Carbon Monoxide The Unseen Antarctic Hazard

MSc Occupational Health Dissertation

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British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Introduction

Carbon monoxide (CO) has always been a hazard of living and working in the Antarctic. While carbon monoxide is one of the most common sources of poisoning in the 'civilised' world, its dangers in extreme polar environments has never been fully understood. The dissertation, based around the venerable Primus® stove and its use in a British Antarctic Survey (BAS) pyramid tent, has shown that carbon monoxide is formed primarily from cooling or quenching of the flame and that this can be directly controlled by simple modifications to the stove and pan cooking arrangements.

CO Exposure

Sampling was carried out at fixed points within a BAS pyramid tent. These were intended to replicate head height during a variety of activities.

Sampling position	Mean concentration during standard stove trials ppm (SD)
Standing	725 (18)
Sitting	662 (28)
Lying	380 (17)

In the UK CO has been allocated both a long term (30pp 8hr TWA) and a short term (200ppm 15 min STEL) Workplace Exposure Limit.

Health effects of CO poisoning

- Headaches may begin with exposures to CO as low as 35ppm, but will consistently develop with exposures in the range of 100-200ppm.
- Loss of judgment is expected with exposures as low as 200pm with collapse occurring at concentrations as low as 300ppm.
- At 650-1000ppm, convulsions may start in 45 minutes and unconsciousness within two hours.
- At 1600ppm, death will occur in less than two hours.

These refer to long term exposures, short term exposures requiring higher concentrations to have an effect.

Flame Chemistry and CO Formation

Simplistically combustion begins with the disassociation of hydrocarbon based fuels into hydrogen and carbon. Hydrogen burns rapidly at the base of the flame maintaining the combustion process. A little further up the flame free carbon and oxygen combine to form CO. If the flame is hot enough, the CO will combust forming CO_2. However, if the flame does not reach the required temperature the hazardous CO is released.

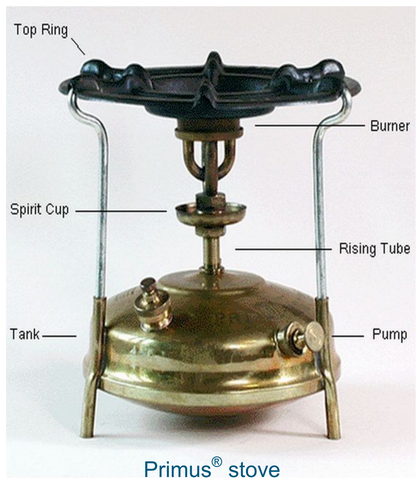
Flame quenching

The flame can be inhibited from reaching high temperatures due to oxygen depletion or by coming into contact with a cooler object such as a pan. This process is known as quenching. Any object in the flame acts as a heat sink, draining energy from the flame reaction process. In most cases, the less contact the flame has with any surface the more complete the combustion process will be and therefore a lower potential for CO release will exist.

A)

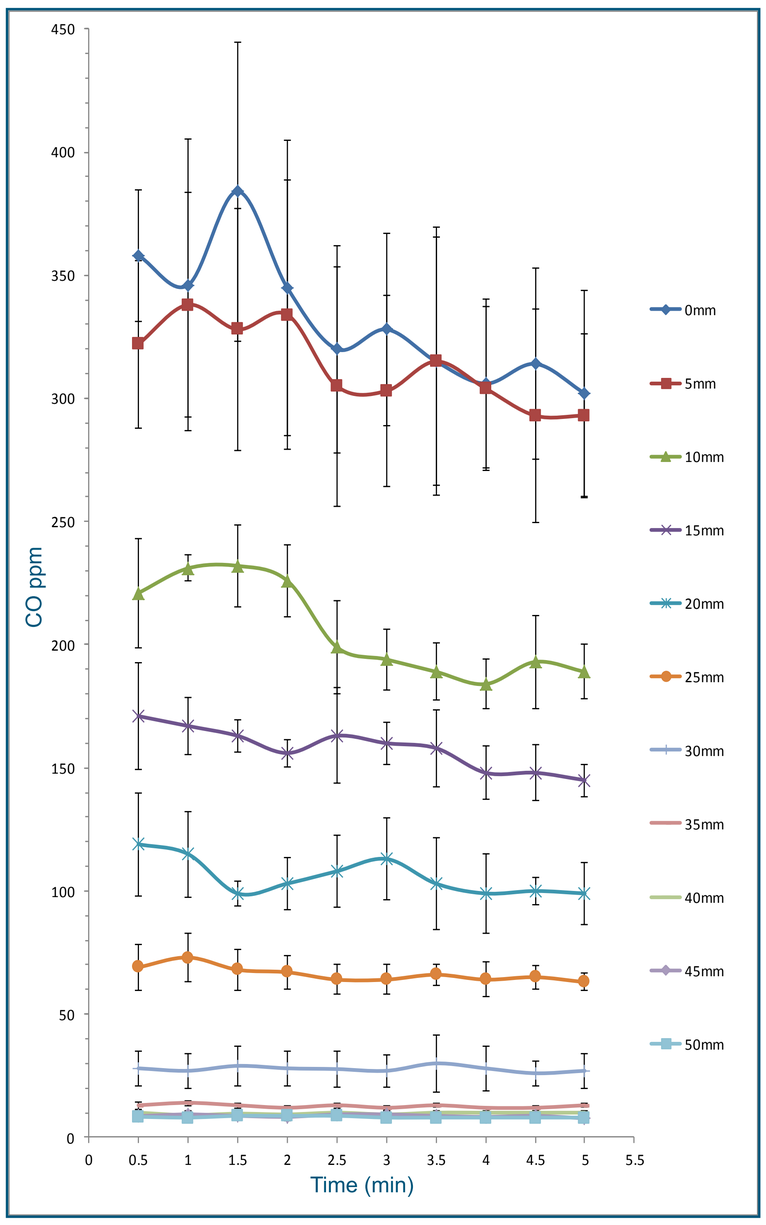
B)

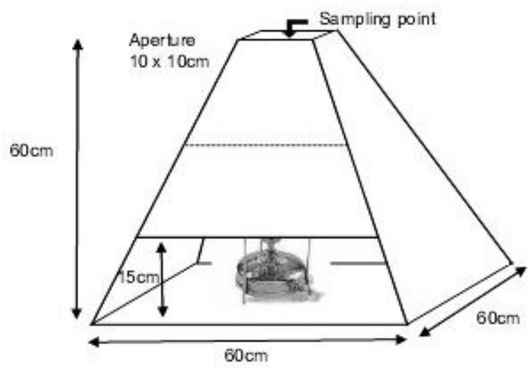
A) Quenched flame, B) Unquenched flame



Primus® stove

Results of pan height trials





Testing of the quenching effect

An enclosure was constructed in order to replicate stove tests under standard conditions. A set of adjustable stove legs were fabricated to allow pan height to be varied. Pan height was increased at 5mm increments. An increase of 30mm was found to offer the optimum compromise of reduced CO generation without drastically increasing boil time.

Pan height adjustment system installed on the Primus stove pan support

Comparison of CO exposures in pyramid tent between standard stove and modified stove

Sampling position	Mean concentration during standard stove trials ppm (SD)	Mean concentration during modified stove trials ppm (SD)
Standing	**725 (18)**	**24 (1)**
Sitting	**662 (28)**	**23 (1)**
Lying	**380 (17)**	**18 (1)**

CONCLUSIONS

- It has been shown that CO is primarily generated on a Primus stove when the flame comes into contact with a cooler object such as a pan, in a process known as quenching.
- It has been shown that it is possible to engineer out this problem to such an extent that excessive CO exposures are unlikely to exist in a pyramid tent. The optimum modification for the Primus stove is to prohibit the use of the top ring and elevate the pan an additional 30mm though the use of extended pan supports.
- It is believed that with a suitably modified stove it is unlikely that excessive CO exposures will result from external influences and poor operational practices such as poor ventilation.

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