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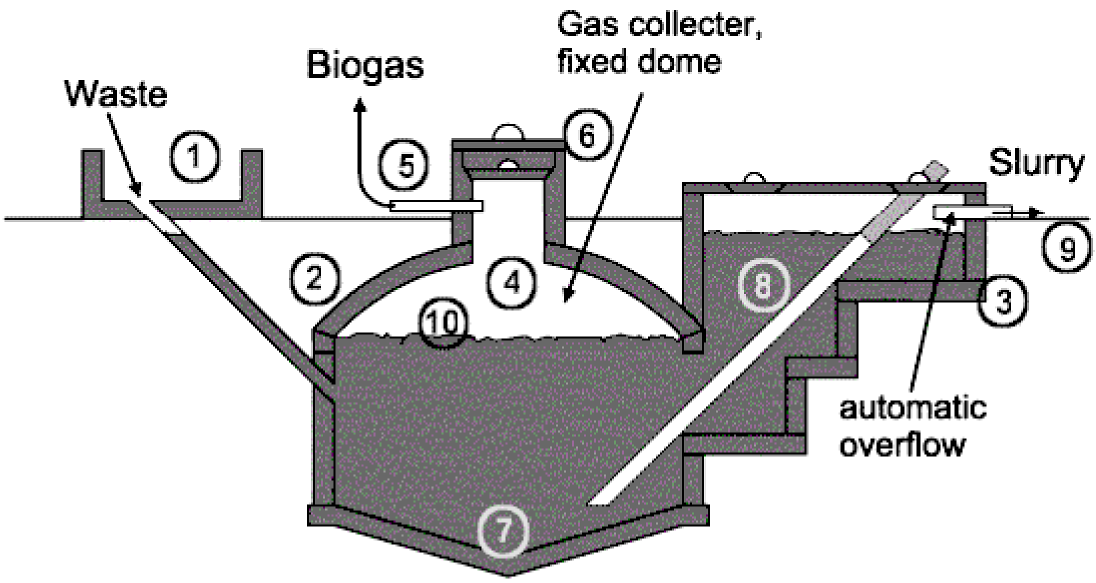
SECOND SUPERVISOR TRAINING ON BIOGAS PLANT CONSTRUCTION



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1. SITE SELECION

1.1. Survey of site

For site selection it is necessary that the contractor together with the client selects the best site for the construction of the biogas plant. It is important to consider the system as a biogas unit.

A Biogas unit is a considerable investment and it should not be looked at as a temporarily structure. The idea of the biogas unit forces the contractor, as well as the farmer, to think of the whole farm complex in which the biogas plant will get integrated.

The agricultural biogas plant belongs to the stable. The distance to the kitchen is of normally of secondary importance. With fixed dome plants, there is no practical limitation to the length of gas pipes, except for the cost. As a matter of principle, sustainability has priority over cost reduction. This means that everything must be arranged in such a way that it is less work to feed the plant than not.

The running costs of an installed unit must be as low a possible. The plant must operate as independent as possible. It should be easier to fill the plant than not to fill the plant. The Biogas must appear as an obviously powerful source of energy. The user must have a “never ending source of energy”. The gas piping system should not hinder any movements at the farm.

The advantage of a stable connected to a biogas plant is that all dung and urine provided by the animal are entering the plant. Fodder residues are not allowed to enter the plant. On sloping ground, the stable than has to be located higher than the biogas plant. On flat grounds either the floor of the stable might be elevated in order to allow dung and urine to enter the plant by gravity or we provide a feeding chamber. The mixture of the feeding material should be free of sand and stones. This might as well be reached by instructions, but the probability that instructions are not followed is high. Thus in many cases a mixing chamber is the better option.

Handling of slurry requires high labour input and can be avoided by proper planning. The utilization of the slurry is a very important point to be discussed at the first site meeting wit the farmer. The workload of the slurry distribution should be calculated and made known to the farmer before signing a contract. The outlet of the biogas plant should be directed towards the fields or it drains directly into fields. Overflowing slurry should never be allowed to accumulate on neighbours or public ground. The biogas unit should be functional even when maintenance and attendance is poor. The owner often cannot oversee the consequences of his decision about the implementation of the Biogas Plant. **Beware of false compromises.**

1.2. Selection for Construction

After observing the general environment of the farm, the master plan of the biogas unit is made on the spot in cooperation with the person having decision-making power at the farm. The contractors must check if the space for the plant is sufficient and must take measurements for the proposed structure providing sufficient space for a mixing chamber if required and the expansion chamber.
Many biogas projects failed because the biogas plant was considered on its own without the other components and the area for slurry distribution and the biogas use points (piping).

To allow swift construction work, access for transport and place for storage of material and excavated soil must be clear before starting. The farmer must be informed about providing of water during the construction period. There also must be agreement on which building materials are to be provided by the farmer and which quality requirements for construction materials are to be observed.

The contractor writes a report about the findings and assessments and gives reasons for the mutual decision made at the site. **Such records are helpful in case of clients complaining about wrong assessments or delays in construction performance etc.**

Before deciding the size of a plant, it is necessary to collect dung for several days to determine what the average daily dung production is. The amount of dung available is determining the volume of the plant and the theoretical gas production.
The important point to be considered is that the size of plant has to be selected on basis of available dung and urine and not on the family size.

The biogas plant should be placed so far from trees that roots will not destroy the construction. It should not be located in areas where heavy machinery move frequently. Biogas plants are not meant to be a playground; thus they should be safe for children and animals.

1.3. Siting for Excavation

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

- Close to the supply of input materials (cow shed) – to reduce transportation efforts.
- In direction the area where the slurry will be used – so that under optimum conditions the effluent can flow by gravity to the fields.
- Not too close to trees – to prevent damage to the structures from the roots of the tree plants.
- At location where the ground water table is low – ease of construction, to prevent seepage during construction
- The edge of the foundation of the plant should be away from buildings to avoid risk of damages.

At any particular site it may not be possible to fulfil all the above criteria. However, effort should be made to meet as many criteria as possible such that the cost is lowered and the operation becomes less cumbersome.

2. The Reference line

When a suitable site is selected and before the excavation work starts, 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 radius length for the excavation **indicated in 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.

Now a temporary reference line for the excavation has to be put in place and levelled roughly **one meter** over ground and passing over the **centre of the excavation from inlet to outlet**. The convenient overflow level (Cero Level) has to be decided and the string of the reference line is tied 100 cm above that point. The posts for the reference line should be sturdy and firmly fixed and should be protected throughout and during the excavation and construction period.

The reference line has to be put before the excavation starts to control the vertical measurements during excavation and keep exact levels from beginning to the end of the excavation and to achieve correct shaping of the hole and cone for the foundation of slap

2.1. Excavation of Digester Hole

The radius of the excavation is given in the drawing and is a bit bigger than the digester radius to allow working space while at the same time ensuring that the space is not too much and result in more workload during excavation and backfilling.

The depth of the digester should always be assured **from the reference line** as digging progress is going on to ensure that the hole stops at the specific depth as given in the drawing **and also required by circumstances on site** (location of expansion chamber; gravity etc) this is very important because a hole that is too deep will interfere with the proper layout of the plant; either too low or too high at completion it causes problems in function. The drawing gives specific space requirements for the biogas plant.

The hole wall should be as vertical as possible and the earth at the ground should be also firm and untouched. If soil is soft, stone or sand packing below the foundation is required. After the dimensions in diameter and depth have been realized in digging it has to be assured that the ground floor is **properly levelled;** now it is time for excavating the base for the cone.
The depth in cm of the cone centre is 1/4 part of the inner digester radius. A deliberate effort should be made to ensure that the cone sides are uniformly inclined. This can be realized by fixing pegs using a water level in the ground all round the hole to mark the depth needed at every point. These measurements should also be controlled **from the reference line**. Provide drainage facilities in case of ground or hill water.

After finalizing digging, excavated soil should be thrown at least one meter away from the hole, so that it does not fall inside the pit when the construction work is in progress. **The areas for inlet and expansion chamber should be kept free from excavated soil.**

After finishing and shaping the hole and the cone according to the measurements the reference line should know controlled again and receive its final levelling respecting the **Cero Point** of the drawing.

The reference line an indispensable tool for the construction of a Biogas Plant. It guides the mason as well as the supervisor through the whole construction to keep the exact levels, which are of outmost importance for the functioning of the system.

The reference line has to be fixed exactly 100 cm (1 m) above the zero level which always coincides with the over flow level of the expansion chamber (point Zero!). This level also has to be extended to a permanent structure like a building nearby (e.g. cow shed or a firm tree) in case the posts were removed accidentally. The string is crossing the whole construction site clashing the centre of the excavation hole, in direction from the outlet to the inlet chamber. The string is fixed in an absolute horizontal position with a hose-pipe level. The reference line remains during the whole construction time at the same place.

Vertical measurements in the drawing are given in relation to this reference line.

In case an existing stable or holding pen should be connected directly to the biogas plant, the over flow (Zero Level!) has to be **at least** 10cm or more below the lowest point of the pen floor level or the mixing chamber level..

In case a new stable will be constructed, the point of the overflow of the extension chamber might be decided accordingly to the convenience of the slurry disposal.

The centre GI pipe is fixed in the centre of the excavation before casting the slab.

3. CONSTRUCTION OF THE DIGESTER

3.1. Basics

The success or failure of any biogas plant mainly depends upon disobeying the measurements and also the quality of construction works. To achieve a successfully constructed biogas plant, the mason should not only respect the dimensions as indicated on the drawing but also follow the correct construction method and use only best quality materials.

A Biogas Plant construction consists of the following elements:

- The slap with the shape of cone
- The vertical wall
- Reinforcements where necessary
- Back filling
- Inlet pipe
- Expansion chamber steps
- Expansion chamber
- The dome
- The manhole
- Feeding chamber

- Lid casting
- Outside plastering
- Inside plastering
- Soil levelling

3.2. Tools for construction

Tools for excavation works:
Shovels/spades
Pick axes
Mattocks
Pangas
Hoes
Shovels
Buckets
Rope
Ladder

Tools for construction works:
Wheelbarrows
Spades
Shovels/spades
Mortar pans
Water storage container, i.e. barrel
Hosepipe
Spirit level
Water Level
Building string
Brick and claw hammers
Rectangular Trowel
Steel and wooden floats
Building squires
Screen for sieving
Rope
Buckets
Hack saw and hand saw
Bending equipment

3.3. Construction Materials

If the construction materials to be used in the plant construction such as cement, sand, aggregate etc. are not of good quality, the quality of the plant will be poor even if design and workmanship involved are excellent. In order to select these materials of best quality, their brief description regarding the specifications has been given hereunder.

3.3.1. Cement

All that looks like cement is not necessarily good cement. There are many grades. But the most serious damage is done to cement by moisture, either by direct contact with water or humid air.

The cement to be used in the plant construction has to be of high quality Portland cement from a brand with a good reputation. It must be fresh, without lumps and stored in a dry place. Bags of cement should never be stacked directly on the floor or against the walls but wooden planks should be placed on the floor to protect cement from dampness.

To concrete something means to form it into mass or to solidify it.
As far as building is concerned, the term concrete means an artificial stone made by mixing Portland cement, sand, stone, and water. This mixture, cast into a form of the desired shape and size, hardens into a stone – like mass: the concrete.

There are basically three materials we start with to make concrete.
- The binding material which is usually Portland cement
- The aggregate which is made up of the fine and course aggregates together, i.e. the sand and broken stones (ballast). The aggregates makes up the main mass of the concrete: its function is mostly just to add bulk.
- The water

When the three materials are mixed together, the cement and water combine chemical to make a cement paste, which surrounds the particles of the aggregate and holds them together.

3.2.2. Cement Paste

The cement paste component of concrete is what causes it to harden; the aggregate simply remains passive (inactive).Thus the cement paste must completely cover the surface of every single particle of the aggregate. His means that each stone, no matter whether tiny or big, must be covered all over by a thin layer of cement paste.
This is achieved by mixing all there components very thoroughly and in the correct proportions
The cement paste fills up all the spaces between the particles of the aggregate and bonds them firmly together as it hardens.
The hardening process requires a certain amount of water; how much cement is added to the mix. An undesirable further reaction if the cement paste is the drying shrinkage sit hardens. Because of the evaporation of the extra after, the volume of the concrete is gradually reduced. The concrete shrinks and develops cracks. This reaction can be effectively reduced, if not prevented, by correct curing as will be discussed later.

The ratio of sand to cement is the greatest determining factor for strength, other things being normal. A concrete floor made of 1 cement : 5 sand : 6 ballast, the concrete is vastly stronger than one made from part 1 cement and 2 parts sand.

Once moisture reached cement, chemical action starts.
On the job, make it a practice to mix, place and finish all concrete within an hour of the time that the cement has first been wetted.

3.4. Sand

Sand for construction purpose must be clean. Thus it should be river sand. By definition, sand is fine rock of particles and in concrete it is called “fine aggregate”. It is found in gravel pit and in the shores of rives and lakes.
Use only clean sand, which is free of slit, loam, vegetables matter and other alien substance to which cement will not adhere. Sand is grated as:

- *Course*: the texture which is about the same as common granulated sugar (1-5mm)
- *Medium*: which is like fine granulate sugar (0-1mm)
- *Fine*: which is like shaker salt
- *Dust:* sand that is like dust in size as well as in other ways.

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 vigorously. The bottle is than left stationary to allow the sand to settle down. The particles of sand are heavier than that of mud so it settles down quickly. After 20-25 minutes, the layer of mud verses sand inside the bottle is measured. Course and granular sand can be used for concreting work but fine sand will be better for plastering work.

Sand for plaster, mortar and renderings must always be chosen with care. The sand used to make mortar for block laying should be well graded, sharp and must not be too fine if a strong mortar is needed (e.g. for footings).
The more fine particles the sand contains, the better its workability in the mix, but more cement paste will be needed to cover the surface of the particles. This means that in order to improve the workability while maintaining the same strength more cement must be added which results in higher costs.

The rural builder is always faced with this problem and it takes a lot of experience to be able to find good compromise.

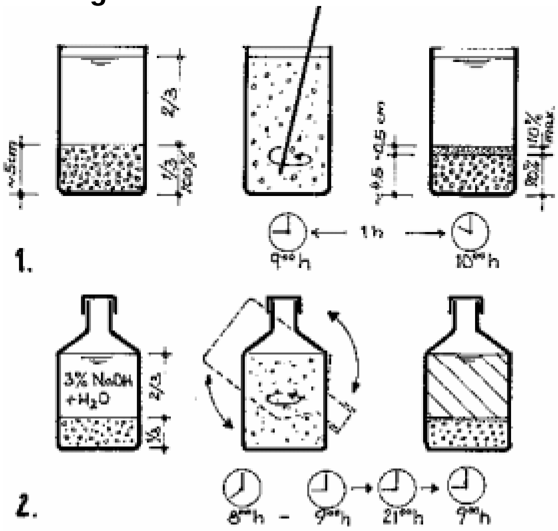
If the sand is found to be too sharp so that it makes the mortar with poor workability, we suggest replacing about 1/3 of it with fine soft sad, but don't replace more than about ½ unless you add more cement. We can do this because the common mix proportion of pour mortar is 1:6, while the sand concrete blocks are mixed in a proportion of 1:8 (cement: Sand. When the fine sand is added, the strength of the mortar is reduced to about the same as the strength of the blocks, which is acceptable.

The information above is meant to show the problems concerning the selection of the right sort of sand for a particular job. This book will address these problems repeatedly as we introduce the different kinds of blocks as well as the different jobs.

Remember: A good mortar should:

- be easy to work with
- harden fat enough not to delay the construction
- stick well to the blocks
- be long lasting and weather proof
- if possible, be a strong as the blocks

Testing of mortar sand:



1. Fines (loam, dust): Water glass sand, 2/3 water. stir vigorously. Leave to stand for one hour. Measure fines: A maximum 10 % of the amount of sand permissible.

2. Organic matter: bottle with stopper (not cork) be filled with 1/3 sand and soda lye (3 %). Shake repeatedly within an hour. Leave to stand for 24 hours. Water colour clear or yellow: good; red or brown: bad.

3.5. Ballast

This is called course aggregate. This is added to sand and cement to increase its hardness and wearing qualities and to increase its bulk. This latter resides the cost per M3 because stone is cheaper than cement. Concrete strength depends on the ratio of sand to cement and also upon the course aggregate. The aggregate be clean and hard. Stones with oily or glassy surfaces to which cement will not adhere are to be avoided.

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 of the chambers are not more than 10 CM thick, gravel should not be larger than 1" (2,5 cm) in size. Furthermore, the gravel must be clean. If it is dirty, it should be also washed.

3.6. 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. Besides these, water is also used for washing sand and aggregates. It is advised not to use dirty water because it has an adverse effect the strength of the structure; hence water to be used must be clean.

3.7. Stones

If stones are to be used for masonry work, they have to be clean, strong and of good quality. Also the shape should be uniform (dressed) in case you use quarry stones. Stones should be washed if they are dirty.

3.8. 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.

Bricks can also be made on site out of cement, sand and ballast chipping if fired bricks are not available or too expensive. The ratio for cement bricks is:

1 volumetric part of Cement + 3 volumetric part of sand + 4 volumetric part of chipping

or 1 volumetric part of Cement + 7 volumetric part of sand

4. CONSTRUCTION DETAILS

4.1. Foundation

The ring foundation and the conical bottom statically fulfil different purposes. While the ring foundation carries the building and the respective earth load (sometimes wet, sometimes dry) on top of it. The bottoms slab caries the sludge. As a conical shape for the bottom slab is more stable and provides additional volume, it is preferred to a flat bottom. The drawing of the digesters gives the measurement of the height of the cone.

A circle should be market out at the base that included the space for laying temporally brick work to enable the laying of the foundation slab. The laying of the foundation slab should be done at a go after mixing the concrete that is enough for the whole slab. The original pegs can now be used to determine the level of the concrete at every point around the base to ensure that the slab is level and also uniform.
It is very important to have the slab levelled since that is where the whole plant will sit and proper distribution of weight ensures that there will be no cracks.
Casting of the foundation should be done early in the day so as to allow sufficient time to place the first layers of brickwork later into the fresh concrete at the same day.

The centre pipe is fixed in the centre of the excavation before casting the slab.

The centre pipe is the heart of the construction. The GI pipe should be exactly vertical; this can be ensured by use of a water level and adjustment with binding wire fixed at pegs on soil top level to hold it in place.
The foundation ring where the brickwork settles is shaped horizontally and levelled before filling the concrete of the foundation. For bigger sizes of Biogas Plants and on weak ground the foundation ring should be armed (ring beam).
A mixture of 1 : 3 : 5 is used (cement : sand : ballast) measured by volumes!

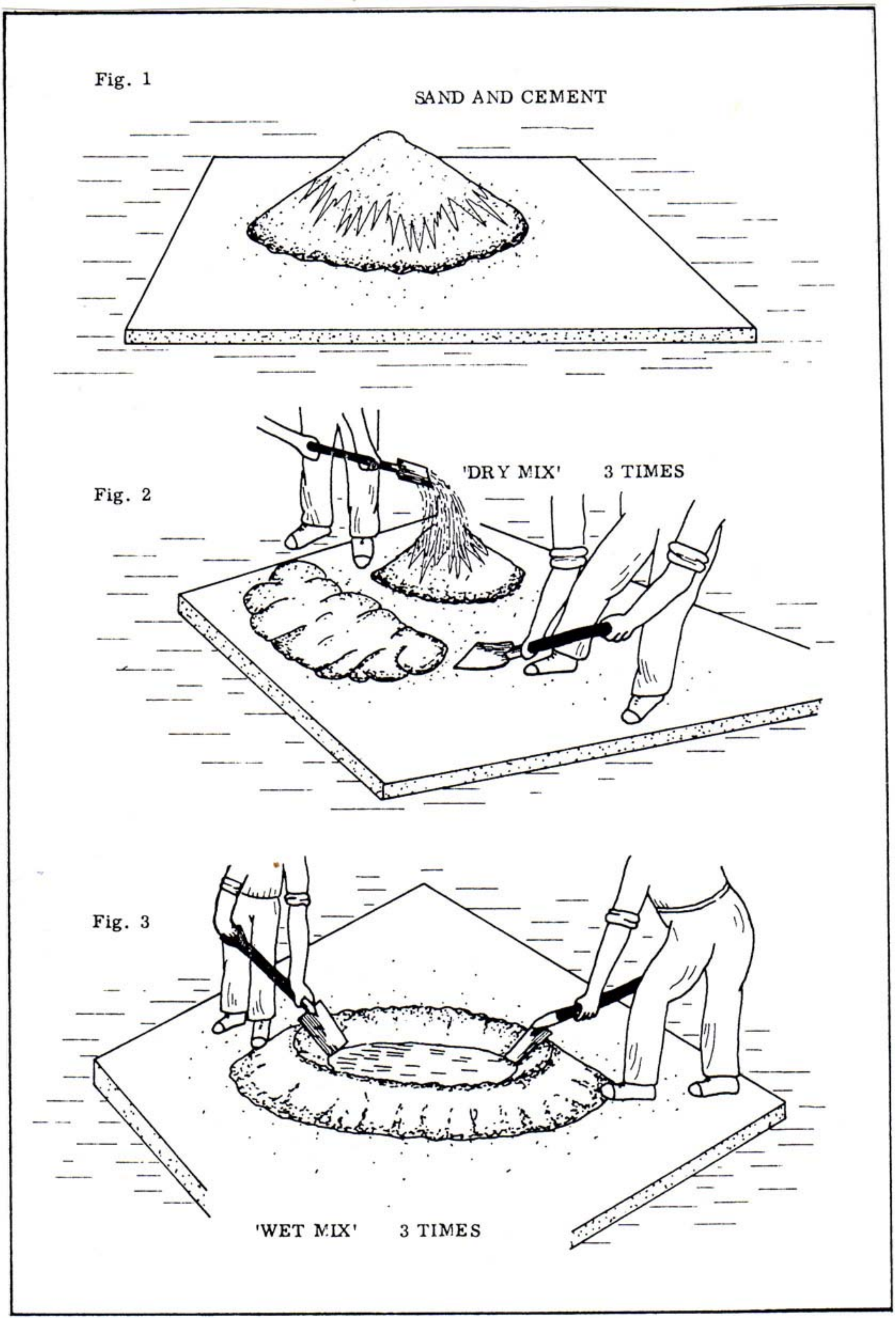
4.2. Mixing Concrete and mortar

Machine mixed concrete, properly attended to make the best job. The hand job is heavy and we therefore suggest the following technique:
To prepare a proper and **clean** mixture you have to use firm surface. Therefore you prepare a lean concrete platform! You never are allowed to prepare mixtures on soil! Ordinarily the ballast is measured out on this platform, then on it the sand and on that again the cement according to the ratio indicated.

The ingredients have to be **measured by volumes**, for example 1 **wheelbarrow** of cement and 3 **wheelbarrow** of sand and 5 **wheelbarrow** ballast!!

Everything is turned over at least four times. The correct method of turning over is the shovel to slide along the floor, pick up the load and spill the load over the top of the new pile. The **two men work** turn about so that one is picking up the other is emptying. The main point is that each shovelful is turned over the top of the new pile and runs down the sides of the cone evenly.

This is the easiest and the best way of mixing dry or wet concrete and all other options should be eliminated.
When the dry mix has a uniform colour it may be considered to be well mixed, but to be sure, turn it over again. When the batch has been thoroughly mixed dry, form a crater or pool, the sides being drawn out toward the edges of the mixing platform. There should be no mixture in the middle of the pool. Now pour in gently, the amount of water you want for the first stage of the mixing.



Turn the shovel over and with the square edge scrapping along the floor, push some of the dry mix out into the pool in such a way that it spreads out, the water under and over it, becoming saturated with the least possible of a washing action which would separate the cement and the sand. When the entire dry mix has been heaped up in the centre of the pool it should have taken up all the free water. As in the beginning, turn this mass over and back at least for four times. Thoroughly mixing is essential to good concrete.

It cannot be too strongly emphasized that too much water will weaken concrete.

Hence, measure out the water carefully. Use what you are sure will be sufficient and mix thoroughly. If a little more is required, measure that too. Follow the batch to the place of deposit and observe whether there is too much or too little moisture in the concrete. It should shake, or spade, or pound into a solid mass without any voids and free water laying on the top. Mix the second batch accordingly.

4.3. Placing Concrete

Concrete bases and forms and all the reinforcement should be in order readiness before the concrete is mixed so that there will be no delay in placing and no disarrangement after placing.

All earth bases and forms should be wetted just enough to prevent the absorption of the water from the concrete and not so much that there will be excess water content of the mixture.

All carrying receptacles should be ready and wetted
All the equipment and tolls necessary for the handling and finishing of the concrete should be ready.
All scaffolds, passage and other items pertaining the safe and prompt handling of the concrete should be in readiness.
We repeat all concrete should be in place and finished within one hour after the water is added to the cement. There should not be a shortage of water during operation.

4.4. Curing

By curing we mean the process for controlling the moisture in new concrete that the maximum strength will be obtained. When concrete first turns white, it has set, and does not increase in strength appreciably if at all, if wetted again.

The purpose of curing is to retain the moisture of the new concrete for as long a period as is practicable.
Concrete kept damp for the first ten days is 72% stronger than if left to cure in dry air. Twenty-one days dampness increases the strength 124% four month 207%.
Warmth is conducive to strength of concrete during the curing period. But protect from frost, vibration, movement, or any work, which will involve scraping, cutting, bruising of the surface.
Concrete supported by posts, beams and forming must be kept supported through out the curing period. Otherwise and concrete will probably and may easily fracture. This applies almost entirely to reinforced concrete floors and beams.

5. BLOCK AND BRICK LAYING

5.1. The Cylindrical Masonry Wall

The digester wall is constructed of either blocks or stone masonry depending on the local availability of these materials. The wall thickness of the wall is usually 15 cm.

Masonry Mortar Mixture for block laying: 1 : 1/2 : 5 (cement: lime : sand).

The construction of the vertical wall starts with bringing down the first blocks on the level part of the concrete slab. To construct the cylindrical masonry wall, a guide square fixed at the centre GI pipe is used which keeps the radius constant. It is very important to make sure that all the blocks are laid out properly with the assistance of the radius square.

The radius square should always be levelled during the laying if the vertical wall. This should be ensured by the use of a spirit level at every point during the laying of the blocks. It's also very important to check that the dimensions are okay at every stage by measuring the vertical distance **from the reference line**.
After 3 to 4 layers of blocks, backfilling and compacting should be done so that the complete part is properly reinforced by the soil.

Note: on sites with high groundwater level the cylindrical wall has to be plastered also from outside before backfilling!

After that space for the outlet steps is immediately dug out and the construction of the vertical wall proceeds incorporating the outlet steps. Completion of the vertical wall construction should include installing of the inlet pipe (slope 45^0C) taking into consideration the location of the inlet mixing chamber. At the level of the expansion chamber the 45º elbow is levelled according to measurement given.
Backfilling should continue until the forming of the ring beam.
The interior part of the digester wall has to be plastered. The mixing ratio is 1 part cement and 5 parts sand, and if the plaster is too harsh, 1/2 part of lime can be added. Before application, the surface of the wall should be cleaned and moistened and then the plaster is applied in one coat of about 2 cm. These plasters are applied to ensure that the structure is firm and watertight.

5.2. Brickwork of Spherical Wall (Dome)

To construct the spherical masonry dome another square is used which leads to create an absolute half bowl shape. The square should be fixed at the central GI pipe according to the measurement given a proper position and level. The radius square should always be controlled during the dome construction: fastening and correct distance from the guide pipe.

A nail at the head of the square is marking the exact distance for the brickwork construction. Each brick of the dome is laid against the nail of the radius stick. It is easier to do than to describe. Just start putting brick by brick, keeping the top of the brick in the same slope as the direction of the radius stick, which radial is pointing to the centre pipe. Automatically brickwork will turn out in spherical shape. Fired Bricks must be of good quality, preferably of 24 : 12 : 9 cm in size. Bricks less than 8 cm in thickness should not be used. The bricks are soaked in water before being laid into 1 cm mortar bed.

The masonry mortar for brick laying: 1 : 1/2 : 4 (1 part cement, 1/2 part lime and 4 parts sand).

For masonry works the mortar brickwork should always include a certain amount of lime. This makes it more workable, and the masonry becomes more watertight.

Gauge boxes or buckets are used to measure the volumes for mixing the mortar. Only sieved and washed river sand is permitted; other wise the amount of cement must be increased if only quarry sand is available. Vertical joints should be "squeezed" and must, of course, be offset. The inner edge o the brick forms always a right angle with the radius stick.

Also the outside part of the dome should be covered by a good plaster layer to reinforce the dome before covering with earth. **Cement plaster should not be applied on a wall while exposed to the sun.** If so the newly applied coat has to be protected against sun.

Even layer of Using the reference line, the expansion chamber is then demarcated, excavated and constructed.

5.3. Plastering or Rendering

5.3.1. Outside plaster of the digester dome

Rendering Mortar: 1 : 5 (cement :sand).

Before application, the surface of the wall should be cleaned and moistened and then the plaster is applied. Only sieved and washed river sand is to be us for plaster. After brickwork has reached a certain level, smooth plaster of 2 cm thickness and a **ratio of 1 volume of cement to 5 volumes of sand** mixture is applied all over the outside. The plaster should harden over night before back filling of soil is done.

5.3.2. Inside plaster of the digester dome

Every inside plaster course has to be done at a go to ensure the gas tightness of the dome. The final plaster of the dome has a smooth surface for better gas tightness it is applied **in seven courses**. Before application, the surface of the wall should be cleaned and moistened and then the plaster is applied. The sand for plastering has to be river sand, clean without dust or other impurities. Before mixing with cement, it has to be sieved! The ingredients have to be **measured by volumes**, for example 1 **bucket** of cement and 4 **buckets** of sand!!

The plaster to make the dome gastight consists of the following layers:

1st layer: cement – water brushing

2nd layer: cement plaster, ratio: 1 cement : 2,5 sand

3rd layer: cement – water brushing

4th layer: cement plaster, ratio: 1 cement : 2,5 sand **with water proof compound**

5th layer: cement – water brushing **with water proof compound**

6th layer: cement plaster ratio: 1 cement : 2,5 sand **with water proof compound**

7th layer: cement – water finish **with water proof compound.**

6. PRINCIPLES OF PIPING SYSTEM FITTED TO BIOGAS PLANTS

6.1. The Problem.

A logical consequence results out of the Biogas Unit approach:
Due to the planning specification that a Biogas plant is connected to a stable, a piping network can be comparatively long. Therefore much stress has to be given on a good quality of the piping. Special training of artisans is required.

Gas piping is in several aspects different from water piping:

- Water condensation can occur in the piping.
- It is difficult to see leakages.
- It is important to avoid dirt in the piping.
- All pipes have to be installed with a slope

6.2. Technical Solution

6.2.1. Material

Under plastic pipes we differentiate PVC, PPR and HDPE. PVC is not resistant against ultra violet rays. As first priority PPR pipes should be used. The piping should have as little amount of joints as possible.

For long distances HDPE pipes are less expensive. But physical damage can happen easily. But usually you can't find fittings which are gastight!

6.2.2. Size of pipes

The smaller the diameter of the piping is the higher the decrease of pressure in the pipe. The high pressure of a fixed dome plant (more than 120 cm water column) can compensate this to a certain extent. The bigger the diameter of the pipe is the better the performance at the consumption points. One size of piping only makes the work easier.

6.2.3. Water traps

General problem: Warm gas condenses to water in cold pipes. In particular underground piping can condense amounts of water which might lead to blockages or at least to a disturbed gas flow. Occasionally water can be transported to consumption points, disturbing the cooking or lighting and lead to corrosion.

Solution:

Water trap preferable automatic, with at least 20cm of security.

A non-automatic water trap, which is made out of a T-joint at the lowest point of the piping, a storage pipe and a water release valve, is a rather sensitive installation. It requires a chamber to be constructed and regular care. The valve can leak.

An automatic water trap is normally underground. Dirt can enter from outside and block the trap. Flooding water or soil erosion causes biggest danger. As the trap is any way at a deep point of the area, it is in or near a waterway for surface of flow. As long as water stands over the pipe, the gas piping is blocked.

6.2.4. Specific problem for fixed dome Plants

Maximum pressure if calculated for 120cm can occasionally rise to 140 cm pressure, especially if the overflow point or outlet pipe is blocked. In that situation an automatic water trap might also save a Biogas Plant from bursting, as high pressure will release gas through the water trap, before damage is caused to the plant. There are different way on how to make the automatic water trap, each of them has its advantages and disadvantages.

- U – Pipe completely underground. Maximum pressure plus buffer 20 cm, one pipe connected to piping, the other end opens to the atmosphere.
- Pipe in pipe, both pipes maximum pressure plus buffer.
- U-pipe with short end connected to piping, pipe open to atmosphere comes out of ground (Sketch).

Comparing these three solutions the third one bares several advantages compared to 1 and 2:

- No chamber required
- In case of problems, customer can easily help himself.
- Only made out of standard fittings
- Not block sensitive against surface water or erosion,
- Less digging work during installation.
- Fast identification of unsatisfactory operation.
- Less material required.

The only disadvantage is that the installation requires careful planning, in particular if the maximum pressure of the connected plant is not standardized.

6.3. Work Procedures

6.3.1. Planning

When using galvanized steel pipes the following principles should be followed:

As much of the piping as possible should be under ground. No unnecessary distances should be covered.

Consider possible future changes on the farm. Define position of water traps (as little in number as possible). The Biogas plant itself can act as a water trap if the piping or a part of it is sloping towards it and the pipe goes through the neck instead of the lid. Logical positions of water traps are depressions in the landscape which is crossed by the piping system. It has to be avoided however that a water trap is positioned where it might disturb like in gangways. Usually there is a possibility to place it near a house wall or some fixed structure.

Special care is required, when roads are crossed. Pipes should be either protected by a concrete casting or positioned in a GI-protection pipe. If the piping is deeper than 30cm sand bedding around the pipe is enough.

Soil erosion has to be considered in this case very seriously. The closer the piping is coming to the surface of the road, the bigger the changes of damages. Ensure that rainwater does not wash away the covering soil.

Consider later changes of the piping, like additional gas consumption points.

T-joints with plugs are not expensive to be installed from the beginning and can save a lot of effort on the day when the additional gas accessories get installed.

  - Consider misuse of exposed pieces of pipes
  - Avoid sharp bending of the pipe, maximum bend 45^o
  - Consider changes in the farm like future structures.

6.3.2. Digging of trenches, chiselling

Ensure that the dug out canals are already equipped with the planned slopes. During rainy season ensure that trenches are not turning to be drainage channels for the running off water (over night).

Don't let the piping disappear under plaster. You cannot avoid leakages completely and forever.

6.3.3. Fixing of pipes

Look and blow through every pipe before installation to prevent blockages and to remove dust particles. Control sloping either towards the plant or towards one of the water traps. At least a slide slope is enough.

Avoid flexible hose pipe connection as much as possible. Use only texture reinforced hose pipes. Garden hoses are not suited. They can bend and reduce gas flow tremendously. The hose is connected to the piping and to the consumption point with a hose pipe connector and gets tightened with a clamp.

PVC pipes have to be protected with a sand layer below and above = all around the pipe before you close the trenches.

6.3.4. Final pressure test by supervisor

When all the gas consumption accessories are installed and **before** you close the trenches a final pressure test is done.

This definitely has to be done by the supervisor. The artisan will always say it is ok as it is difficult to trace a leakage in the whole piping network. To trace leakages, soap form is distributed around the joint of the piping system while under pressure. Leaking joints have to be re-sealed.

6.3.5. Finishing work

Part of the piping is to close up all trenches and holes chiselled in the walls. Explain to the customer what has been done; explain the possible problems that can happen to the trap and how to solve them.

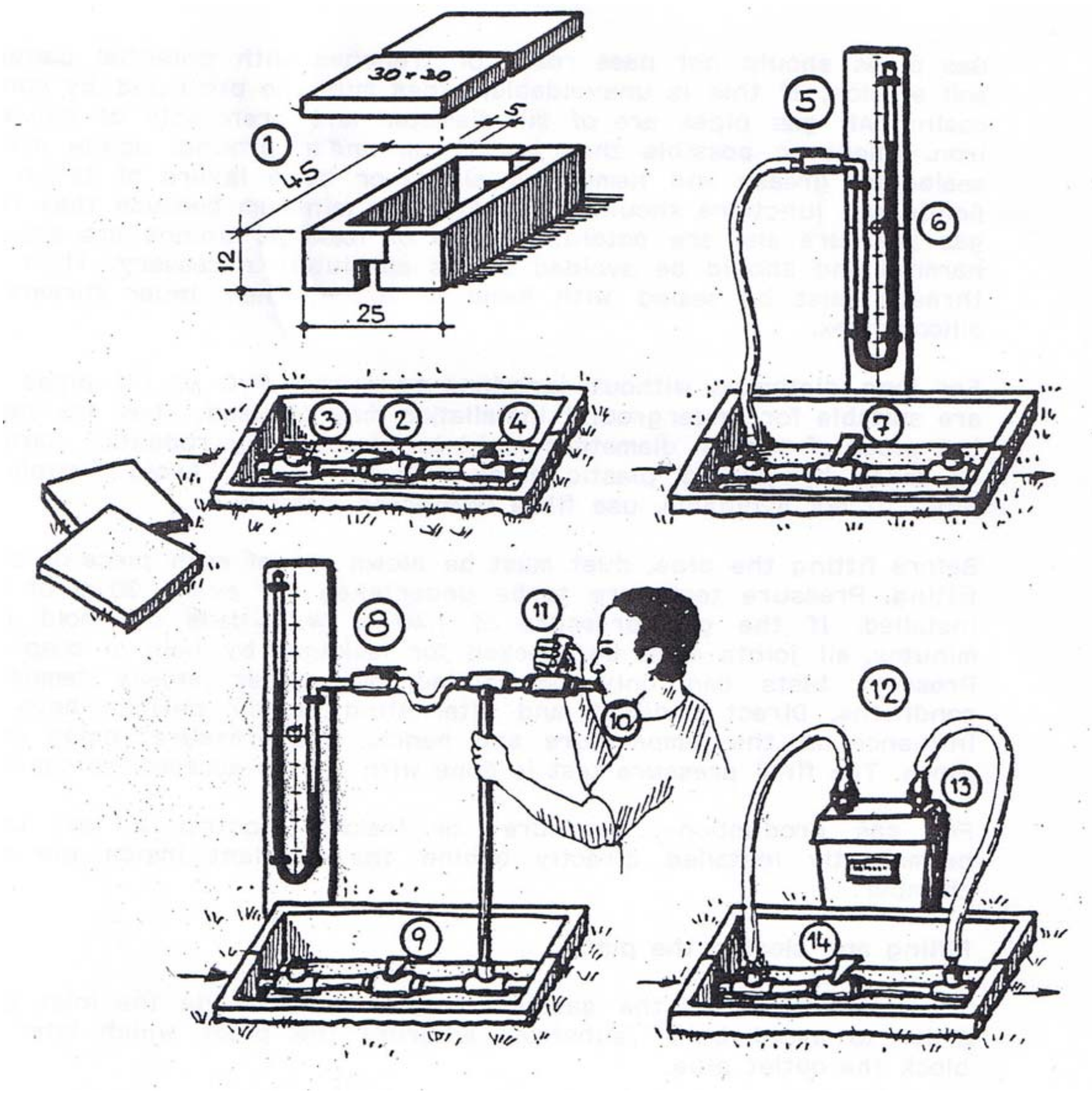
Again the possible rainwater ways and possible erosion has to be considered. Dig preventive rainwater guiding channels if required.

6.3.6. Maintenance of pipes

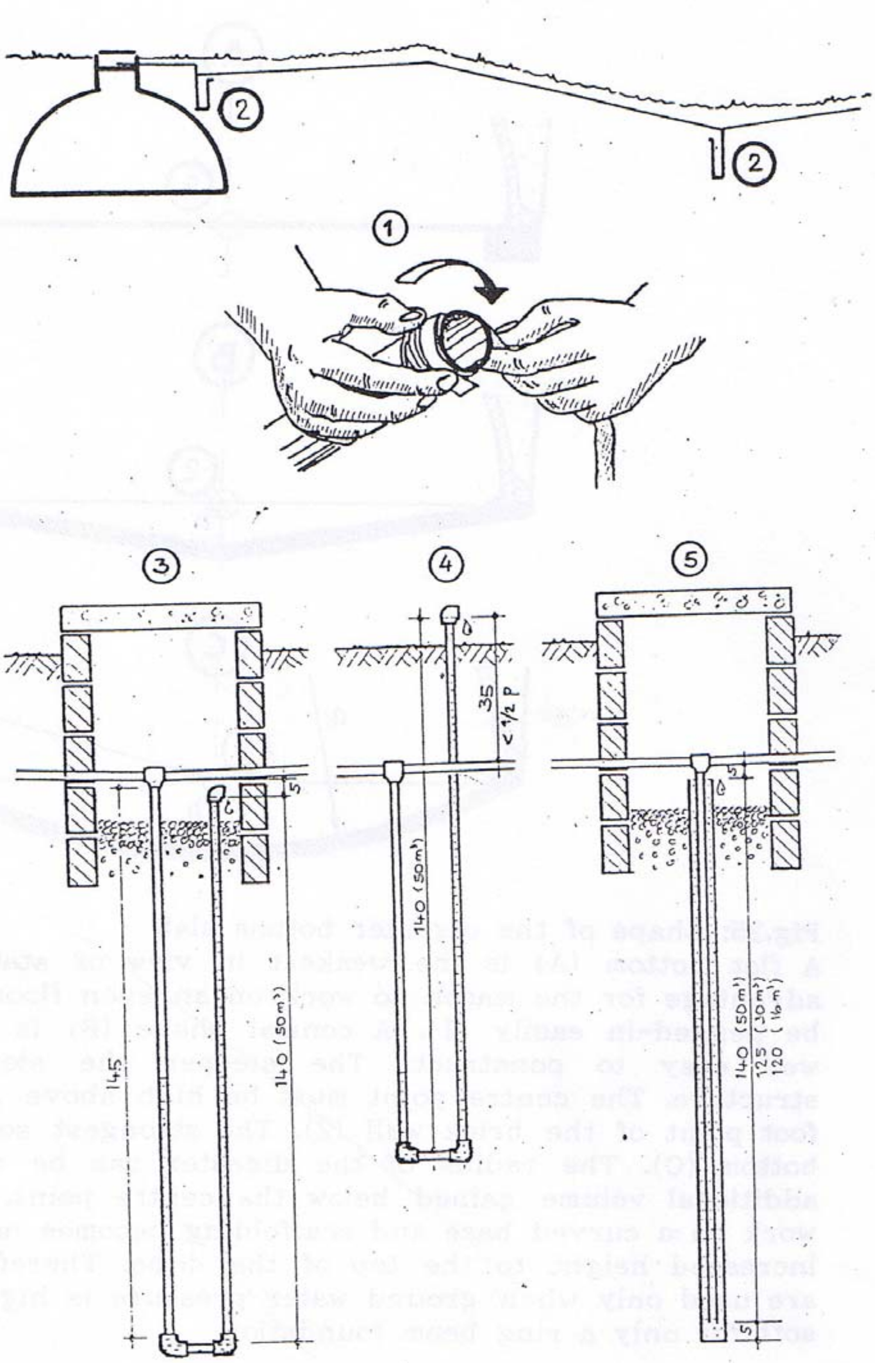
Beside regular check ups every occasion where the customer mentions that the plant is not performing as expected has to include a test of the gas tightness of the piping.

If the gas supply is not satisfactory but neither the piping nor the plant has a leakage, it may happen that the piping blocks.

One possibility for this is that slurry particles are entering the pipe. Another possibility is that the water trap blocks due to material that has entered.



The Test Unit



1
2
2
3
4
5
145
140 (50m³)
5
35
< 1/2 P
140 (50m³)
140 (50m³)
125 (30m³)
120 (16m³)
5
5

Water Traps

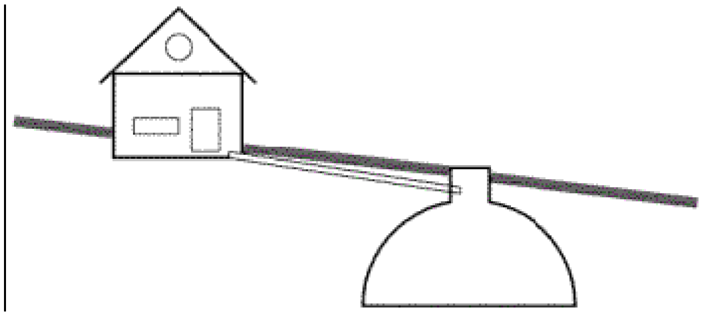


Figure 1:
Piping system with straight slope from the kitchen to the digester. No water trap required as condensation water drains into the digester

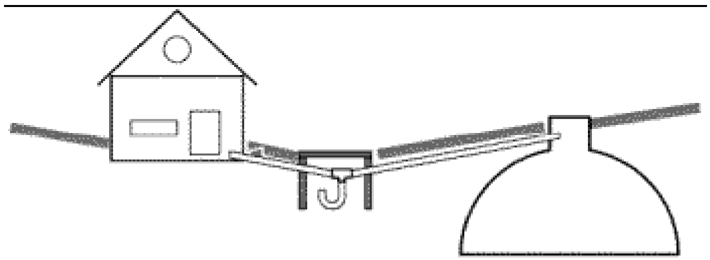


Figure 2:
Wherever condensation water cannot drain back into the digester, a water trap becomes necessary.

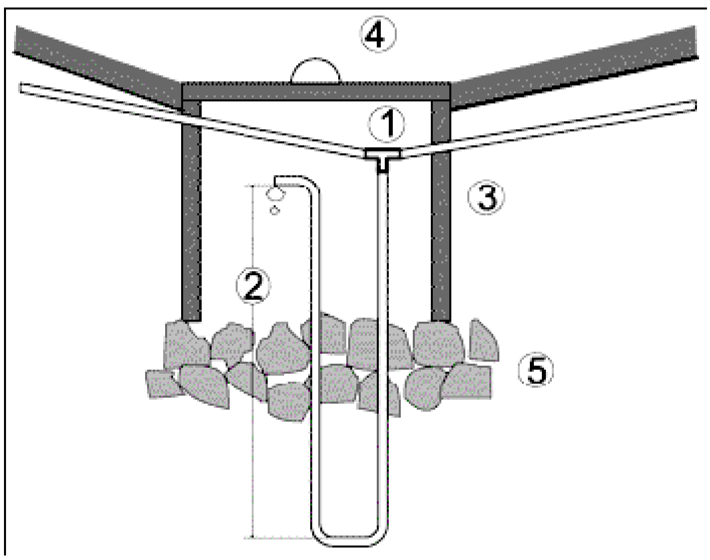


Figure 3:
Automatic water trap: (1) T-joint in the piping system, (2) water column, equal to max. gas pressure + 30% security, (3) solid brick or concrete casing, (4) concrete lid, (5) drainage

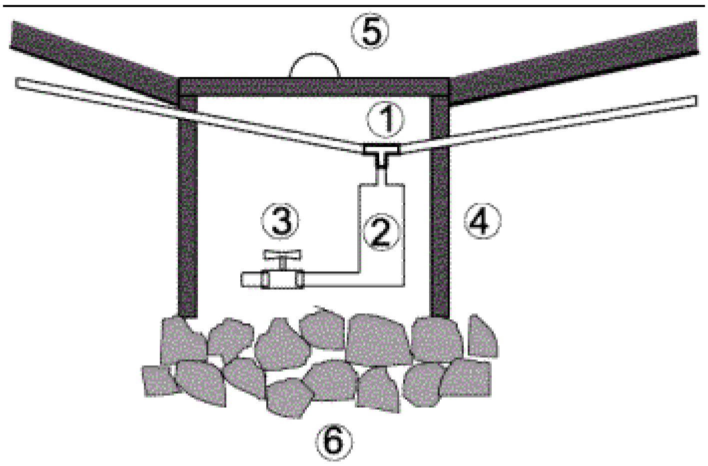
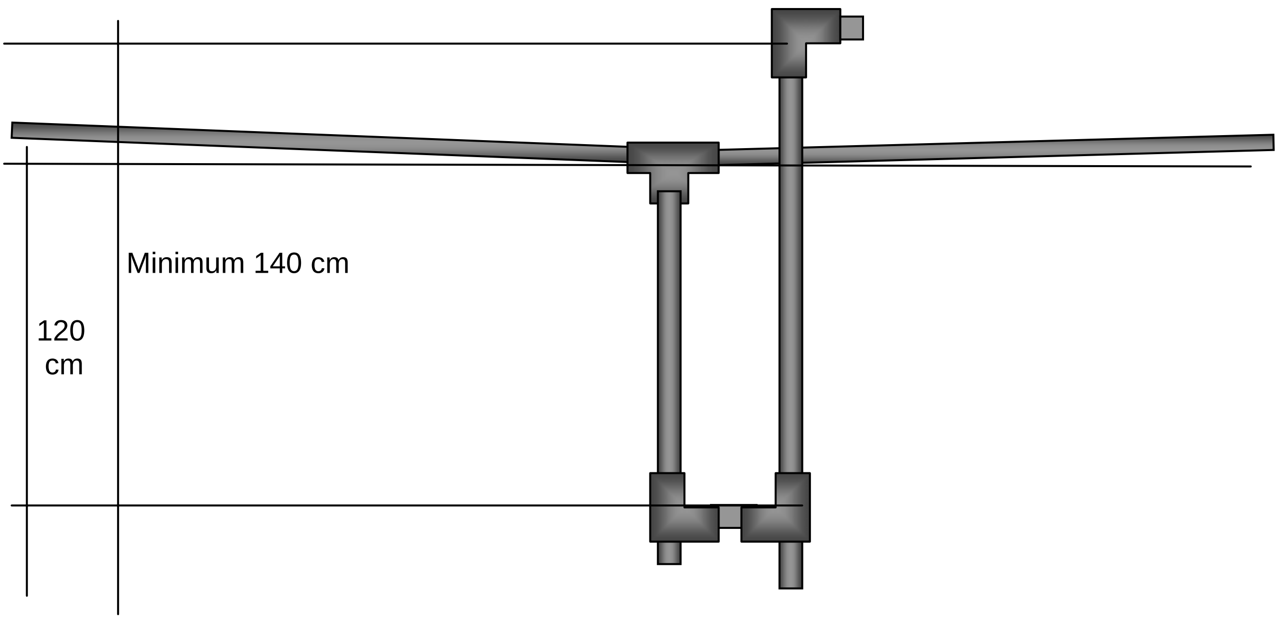


Figure 4:
Manual water trap: (1) T-joint, (2) buffer storage for condensate water, (3) manual tap, (4) casing, (5) concrete lid, (6) drainage

The asymmetrical U-trap (see below) is the best option in terms of cost and operation. The advantages include:



No housing chamber is required

- In case of problems, the customer can easily help himself.
- Only made out of standard fittings
- No block sensitive against surface water and erosion.
- Less digging work during installation
- Less material required

The installation requires careful planning especially if the max pressure of the plant is not standardized.

7. Annexes:

Annex I

Properties of combustible gases

Gas	Composition: Constituents	Composition: %	Calorific value kWh/m³	Density (air = 1) (ρ = 1.2 kg/m³)	Combustion speed cm/s	Air requirement m³/m³
Methane	CH_4	100	9.94	0.554	43	9.5
Propane	C_3H_8	100	25.96	1.560	57	23.8
Butane	C_4H_{10}	100	34.02	2.077	45	30.9
Natural gas	CH_4; H_2	65; 35	7.52	0.384	60	7.0
Town gas	H_2; CH_4; N_2	50; 26; 24	4.07	0.411	82	3.7
Biogas	CH_4; CO_2	60; 40	5.96	0.940	40	5.7

Biogas compared with other fuels

Fuel	Unit u	Calorific value kWh/u	Application	Efficiency η	Net calorific value kWh/u	Biogas equiv. m³/u	1 m³ biogas = u/m³
Cow dung	kg	2.5	Cooking	12 %	0.30	0.09	11.11
Wood	kg	5.0	Cooking	12 %	0.60	0.18	5.56
Charcoal	kg	8.0	Cooking	25 %	2.00	0.61	1.64
Hard coal	kg	9.0	Cooking	25 %	2.25	0.69	1.45
Butane	kg	13.6	Cooking	60 %	8.16	2.49	0.40
Propane	kg	13.9	Cooking	60 %	8.34	2.54	0.39
Diesel oil	kg (ℓ)	12.0	Cooking	50 %	6.0	1.83	0.55
			Engine	30 %	4.0	2.80	0.36
Electricity	kWh	1	Cooking	67 %	0.67	0.20	5.00
			Light	9 %	0.09	0.50	2.00
			Motor	80 %	0.80	0.56	1.79
Biogas	m³	5.96	Cooking	55 %	3.28	1	1
			Light	3 %	0.18	1	1
			Engine	24 %	1.43	1	1

Utilization and consumption of biogas

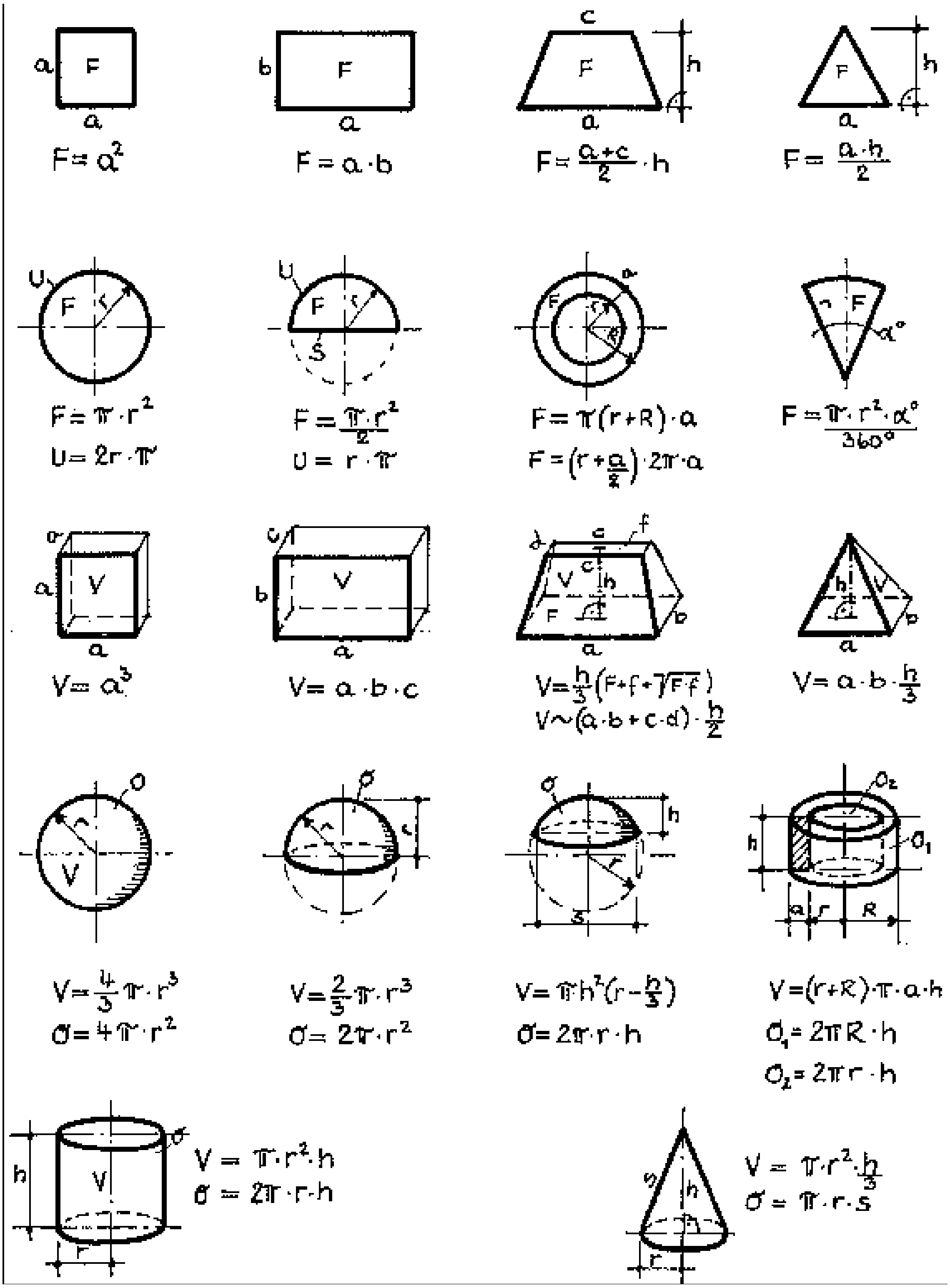
Household burners	200–450 ℓ/h	Biogas/diesel engine per bhp	420 ℓ/h
Industrial burners	1000–3000 ℓ/h		
Refrigerator 100 ℓ depending on outside temperature	30–75 ℓ/h 720–1800 ℓ/day	Generation of 1 kWh of electricity with biogas/diesel mixture	700 ℓ/h
Gas lamp, equiv. to 60 W bulb	120–150 ℓ/h	Plastics moulding press (15 g, 100 units) with biogas/diesel mixture	140 ℓ/h

Biogas for cooking (practical values from India)

Amount cooked	Time (min)	Gas (ℓ)	Amount cooked	Time (min)	Gas (ℓ)
1 ℓ water	10	40	1000 g rice	37	175
5 ℓ water	35	165	350 g pulses	60	270
500 g rice	30	140	700 g pulses	70	315

A family of five consumes 850–2500 ℓ of gas per day depending on eating and other habits (e.g., bath-water?). A family of ten consumes 15–30 % more.

Annex II:


F = a²
F = a·b
F = (a+c)/2 · h
F = a·h/2
F = π·r²
U = 2r·π
F = π·r²/2
U = r·π
F = π(r+R)·a
F = (r + a/2)·2π·a
F = π·r²·α°/360°
V = a³
V = a·b·c
V = h/3 (F+f+√(F·f))
V ~ (a·b+c·d)·h/2
V = a·b·h/3
V = 4/3 π·r³
O = 4π·r²
V = 2/3 π·r³
O = 2π·r²
V = πh²(r − h/3)
O = 2π·r·h
V = (r+R)·π·a·h
O₁ = 2πR·h
O₂ = 2πr·h
V = π·r²·h
O = 2π·r·h
V = π·r²·h/3
O = π·r·s

8. LITERATURE:

Ludwig Sasse: Biogas Plants

Intermediate Technology: Rural Building Course

Intermediate Technology: A Manual on Building Construction

Werner; Stoehr; Hess: Biogas Plants in Animal Husbandry

Christopher Kellner: Biogas Manual for Lesotho

Guenter Ullrich: Taller de Construccion de Biodigestores Agrarios de Cupula Fija

Mike Greig: Plastic Piping Systems, Guide to Design and Installation. ISBN 1904133339*.*

Dr Tarik Al-shemmeri BSc MSc PhD CEng MIMechE of Staffordshire University: *The* Red Book, A Guide to the Design and Installation of Plastic Pipeline Systems. ISBN 1897898819*.*