ALTERNATIVES TO FOSSIL FUELED ENGINE/GENERATORS

Clifford W. Mossberg

For most of us who live in secluded areas and who employ alternative energy technologies to provide us with a contemporary standard of living, looking for more efficient alternatives is second nature. Most of us have wondered about an alternative to the use of fossil-fueled engine/generators to back up our more desirable energy sources.

Photovoltaics and wind energy are intermittent or diffuse technologies which require storage to be effective and are limited in output. Hydro power is site specific and will not be available in many places. Alternative energy generation also costs a lot of money initially and the temptation to go with the cheapest and sometimes only affordable power source is strong. Usually that is a fuel driven engine/generator. There are lots of reasons to use a "light plant", but sooner or later the moment of truth comes: These things are noxious, noisy, take more maintenance than a new born baby, and eat more than a teenager. "Isn't there something else!?"

Yes there is. The advantage to a "light plant" is that by paying the price we are able to create energy in large quantities and at our discretion using easily obtainable and conveniently transported fuel. We are not at the whim of wind, sun and water. So any replacement technology must have, at a minimum, this element of discretionary use.

Steam Power

Historically one of the earliest alternatives to fossil fuels is a wood fired boiler producing steam which powers an engine driving a generator. I've noticed interest in this recently among letters from Home Power readers. I would like to share some perspectives on steam power and its alternatives.

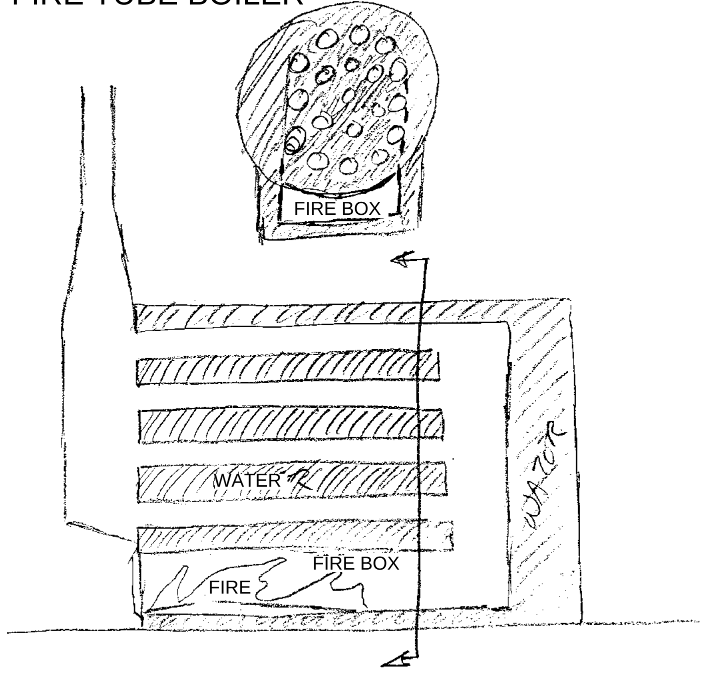
First the good news: Steam CAN be produced from wood; allowing us to use Ma Nature to produce and store our energy for us in our own back forty. This, unfortunately is about the only advantage. The bad news is that steam power has all the disadvantages of an engine/generator and several more all its own. Ma Nature may provide the fuel but we, the user, must "condition" it. The wood must be chopped and carried, cured, split, and fed, just as for any wood stove. Ashes must be handled and hauled. The entire installation requires constant babysitting while it is running -- no walking away from this thing to do the wash! But the real kicker is the inherent danger in steam.

Steam occupies about 1200 times the volume of water at atmospheric pressure (known as "gage" pressure) -- that's ONE THOUSAND TWO HUNDRED TIMES! Producing steam requires heating water to above boiling temperature under pressure. Water boils at 212° F. at sea level. By pressurizing the boiler it is possible to raise the boiling temperature of water much higher. At a pressure of 52 psi gage the boiling temperature is 300°, at 120 psi gage it is 350°. Elevating steam temperature like this HAS to be done to use the the generated steam for any useful work otherwise the steam would condense in the supply lines or inside the cylinder of the steam engine itself. Typical working limits for a small simple "home style" boiler are in the range of those given above.

Fire Tube Boiler

There are two basic kinds of boilers: The first is the FIRE TUBE boiler where the water is heated in a large pressurized tank. To increase the surface area so that heat may be transferred to the water more efficiently there are tubes passing thru the boiler carrying hot flue gases. Essentially these tubes are multiple smoke stacks which run from the fire box through the water before exhausting up a chimney. This type of boiler can hold a significant amount of water.

FIRE TUBE BOILER



Water Tube Boiler

The second type of boiler is a WATER TUBE type. In this unit water is carried through the fire box in pipes. Steam is produced in these pipes and goes to the point of use. This type of boiler has much less water heated and under pressure at a given time.

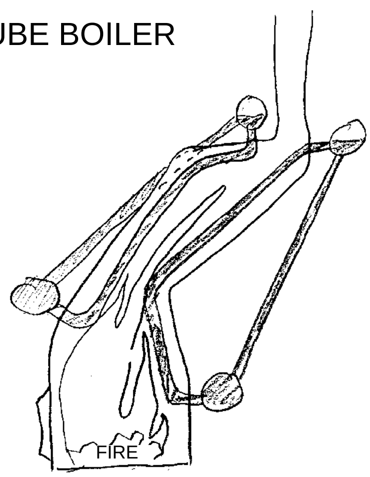
Why worry about the amount of heated and pressurized water? Picture a very small boiler, maybe the size of a fifty-five gallon drum. Rough dimensions of one of these drums is around 24 inches in diameter by about 36 inches long; about 9 1/2 cubic feet of water at 70 pounds per square inch (all pressures are given as "gage" here, which means the atmospheric pressure of about 15 psi is subtracted from the "absolute" pressure reading) and 316° F.

What happens if the boiler springs a leak? Pressure immediately falls. Since there is less pressure on the heated water it immediately starts to boil. As the water boils it produces steam which raises the pressure on the water and inhibits boiling. This condition normally exists in a boiler and produces a controlled reaction. The "leak" is the boiler steam outlet pipe.

But what happens if there is an uncontrolled leak in the boiler such as equipment failure might produce? As pressure drops and water starts to boil there is no restriction to stabilize the pressure and ALL the water can immediately flash into steam. In our example if you start out with 9 1/2 cubic feet of superheated water and reduce the pressure to zero you almost instantaneously have 1200 times 9 1/2 cubic feet, equal in volume to a single story house measuring about 35 by 40 feet. You suddenly have 11,400 cubic feet of steam in a 9 1/2 cubic foot pot and a real -- but short lived -- problem; a massive boiler explosion.

At the core of this explosion is superheated steam at 316°. If the shrapnel and concussion is daunting enough, this 316° steam will instantly cook any flesh it comes in contact with and can literally strip flesh off the bone. Does the average small homesteader want to play dice with this process? (The hypothetical boiler in our example has a total internal working force of about 125 tons applied to it!)

WATER TUBE BOILER



A water tube boiler is more benign. It may only result in an explosive steam volume of one or two "rooms" in the "house" in the example. Therefore a water tube boiler is the preferred design for anyone getting serious about steam. Failure of a water tube boiler probably won't take out City Hall, but it would not be comforting to those in the vicinity.

So why not just opt for a water tube boiler and get on with it? Economics. A fire tube boiler can be fabricated from a cylindrical tank with straight tubes running through it from end to end. A water tube boiler is fabricated as a fire box with many small tubes with complicated bends in them welded inside. There is a lot more precise design, welding, and fabrication involved with a water tube boiler.

Then there is the fact that ALL boilers manufactured or used in the United States must be built to rigid specifications and tested in accordance with regulation and prescribed procedure; not just initially but throughout their installed life. Any boiler is potentially dangerous and expensive.

If you are willing to spend money to acquire a working boiler and operate it what do you have? Let's look at efficiency:

The traditional gasoline engine can be used as a baseline that we are familiar with. It is considered to be about 28% efficient. A diesel engine is considered to be about 32% efficient. This efficiency is a measure of the engine's ability to turn heat energy in fuel into useful work and the figures I've given represent an average of a range of values. A better way of thinking of efficiency is that 72% of the heat developed by gasoline burned in a gasoline engine is wasted; or about seven out of every ten gallons of gas you burn goes to heat the air, either through the radiator, radiation from the engine, or out the tailpipe. How does steam compare?

A typical single acting single cylinder steam engine (the kind most of us might easily acquire) runs from about 7% to 12% efficiency. A high performance double acting multi-cylinder unit might run about 15% to 17% efficiency. A well insulated unit with a vacuum condenser might push that up as high as 22% if you were very lucky. Even were you to go to a very sophisticated steam turbine installation -- totally out of sight financially for most of us -- the efficiency would only be pushed up to about 26%; the lower end of gasoline engine technology. Bear in mind that YOU will bear the direct burden of this inefficiency right on your back. Only 7% of the energy in the firewood you painstakingly lugged out of the woodlot will turn into energy you can use to generate electricity. This doesn't factor in any environmental damage.

I haven't said anything yet about your time. The typical small steam installation will require constant attention to operate. Automatic controls do not adapt well to burning a non-uniform fuel like logwood and are too expensive and complex to find their way into small installations. You will have to hover over this unit to feed fuel, monitor boiler pressure, check feed water, oil equipment, etc. The operator is apt to become the exclusive servant of the machine when it is powered up.

Now that I have painted this bleak picture let's ask if there's any alternative to steam as a replacement for the family "light plant"? YES! The surprising answer is that a conventional gasoline or diesel driven engine/generator set can be combined with wood gas technology to do the job. While it has drawbacks of its own, this marriage is much cheaper and safer than steam.

Wood Gasification Basics

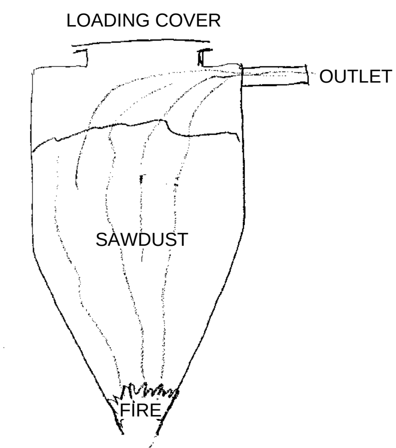
Wood gasification is also called producer gas generation and destructive distillation. The essence of the process is the production of flammable gas products from the heating of wood. Carbon monoxide, methyl gas, methane, hydrogen, hydrocarbon gases, and other assorted components, in different proportions, can be obtained by heating or burning wood products in an isolated or oxygen poor environment. This is done by burning wood in a burner which restricts combustion air intake so that the complete burning of the fuel cannot occur. A related process is the heating of wood in a closed vessel using an outside heat source. Each process produces different products.

If wood were given all the oxygen it needs to burn cleanly the by-products of the combustion would be carbon dioxide, water, some small amount of ash, (to account for the inorganic components of wood) and heat. This is the type of burning we strive for in wood stoves.

Once burning begins though it is possible to restrict the air to the fuel and still have the combustion process continue. Lack of sufficient oxygen caused by restricted combustion air will cause partial combustion. In full combustion of a hydrocarbon (wood is basically a hydrocarbon) oxygen will combine with the carbon in the ratio of two atoms to each carbon atom. It combines with the hydrogen in the ratio of two atoms of hydrogen to one of oxygen. This produces CO_2 (carbon dioxide) and H_2O (water). Restrict the air to combustion and the heat will still allow combustion to continue, but imperfectly. In this restricted combustion one atom of oxygen will combine with one atom of carbon, while the hydrogen will sometimes combine with oxygen and sometimes not combine with anything. This produces carbon monoxide, (CO) (the same gas as car exhaust and for the same reason) water (H_2O), and hydrogen gas (H). It will also produce a lot of other compounds and elements such as carbon, (C) which is smoke.

Combustion of wood is a bootstrap process. The heat from combustion breaks down the chemical bonds between the complex hydrocarbons found in wood (or any other hydrocarbon fuel) while the combination of the resultant carbon and hydrogen with oxygen -- combustion -- produces the heat. Thus the process drives itself. If the air is restricted to combustion the process will still produce enough heat to break down the the wood but the products of this inhibited combustion will be carbon monoxide and hydrogen, fuel gases which have the potential to continue the combustion reaction and release heat since they are not completely burned yet. (The other products of incomplete combustion, predominately carbon dioxide and water, are products of complete combustion and can be carried no further.) Thus it is a simple technological step to produce a gaseous fuel from solid wood. Where wood is bulky to handle, a fuel like wood gas (producer gas) is convenient and can be burned in various existing devices, not the least of which is the internal combustion engine. A properly designed burner combining wood and air is one relatively safe way of doing this.

CRUDE WOOD GAS GENERATOR



Another path to a similar result is to heat wood in a closed container until it is hot enough for the chemical bonds holding the hydrogen and carbon together to break. This is destructive distillation, a quite different process from that of combustion since no outside oxygen is introduced. You might think that such a device would produce only hydrogen gas and carbon But that is only because I have kept this explanation oversimplified for clarity. The products of this process will depend on the make up of the wood and the temperature it is heated to. All wood contains some water and this can be anywhere from about 7% to 50% or higher, so this water is available to play a part in the destructive distillation process. Wood also contains many other wild and wonderful chemicals, From alkaloid poisons to minerals. These also become part of the process. They can be assets or great liabilities.

As a general concept, destructive distillation of wood will produce methane gas, methyl gas, hydrogen, carbon dioxide, carbon monoxide, wood alcohol, carbon, water, and a lot of other things in small quantities. Methane gas might make up as much as 75% of such a mixture.

Methane is a simple hydrocarbon gas which occurs in natural gas and can also be obtained from anaerobic bacterial decomposition as "bio-gas" or "swamp gas". It has high heat value and is simple to handle.

Methyl gas is very closely related to methyl alcohol (wood alcohol) and can be burned directly or converted into methyl alcohol (methanol), a high quality liquid fuel suitable for use in internal combustion engines with very small modification.

It's obvious that both of these routes to the production of wood gas, by incomplete combustion or by destructive distillation, will produce an easily handled fuel that can be used as a direct replacement for fossil fuel gases (natural gas or liquified petroleum gases such as propane or butane). It can be handled by the same devices that regulate natural gas and it will work in burners or as a fuel for internal combustion engines with some very important cautions.

Producer Gas Generators

How do you achieve this? Let's start with the combustion process hardware first: The simplest device I know of is a tank shaped like an inverted cone (a funnel). A hole at the top which can be sealed allows the user to load sawdust into the tank. There is an outlet at the top to draw the wood gas off. At the bottom the point of the "funnel" is opened and this is where the burning takes place. Once loaded (the natural pack of the sawdust will keep it from falling out the bottom) the sawdust is lit from the bottom using a device such as a propane torch. The sawdust smolders away. The combustion is maintained by a source of vacuum applied to the outlet at the top, such as a squirrel cage blower or an internal combustion engine. Smoke is drawn up through the porous sawdust, being partly filtered in the process, and exits the burner at the top where it goes on to be further conditioned and filtered. The vacuum also draws air in to support the fire. This burner is crude and uncontrollable, especially as combustion nears the top of the sawdust pile. This can happen rapidly since there is no control to assure that the sawdust burns evenly. "Leads" of fire can form in the sawdust reaching toward the top surface. Once the fire breaks through the top of the sawdust the vacuum applied to the burner will pull large amounts of air in supporting full combustion and leaning out the value of the producer gas as a fuel. This process depends on the poor porosity of the sawdust to control the combustion air so chunk wood cannot be used since its much greater porosity would allow too much air in and you would achieve full combustion at very high temperatures rather than the smouldering and the the partial combustion you want. Such a burner is unsatisfactory for prolonged gas generation but it is cheap to build and it will work with a lot of fiddling.

For prolonged trouble free operation of a wood gas generator the burner unit must have more complete control of the combustion air and the fuel feed. There are various ways to do this. For example, if the point of our original funnel shaped burner is completely enclosed then control over the air entering the burner can be achieved. This configuration will successfully burn much larger pieces of wood. One of the most widely known burners was developed by Mother Earth News magazine. They produced a complete set of plans for their burner and featured its construction and evaluation in several issues of their magazine. At the end of this article I have listed sources of information and/or hardware for several of the concepts I have written about.

Destructive Distillation Units

If the type of wood gas you would like to produce is to be obtained by destructive distillation then all you need is a canister about the size of a 55 gallon drum that can be loaded with wood and sealed air tight. It must also have an outlet pipe and a source of heat which can be applied to it from the outside. A simple way to do this would be to just build a wood bonfire under the canister. While this has the advantage of being "quick and dirty" it is the equivalent of the simple sawdust burner I described above. It allows little control and requires a lot of time and fussing to make anything work.

The use of a fossil fuel to heat the wood gives good control over the temperature of distillation but defeats the purpose of producing a fuel from wood. An ideal solution to this control problem is to use a combustion type wood gas generator to produce fuel gas, which is then burned to achieve destructive distillation, which produces a higher heat content fuel; a fuel that can then be liquified into methanol.

It is also desirable to mount the canister in such a way that it can be rotated while it is being heated so that the contents inside are evenly "cooked".

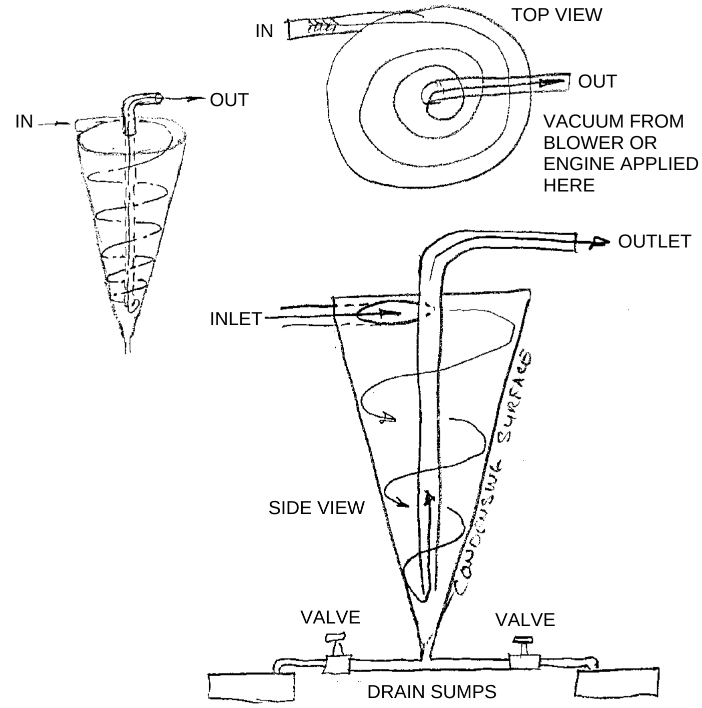
Conditioning And Filtration

However you produce the wood gas you are certainly not home free when your fuel exits your burner. Far from being the nice clean chemical reactions I've used for simplicity, the fuel gas you will actually produce will contain ash, gum, heat, water, creosote, acids, and a lot of other weird things which will render any device you try to burn the fuel in dead on arrival. The fuel must be conditioned and filtered before it can be used.

Probably the best first step to achieve gas conditioning is a cyclone separator to get rid of water and particulate matter. This device is again an inverted cone but the bottom is sealed. After the contaminated fuel gas leaves the burner unit it enters the top on a tangent to the circumference of the side. The exit for the fuel is a pipe which runs up the center of this cone from just above the point at the bottom. Gas coming into the cyclone separator enters with some velocity. Because it has weight and therefore inertia it tries to continue in a straight line even though the sides of the cone are curved. To exit the cone the gas would have to turn 90° toward the bottom and then 180° up the exit pipe if it could take the shortest path. However under the influence of its own inertia the dirty fuel gas is held against the curved outside wall of the cone, where it takes a circular path toward the bottom and the exit pipe. It circles around and around this wall, all the time moving in tighter and tighter circles toward the point on the bottom, thus speeding up its velocity as the circles get smaller nearer the point. The fuel gas is spinning quite fast near the exit pipe. This rotary gas flow is where the separator gets its name.

Within this stream of rapidly spinning gas the ash and water vapor, weighing more than the fuel gas, are thrown outward against the walls of the separator by centrifugal force. When the heavier components in the fuel gas come into contact with the relatively cool sides of the separator the water condenses, wetting the inside of the separator down and flowing downward to a drain at the bottom. Ash and particulate matter are also thrown out against the

CYCLONE SEPARATOR



now wet walls where they get washed out of the gas stream by the condensing liquid. All of this gunk winds up running out the bottom of the separator and into a holding tank, which can be drained at intervals.

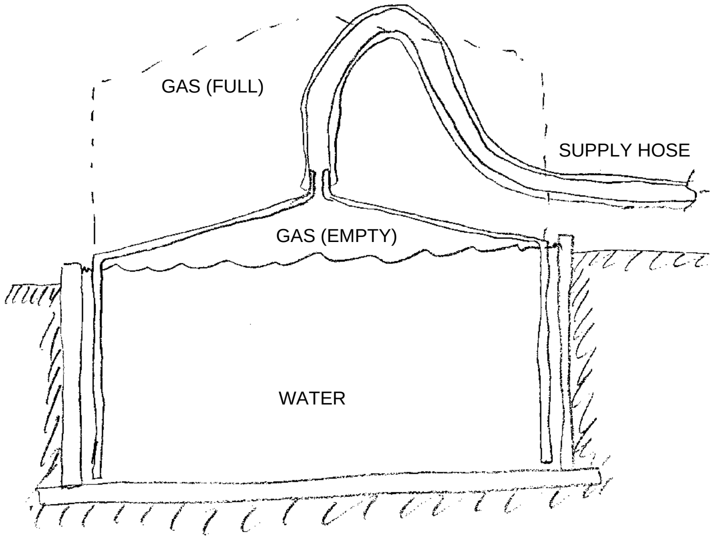
To help the water condense out of the gas stream the walls of the cyclone separator may be cooled by water or an air stream to raise the efficiency of the condensation and scrubbing process.

Upon its exit from the cyclone separator the fuel gas will have to be cooled further. A simple way to do this is to place a vehicle radiator into the gas flow and draw the fuel gas through this. In a perfect world there wouldn't be any water left in the fuel gas after it left the cyclone separator. Unfortunately there is apt to be quite a bit of uncondensed water vapor still left in the hot fuel gas as it enters the gas cooler. As the gas cools the water vapor will condense out further. It may be necessary to use multiple stages to completely cool the fuel gas. That is you may have to use more than one radiator, with the outlet of one connected to the inlet of the next, and so on. Cooling air can be blown through each radiator by an electric cooling fan and each radiator will need a sealed drain canister to carry off condensed liquid.

Once the cool dry fuel gas leaves the cooler it is ready for the last stage of conditioning. It must be well filtered to keep fine ash and particulate matter from being carried into the engine or burner which the gas will be used in.

An alternative to immediate use of fuel gas is storage. The gas can be stored at low pressures -- 3 to 5 psi-- in a simple tank of the type developed to store biogas from methane/solid waste digester. This is an open tank placed upside down in water. When empty, the tank sinks in the water but as gas is forced in the tank rises out of the water. The weight of the tank can be augmented or

LOW PRESSURE GAS STORAGE TANK WITH WATER SEAL



counterbalanced to control the pressure of the gas inside. Fuel gas is pulled from the gas generator by a simple centrifugal bower, which forces it through the conditioning stages and into the storage tank under pressure. It is desirable (but not necessary) to have a storage tank even if the gas is to be immediately used as fuel. Such a reservoir maintains a buffer supply of gas to even out any fluctuations in supply and provides an even, controllable supply of pressure to the end device. It also acts as a cooler and a sink for any impurities which remain in the fuel gas after conditioning. Such a storage tank could pay for itself by saving money on conditioning the fuel gas since contaminants will cool, condense, and settle out in the storage tank and water seal. Two tanks, used alternately, may reduce the need to condition the gas, requiring only the use of the cyclone separator. In this arrangement one tank can be filled and cooling off while the user device is run from the second tank.

If your choice is to produce methane and methyl gas rather than producer gas, then the conditioning process will not be so demanding. You will not have a lot of ash and carbon to deal with. The products of destructive distillation will exit the generator canister under their own pressure. If a blower is used to fill a gas storage tank it should be placed after the gas cooling stages are held at a partial vacuum as condensation occurs, this will improve their efficiency. The final particulate filter can be eliminated, especially if gas storage tanks are utilized.

If your goal is to produce methyl alcohol (methanol) then you will have to catalyze the methyl gas and methane into liquid alcohol. In addition, you will not want to use a cyclone separator since the condensed liquid contains the methanol you are seeking. Gas coming from the generator canister will pass through a catalyzer unit. The alcohol vapor produced by catalyzation is then routed to the gas cooling stages which condense it to liquid methanol. In this case the drains from the cooler carry off the raw methanol distillate rather than waste condensate. This raw methanol will undoubtably require further distillation to purify it and extract excess water.

Catalyzing the methane and methyl gas can be accomplished crudely but simply. The gas which comes out of the generator canister is routed through a copper pipe with a copper "Chore Girl" pot scrubber inserted in it. A one inch copper pipe about twenty feet long attached directly to the generator outlet and having the "Chore Girl" inserted into it loosely should do the job. The inlet of the pipe should be above the outlet so that any methanol condensing in the catalyzer can drain out. Insulating the catalyzer to keep the temperature up will help greatly. Soft copper pipe formed into a large coil makes a relatively compact catalyzer. The outlet from the catalyzer is attached to the cooling (condenser) stages.

I've suggested a copper catalyst (the Chore Girl) because of its availability and cost but it is not the most efficient catalyst. It may well be that a platinum catalyst would be much more efficient but a custom built platinum catalyst would be very expensive. With the common availability of platinum based automotive catalytic converters, use of one of these converters may be a better alternative than what I have described. I have no hands-on knowledge of that though.

Hydrogen Fuel

Another alternative to steam is the use of on-site generated hydrogen as a fuel for an internal combustion engine. Hydrogen makes a very high quality fuel because it burns so cleanly. The only product of idealized hydrogen combustion is water and heat.

The use of hydrogen as a motor fuel is very much in the experimental stage right now. Commercial supply of hydrogen just is not commonly available in quantity. Neither is there a convenient technology for storing it in any quantity. Technologies such as metal hydride storage and liquid hydrogen are beyond the scope of this article and beyond the scope of most users. On-site generation of hydrogen is a viable alternative however.

In the past small scale "home" generation of hydrogen gas was commonly done by electrolysis of water. If a tank is fabricated in a "U" shape with a cathode in one leg and an anode in the other a current can be passed through the water. The electrical energy will disassociate the atoms of hydrogen and oxygen in the water, with each component gas collecting in a different leg of the tank where they can be drawn off in pure form. Using the right combination of pressure, voltage, and current this can be done fairly efficiently. The electrical supply can be from an alternative energy source.

Recently, however, there has been work done on a gas generator which can produce large quantities of hydrogen simply and efficiently using a device similar to a wire feed (MIG) welder. (See Hydrogen Fuel Breakthrough With On-demand Gas Generator, Automotive Engineering, August 1985, Volume 93, Number 8, Page 81) An aluminum wire charged with electricity is fed under water to a rotating drum. The arc from the electrical contact causes the aluminum in the wire to combine with the oxygen in the water. The reaction produces hydrogen and oxygen gas and a slurry of aluminum oxide, which settles to the bottom of the tank. This generator is small, portable, and low tech, and can easily be incorporated into a vehicle.

This technology is very promising since either in a vehicle or in a stationary unit the gas generator can be run by a battery which is charged by alternative energy methods. It is obvious that it can also be charged by the device it supplies, such as an engine/generator unit or a hydrogen fuel cell. This technology also provides a viable alternative to an all-electric vehicle since it takes much less stored battery energy to produce the hydrogen fuel from water than it would to actually power the vehicle entirely with battery storage. This has great potential but I have no hands-on experience with it as yet.

Safety

It's important to cover some of the safety considerations of fuel gas, alcohol, and hydrogen gas:

Unlike steam power there is no storage of massive amounts of latent energy in a wood gas generator of either type. Producer gas generators run under a modest vacuum, while destructive distillation proceeds under relatively low pressure. Obviously all the gases are flammable and the usual precautions taken with more common gaseous fuels, such as natural gas and liquid petroleum gases, should be observed. In addition there are considerations specific to these home brewed fuels.

Hydrogen, either by itself or as a component of wood gas fuels, has the smallest and lightest molecule of any element. Consequently it will pass through holes and pores that would be too small for any other gas. Thus hydrogen is very prone to leak, either from poor connections or right through the pores of material used for tanks, hoses and caulking. On the other hand, the "Hindenburg Syndrome" not withstanding, there is actually less danger from leaking hydrogen exploding because it is so light it rises and dissipates readily in the air.

Carbon monoxide is a large component of producer gas and it is deadly. It's not sufficient for anyone overcome by carbon monoxide to just reach fresh air because the monoxide combines with the hemoglobin in blood to render it permanently inert. Blood so affected can no longer carry oxygen to the body and brain. Thus extensive emergency measures must be taken to treat a victim of carbon monoxide poisoning. This means that producer gas generated by a burner is NOT AT ALL suitable for use in stoves, water heaters, gas refrigerators, or any enclosed area where concentrations of the gas might collect if a flame went out. This gas must only be used in VERY well ventilated areas, preferably outside or under a roof with no walls.

Methanol (wood alcohol) is also quite deadly, including the fumes which might be breathed. Methyl alcohol interferes with the function of the nervous system and will cause blindness and death in small quantities if consumed. The process which produces either a gaseous product from destructive distillation, or which is the first step toward production of wood alcohol, can contain methanol as a hot vapor. Therefore it is not actually necessary to consume wood alcohol to be poisoned by it. Breathing methanol vapor from a poorly sealed generator system will have the same deadly effects.

Power Producing Hardware

Before I discuss the hardware to produce power from wood gas I would like to warn you that I will not be writing about some of the newest and most promising techniques for the simple reason I am not qualified. Things like fuel cells, Stirling engines, and hydrogen fuel will be ignored. My original work with wood gas grew from trying to use wood as a cheap, renewable, locally available fuel. It evolved through through steam technology -- which I found too inherently dangerous -- to wood gas, and into methanol as a fuel. My purpose for writing this now is to discourage people from fiddling with steam power because of the tremendous damage that the energy stored in latent heat can do in an equipment failure. So I will concentrate on machinery which can be readily used to turn wood into power.

As I've already mentioned, the fuel gases you can generate from wood can be used as any other gaseous fuel; either burned in an external combustion burner or used as fuel for an internal combustion engine.

Two further considerations are whether the fuel will be used directly as it is produced from the generator or whether the gas will be stored and then used.

First let's briefly discuss the use of fuel gas in an external burner: If you intend to use fuel gas for this purpose I wish to repeat my warning about the deadly nature of producer gas due to its carbon monoxide content. Producer gas is totally unsuitable for domestic indoor gas use. However gas produced through destructive distillation is useful for this purpose. Since it is methane it is similar to natural gas but unlike natural gas it does not have fractions of the heavier petroleum gases such as propane and butane to fortify the heat content. Fuel gas obtained from destructive distillation is a relatively low heat content fuel and therefore requires larger quantities to do the same job. The significance of this is that a burner will have to be designed to flow larger quantities of gas. In some cases you may find regular stove top and oven burners that will work satisfactory since these are usually highly adjustable so that they can burn either dense LP gas or lighter natural gas. The range of this adjustment may include that necessary for wood gas. Since wood gas is close to biogas in nature the user will find useful information on burners in the biogas literature, which is more readily available publicly than that on wood gas.

Gas from destructive distillation will burn very clean, so clean in fact you may not realize it is burning. In daylight the flame will be almost invisible under the right conditions, The user is cautioned to consider this as a safety hazard in experimentation.

The Internal Combustion Engine

The most valuable use of wood gas is probably as a fuel for the internal combustion engine and here both types of wood gas will work well. The technique for using gas directly from a generator is considerably different from what's required to use fuel from a storage tank. This is a special case of the general information.

On the plus side wood gas burns cleanly in a regular internal combustion engine and as a fuel it has a high "octane" rating or resistance to preignition inside the cylinder. On the minus side it is lower in heat value than other fuels.

The significance of this is that wood gas can be burned in Briggs and Stratton engines, Wisconsin engines, Ford and Chevy engines and even diesel engines. The high "octane" rating may only have significance to the dedicated wood gas user so I will come back to that after covering the disadvantages of the lower caloric value of the fuel.

An internal combustion engine is basically an air pump. The physical dimensions of the inside of the engine limit the maximum amount of air that can move through it. There is no such limitation to the amount of fuel that can be added to the air. So the trick to getting more power out of an engine is to get it to pump more air. However the air and fuel must burn to produce any power and this will only happen within a narrow range of air and fuel mixture ratios (by weight). With a gasoline engine the air/fuel ratio is about 14 1/2 to 1, air to fuel. Reduce the quantity of fuel and ignition of the mixture in the cylinder will soon stop. If you increase the fuel beyond the ideal air/fuel ratio all of the air in the cylinder will burn before all of the fuel can burn. This will waste fuel. Thus an internal combustion engine is limited in output by the amount of air it can "swallow" and this also limits the amount of fuel that can be taken in.

When burning wood gas there is also an ideal ratio of air to fuel but the limiting factor is still the amount of air the engine can pump. You have a fuel that is lower in heat value than other fuels and cannot produce as much power per pound. The net result is that an engine running on wood gas produces less power at the same speed (pumping the same amount of air). It is a loss of about 20%. The engine will only produce about 80% of the power it would if run on gasoline.

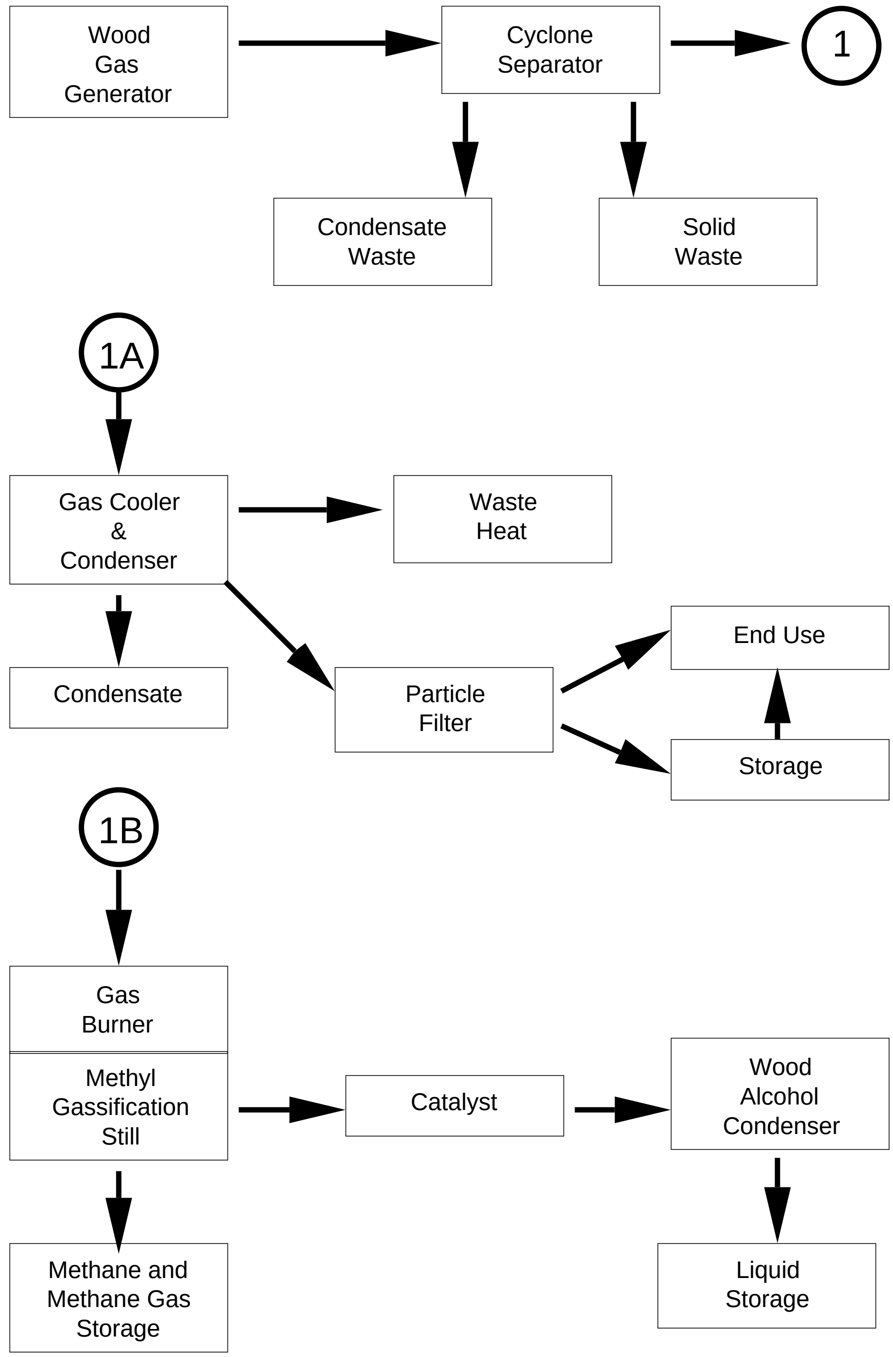
As an example, if we were burning wood gas in a 3 1/2 horse power engine we could only count on getting 2.8 horse power out of that engine. You would need an engine capable of developing 4.2 horse power on gasoline to give you the same 3 1/2 horse power output. For practical purposes its an easy matter to use a 5 horse power engine instead of a 3 1/2 horse power engine, but the necessity for this must be kept in mind.

Another "drawback" of wood gas is its lack of lead. I consider this an asset but some older engines won't. The advantage of fuel gas is that its a relatively safe low tech fuel that can be fed to any old cheap chunk of junk yard iron to develop power. But this older iron was developed with soft valves that depended on tetra-ethel lead to lubricate them. Use with fuel gas will likely cause these valves to burn and the engine will lose compression. The solution here is to try to find an engine designed for low lead gasoline or for natural or LP gas fuels. These engines will have hardened valves and seats.

Wherever possible the wood gas user is advised to use already existing controls to adapt an engine to wood gas use. Gas supplied at pressures of up to 5 psi is close to the pressures used to distribute natural gas. Where it's available natural gas has been in use for many years running industrial and irrigation engines. Controls for supply and mixture of natural gas are readily available and can be adapted with very little trouble. This presupposes that the fuel gas is held in a tank and supplied to the engine at a constant density and pressure. In the case where producer gas is consumed directly from the gas generator the pressure and density are controlled by the engine itself through engine vacuum.

Typically, in a direct installation, gas flow from the burner to the intake manifold is sustained by the running engine. Engine manifold vacuum pulls the "smoke" through the burner and draws combustion air in, it draws circulating fuel gas through the cyclone separator, through the gas cooling stages, and through the final filter into the engine. Because of this the engine must be developing vacuum (pumping air) before the gas generator can work. But the engine must have fuel before it can be run to produce a vacuum. The solution to this "chicken or egg" quandary can be solved several ways.

WOOD GAS BLOCK DIAGRAM

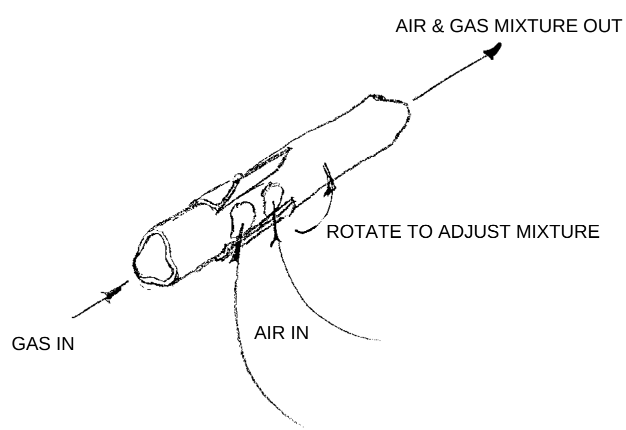


An electric powered blower can be installed in the induction tubing just after the burner outlet. This will provide vacuum to start the burner and will feed fuel gas to the engine so that it can be started and run. The disadvantages are that the blower will be subject to the high heat and unconditioned gas leaving the generator. This will destroy the blower. Moving the blower downstream to the other side of the gas cooler might seem to be the solution here but you will find that the low vacuum which a standard squirrel cage blower can generate is not going to be enough to efficiently draw fuel gas through the obstructions of the cyclone separator and the gas cooling stages. Use of a high speed, high efficiency centrifugal blower of the type used on a blacksmith's forge will partly overcome these restrictions. This is the type of blower you will need if you want to fill a storage tank.

Of course, the user can try and get the fuel in the gas generator burning and then just crank the engine over with the starter until the draw from it pulls enough fuel gas in to start it. You will find that this takes quite a while though. It will require a large battery capacity and will result in the eventual destruction of the electrical starter through overheating.

Another method, used successfully by Mother Earth News in their work, requires starting the engine on gasoline and then switching over to fuel gas on the fly. One way that this can be done is by piping the fuel gas into the top of the carburetor on the running engine. Gasoline is shut off to the carburetor and fuel gas, mixed with air, takes over running the engine. This sounds easy but getting the transition to occur smoothly between fuels (to occur at all) is very difficult. The Mother Earth method of accomplishing this was to place a "T" in the induction system. The carburetor was mounted on one side of the "T" and fuel gas was piped to the other. A flapper valve was placed at the junction of the "T" so it could select one fuel system or the other. This method works smoothly but requires a throttle body in the fuel gas system in addition to the one in the carburation system. The single advantage to piping the wood gas into the top of an already existing carburetor is that speed regulation of the engine is done with the existing hardware of the carburetor itself, thus it could be used with an existing machine (generator, pump, tractor, etc.) without modification. All of these starting methods have specific drawbacks.

CRUDE CHAMBER FOR MIXING AIR AND GAS FOR A CONSTANT RPM ENGINE



The Pony Engine

The method I have finally adopted to get around these disadvantages is to use a small gasoline engine which can be connected and disconnected to the main engine with a clutch. The drawback here is that it is not a compact method and is more useful with a stationary engine where space and weight are unimportant. Using this method the small engine can be started and used to bring the main engine up to speed with the ignition shut off. This has the advantage of prelubing the engine with oil before a load is applied and the main engine can be motored over for as long as it takes to light the burner, draw in fuel gas, and allow the temperature and density of the fuel to stabilize. A flick of the ignition switch will then start the main engine and the "pony" engine is disengaged.

I used a gasoline engine as a "pony" engine because I was experimenting with a 350 cubic inch Chevy V8. If the engine is small enough it could be motored over using an AC or DC motor and either power line or battery current.

The pony engine method of starting works well with a stationary engine or where space or weight are not a problem. Where these are considerations the dual fuel approach is worth the effort.

A diesel engine can also be run off wood gas with almost no modification. In this case the engine will be started and run up on diesel fuel. The fuel gas supply will require the usual air mixer and a throttle body before entering the induction of the engine. If constant speed is your goal you will will also have to add an external governor to control the fuel gas throttle body. Once started and switched over to wood gas the diesel throttle is set at idle and the small amount of fuel injected is used to ignite the air/fuel gas mixture in the cylinders. Speed is controlled by the fuel gas throttle body.

I mentioned earlier that wood gas had a high resistance to "knock" or a high "octane" rating. This has some interesting ramifications for someone who is not content to put up with a reduction of power while burning wood gas. Modern gasolines will tolerate a compression ratio of around 9 to 1 before the engine starts to knock and self destruct. Wood gas and alcohol will tolerate compression ratios up to 13 to 1 before this happens. So it would be relatively easy to build an engine based on a high output modern design, using racing parts, which would recapture all of the lost horse power that wood gas costs through higher efficiencies. The efficiency figure of 28% for a gasoline I gave earlier is not immutable. A crude gasoline engine might only get 20% efficiency while some all out racing engines would get as high as 50%. The typical modern engine with overhead cam, fuel injection, and electronic ignition and control systems will get in the neighborhood of 32%. If your philosophy of power production justifies the expenditure this may be a productive path.

Methyl alcohol is the last fuel I will discuss. Racing engines have been run on alcohol for a long time. The now obsolete Indianapolis 500 engine known as the Meyers Drake "Offy" was a four cylinder engine of about 155 cubic inches which routinely produced 750 horse power on alcohol. An engine burning alcohol fuel has a very high knock resistance and so can use the highest compression ratios to improve efficiency. On the other hand methanol requires a lot of heat to evaporate it into a vapor, this makes an engine very hard to start. In addition methanol has much less heat content than gasoline so it requires much more fuel to do the same work. This means custom jetting carburetors for alcohol -- beyond the range which their manufacturers designed them for. On top of that alcohol is very corrosive and will damage metals, gaskets, fiber parts in carburetors, and hoses not specifically designed to handle it. It is also one of the cleanest burning fuels available. It is quite possible to have a roaring alcohol fire and not even be able to see the flames in the daylight. So methanol is a mixed bag. It's available in quantity but you will need a lot of fairly sophisticated mechanical knowledge to make use of it reliably; more than this article can cover.

The most direct applications for wood gas are straight-forward. For example, running a small gas powered generator to charge your battery bank. But consider some other ideas:

A removable flexible hose carrying wood gas to the intake of your farm tractor so that PTO-driven implements like saw mill, chippers, composting hammer mills, and large electric generators could be driven on wood gas without any change in the farm tractor.

A large 350 cubic inch V8 engine running at 1900 to 2000 rpm could be used to directly drive a large three phase motor. The imposed 60 hertz line frequency would make this overdriven motor act like a synchronous generator, feeding electricity back into the grid and earning income as a small power station.

Installation of a large V8 engine and truck transmission in a bulldozer chassis, along with the wood gas generator and filters. By running in low gear this engine will directly replace the slow speed diesel which normally powers such a machine. I have already built this machine and it is practical.

And of course, as Mother Earth News proved, a wood gas generator can be used to power a car or truck. In fact a lot of Europe ran on wood gas during World War II fuel shortages.

With modest mechanical skills this is a technology you can use now, and it's far safer than steam.

Access

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Plans for wood gas burner units:
The Mother Earth News Plans, POB 70, Hendersonville, NC 28793, Wood Gas Generator, Plan #84030
Parts, hardware, and complete burner units:
Cloidal Cam Engineering Inc., POB 244, Prior Lake, MN 55377
ESMCO, 5555 Boon Ave. N., Minneapolis, MN 55428