Institutional Biogas Installer Manual

Prepared by

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EASTERN AFRICA

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1. Introduction to Biogas Technology

1.1 Introduction

Biogas technology is about capturing the gas that results from the anaerobic fermentation of biomass. The plant uses the natural processes of anaerobic digestion to produce biogas to produce biogas from animal waste or night soil. Biogas is a mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition.

Biogas is a flammable gas produced by microbes when organic materials are fermented in a certain range of temperature and moisture content. Biogas is about 20% lighter than air and has ignition temperature in the range of 6500 to 7500 C. It is odourless and colourless gas that burns with clear blue flame similar to that of LPG gas. Its calorific value is 20Mega Joules (MJ) per M^3 and burns with 60% efficiency in a conventional biogas stove.

Naturally occurring bacteria (methanogenic bacteria) produce biogas during digestion or fermentation of organic matter in the absence of oxygen (anaerobic process). The gas produced consists mainly of methane ($CH_{4)}$ and carbon dioxide ($CO_{2)}$. There are also traces of water vapour, hydrogen, nitrogen and hydrogen sulphide. This mixture of gases is combustible if the methane content is more than 50%. Biogas from animal dung contains approximately 60% methane.

Table 2: Composition of Biogas

Composition of Biogas		
Gases	**Symbol**	**Percentage (%)**
Methane	CH_4	50-70
Carbon dioxide	CO_2	25-35
Hydrogen	H_2	5-10
Nitrogen	N_2	1-2
Hydrogen sulphide	H_2S	Trace
Water vapour	H_2O	0.3

The production of biogas occurs in two stages:

- Bacteria breakdown complex organic materials into short chain, simple organic acids.
- Organic materials and CO2 are either oxidized or reduced to CH_4 by methanogenic micro organism.

In this way methane is formed from fermentation of animal wastes or any cellulose organic materials. For fermentation to take place, several conditions such as absence of air, suitable temperature, necessary nutrients, water contents and maintaining a suitable pH balance should be met.

1.2 Why Biogas

i. Manure for agriculture and aquaculture.

Farmers conceive the importance of biogas units in terms of the availability of larger quantities of better quality manure. A biogas plant in many situations doubles the availability of organic manure.

The manure produced through biogas has a comparative advantage over ordinary manure in terms of both quality and quantity. About 70 - 75% of the original weight of cattle dung is conserved in a biogas unit while in open compost pits 50% or more is lost. Similarly, almost all the nitrogen content in cattle dung is conserved in a biogas unit while a substantial part of this is lost during composting. Biogas manure, known as 'digested slurry' contains a higher percentage of other plant nutrients as shown in the table below.

Table 1: Comparison of plant nutrient content in digested slurry (DS) and farm yard manure (FYM).

Plant nutrient	DS (%)	FYM (%)
Nitrogen (N)	1.5 –2.0	0.5 – 1.0
Phosphorus (P_2O_5)	1.0	0.5 – 0.8
Potash (K_2O)	1.0	0.5 -0.8

It is a good source of micronutrients like zinc, iron, and manganese and copper which have become limited in many soils. Also, the complete digestion of cattle dung in biogas units kills seeds of weeds. Organisms causing plant disease are also killed.

It has been observed that the use of digested slurry as manure improves soil fertility and increases crop yield by 10 -20%. It is recommended that the manure should be applied at the rate of 10 tones per hectare in irrigated areas and 5 tones per hectare in dry land areas. The manure can be used in conjunction with normal dosages of chemical fertilizers. Such practice will help get better returns from fertilizers, minimize the loss of fertilizers from the soil and provide balance nutrition to crops, while improving soil conditioning.

ii. Domestic fuel

Presently, agricultural residues and firewood are used as cooking fuel in rural areas. It is wasteful practice as hardly 9 – 12% of their value is harnessed. Moreover, smoky kitchens are harmful to the health of women and children. Also collection and storage of these materials is problematic, in particular during the rainy season.

Biogas is a clean and efficient fuel for cooking and lighting purposes. It saves the consumption of kerosene, charcoal and wood. It avoids the need to collect firewood and twigs and thus saves the labour of women and children who normally spend considerable time and energy to cover long distances daily to collect fuel. It also eliminates the practice of indiscriminate felling of trees and consequent soil erosion.

It alleviates the drudgery of rural women's lives and provides spare time for women's activities that can make a contribution to the family income.

Children can read under biogas illumination, during erratic supply of electricity or shortage of kerosene.

iii. Sanitation and health

Biogas units are effective means for the sanitary disposal of human excreta. In areas with dry latrines, the practice of carrying head loads of night – soil can be eliminated by attaching latrines to a biogas unit. By putting all human and animal excreta into a biogas unit the problem of waste disposal is solved at the family level itself. During decomposition of night - soil in a biogas unit, most of the diseases – causing organisms are killed. This can serve as an effective control of parasitic diseases, hookworm, roundworm, etc.

The digested slurry remains free from foul smell and most pathogens. Mosquitoes and flies do not breed in digested slurry. Thus biogas units improve sanitation.

The incidence of eye diseases among women and children is also reduced as burning of biogas does not cause any smoke in the kitchen.

Biogas, being a clean fuel, does not cause air pollution. It is considered a better fuel than natural gas and liquefied petroleum gas because it does not contain sulphur. Sulphur, on burning, gets converted into sulphur dioxide which is responsible for many lung diseases.

The danger of explosion of biogas is less as it contains carbon dioxide which acts as a fire extinguisher. It is also lighter than air and thus easily dissipates in to the air making it impossible to reach ignitable concentrations.

1.3 Types of fermentation

- Continuous process
- Batch process
- Plug flow process

In the continuous process, the substrate or feed should be continuously added and at the same time slurry will come from the other end continuously. In the batch process a specific amount of substrate is fed into the biogas plant and left to be digested for a given duration of time after which, more substrate is added. The system is more effective for substrate that is digested slowly over a long period of time, such as straw and leaves. The plug flow process is a comparatively more complicated system that entails the use of monitoring systems to balance the needs of the microbes and that of the substrate during a flow through type of digestion system. The system is mainly for substrates with high water content.

It is important to note that, for our purposes however, the continuous digestion is the most widely applied process.

1.4 The digestion process

The different groups of bacteria responsible for fermentation live in an interacting ecosystem. Each type of bacteria depends on others. Fermentation time is shortest when populations of different bacteria are adequately balanced. The digestion process consists of 2 main phases:

- Acid formation and
- Methane formation

In the first phase, protein, carbohydrate and fat give rise to amino acids, alcohols and fatty acids respectively. Methane, carbon dioxide and ammonia are produced in the second phase.

The slurry becomes thinner during the process of digestion as the carbon components are released in the form of gas. Biogas is slightly lighter than air and has an ignition temperature of approximately 700^{0}C.The temperature of the flame is 870^{0}C.

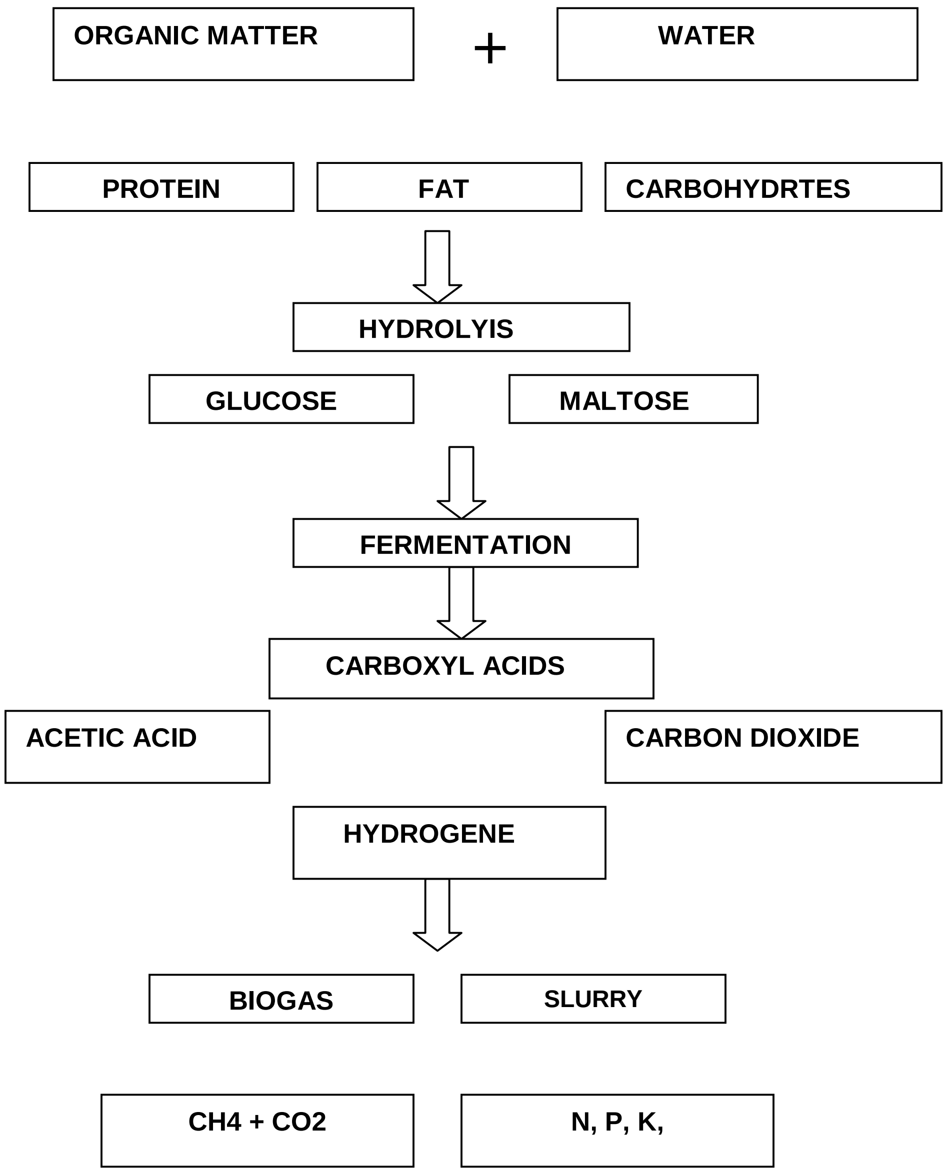


Figure 1: The bio-chemical process of anaerobic takes place in different steps as shown in the figure below:

1.5 Sources of Feedstock

Biogas can, in principle, be obtained from any organic material. The animal waste range from cattle manure, chicken waste, municipal waste, kitchen waste, human waste are potential for being used as a good source of feedstock.

Some other types of feedstock such as straw, leaves and in particular water hyacinths can be digested only in certain types of plants or using special conditioning techniques such as mulching and pre-fermentation. Therefore reliable information or the general validity concerning gas production cannot be given.

All feed materials consist of:

- Organic solids
- Inorganic solids
- Water

Properties of feed materials						
Animal /feed materials		**Daily output**		**Proportions in fresh Feed material**		**C/N**
		Dung	**Urine**			
	Approx kg	**% live wt**	**% live wt**	**% DM**	**%ODM**	
Cattle dung	8	5	4	16	13	25
Pig manure	2	2.5	3	17	14	13
Sheep droppings	1			30	20	30
Poultry manure	0.08			25	16	5
Human excrement	0.5			20	15	8
Straws/ husks						70
Leaves/grass					Approx.80	35
Water hyacinths	25kg/m^3			7	5	25

Key: DM – Dry matter, ODM – Organic dry matter, C/N – Carbon Nitrogen ratio

Table 3: Properties of different feed materials

Biogas is formed by digestion of the organic substances. Inorganic materials, minerals and metals are unused ballast, which are not affected by the digestion process. The water makes the feed material capable of flowing. This is important for a continuously operating biogas plant. It is as well easier for the methane bacteria to come into contact with feed material, which is still fresh when the slurry is liquid.

Slurry with solid content of 5-10% is particularly well suited to the operation of continuous biogas plants.

All feed materials consist to a great extent of carbon (C) and Nitrogen (N). The carbon to nitrogen ratio of 20:1 to 30:1 is particularly favourable. Mixture of nitrogen rich feed materials like chicken manure and carbon rich feed materials like rice-husks give high gas production. Fermented slurry with a lower C/N ratio has better fertilizing characteristics.

1.6 The Role of Temperatures

The rate of biogas production depends on the physical properties of the substrate and the temperature. The following types of digestion are distinguished according to the temperature in the digester:

- Psychrophillic digestion 10-20^{0}C, retention time 100 days.
- Mesophillic digestion 20-35^{0}C, retention time over 20 days.
- Thermophollic digestion 50-60^0, retention time over 8days. (This type is not an option for simple biogas plants).

Simple biogas plants in tropical regions (i.e. Kenya) operate within a temperature range of between 15^{0}C to 35^{0}C. To ensure a constant temperature, the plants are usually constructed underground.

1.7 The pH-Value

The pH of the fermentation slurry indicates whether the digestion process is proceeding without disturbance. A healthy digestion process shows a pH of 7.0 (slurry neither alkaline nor acid).

1.8 Retention Time

The term 'retention time' indicates the period spent by the feed-material in the digester. The retention time is calculated by dividing the digester volume with the daily fed material. The degree of digestion increases with the retention time. The Longer the retention time, the higher is the exploitation rate of the material fed in the plant.

A farmer with a small amount of animals should get a biogas plant with a long retention time. This increases the investment costs on the one hand, but leads to a higher gas production from each kg of dung charged in the plant. A farmer with a lot of animals would rather get a plant with short retention time. The dung is not fully exploited, but it might also not be necessary as he still gets a lot of gas due to the large amount of feeding material. The shorter the retention time, the lower the investment costs. Retention time is also one factor in determining the size of the biogas plant.

Except for the investment costs, long retention time has several advantages:

- The content of methane gas in the biogas mixture is increased,
- The C/N ratio becomes narrower so that the fertilization effects of the output slurry are higher. The big volume of the digester buffers the formation of swimming and sinking layers
- Reduces changes in temperature
- Reduces changes in pH and more energy output.

A long retention time can compensate a low digester temperature. The digestion will be slower, but prolonged.

2 Biogas plant construction

2.1 Understanding the biogas system

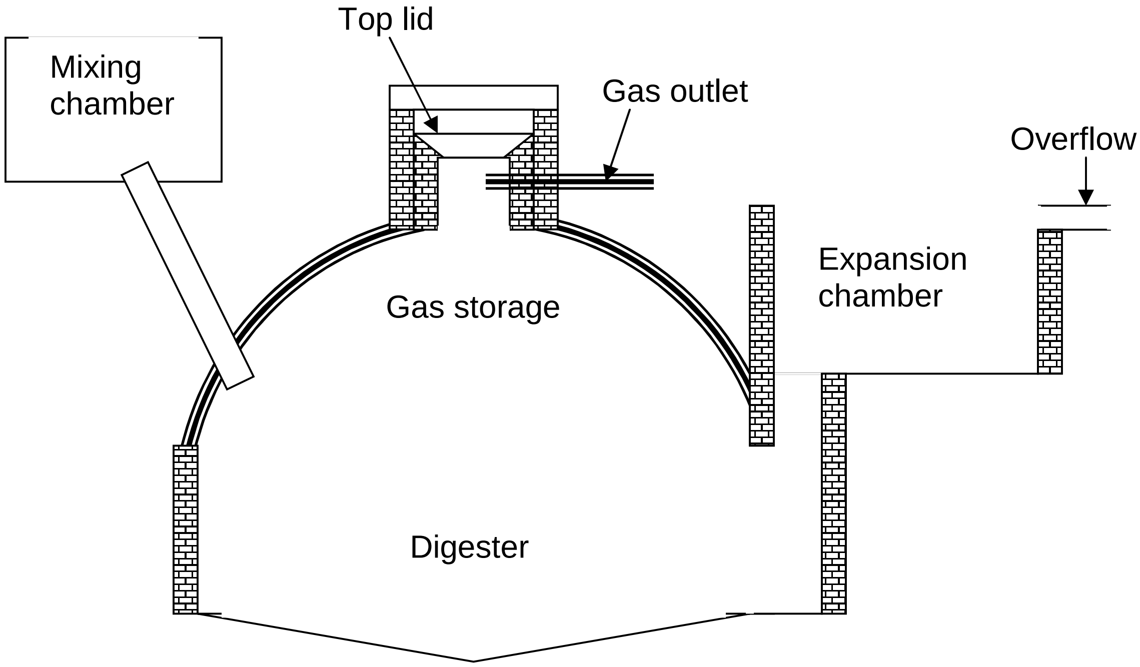


Figure 2: Biogas plant layout

A biogas plant consists of three main components, namely: mixing chamber, digester and expansion chamber. The required quantity of dung and water is mixed in the mixing chamber and this mix in the form of slurry is allowed to flow and be digested inside the digester. The gas produced in the digester is collected in the dome, called gasholder. The digested slurry flows to the expansion tank from the digester through the manhole. The slurry then flows through an overflow opening to the storage pit where it is collected and taken to the fields for application as fertilizer. The gas is supplied to the point of use through a pipeline.

Before deciding on the size of plant, it is necessary to collect dung for several days to determine the average daily dung production. The amount of dung available daily helps in determining the size of the plant. For example, if 1000 Kg of waste and $1m^3$ waste water is collected daily, a 150 M3 biogas plant has to be selected.

The important point to be considered is that the size of plant has to be selected on the basis of available feedstock not on the family size.

The biogas plant consists of three main parts namely:

- **Mixing chamber**: This is where the animal dung, night soil and or kitchen waste are mixed with water before it is re-directed to the digester chamber.
- **Digester chamber**: It is where the feedstock undergoes anaerobic decomposition to release methane and other gases. As the gas increases within the chamber, the slurry is pushed down and out to the expansion chamber. The digester chamber consists of two main parts: Gas holder and Digestion chamber.

- **Expansion chamber**: Collects excess slurry from the digester. If the gas is not being used and fills up the gasholder, it pushes the slurry out through to the expansion chamber. When gas is being used, it reduces the pressure in the digester hence the slurry will flow back into the digester chamber. When the slurry exceeds the volume of the expansion chamber, it will automatically be drained out through the overflow pipe provided for in the expansion chamber.

This system is a dynamic system: that is, as the pressure of the gas inside the gas holder increases, the slurry is pushed to the expansion chamber and when the gas is used, the slurry in the expansion chamber flows back into the digester chamber to push the gas up for usage.

2.2 Types of Biogas Plants

A standard biogas plant is normally a continuous plant with automatic discharge at the outlet. There are three well proven mature designs available:

- The fixed dome plant
- The floating drum plant and
- The plastic covered ditch or tunnel

Fixed dome plants are mostly favoured for extension programmes because they are long lasting and cheaper than floating drum plants. Fixed dome plants need less maintenance but building them require great care in design and workmanship.

2.2.1 Biogas plant sizing

Biogas plants come in different sizes depending on the needs of the user and also the availability of the feed materials.

Sizing of a biogas plant entails determining the size of plant to be constructed. The main determining factors being type and amount of feedstock, energy needs of the biogas owner and material cost relating to affordability by the biogas owner.

If a plant is over sized, it will be underfed, the gas production will be low; in this case, the pressure of the gas might not be sufficient to displace the slurry in the outlet chamber.

This means that the amount of slurry fed into the digester is more than the amount of slurry thrown out from the outlet.

This will cause the slurry level to rise in the digester and into the gasholder and it may eventually enter into the gas pipe and sometimes, to the gas stove and lamp when opening the main valve. Therefore, the slurry should always be fed according to the prescribed amount.

The real and active volume of the digester in fixed dome plants depends on the gas storage space actually utilized. This is normally not exactly known. Therefore an approximate calculation of dimensions is sufficient. The average digester volume VD depends on radius R, the relation between radius r and the volume of expansion chamber (which is equal to the volume of the gas storage space) is based on the depth of the expansion chamber of 0.50 m in order to keep the gas pressure below 1.3 m of W.C (water column), the gas storage capacity should not exceed max. VG.

It is however necessary to note that a number of sizes have been developed and designs made taking into account, the cost versus gas increment and also necessary structural stability.

Contractors therefore need not undertake design of new sizes but should be able to use the standardized sizes or combinations of the standardized designs.

2.3 Construction Materials and equipments

For the purpose of this manual, however, we only discuss issues related to the construction of fixed dome biogas plants. The basic principles are the same for small or institutional sizes.

The success or failure of any biogas plant mainly depends upon the quality of construction works. To have a successfully constructed biogas plant, the mason should not only conform to the dimensions as indicated on the drawing but also follow the correct construction method.

It is important that the construction materials to be used in the plant construction such as cement, sand, aggregate e.t.c be of good quality. The section below describes the characteristics of materials selection for biogas plant construction.

2.3.1 Cement

The cement to be used in the plant construction has to be of high quality. Portland cement is recommended 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 but wooden planks should be placed on the floor to protect cement from dampness.

2.3.2 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, it must be washed. The quantity of impurities especially the mud in the sand can be determined by a simple test using a bottle. This is called the 'bottle test'. For this test, small quantity of sand is put in the bottle. After this, water is poured in and the bottle is stirred or shaken vigorously. The bottle is then left stationary to allow the sand to settle down. The sand particles are heavier than mud particles and therefore settle down quickly. After 20-25 minutes, the layers of mud versus sand inside the bottle are measured. Coarse and granular sand can be used for concreting work but fine sand will be better for plastering work.

2.3.3 Gravel

Gravel should not be too big or very small. It should not be bigger than 25% of the thickness of concrete product where it is used in. As the slabs are not more than 10 cm thick, gravel should not be larger than 3 cm in size. Furthermore, the gravel must be clean. If dirty, should be washed with clean water.

2.3.4 Water

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

2.3.5 Bricks

Bricks must be of the best quality locally available. When hitting two bricks, the sound must be clear. They must be well baked and regular in shape. Before use, bricks must be soaked for few minutes in clean water. Such bricks will not soak moisture) from the mortar afterwards. If the bricks are concrete bricks, they should be made from the correct concrete mixture of: 1 cement to 3 sand 4 gravel i.e. (1:3:4)

2.3.6 Stones

If stones are to be used for masonry work, they have to be clean, strong and of good quality. They should not be porous. Quarry stones are preferable. Stones should be washed if they are dirty.

3 Step by Step Construction procedure

3.1 Site Selection

The following points should be kept in mind when deciding on a site for biogas plant construction.

- For proper functioning of the plant, the right temperature has to be maintained in the digester. Therefore, a sunny site has to be selected.
- To make plant operation easy and to avoid wastage of raw material specially the dung, the plant must be as close as possible to the stable (cattle shed) and water source. If the nearest water source is at a distance of more than 20 minutes walk, the burden of fetching water becomes too much and no plant should be installed in such places.
- The plant should be closer to the point of gas use. If located far way, there will be need for longer piping. This will increase the cost and hence make the plant unnecessarily expensive. Furthermore, longer pipe increase the risk of gas leakage due to more joints in it. The main valve has to be opened and closed before and after use Therefore, the plant should be as close as possible to the point of use so that the above problems are eliminated.
- The edge of the foundation of the plant should be at least two meters away from the house or any other building to avoid risk of damages.
- The plant should be at least 10 meters away from any well or any other under ground water sources to protect water from pollution.
- The ground should be slopping away from the biogas plant to allow for proper drainage during rains to avoid water flooding and also enable the slurry from the biogas plant to flow away from the plant by gravity see fig. 3 below.

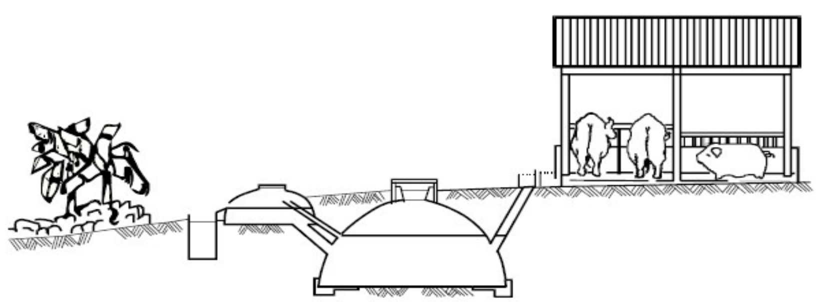


Figure 3: Setting up of biogas system

3.2 The Reference line

A level line marked by a string passing over the centre of the digester from inlet to outlet is set. The line position is determined from the intended position of the overflow outlet pipe. The line will assist:

- To keep the construction at exact levels.
- To be used as a reference for vertical measurements
- To assist in using minimum level for soil covering of the plant

The posts for the reference line should be sturdy and firmly fixed and should be protected throughout and during the construction period. Its level can be extended to a permanent structure like a building nearby or a tree.

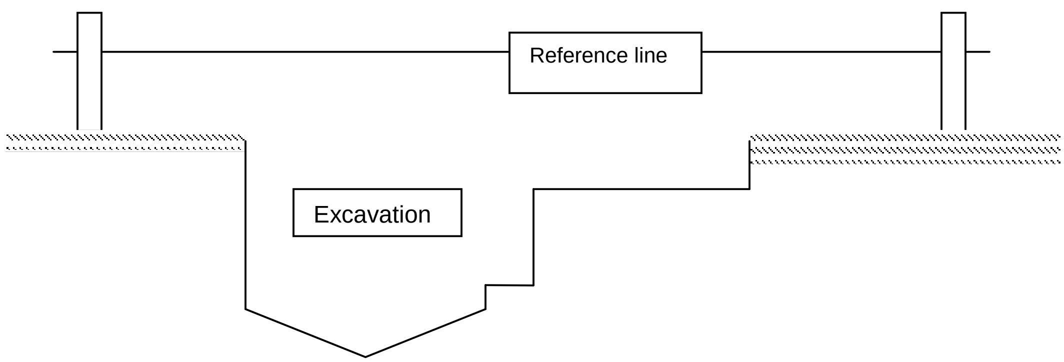


Figure 4: Setting up the reference line

3.3 Digging and Pit Depth

All activities under this section should be done with reference to the selected design drawing given in the annexes.

When a suitable site is selected, a small peg has to be stuck in the ground at the centre spot of the digester. A cord has to be attached to this peg with the length indicated on the drawing. Now this cord is the radius of the digester pit and the circumference can be decided by moving the edge of the cord on circular fashion.

The pit depth is indicated on the drawing. The excavation work should only be started after deciding the location of expansion chamber and outlet storage tank.

The pit wall should be as vertical as possible and, most important, the pit bottom must be excavated into a cone as per the dimensions and the base must remain firm. See figure 4 above.

While digging, excavated soil should be thrown at least one foot away from the layout, so that it does not fall inside the pit when the construction work is in progress.

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 done so that the wall of the digester and dome is supported well by the unexcavated earth around the plant.

3.4 Construction of Round-wall

At the centre of the pit, a straight pipe (the 1" GI gas pipe) must be placed in an exact vertical position. Above ground-level, four sturdy wires are tied to the pipe and fixed firmly on the sides of the pit. To ensure that the pipe remains vertical, a water level is used. After securing the vertical pipe, it has to be checked again to ensure it is still in the up right (90 degrees to the horizontal) position.

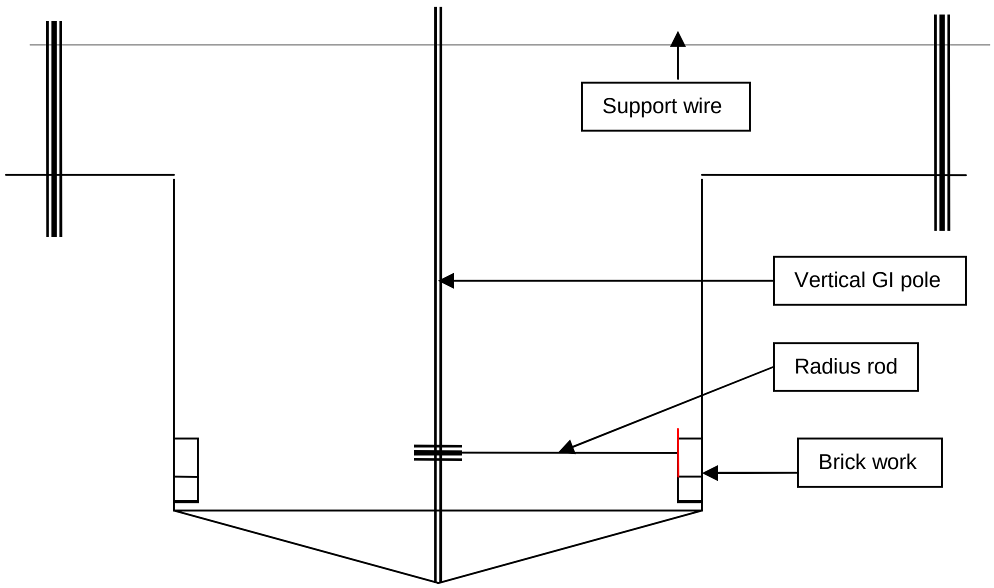


Figure 5: Checking the levels of the plant

A radius rod, made of a straight piece of timber is then fixed to the vertical pipe. The length of this timber can be found on the drawing. One centimetre (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 the same distance away from the vertical pipe.

After deciding the radius of digester, the round wall is constructed. The first row of bricks must be positioned on their sides so that a wide base is made. It is essential that the first row is placed on a firm, concrete base. The next rows of bricks can be positioned on their lengths so that the wall thickness is 4.5".

It is necessary that backfilling between wall and pit-side is 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-4 sand (1:4) to I cement-6 sand (1:6) depending on the quality of the sand.

The height of the round-wall can be found on the drawing when measured from the reference line. The inlet pipe and toilet pipe must be placed in position as per the drawing. To reduce the risk of blockages, the inlet pipe(s) must be placed as vertically as practically possible.

Exactly opposite to the 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 expansion tank through this opening. If a toilette connection is made to the biogas plant, then 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 dung inlet-centres-manhole line (hart line).

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 cement: sand being 1:3.

Figure 6: Inside of round-wall plastered with a smooth layer of cement mortar.

3.5 Dome Construction

When the construction works of the round wall digester as described above is complete, the dome has to be constructed.

On the vertical centre pipe, a mark has to be made as given in the drawing, from the finished floor. A different radius rod that is equivalent to the radius of the dome is then fixed on the vertical wall. The radius rod is now used to lay the brickwork for the dome. Moving slowly round the top of the digester wall, the first line of brickwork is laid. Continuing this process will result in a dome structure at the end of the construction.

It is important that the bricks are placed as close as possible before the spaces between the brickwork are filled with motor. If the spaces are too wide, the dome, by its own weight and that of the concrete, can lead to cracks in the dome. For purposes of holding the bricks in place and allow the cement to set during the dome construction, hooks are used on every course and removed when the next course is being build.

Figure 7: Construction of the dome.

The last course of bricks should be laid to allow for the internal diameter of the hole in the dome to remain as per the drawing.

After completing the dome, a reinforced cast is laid at the base of the neck to hold the weight of the neck unit. The dimensions of the neck unit are as per the drawing.

Using the dimensions in the drawing, a gas outlet pipe is installed in the brickwork at the right height. After the addition of the next courses of brickwork, the locks are installed. The locks are pieces of GI pipes with pieces of metal rods welded on them to ensure they stay firm in the masonry wall.

After completion of the neck, the inside of the dome can then be plastered. On the clean inside surface of the dome, the following plaster coats have to be applied all the way to the neck to make the top structure from the dome to the cylindrical neck gas-tight.

- Cement-water mix to be applied directly to the dome surface using a brush.
- 10 mm layer plaster, cement: sand 1:2 applied immediately after the first layer.
- After one day, apply a smooth 5 mm layer, Water proof cement: cement: sand (1:1:1), punning.
- After two days apply a smooth 5 mm layer, Water proof cement: cement: sand (1:1:1), punning.
- Finally on the last day, apply a smooth 5 mm layer, Water proof cement: cement: sand (1:1:1), punning.
- A plaster coat must be at least one day old before next layer can be added. When a layer of plaster is applied, the work must be executed with the greatest care and without interruptions. The proper functioning of the plant is very dependent on the gas tightness of the dome.

3.6 Construction of expansion chamber

To construct the expansion chamber, excavation has to be done just behind the manhole as per the dimensions in the drawing. The level of excavation can be measured from the reference line by taking the dimension minus the thickness of the digester floor. The earth behind the manhole and under the outlet floor has to be very well compacted otherwise cracks will occur.

The inside dimensions of the outlet can be found on the drawing. The distance from the digester floor to the outlet floor is given in the drawing.

It is important that these dimensions should be accurate as they determine the useful capacity of the gasholder. For the same reason the outlet floor and the top of the walls have to be level. The walls have to be vertical and finished with a smooth layer of cement plaster (mix: cement: sand – 1: 3). On the outside, the walls have to be supported with sufficient earth body up to the overflow level. This again is to avoid cracks. See figure 7.

The expansion tank should be on a slightly higher elevation than the surrounding so that there are no chances of water running into the outlet during the rainy season.

At the same time of dome construction, the concrete base for the expansion chamber should be caste. It is easy to make some additional concrete at this time and the slab will be well cured before the construction of the expansion chamber is constructed. Also the slab for the top opening should be cast with proper reinforcement. The slab must be of such size that it can be handled by 2 men without great difficulty.

3.7 Construction of inlet chamber

The inlet chamber is constructed to mix dung and water. This can be constructed with or without a mixing device. Installation of a mixing device is preferable not only because it makes plant operation easier for the user but also because it improves the quality of mix. When a mixer is installed it has to be firmly attached to the structure, easy to operate, effective in the mixing process and the steel parts in contact with the dung are to be galvanized.

The top of the structure should not be more than one meter high from the ground level and both inside and outside of the pit has to be covered with a smooth layer of plaster (Mix: cement : sand, 1:3).

The bottom of the mixing chamber must be at least 25 cm **above** the outlet overflow level. Even if the mixing device is not installed, the inlet chamber should be round in shape as this is more economical material-wise and easier for hand mixing.

With toilet attachment to the plant it is better to construct without siphon or trap as the pan with siphon needs more water, which may result in excess water inside the digester. It is also not possible to de-block the pipe when the toilet has a trap. The toilet should not be farther than 45 degrees from the hart line (vertical pole position). Additionally, the toilet pan level should be at least 25 cm above the outlet overflow level.

3.8 Lay-out of Pipeline

The gas pipe conveying the gas from the plant to the point of use is vulnerable to damage by people, sun, domestic animals and rodents. Therefore, only light quality galvanized pipe or PVC should be used which must be, where possible, buried 1 foot below ground level. Fittings in the pipeline must be sealed with Teflon tape. Any other sealing agent, like grease, paint only, soap etc. must not be allowed. To reduce the risk of leakage, the use of fittings, especially unions, should be kept to a necessary minimum. No fittings should be placed between the main gas valve and the dome gas pipe.

The biogas coming from the digester is saturated with water vapour. This water vapour will condense at the walls of the pipeline. If this condense water is not removed regularly, it will ultimately clog the pipeline. Hence, a water trap has to be placed in the pipeline. The position of the water trap should be vertically below the lowest point of the pipeline so that water will flow by gravity to the trap. Water can be removed by opening the drain or overflow depending on the type of water trap. For purposes of monitoring, the water trap must be well accessible and protected in a manhole or maintained drain pit.

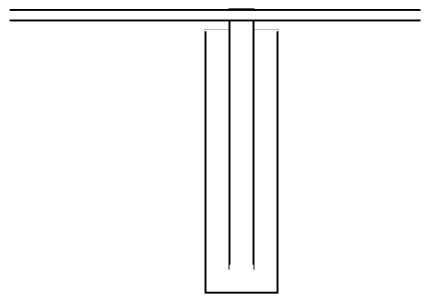


Figure 8: Water trap along the gas pipeline

3.9 Connecting to pints of use

For connecting burners with gas pipelines, use of transparent polyethylene hose must be avoided. Only neoprene rubber hose of the best quality should be used.

As soon as there is gas production, all joints and taps must be checked for leakage by applying a thick soap solution. If there is leakage the foam will make bubbles.

If the concerned mason and plumber strictly follow the above described instructions during the construction phase, the complete plant will be of high quality and with trouble free operation.

Table 4: Summary of possible problems of biogas plants and their solutions

Problems	Reasons	Solutions
Gas does not burn	The first gas coming from the plant may not burn	Remove the gas from the dome once or twice. It will start burning
There is plenty of gas inside the dome but won't come in the stove or lamp	Main valve be closed	Open the main gas valve
	Gas tap or gas jet may be blocked	Clean the gas tap and gas jet
	Pipeline may be blocked	Open main gas valve and water drain. Remove the water or slurry through the water outlet.
Less gas production	May be there is no adequate feeding	Feed the digester as recommended
	May be cold	Insulate the plant with composting
	More water inside the digester	Put less water in the toilet and add water as recommended

	May be due to toxic substance while cleaning toilet	Clean the toilet only with brush and water
	Leakage from the pipe line	Check the joints and fittings with the help of soap water. If bubbles occur repair the leakage
Flame is very weak and red	There may be impurities in the gas tap and stove	Clean the gas tap and stove weekly
	Less gas inside the plant	Close the main gas valve and collect the gas
Gas burns with long flame; slurry comes through pipeline	There may be blockage in the air regulating hole and ring	Clean the hole and the ring
	Inadequate feeding	Feed the plant adequately
	Gas using frequently	Close the valve for about 10 hrs
	Gas leakage	Check the main gas valve and other fittings with soap water and repair the leakage. If the problem is not solved contact the concerned company

4 Operation and maintenance

A biogas plant should be tested for any water seepage and gas leakage before it is put to use.

4.1 Testing

Examine the walls with the help of a small stick by tapping all over the wall and listening to any hollow sound indicating unfilled space in the wall. In these places, the plastered layer should be removed and replaced by a new, fresh layer.

The gas storage dome structure should be examined by fixing a U- shaped safety valve made of a glass tube (manometer) at the gas outlet pipe and then filling the digester with either water or inflating with air using a manually operated air pump to make the column of water in the safety valve rise to at least 90cm. After 24hrs, the water column should be checked for a drop in level.

Under normal circumstances, the drop in water level should be about 2-3 cm. This positive pressure test should be repeated two or three times. However, the estimated pressure, i.e. 100 cm that the dome cover can withstand, should **never** be exceeded.

If the gas escapes, the leak must be located by pouring soap water on all suspected locations outside the gas chamber and around the gas vent pipe joints. Before the leak is repaired the main gate valve should be opened and the hosepipe removed so that internal pressure of the plant equals atmospheric pressure.

If the leak is located at the joint of the gas vent pipe and the dome, the area should be chiselled wide open, the edges roughened and filled in with cement and sand mixture (ratio 1:1) and towelled smooth.

When the gas leak has not been clearly located, the gas chamber should be washed, brushed and coated again with pure cement or a cement and sand mix (ratio1: 1 or 1:2). After the coat has dried, the main gate valve may be closed.

Starting the plant

4.1.1 Feeding

Fill the plant with a correct mixture of dung slurry (dung and water in ratio 1:1) through the inlet chamber.

The gas pipe should be disconnected or the safety valve, if any, should be opened during filling so as to avoid build - up of any pressure in the dome.

The digester should not be filled to more than 75 – 80% of its volume, under any circumstances thus allowing some volume for storage of gas.

The quantity of slurry recommended for the particular size of plant should be added daily.

4.1.2 Gas production and use

The production of gas and filling of the gas chamber would take about 7 – 20 days. The initial gas stored may **not** be combustible and should be allowed to escape. Purge air from all delivery lines by allowing gas to flow out prior to first use.

Ensure that condensed water is able to flow out from the pipeline through the water trap.

The slurry should be added only after the production of inflammable gas has started, i.e. after about 20 days of initial filling of the plant up to the recommended level.

The only stirring which can be done in a fixed dome plant is by moving a bamboo pole up and down in the inlet and outlet openings. This will help in breaking of scum if done at least once a day.

4.1.3 Precautions

(i) Never allow gas pressure to build up in the dome over 1,000mm water column; otherwise the dome will be damaged.

(ii) Always ensure that gas valves are closed to avoid wasting of gas.

(iii) Never allow anyone to enter the gas plant when it has slurry inside.

(iv) Always keep the openings of the outlet and inlet chambers firmly closed by putting concrete covers on them.

4.2 Maintenance and General Care

Daily

(i) Add feedstock slurry to the plant. Keep ratio of feedstock and water at 1:1.

(ii) Make sure that no stones and sand is getting into the plant during feeding.

(iii) Clean gas burner.

Monthly

Check gas pipeline for leaks with a soup solution.

Annually

(i) Check for gas and water leaks and repair them.

(ii) Check gas pipelines for leakages.

(iii) At intervals of some years check for any solid sediment at the bottom of the digester plant by inserting a long stick in the plant and determining the change in depth. It should be completely emptied to allow for removal of the solids and plastering of the inside portion of the plant. Take the necessary safety precautions when performing this task.

Note: *The digested (old) slurry should be recycled along with fresh slurry in order to increase the bacterial population in the digester, for about 100 litres of fresh slurry about 2 litres of old slurry can be added. This will speed up and increase gas production.*

4.3 Common operational problems

Defect	Possible Cause	Remedy
Installation.		
Cracking of digester wall	Sinking of foundation or improper back filling.	Repair and do proper backfilling.
Gas leakage	Improper construction of dome.	Check and repair
Accumulation of water in pipeline.	Improper installation of water trap.	Check water levels and set the water trap at correct position
Operation		
No gas after the first filling of the plant.	Lack of time.	It may take 3 – 4 weeks
Slurry level does not rise in inlet and outlet chambers even though gas is being produced.	i. Gas pipe blocked by water condensate. ii. Insufficient pressure. iii. Gas outlet blocked by scum.	a. Add more slurry. b. Check and correct c. Rotate the agitated slurry with a wood pole.
No gas at stove but plenty in the plant.	i. Gas pipe blocked by water condensate. ii. Insufficient pressure. iii. Gas outlet blocked by scum.	a. Remove water condensate from moisture trap. b. disconnects the outlet valve from the hose pipe and cleans it by pouring water.

Gas does not burn.	Wrong kind of gas	Add properly mixed slurry
Flame far from burner.	Pressure too high or deposition of carbon on the nozzle.	Adjust gas outlet valve and clean nozzle.
Flame dies quickly	Insufficient pressure	Check quantity of gas. Increase pressure by breaking the scum by stirring the slurry.
Unsanitary condition around biogas unit.	- Improper digestion - Improper disposal of slurry	- add correct quantity of slurry - use slurry for composting of crop residues

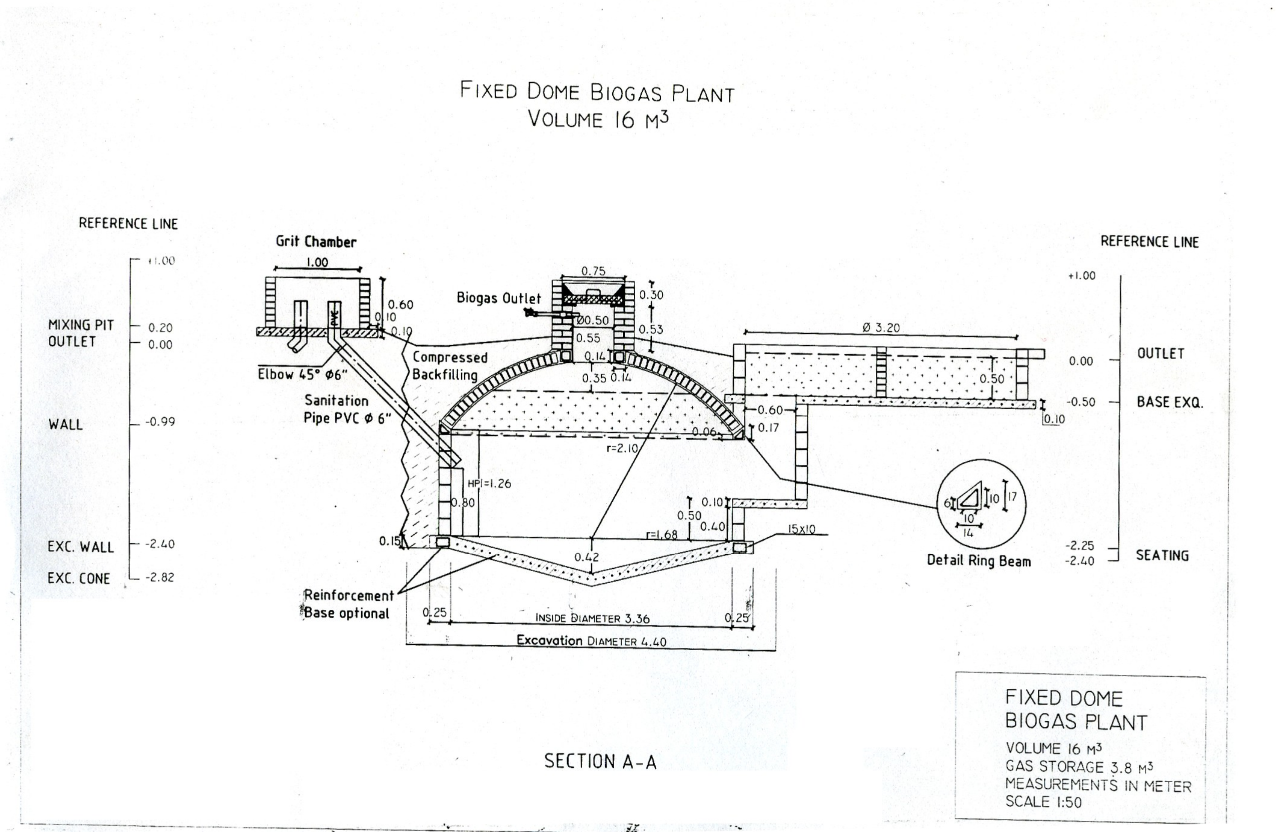
Table 5: Common problems encountered with biogas units and remedial measures.

Leakage of gas from the dome and gas storage area of fixed - dome type biogas plant is the most common problem which occurs mainly due to faulty construction by untrained masons. A rectification procedure for stopping gas leakages is described below:

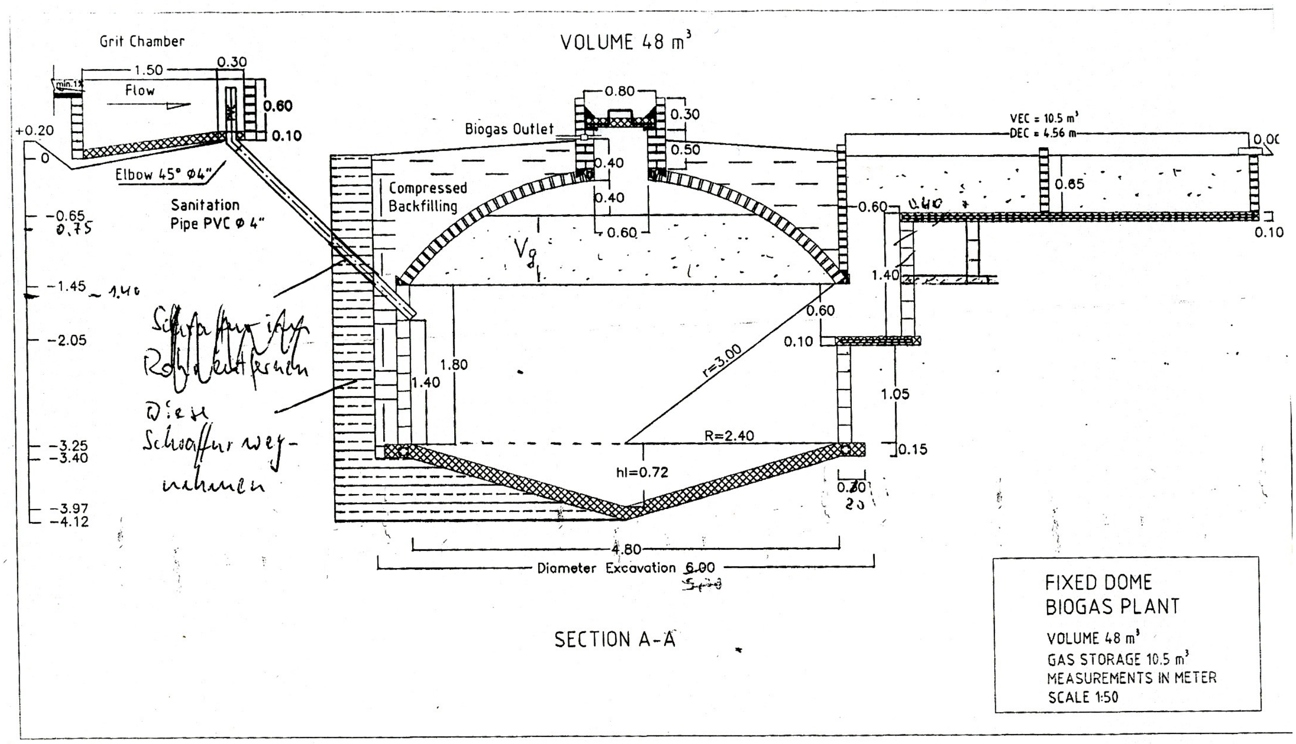
1. Remove the earth from the top of the dome and around the sides of the digester wall up to the inlet and outlet aperture openings.
2. Simultaneously empty the digester and clean the walls thoroughly with water.
3. Look for any cracks developed in the dome portion and the digester wall. If cracks are found, chisel and fill them with cement mortar.
4. Wash the dome and gas storage portion thoroughly with water and ensure complete removal of the slurry.
5. Leave the plant for one or two days for drying
6. Procure materials and repair.
7. Test and check for gas leakages.
8. If no leakage is found, fill the digester with 80% new slurry and 20% old slurry and operate as earlier directed.

5 Basic Drawings of Different Sizes of Fixed Biogas Plants

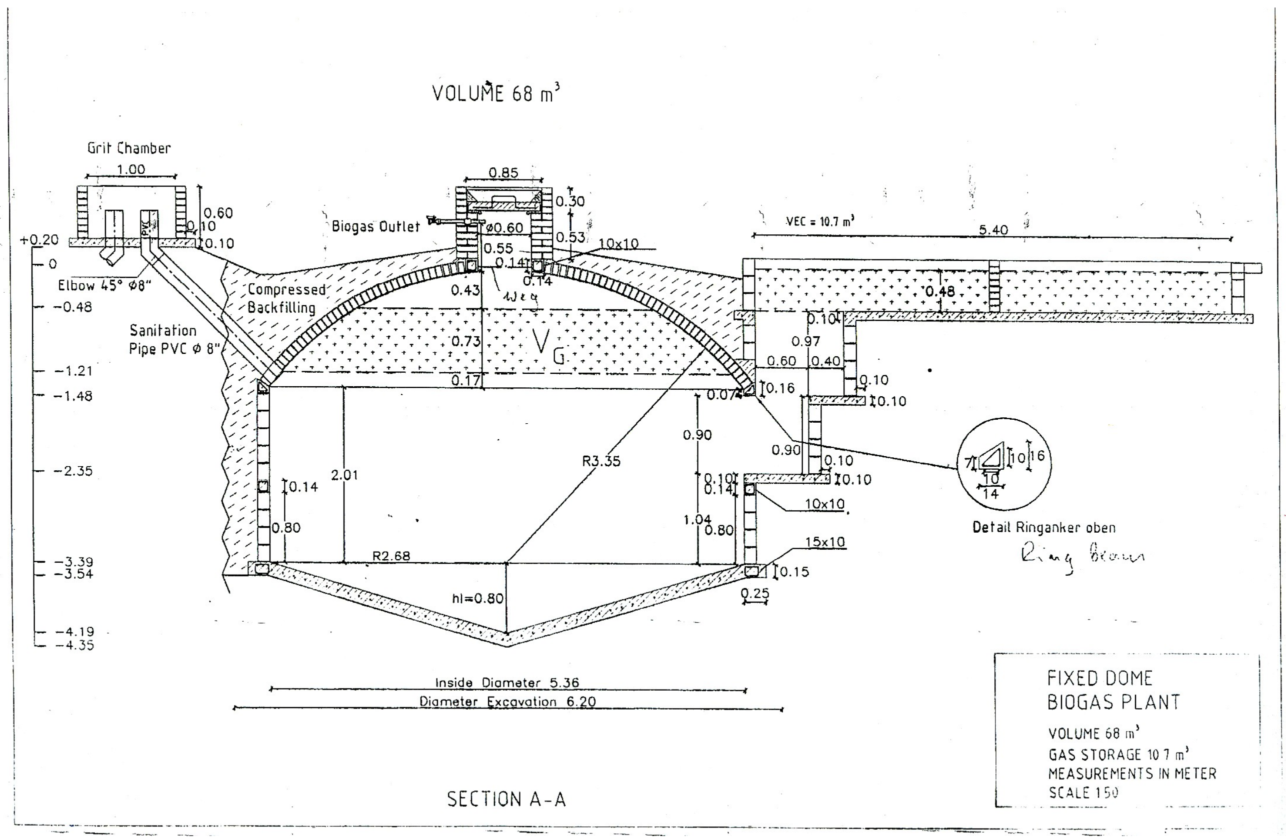
5.1 16m3 biogas plant



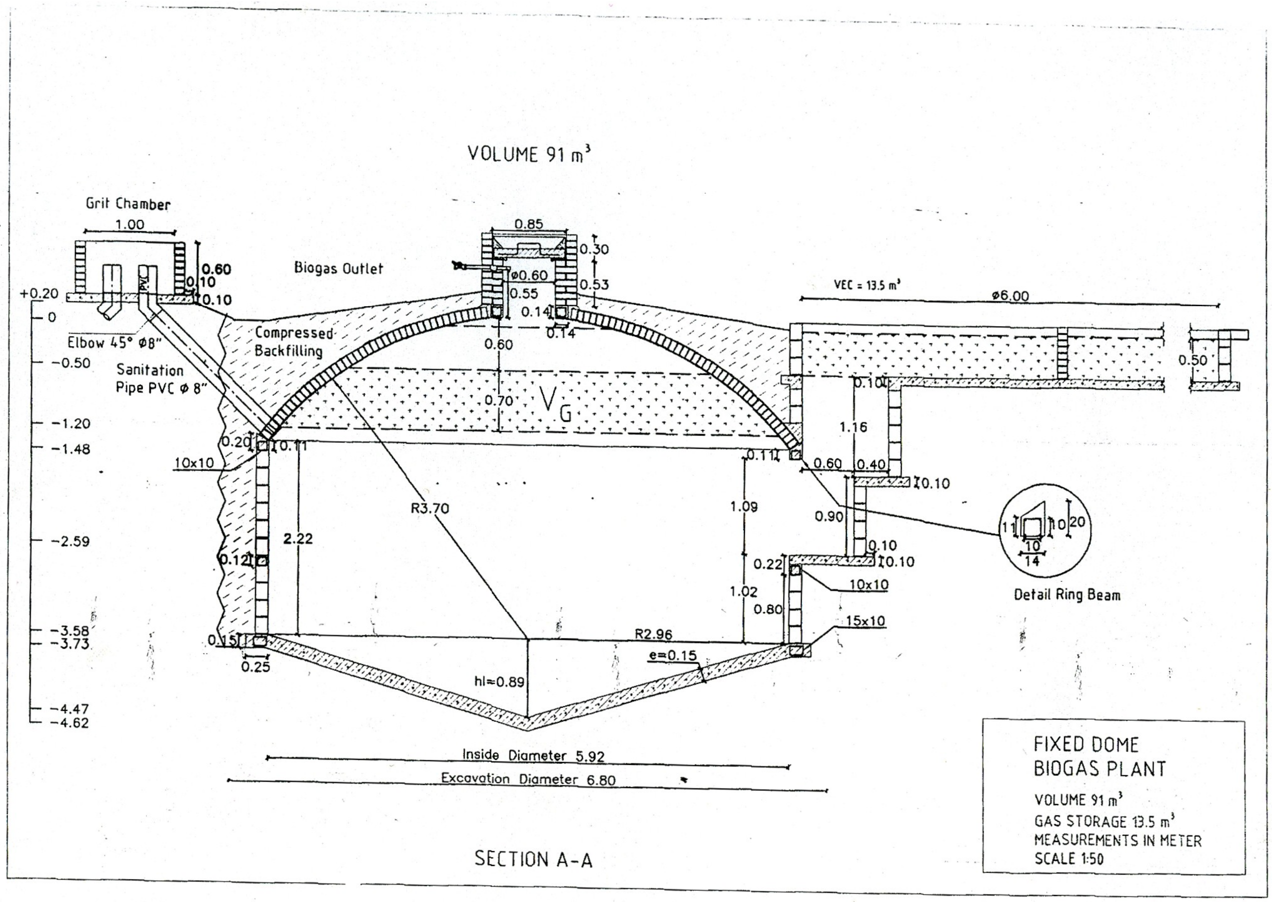
5.2 48m3 biogas plant



5.3 68m3 biogas plant



5.4 91m3 biogas plant



5.5 124m3 biogas plant