selected to keep the digester near 35 degrees Celsius (95 degrees Fahrenheit);
- the area to construct the plant should have an even surface
- the site should be in a slightly higher elevation than the surrounding. This helps in avoiding water logging. This also ensures free flow of slurry from the outlet overflow to the composting pit;
- 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 biodigester from roots

- to make plant operation easier and to avoid wastage of raw feedstock the plant must be as close as possible to the feedstock supply (toilet, animal pen, compost pits, etc.) and water source;
- if a supply of feedstock or water or both is not available then the biogas plant should not be installed.
- gas pipe length should be kept as short as possible. A longer pipe increases the risk of gas leaks because of the increased number of joints; the cost of a longer pipe is also a factor;
- the main gas valve should be opened and closed before and after each use, therefore the plant should be as close as possible to the point of use to facilitate proper operation;
- the edge of the foundation of the plant should be at least two meters away from any other structures to avoid risk of damage during construction;
- the plant should be at least 10 meters away from groundwater wells or surface water bodies to protect water from pollution.

6.3 Plant layout

Construction work starts with the process of layout works. This is the activity carried out to mark the dimensions of the plant in the ground to start the digging work. For this purpose,

- after selection of the plant size and site location, the site layout is marked on the ground surface with wooden stakes, rocks, chalk or other materials
- 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 hart-line);
 - define 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 at 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 'C' Figure 5.2.1 and mark it on the rope;
 - a cord for the radius of the digester is attached to the peg (length indicated on the drawing under dimension „C“, Figure 5.2.1);

- the circumference can be marked by rotating the end of the cord in circular fashion;
- a suitable arrangement must then be marked for the inlet tank, inlet-pipe(s), outlet-chamber, compost-pits and gas piping;
- 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 the outlet plus the wall thickness (for outlet chamber) and half of the size of the manhole (30 cm) plus its wall thickness, 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 the outlet plus the wall thickness to define the outer dimension of the outlet;
- check the size diagonally to ensure that the corners are exactly at 90 degrees;
- use colored powder to mark the dimensions;
- decide on the location of slurry pits while laying out plant digester and outlet;
- after the site layout is marked, the engineer should review the selected location again to ensure the best site has been chosen and will not interfere with other activities normally performed at the planned biogas plant.



Fig 6.3.1 Plant lay-out work

6.4 Excavation (Digging of pit)

After completion of lay-out work, the work for digging the 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:

- the pit depth is indicated on Figure 5.2.1 under dimension 'E';
- the excavation work should only be started after deciding the location of manhole and outlet tank.
- digging should be done as per the dimensions fixed during layout;
- as far as practical, the cutting in the ground should be vertical, however, if the soil is cohesion-less and the 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;
- once the depth of digging is equal to the dimension “E” Figure 5.2.1 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;
- be careful to avoid accidents 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 the digester as per the dimensions in the drawing during the layout;
- horizontal poles have to be placed in the ground level crossing each other at 90 degree in the centre;
- ensure that the poles rest on levelled ground;
- for safety, the pit walls should be vertical and stepped from the ground surface by one meter away from the center of the excavation for each meter in depth excavated;
- excavated soil should be placed at least one meter away from the edge of the dig so it does not fall inside the pit during construction;
- if the design depth cannot be achieved because of hard rock or high groundwater, the design will need to be modified to a smaller plant or wider digester or combination of both;
- it is not recommended to construct the biogas plant at or below the groundwater table elevation. The earth base of the excavation is then compacted using mechanical or manual tools



Fig 6.4.1 Excavation works

6.5 Construction of digester main chamber

The digester foundation is placed using cobblestones and/or gravel as aggregate then filled with concrete or pain cement. The foundation should be 15 cm thick and allowed.



Figure 6.5.1: Cobblestones and Gravel placed on compacted earth floor.

- at the center of the pit, a straight rod or pipe (the 0.5" GI gas pipe¹) must be placed in an exact vertical position. The vertical pipe will be used during the construction as a field-expedient guide to ensure symmetry of the biogas plant;
- at ground level, a rigid pole, pipe or cord is placed horizontally across the diameter of the pit;
- the vertical pipe is secured to the horizontal pipe, pole or cord. After securing, the vertical pipe should be checked to ensure it is still in the plumb/vertical position;
- a string or wire is attached to the vertical pipe. The length of this wire can be found on Figure 5. 2.1, dimension „F“;
- add one cm length to this length to allow space for plastering. Every stone that is laid in the round-wall will be exactly $F + 1$ cm away from the vertical pipe;



Figure 6.5.2: Concrete Foundation for Digester, Center Guide Pipe and Horizontal Cord.

- after the Foundation has cured for at least two days, the round wall is constructed;
- the first two rows of bricks must be positioned side by side so that 23 cm (9") wide base is made;

¹ The domestic gas supply pipe

- it is essential that first row be placed on a firm, untouched and level foundation. Subsequent rows of bricks are positioned on their lengths so that the wall thickness is maintained at 23 cm (9") wide;
- it is not necessary to build in support columns or pillars in the wall however, the backfilling between wall and pit-side must be compacted with great care;
- backfilling should be done no sooner than 12 hours following brick course placement to allow mortar to cure;
- earth should be well compacted by adding water and gentle ramming along the circumference of the digester. Poor compaction will lead to cracks in round-wall and dome;
- the cement mortar used can be 1 part cement to 4 parts sand (1:4) up to 1 part cement-5 parts sand (1:5) depending on the quality of the sand;
- the height of the round-wall is detailed on the drawing in Figure 5.2.1 under dimension 'H' as measured from the finished floor;
- the feedstock inlet pipe (and toilet pipe, if installed) must be placed in position when the round-wall is 30-36 cm high;
- to reduce the risk of blockages, the inlet pipe(s) must be placed as vertical as practically possible
- to the opposite of the main feedstock inlet pipe, a 60 cm wide opening must be left in the round-wall that serves as a manhole. The digested slurry will flow to the outlet tank through this opening;
- additional inlet pipes should be placed as close as possible to the main feedstock inlet pipe with a maximum distance of 45 degrees from the inlet-center-manhole line;
- when the round-wall has reached the correct height, the inside must be plastered with a smooth layer of cement mortar with mix of 1:3 cement-sand;



Figure 6.5.3: View of Manhole in Main Digester

6.6 Dome construction

When the construction works of round wall as described above, is completed, then 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 'J', as given in the figure 5.2.1, 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" diameter pipe, approximately 0.5 m 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 that 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;
- any excess sand or soil that falls on the round wall has to be removed.



Figure 6.6.1: making shape of the dome using template

- it is important that the earth of the 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;
- when the earth mould has the exact shape of the guide, a thin layer of fine sand is spread on the mould-top by gently patting it on the surface. The sand layer will prevent the earth from adhering to the cast;
- the earth used for the mould needs to be damp to prevent dry earth from soaking up water from freshly casted concrete;



Figure 6.6.2: Earth mould with sand layer before placing cast

- before start of the cast work, sufficient labor and construction materials like sand, gravel, cement and water must be staged on the site and ready for use;
- the casting must be done as quickly as possible and without interruptions as this will negatively affect the quality of the cast;
- a constant, adequate supply of concrete (mix: 1 cement, 3 sand, 3 gravel – 1:3:3) 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 the dome while casting, i.e. the thickness near the outer edge should be greater than the thickness at the center;
- 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;

- a continuous application of mortar along the sand mould is necessary as the bricks are placed;
- the brick dome should be placed continuously and use a mortar mix of 1:4 cement to sand;
- once the bricks for the dome have all been placed, the exterior is covered with 1:3 cement to sand plaster;



Figure 6.6.3: Earth mould with sand layer before placing dome

- 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;
- during the casting, the concrete has to be protected against strong sunlight by covering it with wetted burlap, jute bags or straw mats. This protection has to be left in place for at least one week;
- the day after the casting, the turret must be made. The turret is made with brick, 36 cm square and 50 cm tall;

- the turret is plastered with 1:3 concrete. Any delays during dome construction can lead to leakage between main gas pipe and dome;
- following completion of the dome (from the day after the casting onwards), the structure must be sprinkled with water 3 to 4 times a day during the curing period (up to one week);



Figure 6.6.4: Completed dome with turret.

- 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 the gas holder is not made perfectly gas-tight so;
- after approximately one week, depending on the temperature, the earth of the mould can be removed through the manhole;
- when all the earth is removed, the surface of the gas holder has to be cleaned by scrubbing it with water and an iron brush;

- the entire surface of the concrete dome has to be cleaned before starting the plastering on the clean surface of the dome interior, the following plaster coats must be applied to make the dome gas-tight from first to last coats; after cleaning, the following layers of plaster have to be applied to make the gas holder perfectly gas-tight;
- Scrubbing and scratching (chiseling)
- 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 a broom;
 - Layer-2: 10 mm thick plastering with cement sand mortar (1 part of cement and 3 parts of sand) applied with a plastering trowel;
 - Layer-3: 3-5 mm thick cement - sand punning (1part of cement and 2 parts of sand) with a plastering trowel;
 - Layer-4: Plastering with cement and acrylic emulsion paint mix (1 part paint and 10 parts cement) 3 mm thick applied with a plastering trowel;
 - Layer-5: Painting with thick layer of cement- acrylic emulsion paint (1 part of paint and two parts of cement) applied with a painting brush (10 cm wide).
- a plaster coat must be well set before applying the next layer;
- an 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 of each layer has to be ensured 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



Fig 6.6.5 Plastering of digester and gas holder

- for proper insulation during the cold season and as counter weight against the gas pressure inside, a minimum top cover of 40 cm (16") compacted earth is required on the dome;
- if the top cover will be prone to erosion due to wind and rain, proper protection with gravel, circular wall, or straw matting should be applied.

6.7 Outlet Chamber (Tank) Construction

To construct the outlet tank which is also called displacement chamber, excavation has to be done just behind the manhole. The Outlet Chamber excavation and manhole is completed concurrently with the digester vessel and the manhole shares a common foundation with the digester vessel. 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 excavation should be the inner depth of outlet plus the thickness of plaster plus the thickness of flooring ($D+2+7.5$ cm) from the ground level;
- when excavated at this depth, the top level of flooring would exactly reach the top of the manhole;

- the earth in the base of the outlet, behind the manhole, has to be well compacted, otherwise cracks will appear in the outlet floor later on;
- the length and breadth of digging should be the inner dimension plus the wall thickness plus the plaster layer;
- ensure that the distance from the floor of the manhole to the finished floor of the outlet is equal to height 'I' 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 coarse 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 the outlet should be as shown in drawing (A and B);
- while fixing the dimensions, allow at least 2 cm for plastering (in each side). Lay a first layer of mortar (1 cement: 3 sand) and start constructing the wall;
- first, place bricks/stones in the four corners of the tank wall and fix a rope to guide the brick/stone work by tying it with the bricks/stones 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;
- it is better to orient the outlet in such a manner that the length is parallel to the hart-line;
- always construct the overflow in the longer wall;
- the inside dimensions of the outlet chamber can be found on the drawing under length, breadth and depth (A, B and D);
- the overflow level in the outlet wall should be at least 5 cm higher in 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;
- the overflow level is at the top of dimension „D“ and top of the Outlet Chamber walls is dimension „D“ + 15 cm;

- outside of the walls must be supported with sufficient compacted earth up to the overflow level to avoid cracks;

OUTLET SLABS

- the cover slab for the outlet should be cast during the concreting of the gas-holder;
- the slab should be cast on leveled ground as per the dimensions given for different plant capacities;
- special care has to be taken to compact the concrete mix while casting the slab, as small holes left behind will expose the steel reinforcement to corrosive vapor coming from the slurry in the outlet tank;
- this vapor will lead to corrosion of the reinforcement and in the longer run the slab may 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 outlet cover slabs are very essential to protect people, especially the children, and animals from falling inside. Furthermore, it stops the rainwater from entering into the digester and also helps in avoiding excessive vaporization of slurry in the dry and hot season;
- the dimensions of outlet slabs are shown in the table below;

Plant size (m ³)	Slab size (cm)		No. of slabs	Diameter of MS rod (mm)	Weight of steel to be procured (kg)
	Length	Breadth			
4	115	52	3	8	10
6	125	62	3	8	12
8	145	65	3	8	14
10	155	68	3	8	16

Table 6.7.1 Dimensions of outlet 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

Table 6.7.2 other specifications for all slabs



Figure 6.7.1: Outlet chamber slabs in casts.

- the concrete slabs for the Outlet Chamber should be constructed at the same time of dome casting;
- it should be easy to make the additional concrete at this time and the slabs will be well cured before they are placed on the outlet;
- the slabs must be 8 cm thick with proper reinforcement (re-bar) 2.5 cm from the bottom side;
- the number and size of slabs must be designed so that they could be handled by 3-4 people without great difficulty;
- installing re-bar loop handles on the slabs may be useful for the occasional handling of the slabs;



Figure 6.7.3: Slabs in place on outlet chamber

6.8 Construction of Inlet Tank

Usually inlet tank 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 placed in well rammed, hard and levelled surface;
- in the rammed surface, a rectangular portion of the inlet tank has to be 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;



Fig 6.8.1 Inlet tank construction

- 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 device if mixing device is to be installed;
- 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 the finished surface, a circular mark with the help of a thread or cord of 30 cm radius is made 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;



Figure 6.8.2: Inlet Tank during masonry construction.

- 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 galvanized 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;
- even if a mixing device is not installed, the inlet pit should be round in shape as this is a more economical use of material and easier for hand mixing;
- 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;
- the toilet inlet pipe should enter the digester tank no more than 45 degrees from the centerline of the main inlet pipe;
- additionally the pan level of toilet should be at least 15 cm above the overflow level in the outlet walls.



Figure 6.8.3: Complete Inlet Tank with mixer device

6.9 Lay-out of gas pipeline

- The gas pipe conveying the gas from the plant to point of user is vulnerable to damages by people, domestic animals and rodents;
- only light quality PVC pipe should be used which must be, where possible, buried 30 cm below ground level;
- fittings in the pipeline must be sealed with zinc putty, Teflon tape or jute and paint;
- any other sealing agent, like grease, paint only, soap etc. must not be used;
- the use of fittings, especially unions, should be kept to a minimum to reduce the risk of leakage;
- no fittings should be placed between the main gas valve and the dome gas pipe;
- the pipe size, inside diameter should be between 6 and 1 Cm;
- pipe size is determined by the size of the digester, (amount of gas produced) and amount of gas required in the house. (Are the stoves, heater lights going to be used simultaneously?)
- a water drain or trap is installed in the pipeline;
- the position of the water drain should be vertically below the lowest point of the pipeline so water will flow by gravity to the trap;
- the drain must be easily accessible and protected in a well-maintained drain pit since water will be removed periodically by opening the drain

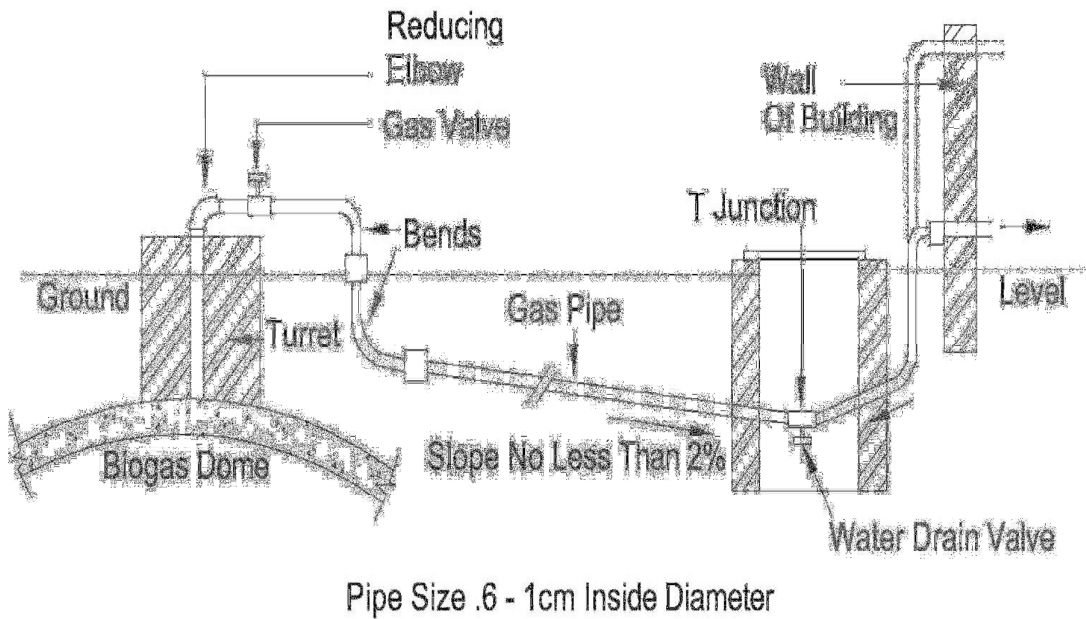


Figure 6.9.1: Schematic for condensate drain Valve in gas line.

- To connect burners to gas pipelines, use of transparent polyethylene hose must be avoided;
- only the best quality neoprene, rubber hose should be used. Other biogas appliances should be mounted and connected to the galvanized iron pipe;
- all joints and taps must be inspected for leakage by applying a thick soap solution and observing for foam movement;

6.10 Compost pits construction

- Compost pits are integral part of the biodigester; no plant is complete without them;
- a minimum of two compost pits should be constructed near the outlet overflow in such a manner that the slurry can flow easily into the pit;
- at least 1m space should be left between outlet wall and compost pit to avoid cracking of the wall of outlet tank;



Figure 6.10.1: Compost pits with brick walls for stability

- 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 earth excavated from the compost pits is used for backfilling of the inlet and outlet chamber and for top filling on the dome;
- 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;

- 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 fertilizer, 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;
- the following table illustrates the detail dimensions of compost pits for different plant capacities

Plant size (m ³)	Minimum dimensions of pit (cm)			Number of pits	Total minimum volume of pits (m ³)
	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

Table 6.10.1 dimensions of compost pits for different biogas plant capacities