

Prologue to Methane Gas

Al Rutan, the Methane Man

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Why gas? What's so good about gas? One could make an argument *ad hominem* and simply say, if gas weren't such a good idea, why is it so abundant in nature. It

Gas Use

What about flammable gas? Why consider it? For those of us who spent much of our youth chopping wood to heat and cook at home, the idea of gas is like something from paradise. The idea and the experience of merely turning a valve to have instant flame without all the "bitching" and complaining involved in "go get that wood!" is amazing.

Almost everyone likes the ambiance around a campfire on an outing with friends. But for the day to day fuel needs, we wish to have it as "automatic" as possible, and for being controlled by a thermostat, gas is unsurpassed.

It is clean and uncomplicated. Clean? Yes, clean. There is no soot that collects in a chimney from the burning of methane gas. Does it need to be vented? It should be, if at all possible. The fumes from any type of combustion should be considered suspect.

Potential problems from the burning of methane are minimal. If the combustion is complete, what is produced is carbon dioxide and water vapor. Yet we have no practical assurance that combustion is always as perfect as it could be.

An interesting note historically is the fact that the Indian government some 40 years ago pushed the development of homestead production of methane because so many people were going blind from the effects of burning cow dung for fuel. Our early pioneers had similar experiences from the burning of buffalo chips. Burning raw manure should always be considered a "no-no."

Low-tech methane production information comes from both India and China—two countries with vast populations,

huge pollution problems from waste, and an immense need for fuel, which isn't readily available.

At Home

Our interest stems from the fact that homestead methane production is one more way to unplug from a utility company and provide access to energy, which substantially contributes to the quality of life.

So, one has to have the heart for it. Unlike electricity, that is for all practical purposes quite mechanical, gas production means tending to living things, like a flock of chickens, a band of sheep, or milking goats. For abundant gas production, there needs to be a sensitivity to the special needs of the microscopic creatures that produce flammable gas as their waste product. This means providing for their basic wants and—don't laugh—giving them a measure of love. All living things—plants, animals, and people—require love in order to flourish. This need extends even to living creatures that can't be seen with the naked eye.

A person we know who had a methane system one day went up to his tank and gave it a good hefty kick as an experiment. The gas production stopped immediately, and started slowly again only after some time had passed.

Because one must assume responsibility for the care of a colony of living entities, producing gas to burn has another dimension some may need to consider before undertaking such a venture.

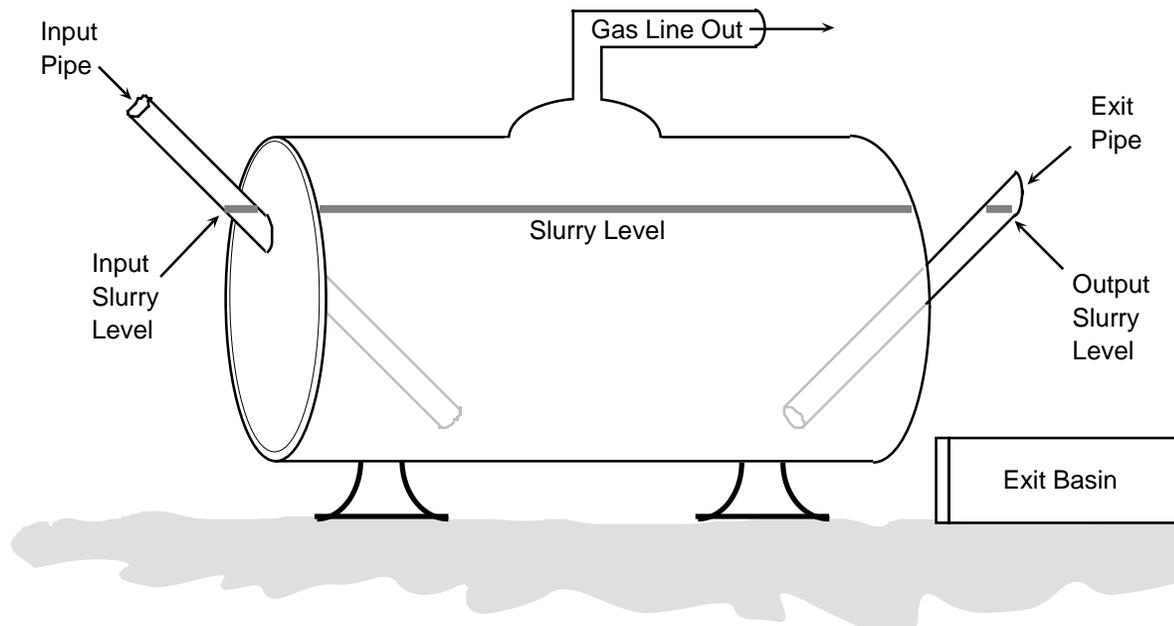
The advantages of gas are many-fold. It is so easy to use. It is so controllable. It is relatively easy to store. It can be used automatically. It will even run your vacuum cleaner if you put the methane gas through a fuel cell which will turn the gas directly into electricity. Plus, it is so clean—no soot, no creosote, no ash, and no chopping. What more could you ask?

Making and Using Methane Gas

Methane is a natural gas. The reason it's called "natural" is because it occurs in nature everywhere. It can be the gas found in a swamp or marsh, the gas found in a coal mine, the smell coming from a septic tank or sewer line, or the gas sold to us by a utility company under the title of "natural gas." The product is substantially the same, CH₄.

We've heard that methane is odorless, and it is. Sewer gas we know is not. So what is the difference? When the process that produces gas is underway, there are a variety of gases produced at the same time. All such gases result from micro-organisms feeding upon organic matter and producing gas as a waste product. Methane,

METHANE TANK CONCEPT SKETCH



which is odorless, is one of them. Hydrogen sulfide, which is smelly, is another. It is hydrogen sulfide which gives us the characteristic sewer gas or "fart" smell.

When these gases are encapsulated in the ground over a long period of time, the smell is purged, leaving an odorless gas. The sewer gas smell can be removed easily from the mixture by simply bubbling all the gas through calcium carbonate, which is simple barn lime, and thereby scrubbing it so to speak. The gas becomes odorless. The gas companies re-introduce an odor to odorless gas before selling it as a safety measure so that our noses can detect "loose gas" that could be potentially dangerous.

All these burnable gases are produced by anaerobic organisms feeding upon organic matter. To say they are anaerobic means they only live when air is excluded from the space in which they are functioning.

They are the same organisms that cause us to have intestinal gas. Each time a warm blooded animal defecates, some of the gas producing organisms are contained in the feces. This is why it can be said that methane occurs virtually everywhere. Wherever air is excluded from the decomposition process, the production of methane and accompanying gases is likely to occur.

Stories are legion about a bunch of guys with nothing better to do than ignite the intestinal gas of one of their particularly "gassy" buddies, and then being amazed at how flammable the experiment was.

The micro-organisms that produce flammable gas are temperature sensitive. They want body temperature in order to function most effectively. In people that is 98.6°F. In a chicken or a pig the body temperature is 103°F. So right around 100°F is the optimum temperature for the process to work most effectively. The action can occur at lower temperatures. As the temperature drops so does the rate at which methane gas is produced.

People will sometimes ask, "Why can't I use the gas off my septic tank to burn in a stove?" The typical septic tank swings through such wide temperature fluctuations, the amount of gas produced is minimal. Each time a toilet is flushed with cold water, the tank goes into "shock." Each time some warm wash water from a bath or shower flows into the tank, it becomes more active until the next shot of cold water. Such tanks are ordinarily in the ground, which stays at a constant 50° to 55°F. The ground is a constant heat sink, draining heat away from the tank. About all one gets from a septic tank, by way of gas, is enough to cause an unpleasant odor. Because the temperature cannot be maintained at the required working level, such tanks have to be pumped from time to time. The solids cannot be efficiently digested and so keep building up.

Key Considerations

It is the concept of a tank which offers us the most practical approach to the task of harnessing the production of methane. Liquid within a tank gives us two immensely important features—transport and the exclusion of air. Both are essential for maximum production.

Some methane production occurs in such places as an ordinary barnyard manure pile. The center of the pile is without air and with the heat generated by the pile some methane gas is bound to be produced. If we want to harness the concept, we will need a great deal of gas. A solid pile to give us what we would need would have to be, literally, a small mountain. In a tank, it's an entirely different matter. It is much easier to have the tank "just bubbling away" so that the amount of gas collected in a short time can be significant.

Key Questions

How much gas do I need? That will determine how much gas must be produced. Next is, how much material do I need to produce this amount of gas? The third question is, how large must the equipment be to produce and store this amount of gas?

Gas is thought of in terms of cubic feet. We can all visualize a cubic foot—12 inches square in each direction. The amount of gas within such a space of 12 inches square is determined by the compression of the gas. Fortunately, when we are working with methane, we are talking about only ounces of pressure—just enough pressure to push the gas to the burner, whether it might be a stove, water heater, or refrigerator.

For "home-made methane," our pressure regulator is not any more complicated than a heavy rock on an inflatable gas holding bag, or the weight of a solid yet expandable gas holder floating in liquid. It's not very complicated.

How Much Gas Does One Need?

To estimate the amount of gas needed, the average family of four burns somewhere around 200 cubic feet of gas a day. This covers the combined tasks of cooking, heating space and heating water. Obviously, individuals can trim this amount considerably by using efficient appliances—such as flow-on-demand water heaters, and high-efficiency space heaters.

The best way to get a handle on this information is to look at the amount of consumption listed on the utility bill of some family you know and then observe their lifestyle.

Processes of Gas

We say that the liquid provides transport. That transport is two-fold. Obviously, we must transport the material to the tank. Equally important, yet not so obvious, is the transport of the micro organisms to the material or vice-versa, so that the material can be digested by the life forms. Within the digestive tract of a warm blooded animal, this action takes place by peristalsis. We imitate this transport by very gently moving the contents within the tank from time to time.

Concerning The Tank

A simple paddle mechanism works the best. Some systems re-circulate some of the gas to provide movement, but this has proven to be less than satisfactory. Often inorganic material is stirred from the bottom of the tank—material such as sand and small rocks if they are present—and the living organisms are injured in the process. The best method is a slow mixing action with a paddle of some sort. The paddle may be on a horizontal axis or a vertical axis. It merely has to move the material very gently a few times each day.

The exclusion of air is essential to have the process work. While we know that even water contains some air—otherwise how could fish breathe—once the activity of gas producing bacteria becomes established, even the air is mostly excluded.

The tank must be closed so that new air is not able to enter. This is done effectively by having both the fill pipe and the exit pipe extend below the water line. So, air exposure to the tank is limited to the surface of the water level in both the fill and exit pipes.

In the past much discussion focused on whether the tank should be horizontal or vertical. It is the consensus that when the tank is horizontal rather than vertical, it can work more effectively. (Note the illustration on pg. 25.) The reason is that the fill and exit pipes need to be spaced as far apart as possible. Then the material entering the tank has greater exposure to the activity within the tank before being moved near the exit pipe.

The gentle stirring action needed, of course, mixes up everything. Yet if the new material is forced to "migrate" some distance before reaching the exit pipe, then the micro-organisms will have more time to feed upon it before it is replaced by incoming material.

How big should the tank be? This is determined by how much material is available to the tank on a daily basis, and ultimately how much gas one wants to generate.

Production Mixture

The input for the tank needs to be a mixture of manure and carbon material. Carbon material is ordinarily understood as waste vegetation, but it can't be just anything. It needs to be something that when soaked in water for a few days becomes very soft. The bacteria don't have any teeth. They have to "gum" it.

Hardness can be misleading. A carrot seems hard, but if soaked long enough it turns to mush. Grass clippings, on the other hand, contain a quantity of lignin, that cellulose fiber that makes wood very "woody." Anything with a high

content of lignin will not work well in a methane tank. Straw for the most part is acceptable. Hay is not.

Even such things as ordinary newspaper work well. Although newspaper at one point was wood, the lignin has been broken down so that when the newspaper is soaked for a day or so, it turns to mush—good stuff for our purposes. The bacteria want a mixture of 30 parts carbon to 1 part nitrogen. Manure is nitrogen rich—about 15 parts carbon to 1 part nitrogen, so manure needs to be balanced with more straight carbon material. This ratio isn't a critical proportion and the process still functions, but 30 to 1 is the ideal.

Potency

The ability of manure to produce gas varies from animal to animal. Chicken manure can be especially potent. I have observed as high a yield as 10 cubic feet of gas from each

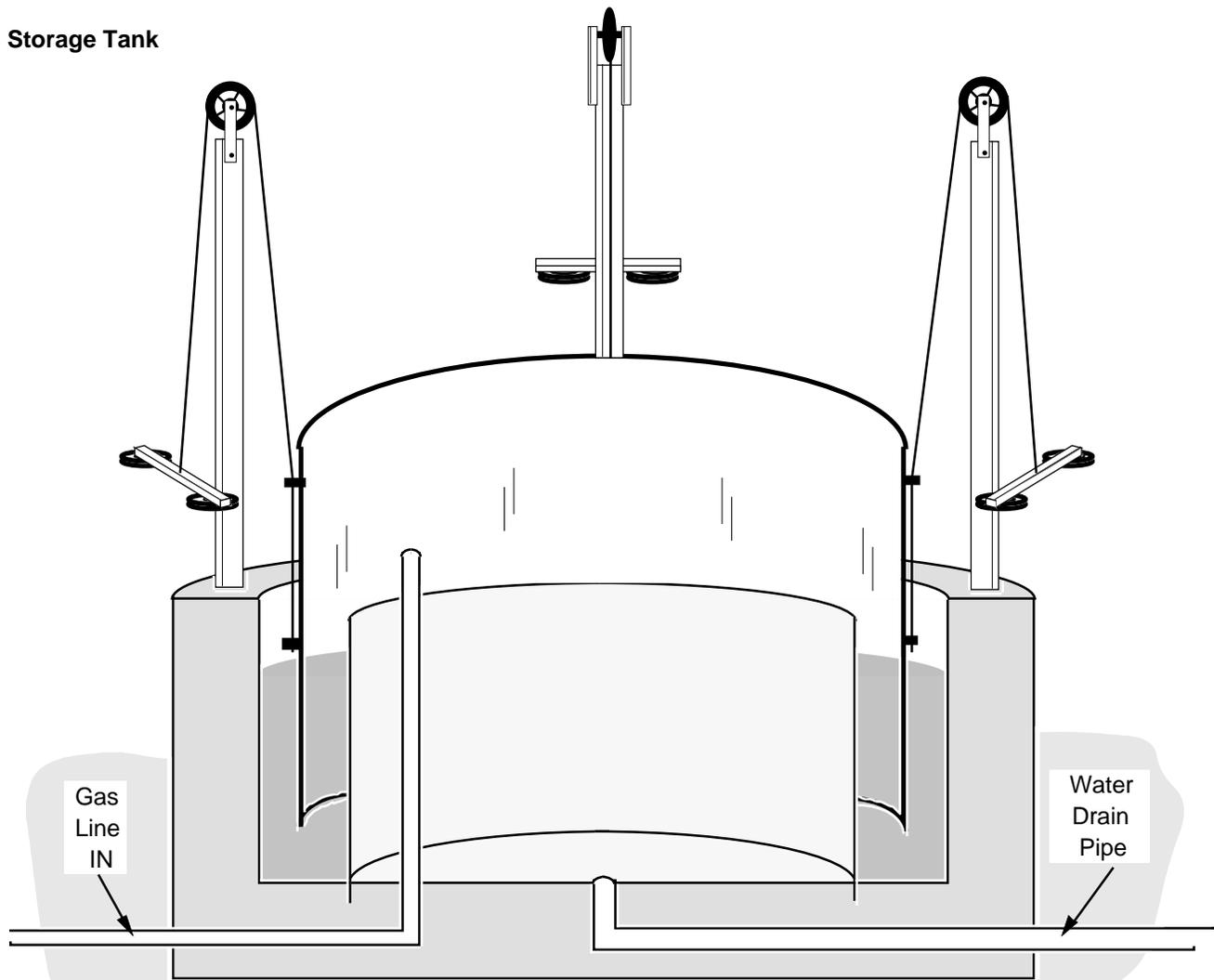
pound of naturally moist chicken manure which was mixed with some finely ground spilled feed.

Hog manure usually yields about 4 cubic feet per wet pound. Cow manure usually yields about 1 cubic foot of gas for each pound of fresh manure. The reason there is such a difference is that much of the methane potential has already been released when the waste goes through the digestive system of a ruminant. There is usually so much of this kind of manure, using it is still worthwhile. Another good feature of the process is that raw manure is changed into something which is aged and totally acceptable to be placed on growing things. With any quantity of raw, green manure, this is not the case.

Sizing the System

Having established that we need around 200 cubic feet of gas a day, we need to set about designing a system that

Gas Storage Tank



will provide this. How much is 200 cubic feet? Visualize an inflatable bag that is six feet wide, six feet long and six feet high, and you're seeing a space of 200 cubic feet.

If we say that a mixture of manures will give us 4 to 5 cubic feet of gas per pound of naturally wet manure we are going to need about 40 to 50 pounds of manure a day. We would need even less manure if we use chicken waste. These forty pounds are going to be mixed with some type of additional carbon material, to which water, preferably warm water, will be added to give us a "slurry." This will most likely be about 15 gallons of bulk. Visualize the content in three five gallon buckets.

Size of the Tank

It is generally a rule of thumb that the size of the tank needs to be 40 times the size of daily input. This means that when 1/40th of the volume of the tank is introduced at the input end then 1/40th of the volume will exit the overflow end simply by being displaced. Allowing some space at the top of the liquid for the gas to collect, the tank should be about 50 times the size of daily input.

Sewage plants that employ the methane process—and many do—like to have a holding time of 90 days. In other words the preference is to have the tank 90 times the size of the daily input. The purpose of this is to totally destroy any potential pathogens. That length of time within the tank does exactly that. Periodic inspections by the various health departments around the country keep a check on such activity and find consistently that the 90 day holding time accomplishes this goal.

Within a 40 day holding period most of the pathogens are eliminated. Because we are not dealing primarily with human feces (although this material may be used with animal waste) the longer holding time is not as imperative. Within a 40 day time span the greatest amount of gas is produced. In a period longer than 40 days, the gas production begins to slow down considerably.

We need a tank that is 50 times the volume of the daily input of 15 gallons, or a 750 gallon tank. Obviously, a 1,000 gallon tank would be ideal to take care of extra demand for production or additional material input.

Tank Choice

A 1,000 gallon discarded milk bulk tank would be ideal. Because bulk tanks already have a system for cooling the tank, this system could be easily adapted for holding the temperature of the tank at 100°F. rather than cooling it. One type has the "radiator" already built-in.

The fact that the tank is stainless steel is also an advantage because it would extend the life of the tank

considerably over ordinary sheet metal. The acids within the mixture do not work rapidly on the tank, but they will deteriorate it over an extended period of time.

Originally, I had an ordinary 250 gallon fuel-oil tank that I used for demonstration purposes. It lasted for several years. It finally rusted through, but considering the fact the metal was relatively light gauge to begin with, the tank served well. Because oxygen is excluded in the process and the pH must be kept at neutral, the deterioration of the tank was not rapid.

Another great feature of a milk bulk tank is the fact it already has a mixing paddle as part of the tank's design. All access ports above the water line would have to be sealed air tight for effective gas production and, more importantly, just common sense safety.

The Gas Holder

Regarding a gas holder, one may use a solid vessel open at the top filled with liquid into which another solid vessel open at the bottom is placed. The gas pushes the top unit up out of the liquid as the gas is produced (see illustration on pg. 27).

The simplest type of gas holder is an expandable bag. It can be something like a waterbed mattress upon which a weight is placed to produce enough pressure to send the gas to the point where it is used—a burner of some type.

One may use simply a vinyl of some type, but the best type of material is a nylon fabric that is impregnated with vinyl—not laminated, but impregnated—which becomes exceedingly durable. If this inflatable bag is placed inside a "silo" of some type, then there is a measure of assurance that the bag is not going to be punctured. The people who work with the nylon impregnated vinyl—one of the trade names is Herculite—seal it by a process of electro-statically welding it. Using an ordinary adhesive may not work because methane has a tendency to dissolve a number of adhesives

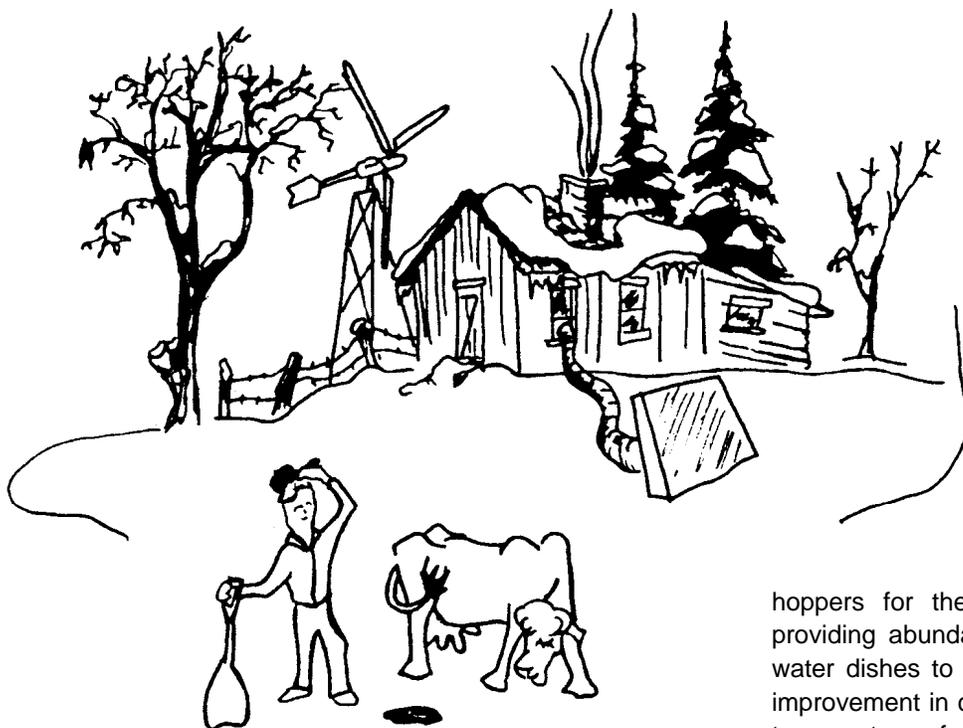
For Now

The process of making methane gas is relatively simple if one is attuned to the basic needs of the process. They are: the right balance of material, the right temperature, and the exclusion of air. Given these three conditions, the methane process is virtually unavoidable. The trick is to be sensitive to the fine-tuning of each of these requirements. As we continue with more methane articles in Home Power, we will do just that.

Access

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More On Methane

Al Rutan, the Methane Man

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In the last issue of HP, the methane article praised the ease with which gas is used – merely turning a valve to have instant vapor fuel. It takes so little effort. If gas is so easy, how does fifty pounds of stuff get pushed around without any effort? Aw...you caught the inconsistency!

The article in HP26 says that we need about 50 pounds of waste daily, a mixture of manure and carbon material to feed the digester that will turn this material into about 200 cubic feet of gas.

The focus of this article is just this problem. As anyone who has done any kind of homesteading knows, there is a

hard way and an easy way to do every job. Part of the endearing quality of American ingenuity is to see how people can approach a task that is downright tedious, and by some clever manipulation, make it easier.

Easy is Better

This really became a lesson taken to heart while living at Red Lodge, Montana. I was in the middle of a project raising rabbits for market – lots of them, about 200 breeding does producing litters.

Feeding and watering this number was a time-consuming chore. I made hoppers for the hay and feed pellets early on, but providing abundant water was a drag. I upgraded from water dishes to water bottles with a valve. This was an improvement in cutting down the labor. The big jump was to a system of watering valves fed by little plastic lines from a central tank with a float valve to control both the water level and pressure on the water lines.

In one situation, the water was put into 200 little water bowls which were constantly being spilled or fouled with waste. In the other, water was supplied by a small pipeline with drinking valves in each cage. The result was the same – water to drink, but the effort needed was totally different. The two situations accomplished the same effect – abundant fresh water.

Consider the Critters

There is another consideration that must be brought to mind at this point. In the methane process, we are working with living creatures. Therefore a moral dimension must be considered if we are going to achieve a measure of serenity for ourselves in this whole process.

To have a genuine sense of well-being about the entire operation, the animals and the space for which the person is responsible must have an ongoing atmosphere of serenity. If this sounds a little bit like St. Francis of Assisi, well, so be it and no apologies. The purpose of life is not merely accomplishment, but accomplishment in a caring and respectful way.

As people, we harness the work of creatures. Some may maintain this is not right. I don't agree. I do feel strongly that the animals with which we work and upon which we depend do have the right to a reasonable quality of life. So at this point we are talking about animal rights. The concept of animal rights means different things to different

people. To me, it means that an animal has a right to a reasonable quality of life. An animal has a quality life when it feels good about itself. This is most clearly evidenced by grooming. Animals, if they feel good about themselves, groom themselves and their friends.

Quality of Life

Death for an animal, or a person for that matter, is not the worst thing that can happen. Quality of life while something is alive, be it plant, animal or person, is of major importance in the scheme of things. One who homesteads can not be mentally well off if such a person is not sensitive to the quality of life of the living things around the homestead. Are the animals feeling good, as evidenced by their grooming?

A Dilemma

Now, why make a point of this if we are talking about methane and manure? We are faced with a dilemma. On the one hand we want to collect waste with the least effort possible and do it as automatically as possible. On the other hand, we need to have a measure of sensitivity to the needs and quality of life for the animals on which we depend.

If the animal wanders about freely, it will be very difficult to collect its waste. On the other hand, if the animal is tightly caged or tied, its quality of life is virtually nil. So what's the answer?

Somewhere there is a middle ground. Chickens, for instance, do most of their pooping while they are perched at night. Milk cows leave a quantity of used grass in the gutter while being milked or held in the barn during the night.

Hogs that are totally confined don't have much of a life. Hogs that are confined only through the night will leave a good share of their waste behind when penned only part of the time.

Chickens do not do well housed on hardware cloth because their natural inclination is to peck and scratch. I've seen a roost system where the area under the roost was wired with large chicken wire mesh. The chickens could not get to the manure to disturb it after a night of roosting. They were free to roam at will during the daytime.

Slatted floors are useful for both hogs and cattle from the standpoint of cleanliness if the animals are not required to stand on them at all times. In all these design considerations for an enclosed area, the needs of the animal must be considered if we are to have happy animals.

Moving the Material While It's Warm

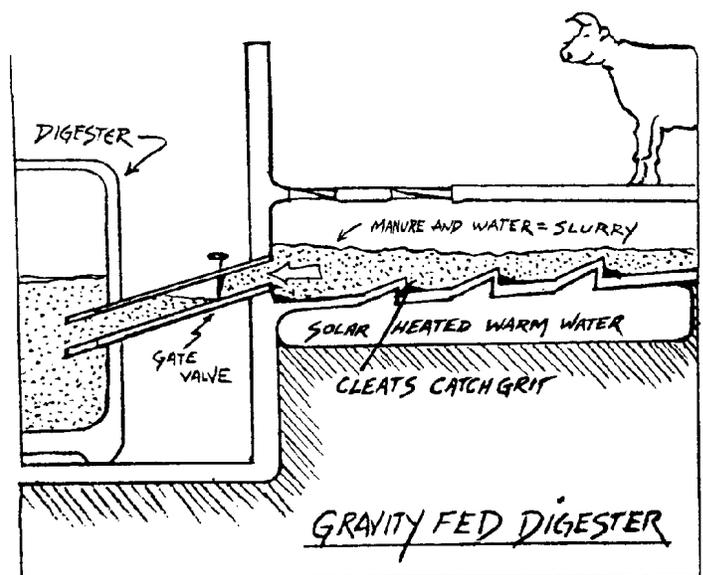
It is the matter of manure itself. How can a person move it with the least effort possible? Manure delivery systems have been devised for various types of critters, except the horse. To my knowledge, there is no device more automatic than a scoop shovel for cleaning out a horse stall.

If one DOES have animals, the feces HAVE to go somewhere. So at that point it makes a great deal of sense to turn the waste into vapor fuel (methane) and compost.

When the waste comes out of an animal, it is at exactly the right temperature – body temperature. As it lies on the ground, it cools off. This cooling during the cold time of the year is severe. The sooner the waste is transported from the animal to the tank the better. If the waste loses heat, then the heat must be restored to have the methane digestive process occur in the best manner possible.

This brings us to the biggest challenges in the entire methane procedure. How do we gather the manure to begin with? How do we gather it as soon as possible after it leaves the animal and before it cools down?

There are two natural forces that work well for us. One is gravity and the other is water. In rolling countryside, barns are commonly built on hillsides. The hayloft is easily accessible by simply driving in rather than having to go through the labor of hoisting every bit of hay with some kind of sling mechanism. The hay is forked down to the animals below, using gravity.



Gravity Works for Free

The more that gravity can be utilized for tasks the better. The animal walks around. It can walk up as well as down. If the housing for the animals can be above the digester, then this saves work.

Water has long been used for transport. Since the development of the flush toilet, in the 1850's in England by Mr. Crapper (no kidding...that really was his name!), we have been using water to move feces.

Using water has a problem. What I am going to say now is exceedingly important. Many an engineer and university professor working with the methane concept cannot seem to grasp a simple fact. It is the nature of liquid – especially water – to release heat. When water is heated, it will not retain its heat. We say, "It cools down."

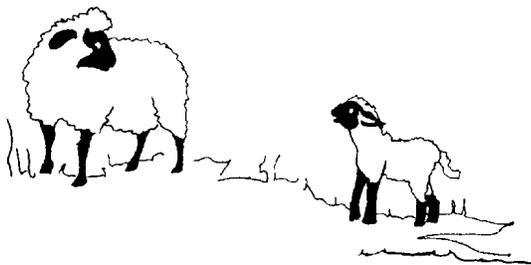
Water Must Be Warm

If we are going to use water in the process of transporting manure, and have it work well, we must understand that water cannot be allowed to stand around waiting for the waste. Warm water can and certainly should be used to wash down a gathering point below a slatted floor. The gathering point had better not be a holding pit in the ground because the whole thing will cool off to ground temperature. Another consideration is that in a pit the methane activity begins right away, so animals above a pit are breathing contaminated air. This is why holding pits MUST have ventilation fans if they are under confinement areas.

Think in Terms of Free Energy

How does one have warm water with which to transport? Each location will have its own plusses and minuses in working out this design problem. A person has to consider all the ways of capturing "free" thermal energy – solar, wind, whatever, and applying it to the situation at hand.

We're most likely looking at periodic washing down of a gathering area with warm pressurized water. This will both increase the force of the wash and cut down on the amount of warm water needed. The more automatic the concept can be and the less labor intensive, the more of a ideal situation a person can enjoy.



Do We Really Need Animals?

So just how practical is the thought of having animals around a homestead? The trend is increasing for relying less and less on animal parts for human food. Folks tend to become more and more vegetarian. We still need the family mule to plow the garden, a few milk goats for the delicious and healthful treat of fresh goat's milk, or a few sheep to produce wool for hand spinning and the cottage loom. There is wisdom in involving some kind of animal support in our homesteading.

Farmers who raise nothing but corn are still hooked into the food "grid" when they drive to the store for their butter, milk, and eggs. Our great grandparents would shake their heads!

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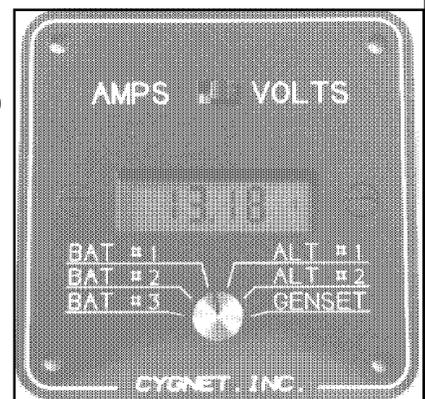
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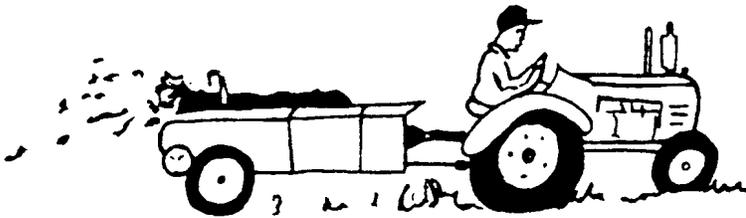
The Methane Process

Third in a series by Al Rutan, the Methane Man

Al Rutan

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Mold and mildew have been seen by everyone. Most people have observed the process of rotting. We know it is common in nature. Methane gas is just as common, but not as observable. Anyone near a sewer manhole or a plumbing vent pipe can get a whiff of the methane process in action. The reason for saying this is to alleviate the apprehension that the methane process is going to be difficult to harness. It's no more difficult than making a loaf of bread. If the conditions needed are present, the desired result will invariably occur.



What we are considering is a biological process in which we use the waste product of bacteria. We shouldn't even call the little creatures bacteria but more accurately "methogenic micro-organisms."

Primeval Life

In the process of evolution, they antedate the formation of bacteria. They are one of the very earliest forms of life. When scientists explore outer space with telescopes that

can separate light spectrums, they look for the presence of methane gas. If the gas is present, there is evidence for the beginning of life.

For our purpose, we are going to refer to these methogenic micro-organisms simply as "bacteria." They are curious little critters. Their waste product burns. Not only does it burn, it burns very well. Combustion produces only carbon dioxide and water vapor. There is no ash, no soot, no tar, no dirt of any kind. It's a very efficient fuel.

Characteristics

This fuel is composed of carbon and hydrogen. Its chemical formula is CH_4 . It has an octane rating of 110 and produces around 1,000 BTUs (British Thermal Units) of heat per cubic foot of gas. Because most gas is invisible, it seems mysterious. If we think about our own chemistry for a minute, it won't seem so strange. We know that we breathe in oxygen and exhale carbon dioxide. So we, ourselves, are gas producing organisms.

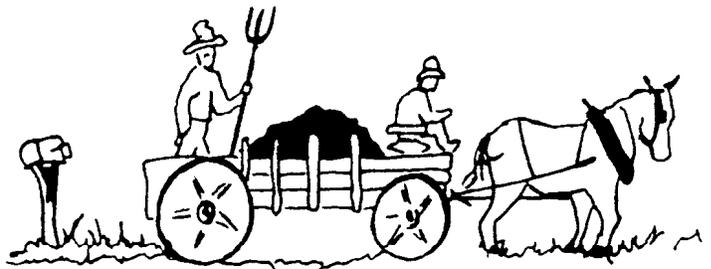
Gas Makers

If we think about this, then the process of the methane bacteria doesn't seem so strange. The part that is "strange" is that it burns. If mixed with sufficient amounts of air, it burns very rapidly... explosion!

In nature, some bacteria operate best in the presence of air because they require oxygen, and some function only when air is excluded. The methane bacteria are of this latter type. When exposed to air, they die. Because they live and function only when air is not present, they are called anaerobic or "without air" bacteria.

Natural Gas and Sewage Gas

What is the difference between natural gas and sewage gas? Virtually none. For all practical purposes the bacteria which make the gas are the same. Natural gas sold by the utilities is 90%, or better, methane. It has been made in the ground over eons of time and in most instances is almost pure methane because the ground has purified or "scrubbed" the gas. The only difference between gas produced in the earth and gas made in



sewage plants is that in the sewage plants the process is speeded up. In speeding up the action there are several gases produced, notably, carbon dioxide. In a sewage plant the mixture is about 70% methane and 30% carbon dioxide, with trace amounts of hydrogen sulfide. The carbon dioxide largely dissipates from "natural gas" over time. The speeded-up process product, including the carbon dioxide, is referred to as "biogas."

Actually all natural gas is "biogas" because all of it was produced from something that was at one time living. The only distinction is that so-called "biogas" is produced in a shorter time from things that have been living recently. Making methane for ourselves, we hasten the process.

How Does it All Happen?

There are two types of "without air" or anaerobic bacteria that work together to make methane. The first type we'll call "acid forming." Their function is to feed upon raw organic material. They produce no methane, only carbon dioxide and some acids and "food" for the second bacteria type, the methanogenic micro-organisms. The "food" consists of simple sugars, simple alcohols and peptides. When the methanogenic micro-organisms in turn feed upon this simpler fare they produce methane. Thus when organic material is placed in a container where air is excluded, both carbon dioxide and methane are produced.

Need for Balance

The methanogenic micro-organisms need the food provided by the acid-forming bacteria, but they also need a neutral environment. If the right balance between acid and base (alkaline) is not present, the methane micro-organisms are in trouble and no methane is produced. They have to have a pH of 7 to 8.5 in order to be normally active.

What Does pH Mean?

I think it's important not to assume that everyone is familiar with pH. Webster's defines pH as "the negative logarithm of the effective hydrogen ion concentration..."

used in expressing both acidity and alkalinity on a scale of 0 to 14 with 7 representing neutrality. Numbers less than 7 represent increasing acidity and numbers greater than 7 represent increasing alkalinity."

So the term pH means percentage of hydrogen, or more precisely, proportion of hydrogen in relation to the hydroxide ion in a given material. It's the negative logarithm of the hydrogen ion concentration, so a pH of 7 means that the concentration of hydrogen ions is 10^{-7} . Aren't you glad you asked?

Anyway, it's important information for keeping the digester healthy and happy. The ideal pH for digestion is from 7.5 to 8.5.

How to Get a Reading

How does one measure pH? This is the easy part. Chemical supply houses and even most drug stores sell rolls of paper (called litmus paper) and/or little plastic strips that turn color when dipped in solution to tell you what the pH is. There is a slightly different color for each of the different pH numbers. You tear off a piece of the litmus paper about 1 1/2 inches long and dip it into a little of the slurry. The paper will start to change color within seconds. When compared to the color scale on the container, you can tell right away what the pH of the slurry is.

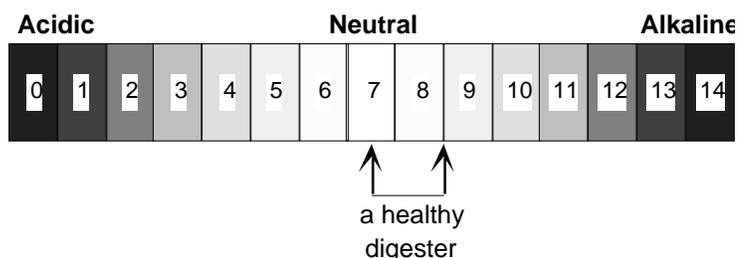
Why the Process May Drag

Generally if there's a problem, it's that the slurry is too acidic (pH below 7).

If there is a lot of new, raw, green material placed in the digester, the acid forming bacteria have a field day. The methane bacteria are so annoyed by the high acid concentration, they simply can't function. When this occurs, it can take a long, long time for the methane process to get under way naturally.

This generally occurs only in the beginning with start up or if too much new material is added at any one time. If a measured amount of new material – no more than 1/40th of the total liquid volume of the tank – is added, then the new material is dilute enough not to upset the balance. At start up, though, there's a lack of micro-organisms, and an inclination towards excessive acidity. Understanding this, we can see why some of the early literature on making methane states that the start-up time can be anywhere from three weeks to three months. This is assuming that one is beginning with totally "new" material without the assist of some already partially digested slurry. A three month start-up would discourage almost anyone from attempting to harness the process.

The pH Scale



Starting Up

Partially digested slurry is kind of like sourdough starter. It has large populations of the right kind of micro-organisms to digest raw material and make methane. You can start from scratch, but it's faster if you can get some activity that's already established.

When I started a small digester in 1976, I seeded it with some slurry from the St. Cloud, Minnesota, sewage plant. The plant engineer told me at the time that the plant was so overloaded with wastes from a local meat packing house that the digester was just "going through the motions" and really not working properly. I took some of the slurry anyway. What the heck. It was free and I needed something to get the tank producing.

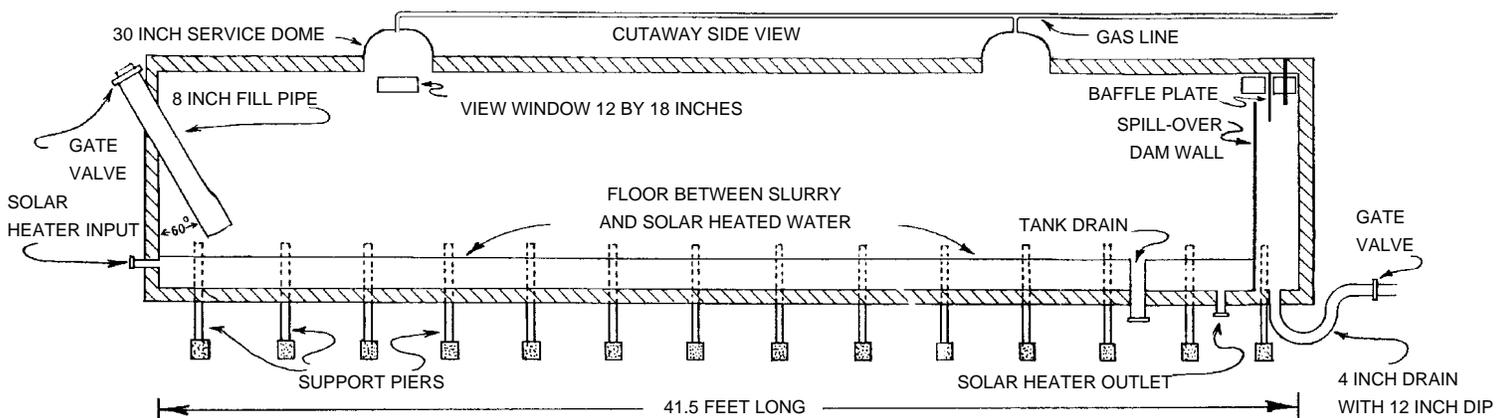
After a few days I started to get methane and then I lost it. The tank was still producing a lot of gas, but it was carbon dioxide – it didn't burn. The pig manure I had begun to feed the digester along with the slurry from the St. Cloud plant was just too much raw material for the process. So there was a lot of carbon dioxide and acid. The acid forming bacteria were having a feast.

I mentioned the problem to friend with whom I was working at the time. He said, "I make a lot of wine at home. Every once in a while I have the same problem. When I do I add a little baking soda. It straightens out the condition right away. The nice thing is it doesn't leave an after taste. In your case that isn't a problem!"

The Benefits of Baking Soda

So I tried the baking soda. It worked like a charm. Within three days I had methane on the way. At a seminar I was presenting a few weeks later, I mentioned this to the group. Baking soda was my "discovery" for straightening out the pH in the digester.

Al Rutan's Methane Digester Design



One of the people at the seminar sent me a clipping from Business Week magazine a couple weeks later. It was dated June 14, 1976. The headline for the article read "Dosing Sewage With Baking Soda." It went on to say this was a whole new idea for treating sewage plants; they used to use large amounts of ammonia.

The article further proclaimed that soda not only assisted in the more efficient digestion of sludge but increased the volume of burnable methane gas. The most surprising statement of all: bicarbonate of soda "acts as a sort of vitamin for bacteria."

This is the secret for keeping your digester sweet and happy. Just add a little at a time until the pH is just right. Keep adding it periodically if the pH keeps dropping until the acid forming bacteria are no longer producing an override of acid. Don't be fooled if a lot of gas starts coming. The baking soda itself will produce some carbon dioxide.

The Nature Of Heat

Heat is essential for abundant methane production. In warm climates the process works with little help when the other conditions needed occur. For many of us who live in a cold climate, making methane work is a challenge.

One needs to keep in mind that heat stratifies, whether in air or water. Heated fluids are less dense and tend to rise. This natural thermal stratification in liquid is, of course, the very reason why the thermal syphon principle in water heaters works so well.

It was this very fact which suggested a digester design with a false floor containing only water. The bottom, the lowest point of the "working" tank, could be heated by a thermosyphon action from some heat source such as solar, or even a little of the gas itself.

Alternative Fuels

The heat from the lowest part of this "double boiler" type design would rise through the slurry so that the very bottom of the "working" tank could more easily be kept at the desired temperature in the entire digesting area. Such a tank would most easily be constructed of fiberglass. It could be virtually any size.

Next time we'll think about the barriers to the transfer of heat – insulation – a critical key to any successful operation. This brings us to the question of whether the operation is a net energy producer or an energy consumer.

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Even More On Methane

Al Rutan, the Methane Man

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Temperature is critical to the success of any methane operation if it is to be considered an energy system. If the primary concern is waste management and not energy production, then a net energy loss is not a major consideration. If the intent is to produce energy, a net energy gain from the process is everything.

Body Heat

Methane activity, in one of its natural situations, is found in the digestive tract of warm blooded animals, people included. For people, the normal body temperature is 98.6° F. In a chicken or pig it is 103° F. So right at 100° F is the ideal working temperature for the methane process. To maintain this temperature outside an animal is a problem if the ambient temperature is cool or cold.

Sewage Plants ≠ Energy Producers

There were several methane farm operations launched in the upper midwest with much bravado and publicity. All of them are now out of business. On the other hand, sewage plants of medium size still commonly use the process to treat toilet waste and destroy pathogens, but in each instance they consume much more energy during the cold part of the year than they produce. The toilet water flowing into each sewage plant is ordinarily cold. It would be exceedingly difficult for sewage plants to be anything but energy users rather than producers at any time except in the hottest part of the summer.

Universities' verdicts at the end of the methane studies were always the same: "It's possible, but it isn't practical. It takes more energy to run the system than the system can provide." In harnessing methane as an energy system, it is important to conserve heat in the process of producing gas. A few years ago a new sewage plant was built at St. Cloud, Minnesota to the tune of 17 million

dollars. I asked the engineer, "Did you insulate the tank?" He said, "Oh yes. The old one used to actually freeze on the north side during the winter." My next question was, "Did you run the insulation into the ground?" His reply, "No. The ground never gets cold." My reply was, "That's right, but it never gets warm either." This sewage plant burned \$750,000 a year in fuel oil to keep the digester at 100° F. It costs big bucks to flush the toilet in St. Cloud.

Capturing Warmth

Heat has to be considered as something that is very slippery. Conserving heat requires understanding insulation. We are fortunate that there are many types of insulation available now that simply did not exist a few decades back. On the other hand, there's a general lack of understanding of insulating properties of common building materials such as wood, metal, and concrete. I recommend *Movable Insulation*, published by the Rodale Press in 1980.

Anyone familiar with insulation knows that if it gets wet, it is no longer insulation. Some "closed cell" insulating materials such as urethane, styrofoam, and polyethylene foam are more impervious to moisture than cellulose or fiberglass insulation. Even closed cell materials can break down if moisture under pressure is present.

Styrofoam is used on the outside of the foundations to provide a frost barrier for basements. Soil pressure and moisture can cause the styrofoam to be less than "bone dry" and thereby lose much of its insulating ability.

Situating the Tank

My personal preference is that the methane tank be as effectively insulated as possible. Insulation should be below the flow line of the material entering the tank, but should not be buried in the dirt, regardless of the insulation. The temperature of the ground several feet below the surface stays quite constant at 50° F – 55° F. To the methane tank, the earth is a "heat sink", a cool mass always ready to absorb its heat. The best way to fight this heat sink is to insulate the tank and build it above the ground. Another good reason for a free-standing tank is access to the grit trap at the bottom. A free-standing tank should be covered with six to eight inches of high quality insulation.

Various people have asked if a buried tank would work. I can't say that it won't, but I've never seen any that work in a cold climate, and I have seen several that don't.

Restoring Warmth

When feces leaves the body, the waste is at exactly the right temperature for working within the methane digester. Whatever heat is lost in the interval between leaving the



animal and entering the digester has to be restored. If the heat needed is significant, there needs to be a heat source available with an abundance of "free" energy, such as solar or wind.

Relation to Fermentation

The methane process is a type of fermentation. Most folks have baked bread or made homebrew beer or wine at one time or another. For instance, after a yeast dough is kneaded, it is put in a warm place free of draft and allowed to rise. A draft could produce cooling. The yeast organisms feed upon the mixture's sugar. This produces carbon dioxide bubbles, which cause the dough to rise. There is a similar activity within the methane tank. The methane organisms feed upon simple sugars, alcohols, and peptides produced by acid forming bacteria. Methane gas, CH_4 , is the result.

I've been asked if the digestion process within the tank doesn't produce some heat, such as the heat produced in a compost pile. It probably does. Because the metabolic activity is so diluted and spread out within the tank, the heat available is minimal in comparison to the target temperature.

Awareness is Essential

You'll need to know how hot the tank is, day to day, season to season. To eliminate the guesswork, install sensors both inside the tank and outside the tank. Record temperature both inside and outside the tank over a period of time. Then you will know how efficiently the tank is retaining heat, at what rate the temperature drops when no heat is added, and how much energy is needed to raise the temperature. If this is done, then a reliable calculation can be made of how much gas is needed to maintain working temperature if "free" heat is not available.

Producing methane gas is relatively easy. The conservation of heat more than any other factor determines whether a methane system will "fly" or not. Of all the systems I've seen that failed, the principal reason is improper handling of heat.

Care and Feeding of your Methane Digester

Having thought about temperature, we can turn our attention to feedstock. I work with a mixture of manure and vegetation. Sometimes the question is asked: can't one use just vegetation to produce methane? It can be done because Mother Nature does. Swamp gas burning over a marsh is just that. Because the methane bacteria are part of the "flora and fauna" of the digestive tract, every time there is a fresh deposit, there is fresh input of the microbiological organisms needed.

How Much Gas Can I Get?

There's a wide range of mixes of material you feed a methane digester. It's similar to what happens when we eat. Some of the material enters our system to maintain it and some of it passes on as waste. When manure is considered, all of it, minus the water, is designated as "total solids", and the part that is digestible to the bacteria is labeled "volatile solids". The numbers of what is and what isn't available for gas production have been gathered repeatedly over the years. Each account is quick to qualify any statement by saying that there is any number of variables when dealing with animals regarding what they are eating and how they are housed. One of the clearest reference sources is a newsletter printed in 1973 by the New Alchemy Institute in California. Their figures correspond to what I've experienced.

The numbers run like this: a cow drops an average of 52 lbs. of feces a day, of which about 10 pounds are solids, the rest being water. Of the 10 pounds of solids, 80% or 8 lbs. are volatile—can be turned into gas. A horse produces an average of 36 pounds of feces a day, of which 5.5 lbs. are volatile solids. A pig produces 7.5 lbs. per day of which 0.4 pounds are volatile solids. A human produces 0.5 pounds of feces a day of which 0.13 pounds is volatile solid. Chickens produce 0.3 pounds a day which 0.06 pounds is a volatile solid.

All of this is good information, but it still doesn't tell us how much gas we can reasonably expect. If you ask an "expert" in the field, you'll get an answer something like, "It all depends..." All manure contains a degree of nitrogen, but because nitrogen exists in so many chemical forms in nature—ammonia (NH_3), nitrates (NO_3), proteins, etc.—it's difficult to test the total amount of nitrogen in a given material.

Why Consider Nitrogen?

The process wants one part nitrogen to every 30 parts of carbon. Manure is nitrogen rich, averaging about 15 parts carbon for each part nitrogen, so all the studies show that gas production is substantially increased by including some carbon material along with the manure. The

Alternative Fuels

nitrogen proportion may be even higher in animal waste if urine is included with the feces because urination is the principle way an animal rids itself of excess nitrogen.

To illustrate, straight chicken manure will produce only five cubic feet of gas for each pound of manure, but chicken manure mixed with paper pulp will produce eight cubic feet of gas for each pound of manure used. My experience was an outstanding ten cubic feet of gas for each pound of chicken manure when the manure contained some ground feed that had been spilled. Cow manure will produce only 1.5 cubic feet of gas per pound, but cow manure mixed with grass clippings will produce 4.5 cubic feet of gas per pound of manure.

The Nature of Biogas

Assume that we have a gas producing system and it's making gas nicely and filling the gas holder. What do we actually have? It's important to understand that it isn't all methane. A proportion of it is carbon dioxide, produced by the acid forming bacteria, which doesn't burn. This fact isn't immediately evident because if one ignites the end of a hose coming from the gas holder, there is a blue flame.

The fact that is important to know is: if we had pure methane we would have a hotter flame—about 1000 BTU (British Thermal Unit) for each cubic foot of gas. With the dilution of carbon dioxide, we have roughly 600 BTU for each cubic foot of gas.

The composition of the gas in our gas holder will be:

- CH₄ methane: 54 – 70%
- CO₂ carbon dioxide: 27 – 45%
- N₂ nitrogen: 0.5 – 3%
- H₂ hydrogen: 1 – 10%
- CO carbon monoxide: 0.1%
- O₂ oxygen: 0.1%
- H₂S hydrogen sulfide: trace

Wouldn't it be nice if we could separate out the methane and dump the carbon dioxide. Interestingly enough, Mother Nature has made it very easy to do just that because these gases all have different specific gravity weights.

How to Get Pure Methane

The specific gravity of methane is about 0.55 in relation to the weight of air, so it rises, as does hydrogen. Carbon dioxide on the other hand is twice the weight of air. Within a vertical gas container, if the gases are allowed to settle, they will naturally separate themselves, the flammable gases rise to the top. This fact suggests that a good design should have a petcock at the bottom of a vertical gas holder. Use it to bleed off the accumulated carbon dioxide. In the right

setting, this isn't environmentally harmful, because the trees and growing things around the yard will welcome a fresh sniff of carbon dioxide.

Next time we'll consider some of the safety aspects needed in working with homemade gas.

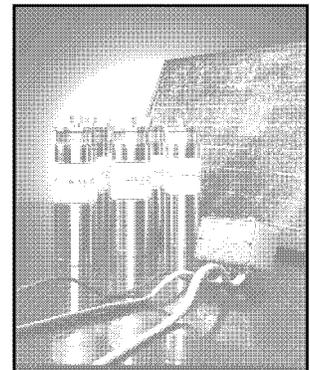
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More on Methane

Al Rutan the Methane Man

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Almost two years have passed since the last mention of methane in these pages. *Home Power* issues 26, 27, 28, and 30 described the basics of methane production from animal feces. I discussed a low pressure storage tank, tank insulation, pH balance, animal treatment, and heat retention. I'd like to share some new information I have learned since then. Some things worked and other things didn't, but all facts whether positive or negative are part of the mastering process.

Currently, my methane demonstration is being upgraded. I am discarding the plastic tank that served as a digestion vessel for the last year in favor of a metal tank. Why the change? For several reasons. First, the problems.

Bonding Difficulties

The primary difficulty is maintaining a vapor tight seal between the fill and overflow pipes and the tank. The plastic tank didn't cost much when new, so it was too tempting to pass up. But experience has shown that it was not a good choice. The tank material is polyethylene and the pipes are PVC plastic. While it's possible to weld polyethylene with heat and produce a bond, it isn't something that an amateur can do easily. I attempted to produce a vapor tight seal with various types of glues and epoxies, which was achieved with some success.

But the tank was often moved from one location to another by the trailer on which it is mounted. The sloshing within the tank caused the pipes to break the bond with the tank.

A second reason for replacing the plastic tank is that it is too short; the tank is three feet in diameter and only

five feet long. The best proportion for a tank is three to five times as long as the diameter. This rule of thumb became obvious when new material was introduced into the tank at the fill pipe. What exited through the overflow was working nicely, still bubbling like crazy.

Slurry Still Working

The supposed "waste" or "spent" bucket wasn't spent at all, but continued to be active after it had been forced out of the tank. A short tank is truly an inefficient design. The fill and overflow pipes are just too close together. Also, the fill and overflow pipes should not be in line with each other. One should be at either the right or left side of center and the pipe at the opposite end of the tank should be on the other side of center. It doesn't make any difference to which side of center the pipes are placed. But it's important that the pipes at the ends of the tank not be in line with each other.

Such a placement of the pipes provides another important advantage — the best position for the stirring mechanism. On the plastic tank, the stirring mechanism was vertical with a crank at the top. After a short time, I learned that this was a poor design for a stirring device. The seal at the top is difficult to keep vapor tight. If the bearings for the stirring mechanism are below the water line, then any leakage is no more than a little moisture, but not vapor.

When the Tank Gets "Cranky"

Also an oversight in the vertical stirring device design was the omission of a bearing point at the bottom end of the shaft. It was left to "float". With the resistance of the material within the tank, the pressure on the one bearing at the crank end of the shaft tended to distort the cover of the tank as the crank was turned.

Ideas that Worked — the Heat Bath

That's the bad news. So what's the good news? The water bath for providing heat to the tank. I originally thought that this would be an effective way to transfer heat from whatever source to the tank. In actual operation, the concept worked even better than anticipated.

Heat is supplied from a two foot square hot water box placed below the level of the water bath. The placement of the source of hot water under the water bath allows the water to circulate via a thermosiphon: hot water rises in a closed circuit of water. The connecting pipes are two inches in diameter — one for supplying warm water and another for the return of the cooler water. The pipes from the hot water box connect to an 18 inch deep metal water bath underneath the tank. The tank is placed on supports six inches above the floor of this water bath.

More Art Than Science

Let's back up for a bit. People will sometimes ask, "Does it take a degree in engineering to understand the methane process?" My answer is, "Not at all. What is most helpful is the experience of baking bread, or making wine or beer. Each of these skills is both an art and a science. There are some things that must be known. But basically, it's experience with the process of fermentation. And in the final analysis, the skill is more an art than a science."

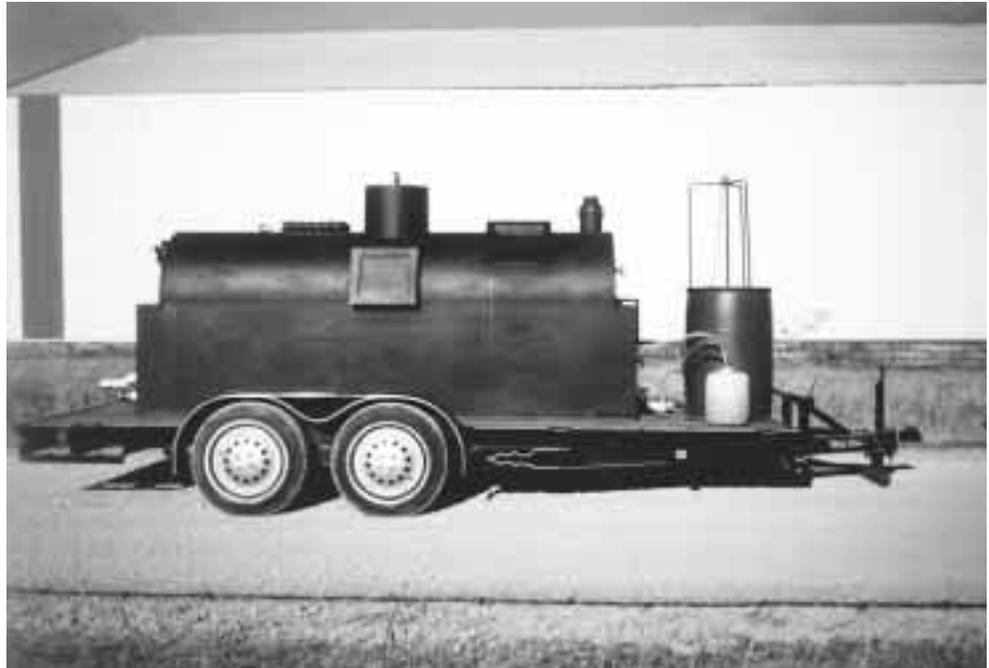
For bread to rise — which is the critical test of whether or not it will be a handsome loaf — and for wine to ferment, the temperature conditions have to be, as we say, just right. The same is true of the methane process, which is another example of fermentation. Methane production occurs virtually automatically in old landfills, but we're talking about maximum production from a minimum amount of input. As for good bread, heat supplied during the rising process needs to be just what bread wants and free of drafts. For maximum methane production, the optimum temperature needs to be supplied evenly.

Written in South Africa some years ago, L. John Fry's book *Practical Building of Methane Power Plants* observed that pipes supplying heat to the slurry had to be hotter than the optimum temperature in order to get enough heat to the mass. This caused two unfavorable effects. The methane organisms in the proximity of the pipe were cooked to the kill point. Such heating caused a crust to form on the heating pipe that eventually caused the heat within the pipe to be insulated from the slurry.

Using pipes for the heat transfer is not the way to go. But body warmth for the process is essential, as is the right temperature for causing bread to rise or beer to ferment. So the next question is, "How best to heat the tank?"

The Key to Even Heating

In my book, *The Do's & Don't's of Methane*, the proposal to solve the problem was a false floor within the methane tank. This would separate the active slurry



Above: The new metal tank methane digester on its trailer.

Photo by Al Rutan

from the water beneath; the warm water provides heat transfer to the slurry above. The false floor thus acts as a double-boiler.

The source of heat is below the slurry, providing heat at the very lowest point. Because the heat transfer is spread over the entire lower surface, there are no hot spots that produce a kill temperature or crusting problem.

Thermosiphon Provides Effective Circulation

Setting the tank in some sort of a water bath was a given. But the surprise benefit in this design is how easily and how well the principal of thermosiphon worked for the heat transfer. The water heater provides heat from either a small gas burner or solar panel. This warm water moves up into the water bath, circulating so effectively that one would assume there is a circulating pump somewhere in the system.

But there is no pump, just a closed circuit of water moving by a heat differential. In the 18 inch deep water bath, the hot pipe enters the bath at the mid point — or nine inches above the floor. The return pipe at the opposite end of the bath is as low as possible. With only a nine inch difference between the input and the return pipes, the circulation is wonderful.

The reason for the input entering the bath at the midpoint is to provide as much of a strata of warm water above the input as possible. And it works amazingly well. The water bath heats the tank evenly

Methane

and effectively from the bottom up so that the working temperature within the slurry is even and constant. This approach to handling the heating problem has been designated the Rutan Design.

What's in the Words

As I write this, a new methane display is being constructed. It consists of a new trailer — a 16 foot car hauler — fitted with metal tank three feet in diameter and ten feet long. The tank has three windows so that one can watch the methane activity within the tank. It will be heated with a solar collector, using some stored gas for backup. With the right kind of feeding and management, this size is large enough to provide the cooking and heating needs for an energy efficient homestead.

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