



# IPGA

INTERNATIONAL  
POLAR GUIDES ASSOCIATION

## **STOVE SAFETY MANAGEMENT RECOMMENDATIONS**

**For guided polar expeditions and trips**

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The purpose of these recommendations is to emphasise the necessity for all polar guides to understand the risks associated with operating a stove inside a tent. The recommendations can be used to manage and mitigate stove-related incidents.

IPGA recognises that alternative techniques, strategies and equipment exist and that it is the choice of the Polar Guide to adopt those that apply best to their own experience, knowledge and circumstances.

These recommendations are the result of an ongoing IPGA charter to document advances and developments in skills and practices.

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# INTRODUCTION

## **Why operate a stove inside a tent?**

Cooking stoves are a necessity on any polar expedition. They are commonly used inside tents, not only for snow melting and cooking and to escape harsh conditions outside, but for convenience and comfort. The habitable environment created inside a tent vestibule and/or inner tent facilitates a warm and comfortable living space which aids physical and emotional wellbeing. It can also be used to create a usable 'workspace' in the event of equipment repair or casualty treatment.

Some guides prefer to operate stoves only inside the tent vestibule (together with a foot well), some do not approve clients to operate stoves at all. This is the prerogative of the guide/guiding company however extreme weather conditions such as severe wind, cold, snow accumulation or unusable vestibule space may create circumstances where a stove must be operated inside an inner tent. Furthermore, blizzard or other conditions may prevent a guide from catering for all team members from an isolated stove source.

It is incumbent upon a guide to be fully prepared and practiced in the event they are obliged to operate a stove inside an inner tent.

## **The hazards of operating a stove inside a tent.**

Operating a stove inside a tent is not without its hazards which include risk of tent fire resulting in loss of shelter and/or severe burns, carbon monoxide (CO) poisoning, oxygen depletion and increased steam and frost. These hazards are outlined in this document, together with mitigation strategies.

## **1. TENT FEATURES**

It is recommended to consider all contingencies for operating a stove inside a tent prior to embarking on an expedition, including provision of approved equipment, access to safety tools, knowledge of safety strategies, allocation of appropriately experienced tent partners and contingencies in the event of mishap.

Polar-rated tents have a number of critical features for wind tolerance, snow loading and practicality, however they must also be safe and practical for operating a stove inside the vestibule and inner tent.

### **a. Inner tent**

Most expedition tents feature an inner tent for additional warmth and comfort. Such tents are more difficult to ventilate adequately and may minimise headroom above the stove. Inner tents must have ventilation ports adjacent to external ports to help mitigate CO accumulation and oxygen depletion.

### **b. Head clearance**

A tent should have enough clearance above the stove for both a primer and running flame to burn safely. Garments should not be hung above the stove during priming.

### **c. Vestibules**

For guides preferring to operate stoves inside a tent vestibule, the stove should be placed with adequate room between the stove and the vestibule wall/roof with unhindered access to an exit door.

### **d. Doors**

A tent should ideally have two exit points for swift ejection of a stove from the tent. All zippers must work optimally and zip sliders should always be consistently positioned for ease of accessibility in the event of an emergency.

Single-door tents are also common in which case a guide should consider alternative strategies for ejecting an uncontrollable stove. Likewise for a tent with an inoperable door.

### **e. Flame retardant additives**

Despite a trend towards chemical-free fabrics in outdoor equipment manufacturing, some tent fabrics are still being treated with flame-retardant chemicals which are proven to break down over time and can have harmful impacts on health. Guides should be mindful that:

- tents may be treated with flame retardant which may expose occupants through inhalation and/or contact
- flame-retardant additives should not be part of a strategy to mitigate fire

### **f. Ventilation**

All polar-rated tents feature vents to facilitate air flow, See Section 2.

### **g. Group tents**

Not all expedition tents have a vestibule. Some guides prefer to use a group tent with more overhead clearance and a single door from inside to outside. A group tent mitigates fire risk and CO accumulation but minimises exit options in the event of an emergency and is more prone to wind and snow loading.

## **2. VENTILATION**

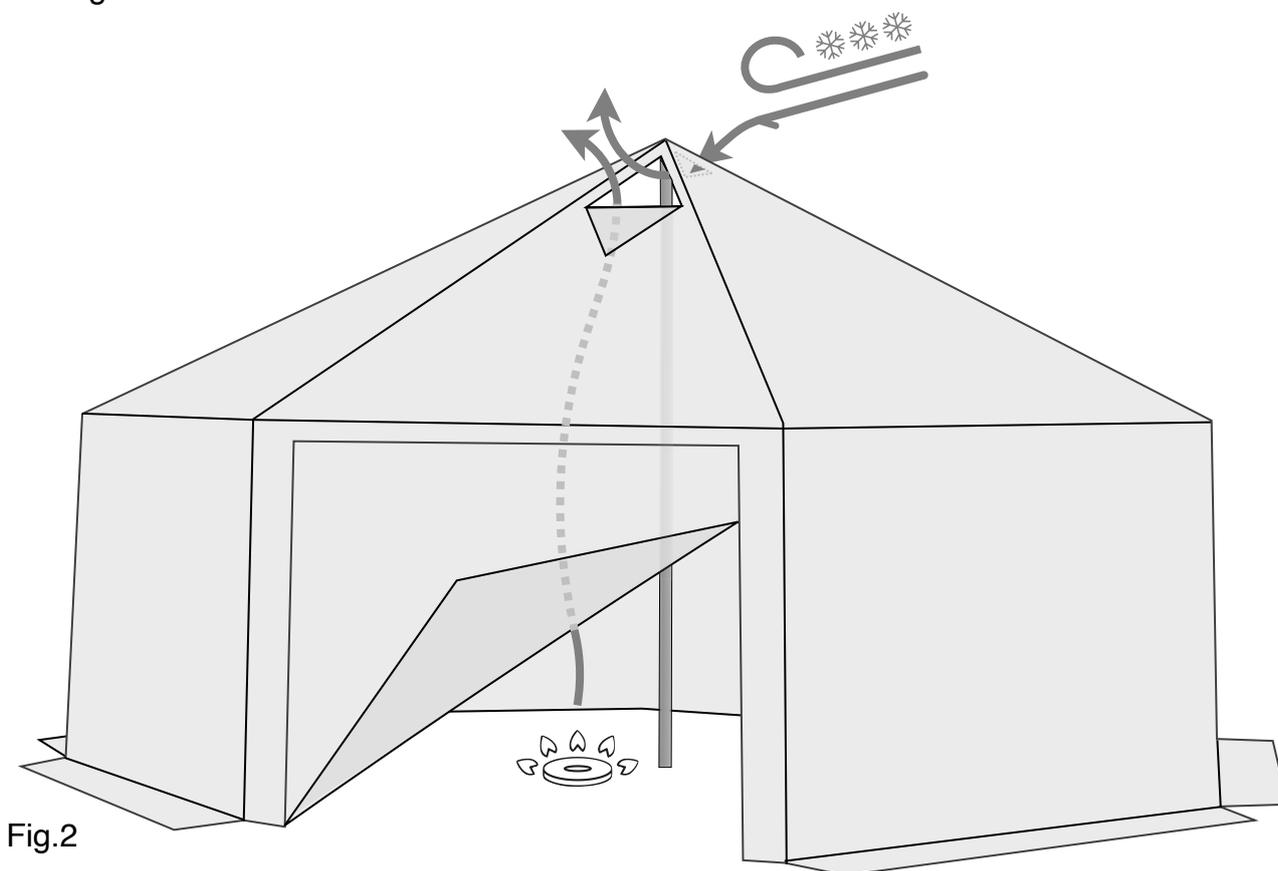
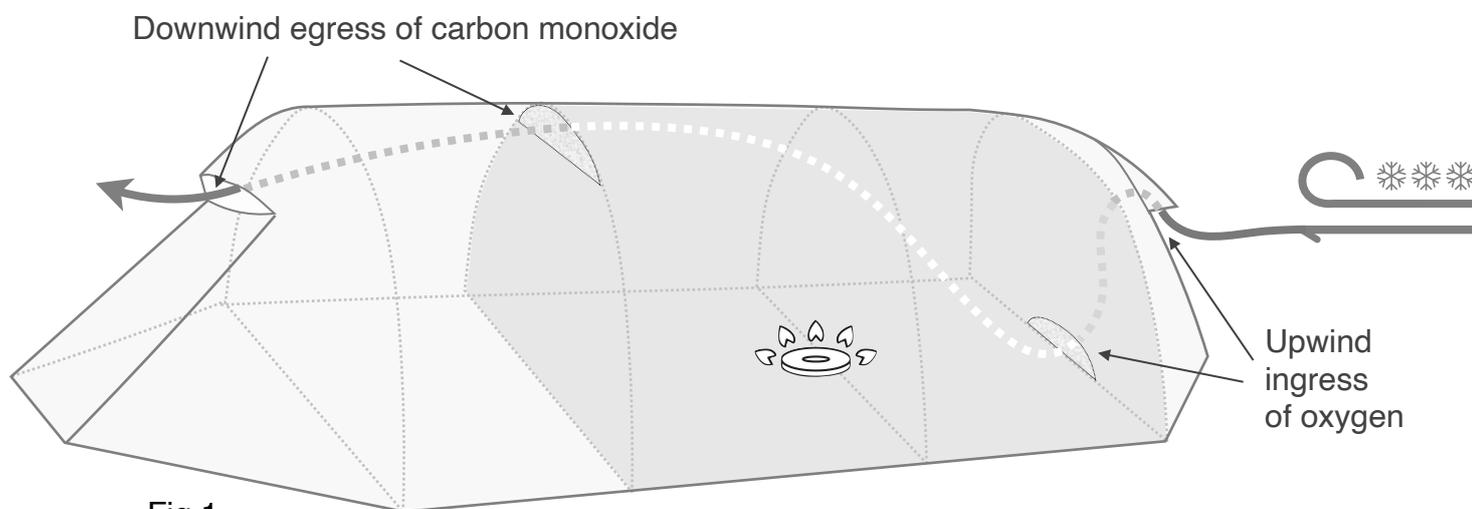
A tent must be adequately ventilated to minimise both carbon monoxide accumulation from operating stoves and moisture build-up from heating water.

### **a. Air Flow**

Adequate ventilation can be achieved by creating a flow of air through the tent, either longitudinally in the case of tunnel/dome tents (Fig.1), or vertically in the case of pyramid-style

tents with a top vent (Fig.2). This is particularly important during the initial stages of stove lighting and snow melting when the flame has not yet reached full pressure. Many polar tents use snow flaps which, when covered with snow, hinder airflow, requiring a tent to feature external windward and leeward closable mesh vents. These should be kept open if operating a stove inside.

In a longitudinal-style tent with inner, air must also flow through the tent to give the desired ventilation required when operating a stove inside. This can be achieved by utilising or creating ports in the inner tent. To mitigate carbon monoxide accumulation, the ingress oxygen port should be created in the lowest part of the upwind inner tent and the egress port should be in the highest part of the downwind inner tent (usually by unzipping the door). This may be more difficult to achieve in a single-door tent. A tent chimney in a longitudinal tent may also be beneficial.



Air flow is less critical in large-volume tents, which often have dual vents in the ceiling/roof for ingress and egress and a single downwind door. This configuration creates a vertical airflow. However these tents are used less commonly on lightweight expeditions in areas prone to severe wind.

#### **b. Wind Strength**

The strength of wind plays a significant role in tent ventilation. In strong winds air can be forced through smaller apertures (zippers included), allowing for partial closure of external and internal vents. Extra care should be taken when there is low or no wind, particularly when camped in valleys or basins, promoting accumulation of carbon monoxide and/or moisture. In such conditions doors may need to be fully opened.

#### **c. Burial**

During a severe snow loading event a tent can become buried, significantly reducing ventilation. Care should be taken to maintain internal airflow where operating a stove. This may require constant snow removal or the excavation of venting airways through the snow to the surface.

#### **d. Consequences of a poorly ventilated tent**

Operating a stove inside a poorly ventilated tent can result in a lethal accumulation of CO toxicity (see Section 5.c)

### **3. STOVES**

All variables of operating a stove inside a tent prior to embarking on an expedition should be considered, including provision of approved equipment, access to and provision of safety apparatus and strategies, distribution of appropriately experienced tent partners and contingencies in the event of problems.

#### **a. Stove types (circa 2022)**

Liquid fuel stoves are typically used in the polar environment. They are efficient, low in maintenance and relatively safe to operate but use highly combustible fuel such as white gas, unleaded auto fuel or kerosine. Many stoves can operate on a range of fuels, requiring the use of a specific jet however pump parts are prone to distortion in severe cold.

Polar guides must be skilled in the operation, diagnostics and maintenance of stoves and pumps, understand how they perform at different temperatures and be knowledgeable in all associated hazards.

The most commonly used stoves on polar expeditions are the MSR (Mountain Safety Research) XGK-EX and MSR WhisperLite International. Both are liquid fuel stoves that can operate on multiple fuels and are easily maintainable in the field.

## XGK-EX

Introduced in 1981, the MSR XGK stove has evolved through a series of updates to the current XGK-EX model which is widely regarded as the most performance-based stove.



### Pros

- Burns white gas, kerosene, unleaded auto gas and diesel
- boils more water per litre of fuel than the WhisperLite International
- pump compatible with WhisperLite International

### Cons

- louder and heavier than WhisperLite International
- does not have a simmer function

## WhisperLite International

Introduced in 1984, the WhisperLite stove has also evolved through a series of updates to the current WhisperLite International model.



### Pros

- has a longer burn time than the XGK-EX
- pump compatible with XGK-EX
- quieter and lighter than the XGK-EX
- simmer control

### Cons

- boils less water per litre of fuel than the XGK-EX
- does not burn diesel
- testing (in 2010) resulted in significantly higher levels of CO toxicity. More recent testing is required to determine if this has been lowered

## b. Fuel pump types

Like stoves, compatible MSR fuel pumps have also evolved to become more efficient and reliable. Two models of pump are available that have advantages and disadvantages under certain conditions. Both are equally prone to malfunction or damage through freezing of

Stove Model Performance (using white gas)		
	XGK-EX	WhisperLite International
Burn time per 600ml of fuel	109 minutes	155 minutes
Boil time per litre of water	3.5 minutes	3.5 minutes
Water boiled per 100ml of fuel	4.9 litres	4.4 litres
Weight (no bottle)	384g	318g

moisture in the pump, over-tightening of the control valve or an erratic plunging pump action. The plunger should always be pushed in while not in use.

A maintenance kit should accompany each stove and a corresponding Expedition Repair kit should be available for major repairs.

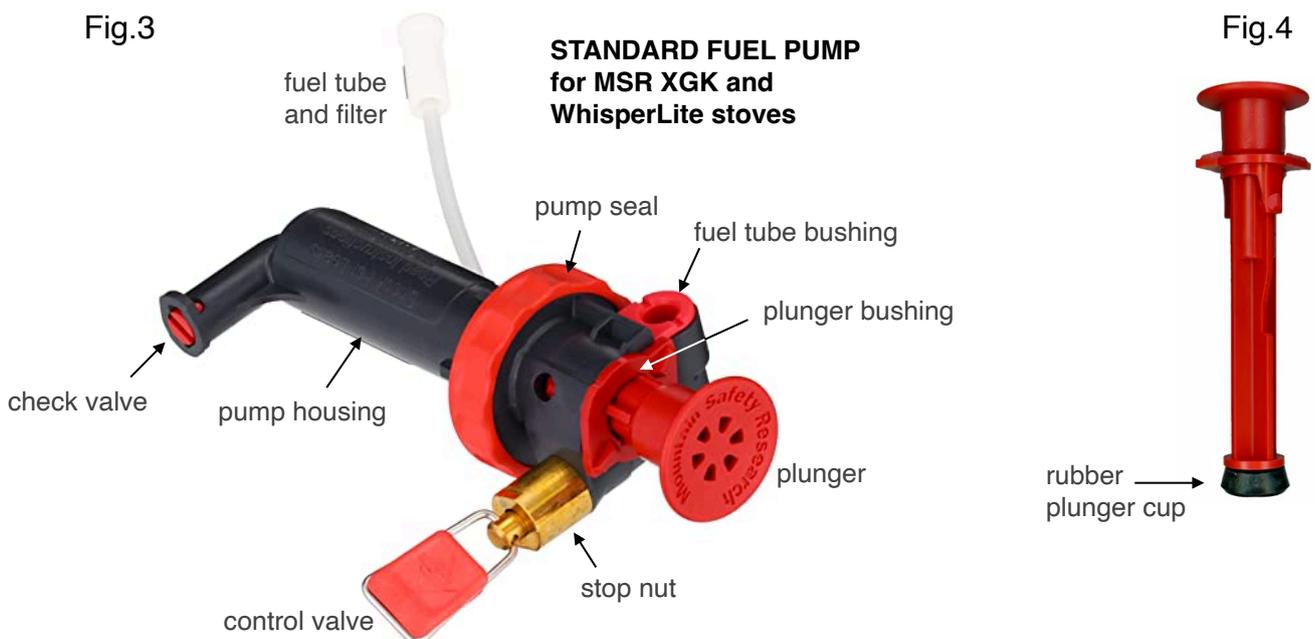
### Standard pump

The standard pump (Fig.3) has been proven to work consistently above freezing and is widely reported to be safe in some sub-zero conditions, in particular any environment where the tent benefits from solar warming. eg. Antarctic summer. As temperatures drop below -20°C the pump seal can shrink and distort, disrupting the airtight seal between pump and bottle. In such conditions fuel may leak and create a fire hazard. All tent occupants must be aware of this possibility and extinguish the stove at the first sign of leakage.

The pump will also benefit from pre-warming which can be achieved through:

- storage in an inner clothing pocket during the day (inside a zip-loc bag to prevent moisture freezing inside the pump)
- heating over a candle before use

In extreme cold, it has been reported that the pump seal can shrink, irrespective of pre-warming. Even during stove operation the seal is prone to cold distortion and brittleness as it is external to the bottle, shielded from stove warmth and in the coldest part of the tent. In this event fuel may leak from the bottle. It also features a rubber plunger cup (Fig.4) which requires regular oiling to facilitate optimum pressure when pumping. The rubber cup is prone to distortion in extreme cold.



## Arctic pump

In 2017 MSR introduced the Arctic Fuel pump (Fig.5) which has specific components that tolerate lower temperatures. The pump seal is made of a more pliable material that becomes firmer in extreme cold and resistant to shrinkage thus creating a more consistent seal between pump and bottle. It is coloured blue to distinguish it from the standard pump (red seal). All O-rings are also made from a different material and should not be interchanged with the standard pump.

It also features a leather plunger cup (Fig.6) which is less prone to malfunction in extreme cold. It has been reported that the cup requires more oiling and re-shaping to provide consistent pressure during pumping.

The Arctic pump should only be used when conditions dictate.

**ARCTIC FUEL PUMP  
for MSR XGK and  
WhisperLite stoves**



Fig.6



### Considerations:

- carry both pump models and exchange as required
- carry pumps next to the body during the day (in a waterproof bag to avoid condensation freezing into the pump)
- pre-heat pumps over a candle
- carry a full range of serviceable parts and oil
- regular maintenance and oiling

### Avoid:

- interchanging parts between pump types

### c. Fuel types

Multi-fuel stoves can operate on a range of liquid fuels including white gas, kerosine, diesel, aviation gas or unleaded auto fuel (95). All are highly combustible and must be stored in appropriate canisters (such as original plastic or metal containers in which the fuel is sold) or MSR fuel bottles. All must be handled with extreme caution.

Fuel Efficiency (MSR XGK-EX)			
FUEL TYPE	Burn time per 600ml	Boil time per litre	Water boiled per 100ml fuel
White Gas	109 minutes	3.5 minutes	4.9 litres
Kerosine	98 minutes	2.8 minutes	5.7 litres
Diesel	170 minutes	4.5 minutes	6.3 litres

MSR Jet / Fuel Compatibility				
FUEL TYPE	White Gas	Kerosine (Jet A1)	Unleaded Auto Gas (petroleum)	Diesel
GK	✓	✓	✓	⊘
X	⊘	⊘	⊘	✓

### d. Toxicity

White Gas is the least toxic stove fuel and should be used as a priority. Alternative fuels are used when white gas is not available but must be treated with caution due to varying CO emissions and effect on stove performance and longevity.

Considerations:

- white gas is the cleanest burning fuel, performs optimally and prolongs stove lifespan
- all other fuels can lead to rapid stove clogging and require more frequent jet and fuel line cleanings
- unleaded auto gas may shorten stove lifespan

Avoid:

- use of leaded fuels

### e. Stove stability

An operating stove is more stable when firmly secured to a solid base such as a board or box, typically made from a strong, light and non-combustible material. Ideally both the stove and bottle are fixed to the base though some older stoves with a solid fuel line only require one or the other to be secured. Securing the stove to its base reduces the likelihood of spillage during pumping, stove handling or any accidental movement of the stove or bottle.

## **f. Stove placement**

A stove should be positioned where accidental contact is minimised and occupants have unhindered door access in the event of a flare-up. The use of a flame guard (heat reflector) while dry-burning (to warm a tent) will mitigate contact of objects with the flame.

A fire blanket, removed from any external packaging and placed in an accessible location, should be considered when using a stove inside a tent. See Section 5a.

Considerations:

- a lip around the board perimeter will help contain fuel spills
- a removable flame guard allows ready access to the stove for operation and maintenance
- an additional board may be useful for hot cookware and for stabilising cups and thermoses

Avoid:

- any base or stove adaptations that hinder flare-up management or stove maintenance
- any base or stove adaptations that increase CO toxicity

## **g. Temperature**

Ambient temperature inside the inner tent, and the temperature of stove parts prior to lighting, play a critical role in stove functionality and safety. Fuel pumps should be adequately warmed prior to usage. Warmed seals and O-rings will minimise the likelihood of distortion and leakage.

Considerations:

- carry pumps next to the body during the day (avoiding condensation build up)
- pre-heat pumps over a candle
- use an Arctic Fuel Pump

Avoid:

- operating a cold pump in severe cold, particularly if the pump is well used

## **h. Modifications**

It is common to exchange/supplement stove apparatus to suit expeditions in a polar environment, such as swapping out heat reflectors and mounting stoves to a base.

Regardless of the modification it is important to maintain the original operational specifications of the stove manufacturer including optimum oxygen delivery to the flame and distance between flame and cookware.

## 4. COOKWARE

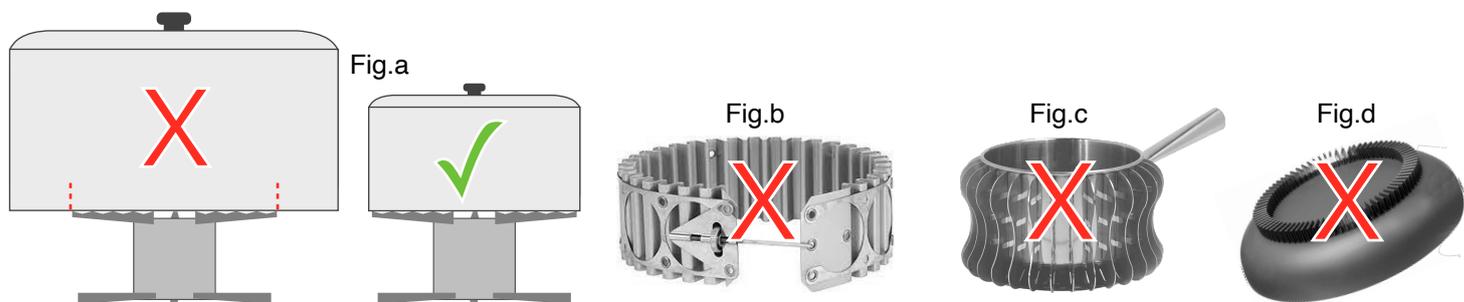
Cookware should be both efficient and safe and match the performance and specifications of the stove. Poorly matched cookware can increase CO toxicity.

Considerations:

- aluminium and titanium disperse heat more readily, reducing CO production during early stage of stove use

Avoid:

- cookware that overhangs the stove supports (Fig.a)
- heat exchangers or any other ribbed devices that promote CO toxicity (Fig.b, Fig.c)
- flux rings (fins) on underside of cookware (Fig.d)



## 5. HAZARDS

Operating a stove inside a tent is the most hazardous daily activity on a polar expedition and care must be taken to adequately mitigate risks, particularly if factors of unfamiliarity, inattention and changing weather conditions are in play. Every participant should be trained in procedures and usage and fully informed of all potential hazards.

### a. Fire

A poorly operated, monitored or maintained stove can lead to a fast-onset tent fire. Operating a stove outside is the optimum mitigation but this is rarely practical in the polar environment, particularly in severe cold and/or wind, therefore other measures must be taken to avoid and reduce the risk of fire.

Mitigation:

- operate stoves outside or in a vestibule
- light stoves inside the vestibule then place inside
- ensure every participant is trained in correct stove usage
- ensure participants are informed about hazards and to maintain vigilance while a stove is operating

- inform participants that stove safety and vigilance is the responsibility of ALL tent occupants, not just the operator
- ensure stoves are maintained and serviced to ensure optimal performance
- if used inside, ensure no garments are hung above the stove during priming
- ensure drying garments are pegged securely
- position a flame guard around the stove whenever it is in operation
- create an uncluttered and easily manageable kitchen - an additional board may be useful for hot pots/kettle and for stabilising cups and thermoses
- avoid any stove adaptations or equipment that hinder flame management or stove maintenance
- minimise movement of tent occupants

Reacting to fire:

- place a fire blanket next to each operating stove, removed from packaging
- demonstrate fire blanket usage as part of expedition preparations
- use fire blanket, pot lid or shovel to contain a large priming flame
- use a fire extinguisher (for base camp operations)
- accessible snow for dousing
- ensure doorways are clear and door zippers are accessible
- allocate roles in the event of fire
- ensure your medical kit includes burn treatments

Never:

- light a stove when spilled fuel is present
- open a fuel bottle or canister while a flame is present

## b. Bottle exchange and refilling

Bottle exchange and refilling can present as hazards if there is an active flame present, if fuel is spilled, if bottles are overfilled or if exposed fingers contact fuel or a cold-soaked fuel bottle. Exchange and refilling should be done with protected hands.

**Bottle exchange:** exchanging fuel bottles (removing an empty bottle from a stove and replacing it with a full one) should be performed in the morning before leaving the tent, while parts are warm and pliable. This task should be competently performed by every tent occupant.

**Refilling:** refilling empty bottles from canisters should be the responsibility of guides to minimise spillage, ensure correct volume and confirm all lids are closed properly.

Mitigation:

- minimise refilling of bottles from canisters by supplying 2-3 fuel bottles per stove, or by carrying all fuel in stove bottles
- ensure bottle lid O-rings have not perished
- check for leakages before lighting, look, feel and smell
- use a fuel float to precisely measure fill amount

- use of a funnel may be beneficial, particularly where original canisters do not pour optimally

Never:

- open a fuel bottle or canister while a flame is present.
- exchange a fuel bottle when a flame is present
- refill inside a tent (unless weather conditions dictate)
- overfill bottles as an air space is required for fuel expansion
- light a stove if spilled fuel is present
- keep spare fuel bottles in the inner tent
- open a pressurised bottle at eye level

### c. Carbon Monoxide poisoning

Carbon Monoxide (CO) is an odourless, tasteless, colourless, non-irritating chemical asphyxiant gas formed by the incomplete combustion of stove fuels. Compared to oxygen, CO binds with haemoglobin in red blood cells with approximately 240 times greater affinity, producing Carboxyhaemoglobin (COHb).

CO can quickly accumulate in small enclosed spaces such as a poorly-ventilated tent or snow cave, causing CO poisoning (Carboxyhaemoglobinemia). Laboratory testing and computer modelling have predicted that operating a stove inside a poorly-ventilated tent could reach a dangerous level of CO and COHb within 30 minutes.

Carbon Monoxide toxicity from stove usage inside a tent should not reach toxic levels if the tent is adequately ventilated and the stove is running dry (no pot) with a blue flame at full pressure. Toxicity will increase with any of the following:

- ventilation is reduced or stopped
- there is no wind
- any pot or kettle is placed over the flame
- stove pressure decreases
- a yellow flame forms
- use of inappropriate cookware

#### Common symptoms:

Headache	Shortness of breath	Seizures
Dizziness	Chest pain	Cardiac arrest
Weakness	Loss of hearing	Loss of consciousness or coma
Nausea and vomiting	Blurry vision	Respiratory failure
Rapid heartbeat	Disorientation	Death

Symptoms of carbon monoxide poisoning may present as other medical conditions or ailments, including flu or food poisoning.

#### Treatment:

- remove casualty from CO-rich environment (turn off stove, open doors, go outside)
- administer artificial oxygen (if available). Carboxyhemoglobin has a half-life of around 300 minutes and can be reduced to 90 minutes with administration of high flow oxygen.
- begin CPR if casualty has stopped breathing

#### Mitigation:

- avoid prolonged stove simmering
- keep stove highly pressurised
- maximise blue flame
- minimise yellow flame
- use a small diameter pot or kettle
- use white, pure fuels
- optimise CO ventilation by keeping external vents clear and using a low upwind inner port for oxygen ingress and a high downwind inner port for CO egress
- regular ventilation (does not need to be continuous)
- additional ventilation in zero wind conditions
- removing tent valances (flaps)
- regular monitoring of all tents
- use of CO detector. Options include:
  - handheld battery-operated units (must tolerate low temperature and high humidity)
  - non-battery detector - graphic sensor that changes colour

#### **d. Health effects of prolonged exposure to CO**

Although the effects on health of severe exposure to CO are well understood, the consequences of prolonged low level exposure to CO are less clear. Studies are beginning to reveal that although diagnosis of poisoning by low concentrations of CO is difficult, long term exposure to low concentrations may cause neurological damage.

It is therefore advised to minimise levels of CO inside a tent or shelter by adhering to recommendations outlined in this document.

#### **e. Oxygen depletion**

Poor ventilation during stove operation can deplete the level of oxygen in a tent. This can be hazardous however a stove flame will reduce or extinguish with inadequate oxygen, a prompt to increase ventilation. The stove may also reduce or extinguish due to inadequate supply of available oxygen to the flame (poorly designed flame guard) or depletion of stove fuel.

#### **f. Condensation**

Condensation and resultant frost inside a tent is not an immediate health hazard but can contribute to the gradual deterioration of clothing and/or equipment functionality and comfort.

Tent condensation is caused by:

- steam from heating water over a stove
- steam emitted from hot drinks and meals
- exhaled breath
- drying damp clothing
- excessive outside air humidity (rare in polar environments)

Minimising condensation and frost is a daily consideration and should be employed routinely by all tent occupants.

Mitigation:

- avoid bringing damp or frosted clothing into the tent
- remove tent frost before lighting stove
- cater sufficient fuel and time for thawing and drying
- maintain tent ventilation
- minimise water boiling
- use a kettle with spout
- add snow to water immediately after pouring heated water
- minimise steam emissions from cups, bowls, pots/kettle etc
- ensure a firm seal on pot/kettle
- select compacted snow or ice to minimise removal of lid
- clean tent thoroughly of ice and snow when de-camping

## 6. STOVE FAMILIARITY AND USAGE

Follow all usage and safety recommendations as advised by the stove manufacturer. If clients are expected to operate a stove inside a tent they should consent to doing so and be adequately trained. Providing a safe environment for all tent occupants through appropriate training is an obligation for every guide.

Considerations:

- schedule stove-lighting seminars prior to departure
- supervise initial lighting and operation of stove inside tent
- provide quick access to reference material such as instructions, troubleshooting and fire/ carbon monoxide mitigation resources

Avoid:

- pairing hesitant or unskilled tent partners

## 7. SOURCES

[msrgear.com](http://msrgear.com)

[www.wemjournal.org/](http://www.wemjournal.org/)

<https://pubmed.ncbi.nlm.nih.gov/>

[zenstoves.net](http://zenstoves.net)

<https://oem.bmj.com/content/59/10/708>

<https://www.forsvaret.no/en/organisation/centre-of-excellence-cold-weather-operations/>

[Carbon\\_monoxide\\_emissions\\_from\\_camping\\_stoves.pdf/\\_attachment/inline/ed2d9e39-d3c4-4c2a-891e-d0cfa51d68ed:65019e7f9211b2053322c7bdb76992a4cab98881/](#)

[Carbon\\_monoxide\\_emissions\\_from\\_camping\\_stoves.pdf](#)