Technology Reviews (*)

Stoves, Tents and Carbon Monoxide – Deadly or not? Part 6: Measurements on Liquid Fuel Stoves

A range of liquid fuel stoves are surveyed at different power levels to assess their carbon monoxide emissions.

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Monitoring Carbon Monoxide from a stove.

Introduction

Buy a small stove these days and it is likely to come covered in dire warnings about the risk of carbon monoxide (CO) poisoning and that you must not use the stove in any sort of confined space. And yet walkers have been using small stoves inside their tent vestibules in bad weather for many, many years with very few instances of trouble. What is the risk, why are all those warnings there, and how seriously should we take them?

This multi-part Series of articles explores the carbon monoxide issue. Part 1 covered the basic theory underlying how stoves work and how they can generate carbon monoxide. A theory was developed as to the cause of carbon monoxide being emitted. Part 2 covered an extensive amount of laboratory testing of a wide range of canister stoves to test this theory. All the results found in Part 2 confirmed the theory for canister stoves: carbon monoxide is generated when the stove flame is quenched by having the burner too close to the pot. Factors such as pot diameter do not affect the result, but burner design does. Keeping the flame from hitting the pot too soon and making sure enough air is available are the keys to low CO emissions.

Part 3 surveyed available canister stoves and showed which ones had a low level of CO emission and which ones were not so good. In general a good range of summer ('upright') and winter ('remote') canister stoves were found to have a clean operation.

Part 4 surveyed a representative group of alcohol stoves, and it was found that alcohol stoves do not have the clean performance of canister stoves. The evidence suggested that the cause of CO being emitted with an alcohol stove was slightly different: most of the problem lay with the basic design of the alcohol stove and the lack of a vigorous pre-mixing of air with the fuel.

Part 5 surveyed several solid fuels at different power levels. Once again, problems with significant carbon monoxide emission were found, especially when the fuel tablets were broken up to increase the heating power.

This Part 6 surveys a range of liquid fuel stoves burning both White Gas (Shellite, Coleman Fuel, aka auto gas or petrol) and kerosene. The brand name 'Shellite' belongs to Royal Dutch Shell and means a fuel similar to auto gas or petrol, but without all the nasty additives and carcinogens (we hope). The name Coleman Fuel belongs to Coleman and is similar. While this class of stove does have a bit of a reputation for dirty and smelly operation, some of the stoves tested delivered fairly low CO emission levels once they had got going, with one stove being outstanding. I will use 'WG' for white gas from here on.

Most of the photos of the stoves have been taken from the vendor web sites. Only the Handy Camper, Optimus 8R and Snow Peak photos were taken by the author.

Recapitulation from Part 1

Part 1 examined the theory behind the combustion process in small stoves, focusing mainly on the three hydrocarbon fuels butane/propane, white gas and kerosene. The conclusions for those fuels and the stoves which burn them are:

- Carbon monoxide can be emitted by a stove under the right conditions.

- This hazard would seem to get worse as we go from butane/propane to white spirits to kerosene.
- Some stove designs may be worse than others because the pot is placed too close to the burner.
- The hazard is not inevitable: there would seem to be ways to reduce it to negligible levels.
- Long flames and yellow flames may indicate a CO hazard.
- Ventilation is crucial under any circumstances.

The CO Test Chamber

Recapitulation from Part 2

Part 2 tested the theory by examining a range of canister stoves of different designs. The conclusions from this testing are as follows:

- Some stoves emit almost undetectable amounts of CO, so a clean canister stove is possible.
- Some other stoves emit quite a lot of CO in their factory state, meaning much care is needed.
- In the bad cases, increasing the separation between the burner and the pot usually decreases the CO level.
- Pot diameter does not have any significant effect on the amount of CO emitted (contrary to rumour).
- Burner design does affect the amount of CO emitted: horizontal flames are best while vertical flames are the worst.
- Inadequate air supply into the burner column (air holes too small) will raise the CO levels.
- Provided an enclosure has at least 9 – 10 square inches of air inlet and air outlet, CO levels should not be raised.
- Integrated windshields may have a bad influence on the amount of CO emitted, depending on the design.

Outline and Scope of Part 6

In this article we test a range of liquid fuel stoves on both WG and kerosene. Note that while it is possible to use unleaded petrol or auto gas in such a stove, it is very unhealthy and we recommend strongly against doing so. Kerosene is fairly uniform, although sometimes it is called 'lighting kerosene'. Rumour has it that some forms of jet fuel are very similar.

Where possible each stove has been tested with both WG and kerosene. Provided the jet size and air inlets are reasonable, most stoves should be able to run the two. However, in some cases either the jet size is wrong or the amount of thermal feedback is inadequate, and the stove will only run on WG. Many of them will however also run on canister fuel.

handle both canister and WG, and some of them can handle all three common liquid fuels: canister, WG and kerosene. A good multi-fuel stove has many advantages, including the chance of using it around the world with whatever fuel can be found.

Another interesting feature coming to light is the return of the vortex burner. This burner is derived from the original Primus kerosene stoves, and these days is characterised by a cup-shaped surround with a small dished plate on top. The vapor squirts up from the bottom, hits the plates, swirls around in a bit of a vortex, and burns. Oh yes: the gas flow here is actually unstable: it oscillates wildly and this results in a vortex burner making quite a roar.

** Should any manufacturer wish to have other liquid fuel stoves included in this article they should contact the author at Backpacking Light. However, please note Backpacking Light cannot arrange shipping.*

Health and Safety Guidelines

Carbon Monoxide Levels

This table was shown in Part 2, but it is repeated here as it is the key reference for gauging the seriousness of the CO emission level.

Conc, ppm	Effect
0 – 1	Normal background
9	Max allowed for short term exposure in a living room, acc to ASHRAE, USA
25	Often encountered on major roads – UK figure
30	Health and Safety limit for 8 hours – UK
35	Suggested max allowable conc'n for continuous exposure for 8 hr – ASHRAE, USA
100	May be encountered on major roads during weather inversions – UK figure
200	Health and Safety limit for 15 minutes – UK
200	Mild headache, fatigue, nausea, dizziness. Limit for transient exposure – USA
200	Slight headache, tiredness, dizziness, nausea after 2-3 hr – ASHRAE, USA
300	Can lead to collapse – UK MoD
400	Frontal headache, life threatening after 3 hrs

ASHRAE: American Society of Heating and Residential Air-conditioning Engineers
UK MoD: UK Ministry of Defense

The Nature of the Fuels

When you buy a bottle of alcohol you normally find the label tells you what is in the bottle. The same applies when you buy a gas canister: it can contain a mix of n-butane, iso-butane and propane. But when you buy a 'liquid fuel' you have very little idea of what is in the bottle. This information can be very significant. There seem to be two reasons you are not told: very few consumers would know what the chemical names mean, and anyhow the manufacturers do not exercise a very tight control over the contents anyhow.

for them. The numbers indicate how many carbon atoms are in each molecule of butane or propane. Well, there are higher-order species or equivalents which we might term C5, C6, and so on. A feature of these hydrocarbons is that the boiling point depends on the number of carbon atoms, so we can expect that C5 will have a higher boiling point than C4, and C6 will be higher than C5, etc.

It will also be remembered that when butane and propane evaporate from a canister, both evaporate together, but at different rates. In particular, even when the canister is above the boiling point of propane but below the boiling point of butane, we still get some butane gas coming off with the propane gas. This makes it hard to separate the two just by using temperature. Well, the same applies to the heavier species C5, C6, C7 etc. What this means for the manufacturer running a refining plant, converting crude oil into refined fuel, is that any 'fraction' tapped off the column will contain a mixture of different species. Kerosene typically contains the species C11 to C16, while diesel typically contains C13 – C18, although this does vary a bit depending on whether it is meant for summer or winter use. This is because the heaviest species can actually freeze into a solid when it is very cold!

But what about auto gas? Well, this typically contains species in the range C4 to C12, but this is partly because the manufacturers deliberately include some butane (C4) to get the very high volatility you need to run a petrol engine. More commonly the original fraction might start at C5. In addition, we often find carcinogenic chemical such as benzene in the auto fuel mix. However, the volatility needed for cars is actually a bit of a danger for walkers running small stoves (or for other industrial users), so the range selected for fuel brands such as Shellite and Coleman Fuel starts a little higher and may be a little narrower too. I can't give exact details for every example of this fuel, but the chemicals in Coleman Fuel should be as follows:

- Cyclohexane (6 carbons in a ring, but not the carcinogenic benzene)
- Nonane (C9)
- Octane (C8)
- Heptane (C7)
- Pentane (C5)

*What I can't give are the percentages – because Coleman doesn't specify them. I suspect they are not really fixed.

An astute reader might wonder whether one could use a pure species of hydrocarbon such as pentane (C5) as a fuel. In principle the answer is yes – after all, one can use butane (C4) as a fuel. If the species has a high number of carbons, such as decane (C10), there may be problems in priming it enough to get it going, so the lighter the molecule the better. The real (ie bigger) problem is that the pure species cost a whole lot more than Shellite or Coleman fuel, and are only available in chemistry labs.

WG vs Kerosene

What then is the difference between WG and kerosene? Basically it is a matter of safety. Kerosene is not volatile at room temperature, while WG is. I have seen a startling demonstration of this by our local Fire Brigade. A burning match dropped on a tray of auto gas creates an instant fire ball. (OK, WG is not quite so bad – but it is bad enough.) A burning match dropped on a tray of kerosene – goes out. Spilt WG around your stove is a serious explosion hazard; spilt kerosene is far more docile. That said, I have to add that kerosene stinks a lot more than WG!

For both fuels it is necessary to prime the stove first. This means heating up the pipe which brings the fuel to the jet so that vapour comes out of the jet rather than liquid. Remember: liquids don't burn; only gases (vapours) burn. With older stoves this means heating up a preheat tube which goes over the flame, but some of the newer liquid fuel stoves

It is easy enough to prime a WG stove: some components of the fuel start to vaporise all by themselves at room temperature or lower. However, it is better if the fuel is raised to about 38 C (100 F), when it starts boiling. In general a liquid fuel stove gets a *lot* hotter than that! However, priming a kerosene stove requires a lot more heat. Kerosene does not boil until about 170 C (340 F).

What to prime a stove with is a good question. You can use WG to prime a stove running WG, although it may be a little smoky for a while. But trying to prime a kerosene stove with kerosene, especially in the snow, is really making life difficult (and very sooty) for yourself. I use a small amount of methylated spirits (ie ethyl alcohol) for priming, and allow some kerosene to mix with it. However, with the most care in the world, priming a liquid fuel stove usually results in a fireball of some size, and this is **not** something you do in a tent. It isn't very good for the atmosphere when done inside a building either. What will come out of the results for the stoves is that a fair bit of CO is given off when priming, along with the soot.

Stove Design as a Function of Fuel

You will notice that only some of the stoves can be used with kerosene, and this is *not* just because of the increase in boiling point with kerosene. While the weight of the fuel matters when you are carrying it, it is the 'volume' of the gaseous fuel which matters when you are designing a stove. Butane and propane are small molecules, with only 3 and 4 atoms of carbon to burn in each molecule. The larger molecules of WG contain more carbon atoms, and so they require more oxygen per molecule. Kerosene goes even further. In practical terms, this means that you need more air mixing with the gas stream coming out of the jet when burning WG compared to butane, and kerosene is even worse. Many stoves are optimised for just WG: they can't drag enough air in to properly burn kerosene. If the stove has been optimised for butane and WG, it is likely that it will be even further from working with kerosene. Some stoves try to compensate for this by giving you different jets for each fuel, but that is only a partial solution and many stove manufacturers don't like asking the user to fiddle with the jets anyhow. So we may expect that many multi-fuel stoves will work worse with WG than with butane.

The original kerosene stove was marketed by Primus of Sweden. It was essentially what we call a 'vortex burner', and was noisy. Early backpacking stoves such as the Optimus 8R and the Svea also used the vortex burner, but over time the market switched to a 'quiet burner', which is that round thing in the middle of a stove with all the little holes. However, this change was not without a cost. The vortex burner is able to suck in as much air as it needs, but the quiet burner uses a mixing column with air inlet holes at the base. This arrangement is much more limited in flexibility. For a while it seemed that only the MSR XGK stove was persisting with the vortex burner design. However, in the last couple of years the vortex burner has come back in popularity, and I believe this is because of its greater versatility. You will find a good mix of stoves listed here: some of each sort.

Safety

All these stoves feature a remote tank, with pump. This means that the tank can be pumped up some more while the stove is running with only a limited risk of a complete disaster. It also means the fuel tank is some distance away from the stove, and therefore not usually at risk of overheating. However, be aware that I know of at least one case where the tank on a WG stove became overheated and burst; the burning fuel hit two campers with devastating results.

We repeat here for good measure: while priming a liquid fuel stove is always necessary, it is a hazardous fireball period when lots of flame, soot and CO is emitted. Managing this inside the Test Chamber took some care.

Each stove has been carefully tested in the laboratory with results as given below. A couple of the stoves have also been tested in the field. These days I prefer a canister stove under nearly all conditions. Results are given for CO emission at two or three nominal power levels: medium and high, and 'low', provided that the stove could be turned down to a low power setting in a stable manner. Not all stoves would operate at low power however: they have a well-known inability to simmer. In addition, all stoves were tested with the pot on the pot supports and about 10 – 12 mm (just under ½ inch) above the pot supports. Test results shown are all for a large diameter GSI Bugaboo pot. Approximate power levels are given for each test, but it should be noted that the power levels varied even during test runs.

It is appropriate to comment here on why it is so hard to get a low power setting. When running an upright canister stove the needle valve is controlling the flow of gas, and this is done with reasonable ease and consistency. However, with a liquid fuel stove the needle valve is trying to control the flow of a microscopic amount of liquid – which subsequently expands to at least 200 times the original volume. Any dirt in the fuel and the needle valve can become blocked. Any jolts to the valve on the tank or even just movement of the tank can alter the flow slightly. It is far easier to open the needle valve to the point where the jet is doing a lot of the flow limiting. Pumping up the tank then increases the power.

The measurement protocol has been extensively discussed in previous Parts of this Series. What is important here is that all stoves and fuels have been tested under reasonably similar conditions. In the field many walkers find that a very tight windshield is highly desirable, but the enclosing Test Chamber proved to be quite sufficient to act as a windshield for these tests.

Figures for the CO emission have been quoted in the table below for 'high' and 'low' power operation, at the factory clearance between pot and stove. These figures are somewhat rough averages with a focus on the later part of the period concerned, and do not include the period when the stove is priming and warming up anyhow. As will be seen from the detailed graphs, CO emissions during warm-up can reach 400 – 600 ppm for half a minute quite easily. You have been warned. As will be mentioned in a few places, significantly lower levels of CO emission can be obtained from many stoves by increasing the clearance.

Stoves Tested

Stove	Total Wt g / oz	Stove Wt g / oz	Pump Wt g / oz	Tank Wt g / oz	WG ppm, LowP	WG ppm, HighP	Kerosene ppm, LowP	Kerosene ppm, HighP
Brunton Vapor-AF	565 / 19.9	378 / 13.3	77 / 2.7	110 / 3.9	10	15	10	15
Coleman Apollo	583 / 20.6	381 / 13.4	85 / 3.0	117 / 4.1	120	200	–	–
Coleman Fyrestorm Ti	418 / 14.7	216 / 7.7	85 / 3.0	117 / 4.1	25	125	–	–
Coleman Peak Apex II	532 / 18.8	318 / 11.2	99 / 3.5	115 / 4.1	340	–	–	–
Handy Camper	221 / 7.8	–	–	–	150	–	–	–

MSR Whisperlite Int'l	380 / 13.4	263 / 9.3	49 / 1.7	68 / 2.4	50	20	270	200
MSR XGK EX	443 / 15.6	311 / 11.0	64 /2.3	68 / 2.4	–	15	–	90
Optimus 8R	783 /27.6	–	–	–	40	140	–	–
Optimus Nova +	519 / 18.3	302 /10.7	116 / 4.1	101 / 3.6	20	135	250	320
Primus Gravity MF	441 / 15.6	242 / 8.5	102 / 3.6	97 / 3.4	220	120	–	–
Snow Peak GS-010A	496 / 17.5	285 / 10.0	83 / 2.9	125 / 4.4	314	317	–	–

Analysis and Comments

Each stove was tested under the same test conditions, but the CO emissions varied over a wide range. Rather than use a common vertical scale for all the graphs of CO ppm levels, the vertical scale used in each case has been optimised to some degree for the data. Thus you will find some graphs range up to 50 ppm (which is low), while others go up to 500 ppm (which is high).

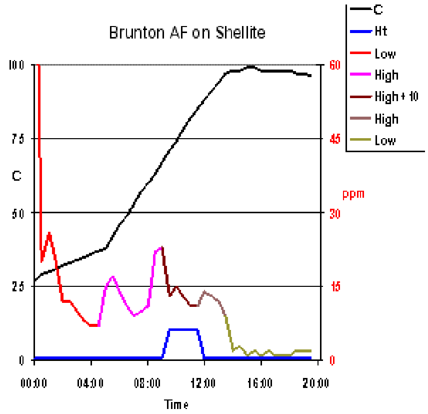
Also, the starting levels for CO emission have frequently been chopped off at the top to better display the rest of the data. You must assume that all the stoves emit a lot of CO at the start as the burner warms up. Since priming these stoves usually requires a small fireball – the size of which I find slightly unpredictable, you should always start these stoves outdoors in a clear space! Whether you subsequently bring the stove inside a tent or a building is entirely up to you. Backpacking Light makes no recommendations here.

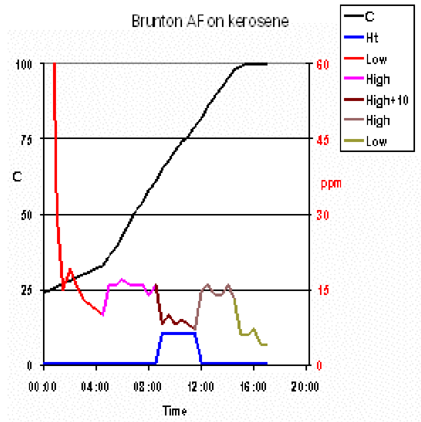
Close inspection of the graphs will show that almost all stoves reduced their CO emission over time as they got hotter. This is good, but do remember that the time period shown on the graph did allow the stove to bring 1.5 L of water to the boil. It may be that typical burn times will be less than this, so you may not get the advantage of the really hot stove in practice.

The sensitivity of the stoves to an increase in clearance between the pot and the burner varied. In some cases, like the Brunton Vapor-AF, the change in CO emission was barely significant. In other cases, like the Coleman Peak Apex II on WG, the MSR Whisperlite on kerosene and the Optimus Nova Plus on kerosene, the reduction in CO emission with an increase in clearance was really significant. This suggests that some stoves already have adequate air intake and adequate clearance while on others both need to be redesigned.

Most of the recent stoves have a similar peak power. I have usually called this 'average'. Think of this as meaning 'typical', not as meaning 'poor'. Older stoves sometimes had a slightly lower peak power, but not by much. However, I never use my stove at peak power – it is far too wasteful of fuel, so I cannot see why the manufacturers have been indulging in this power race. Advertising machismo games I guess. A pity they haven't really found out what walkers in the field need. Far more important to me is whether the stove can simmer, and here the stoves did vary quite a bit. Some simmered very low, others didn't want to know about it. I take 'low' power to mean a heating rate of about 4 C/L.min .

Stoves tested





The Brunton Vapor-AF (ie All Fuels) stove handles canister gas, WG and kerosene. It departs from the traditional vortex burner design in two ways. The appearance is improved by having a really neat orange outer shell, but this is minor. Far more importantly, the orange shell controls a variable air inlet! This is the only commercial stove I have seen so far with this feature, and its significance should not be under-estimated. The variable air inlet can be set to 'G' for canister gas or to 'L' for liquid fuels (but don't try this while the stove is hot!). The latter need more air for complete combustion, and this feature supplies more air. Conversely, too much air with canister gas makes the flame unstable and prone to 'flame-out'. Rather than compromise all around, Brunton have found a design which optimises for both classes of fuels. This is a stove you could take around the world, to use whatever fuel is available.

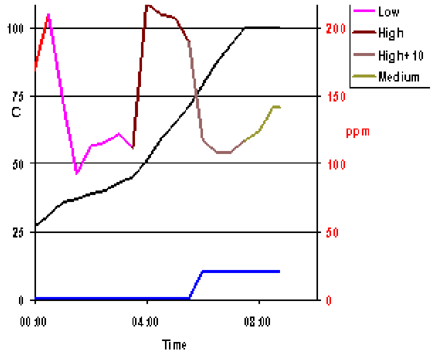
Apart from being a really clean burner, the Brunton Vapor-AF is robust and stable but typically noisy – especially at full throttle. Ah well, at least you can monitor the stove just by listening to it. An added bonus, of considerable value, is the fact that you can turn this stove down to below a simmer and it is still stable. You will see in the temperature graphs that running the stove at a low setting with the water near boiling resulted in the water actually cooling down very slowly: steam was taking heat out faster than the flame was putting it in. Simmering is for real.

Peak power was quite reasonable, but not extreme. Brunton have gone for clean usable performance rather than machismo flame-throwing. This is good.

Inspection of the graphs shows that increasing the clearance between the pot and the burner had little effect. The clearance is adequate.

The stove is not without a problem however. I found the pump quite frustrating. It works all right, but you can't 'feel' the air being pumped into the tank. At first it felt as though the pump was bouncing: not getting any air into the tank at all, but it turned out it was working. This may improve with use.

Coleman Apollo – 583 g / 20.6oz



The dual-fuel Coleman Apollo stove is a very strange beast. The tank, pump, fuel line, valve and preheat tube are common to other Coleman stoves, especially the Coleman Fyrestorm. The legs are large and unique to this stove, but there is nothing special there. However, the fuel/air mixing system is unique. The preheat tube goes over the top of the burner in the conventional manner, and then sprays downwards, into a large chamber below the burner. The mixture then comes up out of this chamber to the burner. This arrangement makes some sort of sense: the preheat tube is very short. However, the large chamber at the bottom has to be heated up properly before the stove will run well – otherwise the fuel vapour will just recondense down there. Preheating all this stuff requires a decent fireball for priming. I dislike fireballs. On the other hand, this stove is about half the price of the Coleman Fyrestorm.

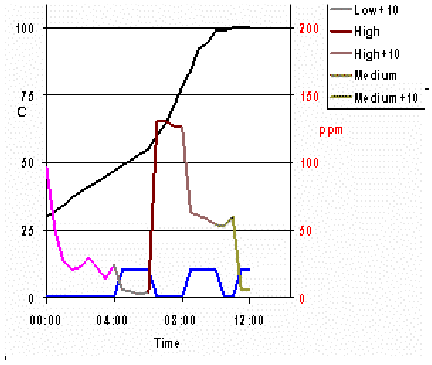
Once burning the stove has high power, but a very strange behaviour. At low power all is well, although the CO emission is higher than I would like. At high power (which is definitely in the machismo range) there is not enough air mixing with the fuel, because the CO levels are even higher and the flames are very long. They stretched out beyond the diameter of the GSI pot I was using – and that is a wide pot! But even more strange is what happens at a medium power: the flame turns from blue to yellow! This suggests that the stove is getting even less air at medium power than at high power. Powerful, but all very strange.

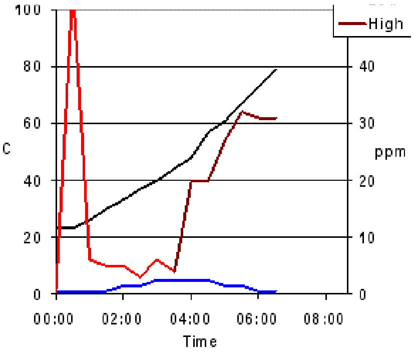
When burning at a low power there can be a bit of a sputtering noise from the flame. I am not sure why. At most settings there is a rattle from the tank, where the fuel line is bouncing around as it sucks in fuel. This sort of oscillation is actually quite common in most stoves; you just don't notice it.

Increasing the clearance at high power has the expected effect: the CO emissions come down to the level experienced at low power. This is better, but still not good.

The stove only burns WG, not kerosene. I did not attempt to light it with kerosene as priming for WG was bad enough.

Coleman Fyrestorm Ti – 418 g / 14.7 oz





The Coleman Fyrestorm Ti is a dual-fuel stove: inverted canister and WG. It has an on/off valve on the tank, with the pump, and a control valve at the stove. The control valve does *not* allow you shut the fuel off; it only ranges from 'low' to 'high' (or 'full'). Coleman explicitly warns against using kerosene in it, and I can confirm kerosene does not work very well! But it does burn canister gas very well, with very low CO emissions and excellent control. The CO emission with canister gas is shown in the right hand graph for reference. Apart from a bit of a glitch when the stove was lit (believed to be an artifact of the CO monitor rather than real), the CO emission with gas is fairly low all the time. It was found that variation in clearance with gas does not have a large effect. So it is interesting to see that the performance with WG is also quite good: clearly Coleman know what they are doing with the design of this stove.

The model shown is the 'Titanium' model; there is also a slightly heavier but cheaper stainless steel model. The fuel line, the valve, the preheat line and the tank are in fact all standard Coleman parts. The preheat line is interesting: it looks like a tube, but when you peer into one end of the tube it looks like three concentric tubes with the inner one having quite a narrow bore. (It may be only two concentric tubes with funny ends: I can't tell.) Through the inner bore goes a fine wire, which ultimately reaches and partially blocks the jet at the end of the tube. The wire can be manipulated backwards and forwards by the control valve; this effectively varies the position of the tip of the wire relative to the jet. Thus the control over the fuel flow is done right at the jet, which is why these Coleman stoves have such excellent smooth control over the power even when using a liquid fuel. The reason is of course that the control valve does not act on liquid fuel but on gas. One caveat though: because of the length of the wire, there is quite a lot of hysterysis in the control action (but it does work quite well). In addition, if you crank the control valve to full 'ON', the tip of this fine wire should come through the hole in the jet: this serves as a convenient built-in pricker. To repeat: this whole control valve and preheat tube arrangement is common to many Coleman stoves.

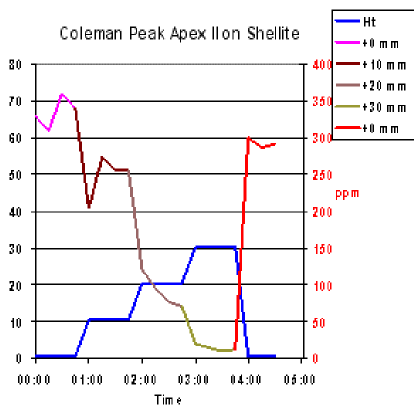
There is also a visible on/off valve at the tank – the round knob above the black pump housing. Make sure this is turned off before detaching the fuel line from the tank. There is also an invisible safety valve inside the fuel line connector at the pump. This safety valve stays shut off until you have connected the fuel line to the tank. However, once you have connected the fuel line to the tank fuel will flow to the stove, and the control valve there cannot stop it. You do need to use the on/off valve at the tank.

While this stove is a delight to use with canisters (even inverted), I found it much more difficult to fire up with WG. Coleman claim that you should just open the control valve (on the stove) to Full, then open the on/off valve on the tank, and light the stove. Well it does not work that way for me with WG unless the weather is very hot. I get a high flame with a fair bit of soot. Once again, a discrete fireball priming seems to be needed to get all the stove hot, otherwise liquid fuel can dribble out from the burner chamber down under the stove, to catch alight in a spectacular fireball later – or maybe I should say 'fyrestorm'? (Yes, this did happen during testing, and it burnt out the electronic cabling on the temperature probe in the Test Chamber. But that was fixable.) The problem here is that there is a fair bit of both the fuel line and the air mixing chamber under the burner, and these parts do not get hot if you put the priming fuel only in the burner cup. It has to go on whatever has been placed under the stove as well – and that had better not be forest floor! However, don't get the idea that this stove is any worse for priming than most other WG stoves: most of them seem to need fireball priming!

level when the clearance is raised by 10 mm. The CO emission rises noticeably at high power (to about 125 ppm), but again increasing the pot clearance reduces the CO emission back down to an almost acceptable level. More clearance might improve things further, but this was not tested. High power is at the average level. All this suggests that the air flow section of the burner has been optimised for use with a canister: canister gas requires less oxygen than WG (by volume) for proper combustion. This makes profound sense to me: why would anyone in their right mind use a stove with WG when they can equally use it with an inverted canister?

Before leaving this stove, please note that like most multi-fuel stoves, the Coleman Fyrestorm has **more** power running on a butane/propane gas canister than on WG. Coleman quotes 14,000 BTU with a canister and 10,000 BTU with Coleman Fuel. The stove uses less weight of fuel for the same job with a gas canister as well.

Coleman Peak Apex II – 532 g / 18.8 oz



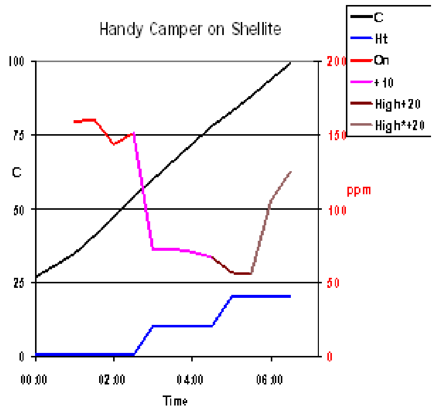
The Coleman Peak Apex II is an old stove, now obsolete. The photo to the left is the nice marketing image courtesy of Coleman; the one to the right is my old stove after many, many snow trips, where it was running on kerosene. I bought it in 1992. The shiny aluminium parts under the burner crumpled under the impact of time and use, so I made replacement stainless steel parts. Heavier, but very robust! I dipped the feet in black rubber solution to stop them sliding and to mask the sharp edges. The black paint work on the base … well, it has seen better days.

I have included this stove here as a reference point for the evolution of liquid fuel stoves. It is one of the first stoves to have had dual valves. The one on the tank serves as an on/off valve, while the one on the stove serves as a variable control valve. This is also one of the first Coleman stoves to have used a long thin wire inside the preheat tube to act as a flow control. It also uses the crinkle-washer burner arrangement, as found in the MSR Whisperlite.

When I came to fire this stove up for these tests I found that the old rubber hose had perished, so that fuel started leaking out along its length. Coleman was kind enough to replace the pump/hose combination. Then I found that the stove I own (in the right hand photo) is *not* the same as the current version: mine was an early model, bought from a very limited production run in 1992. The new hose did not fit the old valve on the stove properly. Coleman came to the rescue again, and sent me a replacement valve assembly. So far so good. However, the preheat tube was corroded inside, and I could only get a very small flow of vapour out the jet. I cleaned out the jet (which was blocked) and the preheat tube, which was a bit corroded, and managed to get a low/medium power out of it. I did not pursue the matter any further as this was enough for these tests. But it did mean that it was not worth while recording temperature for the heating rate.

at +20 mm it is starting to be reasonable, while at +30 it is very good. However, at +30 mm spacing the heating power of the flame does start to be dissipated, so that the heating rate is not as good. There is a trade-off here, as with several other stoves.

Handy Camper – 221 g / 7.8 oz

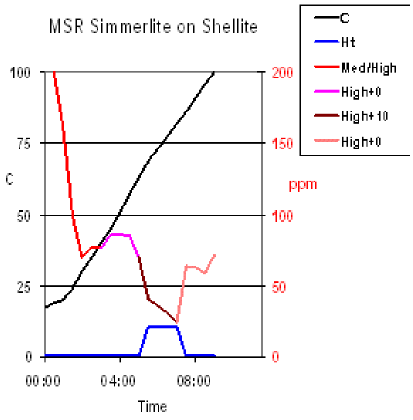


I have to apologise for this stove: it is the first stove I ever owned, in my youth. It is actually a fairly rare collector's item from the early 1960s, but it is interesting to compare it to current stoves. You will see a small blue arrow pointing to the bottom of the copper coil in the photo. There is a pin-hole there: that is the jet. Petrol is sucked up into the copper coil from the brass tank by wicks in both arms, and it is then vaporised in the coil to spray out of the jet, up past the top of the coil. It burns, heating the copper coil, which not only vaporises the petrol in the coil, but also in the tank. This creates the pressure needed to drive the vapor out of the jet. It is effectively a vortex burner, without the usual surrounding cone.

Yes, this stove worked fine – with a little care. Leak a little petrol into the bowl at the base of the coil, apply a match, and away it went. To turn the stove off, you take the cork and quickly jam it into the middle of the coil, thereby blocking the jet. There are no controls of course, and the whole stove does get quite hot after a while. What is perhaps more interesting is that it has every bit as much power as most of the others, while it is clearly the lightest! Have we progressed over 40 years?

It did emit a bit of CO while running, as you can see from the graph. However, increasing the clearance to 10 mm and then to 20 mm showed that the CO emission could be reduced significantly, as one might expect. Not shown in the graph here is the fact that the heating rate stayed about the same at +20 mm as at +0 mm. The excuse of wanting the highest heating power as a justification for having the clearance too low is demolished in cases like this.

There is an abrupt upswing in the CO emission at the end. All of a sudden the sound of the flame changed, and so did the appearance. I believe a small bit of dirt had lodged in the jet, reducing the flow of gas and deflecting the flow towards the back of the coil as well. The lower flow dragged in less air, and by moving to the back, nearer to the baffle, the flow was less able to drag in air as well. In the field this would simply require the skilled use of a fine pricker at the jet – probably while the stove was still running. (Yes, while running: one hopes the pressure could blow the dirt out the hole.)

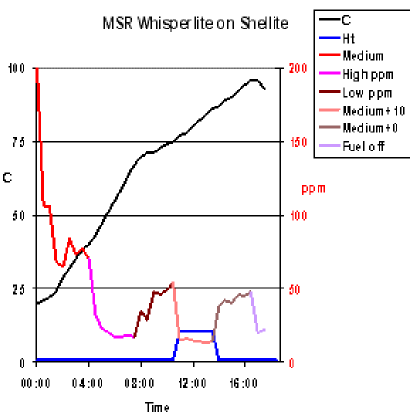


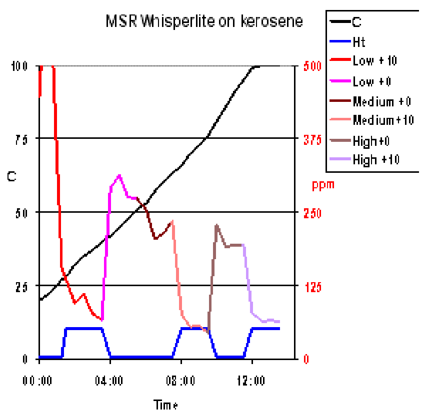
The MSR Simmerlite stove looks a bit like the MSR Whisperlite, but the burner is ‘conventional’. It only works with WG, although the almost identical MSR WindPro works with canisters, upright or inverted. You could think of it as the successor to the MSR Whisperlite.

The stove works well at full power (slightly above average) and medium power, but I had trouble turning it down to low power. Basically, this is not a stove for easy simmering – despite the name. However, it is usually possible to get a fairly low power with this stove if you don’t pump up the tank very much. However, it is not entirely stable at the lowest settings because you are valving the liquid flow, and this is as discussed above rather tricky.

The stove does emit a bit of CO as it warms up, but then the level is ‘typical’. However, equally typical is the reduction in CO level when the clearance is increased. The extra 10 mm makes the stove quite a reasonable performer – and it is very light too.

MSR Whisperlite International – 380 g / 13.4 oz





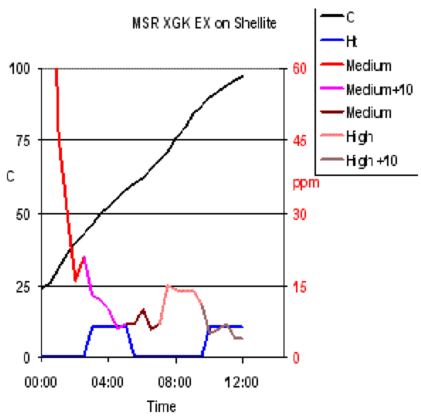
The MSR Whisperlite International succeeded the earlier Whisperlite, and added kerosene as a fuel. The Whisperlite Shakerjet followed, and added a little slug inside the jet body which could be shaken to clear the jet in case of blockage. The Simmerlite is by way of being a successor after that. So the basic design has quite a history. I bought my Whisperlite

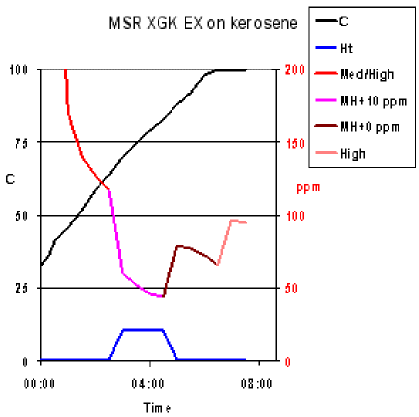
The stove has a built-in priming cup under the jet, with fiberglass wick. This is a serious improvement over the common practice of dowsing the whole stove with fuel and creating a fireball. Gently open the valve and fuel will dribble down into the cup, from where it can heat the whole stove. This works fine with WG, but for kerosene you should start with methylated spirits. Otherwise you get a very sooty stove, and possibly a blocked jet after a while.

As you can see from the graphs, with WG the stove performs quite respectably for CO emission. The maximum heating power is slightly less than for the MSR Simmerlite and slightly less than 'average', but I have always found that the Whisperlite gave quite enough power for the two of us, even in the snow. Increasing the clearance has the expected effect of reducing the level of CO emission, down to a quite respectable level. However, the air flow seems to be optimised for use with WG as using the stove with kerosene does involve a higher level of CO emission. Increasing the clearance for kerosene gives a more rewarding reduction in the CO level.

More peculiar is the fact that the CO emission seems to be less at high power. I am not sure why this should be so, but it may have something to do with the shielding effect of the cup under the burner. At high power the flame reaches *out* of the confines of the cup, and thereby encounters a lot more air. A similar behaviour was seen with the Trekker canister stove which also had such a 'windshield' cup under its burner. The Snow Peak GS-010A stove also has this problem with a cup under the burner.

MSR XGK EX – 443 g / 15.6 oz





The MSR XGK has a bit of a reputation (promoted by MSR of course) as being able to burn anything, including diesel and vodka. I have tested the XGK on diesel fuel: it burnt, but somewhat poorly. Heating oil is another similar fuel but with an even higher boiling point. I tried that too, but the stove never got hot enough for good operation. Maybe it needed more priming – with an LPG torch for instance. This EX model is the latest incarnation.

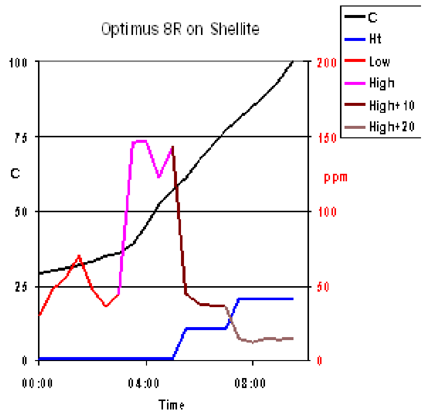
I love the instructions which come with the MSR XGK stove. Under priming in the English instruction manual (Step 4) they say:

> 1. Release only 1/2 tablespoon of fuel
> 2. Light fuel
>
> **A brief soccer ball size flame is normal.**

It is interesting that this stove burns quite cleanly with WG, as you can see from the graph. Increasing the clearance did give some benefit, but not a lot when you are starting from such a low level. However, the CO emission rises when you switch to kerosene. There the improvement given by increasing the clearance is more evident. Obviously, while the XGK can burn most hydrocarbon fuels, it has been optimised for use with WG. That seems reasonable in my opinion.

Oh – I should add that another reputation the XGK has is well deserved: it is quite noisy! Well, all vortex stoves are, but the XGK excels. It is also very rugged, but you pay for this with the slightly increased weight – although there are quite a few stoves which are heavier.

Optimus 8R – 783 g / 27.6 oz



The Optimus 8R is a very old WG stove. My wife and I were using this actual unit in the late 1960s. Compared to modern stoves it is heavy, but we cooked a lot of meals on it and it took a lot of bashing. It even got thrown out of the tent into a storm on one occasion when the tank got too hot and the safety valve started to vent a very long flame! The reason for this is given below. The Optimus 8R has the rare distinction that the design was so popular at the time that it was cloned in the 70s by an un-named Taiwanese company. I have both the original Optimus 8R stove and the Taiwanese clone.

The burner on the Optimus 8R seems a bit small compared with other stoves, but it has plenty of power for boiling and it could simmer nicely as well. Control is very easy. The removable rotating knob drives a slug up inside the jet via a small rack. The slug doubles as a pricker at one end of its travel – more that 30 years before the MSR 'Shaker-jet' was invented.

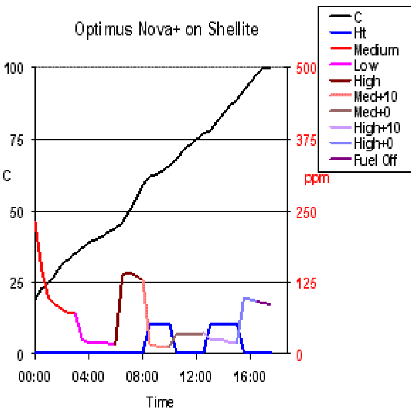
There is no preheat tube on this stove: instead the heat is coupled from the brass burner cone around the jet back into the brass control valve and then back into the tank along the short brass fuel pipe. Once the tank starts getting warm the resulting vapor pressure inside it drives the fuel into the burner. There is a wick from the fuel pipe, dangling into the bottom of the tank. Typically, you prime this stove by removing the fuel cap and blowing, hard, into the tank until fuel dribbles out at the burner. The big brother to this stove actually had a pressure pump, which saved you the taste of fuel.

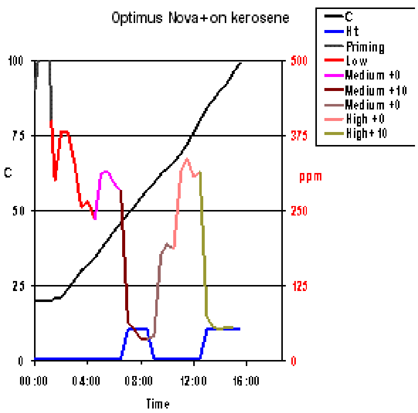
However, while testing the stove for this article this time I noticed that the flame from the burner does come a 'little close' to the prominent round filler-cap on the middle of the tank if the pot is large – like the GSI pot I am using for all these tests. This reminded me of the time I was cooking a lot of pancakes one day on Goon Moor up in the mountains of South-West Tasmania, during a storm. The frying pan was very wide, and the stove ran for a long time. The tank got very hot. The dot in the middle of the slot in the filler cap is a pressure release valve, which prevents the tank from bursting. I everything including the tent. So the stove was turned off and thrown out into the storm outside to cool down. My memory of the incident is that my actions were taken very fast … [Note added during peer review stage: another Backpacking Light Staff member reported have a similar incident with an old Svea stove. The incident was 'seared' into his memory.]

I was very pleased to see that when I added 10 mm extra clearance, the flames were much further from this safety valve. And 20 mm extra clearance gave a luxurious gap between the flame and the filler cap. You will also see a baffle between the tank and the burner. Yes, a pivoting heat baffle indeed. It is removable for starting the stove in very cold weather.

Anyhow, while the stove does emit a bit too much CO at high power, the level drops very nicely when the clearance is increased by 10 mm, and it is very respectable when an extra 20 mm clearance is allowed. The stove may be too heavy for a lightweight walker, but it could still be very usable with new pot supports. As these pot supports just clip in place, changing them and the clearance is very easy.

Optimus Nova and Nova Plus – 519 g / 18.3 oz (Nova+)

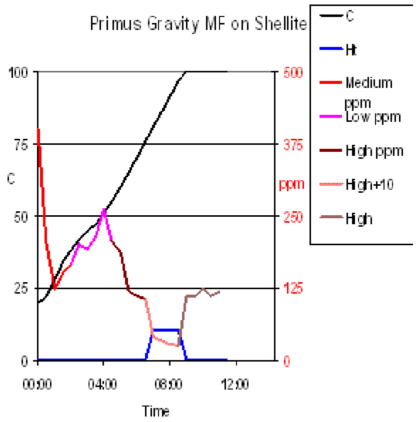


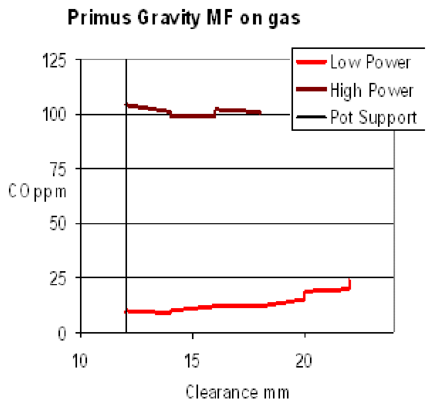


The Optimus Nova and Nova Plus are essentially the same stove but with different hose and control valve arrangements (as far as I can see). They use the same vortex burner. The Nova Plus (or Nova+) does not seem to have a control valve in the picture. The control valve is there all right, at the stove, but it is turned by the green knob at the tank end of the fuel hose. The rotation is carried by the fuel line.

This cunning control method is not without some problems however. It is obviously going to be a bit stiff: you have to rotate that heavy curved fuel line. However, while a bit stiff, the rotation is fairly smooth, and the system works. More of a problem arises when you turn the stove off and let it cool down. The valve has a tendency to get stuck when it has cooled down – thermal contraction maybe. Optimus provide a small spanner specially designed to grab and rotate the valve at the stove when this happens. It sounds as though they had done their own testing …

Unfortunately the stove does emit some CO with WG at the factory clearance, and a bit more with kerosene. Increasing the clearance reduces the CO emission, even to an acceptable level, and this is especially obvious with kerosene. I could get a good low power simmer with both WG and kerosene, but with some CO emission. Clearly the air supply could be improved, and the pot supports definitely need increasing in height. The high power rating is about 'average'.



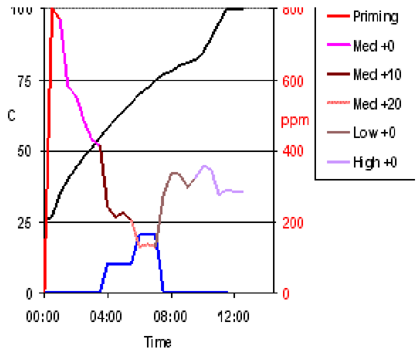


The Primus Gravity MF (Multi-Fuel, canister and WG) is an attempt to make a light stove using thin sheet metal rather than wire. It works OK, but overall the stove does not really impress that much. I think part of the problem lies in the jet and air inlet region underneath the burner: not enough air seems to be entrained. It can be used with canisters and with WG, but not with kerosene, and I can confirm that it does not like Kerosene (very smokey!).

While the CO emissions are not high, the result of raising the pot shows that the clearance allowed between the pot and the burner is too little. As may be seen in the second graph, the stove has a similar problem with canister fuel at high power: not enough air. Like the MSR Whisperlite International, this stove performs better at high power with WG, but not with canister gas. Increasing the clearance at high power further reduces the CO emission, which points the finger at a combination of inadequate air inlets and the muffling effect of the flat 'cup' under the burner. One could perhaps spot-weld a 10 – 15 mm height extension onto the pot supports, but I am not sure how the light sheet metal would take that. I don't think it is possible to remove the flat cup without damaging the entire stove, so it might be better to try to increase the air inlets somehow, so that both gas and WG burn more cleanly.

The stove also takes longer to warm up than I would have expected for such a low mass. I suspect the preheat tube is tucked in too close to the top of the burner. Otherwise it works OK, but I couldn't get it to simmer very low on WG, although it was better with canister gas. Its peak power is actually a bit above average.

Snow Peak GS-010A – 496 g / 17.5 oz



The Japanese sometimes do their own thing, and in this case they have. The stove has not two valves, but three! The stove comes decked with several notices saying that lighting this stove is different from others, due to the third valve. The third valve is on the pump (beside the primary On/Off valve) and is labeled 'Start/Run'. You can see this valve inset into the corner of the right hand photo. You are meant to light the stove in the Start position. I am not sure that using this valve as directed really makes much of a difference to lighting the stove: it simply seems to act as a significant flow restrictor in the Start position. I guess it is meant to limit your ability to flood the stove with fuel when you turn on the primary On/Off valve. Another difference is that the fuel hose is a separate component – fully detachable at both ends. I have included it with the stove for weighing to be consistent.

Anyhow, this stove really is easy to light. There seems to be no priming required compared to some of the other stoves which required a small (or large) fireball. It discharges a small fog of fuel vapour when you turn the main valve on, and this lights instantly. In fact, it is a very good idea to make the flame before you turn the stove on.

The burner is a 'crinkle washer' one, like the MSR Whisperlite, but it is cradled inside a really tight cup. I think the cup is meant to stop the wind from affecting the base of the flames. As you can see from the photo to the right, the cup gets very hot when the stove is running, especially at high power. And while the stove is rated to 'only' 10,000 BTUs, I have to say that it has no trouble reaching that power output. In practical terms I think this stove would prove more powerful in the field than many other WG stoves of similar power ratings. At the same time, I found I could turn it right down to a gentle simmer, using the control valve located on the stove.

However, the design of the burner causes the flame to go straight up in a narrow column, as shown in the photo to the right. This means that it has limited chance to collect more oxygen around the perimeter of the flame, and this is reflected in the high CO emissions – which is a pity for such a nicely-made stove. Increasing the pot clearance does reduce the emissions as expected. I won't say the emissions are good when you add 20 mm clearance, but they are not disastrously bad.

Close examination of the construction of the stove shows excellent engineering, and that you could remove the wire pot supports without any damage to the stove. You could then remodel the wires to maintain the pot height but lower the stove towards the ground, thereby improving the CO performance permanently. Doubtless this would void various warrantees.

Snow Peak markets an almost identical WG stove with a 'Large Burner'. It may be that this stove could have a flame pattern which splays outwards: if so it might have better CO performance. This has not been tested yet. The company also markets this stove with a remote canister attachment, as a different stove.

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