The Simple-Fire:

An easy way to run an engine on homemade wood charcoal.

By: Gary L. Gilmore 2012**Goals**

- To increase the knowledge of charcoal gasification using wood as a renewable resource.
- To simplify the technology necessary to run small (2 – 20 HP) internal combustion engine.
- To share my progress on this experiment, to date.

Warning:

This design is experimental and has NOT been proven through thousands of hours of run time. There are risks associated with this process that you must assume if you want to experiment using this style of charcoal gasifier. Here are some of them:

1.)Charcoal gas is about 20% carbon monoxide. This is a **deadly poison** that you cannot smell or taste. At concentrations as low as .05% your blood starts to lose its ability to get oxygen.

2.)NEVER use this device in an enclosed building!!!!!Charcoal gas will burn in the presence of oxygen. With the correct mixture of oxygen it can explode. This means air leaks in the system may create a mixture of explosive gas that can explode if the engine backfires.

3.)You are using fire contained in a steel container. Do not place it near any combustible material.

4.)This device uses charcoal as fuel. If the charcoal is not well made, tar will be created that will literally gum up an engine. This will cause the valves to stick and will ruin your motor.

5.)Gasoline and gasoline vapors are very explosive. Extreme care must be exercised when priming an engine with gasoline. Only a very small squeeze bottle and quantity should be used, and the bottle should be kept away from any open flame at all times.

This is by no means an exhaustive list of all the risks that are associated with a charcoal gasifier.

Terminology

Air inlet – The place where atmospheric air enters the reactor.

Nozzle – The terminal portion of the air inlet where the oxidation zone starts.

Oxidation zone – The area where charcoal is oxidized in the presence of oxygen to form carbon dioxide.

Reduction zone – The area surrounding the oxidation zone where hot charcoal reduces carbon dioxide into carbon monoxide.

Reactor – The metal container that incorporates the air inlet and holds the charcoal.

Charcoal gas - The combustible gas created by the reduction of carbon and water into carbon monoxide and hydrogen with traces of methane.

Gas filter – A device used to trap dust that may be present in the charcoal gas, thus preventing the dust from getting to the engine.

Exhaust gas re-circulation – The concept whereby engine exhaust gas is routed back to the oxidation zone to lower the temperature of that area as well as to recycle carbon dioxide and water by converting them into charcoal gas.

Wood tar – Thick compounds produced when wood is heated. They begin as a vapor but condense to form a tar-like residue.

Charcoal – The black, lightweight, almost pure carbon material remaining when wood is pyrolized.

Gas hose – Sump pump hose that fits a 1 ¼"fitting. It is inexpensive but will melt around 140F.

The Concept

Charcoal gas is made from burning carbon in a reducing atmosphere. This gas is then cooled, filtered and mixed with oxygen at the engine. It is sucked into an internal combustion engine where the charcoal gas/air mixture is compressed and burns. Charcoal gas provides about 30% less power than the same engine running on gasoline. This is due to the fact that charcoal gas contains less energy than the same of amount of gasoline vapor. Do not expect the engine to produce the same amount of power as if you are running on gasoline. Here's how it works:

The Fuel

The fuel for the Simple-Fire is charcoal. Please do not confuse charcoal with ash. Ash is the white powder left after all the carbon in the wood has been consumed. Ash is the non-burnable component of wood that consists of chemicals such as potassium-calcium carbonate, potassium-calcium hydroxide and silica. Ash is not charcoal. Do not confuse these two different products.

Charcoal is BLACK. It is easily broken apart by hand. It can be made from either hard or soft woods. Since hard wood has a greater density of carbon, charcoal made from it will last longer and allow longer intervals between fueling than will running on soft wood charcoal. The charcoal has to be properly made in that all the wood has to be fully charred. In nearly every batch of charcoal, you will find some "brands" that may look well-charred, but are not easily broken up and show dark brown wood under the charred surface. These brands must not be used as fuel in the Simple-Fire because they will produce wood tar.

The Simple-Fire is not intended to be used with charcoal purchased from the store:

> Charcoal briquettes are made from charcoal dust, coal, lime/clay, sodium nitrate and a binder to hold everything together. These WILL NOT WORK IN THE SIMPLE-FIRE.
>
> Natural lump charcoal or cowboy charcoal MAY work if it is well made, but I doubt it. This charcoal is sold by weight and the more tar left in the charcoal, the heavier it is. If this charcoal is heated to 600F to drive off the tar, then it will be OK.

Charcoal can easily be made using a variety of methods. If you do decide to make charcoal, please respect others by using a method that minimizes or eliminates smoke. It isn't hard and here is one way.

Fuel Size

Fuel size is very important. If the fuel is too small, the charcoal gas will have difficulty getting through the tightly-packed particles. If the fuel is too big, the carbon dioxide created in the oxidation zone will find enough gaps between the charcoal and not get converted to flammable carbon monoxide. Screen your charcoal so it passes a ¾" screen at the large size but does not pass through a 1/8" screen. This means the charcoal fuel will be a mixture of sizes 1/8" or larger but no larger than ¾". No more sizing of fuel is needed.

Putting it all together.

The Reactor

This is a steel container that holds a batch of charcoal which is converted into charcoal gas by a fire within the reactor. Although much flexibility exists as to what you can use to make the reactor from, here are a few rules that must be followed.

The reactor must be air tight. The air MUST enter at the correct place and the charcoal gas must exit at the correct place. Both of these places need to be sealed with a gasket material such as RTV silicone. If the reactor has a lid, this too must be well sealed with a gasket and some method to hold the lid in place. Allowing air to leak into the reactor may set you up for an explosion if your engine back fires. Make sure there are no pin holes from rust, too. The main lid to the reactor must not be bolted or

welded shut; rather, the lid should be held on tightly with springs so as to allow the reactor to open if a "puff" or backfire occurs.

The reactor may get red hot at the bottom or along the side. Use a steel container.

You will need a way to fill the reactor with charcoal. Make sure this can be done through an area that can be sealed air tight. Due to the increased suction created by larger engines, it is necessary to place a 1/8 wire screen on top of the charcoal. This will prevent pieces of charcoal getting sucked into the filter.

A taller reactor will hold more charcoal than a shorter one and therefore will allow the engine to run longer. The width of the reactor is not as important as the height. A larger engine will pull the oxidation lobe further from the nozzle and therefore require a reactor that is larger in diameter.

Air inlet

This component is made from a 1" pipe coupling that is welded to a plate which is in turn screwed to the reactor (using, say, #10 or #8 sheet metal screws). Use RTV high temperature silicone gasket material (red is best) to seal the plate to the reactor. The air inlet should be located on the side of the reactor at least two inches above the bottom of the reactor.

Air inlet pipe

This is a short section of 1" iron pipe that is located inside the reactor and screwed into the air inlet coupling. This pipe should extend between 1/3 to 2/5 of the way into the reactor. In other words, it needs to be less than halfway.

To increase the longevity of this nozzle, you can use a stainless steel pipe or wrap the end of the iron pipe with a tube made from stainless steel sheet metal. For the more ambitious, the nozzle can be made from clay. Care must be taken to allow room for expansion to keep the clay from breaking.

Gas exit

This fixture is a plate with a short 1" pipe welded or threaded in. It is attached to the top of the reactor to allow charcoal gas to exit. It is screwed on and sealed with RTV silicone gasket material. A section of gas hose is attached to this pipe to direct the gas to the filter.

Gas Filter

This unit is must trap any charcoal dust that comes from the reactor. It must be air tight and contain a filter material that can catch fine dust. I have had good success using open cell foam rubber. It is cut to be slightly larger than the canister so that it must be lightly compressed to insert. Neither the container nor the filter material has to be fire resistant since there is no heat reaching it. The charcoal gas enters and exits the filter using the same setup as the gas exit fixture.

Engine gas intake

The IC engine must have an adapter made to attach the gas hose to the air intake. This is usually done by removing the air filter and fabricating a plate to bolt on. The gas hose from the filter is attached to a pipe "T" fitting that is attached to the plate. A valve is attached to the other inlet of the "T" to allow control of the air mixture so that the charcoal gas will run the engine. On smaller engines, I have found it helpful to make this device as lightweight as possible, using as many plastic components as possible. This reduces the amount of stress on your carburetor by the weight and vibration of heavier steel parts.

Engine exhaust return

The IC engine must have an adapter made to take some of the exhaust gas to the air inlet. This will require removal of the muffler and making an adapter to fit a 1" pipe. A "T" is also installed and fitted with a muffler. Only a portion of the exhaust gas will be used and the excess must be vented.

Exhaust return line

This return line takes the exhaust gas from the engine to the air inlet. The exhaust gas is hot so metal pipe is used to move it to the air inlet. 1 ½" flexible automotive exhaust pipe works well for this application.

Exhaust control valve

This valve is attached to a 1" NPT "T" on the air inlet and controls the amount of exhaust gas going into the reactor. It is best to use a ball or gate valve. The exhaust return line is attached to the other end of this valve.

Operational procedure

The Simple-Fire has no start up fan to bring it up to working temperature. Therefore the engine must be started on gasoline to create the movement of air into the air inlet so the charcoal can be lit and gas made. Every engine will have its own starting characteristics; these will only be learned with experience. A process procedure that works for me is as follows:

Fill the reactor with charcoal, fasten the lid on the reactor and attach all hoses. THIS NEXT STEP IS DANGEROUS IF YOU DO IT WRONG. THERE WILL BE AN EXPLOSION IF YOU PUT THE GASOLINE IN THE WRONG OPENING. MAKE SURE YOU UNDERSTAND WHERE THE GASOLINE GOES. IT IS NOT HARD BUT YOU NEED TO THINK.

Open the air mixture valve about half-way. Using a small squeeze bottle squirt about a teaspoon of gasoline into the valve opening. NOTE: THIS VALVE CONTROLS THE AIR/CHARCOAL GAS MIXTURE NEAR THE ENGINE CARBURETOR.

UNDER NO CIRCUMSTANCES PLACE ANY FLAMMABLE LIQUIDS IN THE REACTOR OR THE INLET INTO THE REACTOR. IF YOU DO, THE POSSIBILITY OF AN EXPLOSION IS NEARLY CERTAIN WHEN YOU START TO LIGHT THE CHARCOAL.

Open the engine throttle and pull start the engine and until it runs. As the gasoline in the pipe is used up, the engine will start to die and you will need to give it another squirt of gasoline to keep running. While the engine is running, you need to insert a lit propane torch into the air inlet pipe to ignite the charcoal at the end of the nozzle. As the charcoal starts to burn, you need to keep adding squirts of gasoline to keep the engine running. After about 45 seconds, the charcoal gas should be getting to the engine carburetor. The need for gasoline to keep the engine running will diminish and the air mixture valve will need to be adjusted. Whether more or less air is needed will have to be established by trial and error. Keep the gasoline squeeze bottle far away from the propane torch, and move it away from the engine when finished with the priming.

Once the engine is running on charcoal gas, you will need to adjust the air mixture valve by listening to the engine as you open and close the valve. The setting where the engine runs best is what you desire. This is known as stochiometric mixture, which simply means that mixture where the amount of oxygen in the air is in the correct proportion to the charcoal gas so as to obtain complete combustion. Once this valve is set, it does not need changed even though engine speed may vary between idle and full throttle. Make sure your valve is not affected by engine vibration. One gate valve I used slowly closed as it was vibrated. This was fixed by replacing it with a ball valve.

Exhaust gas regulation

Once the engine is running on charcoal gas, it is time to open the valve that allows engine exhaust gas to enter the oxidation zone. While watching the glow of charcoal through the air inlet, open the exhaust control valve. You will notice the brightly glowing charcoal will darken.

This is caused by the carbon dioxide and water vapor in the engine exhaust absorbing heat as they get broken down into carbon monoxide and hydrogen. How much should this valve be opened will be determined by experience. If left closed, the temperature around the nozzle will reach 3000F and melt it. If there is too much exhaust gas the reaction will be cooled down too much and the carbon dioxide will not get reduced, yielding low quality woodgas. The best quality charcoal gas is obtained when the oxidation zone is slightly cooled. Once this valve is set, it does not need changed even though engine speed may.

Running the Simple-Fire

With the charcoal gas/air mixture valve set, you mostly leave it alone. I find myself checking it from time to time, but rarely make much of an adjustment. If you idle the engine down, you may need to richen the gas mixture. I use a thermometer to determine when to refuel the reactor. The sump pump hose starts to deform at 135 F. I shut off the engine when the temperature reaches 130F. This rise in temperature happens as the charcoal is consumed thereby reducing the amount of insulation between the fire and the gas outlet.

The reactor is refilled after the engine is turned off. Remove the lid to the reactor and dump in more charcoal. There is a slight possibility of the charcoal gas in the reactor igniting. If it does, do not be alarmed. Dump in the charcoal and put the lid back on. This is also a good time to shake out the dust

filter too. Be careful to avoid breathing any charcoal gas when the reactor is open. Replace the lid, fasten it down and try starting the engine. It may run well on the charcoal gas still in the lines, but will probably die out when the slug of diluted charcoal gas gets to the engine. A little gasoline should get it going again quite easily since the system is already warmed up.

Shutting down the Simple-Fire

Charcoal is noted for its ability to retain fire for hours, if not days. The only way to shut down the Simple-Fire is to exclude all the oxygen. This is done by screwing a plug into the air inlet "T" and closing the exhaust circulation valve. This should exclude enough oxygen to let the fire die in an hour or so. If you do not put the plug in the air inlet, the fire can last eight or more hours. Remember the warning about carbon dioxide an enclosed spaces. Do not shut the Simple-Fire down inside a building where people live. BAD IDEA.

Problems

It is not a perfect world and here are a few detractors to using the Simple-Fire. Charcoal is black and dusty. It is not a neat, clean fuel. You will get "dirty" with charcoal.

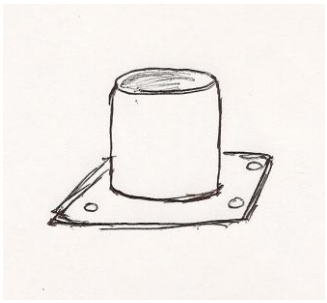
This unit has no bells or whistles. This is a bare bones charcoal gasifier. A starting fan would be nice and if anyone is making a reasonably priced hand operated suction fan, let us know.

Charcoal gas contains moisture and therefore will cause rust inside any steel parts. The reactor and filter canister are expendables. When they develop holes, move the reusable components to a new vessel.

You cannot go down to your local store and get the type of charcoal you need for this reactor. Some how you will have to get it and my hope is you make it.

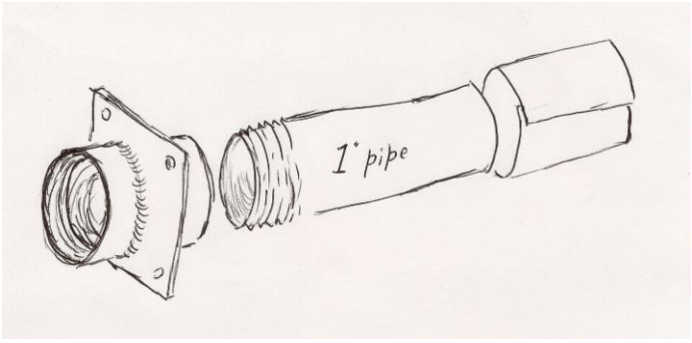
Run time on charcoal will depend on the size of engine you run, the amount of charcoal located above the reduction zone and the density of the charcoal. My little Honda 5.5hp will run the log splitter for 30 minutes on a gallon container of hardwood charcoal. My Commercial Gravely at 8hp will get 15 to 20 minutes on that same volume.

Simple-Fire



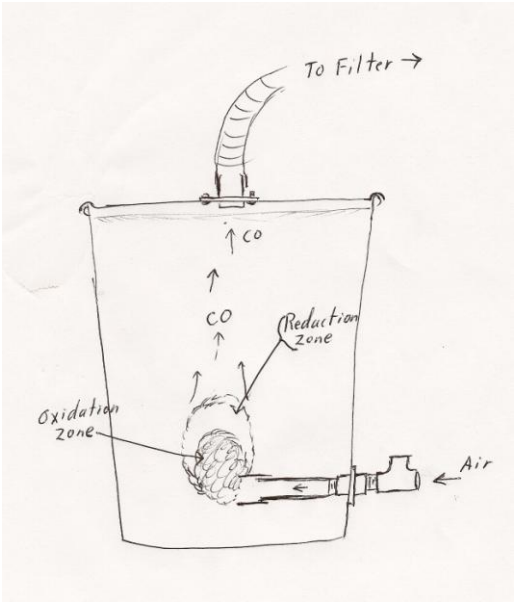
The gas in/outlet.

This is a pipe with a 1 ¼" outside diameter. Sump pump hose makes a tight fit over this fitting. There are four holes drilled in the base to attach it to container. Use #10 screws. Use RTV high temperature silicone to seal the flange to the container.



The air inlet is made from a 1" pipe nipple welded to a 1/8" plate. The air inlet is mounted 3" above the bottom of the reactor. Use RTV high temperature silicone to seal the flange to the container. Use #10 screws to bolt this plate to the reactor.

A short piece of 1" pipe is threaded into the air inlet on the inside of the reactor. This nozzle must be reach about 2/5ths of the way into the reactor. That is less than half way. At the end of the nozzle, you may wrap a piece of stainless steel sheet metal to protect the steel pipe. This sheet metal can be held in place with a pipe clamp and will extend the life of your nozzle.



When the reactor has all the components attached, it will look like this. The air inlet is at the bottom. Inside the reactor is the nozzle with the optional stainless steel protective sleeve in place. At the top of the reactor, the gas in/outlet is attached to the air tight lid. A hose then directs the charcoal gas to the filter. You may want to put a screen on top of the charcoal if you are running an engine larger than 8 HP. With out the screen, some charcoal chunks may get sucked over into the filter.

As air enters the air inlet, it hits the hot charcoal causing it to oxidize and creates carbon dioxide. This hot carbon dioxide is pulled through the surrounding charcoal that strips off a oxygen atom and reduces the carbon dioxide to carbon monoxide. This is the burnable gas your engine will run on.

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