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Stoves, Tents And Carbon Monoxide – Deadly Or Not?

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Research & Testing

Stoves, Tents and Carbon Monoxide – Deadly or not? Part 1: Theory



You've read the warnings and heard the horror stories about cooking in your tent. How dangerous is it really? Part 1 of this series describes: how CO is formed, a warning sign of production, and a simple change you can make to your stove setup to reduce CO.



By Roger Caffin

August 23, 2006



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 article explores the carbon monoxide issue. The first part will cover the basic theory underlying how stoves work and how they can generate carbon monoxide, the second part will cover an extensive amount of laboratory testing of a wide range of stoves, and the third part will cover field tests of some selected stoves inside several tents. It is mainly focused on butane/propane, white gas, and kerosene stoves, although some brief mention is made of alcohol and solid fuels.

Background

First of all, let's make it very clear that a stove can make carbon monoxide or CO gas, and that this gas is poisonous above a very low level. It gets absorbed by the haemoglobin cells in your bloodstream, stopping them from absorbing oxygen. Without that oxygen circulating around in your body, you die.

The hazard from breathing in CO is real.



This is a well-ventilated tent, and it **was** cold outside.

What's more, there have been a few [cases](#)¹ where walking/mountaineering people in tents have suffered from CO poisoning. However, many of these cases have been inside tightly sealed tents at high altitude, and the number of cases is very small. Many other 'tent' cases have involved poorly operating lanterns or even charcoal BBQs in more tourist environments. On the other hand, I have spent a significant part of my life walking and ski touring, usually with my wife, and almost always in a small mountain tent. For the last 15+ years I have always used a small stove to cook dinner, and if the weather has been poor I have used that stove inside my tent. I have never been conscious of any hazards from carbon monoxide, carbon dioxide, or lack of oxygen. Just why that may be so is discussed further on.

Now let's look at the problem from the perspective of a stove manufacturer. Consider the quantity of highly volatile fuel involved with any stove, the potential for all sorts of fires and explosions, and the current propensity for people to sue companies over anything at all. One has to wonder why any sane manufacturer would even consider making and selling stoves! It seems inevitable that the company lawyers will stick as many warnings as possible onto the stoves. Since lawyers tend to focus more on human error and legal risk rather than the actual physics and chemistry of what's going on, one can also expect the company lawyers to do everything short of saying 'don't even use the stove'.

This seems fair enough really, given the hazard and their liability concerns, but it throws the responsibility of understanding the nature of the hazard back onto the consumer, you, the walker. And there is very little real technical information in the market place about the hazard. This article aims to help explain what is really going on.

Overview of Part 1

In Part 1 of this article I start with a brief review of the medical knowledge. The nature of carbon monoxide poisoning is well understood: it can preferentially join with the red blood cells which normally carry oxygen around your body, forming carboxyhemoglobin (COHb) and, basically, cutting off your oxygen supply. It displaces oxygen from your blood supply

Then we review published reports and statistics, which support the idea that carbon monoxide does kill people each year, but the number killed is not great and the big hazards are not with small cooking stoves in well-ventilated walkers' tents, even in the snow. Some medical research into this problem has been done. We list some very useful references under Medical Knowledge. A couple of other key non-medical references into the CO problem are also listed: these can be hard for walkers to find, and have not had the publicity they deserve. They are very much to the point.

Having dealt with the published literature, we will then move on to discuss Flame Chemistry, or what goes on inside those little flames coming out of your stove. As is so often the case, it is not quite as simple as you might think. Well, that's what scientists say of course (and the author is one of them). However, a very simplified version is possible and is quite enough to make the rest of this article clear.

From all the above, the author has developed a fairly simple hypothesis about the source of the carbon monoxide hazard. If this hypothesis is correct, it means that a correctly-operated stove in a tent with adequate ventilation does not present a carbon monoxide hazard. It also explains how you can create or eliminate the hazard. The testing of this hypothesis will be covered in the two following parts of this article.

Medical Knowledge

Just how does CO affect you? The author is not a qualified medical practitioner, so the answers here will consist largely of quotes from published research papers.

Simon Leigh-Smith, MBChB, MRCGP, FRCSEd (A&E) from the Defence Medical Services, United Kingdom, wrote in a [review](#)² of carbon monoxide poisoning in tents:

“Carbon monoxide is a chemical asphyxiant gas with a haemoglobin affinity 200 to 250 times greater than that of oxygen (O₂). Carbon monoxide also interferes with cellular oxidation by binding myoglobin, cytochrome oxidase, cytochrome P-450, hydroperoxidases, and other haem proteins. Because it has an affinity for tissues with a high O₂ demand, its main targets are the neurologic system, cardiac tissue, and fetus.”

My understanding is that this means your blood will prefer to absorb CO rather than oxygen, and that this limits the supply of oxygen to your body. This is not good. In addition, the CO interferes with various processes in your body – all rather critical ones. What levels of CO are medically hazardous? The following quote is from the above paper and gives UK figures in parts per million (ppm):

“Occupational exposure limits in the UK are set by the health and safety executive to avoid a COHb concentration greater than 5% in healthy nonsmokers. The maximum acceptable exposures are 200 ppm for 15 minutes (short-term exposure limit) and 30 ppm (time-weighted average) for 8 hours. Other sources state that in cases of extreme emergency, 200 ppm could be tolerated virtually indefinitely and certainly up to 24 hours without leading to collapse, which requires levels of 300 ppm (Ministry of Defence, unpublished data). To put these figures into context, 25 ppm is commonly encountered on major roads in urban areas and can reach 100 ppm during weather inversions.”

A [paper](#)³ on ‘Carbon monoxide exposure from cooking in snow caves at high altitude’ by Keyes, et al. gives the following American figures, where ‘COHb’ stands for carboxyhemoglobin or haemoglobin which has picked up CO:

“The threshold limit value for CO in industrial exposures is 35 ppm for an 8-hour workday and a maximum COHb of 5%. A concentration of 200 ppm is considered the ceiling level to which a worker may be exposed transiently without raising COHb level.”

different responses, depending on their health and how long they are exposed. When considering cooking in a tent in bad weather, should we worry about the 15 minute 200 ppm figure, or the 8 hour 30/35 ppm figure? Both exposures seem rather low compared to the figures quoted for traffic situations where you can be stuck for an hour – although admittedly the latter can be pretty bad!

A secondary concern is that CO appears to clear out of your blood stream slower at high altitude than at sea level. However, in this case ‘high altitude’ usually means Himalayan altitudes – but Denali would qualify just fine.

It should be noted that there are an awful lot of junk publications around as well. It seems that some ‘medical researchers’ think the best approach is to stick a few uninformed volunteers inside a sealed tent with a running liquid fuel stove, and wait until they stop replying to questions about their health. Well, that may be slightly exaggerated, but not by much! I think it is unethical conduct. References are not listed for these, for obvious (legal/libel) reasons.

Published Statistics

The US Consumer Product Safety Commission collects statistics on carbon monoxide poisoning. In a comprehensive report on [‘Non-Fire Carbon Monoxide Deaths associated with the use of Consumer Products’⁴](#) issued in 2005 the fatalities for 2002 in the USA were analysed. Over the years 1999 – 2002 there were an average of 141 deaths from CO poisoning per year, and 188 in 2002 itself. Space heating systems were involved in 55% of the cases, engines in 28%, charcoal stoves in 5%, and camp stoves and lanterns were involved in 2%. It’s that two percent which concern us: just four people.



Storm-bound and losing ventilation around the edges.

Some 71% of deaths took place at home, while 23% took place in tents and temporary shelters. Most of the latter were, as the previous figures suggest, associated with space heating. It seems that many tourist-type campers have taken heaters into their tents at night – and left them running the whole night – and didn’t wake up.

The report does not even itemize the number of deaths which have occurred to walkers in little tents cooking dinner. It seems that even where a ‘camp stove’ was involved, there may also have been an LPG space heater. One gets the impression that holiday car campers in large family tents are the principal victims, and this is borne out by the following.

A report from the CDC (Centers for Disease Control and Prevention) entitled [‘Carbon Monoxide Poisoning Deaths Associated with Camping’⁵](#) details two cases where people died in tents. In the first case ‘a 51-year-old man, his 10-year-old son, a 9-year-old boy, and a 7-year-old girl were found dead inside a zipped-up, 10-foot by 14-foot, two-room tent at their campsite in southeast Georgia (a pet dog also died). A propane gas stove, still burning, was found inside the tent; the stove apparently had been brought inside to provide warmth.’ In the second case ‘a 34-year-old man and his 7-year-old son were found dead inside their zipped-up tent at a group camping site in central Georgia. They were discovered by other campers just before 9 a.m. A charcoal grill was found inside the tent; the grill apparently had been brought inside to provide warmth after it had been used outside for cooking.’

Two New Zealand Dept of Conservation volunteers died in the Chatham Islands in 1996. They had been monitoring the flight paths of tagged birds in an isolated area. The subsequent [investigation⁶](#) found that the ventilation in their tent was poor – it seems the tent was zipped right up, and it was considered likely that the carbon monoxide had come from a butane gas lantern they had been using inside the tent.



Coleman Fyrestorm fuel tank, with ventilation warning.

The review by Simon Leigh-Smith cited above contains references to other cases, dating back to 1911, in Arctic and Antarctic regions as well as high mountain regions. In all cases it seems that the enclosures were seriously sealed: tents zipped up and iced over for instance. It doesn't take a lot of snowfall to block all air ventilation at ground level for instance, as the photo of the author's orange tent above shows. (That was in the morning, after the storm had passed.) When that happens, all you have left are the top vents.

It is interesting to note that the fuel tank for the latest multi-fuel stove from Coleman, the Fyrestorm Ti, carries a very explicit and extremely sensible warning on it: 'This camp stove consumes air. To ensure its safe and proper operation and avoid health hazards, provide a fresh air opening of at least 10 square inches'. (The fine print underneath does say to not use it in a tent, but that's just the lawyers speaking.) If you think about it, a vent some 5 inches wide by 2 inches high is fairly easy to have at the top of the door in many good tents. Just make sure there is somewhere down low for the air to get in – if necessary, clear the snow away to make an inlet hole at ground level.

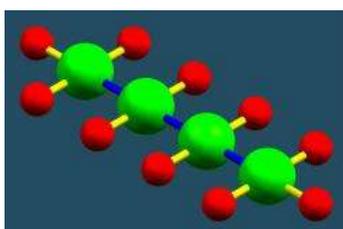
Other References

There is an excellent but very short publication on the carbon monoxide problem from the Geophysical Institute, University of Alaska Fairbanks, by T. Neil Davis entitled 'Carbon Monoxide from Melting Snow, Article #336'. It is available at www.gi.alaska.edu/ScienceForum/ASF3/336.htm. The report briefly covers what causes the carbon monoxide problem, and states 'tests were conducted in 1942 by a group that included two scientists well known in the North, Drs Laurence Irving and Pete Scholander. Somehow in the years that have lapsed since 1942 the consequences of the tests seem to have been forgotten.' The hypothesis I will be testing in the next part of this article is essentially the same as was proposed in 1942.

An [experiment](#)⁷ by Schwartz, et al. into running stoves inside a sealed box showed that measured CO levels quickly soared to very dangerous levels with all fuels, with kerosene apparently being the worst offender. The experiment showed that stoves can keep burning despite high levels of CO being present, thereby exacerbating the problem.

Finally, an article in [Backpacker Magazine](#)⁸ from 1978 entitled 'Carbon Monoxide in Tents' covers a small number of tests done on stoves in tents. Some stoves were found to emit a lot of CO, and the authors found that they could reduce the amount of CO emitted by a simple change to the offending stove: they raised the pot a little above the normal position. Why this happens is discussed below; the effectiveness of this method to control the CO levels emitted in practice will be examined in the next part of this article– but basically, it works. Unfortunately, the information in this article has also been largely forgotten.

Flame Chemistry



Basic hydrocarbon chain of carbon atoms (green) and hydrogen atoms (red), held together by carbon-

(yellow).

What causes the production of CO? Surely the flame from a stove should be producing carbon dioxide and water? Well, yes, it should, but let's look into the chemistry of flames to see what else is happening. It turns out that things get a little more complex when you have atoms flying around in a hot flame which can peak around 2,800 to 3,200 F (1,540 to 1,760 C). Actually, the flame should reach 3,600 F (1,980 C) if it didn't lose heat to the surroundings – but it always does.

Let's start with a basic hydrocarbon molecule containing a chain of carbon [C] atoms with hydrogen [H] atoms hanging off them. The molecule shown symbolically in the picture here has four carbons, and is called n-butane. (Isobutane has the same number of atoms in it, but the structure is slightly different.) If there were only three carbons in the chain the molecule would be propane. When this is heated in a hot enough flame all the bonds between the C and H atoms break, and you get all those individual atoms flying around in the flame. At the same time the oxygen molecules (two oxygen atoms bonded together) break up and you have individual oxygen atoms flying around. All this requires energy (a high temperature) for it to occur.

Then combustion starts, and a carbon atom links up with an oxygen atom to make carbon monoxide or CO, which we write thus:

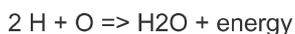


When the carbon atom bonds with the oxygen atom energy is given off, and this helps make the flame hot. (If the flame gets really hot this reaction can be reversed, but that won't happen under our stove conditions.) Now we have our CO. But a molecule of CO can burn too: in a second reaction it links up with another oxygen atom to make a carbon dioxide molecule or CO₂, and in doing so gives off more energy, thus:



Under ideal conditions the combustion should go all the way to CO₂. But the second reaction (CO to CO₂) does not happen under all conditions: the atoms have to be pretty hot for them to get close enough to join, and there has to be enough oxygen around. One could say, for simplicity, that the first reaction of making CO happens more readily. It has to happen first, anyhow.

For those concerned about the fate of the hydrogen atoms, fear not. They too find oxygen partners and get hitched up, giving off energy in the process, thus:



They create H₂O molecules, or water, and you can see this condensing on a very cold pot sometimes right at the start of a cooking exercise. Later on when the pot gets warmer, the steam (for that is what it is) no longer condenses on the pot. It may of course condense on the inside of your tent, or create fog if you are cooking in colder weather.

That the C + O => CO reaction happens first will be seen as the critical factor in stove flame chemistry and unwanted CO emission. Now let's follow a carbon atom in a hydrocarbon molecule coming out of a hole in a stove's burner head and going up the flame. First the hydrocarbon molecule is heated up by the energy from the flame, and when hot enough it breaks apart (dissociates) to give free carbon and hydrogen atoms. The hydrogen burns quickly, giving off energy to keep this process going. A little further up the flame the carbon atom combines with a free oxygen atom to make a CO molecule. So far, so good. Then a little further up the flame the CO molecule comes across another oxygen atom and combines with it to give a CO₂ molecule – if it is hot enough. If it is, the flame gives off CO₂; if it isn't, the flame gives off CO.

So what matters is whether the higher parts of the flame are hot enough for the second burning reaction to take place. If the flame suddenly runs into a 'cold' surface and transfers energy to it, the temperature of the flame is going to drop, and if it drops far enough the second reaction won't happen. This drop in temperature is called 'quenching.'

The key point is this: if the flame is quenched too soon, CO results.

to the flame temperature of about 3,000 F (1,650 C). BUT, if we have enough clearance between the pot and the burner the combustion process will complete before the flame hits the pot.

Does having enough clearance between the pot and the burner to avoid this problem reduce the fuel efficiency? This is unlikely to happen as most of the flame energy will still be in the flame – and with the burning of the CO there will be extra energy added to the flame. A very small amount of energy will be lost through infra-red radiation from the flame as it travels the extra distance up to the pot, but given the short distances involved (about 1 inch or 25 millimeters) and the high speed the gas is traveling at, the amount will be small. Part 2 of this article will examine this question in detail.

Some [researchers](#)⁹ have also suggested that using a very wide pot can cause CO production. If true this would be unfortunate as a wider pot is favoured for efficiency in fuel use. However, it should be clear from the discussion so far that the width of the pot is not a direct factor here. If a wide pot sits too close to the burner so the flame is being quenched there may be a problem regardless of pot width, but raising the pot so the flame is not quenched should solve that. This too will be examined in Part 2.

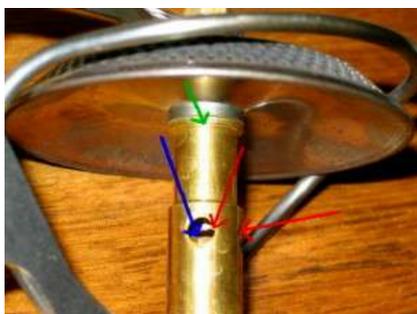
Long Flames and Orange Flames

We should consider what happens if there just isn't enough oxygen present in the fuel/air mixture coming out the stove's burner. In this case some of the fuel could travel quite some distance away from the face of the burner before finding some oxygen from outside the flame. This leads to long flames. You frequently see this with an alcohol stove, where the fuel doesn't get premixed with air.

It is also possible that some of the carbon atoms won't meet up with any oxygen atoms before they reach the edge of the flame and the cold pot. They may start to cool down – but this is relative of course. While they are in the flame they are quite a bit hotter than 'white hot,' and emit mainly in the blue part of the spectrum. That's why the flame seems blue. But as the carbon atoms cool down they pass through the 'red hot' stage, and will radiate just like a red hot bit of steel. They will emit red/orange/white light, and this is seen as an orange tip to the flame. You may notice some soot collecting on the underside of your pot when this happens. A traditional kerosene lantern creates a lot of this free carbon, that's why it makes a bright light. If it is managed poorly, you will see a lot of soot coming off the flame too. Can a kerosene lantern make CO? It shouldn't when properly adjusted, despite the bright flame, because there is little to quench the flame.

So if your stove has orange tips to the flame it means that it is not burning very well. It may be making soot, and it may be emitting CO. This is a warning sign!

Differences between Fuels



The central tube (green arrow) and burner head on an MSR WindPro stove.

The blue arrow points to the jet inside the tube.

The red arrows point to some of the air inlet holes around the jet.

us.

1. None of the common fuels are a single hydrocarbon; rather they are all mixtures of several hydrocarbons. For convenience we will describe propane which has 3 carbon atoms as C₃, and butane which has four carbon atoms as C₄. Following this convention makes white gas a mixture of hydrocarbons ranging from C₄ to C₁₂, while kerosene is a mixture ranging from C₁₁ to C₁₆. Yes, some of those hydrocarbon chains are very long. Why are white gas and kerosene mixtures of hydrocarbons? It would be very expensive to separate all the different hydrocarbons out at the refinery, and anyhow the mixtures actually work better than single hydrocarbons.
2. In a typical stove we have a stream of fuel vapour coming out the jet (blue arrow) and shooting up a central tube (green arrow) to the burner head. The higher the pressure behind the jet, the faster the fuel vapour will come flying out of it, and the more fuel vapour will come out per unit time as well. Many walkers will have noticed that the performance of a white gas stove is affected by how much they pump the tank. The pressure at the jet is controlled by the pressure in the tank and the valve opening.
3. The stream of fuel vapour goes flying past some large holes (red arrows) in the side of the central tube, and the speed of the vapour stream sucks in air through those holes to mix with the fuel vapour. If not enough air is sucked in for the amount of fuel vapour passing by, there won't be enough oxygen inside the flame, the flames may be rather long, and both CO and soot may be emitted. On the other hand, if more than enough air is dragged in, the flames are going to be very short at the burner face, and the metal there is going to get very hot and possibly start oxidizing away. What size holes to provide in the central tube is therefore a trade-off. You may notice with some stoves that when you have the stove turned down to a simmer the flames are short, but when you turn the stove up the flames lengthen and may get orange tips. There isn't enough air coming in at the higher settings. Stove design is quite an art.
4. One of the things you learn in basic physics and chemistry is that the size of the molecules does not really affect the pressure in a gas: all that matters is the number of molecules present. So for a given pressure behind the jet you will have pretty much the same number of fuel molecules streaming out of the jet per unit time.

Now, let us put all this together. We have these molecules of fuel flying up the central tube, and each molecule contains a number of carbon atoms. How much oxygen does a single molecule require for complete combustion? It depends very much on the molecule. The chemical equations for the combustion of some of the hydrocarbons are as follows – you can work out the rest from these:

# Carbons	Name	Chemical equation
3	Propane	$C_3H_8 + 7 O_2 \Rightarrow 3 CO_2 + 4 H_2O$
4	Butane	$C_4H_{10} + 9 O_2 \Rightarrow 4 CO_2 + 5 H_2O$
5	Pentane	$C_5H_{12} + 11 O_2 \Rightarrow 5 CO_2 + 6 H_2O$
8	Octane	$C_8H_{18} + 17 O_2 \Rightarrow 8 CO_2 + 9 H_2O$
12	Dodecane	$C_{12}H_{26} + 25 O_2 \Rightarrow 12 CO_2 + 13 H_2O$

We see that as the number of carbon atoms in a fuel molecule rises, the amount of oxygen needed per fuel molecule rises dramatically. One molecule of propane needs seven molecules of oxygen, but one molecule of dodecane needs twenty five – more than three times as much. What this means is that white gas is going to need considerably more oxygen (or air) than

tube, and that is simply not possible at the air inlet.

As an aside, when Australia switched from coal gas to ‘natural gas,’ which is a form of LPG, every stove in Australia had to have either the jet or the whole burner assembly changed. The fuel/air mixture required for safe operation had changed.

This is why some stove manufacturers provide several different jets with a multi-fuel stove – they have to throttle down the flow of white gas and kerosene relative to butane/propane. For instance, Primus supplies several different sized jets with their Omnifuel and Gravity MF multi-fuel stoves, thus:

Fuel	Omnifuel jet size	Gravity MF jet size
Butane/propane	0.45 mm	0.45 mm
White Gas	0.37 mm	0.40 mm
Kerosene	0.28 mm	0.35 mm

Even so, the instructions on the Primus Gravity MF stove specifically warn against pumping up the tank too hard. If you do, the flames become long, wild and have orange tips. Yes, I have done this, and it is so. It was also slightly scary. A serious case of ‘read the manual!’ I also tried the 0.45 mm jet on the Gravity MF with white gas – by accident. That too was a bit scary, with very long wild flames. Once was enough.

Does this mean that there may be differences in safety between the fuels when they are burning? Obviously the chance of having not enough oxygen for complete combustion is far more severe for kerosene than for butane since it needs so much more. The paper by Schwartz, et al. cited above confirms that kerosene was worse than white gas in their tests, and other small tests suggest that butane/propane is cleaner than both of these. It is notable that all the multi-fuel stoves I have tested seem to work far more reliably on butane/propane than on either white gas or kerosene. The flame patterns are far more stable with butane/propane.

Other Burner Designs



MSR XGK XE burner cup and splash plate, with brass jet visible at bottom pointing upwards.

All of the above discussion has assumed the traditional ‘quiet’ burner with the premix tube underneath, but this is not the only sort of burner available. We also have what is technically known as a ‘vortex’ burner, and this is seen on the big old Primus stoves, the elderly but highly respected Optimus 8R and Svea stoves, and the modern MSR XGK series.

The vortex burner starts with a jet, up from which streams the fuel vapour. It flies up inside a burner cup and hits a ‘splash plate’ on top, and is deflected outwards. Along the way it drags up some air through the slots in the side of the burner cup and the flame starts burning. But owing to the design of the burner head, some of the fuel cycles back downwards to mix with the air coming in through the slots again, and then flies back up the middle. The central column of fuel vapour is surrounded by a vortex of fuel and air, mixing and burning furiously. The heat from the surrounding flame breaks down the fuel molecules in the central column of vapour. In practice this donut-shaped vortex and the flame can oscillate in an

the open ring around the edge of the splash plate.



Very old Optimus 8R with splash plate removed from burner cup to show interior of vortex chamber, with jet and air slots.

Clearly the operation is a bit different here from the silent burners shown before – even though the chemistry is exactly the same. The design of these burners is tricky. It is possible to alter the shape of the burner cup and have the stove just not work. Aficionados of antique Primus stoves (they exist, as whole web-based societies!) are well aware that you cannot fit a burner cup from stove model X to stove model Y and have it always work. The air flow and mixing patterns may not be just right. This is a common topic of discussion. (Do these guys actually **use** these stoves in the field? Probably not; mostly they just polish them.) Editor’s Note: So, Roger, how is it that you are so intimately acquainted with these stove polishers?

What happens if the splash plate burns out while you are on a long trip? The answer should be obvious now – without the precisely designed deflection the original plate provides, you may be in deep trouble. This has happened in the Antarctic in times past – but the trip was pretty epic anyhow. On a very long trip you should carry spares! By the way, even the Optimus shown here, built in the 60’s, had an integral jet cleaning needle inside the jet. Crank the valve over to one end, and the needle cleaned the jet. The ‘Shaker Jet’ concept was not all that novel when MSR introduced it.



Handy Camper stove, with jet drilled in the tube at top of blue line.

Finally, just for fun, we have the classic but somewhat rare “Handy Camper’s Stove”: surely one of the most inspired designs ever created! It was a model of utter simplicity in design and manufacture, but totally lacking in any degree of control. Like the Optimus 8R it uses a wick to get the fuel from the tank underneath up to the preheat tube, which in this case is just one and a half turns of copper tube brazed in place. You light it by sloshing some fuel around in the centre depression, at the foot of the coil. The rusty baffle plate leaning up against the green carry-can behind the coil is normally attached to the coil as a sort of draft-excluder. Was it safe? Well, I used it for some years in my youth, and it never gave me any problems. How hot the tank got has to be an open question, but I didn’t worry about such things in those days. Does the flame get enough air? Well, it was certainly all blue, and there are no restrictions to the airflow.

As I said, there are no controls. You put the flame out by very quickly jamming a cork inside the coil to block the jet hole at the bottom of the coil. The cork, still functional, is to the right of the burner coils. Yes, this is a vortex burner: the two copper coils at the top act as the splash plate. Yes, it worked fine in my youth, but no, I haven’t used it recently!

While we are on safety, it should be mentioned here that CO may not be the only hazard associated with a stove. Most walkers who have used white gas and kerosene stoves will be familiar with the smell of the fuel. This is often noticeable when priming the stove and more so when the stove has just been turned off. I am sure many walkers will be familiar with the practice of putting the stove outside the tent or hut as soon as it has been turned off because of the smell. Is this smell dangerous?



Primus Gravity pump housing with OFF label.

The answer is probably yes, albeit to an unknown degree. Consider what is in white spirits and kerosene. There are high-order hydrocarbons galore, and we do not always know exactly what they are. We do know that auto gas or petrol contains benzene, and that this is carcinogenic. We also know that 'petrol sniffing' can be extremely bad for the brain, due to some of the chemicals found in the fuel. There have been many reports of people feeling unwell after spending some time in a closed hut with a liquid fuel stove. It would seem reasonable to assume that inhaling too much of the fuel vapour would not be good for your health.

The problem with many liquid fuel stoves with remote tanks is that the valve is necessarily located at the tank. This means that when you turn the valve off, some fuel will remain in the fuel line. This fuel will slowly evaporate into your air space if the stove is still inside your tent or hut. In this context, it may be worth noting that the latest [Primus Gravity MF stove](#) features a rotating connector at the tank, and that the instructions explicitly tell you to flip the tank over to drain the fuel line before turning the stove off. The pump housing has 'ON' and 'OFF' labels on the two sides for this.

The connector on the latest [Coleman Fyrestorm stove](#) does rotate, but sadly this does not drain the fuel line for some strange design reason. On the other hand, popular earlier stoves such as the MSR Whisperlite and [Simmerlite](#) have connectors which definitely do not permit this practice.

Alcohol and Solid Fuels

Is any of this relevant to alcohol and solid fuel stoves? Well, not entirely, because in general they don't have the same sort of burner construction and flame dynamics. The basic chemistry still applies of course, but there is no pre-mixing of fuel and air before the flame starts.

The slower flame velocity in open alcohol stoves normally gives the flame plenty of time to get enough oxygen. Even pressurized alcohol stoves have low velocity flames in comparison. However, they can be tested for CO emission, and have been found to offend if the air supply is restricted. Of course, every user of alcohol stoves is familiar with the smell of alcohol being splashed around, but are you aware that methyl alcohol is far more toxic than ethyl alcohol? You might like to check which fuel you are really buying. Some brands of 'denatured alcohol' are a mixture of ethyl and methyl alcohol, and then there is the denaturing agent (methyl ethyl ketone) that is also included. If your alcohol stove is not getting enough air for combustion (e.g., because of a very tight windscreen), it can put out a lot of unburned alcohol and ketone vapors, and breathing these vapors in a confined space (your tent) is not a very healthy practice!

The chemistry in the flame from a lump of solid fuel is a bit different: the basic hexamine is a far more complex molecule. Once it has broken all the way down to carbon and hydrogen atoms the reactions are the same, but getting a complete breakdown is not always guaranteed. Some nasty molecules (ammonia and formaldehyde have been frequently mentioned) can be released under some situations, so these fuels should always be run in lots of fresh air.

carbon or charcoal. But this could be a whole subject in its own right, and is not pursued in this article.

Summary of Part 1

- Carbon monoxide can be emitted by a stove under the right conditions.
- This carbon monoxide really can present a serious health hazard.
- 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.

Preview of Part 2

In Part 2, I will present my actual measurements of carbon monoxide concentration taken in a backpacking situation – when using a backpacking stove inside a tent. (Part 3 will cover field measurements.) Specifically, in Part 2 I evaluate several variables in relation to the amount of carbon monoxide produced:

- Measurement of CO concentration for different models of stoves.
- Measurement of CO concentration as the distance between pot and burner is changed.
- Measurement of CO concentration as the fuel is changed from butane/propane to white spirits to kerosene.
- Measurement of CO concentration as the stove power is varied from low to high.
- Measurement of CO concentration as the pot diameter is varied.

References

1. Foutch RG, Henrichs W. “Carbon monoxide poisoning at high altitudes”, *Am J Emerg Med.* , 6, pp 596–598, 1988
2. Simon Leigh-Smith, MBChB, MRCGP, FRCSEd (A&E), “Carbon Monoxide Poisoning in Tents — A Review,” *Wilderness and Environmental Medicine*, 15, pp 157-163 (2004)
3. Linda E Keyes, MD et al, “Carbon monoxide exposure from cooking in snow caves at high altitude,” *Wilderness and Environmental Medicine*, 12, pp 208-212, 2001
4. Debra S Ascone & Natalie E Marcy, “Non-Fire Carbon Monoxide Deaths associated with the use of Consumer Products,” *US Consumer Product Safety Commission, Directorate for Epidemiology*, 12 July 2005
5. ‘Carbon Monoxide Poisoning Deaths Associated with Camping – Georgia 1999,’ *Morbidity and Mortality Weekly Report*, CDC, vol 48 / No 32, pp 705-6, 20 August 1999
6. Private communication
7. Schwartz RB, Ledrick DJ, Lindman AL, ‘A comparison of carbon monoxide levels during the use of a multi-fuel camp stove’, *Wilderness Environ Med.* 2001 Winter; 12(4):236-8.
8. William Kemsley & the editors of *Backpacker Magazine*, ‘Carbon Monoxide in Tents’ in “Backpacking Equipment Buyer’s Guide” by *Backpacker Magazine*, 1978