

## THE TUBULAR PLASTIC BIO-DIGESTERS

The low-cost tubular plastic digesters was developed by CONDRIT (*Consultorias el para el Desarrollo Integrado del Tropico*) located in Cali, Columbia in early 1980s (Figure 5). The digester was based on a design first promoted in Taiwan, known as the "Red Mud PVC" bio-digester (CONDRIT Ltda, 1995).

In East and Southern Africa region, the technology was introduced in 1993 through the technical cooperation programme of FAO executed in Tanzania, which aimed at the transfer and adaptation of technologies that has been validated in other tropical developing countries.

Later, in 1994, a local NGO known as SURUDE (Foundation for Sustainable Rural Development), submitted project proposals to DANCHURCHAID and the FAO/SIDA Farming Systems Programme (FSP) for the widespread promotion of low cost bio-digesters in Tanzania. Currently more than 40 bio-digesters have now been installed in various villages of Tanzania. SURUDE has also made initiatives to popularise the technology in Kenya and Uganda (Lekule, 1996) with support from FSP.

Most of the digesters installed have a volume of  $5\text{m}^3$  with a capacity of providing gas at a rate of  $0.354\text{m}^3/\text{m}^3$  per day which is enough for a family of six people.

## MATERIALS REQUIRED TO MAKE A TUBULAR PLASTIC BIO-DIGESTER

You can easily make your own bio-gas digester using common and readily available materials. Normally it takes about one day to install the bio-digester. To make a tubular plastic bio-digester you will need the following main components:

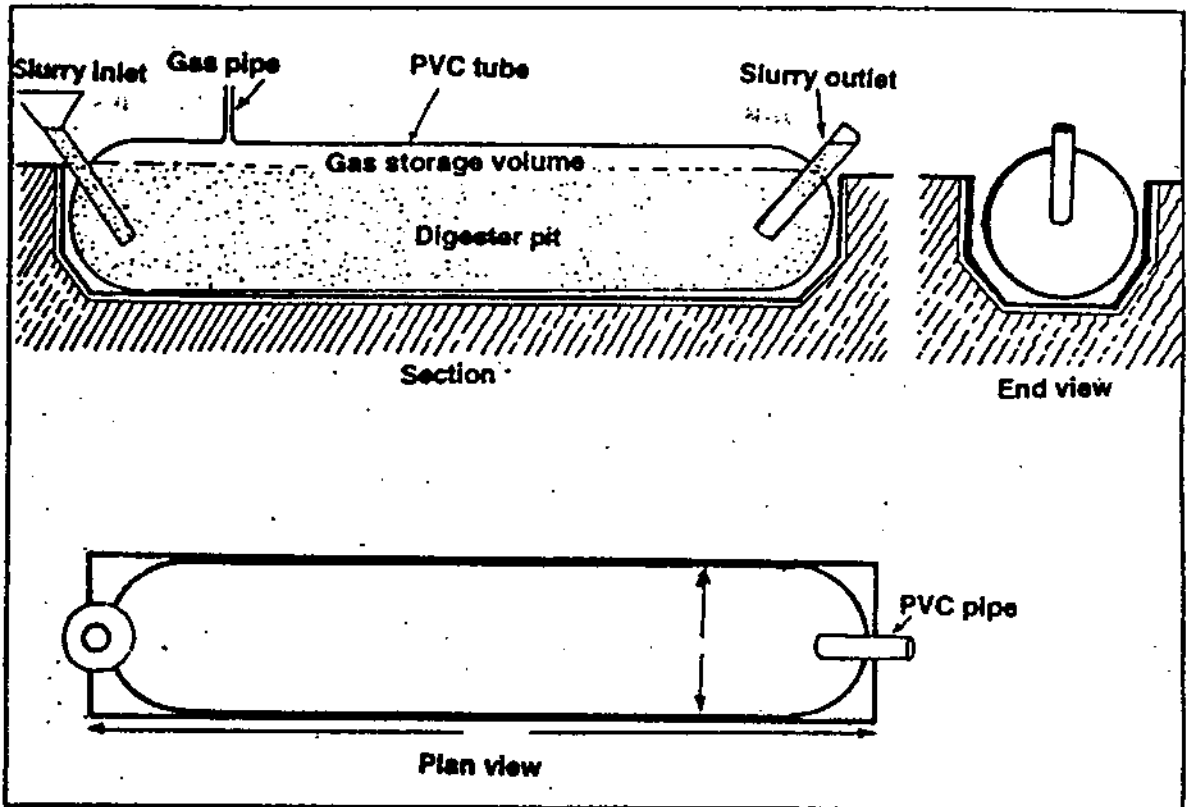
1. A polythene tube of 0.2 mm thickness, with a radius of 45 - 80 cm and 8-10 metres long. (This is the main component of the plant.)
2. A PVC pipe of 120 cm long with a radius of 10 cm. (For carrying gas.)
3. A tube (preferably from an old tyre), which will be used to fit the pipe to the polythene tube.
4. Appliances, a burner for cooking and a bio-gas lamp for lighting.

The full list of materials required is shown below:

### BIO-DIGESTER MATERIALS.

- Transparent polythene tubular film of 280 cm circumference (89 cm diameter, thickness about 0.2 mm). The thickness can be estimated by the weight of a given length of tube which should normally be 10 kg for 20 m of length.
- 2 ceramic or PVC tubes of 100 cm length and 15 cm internal diameter (id).

Figure 5: A low cost bio-digester (original design with in-built storage tank)



- 2 PVC adapters (male and female) of 21 mm internal diameter (i.d.).
- 2 rubber washers (from car inner tube) of 10 cm diameter and 1 mm thickness with a 21 mm diameter central hole.
- 2 PVC washers of 10 cm diameter and 1 mm thickness with a 21 mm diameter central hole.
- 1.2 m of PVC pipe of 21 mm i.d.
- 5 to 20 m of PVC, 21 mm i.d., rigid tube or flexible plastic hosepipe (the length depends on the distance from digester to the kitchen).
- 4 waste inner car tubes cut into 5 cm bands.
- 1 transparent plastic bottle.
- 3 PVC elbow "L" pieces of 21 mm i.d.
- 3 PVC "T"-pieces of 21 mm i.d.

**Single stove for cooking:**

- 3 steel tubes of 21 mm i.d., each 10 cm long.
- 1 tap of 21 mm i.d.
- 1 metal elbow of 21 mm i.d.

**Methodology for construction (Fig. 6):**

A trench is dug to receive the bio-digester. The walls must be firm and the floor must be flat or with only a minimum slope. There must be no sharp stones or protruding roots in the walls or floor. The cross-section of the trench for a tubular film bio-digester of 89 cm diameter has dimensions of 65 cm width at the top, 50 cm width at the bottom and 65 cm depth.

The length depends on the amount of manure available. The average is 10 m which requires manure from at least two cows or eight pigs. Two lengths of the polythene tube are cut, each 11 m long (for 10 m long bio-digester), laid on smooth ground and one inserted into the other (Figure 6).

A small hole is made in the two layers of the plastic tube, approximately 1.5 m from one of the ends. One PVC and one rubber washer are fitted on the flange of the male adapter which are then threaded through the hole from the inside to the outside. A second PVC washer and rubber washer are put on the male adapter from the outside of the tube and secured tightly with the female adapter. The exit of the female adapter is closed temporarily with a small square of plastic film and a rubber band.

A safety valve is made from a transparent plastic bottle, a "T"-piece and three PVC tubes (one of 6 cm and the other two of 30 cm length). Water is poured into the bottle and maintained at 3–5 cm depth (above the mouth of the tube).

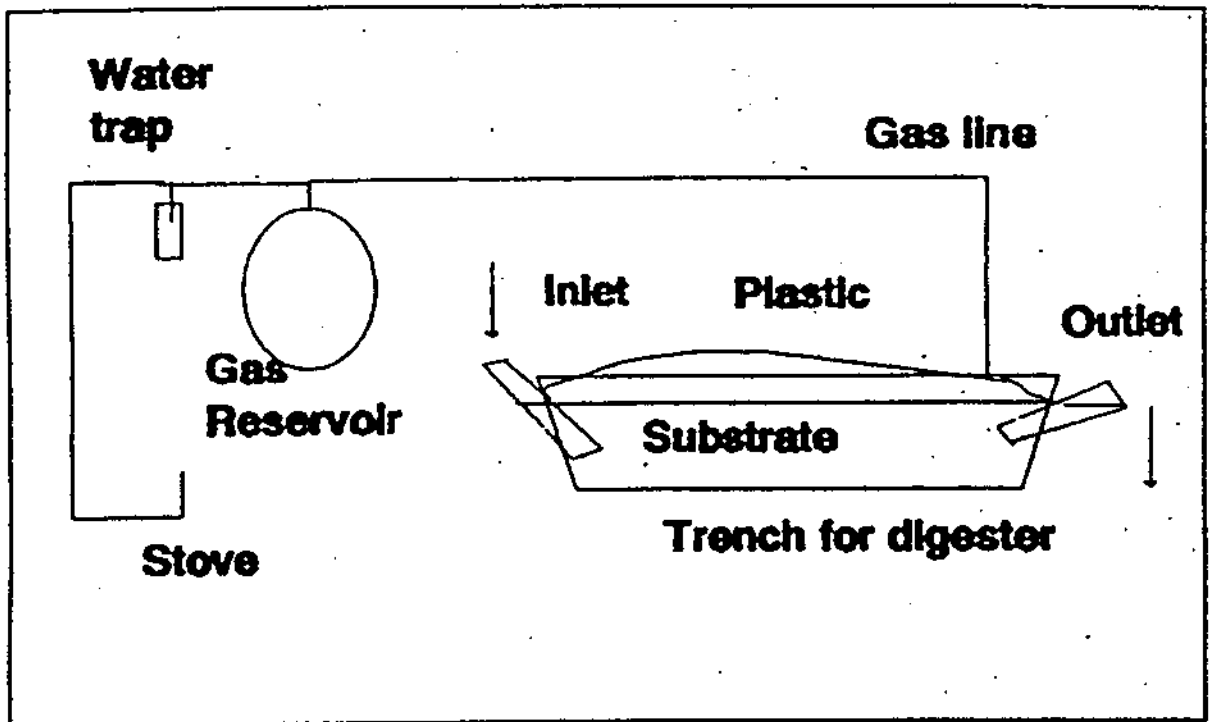
The bio-digester is filled with water up to two-thirds of the depth, moving up and down the outlet (as indicator of the water level inside the tube). The air trapped inside the tube escapes from the safety valve as the volume of water increases. The gas pipe leading to the kitchen is then

A ceramic pipe is inserted to two-thirds of its length into one end of the plastic tube. The plastic film is folded around the pipe and secured with 5 cm wide rubber bands (made from the used inner tubes). The bands are wrapped in a continuous layer to cover completely the edges of the plastic film, finishing on the ceramic tube. The inlet tube is then closed temporarily with a square of plastic (or a plastic bag) and a rubber band. From the open end, air is forced into the tube in waves formed by flapping the end of the tube. The tube is then tied with a rubber band about 3 m from the end so that the air does not escape. The procedure for fitting the outlet tube is the same as for the inlet tube. The complete assembly is then carried carefully to the trench and placed inside. The ceramic tubes are laid at 45° inclination and fixed temporarily.

attached (it must not be on the ground and the water trap should be at the lowest point in the gas line).

The gas reservoir is made from a length of polythene tube (3–4 m) and a PVC "T". It can be located horizontally or vertically but should be shaded from the sun and have a weight (half a brick) suspended from the bottom to increase the pressure. It is fitted into the gas line as close as possible to the kitchen to maximise the rate of gas flow to the burner since the system operates at very low pressure (only 3–5 cm water head).

Figure 6: Features of a plastic continuous flow tubular bio-digester



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Estimated costs of materials for a family size tubular plastic bio-digester (based on the installation cost of bio-digesters in Tanzania)

Item	Quantity	Cost (US)
Polythene sheet (0.2 mm thick)	18 kg	40
Gas pipe (21 mm id)	15 m	9
PVC "T" and "L" pieces	6	3.2
Steel pipe	0.75 m	3
A tap (to control gas flow)	1	3
PVC for inlet and outlet	1.2 m	2.4
PVC, (10mm id)	1	1.2
Inner tube strips	20	0.6
Plastic bottle	1	0.5
<b>TOTAL:</b>		<b>62.9</b>
<i>Source: Lekule (1996)</i>		

## PREPARATION FOR THE BIO-DIGESTER SITE

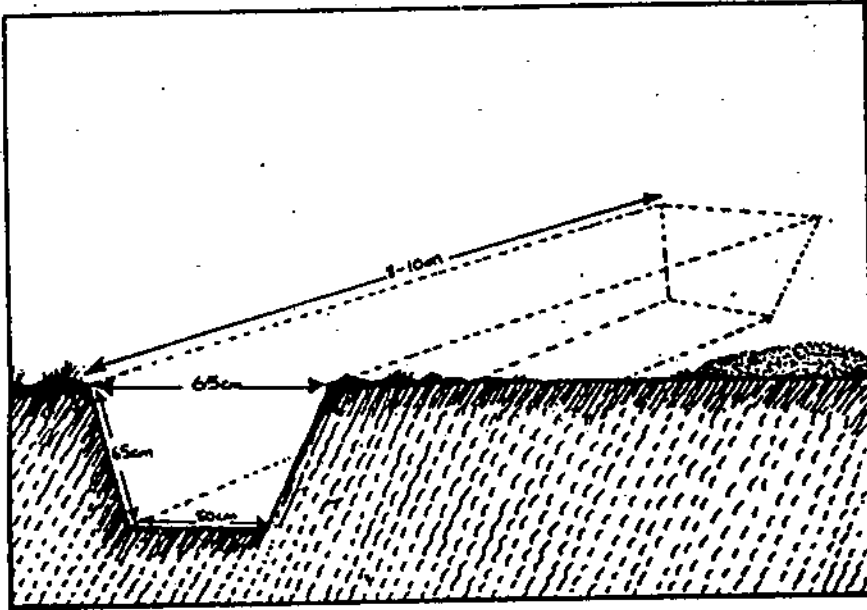


Figure 7:

Select a good site where there is enough source water, e.g. near your house and where you are sure of getting the dung every day. If you have animals, select an area near the animal shed. Mark the pit to required measurements before you start digging.

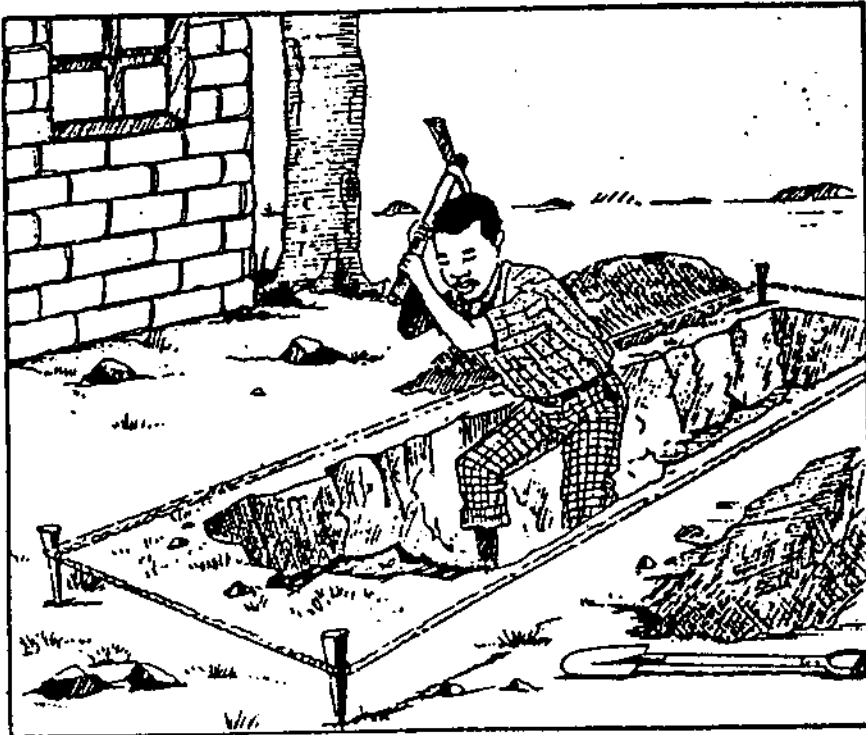


Figure 8:

When digging the pit, the width of the pit at the top should be wider than at the bottom to allow for expansion of the polythene tube as the gas builds up. Make sure the bottom of the pit is level. The length of the pit and the polythene tubing should be the same.

# PREPARING AND INSTALLING A TUBULAR PLASTIC BIO-DIGESTER

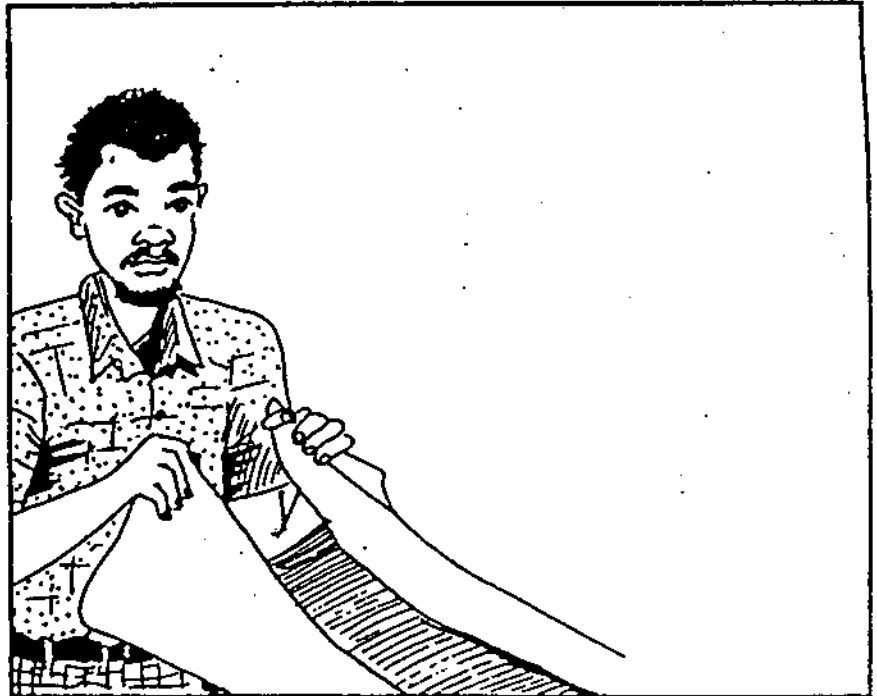
**Figure 9:**

First check the polythene tube for any holes especially around the corners and fold both ends to fit the width of the pit.



**Figure 10:**

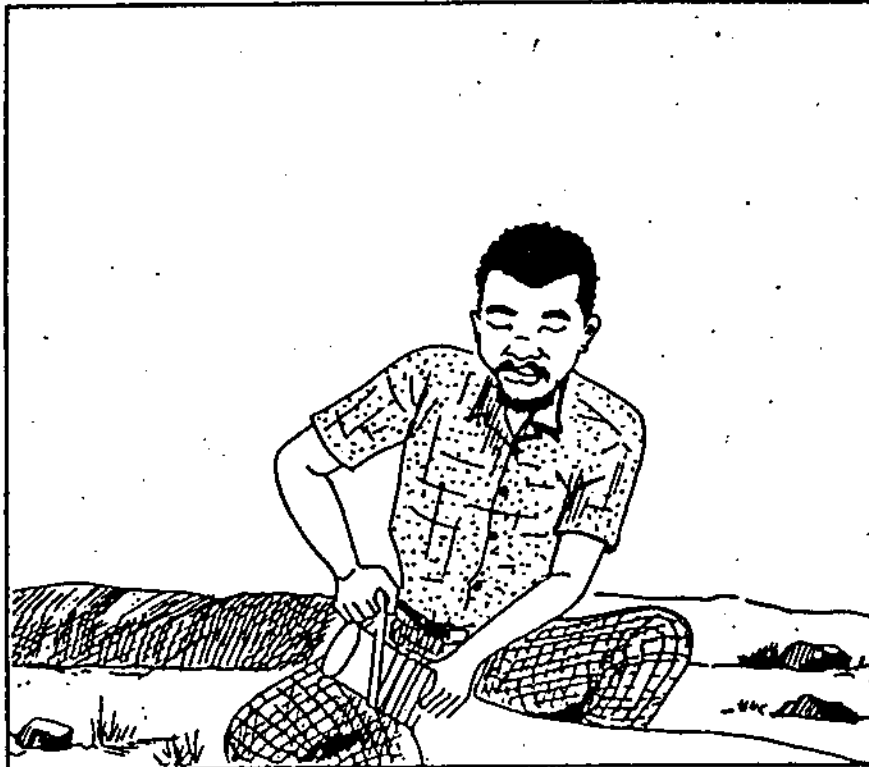
Take the cylindrical polythene tube and measure 8 metres leaving an allowance of half a metre both ends for fitting the PVC pipe.





**Figure 11:**

Cut two 60 cm long pieces of the PVC pipe with a 10 cm radius and insert them into the ends of the poly-thene tube.

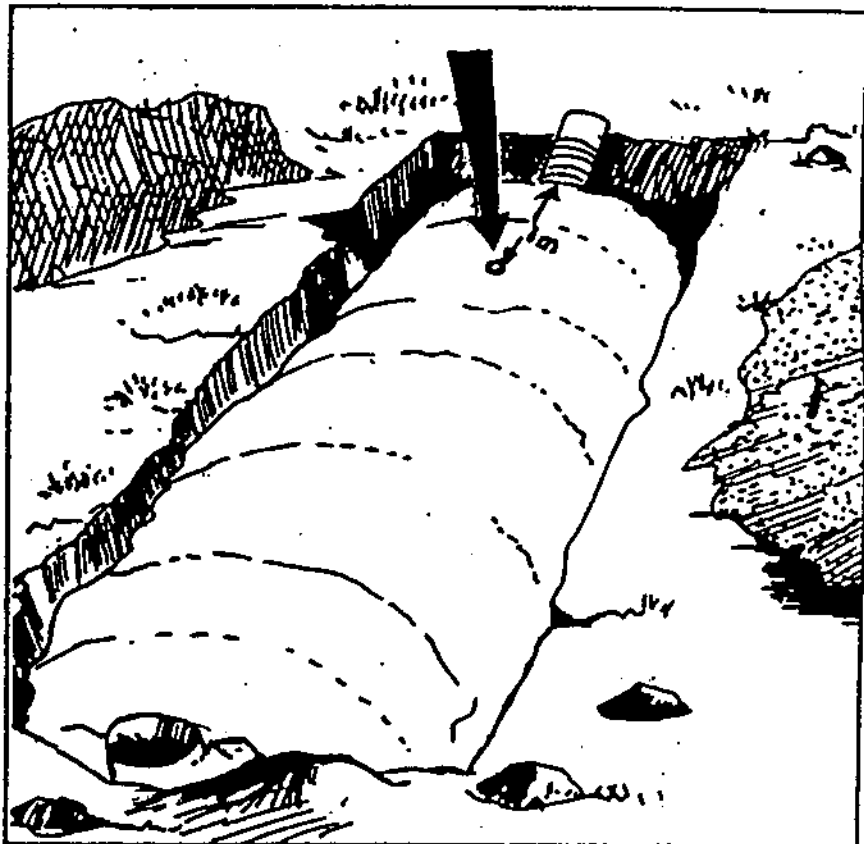


**Figure 12:**

Using the inner car tube, fasten tightly both ends of the poly-thene tube. Make sure there is no allowance for gas to leak.

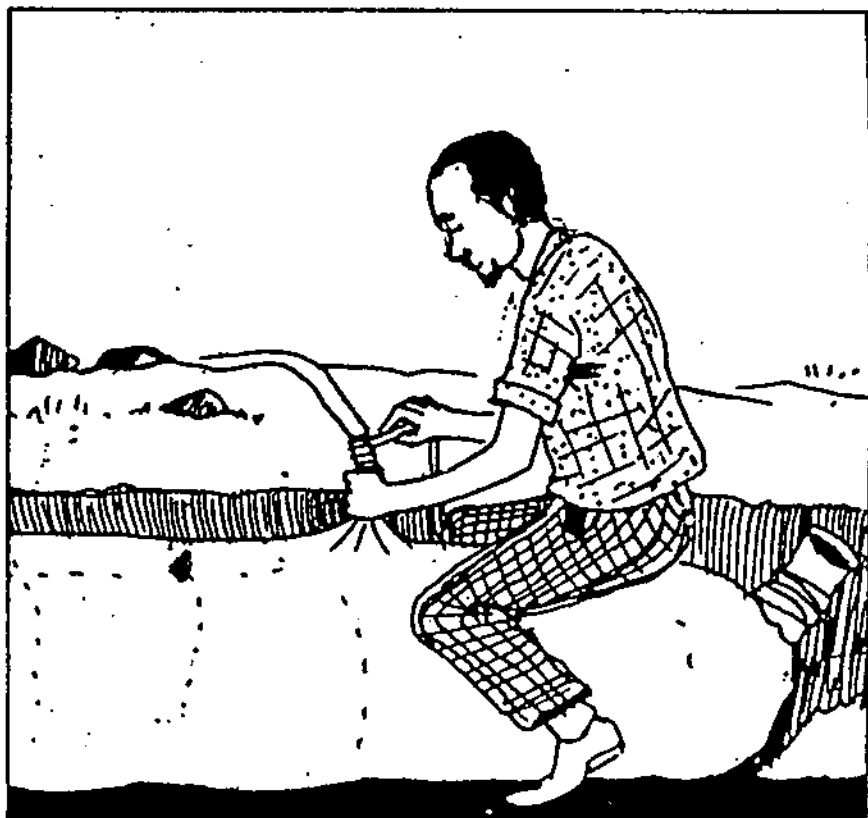
**Figure 13:**

Make a small hole of radius 1 cm at a distance of 1 metre from the beginning of the bio-digester. The hole should be at the top of the polythene when full of gas.

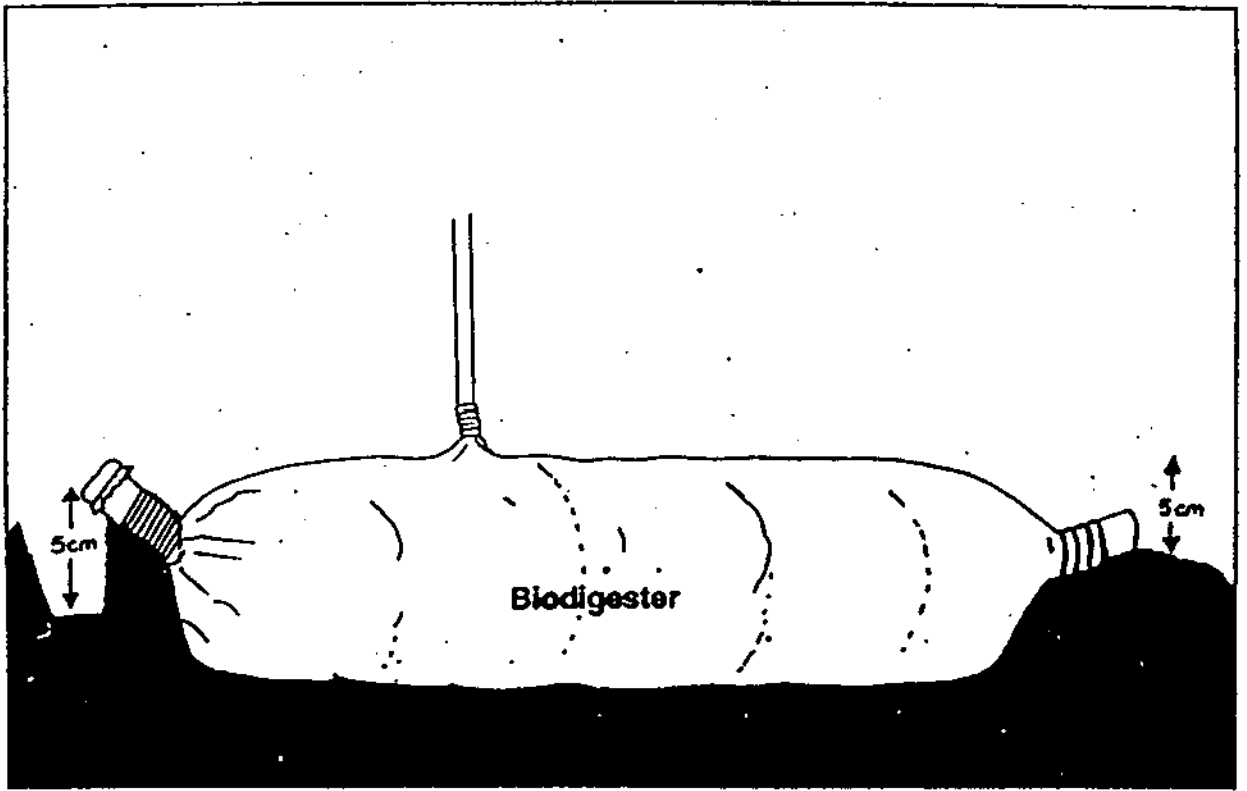


**Figure 14:**

Insert the small plastic pipe (radius 1 cm) into the hole. Use a 2 cm wide piece of the tube for fastening the pipe to the polythene.

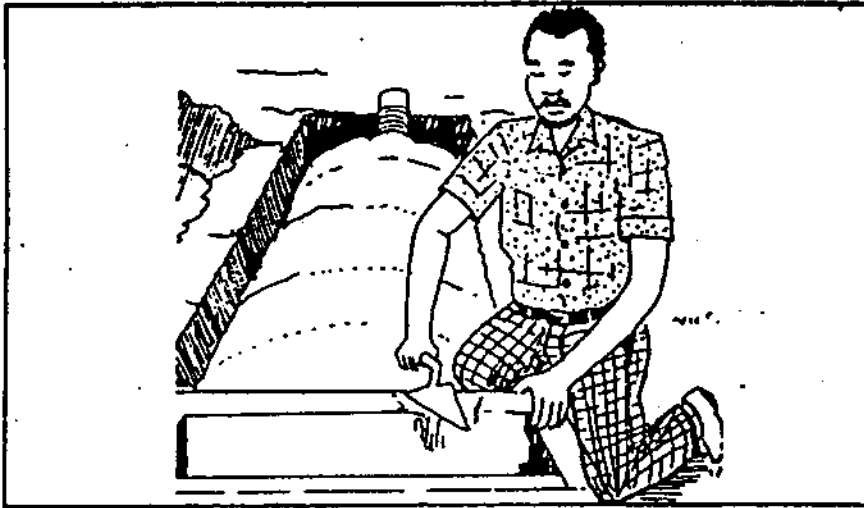






**Figure 15 (above):**

For the bio-digester to function properly, the outlet should be 5 cm below the top of the digester. The inlet should be 5 cm–10 cm above the outlet.



**Figures 16 & 17(left):**

At the inlet make a small pit for mixing the dung with water. Cover the inlet with a small wire mesh to avoid unwanted material in the digester.

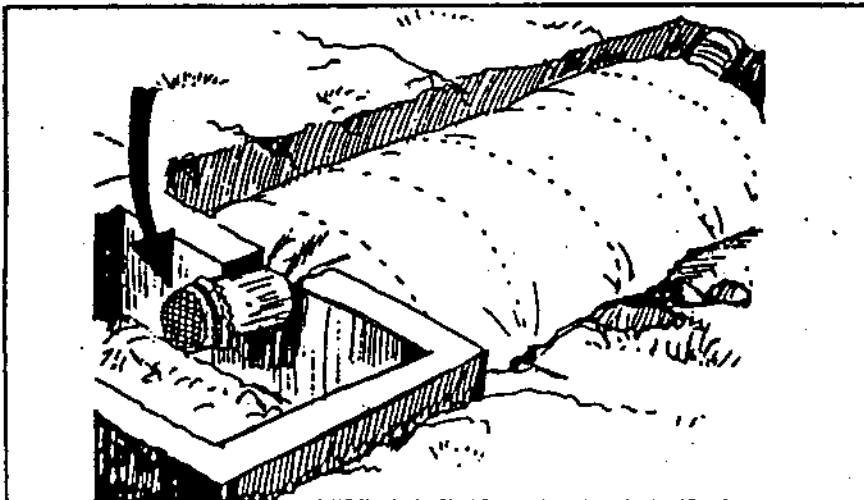


Figure 18 (right):

Make small streams (courses) on both ends of the pit and have pieces of pipe for letting in water and getting out the slurry. This will ensure that the effluent is directed to a field or small collection point for spreading into the fields later.

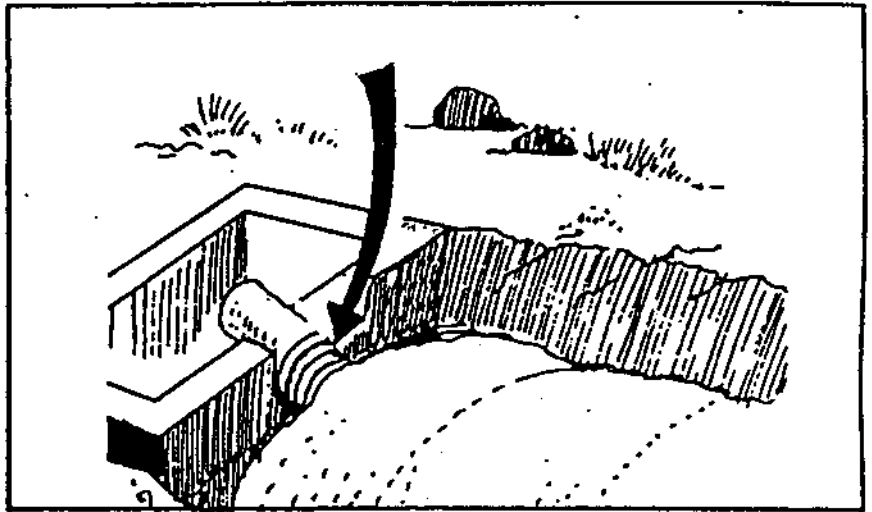
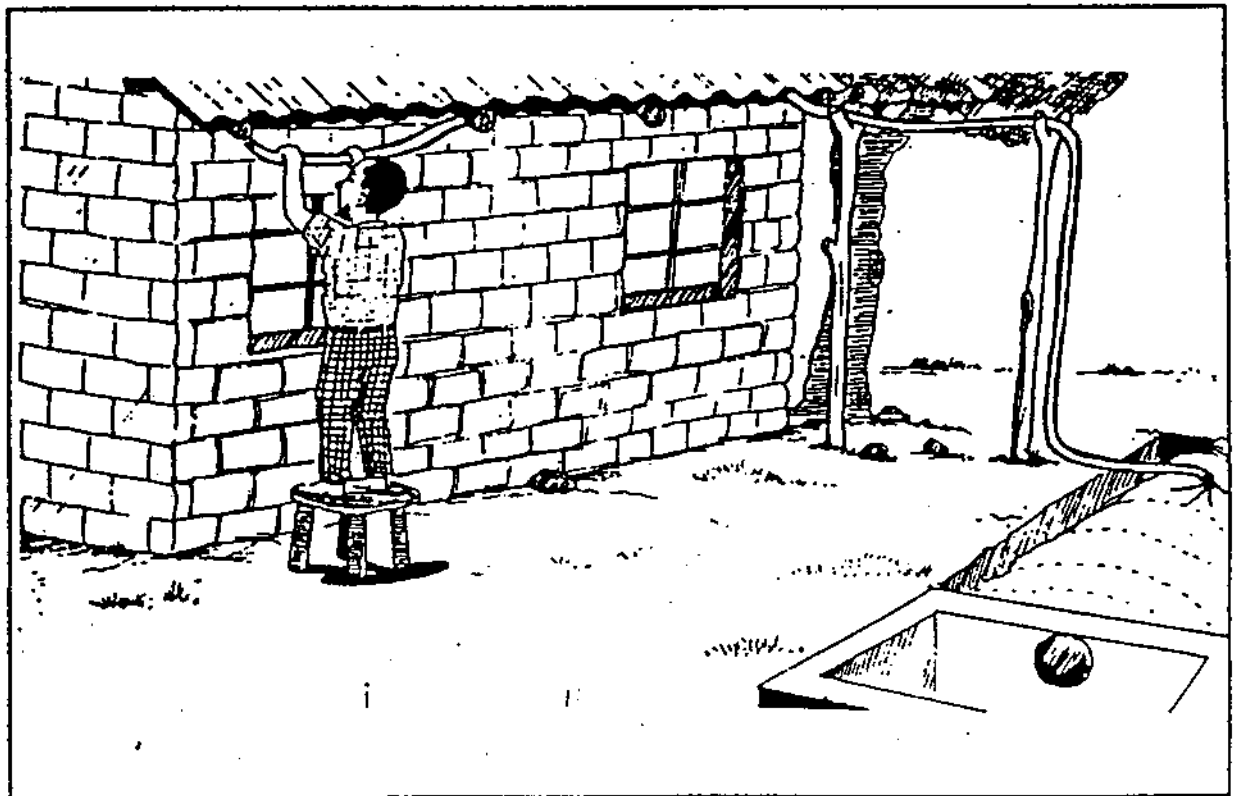
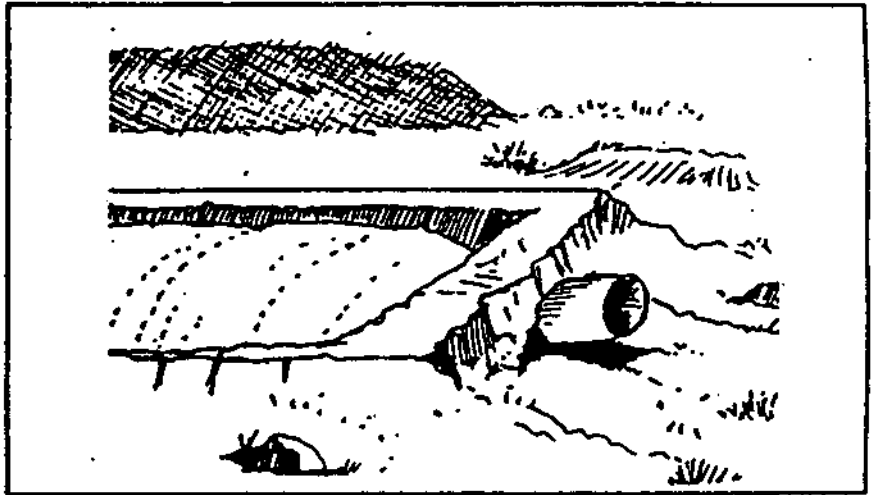


Figure 19 (below):

From the bio-digester, connect the gas pipe to the house. At the end of the gas pipe put a piece of galvanised iron with a gas control knob (valve).



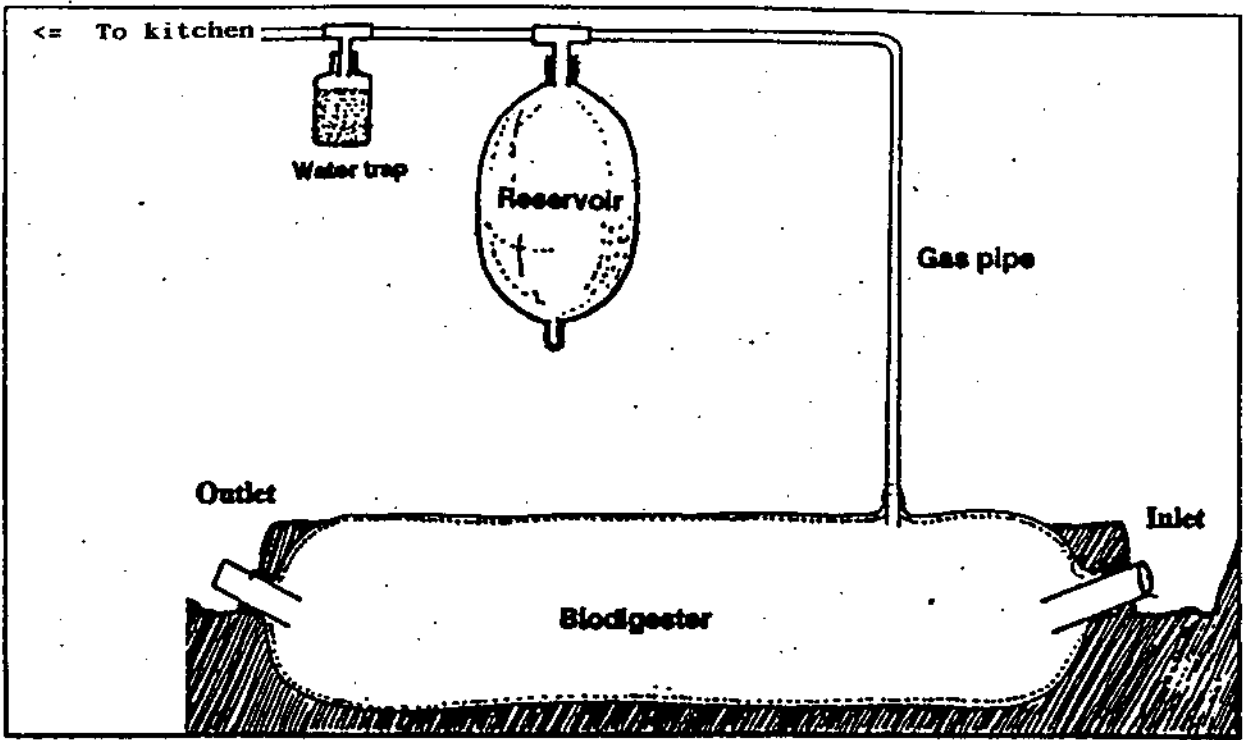
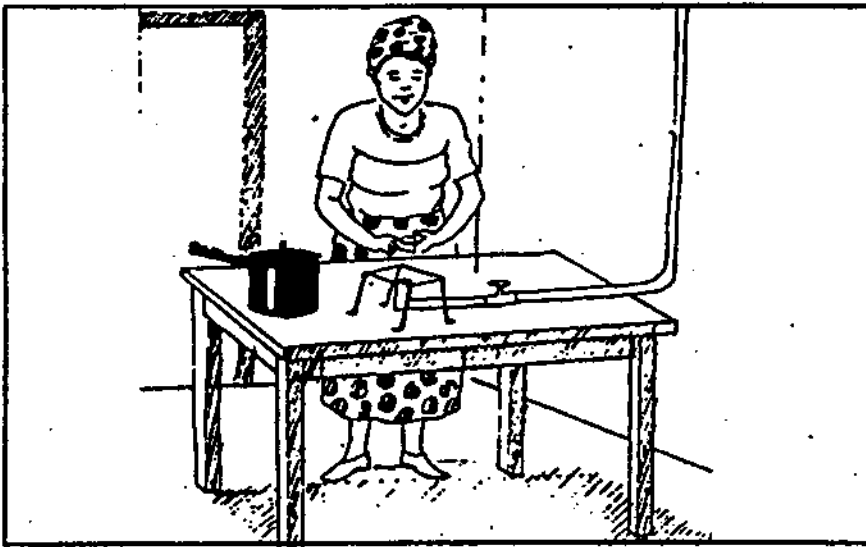
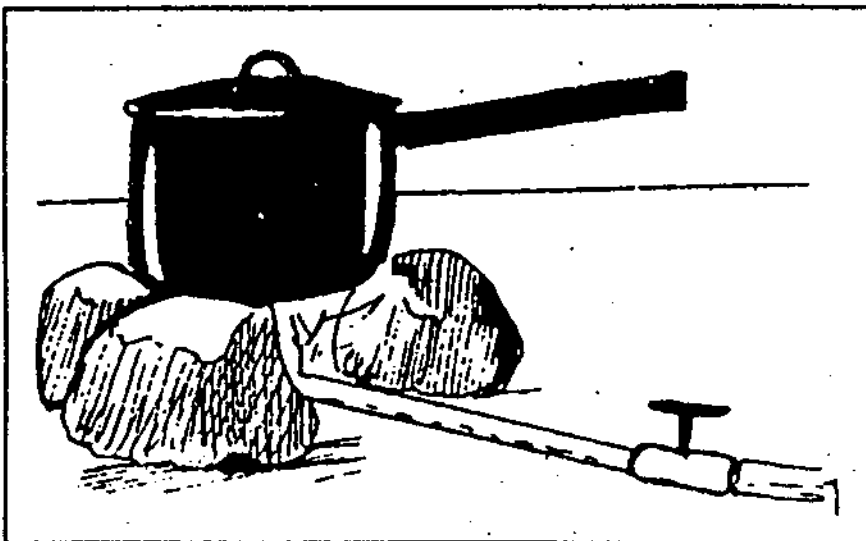


Figure 20 (above):



For a constant supply of gas, make a gas collection tank or a reservoir. The collection tank can be made from the same polythene tube used to make the digester. It is 3 m long and tightly fastened with the tube on both ends. On top of the reservoir, put a "T" shaped pipe, one end receives the gas from the digester and the other end take the gas to the kitchen through a water trap.



Figures 21 & 22 (left):

You can easily make your own cooking stove using iron bar, iron sheet, clay or the traditional three stone stove.

**Figure 23:**

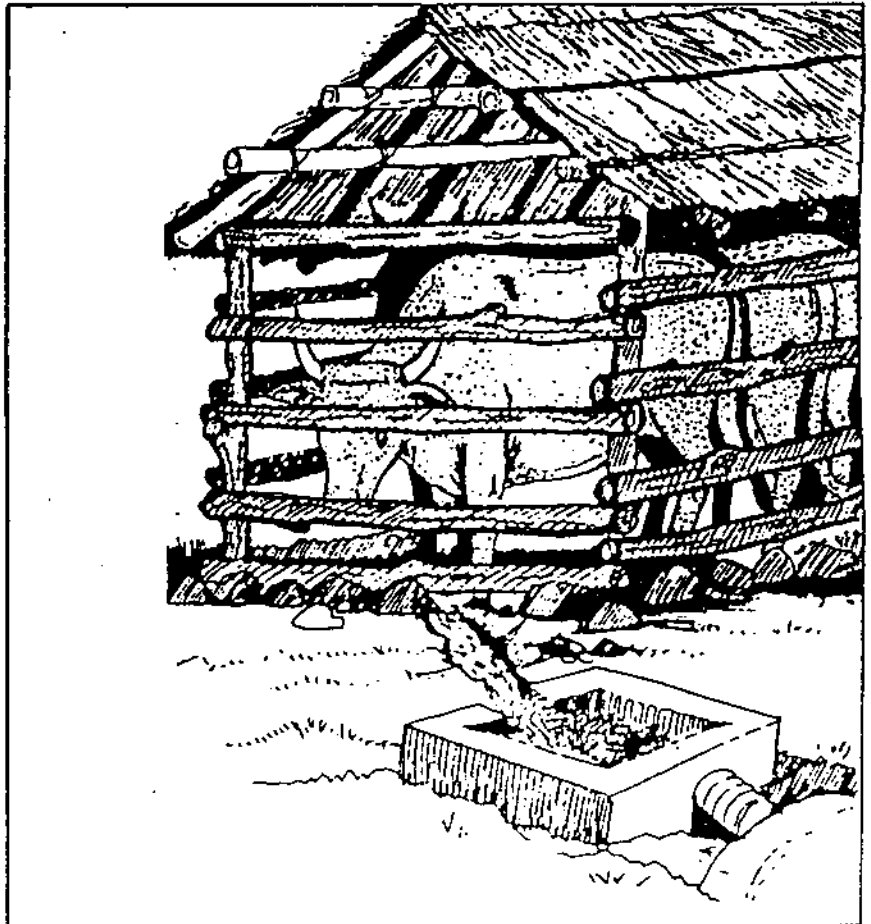
For good supply of gas, feed one bucket of animal dung plus three buckets of water everyday. Gas production will normally start one week after the first feeding of the digester.



**Figure 24:**

If you are keeping your livestock in a shed, make a furrow (a stream) from the animal shed to the small inlet pit for mixing the dung and water.

Make sure your pit is covered with either pieces of wood or iron sheet to avoid birds and other animals from piercing or tearing the polythene tube.



Materials for a family sized polyethylene tubular digester.

#### *Biodigester*

- Transparent polyethylene tubular film of 280cm circumference (89cm diameter; thickness about 0.2mm). The thickness can be estimated by the weight of a given length of tube which should normally be 10 kg for 20m of length.
- 2 ceramic tubes of 100cm length and 15cm internal diameter (id).
- 2 m of 21mm id plastic hosepipe.
- 2 PVC adapters (male and female) of 21mm id.
- 2 rubber washers (from car inner tube) of 10cm diameter and 1mm thickness with a 21mm diameter central hole.
- 2 PVC washers of 10cm diameter and 1mm thickness with 21mm central hole.
- 2 m of PVC pipe of 21mm id.
- 5 to 20m of PVC 21mm id rigid tube or flexible plastic hose-pipe (the length depends on the distance from digester to the kitchen).
- 4 waste car inner tubes cut into 5cm bands.
- 1 transparent plastic bottle.
- 1 PVC elbow of 21mm id.
- 3 PVC "T" pieces of 21mm id.
- 1 tube of PVC cement.

#### *Single stove for cooking:*

- 3 steel tubes of 21mm id, each 10cm long.
- 1 tap of 21mm id.
- 1 metal elbow of 21mm id

#### *Procedure for installing a polyethylene tube digester.*

\*A trench is dug to receive the biodigester. The walls must be firm and the floor must be flat or with only a minimum slope. There must be no sharp stones or protruding roots in the walls or floor.

\*The cross-section of the trench for a tubular film biodigester of 90 cm diameter has dimensions of 90 cm width at the top, 70 cm width at the bottom, and 70 cm depth. The length depends on the amount of manure available. The average is 10 m which requires manure from at least 2 cows or 8 pigs.

\*Two lengths of the polythene tube are cut, each 11 m long (for 10 m long biodigester), laid on smooth ground, and one inserted into the other.

\*A small hole is made in the two layers of the plastic tube, approximately 1.5 m from one of the ends. One PVC and one rubber washer are fitted on the flange of the male adapter which is then threaded through the hole from the inside to the outside. A second PVC washer and rubber washer are put on the male adapter from the outside of the tube and secured tightly with the female adapter. The exit of the female adapter is closed temporarily with a small square of plastic film and a rubber band.

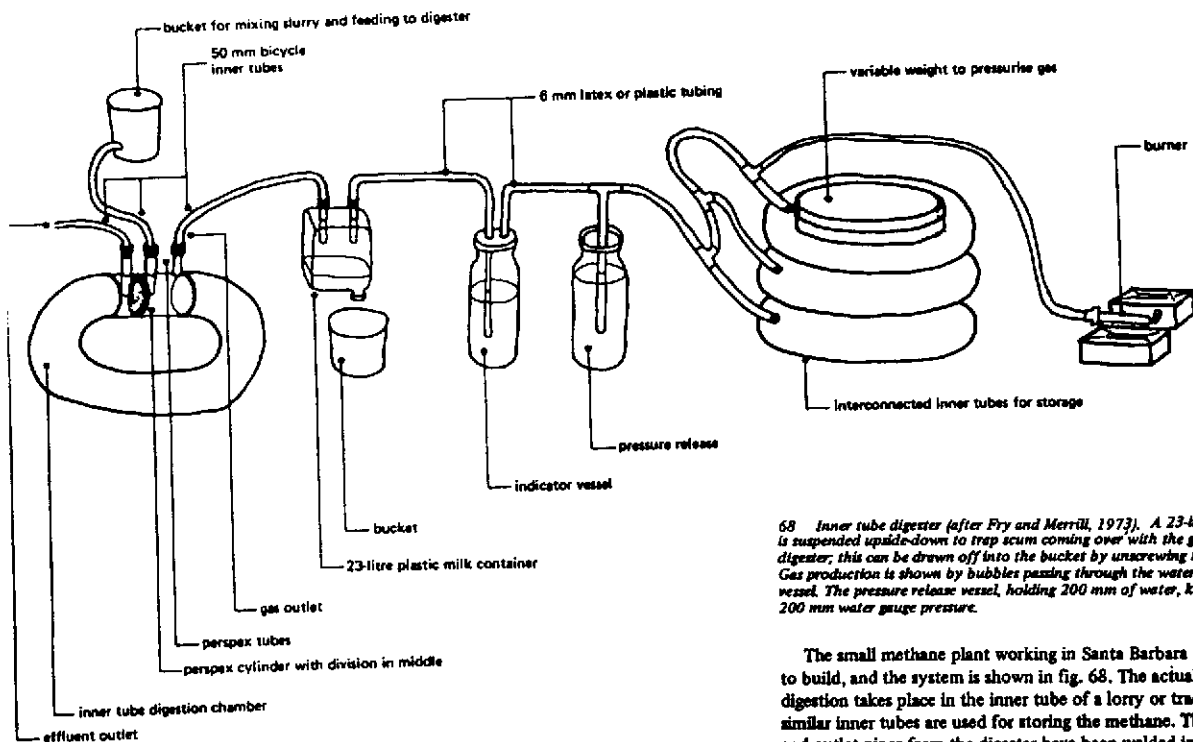
\*A ceramic pipe is inserted to two thirds of its length into one end of the plastic tube. The plastic film is folded around the pipe and secured with 5cm wide rubber bands (made from the used inner tubes). The bands are wrapped in a continuous layer to cover completely the edges of the plastic film, finishing on the ceramic tube. The inlet tube is then closed temporarily with a square of plastic (or a plastic bag) and a rubber band. From the open end, air is forced into the tube in waves formed by flapping the end of the tube. The tube is then tied with a rubber band about 3m from the end so that the air does not escape. The procedure for fitting the outlet tube is the same as for the inlet tube. The complete assembly is then carried carefully to the trench and placed inside. The ceramic tubes are laid at 45° inclination and fixed temporarily.

\*A safety valve is made from a transparent plastic bottle, a T-piece and 3 PVC tubes (one of 6 and the other two of 30 cm length). Water is poured into the bottle and maintained at 5 cm depth (above the mouth of the tube).

\*The biodigester is filled with water up to two thirds of the depth, moving up and down the outlet (as indicator of the water level inside the tube). The air trapped inside the tube escapes from the safety valve as the volume of water increases.

\*The gas pipe leading to the kitchen is then attached (it must not be on the ground and the water trap should be at the lowest point in the gas line).

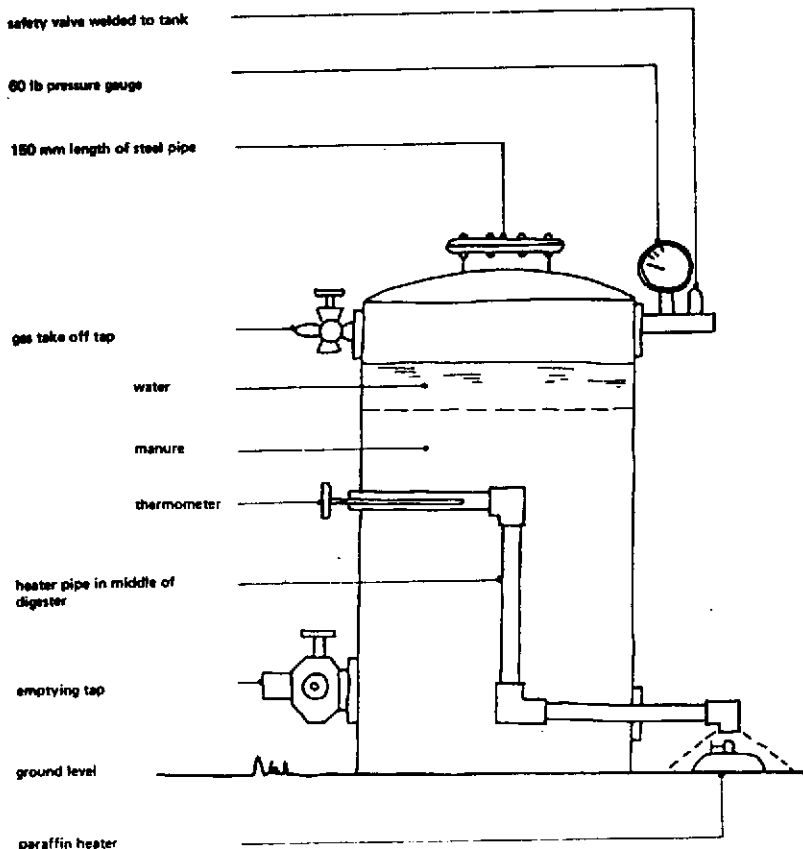
\*The gas reservoir is made from a length of polyethylene tube (3-4 m) and a PVC "T". It can be located horizontally or vertically but should be shaded from the sun and have a weight (brick or stone) suspended from the bottom to increase the pressure. It is fitted into the gas line as close as possible to the kitchen to maximize the rate of gas flow to the burner since the system operates at very low pressure (only 3-5cm water head).



68 Inner tube digester (after Fry and Merrill, 1973). A 23-litre milk container is suspended upside-down to trap scum coming over with the gas from the digester; this can be drawn off into the bucket by unscrewing the container cap. Gas production is shown by bubbles passing through the water in the indicator vessel. The pressure release vessel, holding 200 mm of water, keeps the gas at 200 mm water gauge pressure.

The small methane plant working in Santa Barbara cost around \$20 to build, and the system is shown in fig. 68. The actual process of digestion takes place in the inner tube of a lorry or tractor tyre, and similar inner tubes are used for storing the methane. The perspex inlet and outlet pipes from the digester have been welded into a cylinder of perspex made to the same dimensions as the circumference of the inner tube, and joined to the tube to form a complete doughnut. A circular perspex panel in the middle of the cylinder separates the start of the digestion process, where the slurry inlet and methane outlet are situated, from the end, where the fertilizer effluent outlet is placed. The completed tube digester has an approximate volume of  $0.1 \text{ m}^3$  (depending on the size of the tyre tube used), and is fed daily with 1.4 kg of chicken manure. Chicken manure is preferred as it has a finer texture and the likelihood of scum forming on the surface of the digesting wastes is therefore reduced. The chicken manure is mixed with about three litres of water or urine to a slurry in the bucket, which is then raised so that the slurry is fed by gravity into the digester. The digested slurry can be drawn off from the outlet at the other end of the digester every one or two days, the total amount removed being about half the volume of the daily input to allow for gas production and contraction during the fermentation. About  $0.14 \text{ m}^3$  of methane gas is produced daily with this system, the gas having an average calorific value of  $7.3 \text{ kWh/m}^3$ , which is enough to cook a very simple meal. If the tube digester is constructed in places where the ambient temperature is too low to maintain digestion, the New Alchemy Institute recommends that the inner tube should be placed in an insulated box in which are two 100-W light bulbs connected in series and linked to a thermostat set at  $35^\circ \text{ C}$ . The other features of the inner-tube system are shown in fig. 68.

For some years before the present increased interest in methane plants, Mr H. Bate of Totnes in Devon has been running a methane plant in conjunction with his pig and poultry holding. Part of the gas produced is compressed and used to power his 1953 Hillman car. For Bate's system, digestion is always preceded by aerobic composting for approximately one week. The manure is mixed with straw and other vegetable waste, well watered and piled up into a traditional compost heap. At the end of the week, the materials are loaded into the digester and sealed from the air. Fig. 69 shows the modification of a domestic hot-water cylinder to form a methane digester. During digestion, gas production is estimated to be  $0.3 \text{ m}^3$  for every kilogram of manure decomposed. Bate also suggests modifying a conventional septic tank into a methane digester by fitting a non-return valve to the inlet from the house, fixing a gas outlet in the vent pipe and sealing off the other vents. Gastight holes would have to be made in the lid of the tank, one to take a conventional domestic immersion heater and the other to hold a thermometer to check that the optimum temperature range of  $29^\circ - 32^\circ \text{ C}$ , given by Bate, is maintained. It is uncertain whether this suggestion has actually been tried, although a conventional, unaltered septic tank does process its wastes by anaerobic decomposition, the vent pipe affording a release for the gases produced, which include methane, to the air. However, if the digesting wastes are too dilute, methane formation is inhibited, and the use of a normal WC with a 9-litre flush linked to a modified septic tank would produce a water content in excess of that for optimum gas production.



69 Conversion of 1219 mm x 610 mm domestic water heater to a methane digester (after Harold Bate). The digester is filled through the length of steel pipe welded to the top; the cover of this pipe is fixed with 9 mm bolts. The safety valve and pressure gauge, gas take-off tap, and emptying tap are also welded to the tank. The paraffin heater is replaced by a gas jet from the digester itself once digestion is under way.

## **Deciding on the location of the biodigester**

The first step in installing the biodigester is to identify the most appropriate location. In general this should be close to the source of the livestock pen where the waste is produced. It is a distinct advantage if the washings from the pen pass by gravity directly to the inlet of the biodigester. It is relatively easy to transport the gas by pipeline but difficult and tedious to do this with liquid wastes.

Once the site is selected the next step is to determine the size of the biodigester. As a general rule the excreta produced by 10 fattening pigs will require a biodigester of 4 m<sup>3</sup> liquid capacity. The standard diameters of polyethylene tubular film are 80, 125 and 200 cm. For a small number of animals, it is advisable to use a diameter of 80cm which gives a cross-section area of

$$0.4*0.4*\pi=0.50\text{m}^2$$

On average 80% of the total volume in the tube corresponds to the liquid fraction, thus to provide a liquid volume of 4 m<sup>3</sup> will require a biodigester with a length of:

$$4/0.80/0.5=10\text{m}$$

The recommended dimensions of the trench which will hold a biodigester of the above dimensions are:

Width at the top 90cm; depth 90cm; width at the bottom 70cm; length 10m.

Having decided on the size of the biodigester the upper extremities of the trench should be defined by a string attached to four posts.

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## **The water trap (gas escape valve)**

A "T" is prepared from three short lengths of PVC pipe with the longest arm of a length which will fit into "used" plastic bottle.

A 3\*3cm hole is cut in the upper part of the bottle, just below the neck, through which water will be added to form the gas seal.

Small holes are made either side of the neck to take a length of thin wire which will be used to attach the bottle to some support structure.

The PVC "T" is inserted in the bottle and water is added to a depth of 4-5 cm above the lower point of the "T"

Small holes are punched into the sides of the bottle at a point 2 cm above the lower end of the "T". This ensures that if the gas pressure inside the system exceeds 2cm water column the gas can escape to relieve the pressure.

The "water trap" is now suspended in a convenient place so that the water level can be easily observed and replenished when necessary

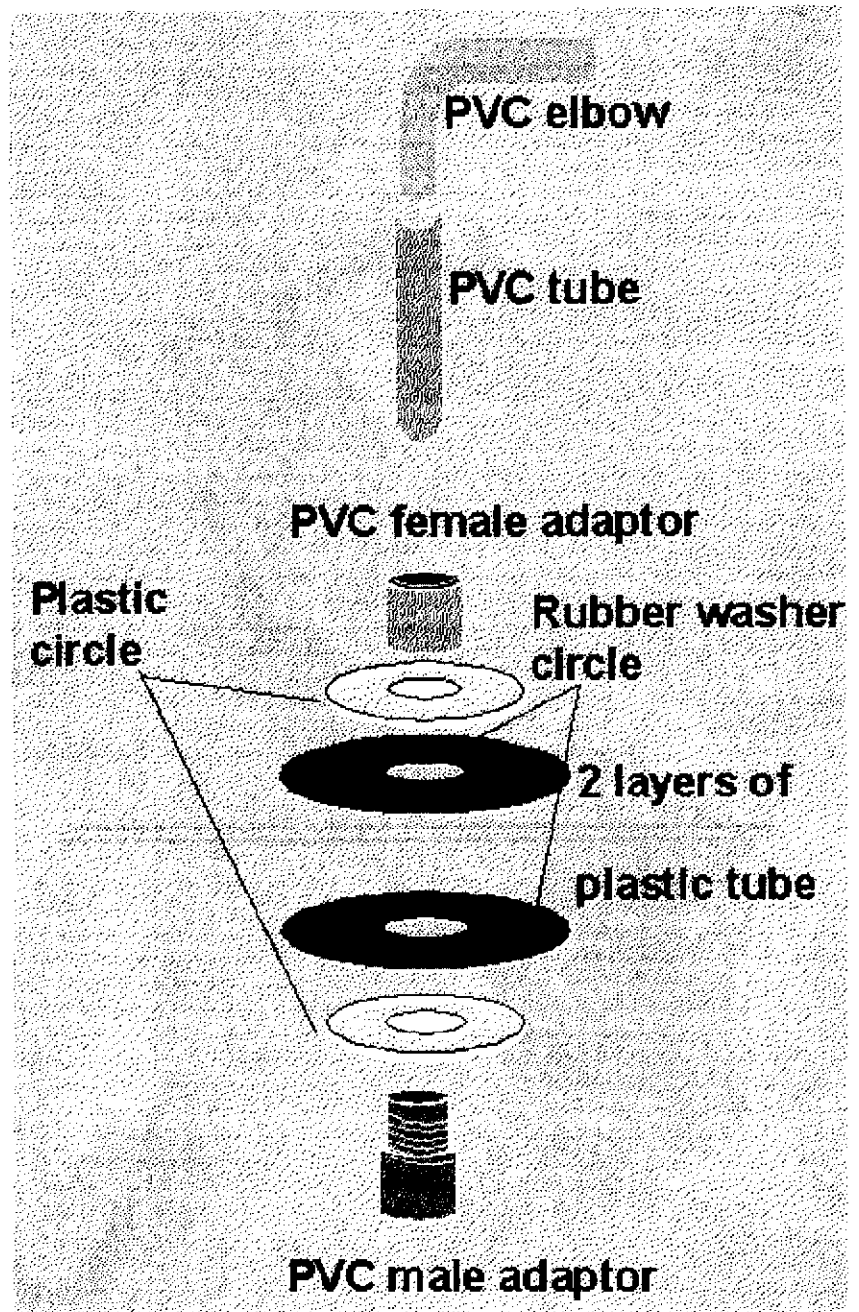
A flexible plastic pipe is attached to the gas outlet and joined to one arm of the "T". The other arm links with another plastic pipe which goes to the kitchen.

## **Linking the biodigester with the gas reservoir**

Either rigid PVC tubing (13mm internal diameter) or flexible plastic pipe can be used to connect the exit of the biodigester with the entrance to the reservoir.

## Fixing the gas outlet

The components of the gas outlet and the order in which they are placed in the plastic tube are indicated below.



The first step is to mark the place where the gas outlet will be placed. This should be 1.5m from the end of the plastic tube and in the centre of what will be the top of the biodigester.

The size of the hole is determined by the external diameter of the PVC male adapter.

The rubber washer circles are cut from a length of "used" motor cycle or car inner tube, using the plastic (Perspex) circles as a guide.

The components are then assembled to ensure the male and female adapters fit together smoothly.

The male adapter, complete with plastic circle and above this the rubber circle, is inserted from within the plastic tube. The female adapter, with the rubber and plastic circles attached, is screwed tightly on the protruding male adapter.

The installation of the gas outlet is now complete.



**PVC elbow**

**PVC tube**

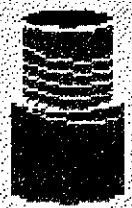
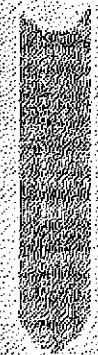
**PVC female adaptor**

**Plastic circle**

**Rubber washer circle**

**2 layers of plastic tube**

**PVC male adaptor**



# The products of the biodigester

These are:

- Biogas
- The effluent

The biogas flows by tube from the biodigester to the reservoir situated as close as possible to where it will be used, usually near the kitchen.

The effluent is produced daily in accordance with the schedule of charging the biodigester. The volume that comes out is equal to the volume that goes in. The residence time (time taken on average for the "digesta" to pass from the entrance to the exit) will vary usually within the range of 10 to 30 days depending on the quantity of manure and water put into the biodigester. The greater the input volume the shorter the residence time. It is desirable that the residence time is of the order of 20 days so as to secure inactivation of pathogenic organisms and parasites.

There should be a pit to receive the effluent large enough to hold at least the output of 2 days. Normally it is not necessary to line the pit as the floor and walls soon become impervious. If the topography permits a pipe should be laid to take the effluent from the receiving pit to the duckweed ponds.

The two products from the anaerobic biodigestion of livestock wastes are:

- Biogas which is rich in methane (55-65%) and used mainly for cooking
- Effluent which is the residue coming out of the digester and which contains all the plant nutrients present in the original manure

This section of the manual deals with the utilization of the effluent as a fertilizer for crop plants. Since the effluent is voluminous (about 98% water) it is an advantage if it is used as close as possible to the site of production. For this purpose it is necessary to select crop plants which have a rapid growth rate (and therefore high capacity to extract nutrients from the medium in which they are growing) and good nutritive value.

For this purpose it has been found that duckweed (*Lemnaceae*) is the most appropriate because it:

- Has a rapid rate of growth (doubles its biomass in 24 hours)
- Is palatable and has high digestibility for monogastric animals (dry matter digestibility over 65% in pigs according to Rodriguez and Preston 1996a)
- Its protein content is almost doubled (from 20-22% to 35-40%) when grown in nutrient-rich water (Leng et al 1995; Rodriguez and Preston 1996b; Nguyen Duc Anh et al 1997)

The simplest way of moving the effluent is with buckets.

If the topography permits a more convenient method is to lay a pipe (5 cm id is enough) connecting the effluent pit with the duckweed pond and in turn to have each duckweed pond connected in series to the next one.

A 1/4 HP electric pump has the inlet pipe connected directly to the effluent pit and the outlet at the highest point of the slope. In a matter of minutes the effluent is pumped into the duckweed ponds.

# Using the effluent from the biodigester

When manure and water enter the biodigester a similar volume of effluent is forced out of the exit pipe.

It is usually adequate to have an unlined pit as very quickly this becomes impervious to filtration.

A pipe from this pit then connects directly to ponds used to cultivate duckweed.

When duckweed is fertilized with biodigester effluent its crude protein content can be between 35 and 40% in the dry matter, making it a valuable supplement for pigs and poultry.

In order to maintain a nitrogen content in the pond water of about 20mg/litre, the volumes of effluent to be added can be calculated from the table below:

- At the beginning when the pond is prepared and filled with water the first time
- Every day (to compensate for the nitrogen removed in the duckweed assuming a daily harvest of 100 g/m<sup>2</sup> pond surface/day)

The calculations are based on a pond of 20m<sup>2</sup> area and 20 cm depth of water. For ponds with different dimensions the data should be adjusted accordingly.

**Effluent daily  
(litres)  
area, m<sup>2</sup> 20  
depth, m 0.2**

**dry matter content of effluent (%)**

<b>N in effluent DM (%)</b>	<b>0.5</b>	<b>1</b>	<b>1.5</b>	<b>2</b>	<b>2.5</b>	<b>3</b>
<b>0.5</b>	288	144	96	72	58	48
<b>1</b>	144	72	48	36	29	24
<b>1.5</b>	96	48	32	24	19	16
<b>2</b>	72	36	24	18	14	12
<b>2.5</b>	58	29	19	14	11	10
<b>3</b>	48	24	16	12	10	8

**Effluent at beginning (litres)  
Pond area, m<sup>2</sup> 20  
Pond depth, m 0.2**

**dry matter content of effluent (%)**

<b>N in effluent DM (%)</b>	<b>0.5</b>	<b>1</b>	<b>1.5</b>	<b>2</b>	<b>2.5</b>	<b>3</b>
<b>0.5</b>	3200	1600	1067	800	640	533
<b>1</b>	1600	800	533	400	320	267
<b>1.5</b>	1067	533	356	267	213	178
<b>2</b>	800	400	267	200	160	133
<b>2.5</b>	640	320	213	160	128	107
<b>3</b>	533	267	178	133	107	89

# The duckweed ponds

If water is not a limiting resource the most appropriate way of using the effluent from the biodigester is for the cultivation of duckweed (Lemnaceae).

Where there is a high clay content in the soil the floor and wall of the pond soon become impervious to filtration of water. But in sandy soil it is necessary to line the ponds with a mixture of soil and cement. For a pond 40cm deep and with an area of 20 m<sup>2</sup>, the required overall quantities are 2.5 kg of cement and 300 kg of soil.

Smaller mixes of 30 kg soil, 2.5 kg cement and 1.5 kg water are prepared and a thin layer of the mixture is applied to the floor of the ponds and to the walls.

After two days the ponds can be filled with water and seeded with duckweed.

The duckweed pond is connected by a pipe with the exit of the biodigester.

The inoculum of duckweed is prepared and distributed on the pond surface at the rate of 400 g/m<sup>2</sup>.

Each pond is harvested daily. It is a simple operation requiring a bamboo pole slightly shorter than the width of the pond and a plastic basket.

Beginning at the mid-point of the pond the duckweed is pushed steadily to the narrow end of the pond and then scooped out of the water with the basket. It is left to drain for few minutes before being weighed and taken to the animals.

These ponds are producing about 100 g fresh duckweed/m<sup>2</sup>/day which is equivalent to about 6 tonnes protein/ha/year.

Duckweed has a balance of essential amino acids slightly superior to soya bean meal (Rusoff et al 1980).

Rice bran and cassava root meal are dry, powdery materials. Duckweed by contrast is very wet (94-96% moisture..!!). Mixing fresh duckweed with either rice bran or cassava root meal, or with a combination of the two, produces a feed with a crumbly texture that is more readily accepted by chickens than any one of the ingredients given separately.

Proposed combinations (all on fresh basis) that will give at least 10% protein in dry matter (suitable for growing and laying chickens) are:

- one part rice bran; one part duckweed
- four parts duckweed:one part cassava root meal
- two parts duckweed: one part cassava root meal: one part rice bran

The same principles apply as for chickens and the same mixtures of duckweed with cassava root meal and rice bran can be used.

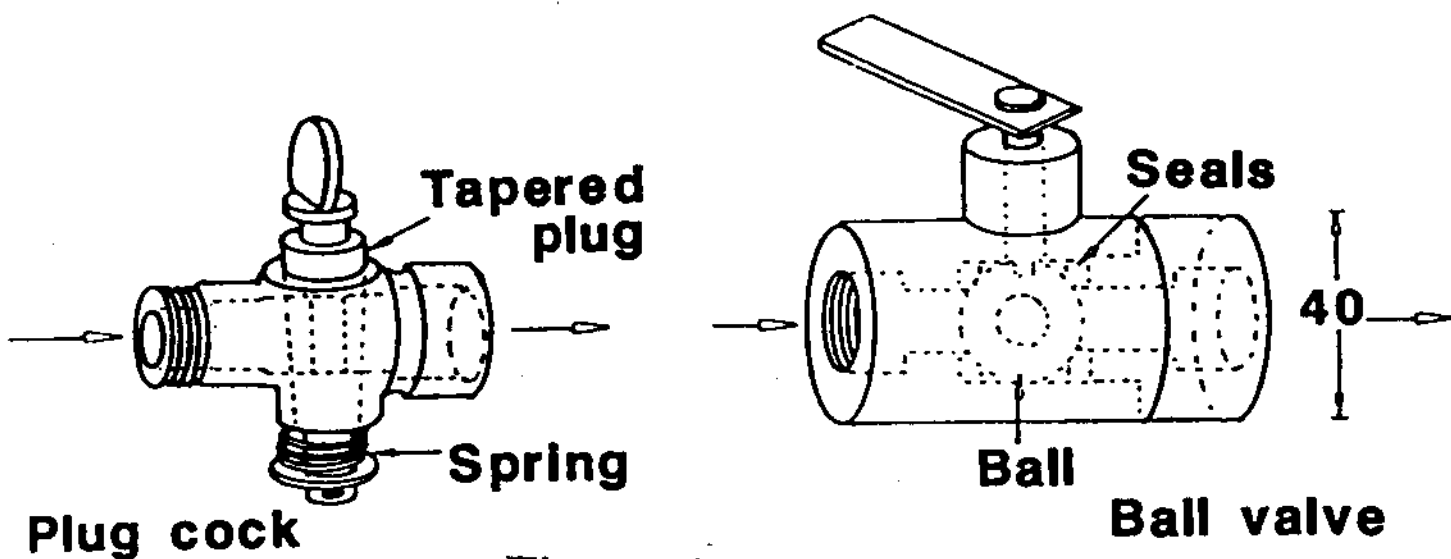
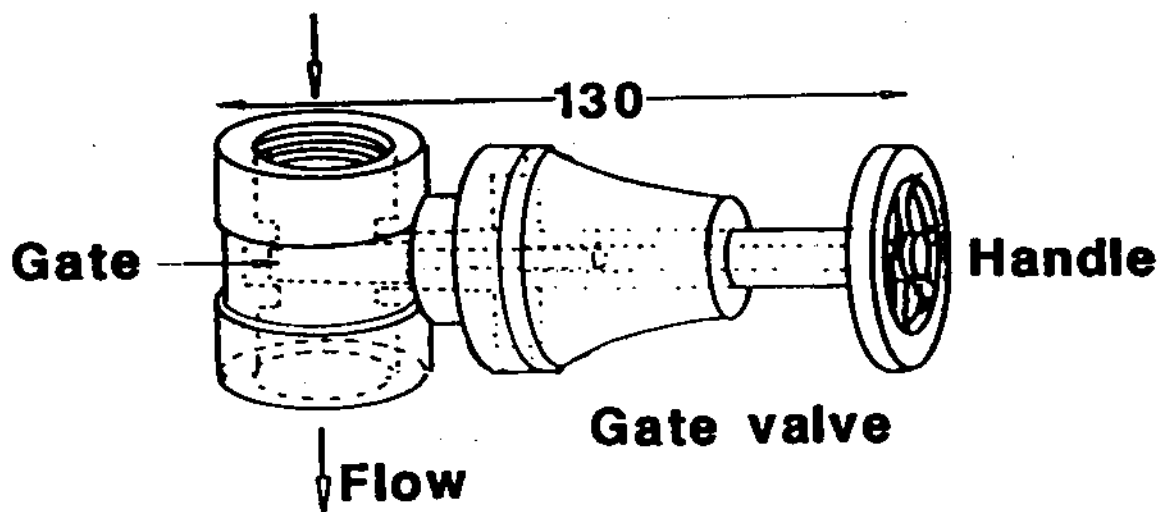


Figure 6.4 Different types of gas valve.

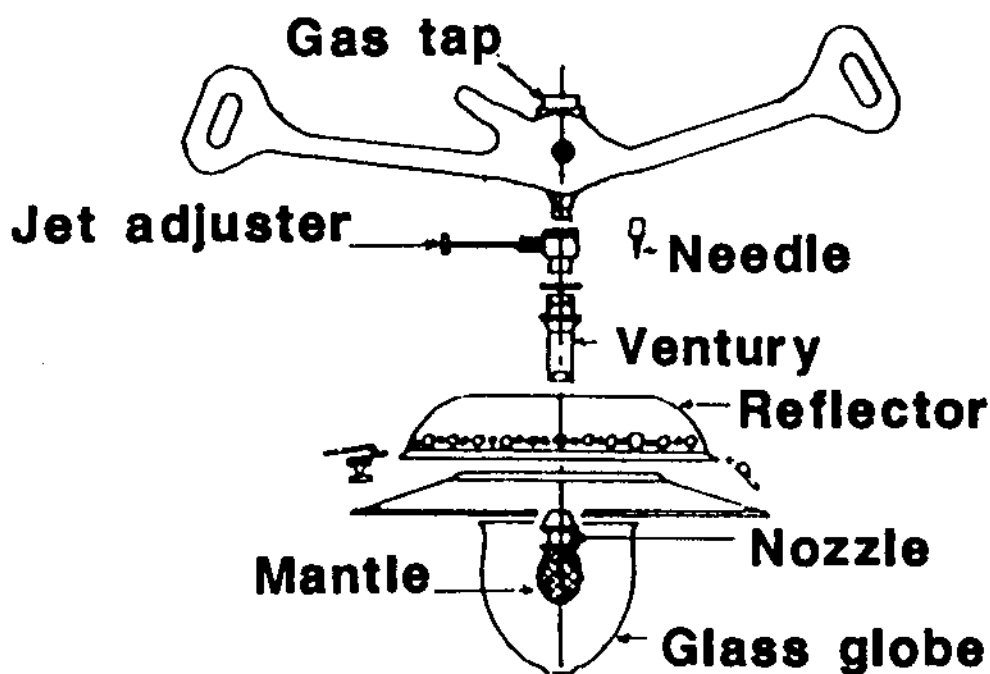


Figure 6.6 Biogas light (made in India)

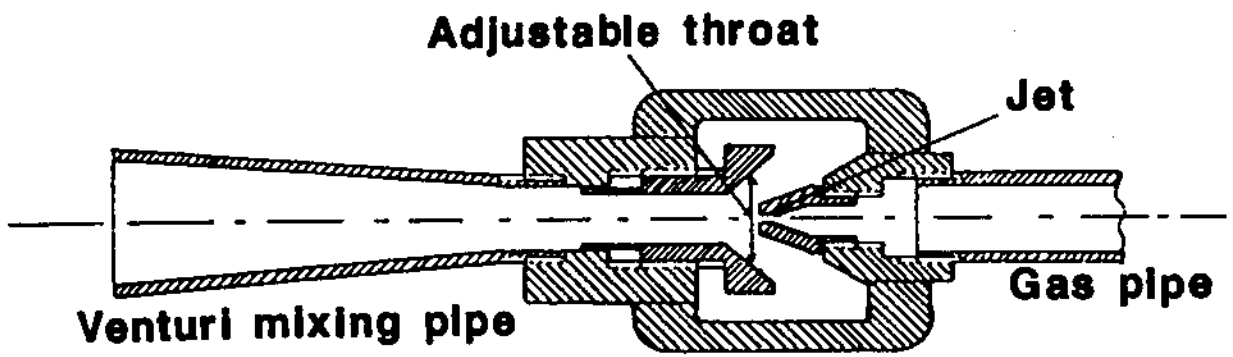


Figure II.6 *Tapered throat design of gas burner*

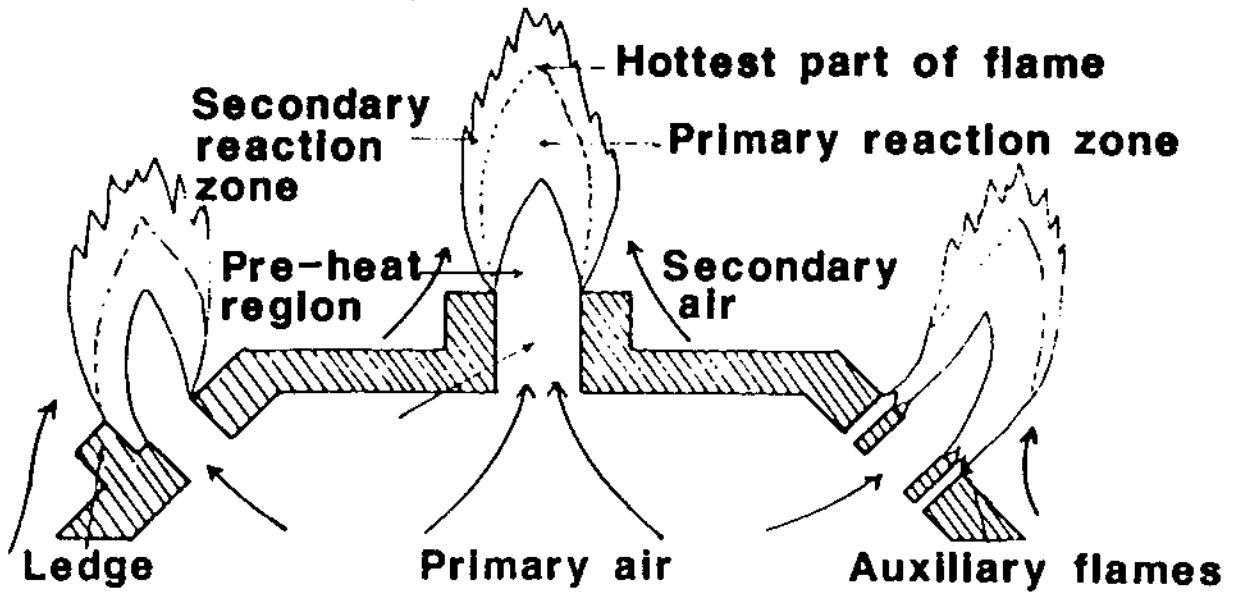


Figure II.7 *Details of gas flame and means of stabilisation*

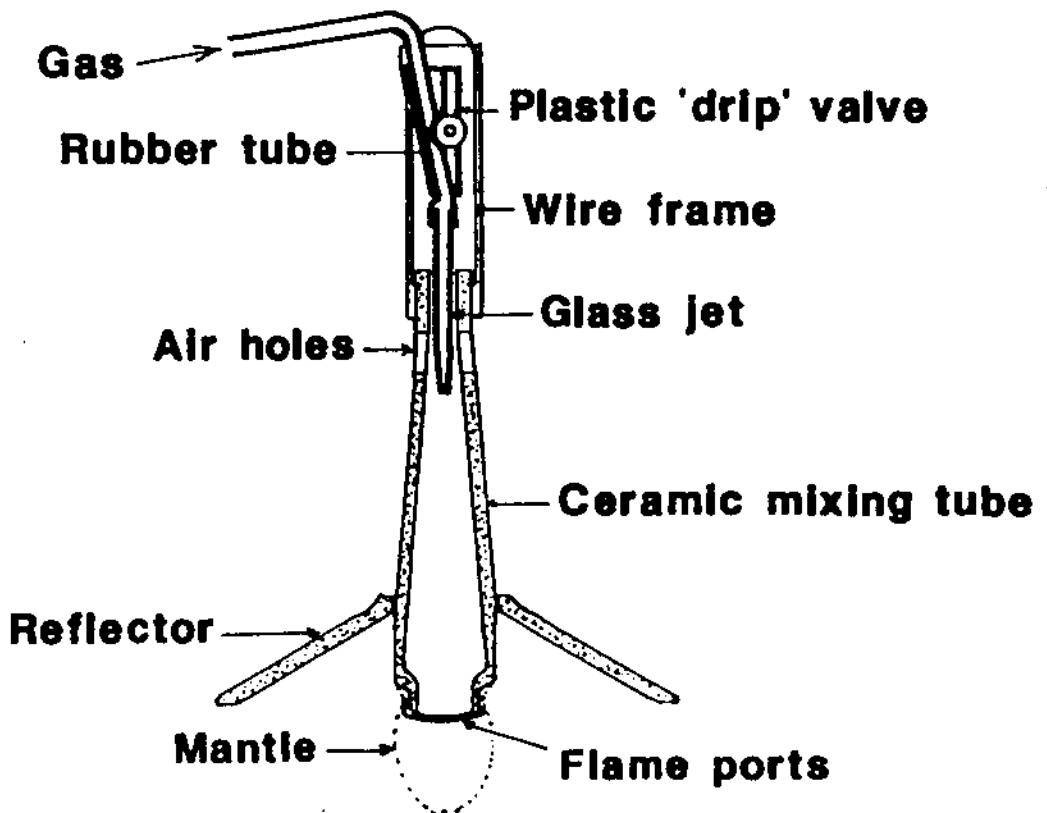


Figure II.8 *Ceramic gas lamp—made in China*

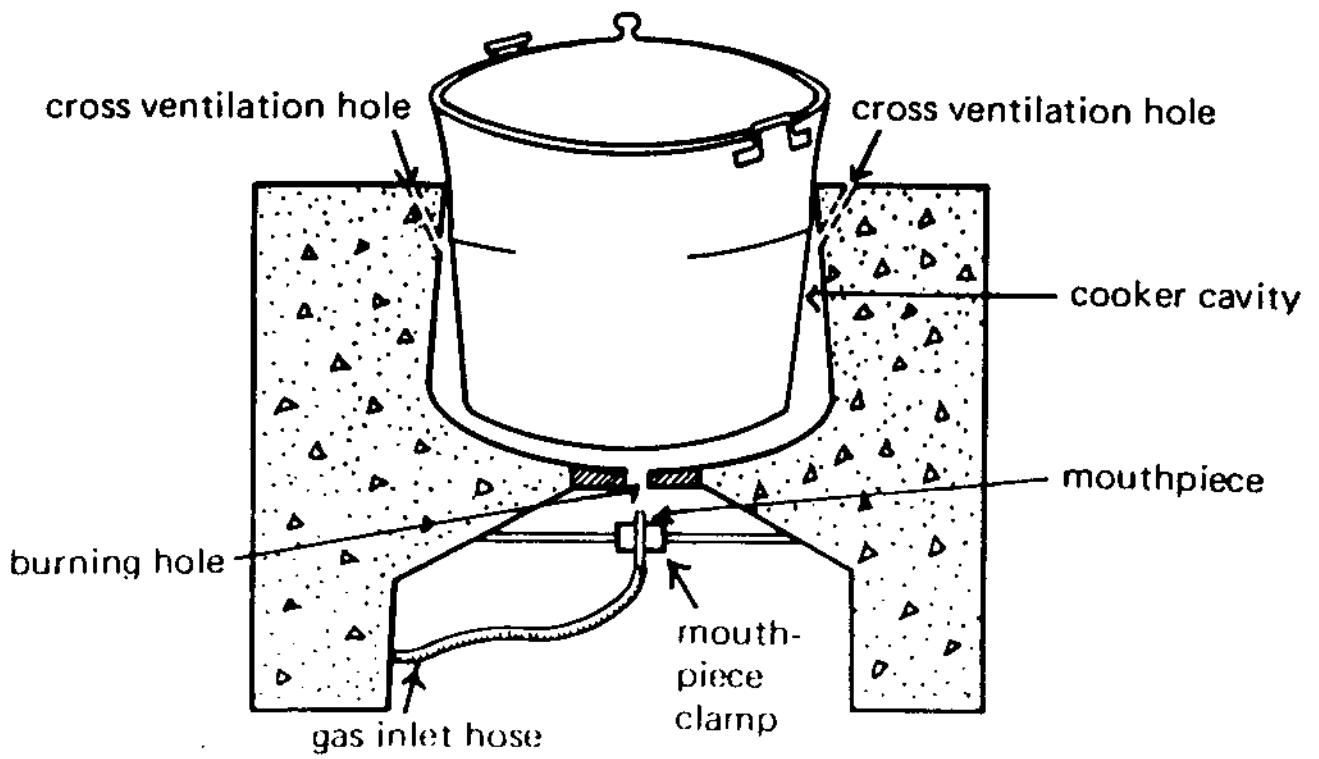


Fig. 7-13. The biogas stove.

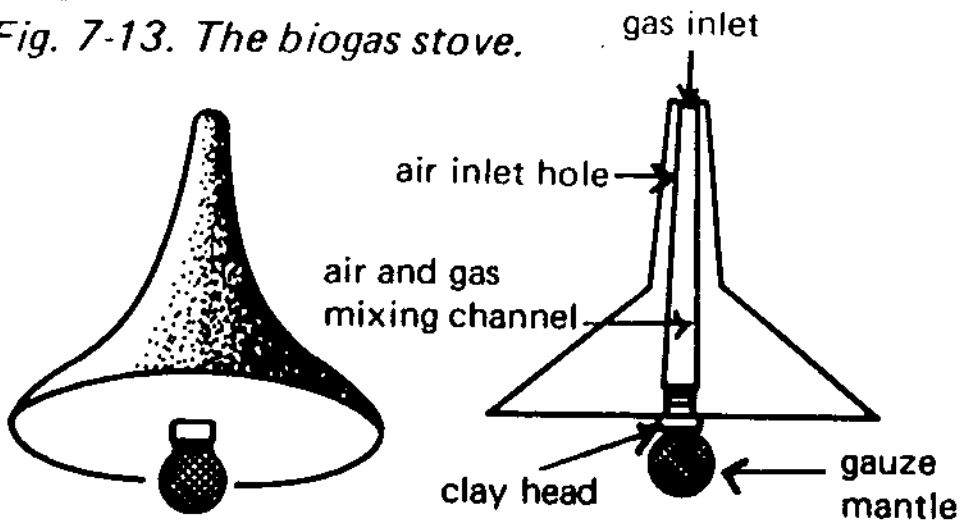


Fig. 7-14. The clay hanging lamp.

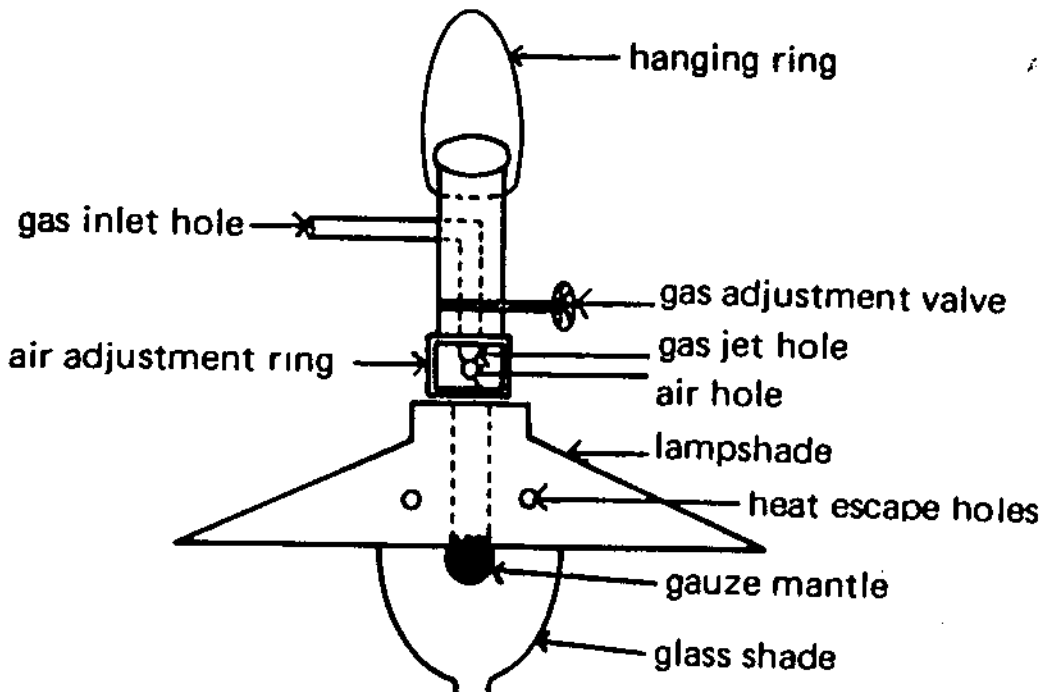
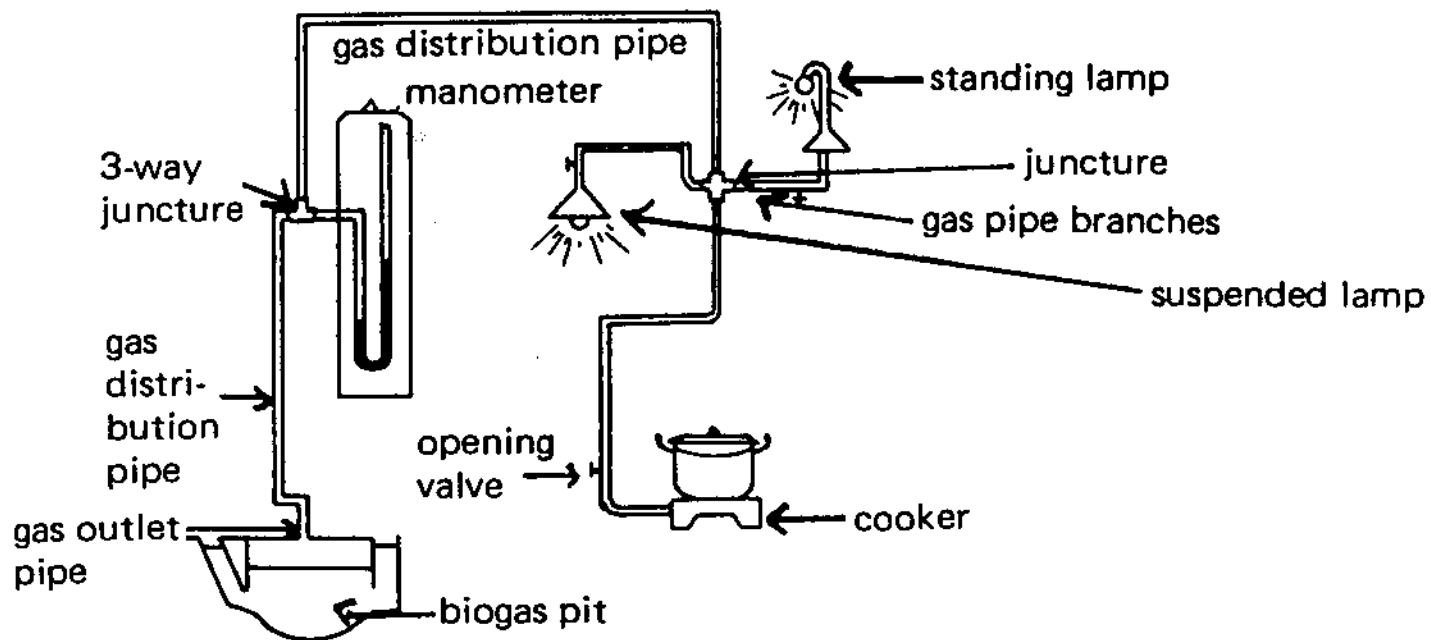
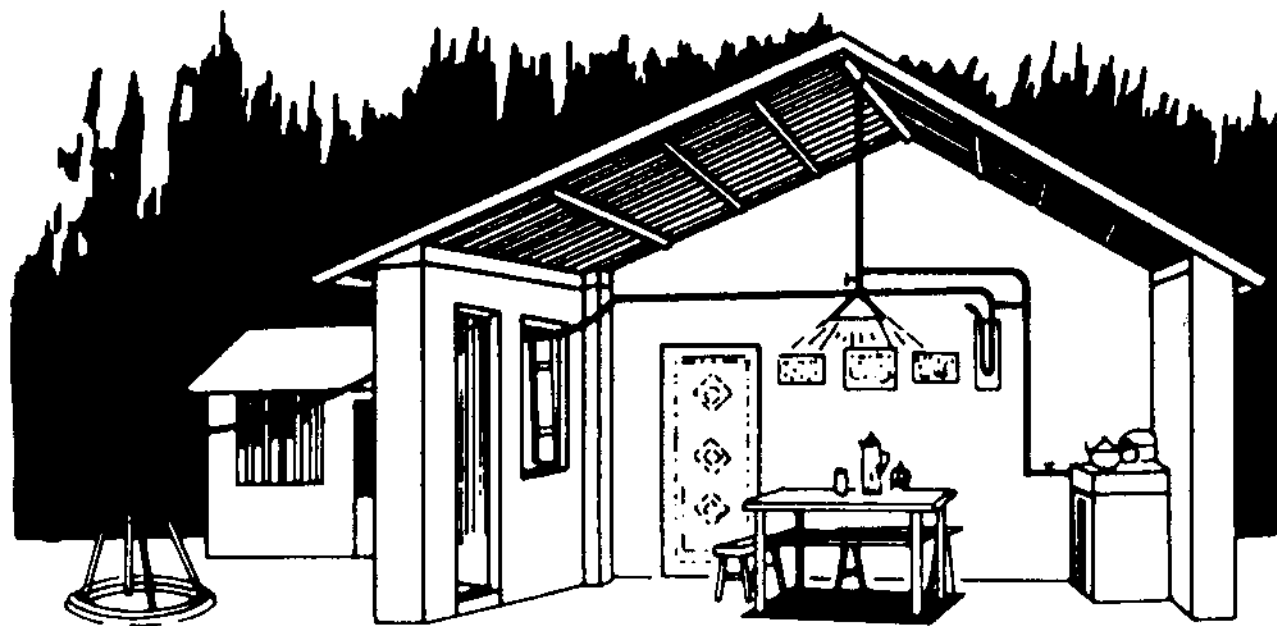


Fig. 7-15. 'Red Star' hanging lamp.



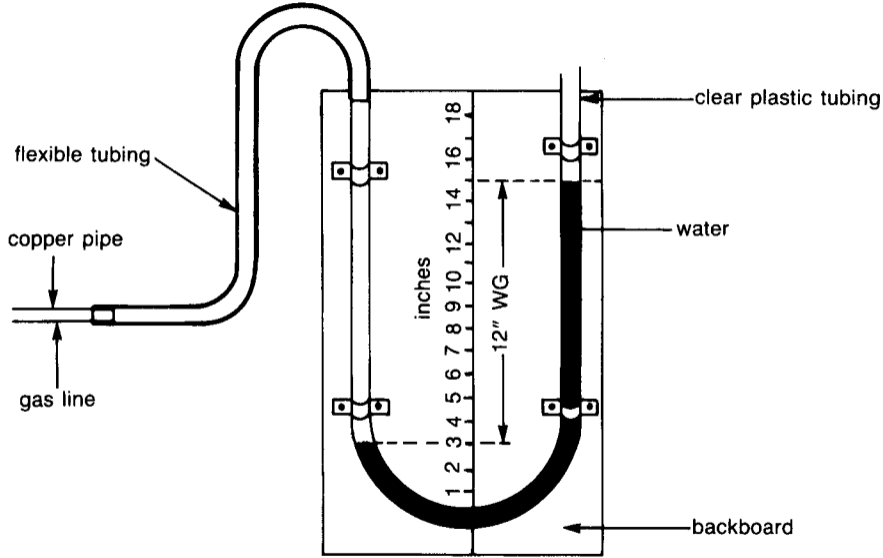
*Fig. 7-16. Rough plan of equipment installation for using biogas.*



*Fig. 7-17. Wall attachment of biogas distribution pipes.*



Figure 14-4. A simple, homemade manometer for measuring gas pressure in an LPG system.



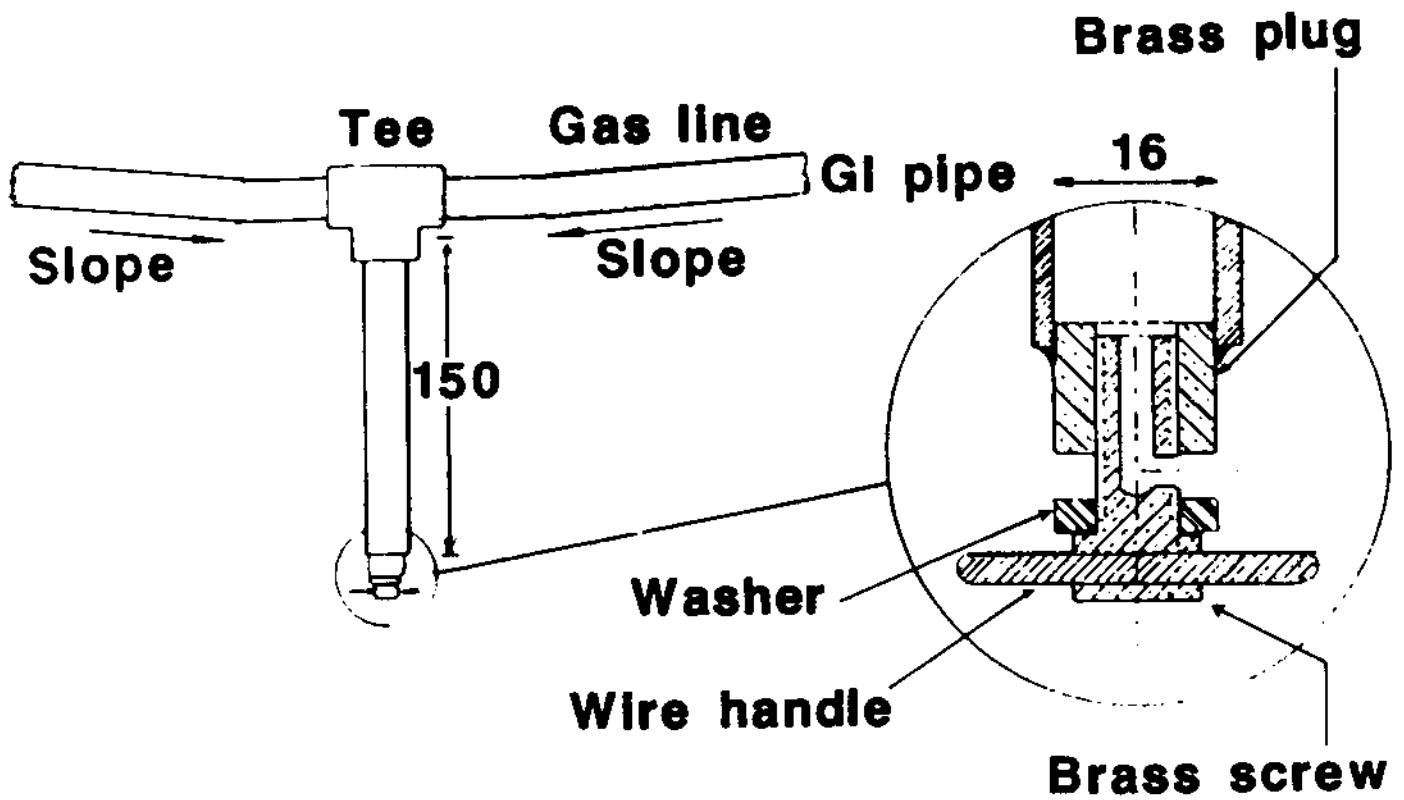


Figure II.1 'T' Type water trap.

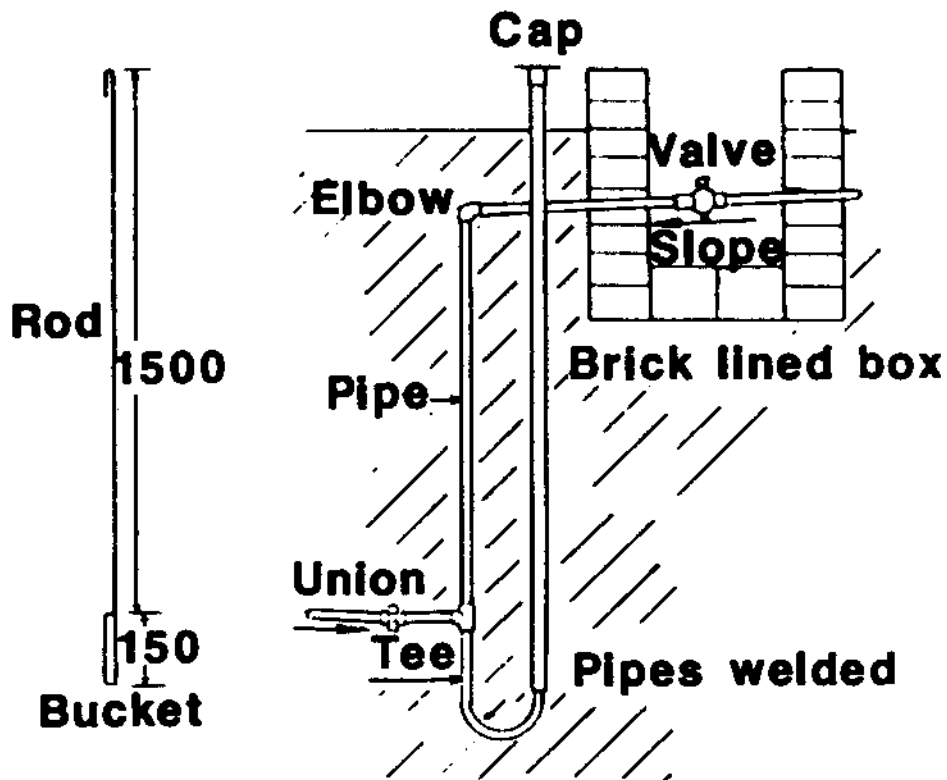


Figure II.2 'U' type of water trap.

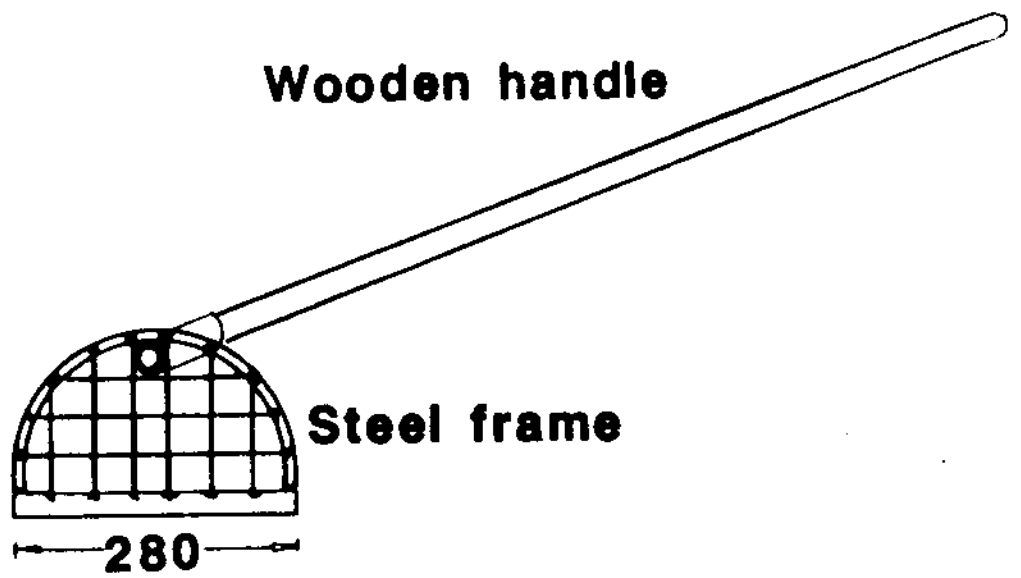


Figure 6.1 *Hand tool for mixing slurry in inlet pit*

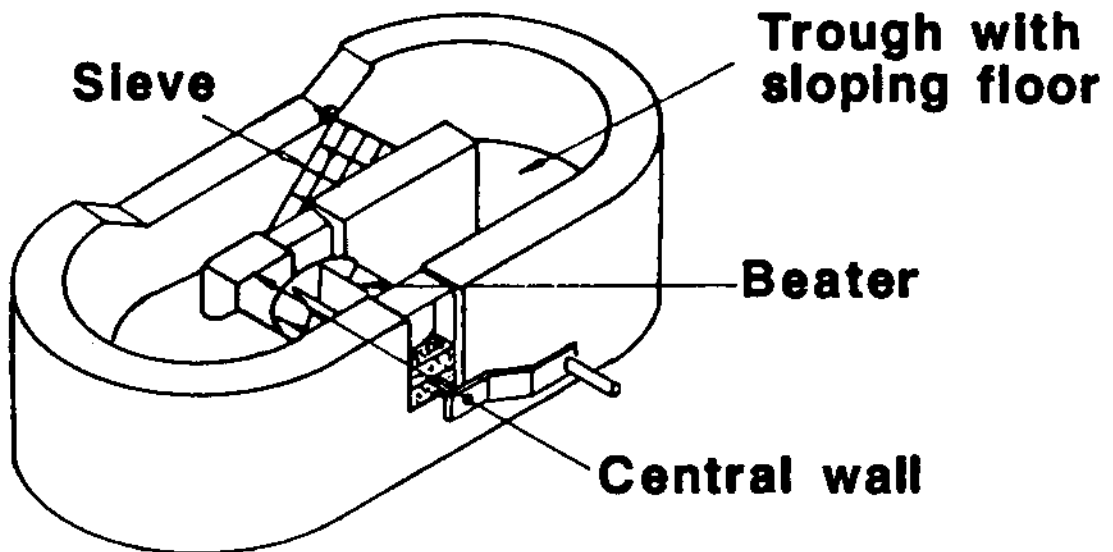


Figure 6.2 *Machine for mixing feed slurry*