Instructions for Caffin's Remote Winter Vortex Burner Stove

Roger Caffin, 5 Mar 2016

On the left we have the first edition of my Winter Stove, made using parts I made plus a burner from a Fire Maple FMS-300T upright stove, weighing 86 g. On the right we have the second edition of my Winter Stove, with all parts made by me, weighing 69 g but without pot supports. The pot support comes later.

The V1 stove is essentially a modified upright burner stove with a remote invertible canister for winter use. The canister connector mates with the three most popular designs for stove canisters. The V2 stove has the same canister connector, but it uses what is known as a Vortex Burner, which is quite different. The closest commercial stove would be the classic MSR XGK (which uses petrol/white gas and weighs a ton in comparison). The V2 has a much wider flame spread than the V1, as you can see.

These are 'remote invertible' canister stoves because a) the canister sits remote from the burner at the end of a hose, and b) the canister can be inverted to get a liquid feed. The advantage of all this is that you can use the stove in severe cold, down to at least -24 C, without any worries about chilling the fuel to the point where it is too cold for the fuel to come out of the canister. With mild planning you can use this class of stove in mid-winter where an upright canister stove would quickly die; with more planning you can go to extreme cold.

The canister connector is custom-made to be able to handle the common screw-thread canister (eg brown Primus at top), the blue French Campingaz canister at left (more widely available in Europe) and the now 'retired' Coleman Powermax canister. The one shown here is actually a rather old Coleman Max canister, from before their marketing guys decided to upgrade the name. The canister itself did not change. One significant feature of my design is safety: in addition to the control valve on the stove body (white knob), you can see a white safety on/off valve on the canister connector in each case. That shuts off all the gas very fast.

One point should be noted: it is normal for an upright canister stove to support the cooking pot on little arms. This Vortex burner stove has **no** pot supports: they must be added outside the stove. You can **not** sit a pot on the burner. The picture shows two titanium wire tripod stands (~20 g) which are discussed later.

You will find it useful to read the Technical Background, as the information in it will make understanding the stove and how to use it much easier. Winter Stove Details covers the stove as a whole, its parts and why bits are the way they are. Operation covers how to use the stove. Servicing is obvious, yes? Debugging covers 'what can go wrong', and how to fix it – often fairly quickly and in the field. And there is a section on the Pot Stand.

Safety and Testing

Every stove is tested at the end of assembly in two ways: it is tested at high pressure and it is 'burn-tested'. However, that is not the end of the matter: see the end of this section for a warning.

Pressure testing

The completed stove, from canister connector through to the jet, is pressure tested at about 100 psi (6.9 bar or 690 kPa). This is as high as my compressor goes. The canister connector is attached to a dummy Lindal valve which is on a flexible pneumatic line. This simulates connection to a gas canister.

First the canister connector assembly is fully immersed in water. Any leaks at the Lindal valve O-ring, the cam valve O-ring or the hose connector O-ring are revealed by bubbles of air coming out. The stove is not accepted if there is more than 1 bubble every 5 seconds visible. In practice there are either no bubbles at all or a stream of bubbles. The latter does not happen very often; causes have included a bit of machining swarf across an O-ring and a defective O-ring. If there is a problem it is fixed and the full test is repeated. A leaking assembly is not accepted.

In addition this tests the crimped hose connection. A leak from the region of the heatshrink tubing at the end of the hose means the hose is defective. It would be replaced and the test repeated. However, no such failures have been seen.

Then the stove body is fully immersed with the valve shut off. Any leaks at the hose connection O-ring or the needle valve O-ring are revealed by bubbles. The same criteria apply. The only failure seen here during testing was due to a missing O-ring on the needle valve. That was rectified (of course!).

The needle valve itself should shut the gas off at the jet. The first few needle valves manufactured showed a faint leak here: the cause turned out to be poor machining of the needle valve seat. Since that was rectified there have been one or two faint leakages due to dirt at the needle valve seat. When the needle valve was cleaned the bubbles disappeared.

Burn Testing

Every stove is burn-tested. That means it is connector to a gas canister and 'fired up'. The stove is allowed to warm up at low power for 10 - 20 seconds or so (this is required in ordinary use too), then it is run up and down in power. It must be able to idle at low power for a gentle simmer, and it must 'roar' at full power. A common user mistake here is to not let the stove fully warm up. A simple check: did the splash plate get red hot?

Then the canister is inverted to check the liquid flow. Typically the flames will alter at this point, becoming either stronger or weaker. That happens in both testing and it the field: it just means that you need to monitor what the stove is doing. This same problem applies to any inverted canister stove I have ever tested.

In addition, there must be no side flames at the jet: such a thing would mean the jet had not been properly seated in the socket. The flame distribution must be uniform around the burner chamber: non-uniformity could mean that there is a trace of dirt in the jet hole sending the gas jet off to one side.

Practical results show that the control range is usually about ¼ turn. A few units have had a smaller control range, but the handle is big enough for control even in the worst case. The source of the variation in the control range is a very tiny variation in the dimensions of the tip of the needle. The very short needle valves on upright stoves are easy to machine; this needle valve is really long and can flex. Machining the tip as a secondary operation has helped to control this somewhat.

Flaring

A special note should be made about inverting the canister before the stove has warmed up or 'primed' – and yes, this stove **does** need to be primed for liquid fuel. If the stove body (the bit under the round stove base) is not warm enough when the canister is inverted, you will get some flaring: bright orange flames. This is due to bits of liquid fuel getting through to the jet and being spat out into the burner chamber. If you have the power turned up at the time, the flaring can reach up the sides of the pot. This is not harmful to the stove, but the flames might threaten your tent.

The two solutions to this are to turn the stove down a bit while it continues to warm up, and to not be so quick to invert the canister. If you are starting with liquid feed (eg with a Powermax canister), just run at low power for a little longer. A simple test: has the stove body at the control knob end become warm yet?

Touch Test

Always remember the 'touch test': never allow the canister to get so hot you cannot happily touch it.

Keep checking (touching) the canister while cooking. To explain: you will say 'ouch' when the metal you are touching gets much above 40 C, but *by law* (actually, USA DoT regulations) the canisters must be able to safely and routinely handle 50 C. In practice they can often go a fair bit higher - think about the insides of a car after a very hot day in the sun. In one experiment I did the canister reached almost 100 C before exploding – but it did explode quite violently. I was out of the way behind a steel wall at this stage.

There are other good tricks to the game for cold weather, like sitting the upright canister in a bowl of cool water and pouring cool water into the dished base of an inverted canister. Note that 'cool water' is necessarily above 0 C, which is the BP of n-butane. Iso-butane has an even lower boiling point.

Fuel Leaks at Canister Connector

One customer has had extended problems with fuel leaks at the canister connector. There were faint leaks at the hose connector, and serious leaks at the cam valve. After much experimenting, it was found that there was dirt under both O-rings, for both the hose connector and the cam valve. The leak was especially noticeable when the cam valve was being operated. In hindsight, that means when the O-ring was sliding across one surface rather than making a static seal.

I believe the dirt came from one canister which most likely had been filled in China. I have experienced the same problem myself with such canisters, with a stove becoming totally blocked up after about 20 seconds operation – twice running. I returned those canisters for a full refund. The problem remains even when a clean canister is used after the dirty one. I believe this means that the gas the Chinese filling company is using has not been filtered or purified adequately after coming out of the gas well – it's cheaper if you don't go the extra distance. White gas stoves usually have some serious filtration inside the fuel tank.

The problem in brief: the dirt comes out of the Lindal valve and gets under the O-ring and allows a faint leak there, past the lumps of dirt. To fix this you need to get the O-ring out of the groove, clean it and clean the groove. Clean both parts. If it happens, you should probably clean both O-rings (cam valve and hose connector) while you are at it. Then you should put that canister aside to be used only with an upright stove. Under really bad conditions this problem can also make the Lindal valve leak all by itself. They try to prevent that by having a very strong spring inside the Lindal valve to close it.

It is worth noting that this problem can affect any stoves which use a remote inverted canister, not just mine. When the canister is inverted the dirt (a fine dust really) will be flushed straight into the hose and the stove. Such dirty canisters also seem to have rather a lot of higher-order paraffins (sticky waxes) in them as well, which adds to the dust problem. And all stoves have some O-rings, at least at the common control valve.

We persisted. My thanks to this customer for his patience and cooperation. Once he had cleaned out both of the O-ring grooves and cleaned the O-rings, there were no more problems. That was a relief.

For what it is worth, I favour the French Campingaz canisters, the old Coleman Powermax canisters, and the Primus Powergas/Wintergas canisters. These seem to be clean.

Technical Background - Useful

Boiling vs Liquid Feed

In any liquid fuel stove, the fuel must first be vaporised into free-floating molecules before it can be burnt. This applies as much to petrol/white gas and kerosene stoves as it does to butane/propane stoves, and also to alcohol stoves. In fact, kerosene and petrol/white gas are the same sort of linear hydrocarbons as butane and propane; the only difference is the length of the carbon chain for each one.

But to turn a liquid into a vapour (this is called 'boiling') takes energy: the latent heat of vaporisation. This energy has to come from somewhere. In the case of an upright burner on top of a canister, the energy initially comes from within the canister, usually from within the rest of the fuel. As that energy is extracted, the temperature of the remaining liquid fuel will drop over time, possibly taking the fuel below its boiling point (BP). If this happens the stove will stop working as no more gas will be coming out of the canister.

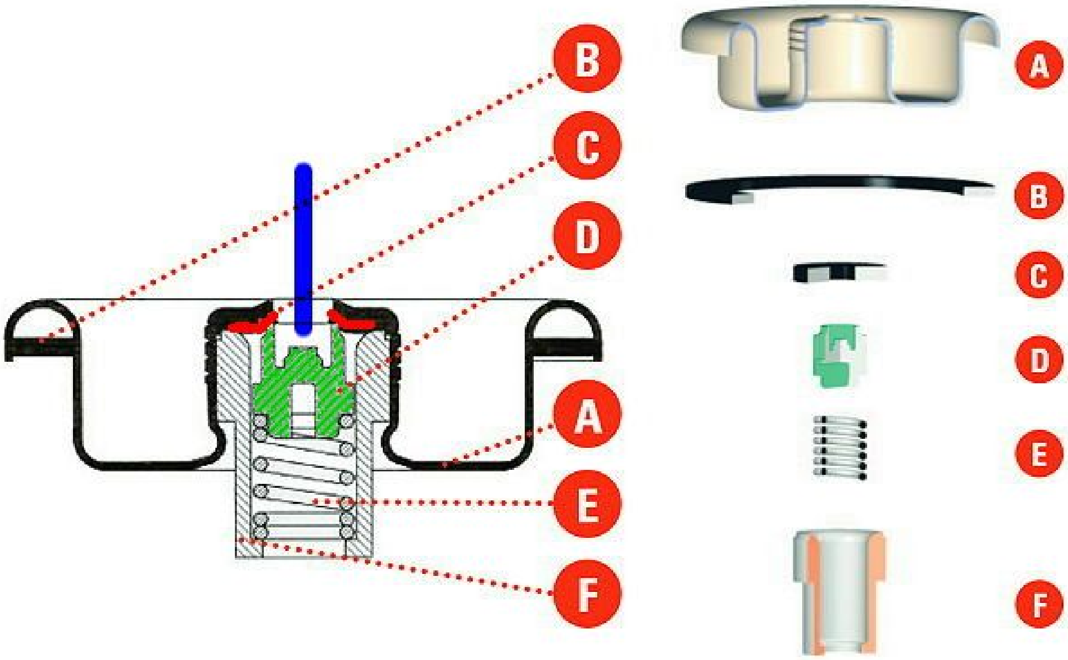
If the fuel in a canister with an upright stove is a mix of n-butane and propane and the fuel temperature drops below 0 C, the boiling point of n-butane, then (roughly speaking) the propane may continue to boil off for a little while, until nearly all of it has been used up. Quite a few people have found (in mid-winter) that their canister was still 2/3 full but no gas was coming out: the remaining n-butane in their canister was now well below 0 C. This happens quite easily in the snow.

A good solution to this problem is to *not* suck energy out of the remaining fuel in the canister, but to feed the liquid fuel to the stove and have it absorb energy from the flames at the stove for the vaporisation. For kerosene stoves the fuel must be heated to well over 200 C before it will vaporise, but for an n-butane/propane mix getting the fuel to just above 0 C is completely sufficient. In the case of kerosene it is essential to pass the fuel through a small preheat pipe running over the top of the stove to get it to this temperature, but such a preheat tube is not needed for any butane/propane mixes. Few commercial stove manufacturers seem to know this, which is why you still see massive but pointless preheat tubes on many remote canister stoves. My V1 stove used a heat shunt instead of a preheat tube – very successfully.

Lindal Valve

The valve at the top of a canister is called a Lindal valve after the German company which developed the concept. They have world-wide sales, mostly in paint cans and aerosols. The actual boss or nipple in the middle comes in a variety of designs, which makes creating a universal canister connector difficult.

Fortunately, the crimped rim of the valve always seems to have the same shape, so we can use that rim to attach the connector to the canister regardless of the fine details around the nipple. The left photo shows a Campingaz valve; the right hand illustration shows how the Campingaz connector works. (I sawed a canister in half for the photo.) The blue lugs hook under the edge of the crimped ring and hold the connector down. The red blocks inside the blue lugs stop them from springing back inwards to release the connector. A fat O-ring (green) seals the connector to the nipple. This French Campingaz attachment method is a far more reliable design than the cheap and nasty half-formed thread on the common screw-thread canister, and it what is used on my stoves. The term 'fat O-ring' will be used in several places for the O-ring shown here.



This diagram (from the Lindal Group) shows the valve part of the Lindal Valve design. A pin (solid blue line) on the stove or in my connector goes into the middle of the valve and presses down on the actual (green) valve plug, part D, pushing it down away from the rubber seat at the top, part C, coloured red. In the case of a small upright stove the pin is fixed to the stove and bears down on the valve plug as you screw the stove onto the canister. In my universal connector the valve actuating pin is driven down by the on/off valve cam. By the way: that spring E is actually quite strong, so the Lindal valve is very reliable.

This diagram does not show the undercut rim: the Lindal Valve is shown here in its **un**crimped form. The part B is a neoprene ring seal which makes sure there is no leakage through the crimp.

Valving

Most commercial remote canister stoves have only one valve, located at the canister. This means you are valving the liquid fuel, not a gas. As the liquid fuel expands by about 250:1 when vaporised, this means the liquid flow has to be microscopic. And that means valving at the canister is tricky and is prone to blockage if the fuel is at all dirty. I have seen some filthy Chinese fuel in my time.

When you valve liquid back at the canister, it always takes a long time for the change in flow to be felt at the burner. I have chosen instead to have a safety on/off valve at the canister and to have the main control valve at the stove, in the **gas** flow. This means you have fast reaction, sensitive control, and much less chance of blockage with either of my Winter Stoves.

Managing the Fuel Temperature and Canister

When a remote inverted canister stove is correctly used the liquid fuel delivered to the stove has the same composition (say 30% propane and 70% butane) as in the canister. A tiny amount of propane vaporises inside the canister and pressurises the liquid fuel to force it down the hose, but the amount of propane needed for this is microscopic. With petrol/white gas and kerosene stoves, the same effect is had by pumping air into the metal fuel tank to raise the pressure inside it, but as fuel is removed you have to keep pumping more air in.

If all you ever do is start and run the stove with the canister inverted the whole time, then you will get the original mixture (eg 30%/70%) right to the end. If you start the stove with the canister upright and then quickly invert it, you will very slowly reduce the percentage of propane in the remaining fuel with each start. Even so, provided you don't run the stove for very long with the canister upright you should have no problems at all.

If you are using this stove in warmer weather, with the canister above (say) +10 C, then you could run the stove with the canister upright the whole time. The stove will work perfectly well like this. The percentage of propane left in the canister will decrease over time, but since +10 C is way above the BP of butane, it won't matter.

But what if you are out in temperatures below -30 C? After all, you can't get any gas out of a canister which is at that temperature. This is true, but it can be misleading. If you have kept the canister and stove in your pack during the day, near your back, they will not be at the -30 C ambient. In fact, if they are next to a water bottle holding liquid water inside your pack, they will be above 0 C. If you have stored the canister at the foot of your quilt or sleeping bag overnight, it will probably be above 0 C as well. Just a little forethought in storing your canister can see you happily cooking at all sorts of quite nasty temperatures.

1.5 L MSR Titan pot sitting on pot stand 75 mm high on light 3-ply base board, with a windshield which is really higher than needed around it.

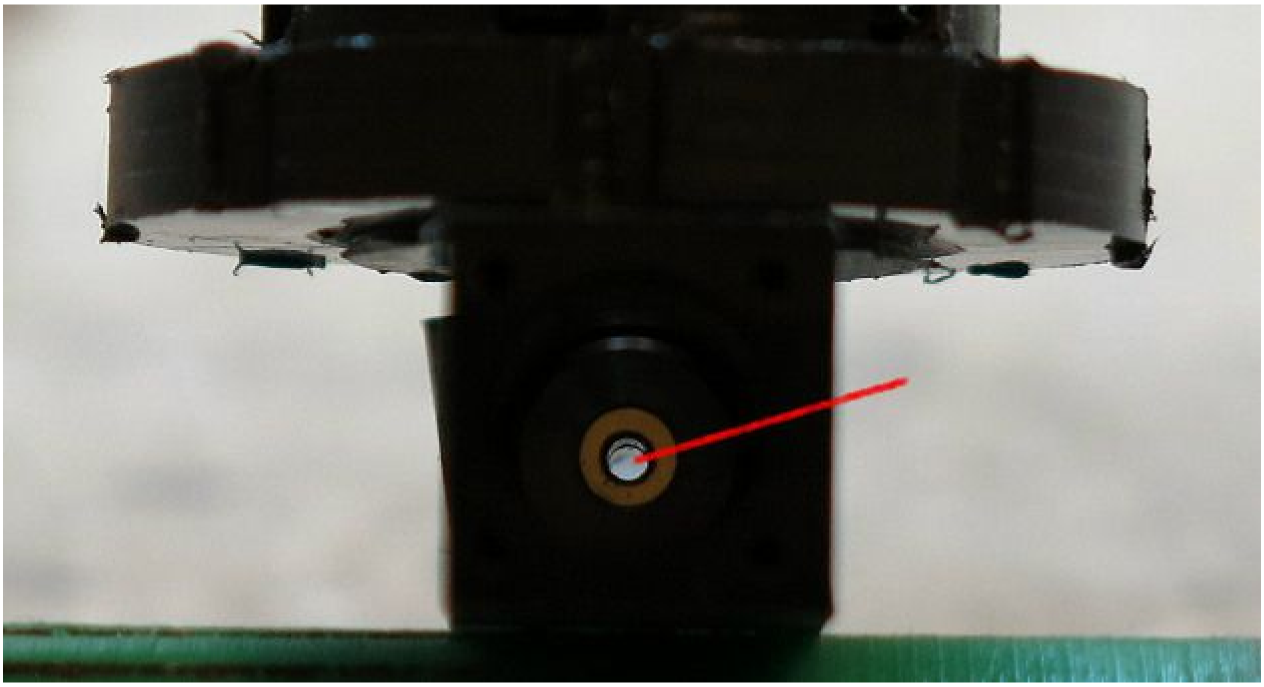
Now consider how you arrange the canister and the windshield while cooking. If you allow the canister to 'see' the flames through the usual gap in the windscreen while the stove is running, as shown here, it will absorb some radiation and warm up slightly. Don't be scared: do this!

Jet

This is the heart of the stove in some ways. It is made from brass hex rod, either 7/32” or 1/4” AF. (I started with 7/32”, but I ran out and could not buy any more. 1/4” is a shade larger.) It is screwed into the stove body snugly but not too hard. There is a special shoulder to the socket which provides a seal. There is a 2 mm hole up the inside of the jet, while the working orifice is at the top and is 0.030 mm diameter. **Do NOT damage the tiny hole!**

Inline Fuel Filters

I have found fine dust and wax in a number of canisters (especially Chinese ones), and they have all given me (or any attempts at inline filters) much grief. I tried putting a filter under the jet, but it was so small it blocked up very easily and stopped the gas flow. A larger filter there might work with a much larger jet (body), as used on some commercial stoves, but there just isn't room in this stove. I have also tried putting a filter inside the canister connector between the safety valve and the hose connector, but I found it too could block up with dirt and waxy condensates from the fuel right where the hole in the hose is, as shown here (red line).

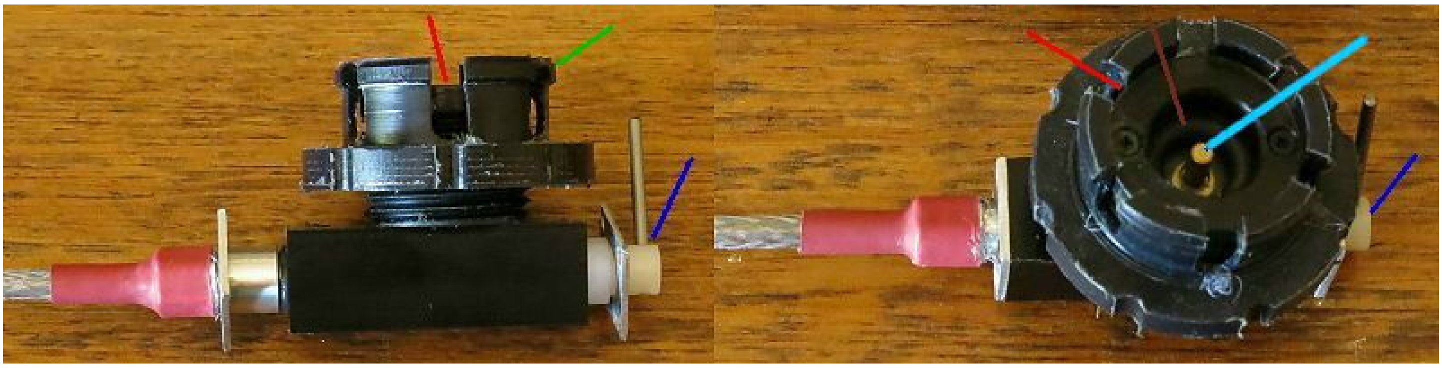


In the end, after several hiccups during field testing (it was getting late and my wife was waiting for dinner), I threw away all the filters and haven't regretted it since.

Without the inline filters all that stuff (well, most of it) usually blows straight through the jet and away. That is 'usually': I have heard of cases where there was enough dirt and wax that it still gave problems without any filters. I have also seen cases where the wax and dirt collected at the needle valve, causing all sorts of problems such as the valve not being able to shut off properly. This problem does not normally happen with upright canister stoves: all the wax and dirt stays at the bottom of the canister. The moral here is to be rather careful with what canisters you try use with **any** inverted canister stove – mine or others.

Winter Stove Details

Canister Connector



This gives 2 views of the canister connector. The lugs referred to above are at the ends of the 'fingers' and are marked by the green lines in the left photo. They are forced outwards to anchor under the crimp ring by the retaining ring marked by the red line. It sits on top of the 'main block'. You first unscrew the 'Spider' with the 6 fingers and lugs so the top end is clear of the retaining ring and the main block. This lets the fingers deflect inwards enough that you can poke the connector into the Lindal valve and get the lugs under the crimp ring. Then you screw the rest of the main block into the Spider so the retaining ring forces the lugs out under the Lindal crimp ring. Describing this is difficult, but after doing it just once it is obvious.

The brown line (right photo) points to the critical fat O-ring (7mmx3mmx13mm nitrile or Viton) which seals the connection. If this O-ring is missing you will have no seal and a lot of gas leaking out. Commercial stoves also have a fat O-ring here. You should screw the Spider onto the main block until you can feel a bit of resistance from this O-ring.

The Lindal valve is opened by the yellow brass pin in the middle with the pale blue line. This pin is driven by a cam on the on/off white safety valve marked by a dark blue line on the right of both photos. When the (titanium wire) handle points towards the canister the pin is pushed into the canister, opening the valve; when the handle points away from the canister the pin is allowed to retract, closing the valve. The handle is shown here in the valve-open position: the wire points towards where the canister would be.

The vertical surface of the retaining ring is not threaded, so it is better able to push the fingers outwards. It also keeps the fat O-ring in place, which keeps a small clear plastic washer in place, which stops the brass pin from falling out. Since it is not threaded, it also stops the Spider from being screwed right off the main block – and falling on the ground and getting lost. That happened only once, a *long* time ago. The retaining ring is held in place by two screws, just visible in the right hand photo.

The hose connects to the main connector block as shown at the left, and is held in place by a retaining plate and two screws (screws not shown). The cam valve is also held in place by a similar retaining plate (again, screws not shown). Both are sealed with O-rings (5mmx1.5mmx8mm nitrile or Viton), and these O-rings are critical to the safety of the stove. (Most O-rings anywhere at all are usually critical.)

In practice it is easiest to gently undo the Spider until it bumps against the retaining ring at the top, then you insert the Spider into the Lindal vale and spin the Spider and canister up the thread to lock the connection. But make sure that the Ti wire handle is pointing away from the canister before you do this.

Hose

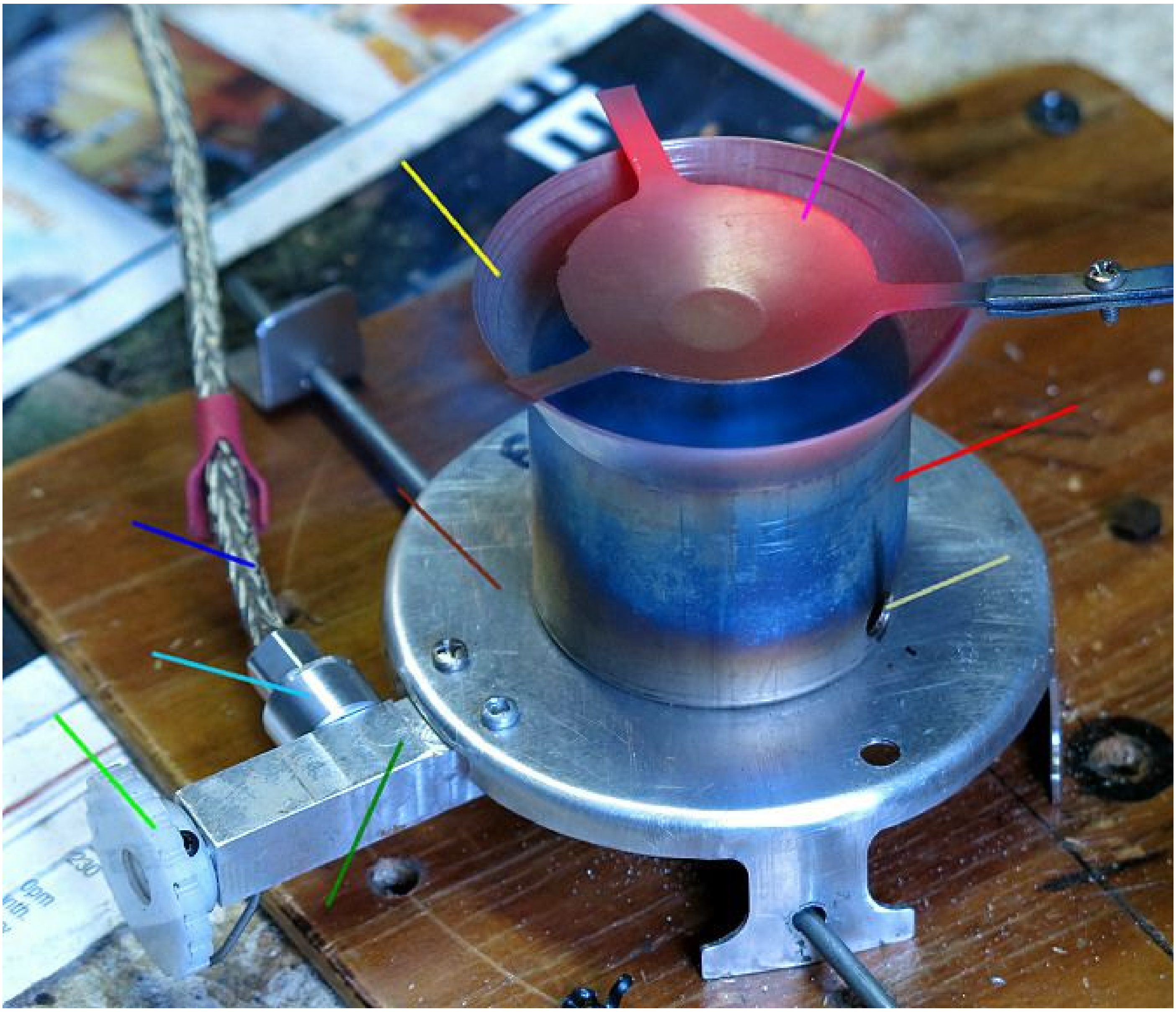
The hose is about 250 mm long. The whitish hose itself is (American) PFA tubing. The shiny reinforcing cover over the PFA hose is Taiwanese stainless steel braid, custom-made to my specifications. The braid is crimped to machined aluminium connectors at each end. They are sealed with O-rings (5mmx1.5mmx8mm nitrile or Viton at the canister end and 3mmx1.5mmx6mm Viton only at the stove end).

The PFA hose is the most heat-resistant and strongest tubing of this size available on the market, better than PTFE. It is also remarkably crush-resistant and kink-resistant, and it has a very high pressure rating, even at high temperatures. It is crimped inside the aluminium connectors at each end to a strength sufficient to handle all the gas pressure and more. Adding the SS braid over the top simply adds to the strength of the connections.

Commercial hose with similar specifications is available, but it is slightly more than double the diameter and far, far stiffer, and is a right pain to handle in the field. It is made as a fuel line for high performance race cars, so they want it stiff. Many commercial stoves use it anyhow (because they can buy it by the reel), even though the stuff handles like a wooden handle on a sledgehammer. My hose is far more flexible.

Stove Burner Design

This photo shows my rather 'used' (knocked around) development stove. It stands about 59 mm high.



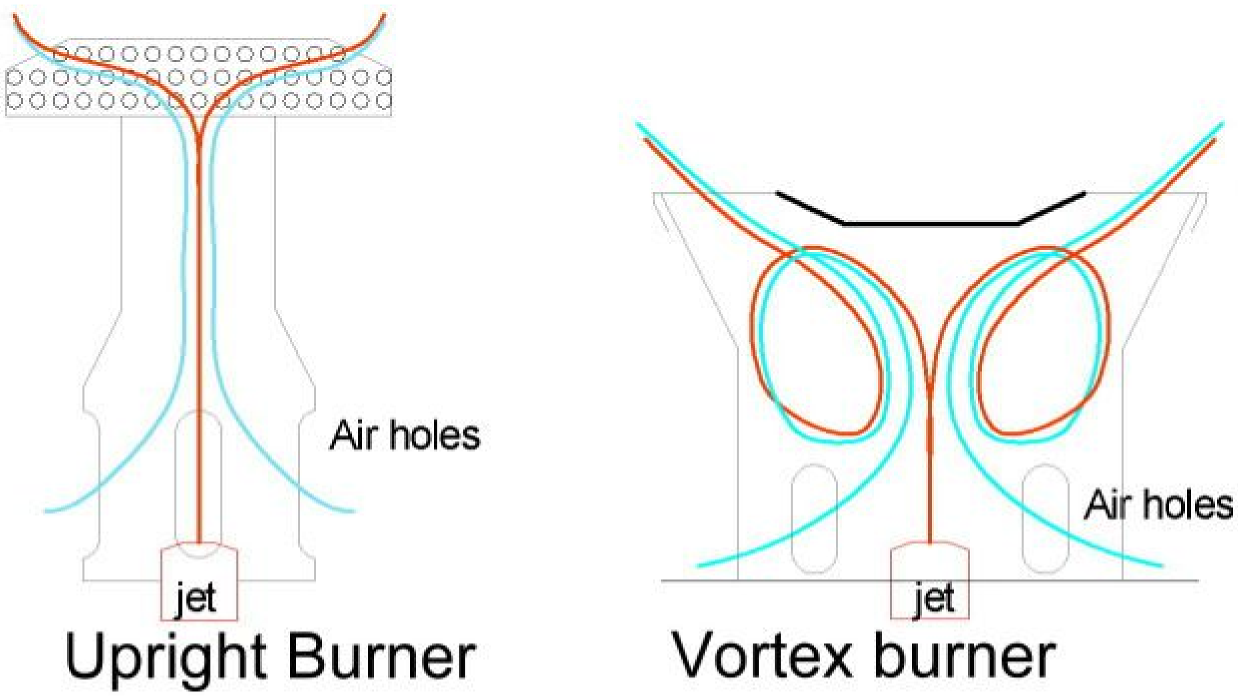
First, some names. This is a Vortex burner, it roars, and it sounds rather like an XGK. If you want a silent stove, this is not for you – but at least with this stove you will know when dinner is cooking.

The 250 mm long fuel hose (dark blue line) attaches to the aluminium stove body (dark green line) via the hose connector (light blue line). The round white control valve (needle valve) knob has a light green line. The titanium Vortex Burner Chamber has a red line. The top edge has an essential flare, yellow line. In this photo there is an optional hole at the bottom edge (khaki line) for ignition, but I don't normally use that hole and may omit it in future. The long needle valve which does the fine control is inside the stove body, with the actual valve seat in the middle of the Vortex Burner Chamber. There is of course a jet there surrounded by air holes. The long needle valve and stove body form the heat exchanger which vaporises the liquid fuel.

The large (70 mm diameter) aluminium alloy Stove Base Plate has a brown line, and several features. It has four support legs which allow air to get underneath and into the stove, and they are matched in height to the diameter of the control valve - which acts as a fifth support leg. There are some holes near the top edge of the Plate which allow you to insert hold-down stakes to stop the stove from skittering around (picture on page 12). One of the surprises was that this stove is so light it can be knocked sideways a bit more easily than the really heavy commercial stoves. The stakes work extremely well. The Stove Base Plate supports the Burner Chamber and the stove body, and has the air inlet holes.

The thing at the top (glowing red) with a purple line is the titanium Splash Plate. This is basic to the functioning of the stove, and the depression in the middle is critical to the design. Months were spent on this. The funny bit sticking out to the right is a clamp holding the splash plate at various heights above the rim of the burner during testing. In this photo I was trying to find the best position or height above rim for the splash plate and the best shape for it. Actual measurement beats guessing every time.

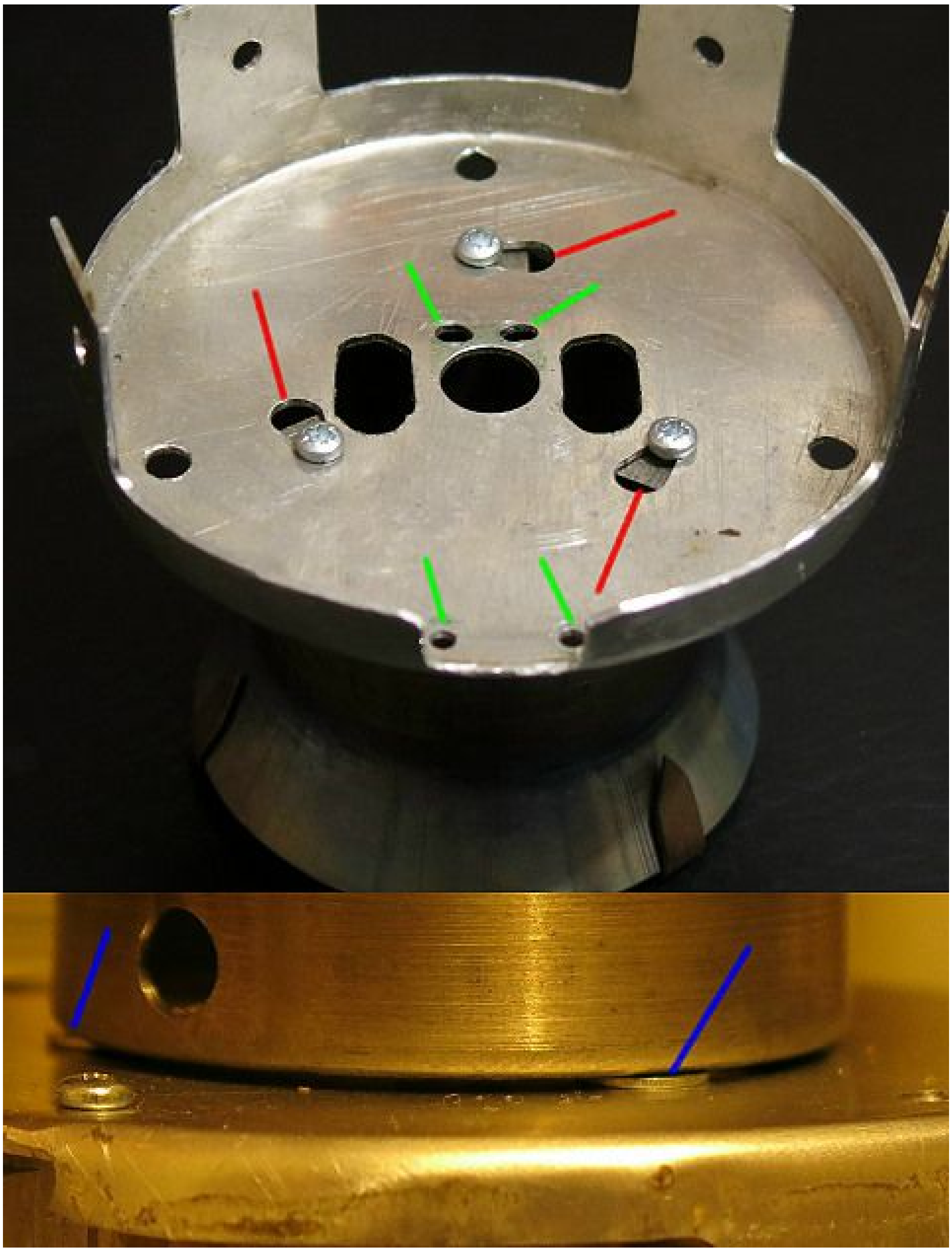
And now we get an explanation of the Vortex name. The diagram here shows the difference between an 'upright' burner and this 'Vortex' burner. (I am not a good artist.)



The jet in an Upright Burner (left) sends a jet of vapour up into the burner head, drawing in air through the air holes as it goes. The jet in the middle of the Vortex Burner (right) also shoots fuel vapour upwards, drawing in air through the air holes. (The air holes are shown in the walls of the burner chamber here to parallel how they are in an upright stove, but they in practice they are in the base plate.) The fuel hits the Splash Plate, shown in heavy black, and swirls around in a burning vortex inside the burner chamber. The vortex is chaotic, and that makes the roaring noise. Without that swirling vortex the stove does not work properly.

A side effect of having the flame inside the burner chamber is that the jet and the base plate get hot (not to mention the burner chamber and splash plate), and this heat is conducted back into the stove body, where it rapidly boils the incoming liquid fuel into a vapour. That's why this stove does not need a 'pre-heat' tube over the top: the stove body and the needle valve make an excellent heat exchanger.

Heat flow into the Stove Body and Base Plate



This is actually a bit technical, and it took a long while to get it right.

The burner chamber is attached to the Stove Base Plate by 3 small screws. You have to remove the burner chamber to access the jet, but those small screws are a bit tricky to get back into the threaded holes in the rim of the burner chamber: the screws are only M2 or 2 mm. This is hard enough in the lab; it is really hard in the field in the dark! (I know.) So the attachment has been made 'easy to remove' as shown here. The heads of the 3 screws first go into the big end of the keyholes, as shown by the red lines. Once all the screw heads are through the keyholes, the burner chamber is rotated a few degrees to the position shown and the screws gently tightened up. Force is not needed here. To remove the burner chamber, slacken the screws just a bit, rotate the chamber and extract the screw heads from the keyholes.

During development I found that the aluminium Stove Base Plate and from it the aluminium stove body were getting too hot. Eventually I found that the heat was not coming directly from the flames, but mostly down through the titanium wall on the burner chamber and across the mating face of the rim to the aluminium. Yes, titanium does have a low thermal conductivity, but the glowing red top flare was well over 500 C. Heat was travelling down the wall. (I have skipped some other factors here for simplicity.)

This problem of excess heat flow was partly solved by placing steel M2.5 washers between the burner chamber wall and the Stove Base Plate, as indicated by the blue lines in the lower part of the illustration. The contact area is now very small (just the washers), and the heat flow from chamber wall to base plate is much reduced. Make sure you don't lose these washers.

In addition, heat still flows from the hot Stove Base Plate – which can easily get over 100 C, to the stove body. It has to of course, to vaporise the fuel, but there was a bit too much heat flow at first. The mating area between the Base plate and the stove body was significantly reduced and small red fibre insulating washers were placed between the Stove Base Plate and the Stove Body at the 4 mounting screws. These screws go through the holes indicated by the green lines, and are done up fairly tightly. Don't lose these insulating washers either, although you should never need to separate the two parts.

In principle I try to keep the stove body near the hose connector at a touchable temperature: at or below 40 C. This is of course quite hot enough to vaporise the incoming liquid fuel. As the PFA tubing and the Viton O-rings can all handle more than 200 C, the system is fairly safe. The plastic knob might actually be the first thing to suffer heat damage, so it is a tight fit to the shaft of the needle valve and then it is pinned to the shaft. That said, the plastic knob can take either 110 C or 120 C (depending on production batch) as a routine operating temperature, with a short-term peak of around 200 C. It should never reach 100 C in practice.

Operation

Starting

First of all, before you even get your stove out, make sure you have somewhere level and stable to put the stove. Also make sure there are no heaps of flammable material nearby: dead grass, dried leaves, your clothing or gear …

Morning tea – boiling the kettle, on a day walk. The severely battered old folding windshield lives in my day pack. The ALOCS kettle was reviewed recently.

I use a plywood base board, shown in some of the pictures here. It is strongly recommended and very easy to make. Light 3 ply is good, and coating it with varnish or oil or a PU resin to make it waterproof is excellent. Thin chipboard (particle board) is useless: it falls to pieces. MDF is like heavy cardboard: useless if it gets wet. Foam is flexible and can wobble around and even melt: I don't like it for this. My base board has some holes in it for hold-down stakes going through the Stove Base Plate: you can just see them in use here (small green dots) at the sides of the stove. Better variations on the pot stand are discussed later.

Then I remove the cap from the canister and attach the stove, making sure before I start that the safety valve on the canister connector is OFF (handle pointed away from canister). I place the stove on the base board and stake it down. I place the canister upright at the start, unless it is a Powermax canister or the weather is very warm. Then I arrange the pot support around the stove – see later for suggestions here.

The next thing I do is to put water in the pot, for several reasons. The first is once I have a flame, why waste the gas, a second is because a full pot above the stove is a good baffle in case of any flare-ups, and a third is because a full pot does tend to stabilise everything. A fourth reason is because you can melt an empty aluminium pot with one of these stoves: you **need** the water there!

Now that everything else is in place, it is time to light the stove. There are two different ways to do this, and you will have to decide which you prefer. Both require the use of both hands.

The first method turns the stove on at the safety valve. I turn the round control valve OFF, then open it slightly. You will have to calibrate how far you open the valve by experience here. I light my Bic lighter, hold it near the edge of the flare on the burner chamber, and then turn the safety valve to ON. There will be a small pause before anything happens: it takes time for the fuel to travel down the hose, through the nearly closed needle valve, and to the jet. It has to blow the air out first. If you are not careful, the rush of air can also blow the Bic flame out. When the fuel arrives, the stove lights. I adjust the flame to a low level at the start and put the pot straight on.

A practical note: point the Bic upwards and have your hand below the level of the rim. That way you will keep the hairs on the back of your hand a bit longer. Do not open the valve very far when starting, or you may blow the Bic flame out anyhow.

If the stove does not light, I usually quickly move to open the control valve a shade more. It's a delicate balance: you don't want the control valve wide open as that will release a fair bit of liquid fuel, which will flare, but you do want some fuel coming out. Once you have done this a few times, you will know what to expect. Try learning at home and outdoors maybe?

The second method turns the stove on at the control valve. This will give you more control over how the stove lights. For this method you turn the control valve off, then you turn the safety valve on, then you gently turn the control valve on with your lighter already burning at the edge of the flare. Personally, I favour this method.

In either case, you may find that the flame is a bit 'wobbly' at the start. This is because the vortex flow has not yet established itself fully. You may (sometimes) find it helpful to *slightly* increase the gas flow in this case. I find that once the burner chamber has started to heat up the flame stabilises and all is well: the stove is now 'partly primed' and running. The whole flame stabilisation process lasts only a few seconds. You do *not* need the football-sized fireball common with white gas stoves! But this is **not** the full priming cycle!

If you are starting with the canister upright, you will be getting gas down the hose. Allow the stove to warm up for 15 – 20 seconds (so the stove body near the control knob feels a little warm) and then very gently invert the canister to get a liquid feed. At this stage you will understand why staking the stove down is so utterly valuable: if it is loose it may also invert! But the connections at both ends of the hose can rotate, so you can rotate the canister upside down while not moving the stove. That's part of the design.

What happens when you invert the canister? Well, the liquid fuel will travel down the hose, hit the stove body (which should by now have warmed up a bit), and start to vaporise. But the liquid fuel will be travelling much more slowly down the hose than the gas was, so there will be less pressure drop down the hose. This means the stove may seem to increase in power a bit when the liquid fuel arrives. Fine – readjust the flame to suit. On the other hand, sometimes the stove dies down a bit instead: adjust the valve. The physics of microscopic fuel flows is complex...

If you are starting with the canister already inverted, something else may happen. Start with the control valve almost closed, because what will come out at the start may well be liquid fuel. There could be a slight flare-up. But once you have a flame inside the burner chamber, any more liquid fuel coming out will get vaporised very quickly by the radiation from the flame. Even so, at the start you will be valving liquid fuel, so keep the flow down low, for safety.

Eventually the stove body will heat up and vaporise the fuel – it does not take long. Then some funny things happen: the stove will sputter as though it is about to die. It isn't: the sputtering is just the last few drops of liquid fuel between the needle valve and the jet passing through the jet, among the gas flow. Once they are all gone the stove will quieten down – but it will now most likely be running at a very low flame. You will have to turn it up a bit.

What is generally happening here is that the flow through the needle valve has gone from liquid to gas, and the valve has to be a bit more open to let the same amount of fuel (in energy terms) through. The reduction in fuel flow can be so severe that the flame almost goes out, so listen carefully to the stove if you are starting it with liquid fuel. Once you get used to this it becomes automatic and easy. If you are using Powermax canisters this is standard operation.

Stopping

There are two possibilities here: you are just turning the stove off for a short while between courses, or you are turning it right off to pack it away.

If you are turning the stove off for just a short while, you should be able to do this via the control valve. Just turn it off. Restarting is simple: there is fuel in the line and the stove will not be too cold. But of course, start gently.

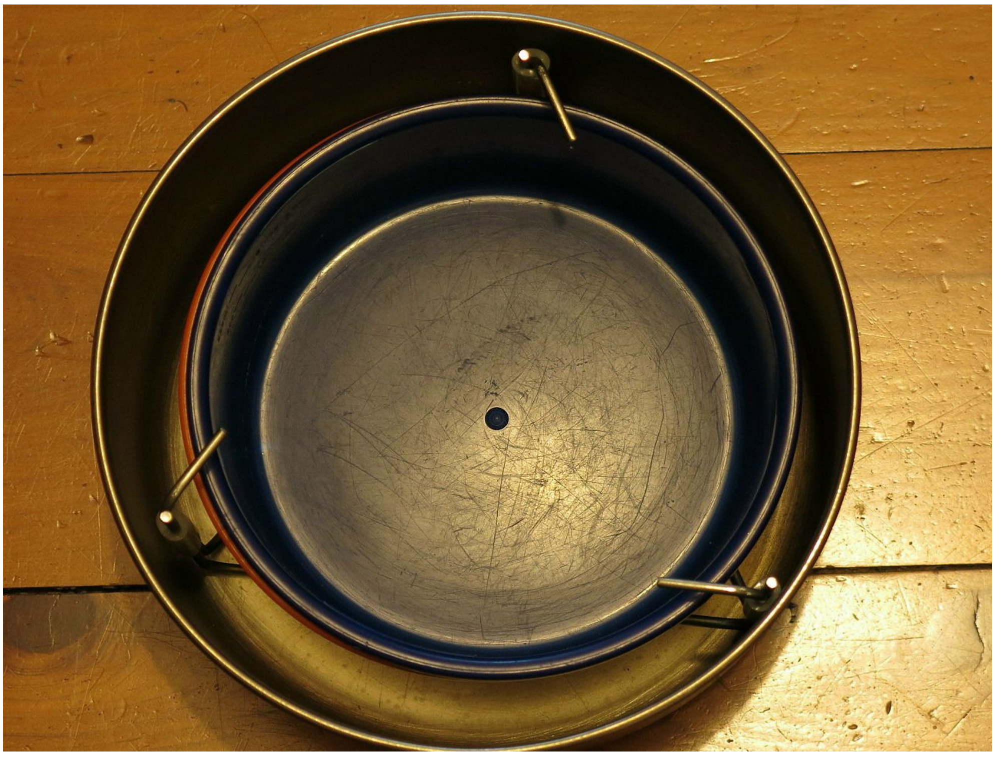
However, if you want to pack the stove away, first turn the safety on/off valve, and let the flame die of its own accord. Do not turn the control valve off. This will use up all the fuel stored in the hose: you don't want to spray that around, especially if there are any other flames around.

It makes sense to store the stove with the control valve slightly open: that way you won't damage the valve seat.

Pot Stands

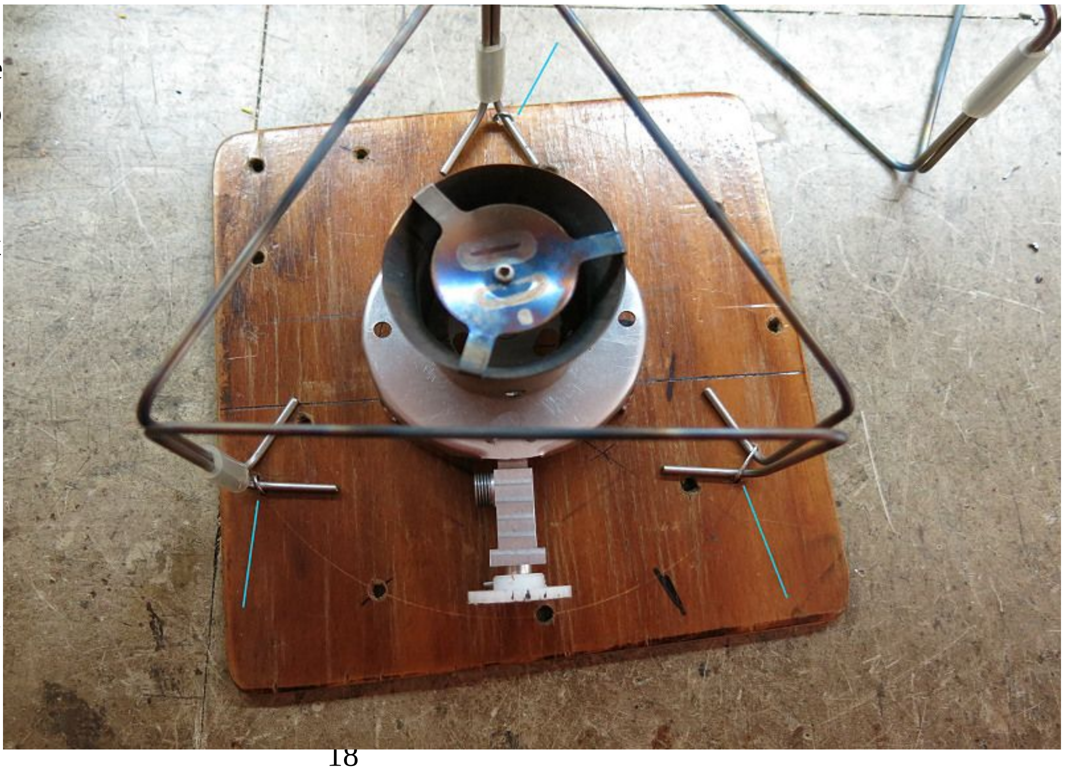
You could use three rocks in the time honoured manner, but a portable pot stand is more convenient. Previous pictures of the stove have shown an early tripod pot stand of fairly conventional design; it has improved since then. What is I think new is how the legs are held together. Others have used wrapped wire and clips: I use a short length of silicone rubber tubing.

The height of this stand is ~75 mm, the width of each part is ~126 mm, and the three bits of Si tube are about 25 – 30 mm long. The length is hardly critical.



Such silicone rubber tubing is flexible and can be threaded onto the Ti wire over bends. It can take quite a high temperature, and anyhow the bottom ends of the titanium wire legs do not get very hot. However, you can only lock two joints together this way if you want to be able to collapse the tripod down flat. Two joints is sufficient, although three joints is possible IF you can figure out how to pack the assembled tripod.

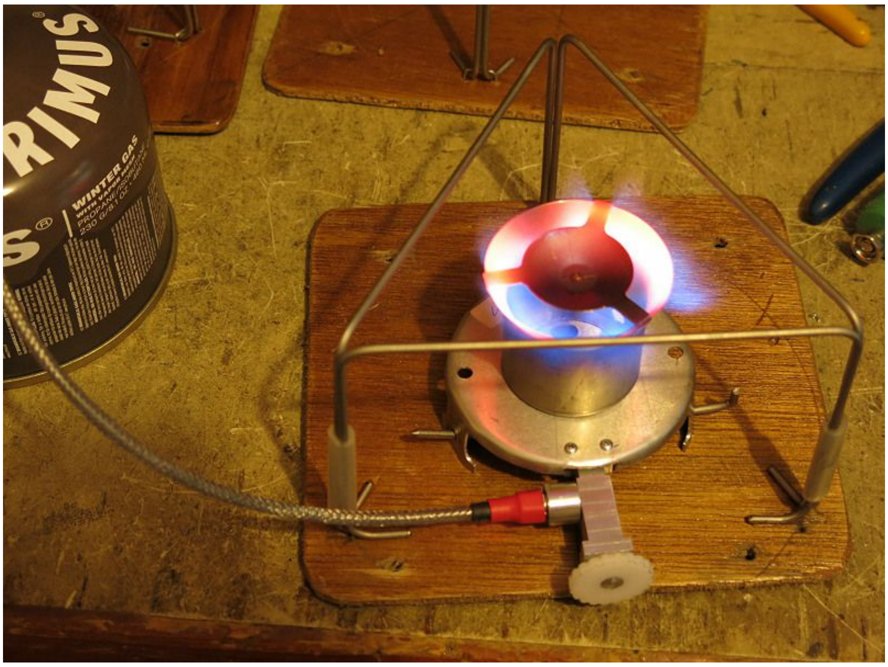
This photo shows an older tripod with three locked joints nested around our two GSI bowls inside our titanium cooking pot. They all nest very nicely. The stove gets wrapped in a bit of old tea towel (to protect the bowls!) and sits in the bowls, with my Bic lighter and a few other cooking bits.



The production tripod is shown here. Every part of the tripod has two bent legs. Two Si rubber sleeves are used to keep the legs together (top and left), while the third joint (right) is unsecured.

Some of the bent legs are secured to the 3-ply base board, as indicated by the pale blue lines. The anchors are loops of 1 mm SS wire through small holes in the base. The joint without the Si tube is anchored by the wide loop, at the front right.

I first insert the right hand bent end of the (unsleeved) front leg into the wide loop at the right, and then the left hand end of the same support into the smaller loop at the front left. This stabilises the whole assembly. Then I insert the front bent leg of the right hand (unsleeved) support into the large loop. Finally, I insert the back bent leg of the same support into the small wire loop at the back. The explanation sounds complex, but a quick check of the picture will make it all very clear.



It is possible to stake the stove to the ground, as shown previously. However, that does not work in the snow, as the stakes get a little warm. The photo here shows the stove held down onto the base board by a Ti wire through holes two legs. There is another small loop of 1 mm SS wire under the middle of the stove to capture this wire. The wire itself has a bend at the end to allow you to get it through the second leg easily.

The end result is an assembly that can literally be waved around with nothing coming loose. One or two micro-stakes can be added through some of the holes at the edge of the baseboard and the whole thing is a stable as a rock. This even works in the snow as the stakes through the baseboard do not get warm.

A secondary advantage of this design is that when you remove the pot stand from the base board, you can fold it up for packing. Only two of the three joints are sleeved.

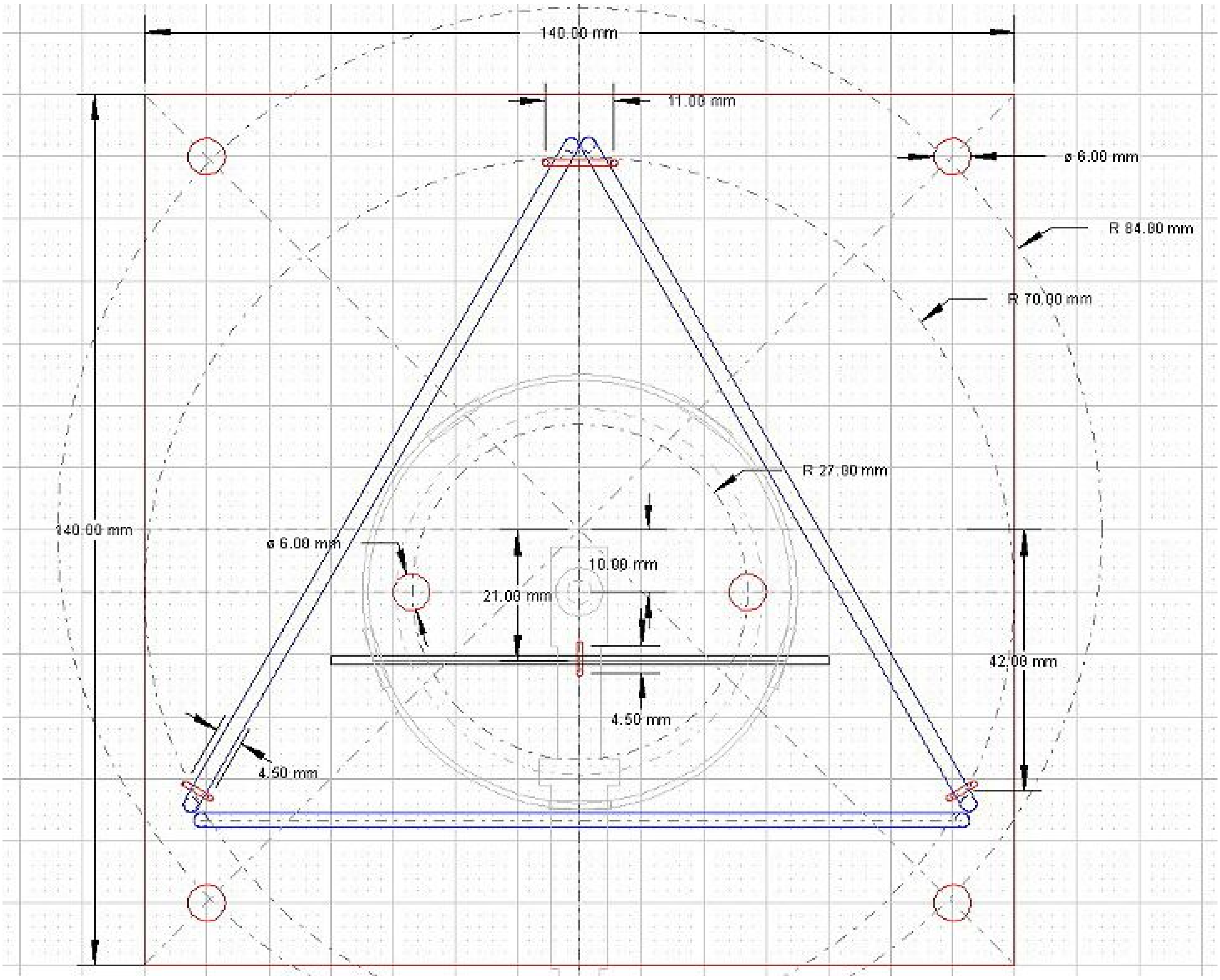
For those who want to make their own support bits, I will describe both the tripod and the baseboard as I make them.

The tripod uses 2.4 mm Ti 6Al4V straight wire. The best source for this is as 3/32” Ti welding wire, in 36” lengths. You can get this is several alloys, including 6Al4V. It can be expensive if bought locally, because not much is normally stocked at welding shops (how many get to weld Ti?), but I found good prices from China on eBay. You might also be able to use Ti bicycle spokes if they are thick enough. For the first version of the tripod I chopped my 36” length into 3 bits of 12”. I marked the middle of each bit and then bent two legs at right angles with about 120 mm between them. (Sorry about the mixed units.) Then I bent small feet at the ends. I used a custom bending jig, but you could use round-nosed pliers with some care and a *lot* of force.

I found that this tripod was, if anything, a shade large. Version 2 is slightly smaller and more suited to small one-man cooking pots, although it is still quite large enough for my '2-man' Titan cooking pot. It has about 100 mm between the legs, and the dimensions of the baseboard are correspondingly shrunk.

Some cautions: Do NOT try to make the bends sharp: the Ti will crack. Do not try to re-bend the Ti wire several times: it will crack. Do not try to bend the Ti wire after it has been heated: it will crack. The wire is usually delivered annealed or in a 'soft' state, but heat will temper it to a hard state. If you do need to change the bend later, you can do it fairly easily by holding the wire with some pliers and bringing it up to red heat before bending. Using some round-nosed pliers for the actual bend works fairly well.

Then I used 2 bits 25 - 30 mm long of silicone tubing for the hinged joints. The bore of the tubing was about 3.5 mm (probably 1/8”). Pushing it over the bends is hard but is possible: a bit of lubrication does help. With only two hinges the lot folds flat; with three hinges you need to pack it in your pot as shown earlier. But that works fine too.



This is the engineering drawing I use for the baseboard for the larger 120 mm tripod. The background grid is 1 cm. The big holes are 6 mm – roughly. The small holes are about 2 mm. The idea is to space the wire loops such that the legs are snug or just slightly sprung. For the smaller tripod this diagram is just scaled down a bit at the leg attachments. The stove parts stay the same size of course.

Note that the stove centre is not at the centre of the board: it's 10 mm south of it. That is also the centre of the pot stand triangle. The wire loop used to hold the stove down is 21 mm south of the centre of the board.

Also note that the control knob is now clear of the board. Once the stove has been secured to the board, a fifth point of support (as mentioned in Part 4) is no longer needed.

I use a light pine 3-ply for this. Chip board and MDF are entirely unsuitable, imho. I paint the baseboard with something to stop it getting wet and disintegrating – at present I use Linseed Oil. Old fashioned, but it works well and I have a LOT of it.

Servicing

Included with each stove are two small tools, usually tied together with nylon string so they don't get lost too easily. The first is a small spanner for the jet. It is deliberately short so you cannot exert too much force when doing up the jet. Excess force could strip the threads in the stove base, which would be 'unfortunate'.

The second is an old-fashioned 'pricker': a strip of aluminium with some fine SS wire crimped into the end. This wire is about 0.2 mm diameter, comfortably smaller than the 0.3 mm hole. It is meant for cleaning the jet hole. Don't bend the wire too often or it will break off. And do **not** damage the jet hole!

I have not been able to supply tiny Posidrive or Phillips head screw drivers so far – sorry about that. I can't find any.

Sometimes it seems there are so many things which can go wrong, but once you understand how your stove works, the answers to any problem are usually fairly simple. Preventative maintenance is always good, provided it is not overdone. It makes good sense to do the following maybe once a year:

- Check the fat O-ring visible in the canister connector for any damage, and smear a drop (a small drop) of silicone grease around it from the outside. A matchstick is good for this; sharp metal is not.
- Remove the needle valve completely from the stove body, check and grease the O-ring on it, clean the tip and clean the valve seat down at the bottom end of the long hole. A cotton bud is excellent for getting to the valve seat. Anything hard or sharp is **very bad**: it will damage the valve seat. Yes, there may be some dirt or wax accumulating down there: it comes from the canister. Replace the needle valve carefully, easing the O-ring into the hole at the end. If the O-ring shows any signs of damage consider replacing it. See below for how.
- Remove the Burner Chamber by loosening the 3 small screws (see previous section on Heat Flow), remove the jet, clean the jet socket and the inside and outside of the jet with something soft. Check the hole by sighting through it to sunlight. *Do not damage the jet hole.* Do **not** try to use a pin or a needle. Replace the jet without crossing the threads, and tighten a little so there are no leaks at the side when the stove is running.
- Check all the tiny screws on the canister connector. They come in pairs, they should be gently tight, but do not over-torque them and damage the plastic or metal they go into. Do not remove them unnecessarily.
- Any problems, email me. I want to know about any problems for the future. I *will* support the stove.

Replacing O-rings

These are sensitive and delicate little things which do a marvellous job. Well, actually they are fairly reliable, provided you treat them with care. You can get them out of their grooves by squeezing them so a bit of the ring pops up out of the groove (left top photo) and then slipping a blunt pin underneath the protruding bit (right top photo). The squeezing bit is hard to describe, but try it and you will see. It helps to wipe any silicone grease off the O-ring before you do this of course. Then pull the O-ring gently out of its groove. They will stretch a bit. **Do not spike or cut or damage the O-ring doing this.**

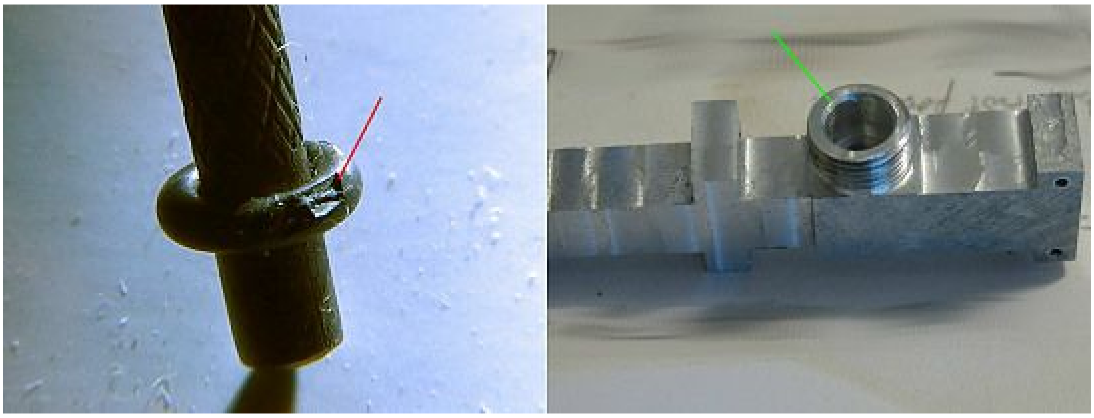
Now for an important bit. IF you have to get the O-ring off the shaft, that may take it over sharp edges like threads (visible in top right photo) and do lots of damage. Do **not** just drag the O-ring over any sharp edges

(like a cut thread)! You will damage the O-ring, and gas will leak out. Bad things happen then. Very often it suffices to get the O-ring just out of the groove (move it to the right in the photos) and to clean the groove, lightly grease it, and push the O-ring back into the groove, and lightly grease it from the outside too..

If you have to get the O-ring right off, cover any sharp edges with some sticky tape, so the O-ring slides easily across. The same applies when replacing the O-ring. A little silicone grease spread over the top of the tape may help, but keep the metal clean as any silicone grease will kill the adhesive on the tape. This particularly applies to the needle valve. In the bottom photo I have used some thin slippery heat-shrink tubing as a sleeve over the threads: that worked very well. Not all heatshrink is thin and slippery though.

The O-rings on the stove body get hot. If you have to replace them, they are all metric sizes (**not** imperial) and you must only use Viton O-rings on the stove body. Cheap O-rings cannot take the heat. In an emergency you could use Nitrile O-rings on the stove body, but I advise against it. The hose connector O-ring is OR3x1.5 mm, while the needle valve O-ring is OR4x1.5 mm. The 3x1.5 bit means the ID is 3.0 mm and the thickness is 1.5 mm, so the OD will be 6.0 mm. If you measure the O-ring in place it should seem to be slightly oversize. It has to, so it will seal.

The O-rings in the canister connector do not get hot, so nitrile (NBR) O-rings are suitable there. Again, they are metric, not imperial. Use the right sizes. All O-rings like a *little* bit of silicone grease. The O-rings on the cam valve and the hose connector are both OR5x1.5 mm. The O ring which seals against the canister is OR7x3 mm. The latter is close to but *not* the same as the BS011 O-ring used on many commercial stoves.



Inserting an O-ring on a shaft into a hole must be done with care. If done wrongly you can pinch the edge of the O-ring and take a lump out of it: see red line at left. This happened during my development work because the edge of the O-ring socket was sharp and I was not careful enough. I have since included chamfers on all edges in the CNC programming, as shown by the green line on the right. Ease those O-rings in gently.

A special note for the hose connector at the stove body, as shown here. If you disconnect the hose (by unscrewing the external round nut), you will find that the little O-ring stays inside the aluminium stove body, in the hole shown above by the green line. Do **not** try to push the end of the hose back into the O-ring while it is in the aluminium hole: you won't succeed and you *will* damage the O-ring. (I have tried...) Gently remove the O-ring from the hole with a matchstick or a toothpick, lightly grease it and put it back on the end of the PFA hose, then gently insert the hose and O-ring into the connector hole. Actually, you should never need to do undo this connection.

Removing the Jet

Do **not** attempt to remove the splash plate from the burner chamber: that will probably break it. Instead, remove the burner chamber from the stove base plate by loosening the 3 holding screws and rotating the burner chamber, as previously described.

Removing the jet will require a spanner of some sort (such as the one provided). It is screwed in fairly tightly to prevent gas leaks out the side. When replacing the jet, make sure you do not cross the threads: it should go in easily without any force at all. Then, when it is screwed right in by finger tip, tighten it up *a little* with a spanner to get a metal-to-metal seal on it. Not a lot of force is needed, but it must seal. No gas should be leaking out from the threaded junction when the stove is running – it will make little flames there if it does.

The older versions of the jet take either a 5.5 mm or 7/32” spanner; the later versions take a 1/4” spanner. The jet hole itself is 0.30 mm. I do not know of any commercial equivalents. Do not try to alter the jet hole diameter.

Major Disassembly

Yes, the stove can be stripped right down into the component parts – except for the hose. That has been crimped together. Do not try anything there. But you should not need to do this.

If you think you have a problem which needs significant disassembly, maybe email me first?

If you want to partly or fully disassemble the stove, I strongly recommend you spread out a large white handkerchief on the floor or ground, sit down at ground level, and do all disassembly with the stove on the handkerchief on the ground. Inside your tent on the groundsheet is good. That way small parts (like screws especially) won't travel very far.

Debugging

The stove has been extensively tested both in the field and on the bench, but it is still in a beta test stage. First, if you can, email me with the problem. I want to know what can go wrong. I should be able to help. Otherwise, run down this check list. I will add to it as I get feedback.

- No gas coming from canisters
  - Empty canister (it has happened!)
  - Connector not screwed down far enough (feel O-ring resistance as you twist)
  - Safety valve not opened properly: point handle right down
  - Blocked jet (see previous instructions), dirt from the canister is a possibility here.
  - Blocked hose: you will have to contact me.
- The flames are skewed off to the side, or is mainly inside the burner chamber
  - Jet is partly blocked inside, usually by canister dirt. This is a known problem, and it should be fixed ASAP as it can overheat the stove body. Clean the jet carefully.
  - It can happen right at the start that the vortex flow has not yet sorted itself out. Try running the flames up and down to see whether they suddenly sort themselves out.
- When lighting the stove, the blast of air seems to blow the Bic flame out rather than catch alight
  - The first blast of air (1 – 2 seconds) contains no fuel: it has not reached the jet yet. So that is normal.
  - If this keeps happening, the jet may be partly blocked. This makes the flow velocity higher, which sucks in more air, which makes the fuel/air mix too lean to light. Clean the jet.
- The flames are big and bright orange
  - See 'Flaring' under 'Safety and Testing' for an explanation. Basically, you have not allowed the stove to warm up enough.
- After use there seems to be a liquid around the jet hole
  - The liquid is a heavier hydrocarbon from the canister. It is not really a problem unless it blocks the needle valve. You may ignore it on the jet and clean the needle valve, and consider buying a different brand of canister.
- Spider falls off the main body
  - You have unscrewed the Spider so far and/or so hard in the wrong direction that you have forcibly removed the holding screws which retain the top ring on the main body. This has damaged the screw holes, and you may have lost the screws and the top ring. You may also have lost the fat O-ring and other parts. The problem is however not terminal: contact me.
- Gas leaks from the region between the canister and connector
  - You may have lost the fat O-ring
  - You may not be tightening the connector down onto the fat o-ring enough: you should feel some resistance when tightening
- Flames where there should not be any
  - First, turn off the safety valve! The flames will go out when the gas supply is removed. Then

stop and think.

    - You may be missing an O-ring, have a damaged O-ring, a dirty O-ring, or may not have done something up enough. Feel free to contact me, please.
- The needle valve does not open
    - You may have lost the pin or screw which locks the round handle to the needle valve
    - You may have got the needle valve really jammed
    - In either case, contact me
- The needle valve will not shut off: a small flame persists
    - Most likely the tip of the needle valve and/or the seat for the needle are dirty. Remove the needle valve and clean both the tip (use TP) and the valve seat (cotton swab, **not** metal). You should probably also contact me for further checking. The valve did shut off before shipping.
- Help: I have lost some of the screws (or any other such problems)
    - Contact me: roger@backpackinglight.com