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ABSTRACT

Twenty-one ten-man acrtic tents were examined during a winter infantry exercise at Fort Churchill, Churchill, Manitoba. Interior temperatures, relative humidities and carbon monoxide levels are reported. Some observations regarding the provision of hot water and heated rations are included.

RÉSUMÉ

On a examiné vingt et une tentes arctiques de dix hommes lors d'un exercise d'infanterie qui s'est déroulé en hiver à Fort Churchill, Churchill (Manitoba). Les rapports traitent des températures, des niveaux d'humidité relative et des concentrations d'oxyde de carbone. On y inclut quelques observations sur la fourniture d'eau chaude et de la nourriture chaude.

INTRODUCTION

An examination of the microclimate of a standard ten-man arctic tent was initiated in 1975. Some preliminary studies were carried out in February of 1976 at Fort Churchill, Churchill, Manitoba. The results of these studies are reported in detail elsewhere (1). Briefly, peak-to-floor temperature differences on the order of 60^{0}C were characteristic of a tent heated by open-flame combustion stoves. The relative humidity was low. No significant levels of carbon monoxide were measured when the stoves were used solely for heating the tent. Unless some provision was made for the entry of cold air at low levëls in the tent, ventilation rates were low. To assist in quantifying the results of all the tests conducted, a living zone was defined at that colume of the tent between heights 0.15m and 0.85 m, and from the pole to a radial distance of 1.6m. Living Zone Average Temperatures (LZAT) were measured under various weather and heating conditions. It was estimated that the minimum LZAT required for comfort was 16^{0}C.

As the above results were obtained under controlled and somewhat artifical conditions, it was felt that additional measurements should be obtained under operational conditions. Therefore, measurements were taken on tents used by C company 1 RCR during Exercise Passage North near Churchill, Manitoba during February 1977. The results of these measurements are presented in this report. As well, some observations of the ventilation of tents and the systems used for heating water are presented.

PROCEDURES AND EQUIPMENT

Standard ten-man arctic tents were used during the exercise. All tents except one had liners made of closely woven Saran with a low air permeability of 4 $\ell/m^2/sec$. The one exception employed a liner made of Vinyon with an open weave and air permeability of 1800 $\ell/m^2/sec$. Due to the separate movements of individual platoons, not all of the tents were available each evening. Twenty-one sets of measurements were taken as part of the study. Measurements were made on the fourth, fifth and sixth evenings of the exercise between 2000 and 2300 hours. Ambient temperatures during the three evenings were -13^{0}C, -24^{0}C and -17^{0}C, respectively.

Temperature

Both exterior and interior temperatures were measured with a Fisher all-metal thermometer with a range of from $-50^{0}C$ to $100^{0}C$. The thermometer was graduated every $2^{0}C$, with a guaranteed accuracy of $0.75^{0}C$. An examination of data from previous testing (1) indicated that an estimate of the LZAT could be obtained by substracting $6^{0}C$ from the temperature obtained at the top of the first section of the telescoping tent pole. This height (0.95m) was chosen as it could be conveniently located in each tent. The data used to arrive at this figure are presented in Table I. These data were obtained in a tent with a highly permeable Vinyon liner. The effect of the Saran liner, which is windproof, on the ventilation and temperature distribution of the tent was not determined.

Relative Humidity

A Bacharach sling psychrometer was used to measure wet- and dry-bulb temperatures at two points in each tent. The two points were situated approximately 0.15 m below each drying line at a point at least 2 m from a Coleman 421-C two-burner camp stove which was situated below the open cookhole.

TABLE I

Estimating LZAT From Pole Temperature (t_p)

Heater	t_p at 0.95m height (^{0}C)	LZAT[a] (^{0}C)	t_p - LZAT (^{0}C)
Lantern and 421-C	29 ± 2[b]	23	6 ± 2
Lantern and 421-C	24 ± 2	19	5 ± 2
Lantern and 421-C	39 ± 2	32	7 ± 2
Lantern and 421-C	32 ± 2	27	5 ± 2
Two M1950 Mountain	34 ± 2	28	6 ± 2
		Average	6 ± 2

a Temperatures are in degrees Celcius above ambient.

b Estimated error.

Carbon Monoxide

A Drager Multi-Gas Detector, Model 31, was used to sample CO levels at a height of about 1 m in each tent.

RESULTS AND DISCUSSION

The average conditions encountered in tents during Exercise Passage North are presented in Table II. For reference purposes, the data from which these averages were obtained are given in Table III (Appendix A).

During the three evenings the average LZAT was 15 ± 4°C. Only one tent group voiced concern about the interior tent temperature. Surprisingly, in this tent the actual LZAT was 26 ± 2°C and all vents were closed. This was the warmest tent encountered on the exercise. In fact, it was distinctly uncomfortable to stand in this tent because of the high temperature in the upper levels.

Coffey and Ross (2) surveyed tent temperatures during several exercises near Fort Churchill in the winter of 1953-54. On only three occasions did the occupants feel uncomfortably cool. In two of these cases, the temperature at the tent pole at 0.91 m was 12 °C, and the third, 8 °C. These temperatures translate approximately to living zone average temperatures of 6°C and 2°C.

It was observed that the stoves were not used to their maximum level of heat output during Exercise Passage North. The most commonly used combination of heat sources was two M1950 Mountain stoves, one burner of a Coleman two-burner stove, and a lantern. Extra heating could be obtained easily by lighting the second burner of the Coleman, stove, a procedure which may easily and safely be carried out without leaving the tent. In all cases the snow floors of the tents were icy and wet.

Interestingly, the tent with the porous Vinyon liner had higher interior temperatures than the tents with the impermeable liner, on the night it was surveyed. This may have been due to a lower ventilation rate, or higher heat power from the stoves.

Humidity

The relative humidity in the tents was substantially higher than that measured in the preliminary study (1). It had been estimated that the average dew point of the air in an occupied tent with 5 kilowatts of heating would be about 2°C, based on measurements of dew point in a tent with an air-permeable Vinyon liner. The dew point at the lower drying line was a reasonable estimate of the average dew point throughout the tent. In the present study, the average dew point at the lower drying line was 13°C. The difference is probably due to an increase in the supply of water vapour rather than a decrease in the dehumidification efficiency of the tent due to the difference in liners. The observation that the tent with the Vinyon liner had a dew point of 14°C at the lower drying line tends to support this conclusion. Additional sources of water vapour include pots of heated water, drying clothing, and possibly the melting floor. The relative contribution

TABLE II

Average Conditions Found In Tents During Exercise Passage North

	Ambient Temp (°C)	LZAT[a] (°C)	Upper Drying Line Temp (°C)	Upper Drying Line Rel Hum (%)	Upper Drying Line Dew Pt (°C)	Lower Drying Line Temp (°C)	Lower Drying Line Rel Hum (%)	Lower Drying Line Dew Pt (°C)	CO Con. (ppm)
	- 13	20 ± 3	30 ± 5.4[b]	41 ± 9[b]	13 ± 1.5[b]	26 ± 5.1	51 ± 13	15 ± 2.5	18 ± 17[b]
	- 24	13 ± 4	26 ± 6.8	46 ± 14	13 ± 2.4	22 ± 5.9	55 ± 13	12 ± 3	37 ± 30
	- 17	14 ± 2	30 ± 4.6	37 ± 3	14 ± 5.1	26 ± 3.8	46 ± 5	12 ± 3.7	
average	- 20 ± 5	15 ± 4	28 ± 6[b]	42 ± 11[b]	13 ± 2.9[b]	24 ± 5.4	52 ± 12	13 ± 3.1	30 ± 29[b]

[a] Estimated by subtracting 6°C ± 2°C from the temperature at the top of the first section of the tent pole.

[b] Value for tent with vents closed not used in average.

of these sources to the overall humidity in the tent was not established.

In the tents examined, frost buildup was limited to vertical sections of the tent wall. In one case, it extended to 0.30 m below the lower drying line. In two cases, frost could be found at the lower drying line where the liner and outer wall were forced into contact. Similar patches could be seen between the drying lines, caused by a poorly fitting liner.

Ventilation

For the first two evenings, the tents were pitched on hard and shallow snow on the open tundra. This made it more difficult to completely wind-proof the base of the tent, as the hard snow could not be shovelled onto the flaps of the tent in a powdery form, but tended to break into large pieces. As the tents were in the same position for two days, depressions formed under the doors allowing an inflow of cold air. Two tents had door zippers which were only partially operative. Stove-pipe holes were open at all times. As a result, on these two evenings at least, the ventilation rates were probably somewhat higher than in the tent which was used for the previous measurements (1) as the base of that tent was carefully sealed, and the stove hole was closed. The higher ventilation rate was acceptable because of the relatively mild conditions and the increased heat power.

On the third evening, the encampment was located inside the tree-line in deep, soft snow. The situation was tactical, and little outdoor movement was permitted. As a consequence the tents were better sealed, and the door was opened less often, probably resulting in a lower ventilation rate than on the first two evenings.

Carbon Monoxide

Carbon monoxide levels were measured during two evenings only. In tents in which water was being heated or snow melted, the concentration varied over a wide range, readings from 10 to 90 ppm being obtained. When the stoves were being used solely for space heating, the average CO concentration was 8 ± 2 ppm. It has been shown that Coleman two-burner stoves and the M1950 Mountain stoves do not produce CO when used for space heating, but do produce CO when used to heat pots of water or snow (3). As 14 of the 21 tent groups were heating water throughout the time they were visited, it can be estimated that water is being heated for two-thirds of the time that a tent is occupied during the evening.

As previously noted, the ventilation of these tents on the first two evenings may have been better than on the third when CO levels were not measured. The threshold limiting value for an 8-hour exposure to CO was formerly 50 ppm. Because of recent doubt about the long-term effect of exposure to low levels of CO, the U.S. Environmental Protection Agency has recommended 9 ppm for 8 hours, and 35 ppm over 1 hour (4) as the exposure limits. The eight-hour maximum was equalled or exceeded in 12 of 16 tents, the one-hour maximum was exceeded in 3 cases. The highest level of carbon monoxide measured was 90 ppm.

Water Heating

The inadequacy of the 3-quart pot as a snow melter was evidenced by the presence, in most tent groups, of billy cans with wire bails, to supplement the pot. Using three stoves and three containers reduces the time required to produce a sufficient quantity of hot water from snow for 8 to 10 men. As the pot is uninsulated, the water cools quickly if it is removed from the stove. It is therefore usually left on a low flame or just to one side of the burner of the Coleman stove. This results in a continuous production of CO and other unburned hydrocarbons, as the flame is quenched.

Fuel Economy

In the early part of this century, long, unsupported exploring trips were undertaken on a daily fuel ration of 0.11 ℓ/man (5). Fuel was used only for heating water and food in a Nansen cooker, which concentrated the heat from the stove so that over 90% of the theoretical heat content of the fuel was used to heat its contents (6). Much discomfort and hardship resulted from this fuel ration, as clothing could not be dried, and tents were never heated. By 1930, the importance of space heating to dry clothing and equipment began to be realized. The Nansen cooker was abandoned, and tents were heated for a few hours in the morning and evening. The daily fuel ration was increased to 0.32 ℓ/man (7). The daily fuel ration of the Canadian Forces on arctic exercise is approximately 1.1 ℓ/man. As heat is required throughout the night to warm sleeping soldiers and to warm sentries (which must be changed as often as every fifteen minutes in cold weather), tents are heated for 20 out of 24 hours. The average patrol lasts less than 4 hours (8).

Changes in tent group routine could result in considerable fuel savings. A prerequisite to any change is improvement of the clothing and sleeping systems. It is likely that greater fuel savings could be realized through this means than by any easily foreseeable changes in tent or heater design.

CONCLUSIONS

1. The average temperature of the living zone of the tent in cold weather was 14 ± 4°C. This was sufficient under the prevailing conditions to provide comfort without the need of a parka, and in many cases, without the need of a sweater.

2. The heated tents were found to have a drying atmosphere for clothing, at the upper and lower drying lines at temperatures down to -24°C, under normal winter living conditions.

3. Carbon monoxide concentrations as high as 90 ppm were measured when the stoves were being used to heat water.

4. The current issue pot and stove combination is a slow and inefficient system for production of hot water from snow.

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TABLE III

Ambient (°C)	Pole (°C)	Lower Drying Line Dry Bulb (°C)	Lower Drying Line R.H. (%)	Lower Drying Line Dew (°C)	Upper Drying Line Dry Bulb (°C)	Upper Drying Line R.H. (%)	Upper Drying Line Dew (°C)	CO ppm	Heating[a]
- 13	26	32	44	18	-	-	-	5	CML
	24	25	60	17	30	40	15	50	CML
	32	-	-	-	38	42	23	7	CML[b]
	24	24	55	14	27	48	15	7	CML
	-	19	64	12	23	52	13	25	C3ML
	23	24	55	14	27	40	12	10	2CL
	29	32	29	12	34	26	12	10	C2ML
- 24	14	20	48	8	22	43	8	90	C2ML
	18	23	64	16	25	49	13	30	C2ML
	24	26	57	17	29	47	16	7	C2ML
	15	16	73	12	20	64	13	30	2CML
	16	18	62	11	22	58	13	10	2CML
	24	26	44	13	29	37	13	80	C3ML
	17	25	41	11	28	35	11	10	C2ML
	26	31	35	14	41	21	15	10	C2ML[c]
	13	12	70	9	19	62	11	10	C2ML
- 17	20	24	39	9	27	34	9	-	C2ML
	22	28	49	16	33	38	17	-	C2ML
	20	22	51	14	26	39	11	-	2C2ML
	18	26	44	13	29	34	12	-	C2ML
	21	32	46	19	37	39	21	-	C2ML

[a] C - a burner of the Coleman two-burner stove
M - a M1950 Mountain stove
L - a lantern
For example, 2C2ML stands for two burners of a Coleman stove, two Mountain stoves, and one lantern.

[b] The stove hole and all vents of this tent were closed.

[c] This tent had a permeable Vinyon liner.

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