Water for the World

Designing a Biogas System

Technical Note No. SAN. 3.D.4

A biogas system is a means of digesting animal manure anaerobically to produce methane gas which is burned to provide heat or light. The system consists of one or more digester tanks, a gas holder, an arrangement of gas pipes, and one or more fixtures to burn the gas. Designing a biogas system requires the services of a project designer experienced with these systems. Designing involves selecting a location; calculating the size of the digesters and the gas holder; and determining the labor, materials, and tools needed for construction. The products of the design process are: (1) a location map, (2) design drawings of the system, and (3) a detailed materials list. These products will be given to the construction foreman prior to construction.

This technical note describes how to design a biogas system. Read the entire technical note before beginning the design process.

Useful Definition

METHANE - A gas produced when organic material such an manure decomposes in an airless environment; methane burns with a violet flame without smoke; it is explosive.

Materials Needed

Measuring tape - To obtain accurate field information for a location map.

Ruler - To produce a location map.

General

A biogas system requires a constant and large supply of manure. A system serving one family needs the daily manure production of either 10-15 pigs, two or three horses, or two cows.

All components of a biogas system must be gas-tight. Gas leaks are dangerous because certain mixtures of methane gas and air are explosive. Therefore, the design, construction, and operation of these systems should be undertaken only by experienced or carefully trained personnel. There are a number of types of biogas systems. One design requires at least two digesters to ensure continuous gas production. While one digester is producing gas, the other can be emptied of digested material and reloaded with fresh manure and water.

Some components of the system may be built but some must be purchased. The digesters and the floor and walls of the gas holder are generally made from reinforced concrete and usually are built on the site. However, the gas holder is typically circular and requires special construction skills to build. Components which must be purchased include the metal cover for the gas holder, guide wheels, guide posts, gas pipes, valves, petcocks, and fixtures used to burn the gas. These items make a biogas system relatively costly.

The gas holder and digesters are designed to be installed partially underground. This is done for ease of loading and maintenance, while allowing a portion of the system to be exposed to sunlight. In temperate climates, this kind of installation helps keep the temperature in the digester more uniform.

Selecting a Location

The system should be located:

- alongside the stable, pig sty, or other manure source to avoid excessive handling of manure,

- near the dwelling to minimize the amount of gas piping,

- in an unshaded area to make use of the maximum available heat from the sun.

When a location has been selected, draw a location map similar to Figure 1 and give it to the construction foreman.

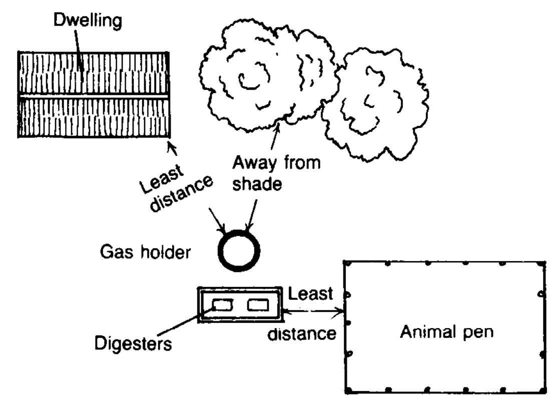

Figure 1. Location Map

Calculating Size

The size of the system depends on the desired volume of daily gas production. The volume of the gas holder should equal one day's gas production, with a minimum size of $2m^3$.

Table 1 provides approximate quantities of gas required for some domestic activities.

Table 1. Approximate Gas Requirements

Activity	Volume of Gas
Cooking for a family of 5 or 6 persons	$2m^3$ per day
Heating water in a 100-liter tank	$3m^3$ per day
Lighting one lamp	0.1-$0.15m^3$ per hour
Operating a two-horsepower stationary engine	$0.9m^3$ per hour

To estimate the volume of the gas holder, add together the gas needed for each expected activity. For example, if the family expects to burn methane to cook, light one lamp for two hours each night, and operate a two-horsepower engine for two hours each day, the size of the gas holder should be:

$$2m^3 + (2 \times 0.1m^3) + (2 \times 0.9m^3) =$$
$$2m^3 + 0.2m^3 + 1.8m^3 = 4.0m^3$$

The floating cover of the gas holder should have a volume equal to at least $4.0m^3$. The volume of a circular cover equals 3.1 times the radius squared times the height. One configuration which would contain the required volume would be 1.6m in diameter and 2.02m in height:

$$\text{radius} = \frac{\text{diameter}}{2} \text{ so radius} = \frac{1.6m}{2} = 0.8m$$

$$3.1 \times 0.8m \times 0.8m \times 2.02m = 4.0m^3$$

Worksheet A, Lines 1-5

The actual height of the cover equals the calculated height plus 150mm to allow for placement of the weep-holes, which will provide an escape for an excessive amount of gas.

Worksheet A. Calculating Dimensions of a Biogas System

1. Expected daily volume of gas = 4.0 m^3

2. Minimum volume of gas holder = Line 1 = 4.0 m^3

3. Proposed diameter of floating cover = 1.6 m

4. Proposed radius of cover = $\frac{\text{Line 3}}{2}$ = $\frac{(1.6\ m)}{2}$ = 0.8 m

5. Calculated height of cover = $\frac{\text{Line 2}}{3.1 \times \text{Line 4} \times \text{Line 4}}$ =

$\frac{(4.0\ m^3)}{3.1 \times (0.8\ m) \times (0.8\ m)} = \frac{(4.0\ m^3)}{(1.98\ m^2)}$ = 2.02 m

6. Design height of cover = Line 5 + 0.15m = 2.02m + 0.15m = 0.17 m

7. Inside height of gas holder = Line 6 + 0.25m = 2.7 m + 0.25m = 2.42m

8. Inside diameter of gas holder = Line 3 + 0.15m = 1.6 m + 0.15m = 1.75m

9. Volume of each digester volume should not exceed 8.0m^3 = 2 x Line 1 = 2 x 4.0 m^3 = 8.0 m^3

10. Proposed length of digester = 2.0 m

11. Proposed width of digester = 2.0 m

12. Height of digester = $\frac{\text{Line 9}}{\text{Line 10} \times \text{Line 11}} = \frac{(8.0\ m^3)}{(2.0\ m) \times (2.0\ m)}$ =

$\frac{(8.0\ m^3)}{(4.0\ m^2)}$ = 2.0 m

In the example given, the actual, or design height is:

2.02m + 0.15m = 2.17m
Worksheet A, Line 6

The inside height of the gas holder equals the design height of the floating cover plus 250mm. The inside height for this example is:

2.17m + 0.25m = 2.42m
Worksheet A, Line 7

The inside diameter of the gas holder equals the diameter of the cover plus 150mm. The inside diameter for this example is:

1.6m + 0.15m = 1.75m
Worksheet A, Line 8

When the dimensions of the gas holder have been calculated, prepare a design drawing similar to Figure 2 and give it to the construction foreman.

The volume of each digester should equal twice the volume of the gas holder, with a maximum size of 8.0m^3.

In the example given, the volume of the gas holder is 4.0m^3. Twice this volume equals: 2 x 4.0m^3 = 8.0m^3. This does not exceed the maximum. Each digester should have a volume of 8.0m^3. One configuration that has this volume is 2.0m wide by 2.0m long by 2.0m high:

2.0m x 2.0m x 2.0m = 8.0m^3
Worksheet A, Lines 9-12

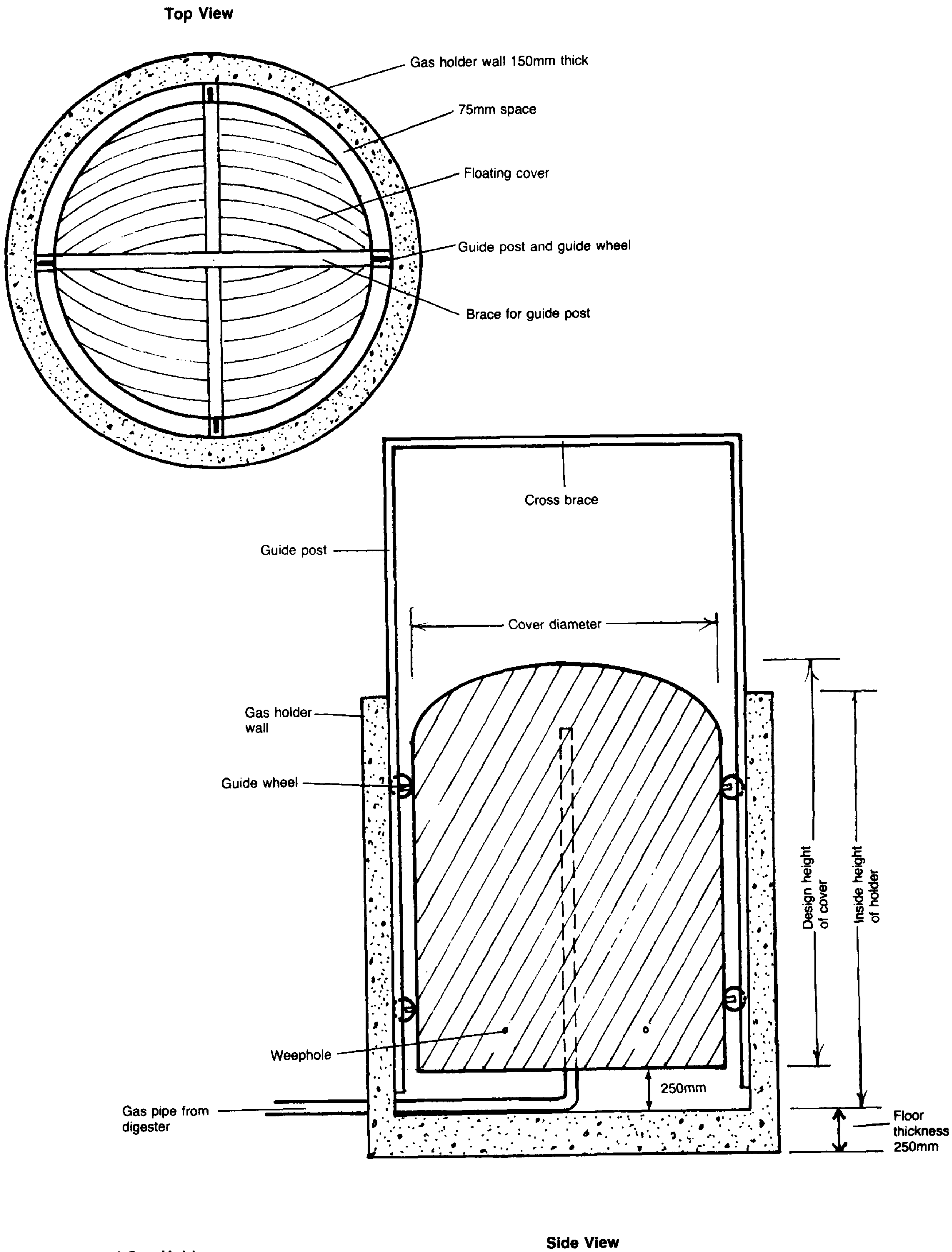

Figure 2. Design of Gas Holder

When the dimensions of the digesters have been determined, prepare a design drawing similar to Figure 3 and give it to the construction foreman.

The digesters and the gas holder, not including the cover, are made from reinforced concrete. The thickness of the concrete is summarized in Table 2. Add this information to Figures 2 and 3.

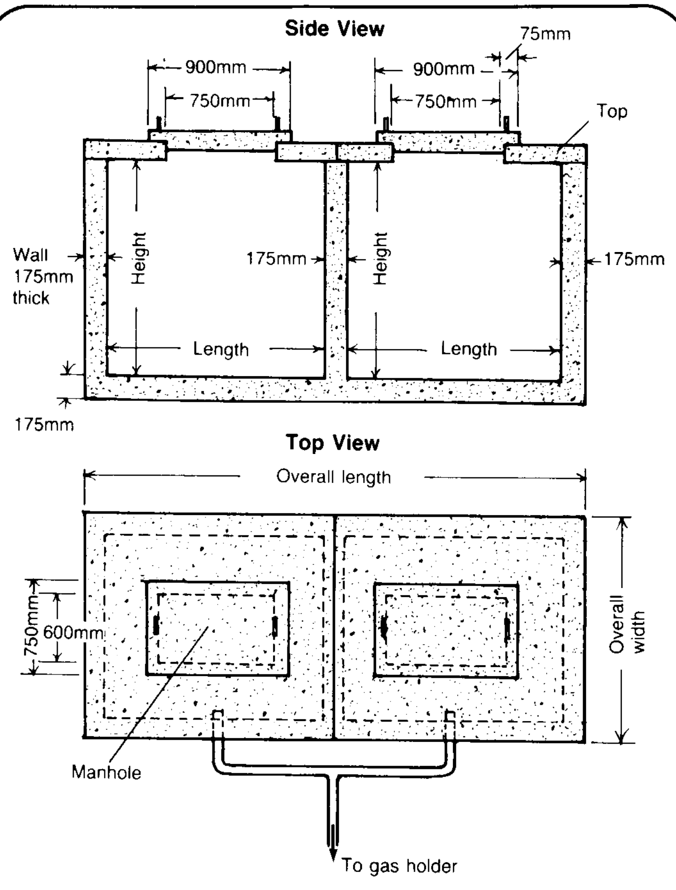

Figure 3. Design of Digesters

Determining Labor, Materials, and Tools

The primary labor requirement is a construction foreman familiar with these systems. An experienced pipe-fitter is needed to install the gas pipes. At least one worker should have some experience with reinforced concrete. Unskilled labor can be used for making excavations, mixing concrete, and hauling materials.

Table 2. Concrete Thicknesses

Feature	Thickness
Digester:	
walls	175mm
floor	175mm
top	150mm
Gas Holder:	
walls	150mm
floor	250mm

The floating cover for the gas holder is made from sheet iron 2-3m thick, reinforced with angle iron or cross-braces. Because of its strict design specifications, it must be purchased unless an exceptionally skilled sheet metal worker can be found.

Gas pipes are 12-25mm in diameter and are made from copper or galvanized iron. Valves and petcocks are placed at key control points along the gas lines. To determine the amount of pipe needed, and the number of valves, pet-cocks, and pipe-fittings, prepare a drawing similar to Figure 4 showing the layout of the system.

Fixtures are needed to burn the methane gas. These are generally purchased.

Materials for reinforced concrete include cement, sand, gravel, water, reinforcing material, and materials to build forms. For complete details see "Designing Septic Tanks," SAN.2.D.3.

Tools needed include picks and shov-els for excavation; hammer and saw for building forms; trowel for working concrete; wrenches, hacksaw, and threading tool for installing gas pipes, and a device for checking leaks.

When all determination for labor, materials, and tools have been made, prepare a materials list similar to Table 3 and give it to the construction foreman.

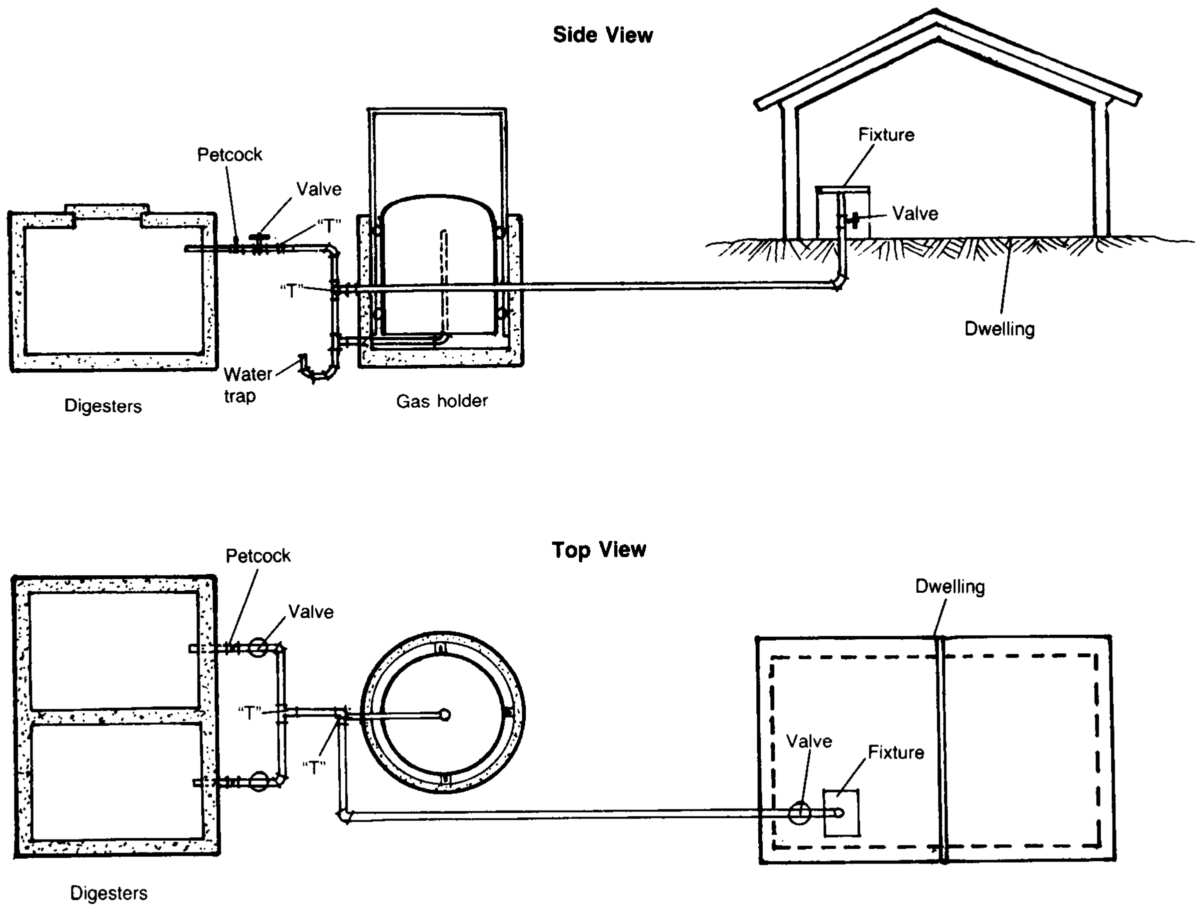

Figure 4. Typical Gas Pipe Arrangement

In summary, give the construction foreman a location map similar to Figure 1, design drawings similar to Figures 2 and 3, a system layout similar to Figure 4, and a materials list similar to Table 3.

Table 3. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Construction foreman experienced with biogas	1	_____
	Worker experienced with pipe fitting	1	_____
	Worker experienced with reinforced concrete	1	_____
	Unskilled workers	4	_____
Supplies	Prefabricated floating cover: 3mm thick sheet iron; 1.60m diameter; 2.17m high	_____	_____
	Guide posts; galvanized iron	_____	_____
	Guide wheels	_____	_____
	Gas pipe: 18mm diameter	_____	_____
	Valves	_____	_____
	Petcocks	_____	_____
	"T" fittings	_____	_____
	"L" fittings	_____	_____
	Fixtures	_____	_____
	Concrete mix	_____	_____
	Reinforcing material	_____	_____
	Material for forms	_____	_____
	Sealer for digester manholes	_____	_____
	Other	_____	_____
Tools	Shovels	_____	_____
	Picks	_____	_____
	Hammers	_____	_____
	Saw	_____	_____
	Trowels	_____	_____
	Wheelbarrow	_____	_____
	Containers: for mixing concrete	_____	_____
	Pipe wrench	_____	_____
	Threader	_____	_____
	Hacksaw	_____	_____
	Other	_____	_____

Total Estimated Cost = _____