

# **Methane Digester Production System**

## BASIC PROPERTIES

2.

Methane is a colorless, odorless gas in the group of hydrocarbons. It is of course, a flammable gas. Its chemical representation is  $\text{CH}_4$ . Depending on the area found, Methane gas makes up to 85 to 90% of our natural gas reserves.

Since natural gas is composed mainly of methane, the two gases in separate states offer similar thermal characteristics. A cubic foot of Natural gas yields a thermal value of about 1000 British Thermal Units. The gas produced by the following procedure will have other "diluters" within it, therefore having a lower thermal value. This type of Methane gas actually offers about 600 BTU's per cubic foot.

In Vehicles, about 220 cubic feet of gas equals 1 gallon of gasoline. Internal combustion engines require 18 cubic feet of methane gas per horsepower per hour.

The concept of producing Methane gas by the process of Anaerobic Digestion is not a new one. Methane was produced by this process as early as 1870, with methane productions programs set up in India as early as the turn of the century. Of course the second World War motivated Germany to produce methane gas in digesters. This gas was then used to run tractors and other vehicles, and the final by-product which makes a good fertilizer was spread upon the fields. Digestion to produce methane gas also can occur in natural conditions, often being produced in murky swamp waters. This has brought about the term "swamp gas" in reference to methane. There are currently thousands of digesters in use all over the world, varying from extremely complex commercial plants to backyard farm units. Countries that are predominant in this area are: India, South Africa, France and several others in Africa.

## ANAEROBIC DIGESTION

Anaerobic Digestion is one of the most common biological procedures in nature. As the name implies, it means decay or breakdown in the absence of air (more specifically oxygen). This process is similar to fermentation, since tiny micro-organisms called anaerobes bring about the transformation. Like in the production of ethanol, digestion or fermentation must take place in two steps. Firstly, in the medium of digestion, certain micro-organisms break down the materials into simple sugars, alcohol, glycerol and peptides. When these components are present in the correct amounts and the conditions are correct, a second group of micro-organisms convert these simpler, broken down molecules into methane gas. These methane producing micro-organisms are particularly sensitive to environmental conditions.

Temperature and acidity are two areas that require close attention. Anaerobic digestion occurs within a temperature range from  $32^{\circ}\text{F}$  to about  $150^{\circ}\text{F}$ . However, there are optimum conditions of temperature

that promote maximum activity of the micro-organisms. This will produce more methane gas. Temperatures below 60°F produce little gas. The best temperature to operate the digester at is the range between 85 and 95°F. In some climates, this will be difficult to maintain, so efforts to get as close to this range as possible is all you can do. Acidity in Anaerobic Digestion is important as well. A pH range of 7 to 8 is desired. Adding too much raw material to an existing digester that is producing gas, may slow the procedure down until the bacteria can digest enough of it to create an environment with a pH range of 7 to 8. Gas production should then occur. On the other hand, a fermenting solution with a low acid level will cause the fermenting process to slow down until the bacteria can produce enough acid (acidic carbon dioxide) to restore a balance.

The two variables can be measured of course; a thermometer for temperature and a simple acid measuring system like litmus paper to determine the pH level in the solution. A low pH implies too much acid, whereas a high pH implies a low level of acid.

Two other components that are important in the digester are the elements Carbon and Nitrogen. Both elements are required by the bacteria to live in the digester. However, the bacteria consumes Carbon at the rate of about 30 times that of Nitrogen. Consequently, the system will produce maximum amounts of gas when the material put in the digester has a carbon/nitrogen ratio of about 30 to 1. As in the case of the acidity, the bacteria will usually compensate for the imbalances and create this ratio it needs. This occurs at the expense of a low gas producing rate until this ratio is achieved.

The gas produced in these simple digesters is not pure methane. It normally contains 3 parts methane to 1 part carbon dioxide, with trace amounts of hydrogen, nitrogen and other elements characteristic to the original materials used in the digester.

The slurry that is normally left after the digestion is complete, is mainly composed of organic humus, with smaller amounts of nitrogen, phosphates and potash. This final by-product is a valuable source of fertilizer for further productions on farms of vegetation.

Figure 1: Composition of Gas Produced and Resultant By-Product

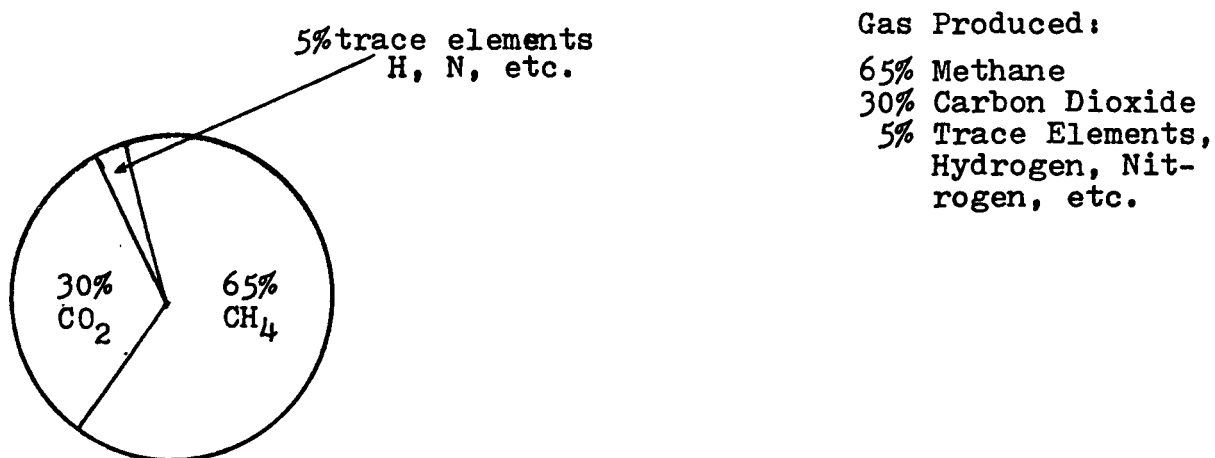
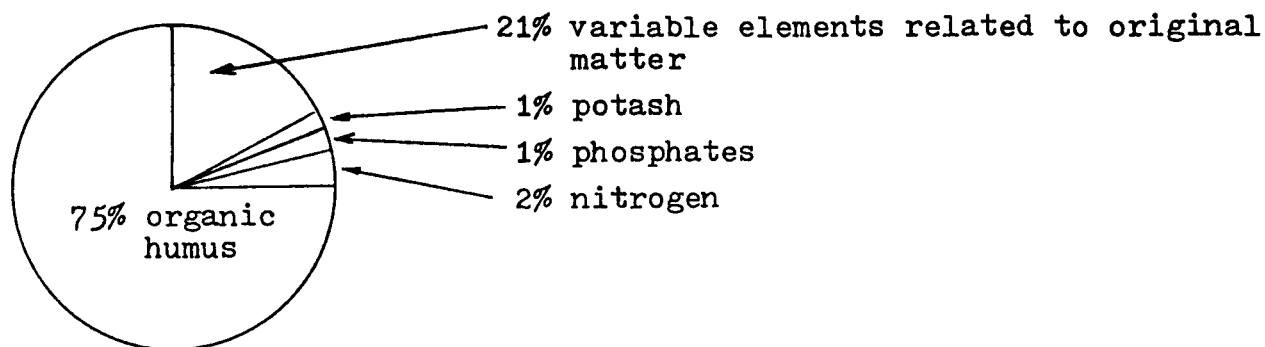


Figure 1 Cont'd: Resultant By-Product after Digestion



Incidentally, the time factor involved in starting this type of system can be as long as a month, but often requires 2 to 3 weeks. A great deal of patience is required when starting up this type of system. Don't get too discouraged- remember, the bacteria will require time to break down the molecules in the slurry into alcohols and sugars, before the second type of bacteria can produce gas. Lastly, it may be necessary for the second bacteria type (the gas producing ones...) to adjust the Carbon/Nitrogen level or the acidity before substantial amounts of gas can be produced.

## SIMPLE ANAEROBIC DIGESTER

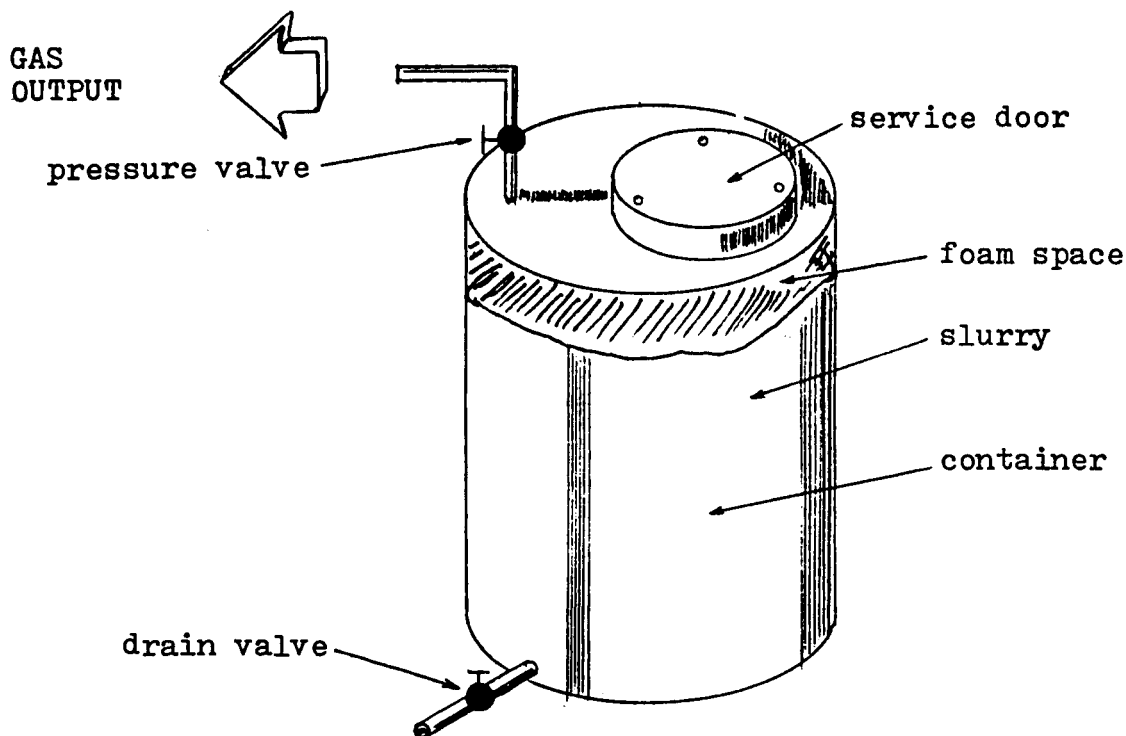
A Digester can be a very simple system. The main component required to make a simple digester is the vessel that will contain the slurry, in order to produce gas within. There must be a way of filling the vessel, as well as a way of extracting the gas as well. On page 5 is a simple digester, shown purely for demonstrative purposes only, and is not recommended for construction in its exact state. Although correct in concept, it lacks a method of gas storage in a safe manner.

## GAS STORAGE

Once the gas is produced, a practical and SAFE means of storing it is essential. Any container that has air in it will mix with the Methane gas as it enters it, producing an EXPLOSIVE combination.

It is therefore necessary to construct a container with ABSOLUTELY NO AIR inside of it, before the methane gas is introduced into the storage vessel.

Figure 2: Basic Anaerobic Digester



This basic digester will produce a modest amount of Methane gas, It is a good model to try out, in order to familiarize yourself with the concept of methane production. A simple container for storing the gas is still required. This must be done of course in a safe manner.

This digester is called a batch-feed system, where a slurry is introduced into the digester by way of a service door, and then sealed. After a couple of weeks, when the conditions within the tank have been adjusted by the bacteria, fermentation commences. An airspace must be left at the top for two reasons: Firstly, the first group of bacteria (the aerobes) require some oxygen to break down the slurry into simple molecules. Secondly, foaming usually occurs during the digestion process, especially in the aerobic stage. If the space is not adequate, foam will travel into the pipes above. After a couple of months, the batch will no longer produce gas. At this point, the drain valve may be opened, and the decomposed matter removed. The container may be flushed out through the service door, but leaving a small amount of old slurry in the container will speed up fermentation when the new batch is introduced.

The following page outlines the construction of the basic Anaerobic Digester, on a batch feed basis...

## LEGAL WAIVER

These plans are your guidelines only. We take no responsibility in regards to the success or safety of this project. Acceptance of these plans warrants this on your part. Proceed with this project entirely at your own risk.

Remember that methane gas is a very flammable gas. Always use common sense when dealing with the production, storage and consumption of methane gas. Methane gas is equivalent to 120 Octane gasoline. When mixed with air it becomes an explosive combination! Always wear protective eyewear when near the digester, or when handling the gas in any manner. Like propane and natural gas, methane can asphyxiate a person in an enclosed area.

## BATCH DIGESTER CONSTRUCTION

This little digester will produce enough free gas to provide heat on a stove for at least 1 meal per day. Modest applications, like lighting small rooms by way of lanterns and cooking are ideal for this system. It can be built for a very small amount of money as well. A simple inner tube from a large tractor tire will make a perfect container for the gas because:

- it is relatively inexpensive and easy to obtain
- it may be purged\* easily by rolling into a tight mass
- it automatically creates a pressure for feeding into appliances, which is safe
- it is about the right volume that this generator can produce, therefore making it compatible to the digester.

\*PURGING a container or line means to remove all the air from it. This is important from a safety viewpoint to prevent an explosion of methane and air, as mentioned earlier. There are two simple ways of doing this:

- Collapsing the container, and exhausting the air from it
- Displacing the air with another substance in rigid lines and containers

The container used in this system will be a standard ~~44~~ gallon oil drum. Make sure that the one you get is relatively clean, with no rust whatsoever. If there were any toxic chemicals, like cleaning fluids, solvents, etc., flush out the tank several times with soap and water, followed by a flush with cold water for several minutes.

A secure base can be made out of a few concrete building blocks. It is best to keep the container off the ground a few inches, to prevent moisture underneath the container from forming rust.

There are normally two vent holes, about 2½" wide on the top of the drum. These alone may be adequate for filling the drum with your slurry mixture. Remember that these must be in good condition and seal gas tight. If a larger access door is required, a gas tight plate can be added after cutting out the appropriate hole. An automotive air filter housing makes a perfect, easy to find plate for this purpose. Since they are normally secured with one or two bolts to the top of the auto's carboretor, a small bracket will have to be fastened across the bottom of the housing, with a bolt to facilitate attachment of the plate.

Figure 3: Optional Access Plate Configuration

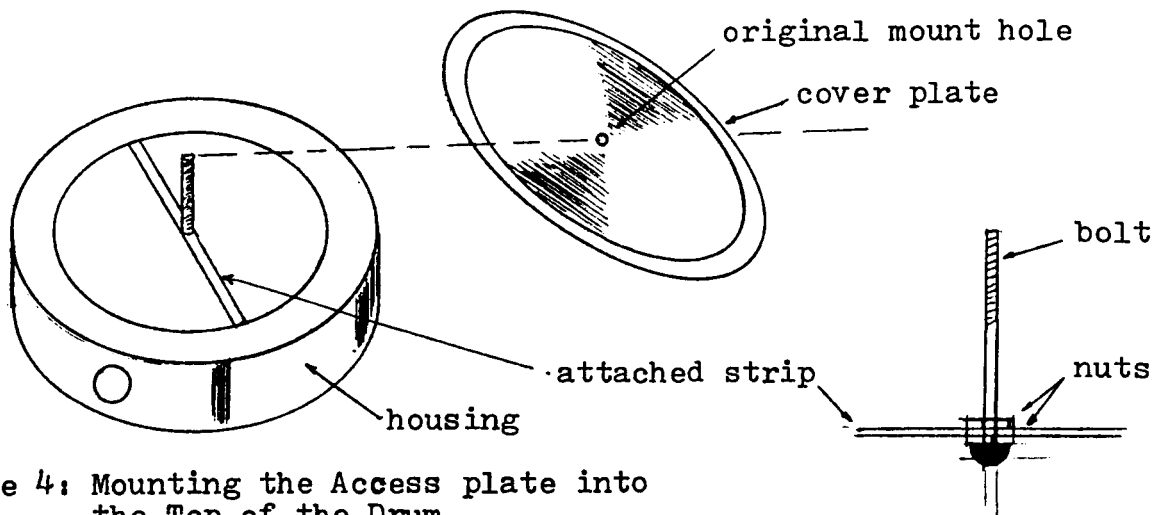
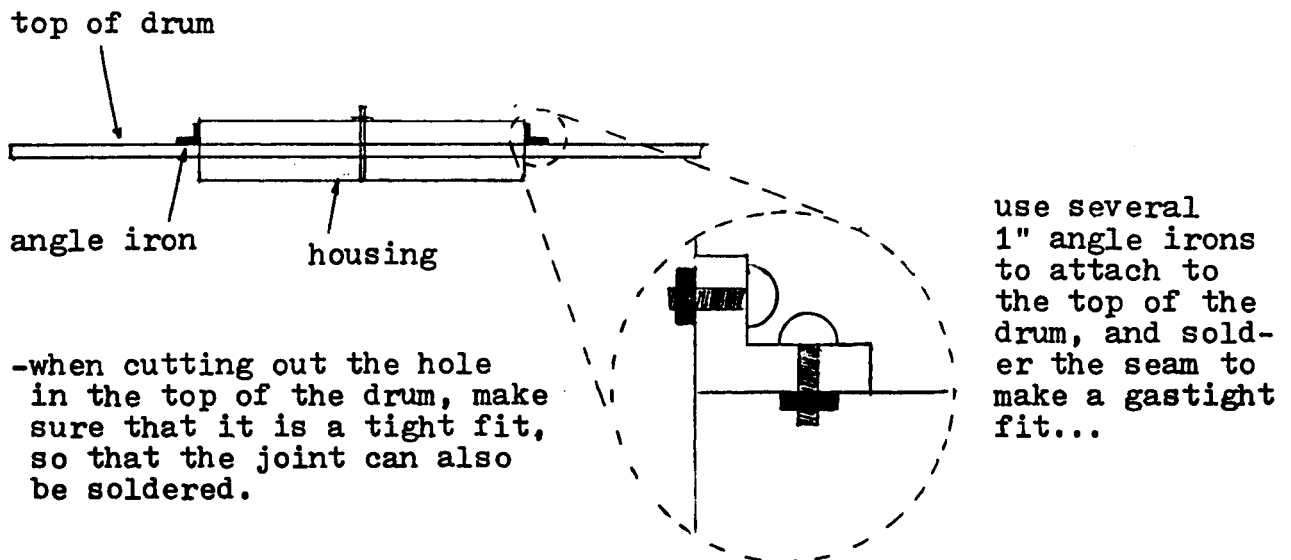


Figure 4: Mounting the Access plate into the Top of the Drum



Lastly, drill a snug fitting hole of  $\frac{3}{4}$ " into the top of the drum at some convenient location and install the following:

Figure 5: Pressure Valve Configuration

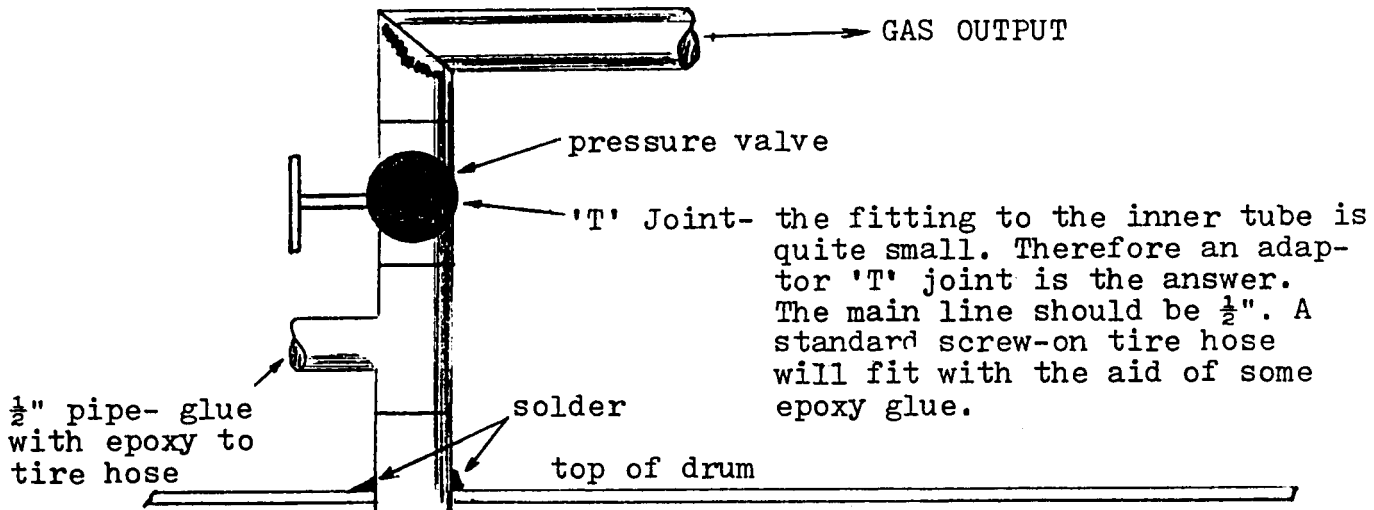
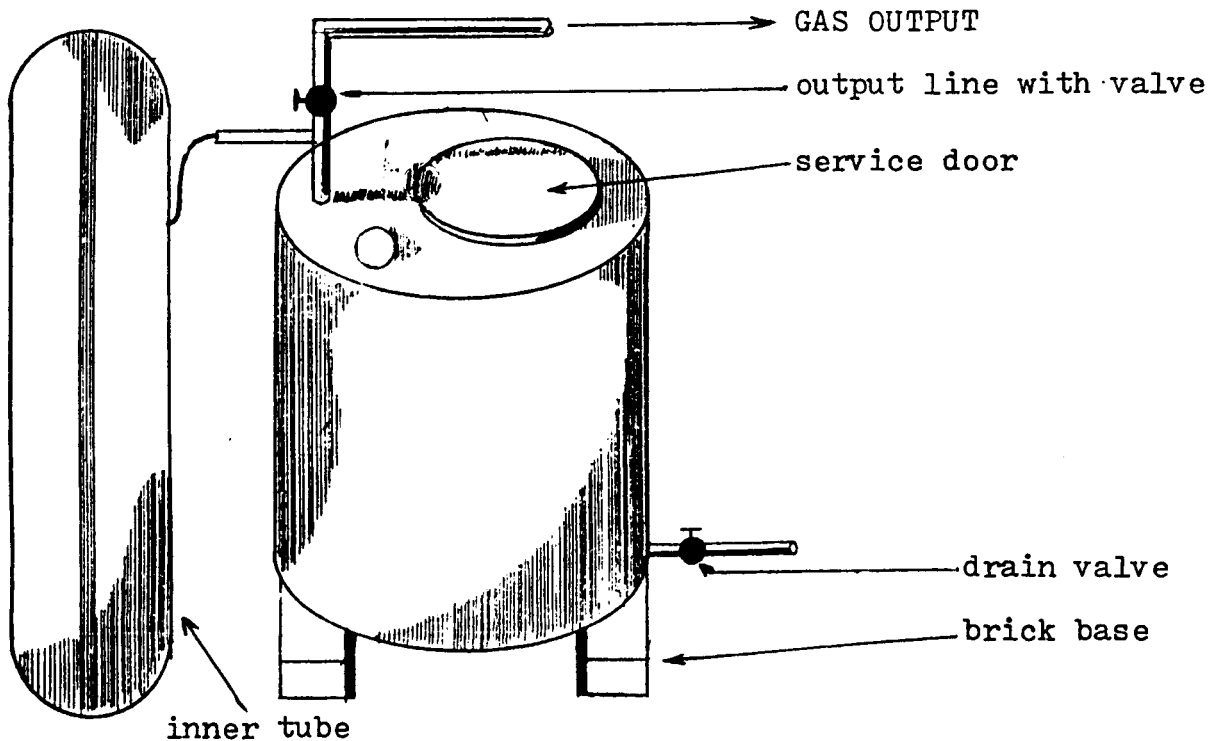


Figure 6: Completed Digester



For larger outputs, this unit can be joined to another in a series configuration, for double gas output. Since these digesters are simple to build, three or four can be employed for added output...



## OPERATION OF DIGESTER

The composition of the slurry, of course will determine the degree of success of your new digester. As mentioned earlier, a carbon/nitrogen ratio in the slurry of 30 to 1 is what is needed. The almost foolproof substance for this system is some sort of manure (!) whether it is from cows, pigs, chickens, horses or whatever. Adding other material like grass cuttings or leaves is acceptable, however by themselves they contain almost no nitrogen. They will therefore not ferment, or ferment at an insignificant rate. With unknown materials, it will be impossible to determine the carbon to nitrogen ration without the aid of a lab analysis. The other alternative is to go ahead by trial and error.

On the farm, manure of some sort should be readily available. As a result, operating a system like this one should be quite easy.

In the city and suburban areas, manure is of course not readily available. However, leaves and grass clippings can be used from the backyard. These substances can be mixed with most of your organic garbage that is normally discarded as trash. The only garbage that is useless is the group of dry goods like paper, cereal boxes, cellophane plastics etc. With a good variety of trash, it is quite probable that the system will eventually deliver free methane gas. You'd be surprised at the amount of organic waste that the average household produces in just one day. Moreover, a high degree of variety in the nature of these organic compounds will more than likely offer the correct acidity and carbon to nitrogen conditions that are required.

Ideally, the slurry that works the best in the digester consists of:

- 3 to 4 gallons of liquified manure
- 10 gallons of water
- enough grass cuttings and leaves (a 50-50 ratio) to fill the container to within a foot of the top.

Then stir the mixture well.

This system, with solids will produce gas after about 2 weeks, peak in production after about 8, and then diminish in output. There will be little, if any, significant production after about 12 weeks.

Liquid animal wastes offer good output after only about 1 week of incubation, however liquid waste is difficult to accumulate and handle on the farm.

Shut the pressure valve off, and place the tube normally leading to the inner tractor tube into a glass of water. When bubbles begin to occur at a steady rate, the system is generating gas.

DO NOT ATTEMPT TO LIGHT THE GAS. Remember, there is still air inside the foam space in the drum. This may cause an explosion. Also, leave the valve shut and let the gas escape out of the side pipe for a few days until you are CERTAIN that all the air has been pushed out into the atmosphere by the methane.

Then, take the inner tube and remove the tire valve. Roll the tube very tightly, thus pushing out all the air in the tube. When all the air is expelled, replace the tire valve and screw on the tube from the "T" joint. The system should now be free of any air (make sure) and ready to accept an appliance, such as a lantern or a small stove.

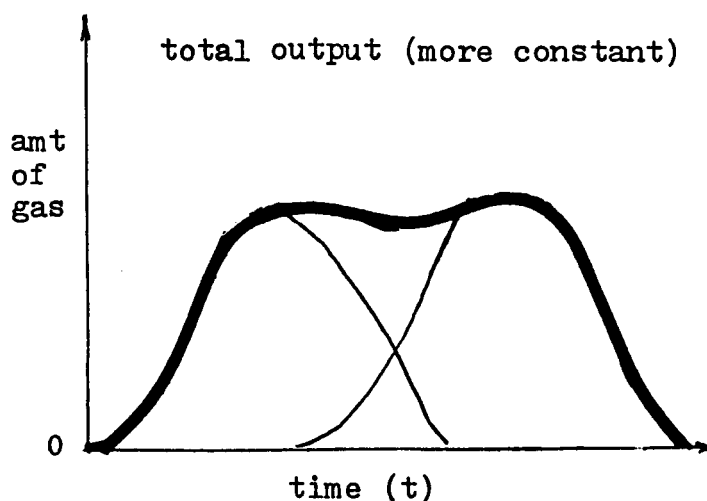
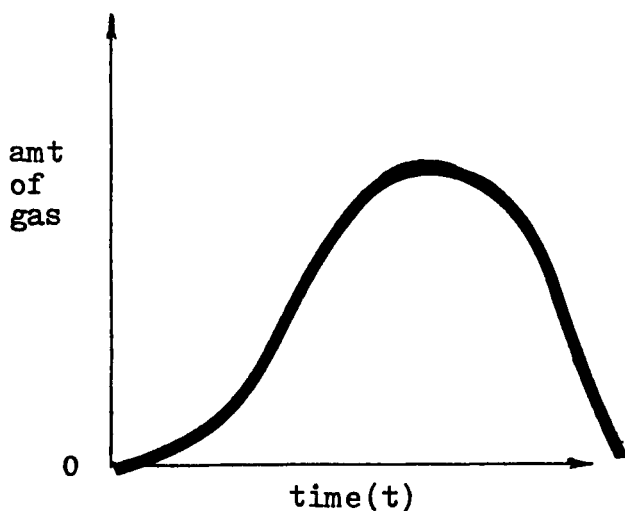
Don't forget to purge every line that is added onto the system so that no part of the system at all has air within it. It is a good idea to let a stove or lamp run for a short time ( a few minutes) without lighting it, to ensure that all the air is pushed out of the system. This only applies when hooking up for the first time, and subsequent reattachments to the digester. Of course purging these systems and appliances should never be done in an enclosed area. Unlit gas can explode or even asphixiate an unsuspecting operator much like natural gas or propane can.

Any natural gas appliance should need no modification, however appliances designed to run on propane (like camping stoves) require larger orifices to burn properly. Also, with a lower pressure, use 3/4" lines to convey the gas, since the smaller lines used normally will not perform with this low pressure gas of lesser thermal value.

## DIGESTER PERFORMANCE

Since we consume energy at a fairly steady rate, this system by itself will offer some drawbacks. Gas is not produced at a steady rate as we would like. The solution is to build 2 digesters so that one is declining in production while the other increases. Their total output will be more constant.

Figure 7: Performance Output of One drum Generator and Two in Series  
a: Drum Digester                      b: Two Drum Digesters



**PARIS:**

- |  |                |
|--|----------------|
| -1 44 gallon oil drum                              | tools: hacksaw |
| -1 optional air filter housing<br>for service door | electric drill |
| -4 bricks for base                                 | propane torch  |
| - supply of 3/4" copper piping                     | solder         |
| -1 'T' joint with 1/2" side fitting                | screwdrivers   |
| -2 valves  | pliers         |
| -1 large tractor inner tube                        | solder         |
| -1 tire hose (screw on type)                       | marking pencil |
| -4 angle irons for service door                    |                |

**CONTINUOUS OUTPUT DIGESTER**

A more desirable system is one that offers a more or less constant output to match our fairly steady needs. Most of the theory that applies to the smaller digester can be extended to a continuous feeding system. Continuous output is achieved by way of continuous feeding of the slurry into the digester. There are several complications that arise in this situation, but they shall be explained later.

Once the system is fermenting, a cycle is determined where it is found that most of the material is digested. With the following design a 30 day cycle is about the best. Normally, the larger the digester, the longer the cycle. Large digesters require up to 120 days to use all the potential within a given mass of slurry.

With this 30 day cycle, day 1 is measured once the digester is fermenting and producing gas, (again within 2 weeks), and 1/30th of the digester's volume, more specifically the volume of the slurry is added daily. Also, 1/30th of the used slurry is taken out.

**Example:**

If the digester is 275 gallons, and the volume of the slurry is 240 gallons (remember the space for foaming), then 1/30th will be added daily, as well as removed. That is, 8 gallons.

There is a simple way of differentiating between the new slurry and the used slurry. As the slurry is digested, the slurry loses mass in a given volume. Therefore, the intake pipe should be placed near the bottom of the digester, and the exhaust pipe near the top.

Since there will eventually be gas at a slightly higher pressure than atmospheric pressure in the foam space, a self contained filling chamber will need to allow the slurry to enter the digester without losing some of the generated gas. This filling chamber will use gravity to allow the slurry to enter the digester.

## CONTINUOUS DIGESTER CONSTRUCTION

A fairly large digester can be built from two 275 gallon furnace oil tanks. One can be used as the actual digester, and the other can be the holding tank.

A feed chamber can be placed at the end of the digester, with an airtight valve at the top and bottom of its column.

The exhaust tube can be placed up near the top of the tank, but low enough so that the level of the used slurry flows out of the digester, (about 8 gallons) will come out. On the other hand, a pipe too low will be exhausting slurry that is still digestable. A simple way of getting the correct height is to add exactly 8 gallons of liquid slurry when filling, at the point where slurry just starts to overflow out of the exhaust pipe. Close the valve, and add 8 gallons more.

The holding tank should be equipped with a pressure guage of some sort, measuring up to 50 pounds per square inch. The pressure of the gas should be monitored closely, and any excess pressure should be either consumed or vented off.

The holding tank of course, cannot be collapsed. Therefore, the second method (displacement by another substance) must be used to purge the tank. This can be done by filling the tank with water to the very top, ensuring that there is no air present in the tank whatsoever.

Once the feed line from the digester is purged (let it run for a few days after fermentation like the drum digester) it may be attached to the holding tank. The methane will displace the water, which will flow out of the exhaust tube. Once all the water is removed, the valve to the exhaust tube on the holding tank can be closed. The tank is now purged, and filled with methane, ready for use.

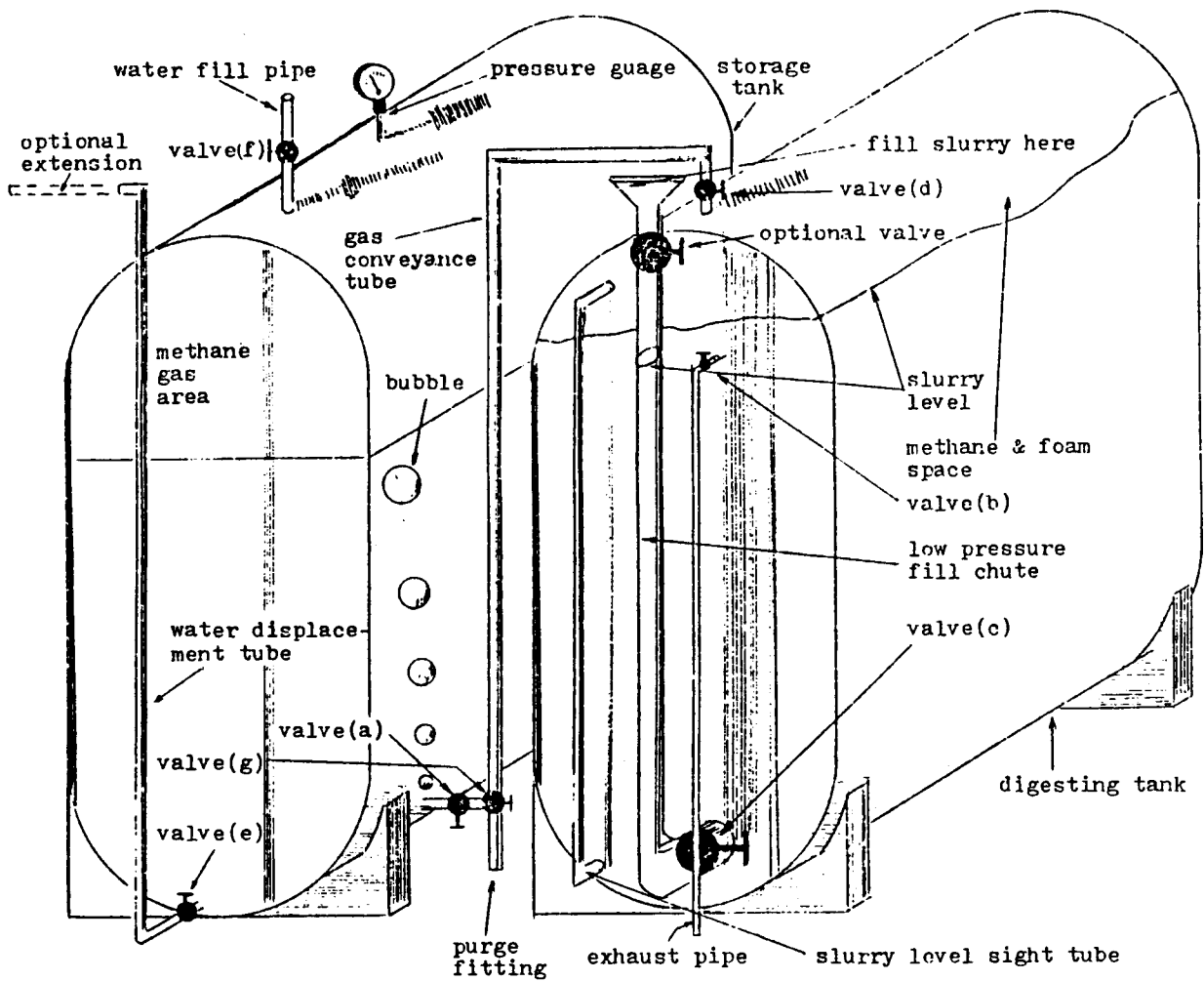
Again- monitor the pressure daily, and make sure that a pressure of 50 psi is not exceeded.

### PARTS

- 2 275 gallon oil tanks
- supply of 3/4" copper tubing
- 6 valves to fit 3/4" pipe above
- 1 pressure guage with fittings up to 50 psi
- length of plastic hose for sight tube
- 2 hose clamps to attach sight tube to copper fittings
- 1 valve to fit 4" copper pipe
- length of 4" copper pipe for fill chute
- 1 optional steel funnel placed on top of fill chute to aid in filling

Special Note: If your continuous digester stops operating, check whether a layer of scum has built up on top of the slurry. Break the layer with a broom handle and remove it...

Figure 8: The Continuous Output Digester



## OPERATION

1. To start system, close all valves.
2. Open valve(g), valve(c) and valve(d).
3. Fill the low pressure chute with slurry until the sight level tube shows slurry near the top in the tank (1 foot space from top). The slurry will seek its own level. Therefore there will

still be slurry in the fill chute, up to the level of the slurry in the digester. This slurry should be allowed to sit and "pre-ferment". A cover may be fitted on top of the chute if desired, since this small amount of slurry should not create a high pressure in the fill chute. Remember to close valve(c) after initial filling and after daily filling.

4. As gas passes through valves(d&g), the system is purged, and air is displaced. Fit a hose to the purge fitting and place the other end of the hose in water to check for bubbles of gas. Purge for a few days once the system is fermenting. Make sure no air is present in the line.

5. Open valve(f) and fill holding tank with water right to the top, making sure to expel all air. Then close valve(f).

6. Open valves(a&e) and let gas enter the holding tank, thus displacing the water out of it. It will be forced out of the water displacement tube. An optional extension may be placed on top of this tube, however make sure that the pipe passes above the top of the tank, since the water will seek its own level.

7. A hose may be fitted to the water fill pipe, and the gas consumed, by opening valve(f). Close valve(e) once all water is displaced.

8. Monitor the pressure guage daily. If the pressure is high in the system, gravity will not be enough to push the slurry down the fill chute. A circulation pump, would then have to be installed. However, if the pressure is within the specified range (50psi) there should be no problem.

9. To refill daily, close all valves. Open valve(b) and let 1/30th of the slurry come out (this slurry at the top is already digested). Then close valve(b) and replace with 1/30th the slurry volume by way of the fill chute.

## APPLICATIONS

Methane gas, as mentioned earlier, makes up to 90% of our natural gas. Therefore, just about any natural gas appliance, such as a stove, a lamp or a small heater will probably work with no modifications. Appliances that are run on hotter gases like propane, will require larger orifice fittings to handle this gas of a lower thermal value. One interesting possibility is running a natural gas refrigerator, commonly found in campers. Their limitations is that they are quite expensive to purchase. Remember that the gas that you are using is at a low pressure. Always use a 3/4" copper line to convey the gas anywhere, otherwise the gas will be too constricted and ineffective.

The other possibility worth discussing is that of running gasoline engines. An engine running at a constant speed (like a generator) can usually be run simply by introducing the methane line into the air filter housing. If attached to an engine, try introducing the gas into the carburetor, just below the choke plate. Then the mixture will be throttleable. Remember that the engine requires reserve pressure. Otherwise, when the throttle is open fully, there will be too much air and not enough methane which will cause the engine to stall. Practice on an old engine. Sometimes Hydrogen sulfide present in the gas may slightly corrode an engine. However, engines have been run on methane gas for years with no damage. Always keep an eye on any engine running on methane for potential problems.

