JUNE 1972

DCIEM OPERATIONAL REPORT NO. 869

PRELIMINARY INVESTIGATION OF VARIOUS TOXIC FUMES PRODUCED BY NAPTHA FUELED EQUIPMENT

(Lieutenant) B.M. Hoffert

Operational Life Support Unit
Defence and Civil Institute of Environmental Medicine
1133 Sheppara Avenue West, P.O. Box 2000
Downsview, Ontario

DEFENCE RESEARCH BOARD --- DEPARTMENT OF NATIONAL DEFENCE ---- CANADA

CONTENTS

ABSTRACT

An attempt was made to determine the type and level of toxic fumes produced by naptha pressure stoves and lanterns under field conditions. The phenomenon of "Tent Eye" was of particular interest. The tests were done in-situ during a DREO Arctic Acclimatization Exercise at Gatineau Park. Levels of CO_2, CO, NO_2, COH_2, Olefins and hydrocarbons were measured using a Draeger apparatus; concentrations were compared to their respective Threshold Limit Values (1) to assess their toxicity. Non-toxic levels of CO_2, CO and NO_2 were determined. Concentrations of COH_2, Olefins and Hydrocarbons were too low to measure. No "Tent Eye" was experienced.

INTRODUCTION

The use of naptha pressure stoves in the Arctic is required due to the lack of substitute sources of heat in the environment and the need for a quick, portable and efficient source of heat for use by the soldier. Problems can occur when weather conditions deteriorate to a point where extensive protection from the elements is necessary to ensure survival of personnel. Improvised shelters, ie, tents, must therefore accompany the Arctic soldier.

The design of tents currently in use is such that air space is contained within, hindering transfer of air in and out of the tent. The use of stoves is necessary to further warm the internal environment of the tent, to melt snow into drinkable water and to cook food.

The fumes produced by the stoves, while not severe under normal conditions, can build up to toxic levels if proper ventilation is not maintained. However, under adverse weather conditions it is sometimes necessary to reduce ventilation to preserve heat in the tent.

"Tent Eye" can be defined as a reddening of the eyes with accompanying irritation and light sensitivity[2] observed during prolonged exposure to stove fumes in Arctic tents. Since this affliction is a constant problem to the Arctic soldier, an investigation into the cause and possible prevention of "Tent Eye" was initiated. This report describes the preliminary study concerned with the various toxic fumes produced by naptha pressure equipment. Because of the many possible variables, certain factors, eg: combustion efficiency and type of fuel, were set constant to facilitate interpretation of results.

Investigations into the cause of "Tent Eye" were done in 1952 by E.S. Gibson, F. Hunter and M.G. Whillans (2). Their results showed that the causative factors appeared to be low molecular weight organic acids, aldehydes and acrolein. Field stoves (some still in use) were tested in a cold room for CO production and "Tent Eye". Certain stoves were observed to be potential producers of toxic levels of CO and eye-irritating fumes.

The Coleman #500 and #421-C stoves and the Coleman 500 c.p. lantern were studied with respect to the production of eye-irritating fumes. At present the Coleman #500 stove and 500 c.p. lantern are being used by some units in the Arctic. Personnel are also using the Coleman #421-C stoves. This stove, however, is their own personal equipment and not Service issue. Previous work (2) has shown that the Coleman #500 did not appear to cause eye irritation or to produce toxic levels of carbon monoxide even when the combustion efficiency was reduced.

Experiments were carried out in an Arctic 5-man tent erected in Gatineau Park, near Ottawa, at temperatures of 10° to 20°F and winds of 0 - 5 mph. The tests were of one day duration and were restricted due to operational requirements of the overall exercise.

METHOD AND PROCEDURE

(1) Equipment

(a) The types of equipment used were:

(i) The Coleman #500 stove, a standard item of issue by the CAF.

(ii) The Coleman #421-C stove, a personal item not purchased or issued by the CAF.

(iii) The Coleman 500 c.p. lantern, a standard item of issue by the CAF.

(b) Naptha gasoline 3-GP-27 was used, a pure straight-chain petroleum derivative free from any impurities including lead or other anti-knock compounds, which on burning should not produce any objectionable odours.

(c) CAF Arctic 5-man tent, measuring 92" x 92" x 141" with a pentagonal base 41" high and an apex 100" high. Total volume was 272 cu ft. Air permeability for the liner was a maximum of 26 cu ft/sq ft/min using Test Method #36(3) and for the outer material was 60 cu ft/sq ft/min using Test Method #36.

(d) A complete Draeger Kit Model 19/31 with assorted detector tubes was used to test for toxic fumes. Types and ranges of tubes were as follows:

	TYPE	RANGE
(i)	Carbon Dioxide 0.1%	0.1 - 6% by volume
(ii)	Carbon Monoxide 5/c	5 - 700 ppm
(iii)	Formaldehyde 0.002	2 - 40 ppm (0.002 - 0.05 mg/1)
(iv)	Hydrocarbons 0.1%	0.1 - 1% by volume
(v)	Nitrous Fumes 0.5/a	0.5 - 10 ppm (Nitrogen Dioxide)
(vi)	Olefins 0.05%/a	1 - 55 mg/1

(e) 500 cu. in. evacuated D-2 cylinders

TESTS

Tests were carried out primarily to produce conditions under which toxic fumes were likely to occur. The number of stoves operating and the amount of ventilation were varied in the tests. Equilibrium was assumed to be present 20 minutes after a change in conditions. Duplicate samples were taken to ensure equilibrium was reached. Readings were taken at head level (6 ft) and sitting level (3 ft). The D-2 cylinders were opened immediately after Test #7 at head level.

Test #1 was a test at sitting level to analyse the fumes produced by the Coleman 500 c.p. lantern. The ambient temperature was recorded and CO and CO_2 levels were measured. Number of occupants in the tent was three and vents were open.

Test #2 was done at sitting level with the Coleman 500 c.p. lantern and the Coleman #500 stove on. The ambient temperature was recorded and CO, CO_2, Formaldhyde, Hydrocarbons, Olefins and Nitrous Fumes levels were measured. Vents were closed and there was only one occupant.

Test #3 was similar to Test #2, but done at head level.

Test #4 was done at sitting level with the Coleman lantern and #500 and #421-C stoves on. The ambient temperature was recorded and CO, CO_2, Formaldehyde, Hydrocarbons, Olefins and Nitrous fumes levels were measured. Vents were open and there was only one occupant.

Test #5 was similar to Test #4, but done at head level.

Test #6 was done at sitting level with the Coleman lantern, #500 and #421-C stoves on. The ambient temperature was recorded and CO, CO_2, Formaldehyde, Hydrocarbons, Olefins and Nitrous fumes levels were measured. Vents were closed and there were two occupants.

Test #7 was similar to Test #6 but done at head level.

RESULTS

The following table compiles the results obtained in Tests 1 - 7 as described in the Method:

RESULTS OF DRAEGER TESTS

TEST NO.	CO(ppm) ±10%	CO %±10% BY VOLUME	NITROUS FUMES (ppm)±10%	TEMPERATURE
1 a.	0	0.17	0	
b.	0	0.17	0	
Average	0	0.17	0	3.3°C
2 a.	8	0.40	0.7	
b.	2	0.40	0.7	
Average	5	0.40	0.7	14.4°C
3 a.	5	0.47	2.0	
b.	3	0.45	2.0	
Average	4	0.46	2.0	32°C
4 a.	6	0.50	1.5	
b.	10	0.50	1.25	
Average	8	0.50	1.38	24°C
5 a.	5	0.55	2.0	
b.	6	0.50	2.0	
Average	5.5	0.525	2.0	40.5°C
6 a.	7	0.61	2.0	
b.	7	0.75	2.0	
Average	7	0.68	2.0	35°C
7 a.	8	0.90	3.0	
b.	8	0.90	2.5	
Average	8	0.90	2.75	52°C

Formaldehyde, Hydrocarbons and Olefins results were NIL.

The D-2 cylinder contents were analysed using a Beckman IR4, an infra red spectrophotometer with a gas cell having a path length of 10m. Due to insufficient quantity of gaseous sample to obtain the standard operating pressure of 140 psi, sensitivity was low, although a faint hydrocarbon peak and a carbon dioxide peak equivalent to approximately 5200 ppm were detected.

Formaldehyde, Hydrocarbons and Olefins concentrations were too low to be measured with the detector tube although the IR4 detected a trace amount of Hydrocarbons. Minimum detection levels were 2 ppm, 0.1 volume %, and 1 mg/l respectively.

Although the tent became uncomfortably hot at head level no eye irritation was experienced. There was, however, a slight aromatic odour, possibly indicating the presence of some hydrocarbons.

DISCUSSION

According to the Draeger tests the levels of carbon dioxide rose to 9000 ppm. The sample tested with the IR4 contained 5200 ppm. Although unlikely, this discrepancy could have been due to air leaking into the evacuated cylinder through a faulty valve lowering the carbon dioxide level. Another possibility was malfunctioning Draeger tubes. The hazards of the highest value (9000 ppm) were considered in order to estimate the maximum effect carbon dioxide would have on personnel in this situation. 9000 ppm presents a toxicological hazard only if the oxygen supply is inadequate (3). Since this is unlikely to occur in an arctic tent, the maximum value at head level of 9000 ppm appears to be safe (carbon dioxide by itself is unable to produce eye irritation (3)).

The levels of carbon monoxide and nitrous fumes, 8 ppm and 3.0 ppm respectively, were too low to comprise a toxicological danger (3).

Both the Draeger detector and the IR4 were not sensitive enough to conclusively determine the presence of Formaldehyde, Hydrocarbons and Olefins. A high-resolution, high-sensitivity IR might successfully qualitate hydrocarbons in the ppm range.

CONCLUSIONS

It was concluded that with adequate ventilation the use of the tested stoves in the arctic five man tent is not likely to present a toxicological hazard. It must be noted, however, that conditions which would reduce the combustion efficiency of the stoves, ie: melting snow, boiling water or cooking food, were not tested. These conditions have been shown to cause the greatest severity of eye irritation (1).

RECOMMENDATIONS

Although the Coleman #500 and #421-C stoves appear to present no toxicological hazards when used in the arctic five man tent under normal conditions, it is recommended that more extensive tests be made in a controlled situation.

The Draeger equipment is not always sensitive enough to accurately measure threshold values of some toxic materials. It is suggested that the instrument be used as a backup or a check of results obtained from the analysis of the air by an infra red spectrophotometer. This analysis can

be done by filling evacuated cylinders at the test site and analysing the air in the cylinder back at the laboratory.

REFERENCES

1. Documentation of the Threshold Limit Values by the American Conference of Governmental Industrial Hygienists, Third Edition, 1971.

2. Factors Causing Eye Irritating Fumes and Carbon Monoxide From Gasoline Pressure Stoves, by E.S. Gibson, F. Hunter and M.G. Whillans, Physiology Section, DRML, DRB Project No. D-49-69-10-03.

3. Canadian Government Standards Board (CGSB) Specification 4-GP2.