BIOGAS PRODUCTION

We have had it good for many years, using and misusing fuels supplies at will for countless years. In the United States, the average consumption of oil equates to three gallons per day. That is for every man, woman and child of the population! This makes an annual consumption of over 2 billion gallons. This is probably the most wasteful of the developed nations, but still not extremely far ahead of the others.

This practice will necessarily have to come to a halt at some point in the near future, since the present rate of consumption should exhaust the known reserves of refine able crude oil in about thirty years. The constant efforts of our oil companies to sell more and more of the black gold make it unlikely that today's consumption will not increase in the future.

So what should we do about it? Obviously the number one priority is to do some serious thinking about the use of power per head and in total. The second pressing need is to find an alternative and ecologically sound source of power for the future, unless we want to face rocketing power prices and possible rationing in our lifetimes.

And we already have possible alternatives on our doorstep. One huge source that has barely been used up to now is methane.

Millions of cubic metres of methane in the form of swamp gas or biogas are produced every year by the decomposition of organic matter, both animal and vegetable. It is almost identical to the natural gas pumped out of the ground by the oil companies and used by many of us for heating our houses and cooking our meals. In the past, however, biogas has been treated as a dangerous by-product that must be removed as quickly as possible, instead of being harnessed for any useful purposes. It is only really in very recent times that a few people have started to view biogas in an entirely different light, as a new source of power for the future.

One of these pioneers is Ram Bux Singh, now the director of the Gobar Gas Research Station in Aiitmal, northern India. Research was done into this topic in Europe during the fuel shortages of the Second World War, and biogas in various forms was indeed used in a restricted fashion, but the world centre of biogas research is today to be found in India.

There are good reasons for this: The pressure of population has reduced India's forests to a few scrubby trees way out on the horizon, causing extreme fuel shortages in rural areas. To compensate for this, about three quarters of the billion tons of cow manure produced annually is burned for heating or cooking. Anyone who has visited India will remember the acrid smell of burning manure. This, however causes tremendous medical problems. The acrid smoke leads to endemic eye disease, and the drying manure is a perfect breeding ground for flies of all types. The manure would also go a long way to improving the quality of the soil and hence increasing the harvest if these valuable minerals were returned to it instead of going up in smoke.

The Gobar Gas Research Station (Gobar is Hindi for cow dung) was founded in 1960 as the newest of a long series of Indian research efforts started some time in the 1930s. As one might guess from the name, the Gobar Gas Research Station has concentrated on studying the production of biogas from cow manure. Ram Bux Singh and his colleagues have biogas plants in operation ranging in size from about 8 cubic metres per day to 500 cubic metres per day. They have plants using heating coils, filters and mechanical agitators to test the change in efficiency, and have also tried various mixes of manure and vegetable waste. There is an immense amount of documentation of all their projects since every detail has been recorded for analysis and future reference.

The facts about biogas from cow dung:

Cow dung gas is 55-65% methane, 30-35% carbon dioxide, with some hydrogen, nitrogen and other traces. Its heating value is around 600 B.T.U. per cubic foot.

Natural gas consists of around 80% methane, yielding a B.T.U. value of about 1000.

Biogas may be improved by filtering it through limewater to remove carbon dioxide, iron filings to absorb corrosive hydrogen sulphide and calcium chloride to extract water vapour after the other two processes.

Cow dung slurry is composed of 1.8-2.4% nitrogen (N_2), 1.0-1.2% phosphorus (P_2O_5), 0.6-0.8% potassium (K_2O) and 50-75% organic humus.

About one cubic foot of gas may be generated from one pound of cow manure at around 28°C. This is enough gas to cook a day's meals for 4-6 people in India.

About 1.7 cubic metres of biogas equals one litre of gasoline. The manure produced by one cow in one year can be converted to methane which is the equivalent of over 200 litres of gasoline.

Gas engines require about 0.5 m^3 of methane per horsepower per hour. Some care must be taken with the lubrication of engines using solely biogas due to the "dry" nature of the fuel and some residual hydrogen sulphide, otherwise these are a simple conversion of a gasoline engine.

FERMENTATION

There are two basic types of organic decomposition that can occur: aerobic (in the presence of oxygen), and anaerobic (in the absence of oxygen) decomposition. All organic material, both animal and vegetable can be broken down by these two processes, but the products of decomposition will be quite different in the two cases. Aerobic decomposition (fermentation) will produce carbon dioxide, ammonia and some other gases in small quantities, heat in large quantities and a final product that can be used as a fertiliser. Anaerobic decomposition will produce methane, carbon dioxide, some hydrogen and other gases in traces, very little heat and a final product with a higher nitrogen content than is produced by aerobic fermentation.

Anaerobic decomposition Is a two-stage process as specific bacteria feed on certain organic materials. In the first stage, acidic bacteria dismantle the complex organic molecules into peptides, glycerol, alcohol and the simpler sugars. When these compounds have been produced in sufficient quantities, a second type of bacteria starts to convert these simpler compounds into methane. These methane producing bacteria are particularly influenced by the ambient conditions, which can slow or halt the process completely if they do not lie within a fairly narrow band.

ACIDITY

Anaerobic digestion will occur best within a pH range of 6.8 to 8.0. More acidic or basic mixtures will ferment at a lower speed. The introduction of raw material will often lower the pH (make the mixture more acidic). Digestion will stop or slow dramatically until the bacteria have absorbed the acids. A high pH will encourage the production of acidic carbon dioxide to neutralise the mixture again.

CARBON-NITROGEN RATIO

The bacteria responsible for the anaerobic process require both elements, as do all living organisms, but they consume carbon roughly 30 times faster than nitrogen. Assuming all other conditions are favourable for biogas production, a carbon – nitrogen ratio of about 30 – 1 is ideal for the raw material fed into a biogas plant. A higher ratio will leave carbon still available after the nitrogen has been consumed, starving some of the bacteria of this element. These will in turn die, returning nitrogen to the mixture, but slowing the process. Too much nitrogen will cause this to be left over at the end of digestion (which stops when the carbon has been consumed) and reduce the quality of the fertiliser produced by the biogas plant. The correct ratio of carbon to nitrogen will prevent loss of either fertiliser quality or methane content.

TEMPERATURE

Anaerobic breakdown of waste occurs at temperatures lying between 0°C and 69°C, but the action of the digesting bacteria will decrease sharply below 16°C. Production of gas is most rapid between 29°C and 41°C or between 49°C and 60°C. This is due to the fact that two different types of bacteria multiply best in these two different ranges, but the high temperature bacteria are much more sensitive to ambient influences. A temperature between 32°C and 35°C has proven most efficient for stable and continuous production of methane. Biogas produced outside this range will have a higher percentage of carbon dioxide and other gases than within this range.

PERCENTAGE OF SOLIDS

Anaerobic digestion of organics will proceed best if the input material consists of roughly 8 % solids. In the case of fresh cow manure, this is the equivalent of dilution with roughly an equal quantity of water.

BASIC DESIGN

The central part of an anaerobic plant is an enclosed tank known as the digester. This is an airtight tank filled with the organic waste, and which can be emptied of digested slurry with some means of catching the produced gas. Design differences mainly depend on the type of organic waste to be used as raw material, the temperatures to be used in digestion and the materials available for construction.

Systems intended for the digestion of liquid or suspended solid waste (cow manure is a typical example of this variety) are mostly filled or emptied using pumps and pipe work. A simpler version is simply to gravity feed the tank and allow the digested slurry to overflow the tank. This has the advantage of being able to consume more solid matter as well, such as chopped vegetable waste, which would block a pump very quickly. This provides extra carbon to the system and raises the efficiency. Cow manure is very nitrogen rich and is improved by the addition of vegetable matter.

CONTINUOUS FEEDING (MOSTLY LIQUIDS)

The complete anaerobic digestion of cow manure takes about 8 weeks at normally warm temperatures. One third of the total biogas will be produced in the first week, another quarter in the second week and the remainder of the biogas production will be spread over the remaining 6 weeks.

Gas production can be accelerated and made more consistent by continuously feeding the digester with small amounts of waste daily. This will also preserve the nitrogen level in the slurry for use as fertiliser.

If such as continuous feeding system is used, then it is essential to ensure that the digester is large enough to contain all the material that will be fed through in a whole digestion cycle. One solution is to use a double digester, consuming the waste in two stages, with the main part of the biogas (methane) being produced in the first stage and the second stage finishing the digestion at a slower rate, but still producing another 20 % or so of the total biogas.

BATCH FEEDING (MOSTLY SOLIDS)

There are biogas systems designed to digest solid vegetable waste alone. Since plant solids will not flow through pipes, this type of digester is best used as a single batch digester. The tank is opened, old slurry is removed for use as fertiliser and the new charge is added. The tank is then resealed and ready for operation.

Dependent on the waste material and operating temperature, a batch digester will start producing biogas after two to four weeks, slowly increase in production then drop off after three or four months. Batch digesters are therefore best operated in groups, so that at least one is always producing useful quantities of gas.

Most vegetable matter has a much higher carbon – nitrogen ratio than dung has, so some nitrogen producers (preferably organic) must generally be added to the vegetable matter, especially when batch digestion is used. Weight for weight, however, vegetable matter produces about eight times as much gas as manure, so the quantity required is much smaller for the same biogas production. A mixture of dung and vegetable matter is hence ideal in most ways, with a majority of vegetable matter to provide the biogas and the valuable methane contained in it.

STIRRING

Some method of stirring the slurry in a digester is always advantageous, if not essential. If not stirred, the slurry will tend to settle out and form a hard scum on the surface, which will prevent release of the biogas.

This problem is much greater with vegetable waste than with manure, which will tend to remain in suspension and have better contact with the bacteria as a result. Continuous feeding causes less problems in this direction, since the new charge will break up the surface and provide a rudimentary stirring action.

TEMPERATURE CONTROL

In hot regions it is relatively easy to simply shade the digester to keep it in the ideal range of temperature, but cold climates present more of a challenge.

The first action is, naturally, to insulate the digester with straw or wood shavings. A layer about 50 – 100 cm thick, coated with a waterproof covering is a good start. If this still proves to be insufficient in winter, then heating coils may have to be added to the biogas digester.

It is relatively simple to keep the digester at the ideal temperature if hot water, regulated with a thermostat, is circulated through the system. Usually it is sufficient to circulate the heating for a couple of hours in the morning and again in the evening. Naturally, the biogas produced by the digester can be used for this purpose. The small quantity of gas "wasted" on heating the digester will be more than compensated for by the greatly increased gas production.

GAS COLLECTION

The biogas in an anaerobic digester is collected in an inverted drum. The walls of the drum extend down into the slurry to provide a seal. The drum is free to move to accommodate more or less gas as needed. The weight of the drum provides the pressure on the gas system to create flow.

The biogas flows through a small hole in the roof of the drum. A non-return valve here is a valuable investment to prevent air being drawn into the digester, which would destroy the activity of the bacteria and provide a potentially explosive mixture inside the drum. Larger plants may need counterweights of some sort to ensure that the pressure in the system is correct.

The drum must obviously be slightly smaller than the tank, but the difference should be as small as possible to prevent loss of gas and tipping of the drum.

ABOVE or BELOW GROUND?

Biogas plants constructed above ground must be made of steel to withstand the pressure within, and it is generally simpler and cheaper to build the digester below ground. This also makes gravity feed of the system much simpler. Maintenance is, however, much simpler for systems built above ground and a black coating will help provide some solar heating.

This should make it clear that biogas is not just a dream, but a practical application and use of a waste product. India already has around 3000 biogas plants of varying sizes.

The near half billion cattle, pigs and chickens in the US produce over two billion tons of manure every year, an incredible amount. This can be seen as a valuable natural resource capable of producing combustible gas that would reduce our consumption of irreplaceable natural gas and also a fertiliser more valuable than the raw manure.

This would become a valuable source of biogas for power, instead of a pollutant of our water sources in the form of runoff. Ecologically and economically viable in all cases!