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Jim Wood's SUPER CAT Alcohol Stove

As an experienced, lightweight, mostly solo backpacker, I have, over the years, tried just about every stove technology available. I've used a variety of white gas (Coleman), kerosene, propane, alcohol and solid fuel tablet (Esbit) stoves and appreciate the advantages and disadvantages of each type. The option that I currently favor for general-purpose backpacking, however, is the isobutane/propane canister stove. Ultralight models equipped with piezo-electric lighters are made by MSR, Primus, Gaz, and Snow Peak (among others) and are convenient, dependable, quiet, efficient, and though hot burning, can also simmer well. In addition, analysis has shown that even for gram-counting long distance hikers, these stoves compare very favorably with other types of stoves from a weight-to-performance point of view.

Nonetheless, these stoves are not perfect. My biggest complaint is that the fuel canisters themselves are not refillable by the user, which means that it's often difficult carry just the amount of fuel that you think you'll need for a given outing. It seems that on almost every trip, I require just slightly more fuel than is contained in either an 8 ounce or 16 ounce (fuel weight) canister, so I end up having to carry an extra, usually at a weight of 12 ounces or more. Over time, I also tend to end up with a large collection of partially-used canisters, further complicating the problem. In addition, compatible canisters are sometimes difficult to find outside the U.S. or when re-supplying on long hikes. They also can't be transported on commercial airliners.

Recently, it occurred to me that probably the best solution to all of these problems would be to carry a second, backup stove that would burn a variety of fuels, at least one of which could be found almost anywhere, and which could also be carried in any quantity. I wanted this backup to be compact, ultralight, easy to use and utterly reliable. It could occasionally substitute for the main stove to in order to "fill in the gaps", but it didn't need to be a full-featured replacement. All it really needed to do well was boil water in a reasonable amount of time, which would also allow it serve as a second burner in the preparation of some meals.

When surveying the alternatives, only the alcohol stove satisfied all my criteria. These stoves can burn ethanol (found in spirits), methanol (wood alcohol), or even, in a pinch, isopropyl (rubbing) alcohol. The fuel can be found in various forms at liquor, hardware, automotive or variety stores. The kind most commonly used by backpackers seems to be denatured alcohol, which typically contains a combination of mostly ethyl and methyl alcohols. Though the energy content is less than most petroleum-based fuels (typically about half), alcohol fuels are usually safer to handle and can be transported in ordinary plastic bottles.

I spent some time searching the Internet to update my knowledge of both commercial and do-it-yourself models and found plenty of both. There are some very clever and well-tested designs available. Nonetheless, I had an idea for a type of stove that didn't seem to be represented by any of the models I found, though it's certainly possible that someone has employed this design before. If so, I apologize for the lack of attribution, but note that I did arrive independently at my conclusions.

Disclaimers

Before proceeding, I should point out that I am not a chemist, nor an expert in stove technology. I am just a backpacker that has struck upon something that I think is interesting and worth sharing with my fellow hikers. All experienced outdoors people already understand that any stove is potentially dangerous and should be handled with care, especially when operated in the vicinity of a tent or tarp. Besides presenting a fire hazard, many stoves can also emit fair amounts of carbon monoxide which can be deadly if concentrated in closed spaces. **If you decide to build your own Super Cat, you're on your own - I can't guarantee your safety nor indemnify you against accidents. I would, however, warn you not to attempt to use this stove with petroleum-based fuels such as automotive gasoline, kerosene or white gas (Coleman fuel). These fuels are much more volatile than are alcohol-based fuels and are dangerous to burn in open containers. Petroleum vapors can pool in low-lying areas and explode when exposed to flame.** And just in case you're feeling adventuresome and are tempted to try a higher energy content fuel (like white gas) in the Super Cat, you should also know that the elevated burn temperatures will probably melt the stove.

That said, alcohol-based stoves seem to be generally accepted as safe by most backpackers who use them, as long as they're handled prudently. They are also said to emit little carbon monoxide, especially when compared with petroleum-fueled stoves, but I haven't seen any conclusive data on this point thus far.

Nonetheless, because of the Super Cat's negligible weight and other design features, there are a few potential hazards (described below) that are unique to this stove.

The Design

There are probably at least two dozen do-it-yourself alcohol stoves currently described in various places on the Internet. Most of these stove designs seem to fall into one of two categories: (1) non-pressurized and (2) pressurized. Non-pressurized models work by simply housing an open flame that's created by burning expanding alcohol gases. These gases exist anytime that liquid alcohol is warm enough to evaporate, where the warmer the liquid, the faster the rate of evaporation. Examples include Roy Robinson's Cat Stove and the Robert Crowley Plumber Stove.

Pressurized models restrict the expansion of this gas in some way in order to create gas "jets" that are purported to burn a little hotter than do non-pressurized flames. Since I've done no testing on my own, I can't say for sure that it really makes any difference, but in either case, the Super Cat would probably be classified as a pressurized design. The term "pressurized" may also be a bit overstated, since the amount of back-pressure created by restricting the gas flow is very small - just enough, in fact, to force the expanding gas out through a series of burner holes. It's nothing like the pressure, for example, that's created by manually pumping an MSR white gas fuel bottle.

Probably the most significant thing that sets the Super Cat apart from other pressurized stoves such as Scott Henderson's Pepsi-G, the Anti-Gravity Gear Tin Man, or the Brasslite stoves, is the simplicity of design. Most pressurized stoves require multiple components that must be taped, epoxied, or welded together in order to create their pressure chambers. The Super Cat's pressure chamber, on the other hand, is created simply by placing a pot on top of the stove, thereby blocking the ability of the expanding gas to escape through the top, forcing the flames out through the vent holes on the sides.

The Super Cat design is also simpler than most others because it doesn't require the use of a separate pot stand. The stove itself serves as both the burner element and the stand, since the pot is placed directly over the top of the stove.

Incidentally, this stove is named "Super" because it burns hotter and faster than other alcohol stoves whose specifications I've seen. I have consistently (under ideal, no-wind conditions) brought two cups of water from cool room temperature (60°F) to a full rolling boil in under four minutes, which is the fastest time I've noted so far, though I can't guarantee the consistency of the test conditions. It's also called "Super" since it's super-easy to make and, at a weight of less than ¼ of an ounce, super-light. The "Cat" portion of the name was derived from its construction using a single, small, aluminum cat food can.

Construction

The key materials necessary to build the Super Cat are shown below (Figure 1). Once these items are collected, the project should take only 10 or 15 minutes to complete.

Fig 1: Required materials

The construction process involves punching two rows of holes in a clean, three ounce cat food can (or equivalent). Holding the can in one hand, use an awl in the other hand to create the holes as described below. Note that a drill can be also be used to make the holes, but I find punching to be faster and easier. The soft aluminum will yield quickly to a sharp awl or similar tool that's turned against the walls of the can. Though not mandatory, I'd suggest that you protect the hand holding the can (I use a heavy leather glove) in order to avoid puncturing yourself along with the can and would further recommend the use of safety glasses.

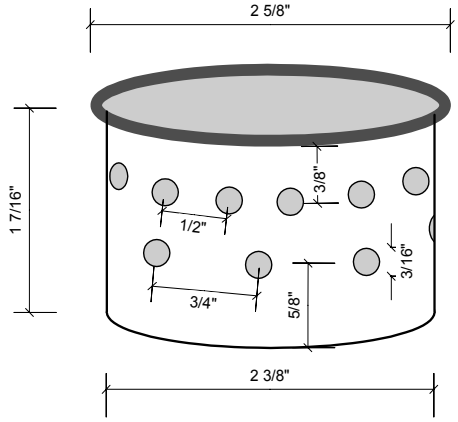

Fig 2: Super Cat stove dimensions

Start by punching a first row of holes, about 3/16" in diameter, with centers located about 5/8" from the bottom of the can, and spaced about 3/4" apart. This spacing should allow about 10 holes in the bottom row. You might want to first mark the positions with a felt-tipped pen.

Next, punch a second row of the same size holes near the can's top lip. The hole centers should be about 3/8" from the top edge and approximately ½" apart. This spacing should yield 15 or 16 holes in the top row (See Figure 2).

When the holes are punched, you'll notice a ragged-edged "collar" around each hole inside the can. These collars can create turbulence in the flame jets, so it's best to flatten them in order to get the smoothest possible gas flow. Use a pair of pliers with curved pinchers (so that you don't also flatten the can rim), to gently "smash" down these edges. The photos below illustrate the process. Your Super Cat is now ready to test.

Fig 3: Vent holes before flattening collars

Fig 4: Flattening vent hole collars

Fig 5: Completed stove (this one with 4 extra vent holes)

Starting and Using the Stove

First, position the stove on a stable surface that won't be damaged by high temperatures. The bottom of the stove will get very hot during operation, so don't test it, for example, directly on your kitchen counter (unless you're already planning to replace the surface). Also be certain that the stove is sheltered from winds. The Super Cat is extremely lightweight and you don't want it to blow over while burning, possibly spilling flaming alcohol or you or your equipment.

Next, measure about one fluid ounce of alcohol fuel and pour it into the bottom of the stove. Never, of course, fill a stove that is still hot from previous operation – it should be cool to the touch when adding fuel. **Be sure to clean up any spills on your hands or other surfaces before proceeding. Also, place any flammable items (like matches or your fuel bottle) well away from the stove.**

Now ignite the fuel, probably most easily done by extending a lighted match through one of the lower vent holes, or alternatively, into the stove from the top. Once the fuel has ignited, flames will emerge through the top, though it may be difficult to see in bright daylight. Placing your hand near the top of the stove will allow you to feel the warmth in order to confirm ignition.

Fig 6: Fuel ignited

Wait 30 seconds or so to allow the flames to warm the stove and liquid alcohol, during which time you'll note an increase in heat output. After this brief warm-up period, place your pot or other cooking container directly on top of the stove, making sure that it both covers completely, and is centered over, the top stove opening. With the pot in place, the combustion chamber should now pressurize and the flames should shift from emanating from the top of the stove to emerging from the side vent holes.

Fig 7: The Super Cat in operation

Note that if the flames are extinguished when placing your pot on the stove, then your stove is probably starved for oxygen (i.e., it's running too "fuel rich"). To fix the problem, either add a few more vent holes or enlarge the existing ones slightly. Proceed slowly with this process, however. Too much oxygen will cause the flame to become "fuel lean" and turn yellow, significantly reducing the efficiency of the stove (more on fuel/air mixtures below).

Now cook for the desired time. You'll find that one fluid ounce of fuel will last for 7 or 8 minutes, more than enough time, under most circumstances, to bring two cups of water to a boil. Beginning water temperature, wind conditions, elevation, and other factors will affect your boil times, so you can adjust your fuel "load" as appropriate.

To maximize your fuel efficiency, it's best to use a tight-fitting lid on your pot and to surround the stove and pot with a windscreen if there's even the slightest breeze. Directions for building windscreens can be found on many of the web sites referenced below along with lots of other useful information about alcohol stove burn times, efficiencies, fuel types and other matters that are beyond the scope of this description.

Finally, be careful if you need to remove the pot from the top of the stove while the stove is in operation. Some of the things that can happen:

(1) Lifting the pot quickly and vertically off the stove can create a momentary vacuum inside the combustion chamber. The flames on the sides of the stove will disappear, but an instant later, will likely re-appear with a "whoosh" back inside of the stove. What's happening is that the expanding alcohol gases go unburned for a moment when the outside flames are extinguished, but then ignite again inside. I don't think this phenomenon is particularly dangerous, though it can be a bit startling the first time it happens. It's not nearly as significant, however, as the flare-ups that can sometimes occur with white gas stoves when they ignite.

The best way to prevent this from happening is to lift the pot slowly and move it sideways off the burner. This way, the transition from outside flames to inside flames can occur smoothly, without a flame-out/re-ignition cycle. Should the flame extinguish, but not re-ignite on its own, you'll need to manually re-light it.

(2) Sometimes during operation, a little alcohol might collect on the underside of your pot. When you remove the pot from the stove, this alcohol can continue to burn for a few moments, making it appear as though the bottom of your pot is on fire. This small flame is easy to extinguish, however, by either blowing it out or by setting the pot on the ground to smother it.

(3) If the bottom of your pot or the top rim of the stove becomes gummy with cooking residues, the stove could (because it's so lightweight) actually stick to the pot bottom. When you then lift the pot, the stove could lift along with it. A moment later, it could also "un-stick" and fall, spilling flaming alcohol everywhere. To avoid this problem, always keep the pot bottom and top stove rim free of sticky substances.

Stopping the Stove

As with most alcohol stoves, you should usually plan to let the stove burn itself out. Unless the fuel is almost spent, it's probably fruitless to try to blow out the flame. The Super Cat may, however, be stopped prior to burn-out in a couple of other ways:

1. In an emergency, you can douse the stove with water. The flames can be extinguished in this way without concern about spreading them (as with a grease fire).

2. The flames can also be quickly extinguished if deprived of oxygen. One way to suffocate the burn is to use your empty cook pot as a "snuffer" by inverting it over the stove. The less air that is trapped under the pot, the more quickly the flames will extinguish. I normally use a Snow Peak Trek 1400 titanium cook set (shown in the photos) whose top is also a small (2 cup) fry pan.

When this fry pan is used as a snuffer, the flame goes out in a second or two. You can also make a dedicated "snuffer cup" from any lightweight aluminum can that is slightly larger than the stove. A standard 5.5 ounce pet food can works perfectly and weighs only about ½ an ounce.

Fig 8: Super Cat stove with "snuffer cup"

If there's fuel remaining after a "snuff-out", it can be returned to your fuel bottle after first making sure that it's had time to cool. It may, however, contain debris or other contaminants that you might not want to empty into your clean fuel supply. If left in the stove, this fuel residue will quickly evaporate.

Fuels and Capacities

In the course of testing the stove thus far, I have tried four kinds of fuels. The best results have come from denatured alcohol, which burns hot and clean with virtually no odor or soot production. Denatured alcohol is widely available; the type I used was found in the paint department at Wal-Mart and cost $3.67 a quart.

Fig 9: Fuels tested

I also wanted to try ethyl alcohol (the kind in alcoholic beverages), but the most concentrated form I could find was in Bacardi 151 proof rum. Pure grain alcohol, at 200 proof, is not available in this area. The Bacardi burned well, but the internal vapor pressure was not quite sufficient to cause the flames to switch to the outside of the stove. Bacardi 151 could therefore be used as a fuel for the Super Cat, but only in non-pressurized mode using a separate pot stand (three tent stakes placed around the stove at the proper distances and heights work well as pot supports).

91% isopropyl rubbing alcohol (from the drug store) worked reasonably well, with boil and total burn times only slightly longer than denatured alcohol. However, isopropyl is somewhat smelly when burning and also leaves a coating of black soot on the bottom and sides of the pot.

I was also curious to see if the stove would work when burning Esbit solid fuel tablets that are popular with many long-distance backpackers. Though the heat output from the tablets seemed to be about the same as with denatured alcohol, the combustion chamber would not pressurize. The tablets also left a gummy reside inside the stove and on the underside of the pot.

And finally, I will note that the fuel reservoir capacity of the Super Cat described here is around 1.5 fluid ounces, which should provide a burn time of up to 12 minutes or so (depending on conditions) if full. To increase the effective burn time, one could use two stoves, moving the pot back and forth between them. As stove #1 showed signs of burning out, stove #2 could be lighted and the pot could be transferred a few moments later. Stove #1 then could then be allowed to cool, then re-filled and re-lighted if desired. The total burn time in this case would be limited only by the available fuel supply. Alternatively of course, one could also try building a larger version of the stove.

Additional Notes

Because I've already accomplished my primary goal with the Super Cat, I will probably now suspend my R&D efforts. At this point, I happily place what I've learned about this stove into the public domain, and anyone who has an interest in pursuing the design further is free to do so. To support those efforts, I will offer a few observations that I've made in connection with some of the design modifications I've tried:

1. Although the Super Cat described above is made from a 3 oz aluminum can, other cans might work just as well. I have found, however, that it becomes more difficult to adequately pressurize the alcohol gas if larger cans are used. I've also discovered that the greater the interior volume of the stove, the larger and/or more numerous the vent holes need to be. I've further noticed that larger vent holes create "fatter" flame jets that seem to be more prone to disturbance by air movements than are smaller-sized flame jets.

You might decide to try a different can if you're concerned about supporting heavier loads. For example, you could use a steel, rather than aluminum can for added strength. If a particular can has the right diameter but is too tall, it can probably be cut down with tin snips, though a drill may need to be used to create vent holes in a steel can.

When considering other cans, just remember that because the cooking flames emanate from the sides of the stove, you don't want to use a can that's too wide relative to the width of your cook pot. Otherwise, most of the heat will go up the sides of your pot. Likewise a can that's too small will create an unstable platform, possible causing your pot/stove to tip over. If you use multiple pots on the trail, you can always take along multiple Super Cats of varying sizes that can be nested inside of one another during transport.

2. The size, number and placement of the stove vent holes will have an impact on the fuel/air mixture, the maximum temperature of the burn, the fuel capacity of the stove, and the strength of the stove side walls. The hole configuration described above is a good starting point, but feel free to experiment. More or larger holes may increase the burn rate and/or flame temperature, but may also weaken the walls of the stove along with its ability to support your pot. Likewise, moving the bottom row of holes too close to the bottom of the can will decrease the fuel reservoir capacity of the stove and, correspondingly, increase the likelihood that fuel will splash out when the reservoir is filled.

   If you find that the stove's flame is a consistent dark blue color (best observed in dim light), seems to be weak or struggling, "pumps" or pulsates while burning in calm air, or is extinguished when the pot is placed on the stove, then it's probably not getting enough oxygen (burning too rich). Either add a few holes or increase the size of existing holes, As noted above, however, proceed slowly with your modifications, since the balance can quickly switch to burning too lean.

   If the flame is burning mostly yellow, then the stove is probably getting too much oxygen. This problem is harder to fix since once a hole is made, it can't be unmade. If this happens, either start over with a new stove, or try using high-temperature flue tape (made by 3M and others) to create small, temporary patches that can be applied over existing holes. You can then conduct one or more experiments, applying and removing patches as necessary, to arrive at an optimal fuel/air mixture. Once you get the hole configuration right, you can then apply it to a new stove. The temporary patches probably would not last very long in the field.

   I have found that the ideal flame color is mostly medium blue with occasional flashes of yellow. An efficient flame will also burn at a steady pace in calm air.

3. I tried lining the bottom of the stove with a small amount of fiberglass wicking material, held in place by a patch of aluminum screen. Many of the alcohol stoves described by others use fiberglass as a wicking agent, so I thought I'd give it a try. About the only impact it had was to slow the stove down a bit. Boil and total burn times both increased by about 25%.

4. The Super Cat is clearly not optimized for simmering. If I need to simmer a meal, I will simply cook it on the canister stove. Other alcohol stoves use rings or spacers to allow for simmering, but I've not tried any of these methods with the Super Cat. This might be an interesting project for someone else to take on.

5. I've also not tested the stove under very cold or high altitude conditions. It's been reported that denatured alcohol has problems vaporizing when seriously chilled. In this situation, it might be possible to fill the reservoir with fuel, then carefully warm the underside of the stove with a lighted match in order to get the fuel to vaporize. In extremely cold conditions, however, one is probably better off using a white gas stove.

   High altitudes will almost certainly impact the fuel/air mixture of the Super Cat, but I've not yet tested these effects. I hope to do so this summer.

Contact Information

I'd be interesting in hearing about your experiences with the Super Cat. Please feel free to email me: jwood@timberwolf.us.

Reference URLS

There are a great many Internet web sites that can provide additional information about alcohol stoves. Some of the better ones I've found:

WINGS - The Homemade Stove Archive
http://wings.interfree.it/html/main.html

The Lightweight Backpacking Forum
http://www.backpacking.net/makegear.html

The Thru-Hiker Backpacking Forum
http://www.thru-hiker.com/workshop.asp

Sgt Rock's Backpacking Forum
http://www.hikinghq.net