How a Backpacking Stove Works

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How Backpacking Stoves Work

Ever wonder how a backpacking stove works? Alcohol is a pretty easy fuel to burn and the basic point of the stove is simply to hold the fuel and possibly adjust/control the heat output. On the other hand, liquid petroleum fuels are a bit more difficult to handle. These fuels generally must be vaporized and metered with oxygen to burn optimally and safely, which adds to the complexity of making and design. How about gas, wood and even candle stoves? Just read on.

Flame Chemistry

Flame chemistry is much more complex than one might think. There can be thousands of reactions occurring simultaneously with some surprising end products created in the process of burning fuel. The following is a very basic overview of what happens in a "generic" stove.

Most stoves require vaporization of fuel for it to burn. Propane and butane fuel should already be pressurized, but most multifuel stoves require priming and vaporization through either a generator tube or heat sink. Pressurized fuel is generally shot through a jet and through a tube where it mixes with oxygen before it hits a burner or diffusion plate.

At 800-900°C larger hydrocarbons are depolymerised as C-C-bonds are cleaved by the heat (pyrolysis) to form carbon radicals.

$$\text{C-C-C-C} \rightarrow \text{C-C}\bullet + \bullet\text{C-C}$$

At 1150°C ethylene (C_2H_4) is striped of two of its hydrogen atoms (dehydrogenation), forming acetylene.

$$H_2C\text{-}CH_2 \rightarrow HC{\equiv}CH + H_2$$

Acetylene is further decomposed into carbon and hydrogen.

$$HC{\equiv}CH \rightarrow 2C + H_2$$

Hydrogen molecules are broken down into hydrogen atoms by thermal dissociation.

$$H_2 \rightarrow H\bullet + \bullet H$$

Hydrogen atoms react with O2 to form water, which in turn releases energy that heats up surrounding carbon atoms.

$$4H\bullet + O_2 \rightarrow 2H_2O + \text{energy}$$

Heated carbon reacts with O_2 to form CO.

$$2C + O_2 \rightarrow 2CO + \text{energy}$$

With sufficient levels of heat (1000°C) and O_2, CO will combine with oxygen to form CO_2 and release a great deal of the fuel's heat potential.

$$2CO + O_2 \rightarrow 2CO_2 + \text{energy}$$

If there is insufficient heat, O_2, and/or disruption in the flame, you may get incomplete combustion with incandesence of the carbon (yellow flame) and release of CO with/without soot. Note: fuels with unsaturated hydrocarbons, branched species and aromatic compounds may need higher temperatures to fully pyrolyse.

Flame Color/Chemiluminescence

Incombustible elements that may be present in fuel can cause a myriad of colors when heated. Besides this, the color of a flame is primarily dependent on the air-fuel ratio. This air-fuel mixture is often referred to as lean if there is more oxygen than required for complete combustion or rich if there isn't enough oxygen for complete combustion.

Color	**Chemical**
Carmine	Lithium Chloride
Red	Strontium Chloride
Orange	Calcium Chloride (a bleaching powder)
Yellow	Sodium Chloride (table salt) or Sodium Carbonate
Yellowish Green	Borax
Green	Copper Sulfate
Blue	Copper Chloride
Violet	3 parts Potassium Sulfate 1 part Potassium Nitrate (saltpeter)
Purple	Potassium Chloride
White	Magnesium Sulfate (Epsom salts)

The light from a hydrocarbon flame comes from the energy released by electrons returning to a lower energy state after a higher energy state during combustion. Dependant of the amount of energy released, is the frequency of light and thus the color. Low energy equals low-frequency red light; medium-frequency equals medium-energy yellow, green and/or orange light; high-energy equals blue or violet high-frequency light. If you have a wide range of energy levels, you end up with white light.

> Blue-violet due to excitement of large amounts of high-energy carbon and hydrogen radicals in a lean flame.
>
> Green due to C_2 molecules breaking free, and the high-temperature products can glow red from the CO_2 and H_2O produced during combustion if flame is a tad rich.
>
> Intense yellow results from incandesence of carbon particles in the flame. This is similar to turning on a light bulb - you get light but the filament remains unburned. If carbon in a yellow flame isn't burned in a different flame zone, the result is usually carbon monoxide, soot and lost potential heat.
>
> Black may be seen on the outer edge of a yellow flame in a very rich flame caused by soot particles.
>
> White flame is from a flame with a mix of chemical reactions occurring simultaneously with a blend of visible radiation energy that's spread out more evenly across the spectrum.

If your stove is producing a yellow flame, you aren't producing as much heat as you could and may need to make some adjustments, such as repressurizing your fuel, cleaning your stove, changing jet size, adjusting pot height, or increasing ventilation to the stove. Yellow flames also seem to correlate with increased carbon monoxide production.

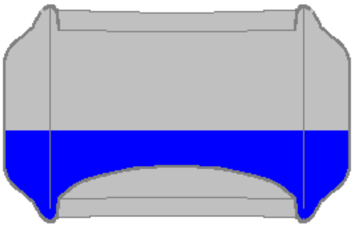
Hottest Part of Flame

A blue flame is hotter than a yellow flame but that's not the end of the story. The luminous part of a flame is actually typically less than 1 mm thick and the hottest area of the flame is generally at the apex where heat is most concentrated.

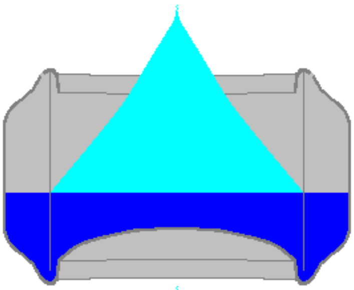
If you hold a sparkler in the blue flame of a regular disposable butane lighter, your lighter will melt before you ever get your sparkler lit. If you hold the sparkler at the very tip of the yellow flame, you should be able to get it to burn, since there is a better concentration of heat there. In other words, an acetylene torch burns hot and blue, but doesn't put out as much heat a a red and yellow forest fire. If you suspend a whale above a forest fire or in the torch, guess which will do a better job of roasting it. Neither is recommended for barbeque.

Dynamics of Various Stove Types

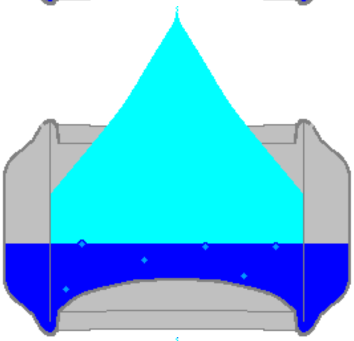
Open Jet Alcohol Stove



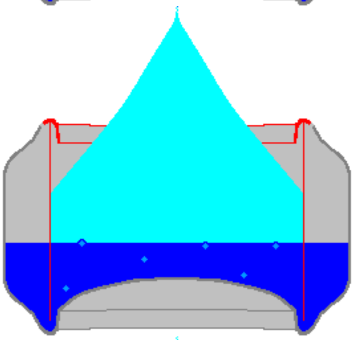
An Open Jet Alcohol stove has an inner and outer fuel chamber that are connected by weep holes on the bottom of the inner chamber



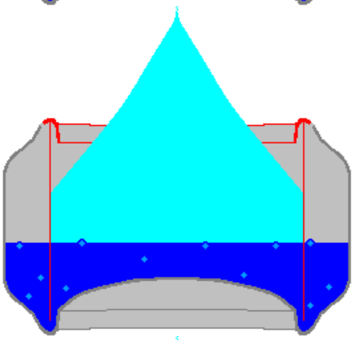
First the inner chamber is lit



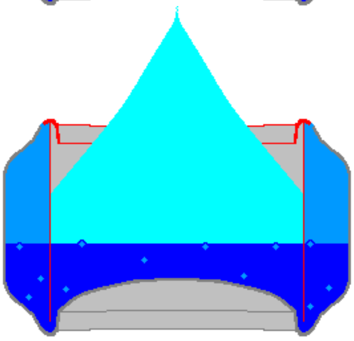
This heats up the stove and fuel, causing the fuel to increase it's vapor pressure and boil



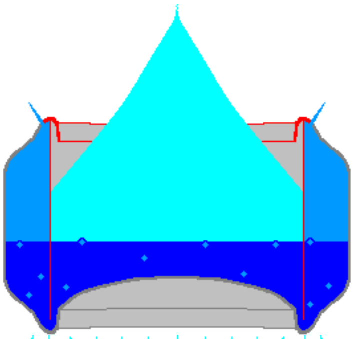
As more fuel vaporizes, more is burned and the stove heats up even more



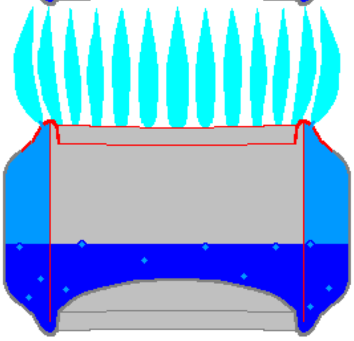
Heating of the inner on outer walls helps heat up the fuel in the outer chamber



Vapor pressure builds up in the outer chamber



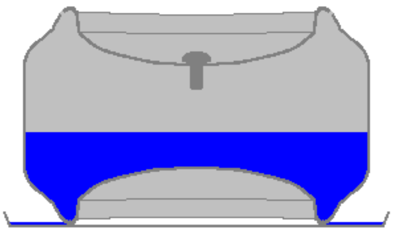
As the outer chamber's pressure builds up, pressurized fuel is shot out the jets



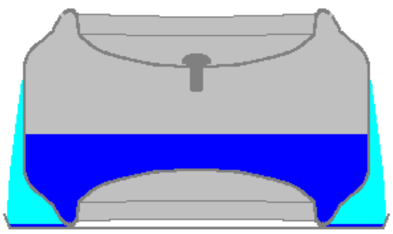
These jets ignite from the center flame and heat from the burning jets continues to heat up the stove, continuing the cycle until extinguished or all fuel is consumed.

Vaporized fuel will continue to exit the center chamber (ignited by the flames around it) unless your design allows you to set your pot on the stove and seal off the center chamber.

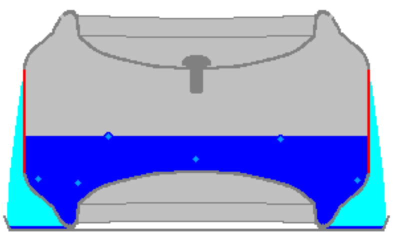
Pressurized Jet Alcohol Stove



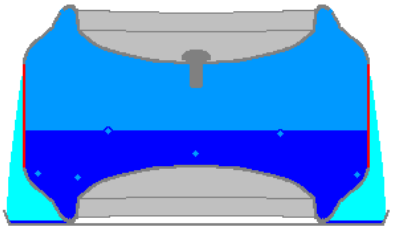
A Pressurized Jet Alcohol stove needs to be sealed by some means and generally needs a primer pan



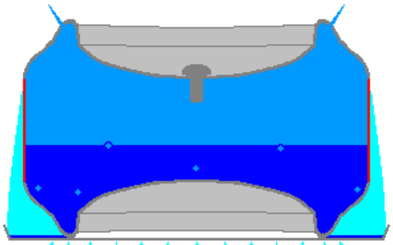
First the primer pan is lit



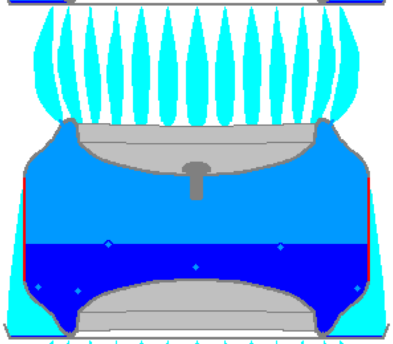
This heats up the stove and fuel, causing the fuel to increase it's vapor pressure and boil



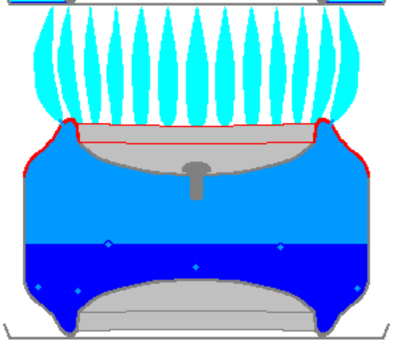
As more fuel vaporizes, the stove builds up pressure



As the pressure builds up, pressurized fuel is shot out the jets



These jets ignite from the primer flame



The lit jets continue to heat up the stove, continuing the cycle until extinguished or all fuel is consumed

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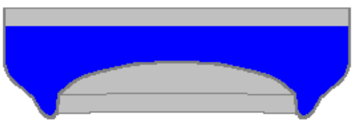
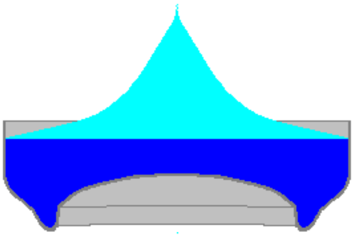
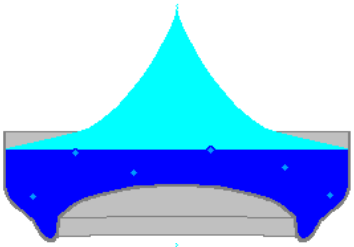
Open Flame Alcohol Stove

An Open Flame Alcohol stove can be very simple to construct

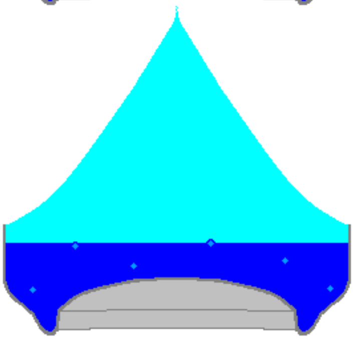




First the stove is lit

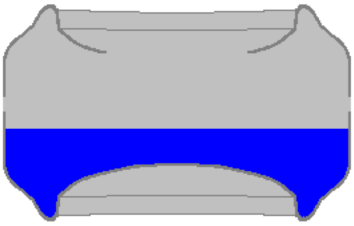


This heats up the stove and fuel, causing the fuel to increase it's vapor pressure and boil

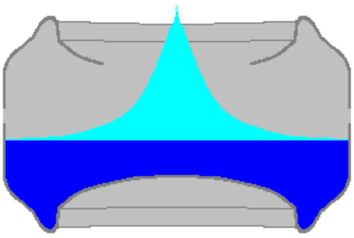


As more fuel vaporizes, the stove burns more fuel

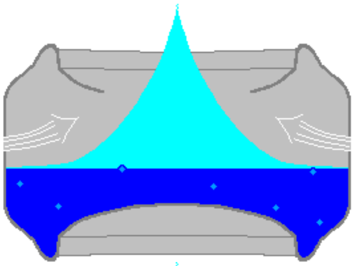
Open Vented/Chimney Alcohol Stove



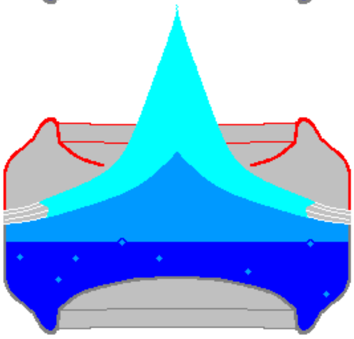
A Chimney Alcohol stove needs a center hole and ventilation holes on the side of the stove



First the stove is lit



As the hot gasses from the burning fuel rise, fresh air is drawn into the stove through the side vents



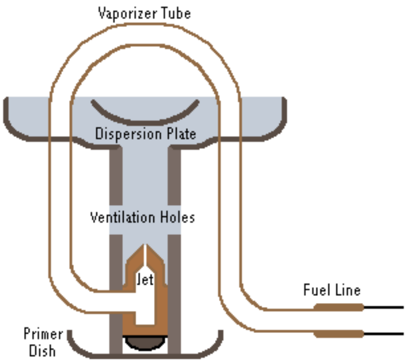
This forced air created by the updraft feeds the fire oxygen and increases the rate fuel is burned.

The amount of ventilation can be adjusted by covering or partially covering the vents with a simmer adapter, which will in turn limit the amount of fuel burned.

Designing vent holes that create a swirling effect inside the stove may also increase air-fuel mixture and produce nice visual effects.

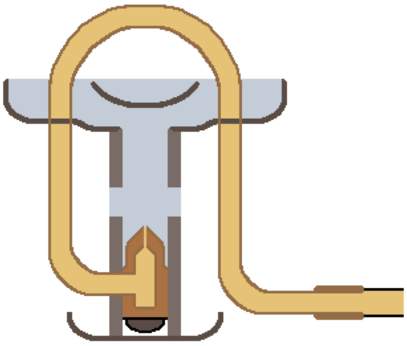
A second outer wall with lower ventilation holes may help guide the flow of air and protect it from the wind.

Pressurized Petrol Stove

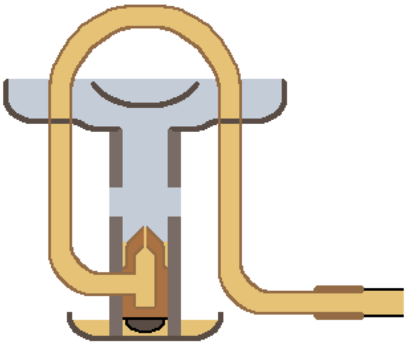


A pressurize petrol burning stove must be constantly fed fuel and may be fed fuel by gravity (tank mounted higher than stove jet), via a pressurized fuel tank (hand pump or self pressurized via thermal feedback), or by a capillary jet or electric pump.

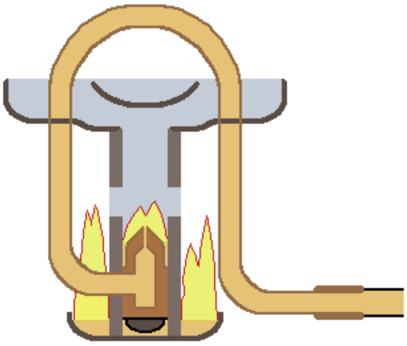
The first step for most backpacking petrol stoves is to pump up your tank to pressurize your fuel.



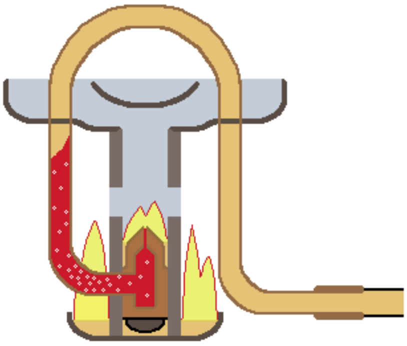
Open the flow valve a bit to allow fuel to flow out of the tank and into the jet.



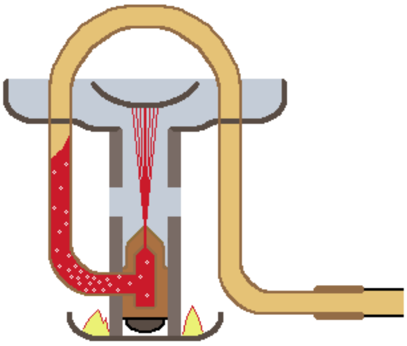
Allow a little fuel to spill onto the primer dish or wick, then shut off your valve.
If you are using kerosene, diesel or another oily fuel, you may want to use alcohol or primer paste to preheat your stove to decrease the amount of soot.



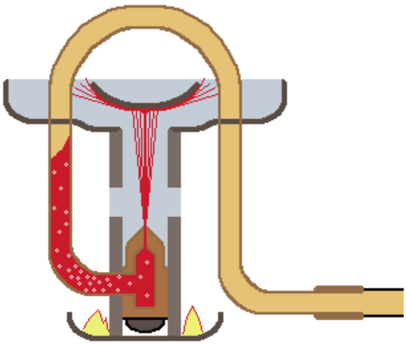
Light your stove and wait for it to heat up the fuel line.



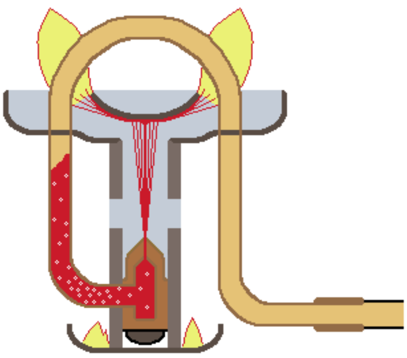
As the fuel line heats up, the liquid fuel will likewise heat up and begin to boil and vaporize.



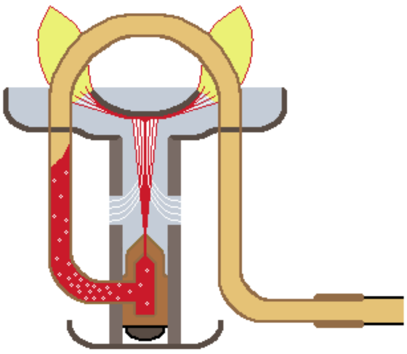
When the preheat fuel is just about out, turn on your fuel valve. Vaporized fuel will be forced out of the jet and into the flame dispersion plate.



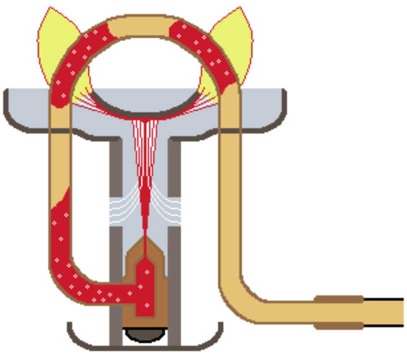
There are various designs for the dispersion plate, each with the purpose of spreading out the jet and stopping it from just going straight up in the air.



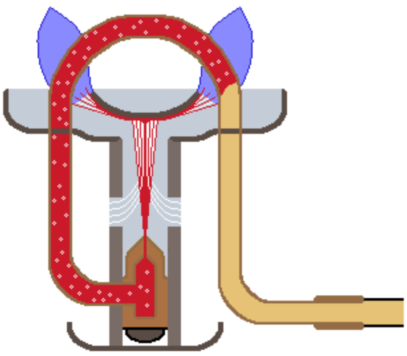
The atomized fuel vapor is ignited by the primer flame, or with a match.



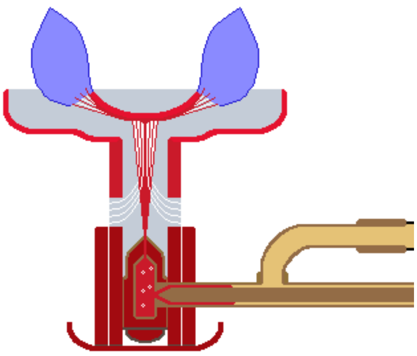
The fuel jet and burning fuel creates an updraft that pulls in air from the ventilation holes just above the jet.



The oxygen rich fuel heats up the fuel line running over the flame, vaporizing more fuel. The fuel line that passes over the flame is often referred to as a generator tube, primer tube, or a vaporizer tube.

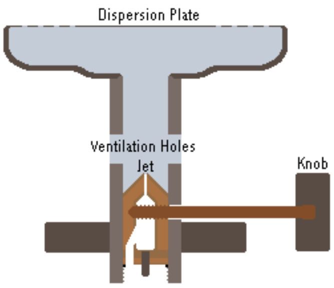


Once the stove gets going, it continues to feed itself hot vaporized fuel mixed with cool oxygen from the vent tubes. If the fuel doesn't completely vaporize, you will end up with incomplete combustion, yellow flames and possibly a clogged jet.

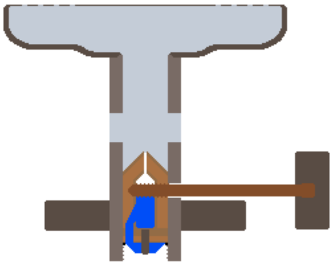


Note - Some petrol stoves don't have a vaporizer/generator tube and rely on the stove to heat up enough to keep the incoming fuel vaporizing near the jets. This is the case with most petrol stoves that have a second valve near the jet, designed for better fuel control and simmering.

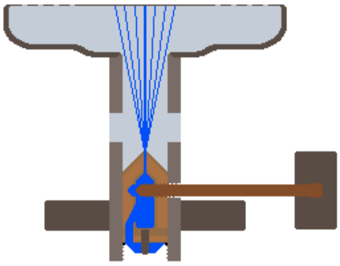
Canister Stove



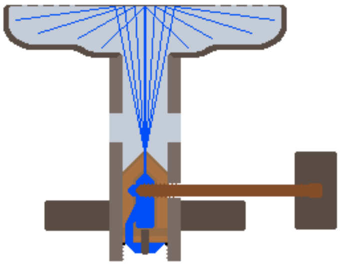
Canister stoves generally have very simple designs.



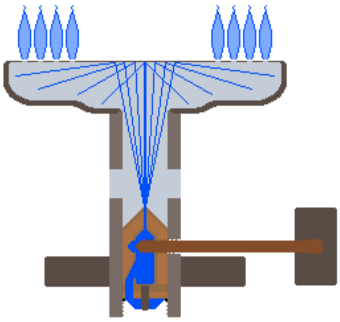
First screw or otherwise lock your stove onto your canister.



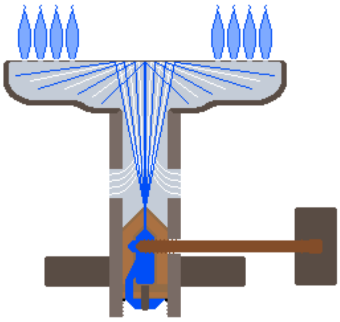
Twist open the valve a bit. Pressurized fuel vapors should shoot out of the jet.



Once the pressurized fuel hits the dispersion plate, it should spread out under it.

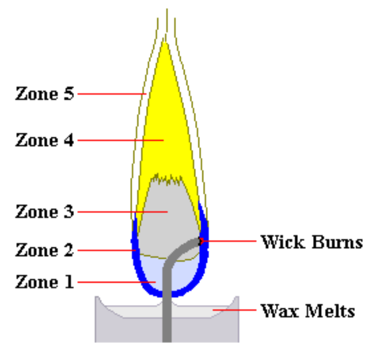


Light your stove and the pressurized vapors should easily ignite.



Cool air should be drawn in through the ventilation holes by the updraft created from the fuel jet and burning fuel. Air mixes with the fuel and enhances efficient burning.

Wick Stove/Candle



Zone 1 (Non-Luminous Zone) - Fuel on the wick evaporates. There is insufficient oxygen for fuel to burn. Temperature is about 600°C near the wick.

Zone 2 (Blue Zone) - There is a surplus of oxygen and the flame burns clean and blue. Temperature is around 800°C. If you are using solid fuel such as a candle, the heat from this zone melts nearby solid fuel to allow for wicking.

Zone 3 (Dark Zone) - Pyrolysis (cracking) of the fuel begins due to the shortage of oxygen creating minute carbon particles. The temperature is about 1,000°C.

Zone 4 (Luminous Zone) - This area is bright yellow. There is still insufficient oxygen for complete burning so pyrolysis continues and larger carbon particles are produced. The temperature is around 1,200°C.

Zone 5 (Veil) - There is oxygen surplus in this non-luminous zone and carbon particles burn faster and more completely at the boundary between Zone 4 and Zone 5. The temperature is around 1,400°C. If a draft lowers the temperature below 1,000°C, soot particles cease burning and end up on your pot or in your lungs.

Wood Gas Stove

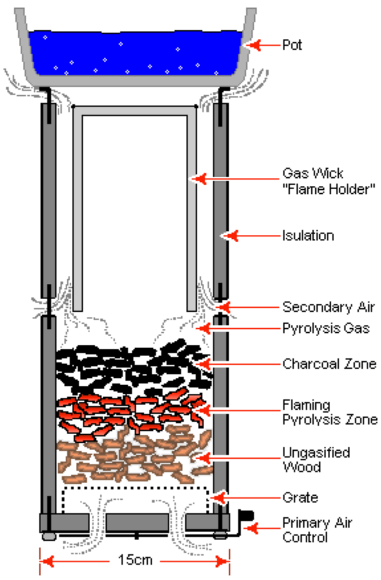


Image modified from:
[A Wood-Gas Stove for Developing Countries](#)
[T. B. Reed and Ronal Larson](#)

There are several designs for wood stoves and a lot of theory and research going into producing better stoves, engines and generators for the future. The following is but one example of an inverted downdraft gasifier by [T. B. Reed and Ronal Larson](#).

Primary Air Control - Rotating valve allows for coarse and fine control of primary air.

Grate - On the very bottom of the stove is a grate that allows better distribution of in coming air from the bottom of the stove. Fuel is tightly packed on top of this grate and is lit on top of the fuel.

Ungasified Zone - This is fuel that's still unaffected by the heat produced above it.

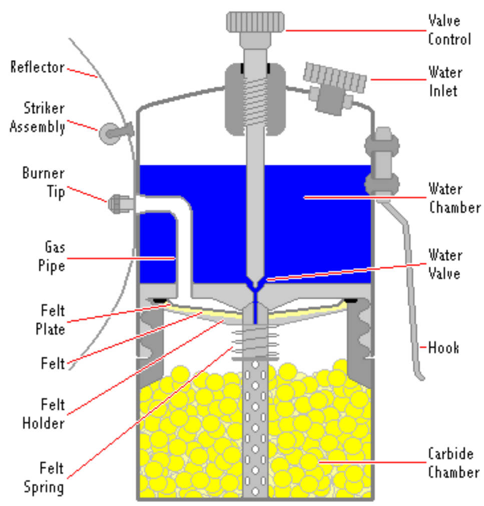
Flaming Pyrolysis Zone - Beginning at around 150°C, cellulose begins to breakdown forming gasses and char. At about 260°C the gasses begin to break into individual atoms. Some of the hydrogen and carbon atoms are oxidized in this zone by the oxygen drawn in from below, while the remainder of the gasified wood ascends through the stove. These flames heat the wood in that zone and perpetuates the cycle of pyrolysis and combustion.

Charcoal Zone - Pyrolyesed fuel has taken the form of charcoal which can be saved or allowed to slowley burn.

Pyrolysed Gas - Pyrolysed gas mixes with secondary air to form a leaner fuel mixture and combusts. In turn larger particles in this mixture are pyrolysed and oxidized by the surrounding oxygen.

Gas Wick "Flame Holder" - Draws heated fuel and air up towards pot to optimizes draft and stabilizes the flame position. Unburned gases exiting the top of the stove are oxidize by oxygen surrounding the stove.

Carbide Lamp



Most carbide lamps and acetylene generators are made up of two major sections the either crew or clamp together. The bottom section holds carbide rocks and the upper section holds water.

The Water Control Lever (or Valve Control) is twisted to open the Water Valve. Water flows into the Carbide Chamber and reacts with the carbide rocks there to create acetylene (C_2H_2), lime (CaO - calcium oxide) and heat.

$$CaC_2 + H_2O \rightarrow C_2H_2 + CaO + heat$$

Water also reacts with the newly formed lime to produce calcium hydroxide - a pretty caustic byproduct of carbide lamps.

$$CaO + H_2O \rightarrow Ca(OH)_2$$

The creation of acetylene increases the pressure inside the Carbide Chamber and forces newly created gas through the Felt (used to keep carbide rocks out of the Gas Pipe), into the Gas Tube and out the Burner Tip.

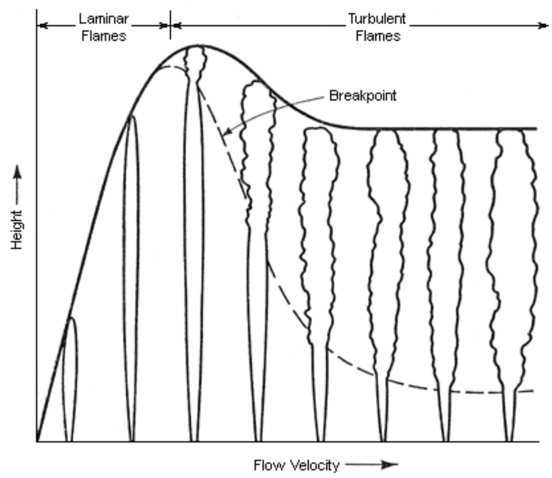
The Striker Assembly (steel wheel and flint) is used to ignite the acetylene creating carbon dioxide, water, heat and a bright white light.

$$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O + heat$$

Fundamentals behind Flames and Flame Structure

The chemistry and physics behind the flames can get pretty complex and still isn't fully understood. Therefore, the following is only a very basic overview of some of the themes seen in flames.

Laminar Flow vs. Turbulent Flow



Laminar flow - a fluid flow dominated by molecular viscosity in which transport of heat, mass, and momentum transverse to the flow is by molecular conductivity, density, and viscosity.

Turbulent flow - an irregular three-dimensional flow composed of eddies (Transport of heat, mass, and momentum is several orders of magnitude greater than by molecular conductivity, diffusivity, and viscosity.)

Laminar flow is what you get when low velocity fuel vapors are released from a stove. As you increase the velocity of the fuel vapors, the fuel stream and therefore the flame becomes longer. The flame continues to increase in length as velocity increase until turbulent mixing occurs. This first occurs at the tip of the flame and progressively moves downward as velocity increases. As turbulence increases, so does the flame height and transition point between the laminar flow and turbulent flow (breakpoint) until a stage is reached where further increases in velocity don't change the flame height or breakpoint position.

A phenomenon know as *lift* occurs in the turbulent area (possibly due to the entrainment of air at the base of the jet) once a certain velocity is reached. As velocity increases, lift causes progression of the flame further and further above the base of the jet until the flame reaches the point of *blow-out*. Lifting and blow-out can be seen in over-primed pressurized alcohol stoves. The hotter the stove becomes the further and further the flames get from the stove until they blow-out. The smaller the jet, the higher the velocity of the jet stream and the greater the likelihood of lifting and blowout.

Increasing turbulence increases flame propagation in theory. But too much turbulence intensity causes propagation rates to decrease and leads to flame extinguishment.

Premixed vs. Diffusion Flames (non-premixed)

A premixed flame is one where the fuel and oxidizer are mixed into a flammable mixture prior to ignition. A good example of this is with an acetylene torch that requires both oxygen and acetylene to be metered together and then ignited.

A diffusion flame is a flame that comes straight out of a stove without mixing with any oxygen prior to ignition. A good example of this is a candle, where molecules of broken down paraffin particles diffuse into the flame zone and are oxidized by the oxygen surrounding the flame.

In a partially premixed flame, some of the oxygen needed for combustion is mixed with the fuel prior to ignition. Happens with Bunsen burners that have air inlet hole at the base of the burners.

	Laminar	**Turbulent**
Premixed	Acetylene Torch set on low	Acetylene Torch
Partially Premixed	Open Vented/Chimney Alcohol Stoves	Most Petrol Stoves
	Gasified Wood Stoves	
	Most Gas Stoves (unless turned up high)	
	Bunsen burner	
Diffusion	Candles	Pressurized Alcohol Stoves
	Wick Stoves (oil lamps, kerosene, etc)	Fan Powered Wood Stoves
	Wood Fire	
	Open Flame Alcohol Stoves	
	Low Pressure Sideburner Alcohol Stoves	

This is far from the end of the flame story. The flames from stoves often come in contact with the pot which impacts the flame in several ways. First off, pots cause flame quenching (cooling of the flame) which can have very detrimental affects to combustion. But collision with a pot may also cause a lot of useful turbulence and often new areas of flame propagation. Turbulent fuel streams that may have been blown out from pressurized stoves may ignite because of contact and reflected radiation from pots.

From an email post from the Appalachian Trail Mailing List:

[at-l] Alcohol Stove Design Theory

* Subject: [at-l] Alcohol Stove Design Theory
* From: brian_a_robinson@hotmail.com (Brian Robinson)
* Date: Wed, 23 Oct 2002 14:41:09 -0700

Aaron,

I don't know how to say this gently, but in my opinion you've stated as fact several things about alcohol stove design that are false. Allow me to be specific.

You said:

> *There is no question that a pressurized type of alcohol stove (like the photon or brasslite) will achieve boil faster than an open type, because the pressure causes the fuel to dump its BTUs faster, therefore heating the water more quickly.*

Sorry, but this is completely bogus. A bigger hole could more than make up for any pressure effect, even if higher pressure increased flow rate, which it often doesn't. Fluid transport is a VERY complicated non-intuitive science, and compressible fluids, like vaporized alcohol are even more complicated. It turns out there are two basic types of fluid flow, laminar and turbulent. Laminar flow is MUCH more efficient at transferring fluid than turbulent flow is. If you've ever watched a creek flowing across a smooth granite surface, you've seen both. At first, the water is clear, then white. The clear water is laminar flow. It moves faster than the turbulent white water ahead of it, thus it is shallower. The turbulent white water ahead is deeper because it's moving more slowly. So it turns out that even for a given hole size, flow rate is highly dependent upon whether the flow is laminar (fast) or turbulent (slow.) Stoves like yours and soda-can stoves use small holes because they create MORE turbulence. (I'll tell you why next.) But the flow rate is REDUCED, not enhanced by this. A large-hole stove like the Cat Stove uses the one large hole because this is the best way to achieve laminar flow.

If laminar flow is so great, why does a soda-can stove use small holes? It's because turbulent flow is very efficient at mixing the vaporized alcohol with oxygen. Fire requires fuel, oxygen and heat. The turbulent flow of a soda-can stove ensures that all the alcohol burns very close to the holes, i.e. under the pot.

Fire under the pot is where we want it right? Well, sort of. We want the fire as close to the bottom of the pot as possible. With a soda-can stove, the fire's down low, so it's best to set the pot low, near the burner. However, this tends to block oxygen flow, and the turbulent nature of the design doesn't help oxygen flow in from the surrounding area. These stoves have a pretty blue flame when they're uncovered, but it's often not as pretty under a pot and windscreen.

The Cat Stove works much differently. It uses laminar flow, so the vaporized fuel easily and quickly flows from the stove up toward the pot. This creates a chimney effect which draws large amounts of oxygen in the intake holes. The problem with laminar flow is that it's not very efficient at mixing the fuel with oxygen. There's large amounts of both flowing up toward the pot, but until they mix well, there's not much fire. Fortunately, the pot itself interrupts the flow, creating some turbulence. This means that much of the fire is automatically created right where we want it, on the bottom of the pot. This can be seen when the Cat Stove is in use. If there's no pot, an inefficient cold yellow flame shoots about a foot above the stove, but when the pot is in place, the flame turns blue (hotter and more efficient) and stays under the pot.

So which is better? It's not at all clear from the theory. Properly constructed, either works very well. In my experience, the turbulent flow design is much harder to get right. The diameter and placement of the holes is critical. If the holes clog up with soot, performance suffers. If the stove gets bent or damaged, performance suffers. If the pressure leaks out, performance suffers. It takes a good tinkerer to get a soda-can stove working really well.

The Cat Stove is much more forgiving. Lots of geometries work quite well. As long as the air flow stays laminar, it works. This means more people can successfully make and use a Cat Stove.

You said:

> *There is some trade off in efficiency. Sgt Rock has shown that the open mouth designs use fuel more frugally, albeit creating a significantly longer boil time. Time is one thing we seem to have plenty of in the woods, and many people don't care that they take longer. The open designs can also simmer better because of this slower burn. Time to achieve boiling is an elusive thing. I would like to again caution you (and your wife), to not get too hung up on this particular number. Weight of the stove is a static number that remains constant (assuming the scale is calibrated correctly). I can say with confidence that the Solo weighs 1.150 ounces. But boil time is affected by a plethora of factors including water and air temp, stove temp, fuel temp, wind, type of pot used, construction and position of windscreen and even lighting technique. The type of pot and lighting technique seem to be especially volatile. Boil time can even be significantly lowered by darkening the outside of a pot. These factors explain the wide range of reported numbers.*
>
> *Aaron*

For the record, all contests to date have shown the Cat Stove as the fastest to boil water. (But not by enough that anybody really cares.) Sgt. Rock showed that it's MORE fuel efficient than any commercial or home-made alcohol stove out there except his own design, which takes about twice as long to boil water. This more than makes up for the weight penalty of the Cat Stove vs the soda-can stove.

Plans for the Cat Stove can be found at:
http://royrobinson.homestead.com

Sorry for the soap-box sermon. Can you tell I'm an engineer?
Flyin' Brian

Flame Quenching

Flames and hot gasses generally lose heat if they come in contact with the cooler walls of the stove or pot. The surfaces act as a "third body" and drain energy from recombination. Solid surfaces also provide a means for breaking the chain of flame propagation. Free radicals tend to diffuse toward the surfaces of these solid bodies where they can be retained for longer periods and can recombine more easily than in the gas phase.

Flame quenching increases as the surface to volume ratio of a combustion area increases. Since the smaller the diameter of a cylinders becomes, the greater the proportion of surface area to volume, a point is eventually met where a cylinder is too small for flame propagation at a given ambient pressure. This is referred to as *quenching distance*. This is what stops *flashback* from occurring in stoves. Mesh, gauze, burner plates and secondary burner jets are often used to prevent flashback in stoves. This is why jets (most gas stoves) and spaces between burner plates (e.g. MSR SimmerLite) for stoves are generally less than 2-3mm.

Flame quenching is an important factor in incomplete combustion and carbon monoxide production. In most cases, the less contact flames have with a pot, the greater the amount of complete combustion. Therefore, smaller diameter pots and positioning pots higher above the flame source should aid in combustion. Pot position can become complex as, complete combustion isn't the most important aspect of stove performance. Keeping a pot in contact with the flames may actually transfer more heat into the pot that a more efficient combustion position. There are also questions about pot stability, wind protection and integral aspects of the pot as part of the stove system itself (particularly with alcohol stoves).

Jet Sizing

Most gas and petrol stove design incorporate a mixing tube that allows for mixing of oxygen with vaporized fuel prior to ignition. As a general rule, larger molecules need greater amounts of oxygen to burn lean than smaller molecules. Therefore, in stove designs that use a mixing tube, alcohol needs the largest sized jet for optimal performance, followed in descending size by propane and then butane, naphtha (white gas), kerosene and then diesel. See Jet Sizes for more information on sizing.

Approximate Range of Jet Sizes Used

Alcohol	0.51mm
Butane	0.45mm
White Gas	0.37mm
Kerosene	0.28mm

For alcohol stoves that don't have a mixer tube, jet hole size can vary greatly. Smaller jets require less pressure to function and produce smaller gas streams, while larger jets are more forgiving to poor quality fuels such as isopropyl (diluted or pure).

Generator Tubes

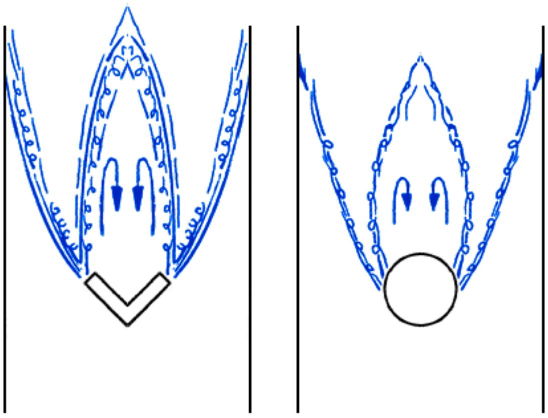
Most fuels must be vaporized and metered to burn in a camp stove. The larger the size of the fuel molecule, the great the importance of vaporization for complete combustion. Larger hydrocarbons also require more preheating to vaporize. Therefore, generator tubes for butane (only necessary for cold environments or with remove fed canisters where fuel vapors may condense) are smaller than those for white gas, which are smaller than one made for kerosene. Expedition style stoves such as a MSR XGK have very large generator tubes designed for high output as well as to vaporize heavy fuels in cold environments.

Many simple alcohol stoves work as a giant vaporizer tube. Thermal feedback from the flames continue to reheat the stove and perpetuate the vaporization of more fuel. In this case, it is important the that materials used in stove construction are suitable for heat transfer (i.e. not excessive in mass and good conductor of heat). It may also be important to position the jets so that the stove itself is directly exposed to the flames, as the lower the position of the flames, the greater the thermal feedback to the stove.

Flame Stabilization

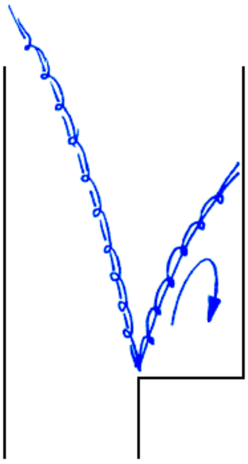
There are a few tricks to stabilizing a flame.

Recirculation Holding - This method is used to hold a high-speed premixed flame at a certain point. A dispersion plate in a multifuel stove uses recirculation to hold the flame at that point and prevents the jet from shooting straight up and colliding with whatever was directly above the stove at that time.



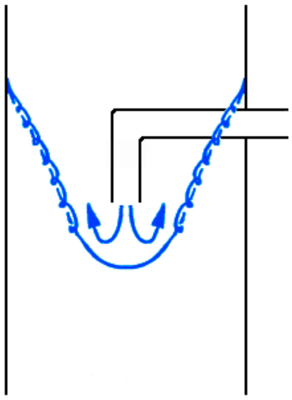
Buff Bodies

Bluff Body Recirculation - A body is placed in the jet stream creating a region of low pressure behind it. This draws fuel gasses into it in a recalculating flow pattern and creates an anchored area for continual re-ignition of the flame, sustaining combustion.



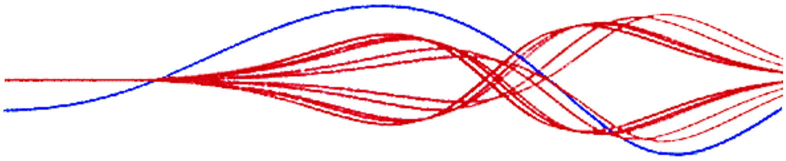
Sudden Expansion

Sudden Expansion - This happens when a flow chamber suddenly expands causing a circular vortex at the bas of the jet. This draws fuel gasses into it in a recalculating flow pattern and creates an anchored area for continual re-ignition of the flame, sustaining combustion.



Opposed Jet

Opposed Jet - This uses an induced region of backflow from an opposed jet.



Swirl

Swirl - Either injected air or fuel is forced into a swirl motion resulting in centrifugal force forcing the flow outwards in a spiraling motion. A low pressure region is produced that draws gas flow back into the center. This phenomenon is known as vortex breakdown, and can take on several forms (bubble, spiral, double helix, growing bubble form). A quarl (diverging section) placed immediately after the swirler, helps maximize the effects of swirl. This concept is used with the Steel Cyclone. For backpacking stove, Japanese Stovers seem to be the few experimenting with this idea (see Ikaros 295stove Blog and AVI movie).

Spacing of Multiple Jets - In alcohol stoves that use more than one jet, spacing becomes important. If adequate space is provided in relationship to the size of the jets, jets will be able to re-ignite adjacent jets if blown out. The smaller the jet, the closer they need to be to each other. Colliding jets, such as those use in Don Johnston's Photon Stove are another way of keeping jets ignited.

Acoustic Field Coupling - A yellow flame coupled with an appropriate pulsating frequency will convert to a more efficient blue flame. This is only mentioned for educational purposes and is probably not at all useful for backpacking stove science.

Air Temperature

The temperature of air being input into a system has some impact on the flame itself. The colder the air is, the more it hinders the chemical reaction within each phase of the flame.

So why do racecars and jet aircraft strive to get cooler air? Colder air is denser and for turbine and internal combustion engines the benefits of getting more oxygen forced into the system outweighs the loss in temperature caused by cold air. Stoves on the other hand should work better if incoming air is preheated and shielded from the surrounding colder air around the stove.

Please feel free to link to this site so that others can find it. It's easy to link to this site - simply copy the text below onto your web page or see How to Link To Zen Stoves for other linking options.

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