DIY Gasifier Project

Contributed by Administrator
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Do it yourself gasifier project

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2003 Wood Gas Conversion Most folks don't know that motor vehicles can utilize wood as fuel, but given the recent spike in gasoline prices, I expect that this spring there's going to be a lot of folks taking a fresh look at this old-time technology. Converting one of our rigs to run on wood gas has always been on the "long list" of things I'd like to do here. Now, with gas hitting two dollars a gallon, I'm freshly motivated to move it to the head of my renewable energy project list.

Our workhorse vehicle for heavy hauling is a 3/4 ton Chevy pickup we bought at the Pine Grove auction some years back. Since then, we've worked it hard and steady, and it's always come through for us. Looks pretty rough, for sure, but it does the job day in and day out, and that's what counts back here in the woods. Converting a Chevy 350 engine to run on wood isn't a trivial undertaking, so The Plan is to proceed via a series of steps which would insure that the truck wasn't down for very long at any one time. This is the same way we undertake any large and/or complex project; we break the project down into discrete steps that can be pursued as time and resources allow. It's the process of "take little bites, and chew real well" that insures that we don't bite off too much at any one time, and choke on our ambitions.

Heinlein phrased it another way when he said that in order to master a task or system that is too large or complex to cope with, tackle the parts that you are able to cope with, and thereby whittle it down to a manageable size.

Phase One of the conversion project involved rebuilding the truck's running gear.

It's a tough old truck, but it's got more than 200,000 miles on it, and one goal of the conversion work is to enable it to do keep doing the long runs for years to come. the passenger side 20 gallon gasoline tank

And so, while I was recovering from carpal tunnel surgery, the truck went into the shop to have new wheel bearings installed front and back, and with new brakes and new locking hubs, the rolling part of the truck is pretty much as good as new. Indeed, I'd say "better than new" since new trucks just don't have the heavy steel construction and drive train that the older trucks have. For example, most new trucks have belt driven transfer cases that just don't perform under heavy loads like the older, gear to gear transfer cases.

A lot of the "country vehicles" sold to city folk are more show than substance. I'm thinking of the folks who showed up here a few years back who figured that since they had an SUV, they were prepared for winter in the mountains. It was an underpowered, two-wheel drive pretender, with an automatic transmission no less, but it sure did have a great sound system. the 20 gallon propane tank ready to install

Phase Two involves converting the truck to a dual fuel system which can run on either gasoline or propane.

Wood gas and propane are both delivered to the carbureator as a gas, instead of as a liquid as is gasoline, so this phase of the conversion is focused on getting the engine modified to where it can run off either a liquid fuel or some kind of gaseous fuel such as propane, hydrogen or woodgas. Once that's up and running, we'll address the modifications need to be able to switch between two gaseous fuels: propane and wood gas.

Chevy work trucks come with two 20 gallon gasoline tanks, one under each side of the truck. The first step in Phase Two involved removing one of the gasoline tanks in order to make room for the 20 gallon propane tank. That was straight forward enough. The second step involves mounting a 55" long 20 gallon propane tank up in the space where the secondary gasoline tank used to be, a fairly tedious matter of working it up into place, checking for clearance and the best place to drill the frame for the holes needed to attach the mounting brackets, removing the tank, drilling the frame and then working the tank back into place to check and adjust. Repeat as needed until you get all the mounting holes drilled and everything lines up right. finished installation complete with safety chains There's nothing much of a challenge about this part other than having to figuring out how to repeatedly jack a hundred pound propane tank up into position under the truck without having it fall on you. It's awkward, but otherwise straight forward enough.

Once in place, two safety chains were added to secure the tank to the frame in case the mounting bolts should fatigue and break someday. Anytime you do a non-standard installation in a situation subject to vibration and stress, it's a good idea to have a secondary "hold safe" system in place, just in case. Mounting the Propane Tank The truck that's being converted to run on propane is 23 years old, so there's a number of systems that need repair, replacement or modification as part of the conversion process. This step involves the truck's heater system.

The natural question would be "What does the heater have to do with running the engine on propane?" Actually, it plays an essential role in the process of getting the propane out of the tank and into the engine. We think of propane as a gas, but it's actually stored in the tank as a liquid under pressure. Since propane's boiling point is below the surrounding temperature, it wants to boil and will boil until the vapor pressure above the liquid rises to the point where the vapor starts to condense again. Any gas drawn off from the top of the tank will be immediately replaced as the drop in pressure allows some of the liquid propane to boil.

The equilibrium pressure that balances the tendency of the liquid to boil, and the vapor to condense, is a function of the temperature of the liquid propane. As a liquid turns into a vapor, the liquid becomes cool because it takes heat to convert any liquid into a vapor. This heat, called "the heat of vaporization," has to come from somewhere. Initially it can come from the room temperature heat of the liquid propane itself, but as the liquid propane boils, it gets cooler. If you draw off enough propane fast enough, it will actually freeze into a solid block of propane. So if you tried to run your engine by drawing vapor off the top of the tank, that would work for a while, but before very long, your fuel would freeze solid and you'd be stuck by the side of the road waiting for it to warm up again.

The way this problem is dealt with is by drawing the propane, not from the top of the fuel tank as a gas, but rather from the bottom as a liquid. The fuel line conducts liquid propane to the engine compartment where a device called an evaporator uses the water circulating through the car's heater to provide the heat of vaporization needed to convert liquid propane into a gas. And so, that's why the next step of the conversion involved refurbishing the heater system. The heart of a car's heater is a miniture radiator, and after 23 years of use, it was time to replace it. I installed a new heater core installed and all new hoses, and so that part of the work is done. Wood gas generator construction details along with an overview of the reactions
involved at each stage of the process

The design we're building is called a "down-draft generator," and construction-wise, it can be described as a tank within a tank within a tank.

A key goal for this stage of the project is to incorporate as much "off the shelf," or more accurately "out of the scrap pile," materials as possible. There's nothing wrong with making components from scratch if you need to, but no design of this level of complexity is likely to give optimal performance in its original form, so the first goal is to get an initial unit up and working as quickly, and cheaply, as possible and then "kaizen" from there.

[kaizen - achieving a perfection of design through small, incremental improvements] For an outside shell, we're using an open-top 55 gallon drum. Inside of that is another 55 gallon drum that's been cut down, compressed and fastened together to create an inner wall that's about two inches smaller in diameter than the outside drum.

The interior of the generator is a heat exchanger in which the heat from the exhaust gas cooks off the pyrolytic gas from the wood chips. One design goal is to keep most of the heat within the generator driving the initial pyrolytic phase of the conversion process, instead of heating up the environment around the generator. [pyrolysis - to break down a compound by heating it in an anaerobic atmosphere.]

[anaerobic - having to do with an oxygen free environment.] In order to keep the reaction heat within the core of the gassifier, the space between the two drums will be filled with castable refractory insulation.

The innermost drum is a 40 gallon civil defense drum. This is the part of the tank that gets filled with wood chips. This tank forms the generator's "upper zone" - the place where the feed wood is pyrolysed.

What you're seeing in the picture is a lid for a 55 gallon open-top drum that's had a round hole cut in it just the right size to take the 40 gallon inner drum. When complete, this internal reactor will be nestled down inside the insulated 55 gallon drum, and a standard drum clamp will provide the final seal.

Pyrolytic gas is a hodgepodge of organic compounds including methane, methanol, ethane, ethanol, methyl ethyl ether and a host of tars and heavier compounds formed when the sugars, cellulose and lignins in the wood are broken down by heat. This gas will burn, but it is a low quality fuel that will quickly clog up your piping as the water and tars in the gas condense out. Very messy.

Very unsatisfactory. Which is why there are two more operations happening within the generator: oxydation and reduction.

The first stage of the process involves cooking off the wood to produce pyrolytic gas, a process which starts at about 451 °F, and is pretty much complete by around 800 °F. What you're left with is charcoal. Most of the wood gas automotive systems used during World War II used charcoal, instead of raw wood, so that they could skip the pyrolytic phase and minimize the size of the generator. Doing it all in one generator requires a larger, more sophisticated unit, and if you have room, then it's the way to go, and go farther, since you get more energy out of a pound of wood if you burn both the charcoal and the pyrolytic gases.

By the time the wood works its way down to the bottom of the 40 gallon drum, it's been converted to charcoal; that's when things really start to heat up. The section of the generator immediately below the pyrolytic chamber is the oxydation hearth. This is where a portion of the charcoal is burned to generate the heat that drives the process.
hearth ring, shown upside down

Charcoal burns in air at between 2,000 °F and 3,000 °F, giving off carbon dioxide [C02] and carbon monoxide [CO] depending on how much oxygen is available.

[air - a 20% active mixture of oxygen and inert gases. The key point here is that it takes energy to heat a gas from room temperature to combustion temperature. If you're using air as your oxygen source, you have to heat four pounds of inert gas (i.e. nitrogen) in order to "burn" a pound of oxygen. The woodgas generated will be diluted by the presence of the inert nitrogen, and have a correspondingly lower energy content than it would if pure oxygen was used as the oxydizer.]

It's here in this middle zone, the hearth zone, that we'll generate the heat needed to drive the chemistry; the pyrolysis above, and then the reduction below. [endothermic - a chemical reaction that requires a continuous input of heat in order for it to proceed.]

[exothermic - a chemical reaction that gives off heat as it proceeds.] For this initial model, I built the hearth out of mobile home tire rim. Turned out that the outer rim was just barely larger than the inner lip of the 40 gal CD drum. All it took to secure it in place was a few metal screws to keep it centered.

As mentioned before, this wood gas generator is a downdraft design. Air isn't blown into the generator; rather, air is drawn down through the generator by the vacuum created by the vehicle's engine. Essentially, an internal combustion engine functions as a vacuum pump. As the pistons descend, they create a vacuum which in turn draws air and fuel into the cylinders through the engine's intake manifold.

When running on wood gas, the engine draws the fuel gas, a mixture of H_2, CO and inert N_2 from the generator, into the intake manifold, and from there, into the engine. As the engine creates a vacuum in the generator, air and superheated steam are drawn into the hearth ring through a 2" coupling welded to the side of the hearth. That feeds into a distribution chamber created by welding a 5" strip of steel plate to the rim; this chamber distributes the air/steam mixture around the hearth ring.

The hearth ring has a dozen 3/8" holes drilled into the lower portion of the chamber through which the incoming gas is sucked into the burning charcoal.
At that point, the primary exothermic reaction is: 1) $C + O_2 \Rightarrow CO_2 + Heat$

In addition, there are two exothermic secondary reactions happening: 2) $2 C + O_2 \Rightarrow 2 CO + Heat$

the partial oxidation of the glowing char, and 3) $C_XH_{2X} + O_2 \Rightarrow 2 CO + H_2O + Heat$

the partial oxidation of the pyrolytic gas.

As noted above, each of the reactions happening in the oxidation zone give off lots of heat which turns the remaining charcoal into what's known as "glowing char."

Next stop, the Reduction Zone - the place where the digester does it's magic. reduction bowl, and retaining ring To recap, raw wood was heated in the first, uppermost chamber to the point where the volatile pyrolytic gases were released, and the wood was converted to charcoal.

In the second chamber, the hearth zone, air was introduced and part of the charcoal was burned, thereby releasing a lot of heat and converting the remaining charcoal into what's known as "glowing char." It's the glowing char that does the work in the reduction zone.

As the glowing char falls through the hearth zone, it is captured in a stainless steel bowl; i.e. the reduction bowl. The bowl is made from a stainless steel mixing bowl that has lots of holes, sort of like a very coarse sieve, and is held in place under the hearth ring by the metal ring shown above the bowl. The ring was brazed to the bottom of the hearth, but the bowl just sits loose in the ring so that it can be mechanically shaken periodically in order to allow the ash to pass through and collect at the bottom of the generator.

It's when the gases are drawn through this bed of glowing carbon that the endothermic reactions take place:

1) $C + H_2O + Heat \Rightarrow CO + H_2$ This reaction is known as the "water gas" reaction, and it was the primary

that gas was made for industrial and domestic use a century ago. Later, the construction of a web of pipelines made it possible to pipe "natural gas," a mixture of methane and carbon dioxide, around the country, and the water gas plants were shut down in favor of the cheaper energy source.

Glowing char is so agressive that it strips the oxygen atom away from the water molecule leaving you with two combustible gases, carbon monoxide and hydrogen. These two gases are what will fuel the engine and move us down the road. the gassifier core shown laying on its side with the reduction bowl and retaining ring installed The same sort of thing happens to any oxygen-containing carbon compound produced during the pyrolytic stage, compounds such as methanol or methyl ethyl ether. That's nice, but it's not necessary since those compounds would have burned in the engine anyway. What is very important is that the more complex oxygen containing compounds called "tars" are also deconstructed into combustible gases during this phase of the process. That's important because these compounds would condense out long before they got to the engine, gumming up the works along the way.

While our goal in this project is to convert wood into a viable motive fuel, wood gas generators are also a very efficient way to generate controlable heat in a stationary application. By converting solid wood into a combustible gas in the generator, and then piping that gas to a utilization site such as a furnance, the process can be made far more controlled and efficient than it would if you just tried to burn an equal amount of wood in a woodstove.

Furthermore, if you were using the gas for combustion purposes, there wouldn't be any need to cool the gas down as we must do in order to effectively fuel an internal combustion engine (more on that later). Instead, the volatilized tars could just be passed along to the burner and consumed. One of the key reasons for using the downdraft gassifier design is the need to break down these tars before they exit the wood gas generator and start to clog up the rest of the system.

a view down into the gassifier core 2) $C + CO_2 + Heat \Rightarrow 2CO$

The aggressive nature of glowing carbon is quite remarkable. It's so oxygen hungry that it will even force a molecule of carbon dioxide to "share" it's oxygen, thereby converting a solid carbon atom and a molecule of an inert gas into two molecules of a combustible gas. Pretty neat trick.

Once the gassifier is up to temperature, the only things coming out are combustible, non-condensing gases such as carbon monoxide and hydrogen, steam and some ash.

From here on, it's a matter of heat-exchangers designed to conserve heat within the reactor, a steam feedback loop to keep the reaction at around 2,300 F°, filtering to keep ash away from the engine, and cooling to increase the density of the gas delivered to the engine. Project update Feb. 2004

The following is from a response to an email inquiry as to the status of the wood gas generator. At 10:45 AM 2/9/04 -0600, you wrote:

>I read with great interest your article in "Notes from the Windward Vol.
>63" regarding the construction of the wood gas generator.
>
>Will there be a follow up in Vol. 64?

That's what the plan is. The project is to the point where we need to mount the generator on a trailer. What I've got in mind is a trailer made from the back end of a small "Luv&quto; style pickup truck where the front part of the frame is bend in to form a triangle in front of the pickup box.

The point is that in order to keep the grate from choking up with ash, it has to be jiggled periodically. That happens naturally when the trailer is going down a bumpy road, but when the generator is stationary, or going down really smooth road, the ability of the reformer to process gas goes way down. We actually plan on using the generator in stationary mode, and having it mounted on a trailer just makes it easier to move from location to location. Consequently, being able to keep the grate clear of ash is key to making this design work.

By mounting it on the forward triangle of the trailer, we'll have easy access to the underside of the generator, something which will facilitate the shaker design that we're planning on using. I've got my eye on a trailer made this way, and haven't heard back from the owner. Of late, we've been hunkered down for the winter, and have been focusing on keeping animals watered and people washed during the cold temps. Now that spring is just around the corner, we're starting to think in terms of moving forward on this project.

Especially since over the winter we were able to acquire a PTO mounted wood chipper. A woodgas generator isn't a whole lot of use without a ready supply of coarse wood chips to feed it, so now that we've got that bottleneck solved, we're ready to get back to building a unit to convert those chips into woodgas. Another aspect is that there have been some very impressive developments in the conversion of woodgas into methanol, specifically a new catalysis step up which looks like it will enable us to convert our wood chips into methanol, at which point we'd switch over to running a gasoline/methanol blend in our vehicles.

Anyway, that's were we are on the project. with best wishes,

Walt