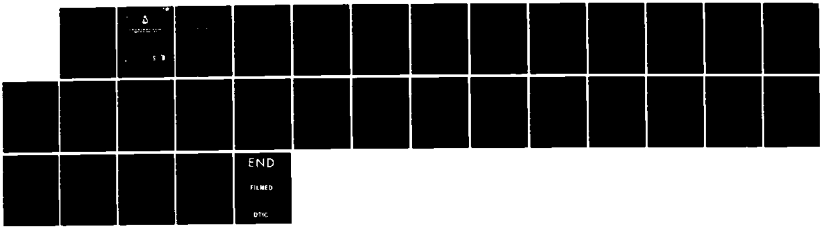
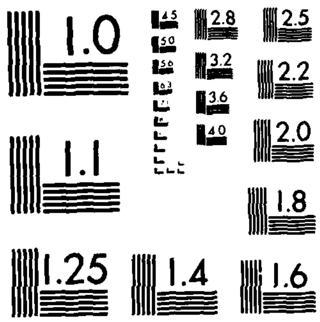
AD-A151 755 AN INITIAL INVESTIGATION OF THE HEATING PROPERTIES OF CONICAL TENTS(U) DEFENCE RESEARCH ESTABLISHMENT OTTAWA (ONTARIO) B CAIN JUN 84 DREO-TN-83-32 1/1

UNCLASSIFIED F/G 13/13 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

National Defence Défense nationale

AD-A151 755

AN INITIAL INVESTIGATION OF THE HEATING PROPERTIES OF CONICAL TENTS

by

Brad Cain

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 83-32

Canadä

June 1984
Ottawa

National Defence Défense nationale

AN INITIAL INVESTIGATION OF THE HEATING PROPERTIES OF CONICAL TENTS

by

Brad Cain
Environmental Protection Section
Protective Sciences Division

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 83-32

PCN
14B10

June 1984
Ottawa

ABSTRACT

The following aspects of the heating of the CF 10 Man Arctic Tent were examined: the effect of lining the tent; the time response of the internal tent temperature to a step increase in heat transfer to the tent; radiative heat transfer to the tent and convective heat loss from the tent. The internal tent temperatures were found to be significantly affected by the provision of a tent liner which increased the relative temperature per unit of heat input by 60% to 100%. Change in the radiative heat transfer to the tent also changed the internal tent temperature significantly. A hypothesis on the circulation pattern within the tent was proposed to explain the temperature distribution within the tent. The thermal response of these tents were found to be exponential with time constants of 1000 s and 1800 s for unlined and lined tents respectively. Internal tent temperatures of heated tents were found to remain approximately constant for wind velocities less than 5 m/s.

RÉSUMÉ

La tente dix places pour l'Arctique des F.C. a été examinée sous les aspects suivants: effet d'une doublure; temps de réponse de la température interne à un transfert de chaleur dans la tente par étapes; apport radiatif et perte convective de chaleur. La présence d'une doublure influe beaucoup sur la température interne dans la tente, dont l'augmentation relative est alors de 60 à 100 % par unité de chaleur fournie. La variation de l'apport radiatif de chaleur est aussi un facteur déterminant. Un modèle de circulation de la chaleur dans la tente est proposé pour expliquer la répartition des températures. La réponse thermique de ces tentes est une exponentielle dont la constante de temps passe de 1000 s à 1800 s selon que la tente est simple ou doublée. La température dans une tente chauffée varie peu sous des vents de moins de 5 m/s.

1.0 INTRODUCTION

Very few comprehensive scientific investigations of tentage have been published, and these have dealt mainly with the structural properties of tentage. Much of what is known about tents is specific to the type of tent studied and generalized theories are lacking.

A project was therefore undertaken to develop a scientific basis for the design of tentage. The first objective of this project is to identify and quantify the mechanisms of importance in the heating and ventilation of tentage. The ultimate goal of this portion of the project is to produce a manageable, scientifically sound algorithm which can be used to predict accurately the heat and ventilation properties of tents without having to perform extensive field tests.

In general, heat may be transferred to or from a tent by any or all of the following mechanisms:

(1) Conduction through the air, the tent walls and the floor;
(2) Convection inside and outside of the tent;
(3) Radiation to the tent walls and floor from objects both inside and outside of the tent;
(4) Ventilation;
(5) Evaporation of water from the tent walls and roof.

The relative importance of each method of heat transfer is not yet fully known. It is expected that convection, radiation and ventilation are responsible for the bulk of the heat transferred from a tent.

It is hypothesized that tents derive much of their thermal resistance from the boundary layers of air which form on the tent membrane or liner surface. A boundary layer is a region of the flowing fluid (in this case air) which, because of vicosity effects near a solid surface, moves at a lower velocity than the main fluid body. In the boundary layer region, convection is impeded by the solid surface which in turn reduces the rate at which heat can be transferred through the fluid. It has been found for air that a thermal boundary layer exists which is of approximately the same thickness as the dynamic boundary layer [1]. Because of the thinness of the fabric, the intrinsic thermal resistance of the fabric is usually negligible compared with the thermal resistance of the boundary layer.

This report is the first of several proposed reports to discuss the aspects of tent heating and ventilation. The tents used for this report were CF 10-Man Arctic Tents. While the data presented will be peculiar to these tents, the concepts discussed will be generally applicable to all tents.

2.0 EXPERIMENTAL APPARATUS

The tents were tested at the DREO Tent Research Facility. Temperatures were determined by using arrays of five thermistors (YSI 44004) installed along the centre-pole of each tent. Equation 1 was used to convert the measured thermistor resistances to temperatures. The three empirical constants were determined from the manufacturer's data provided with the thermistors for temperatures of -20, 0 and 20°C. The calculated temperatures agree with the tabulated values to within 0.02°C over the range -40 to 40°C. This was deemed to be sufficiently accurate as the reported precision of the thermistors is 0.2°C.

$$T = 1/(A + B\ln(R) + C(\ln(R))^3) - 273.16 \qquad (1)$$

where: T = temperature in degrees Celsius
R = thermistor resistance in Ohms
ln = natural logarithm base "e"
A = 1.4649×10^{-3}
B = 2.3879×10^{-4}
C = 9.9321×10^{-8}

Data were collected using a HP3054A Data Acquisition System which was controlled by a HP85A desktop computer and then stored on a HP9895 Flexible Disc Drive. The HP3054 scanner was used in a "Single Ended" mode with common guard and low leads for all thermistors. A 100 micro-ampere current source was used to drive the thermistors.

The CF 10-Man Arctic tents used in this study were nominally 259 cm tall, with a floor area of 16.26 sq.m. A vertical wall extends upward 61 cm from the floor and meets a five-sided conical roof which extends to the tent apex. The membrane is a cotton/nylon Oxford cloth which weighs 181 gm/sq.m. Some of the tents were equipped with a tent liner consisting of a single layer of material hung from the tent membrane. A polyvinyl chloride (Nomex) liner was used in all but one instance. A new material made of polypropylene (Evolution 3) was used to line the tent in this case. A schematic of the tents showing the nominal dimensions is given in Figure 1. A schedule of thermistor positions used in this study is given in Table 1.

Measurement of the wind speed was made with a Weathertronics "Low Threshold Wind Speed Indicator". Data were collected and averaged over the interval between thermistor readings. Heat was supplied to the tents by electric convection heaters which had a nominal heat output of 1300 Watts.

A 15 cm "Globe Thermometer" [2] was used to provide qualitative information on the radiant heat transfer to the tents. The Globe Thermometer gives a measure of the heat transfer by radiation. It is a hollow, black sphere suspended in an open area. The internal air temperature of the sphere is measured. Unfortunately, the globe temperature is a function of the ambient temperature, the mean background temperature of the ground and sky, the wind velocity, the sphere diameter, and the emissivity of the sphere. The Globe Thermometer gives only a qualitative indication of the importance of radiant heat transfer which affects the heating of a tent.

3.0 DATA ANALYSIS

The data are presented both as "the relative temperature" and as "the relative temperature per watt of heat released in the tent", whichever is the more informative. The local relative temperature (Ti) is defined as the difference between the air temperature in the tent at position "i", (T), and the ambient air temperature, (Ta),:

$$Ti = T - Ta \qquad (2)$$

The mean relative temperature per watt of heat input (T') for the tent is defined as the integral of the relative temperature rise over a volume of the tent divided by the heat input (Q) and the volume of the tent (V):

$$T' = \int (T - Ta)\, dV/(Q*V) \qquad (3)$$

Table 1. Thermistor Location Schedule.

	Unlined	Lined: Nomex	Lined: Evolution 3
No.	Height (cm)	Height (cm)	Height (cm)
1	216	220	220
2	186	175	180
3	150	117	125
4	75	75	70
5	0	0	0

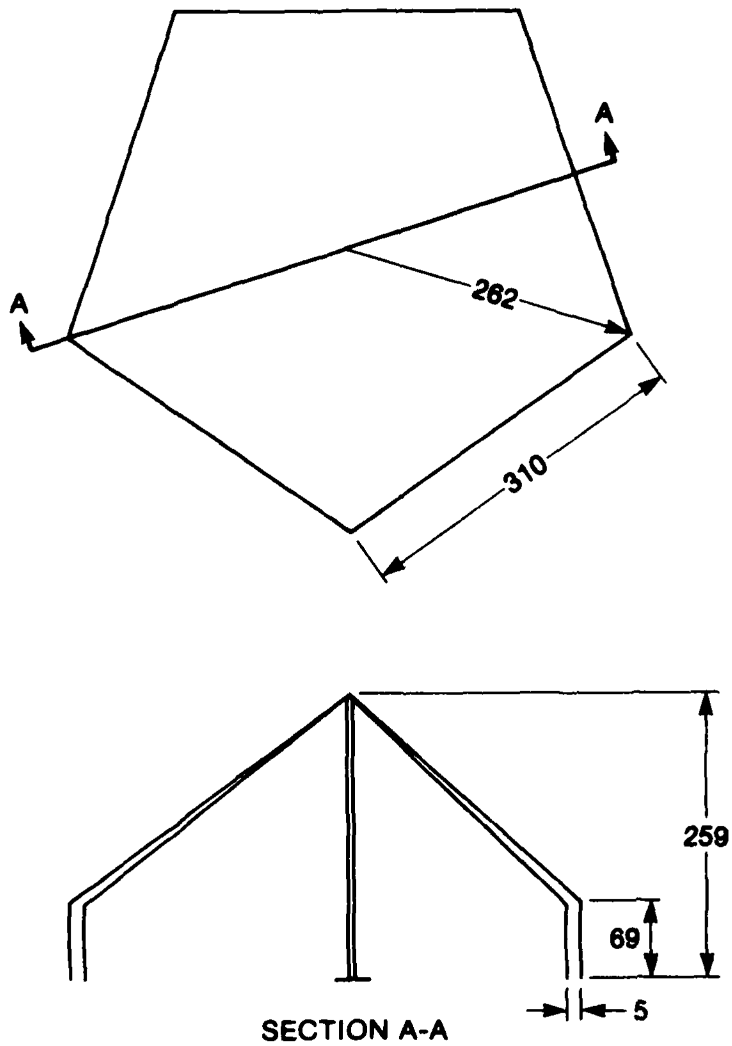


Figure 1: Schematic of a 10 Man Arctic Tent and Liner with Nominal Dimensions (cm).

An approximation to equation 3 is used in this study. A local value of the relative temperature rise per watt of heat input was defined using equation 3 to be:

$$Ti' = (T - Ta)/Q \quad (4)$$

Investigations of the distribution of Ti and Ti' along the centre-pole for similar tents should provide a qualitative comparison between tents even though it neglects variations of temperature present throughout the rest of the tent. These two parameters are both useful, but since Ti' is insensitive to the heater output it can be used to compare tents with different heating rates. Ti' is similar to an equivalent thermal resistance of the tent, but as it is a function of some external variables it is not a material property of the tent.

It has been reported [3] that the use of fans for additional circulation can significantly improve the habitability of a tent by reducing the temperature gradient in the tent. The importance of the buoyancy flux and the inertia flux of the plume from a heater on the circulation rate have not yet been quantified, and will be the topic of a subsequent investigation.

The difference between the ambient temperature and the globe temperature (equation 5) gives a measure of the effect of the radiative heat transfer rate relative to the convective and conductive heat transfer rates.

$$dTa = Ta - Tg \quad (5)$$

4.0 RESULTS AND DISCUSSION

4.1 General

Experiments were carried out under field conditions and thus were subject to changes in the weather. Figure 2 shows the variations in tent temperatures during periods when the ambient conditions were particularly variable. During the three days over which this experiment took place, the tent experienced many changes in the ambient conditions, often with more than one change occurring simultaneously. In this experiment, an unlined tent was continuously heated with a single electric heater.

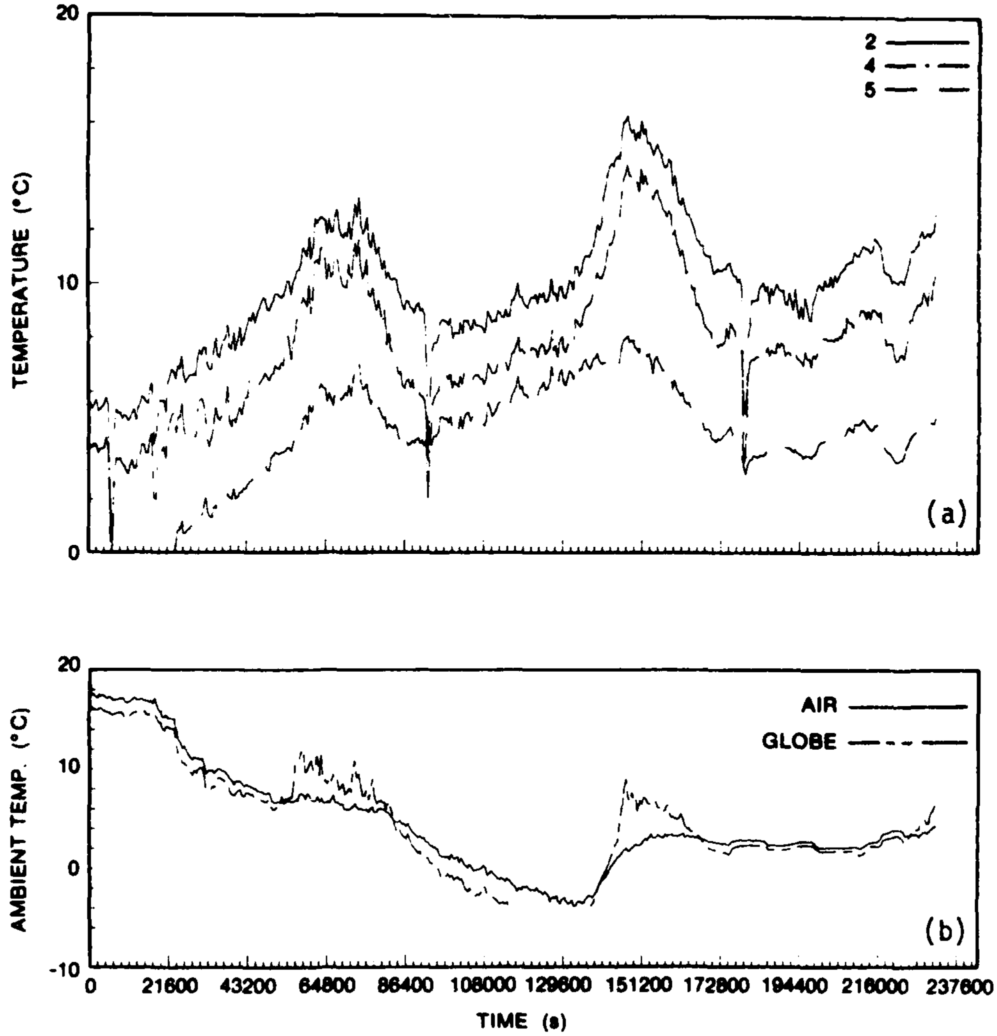


Figure 2: Typical Data Plots of

(a) Tent Temperature Rise vs Time.
(b) Ambient Temperature vs Time.

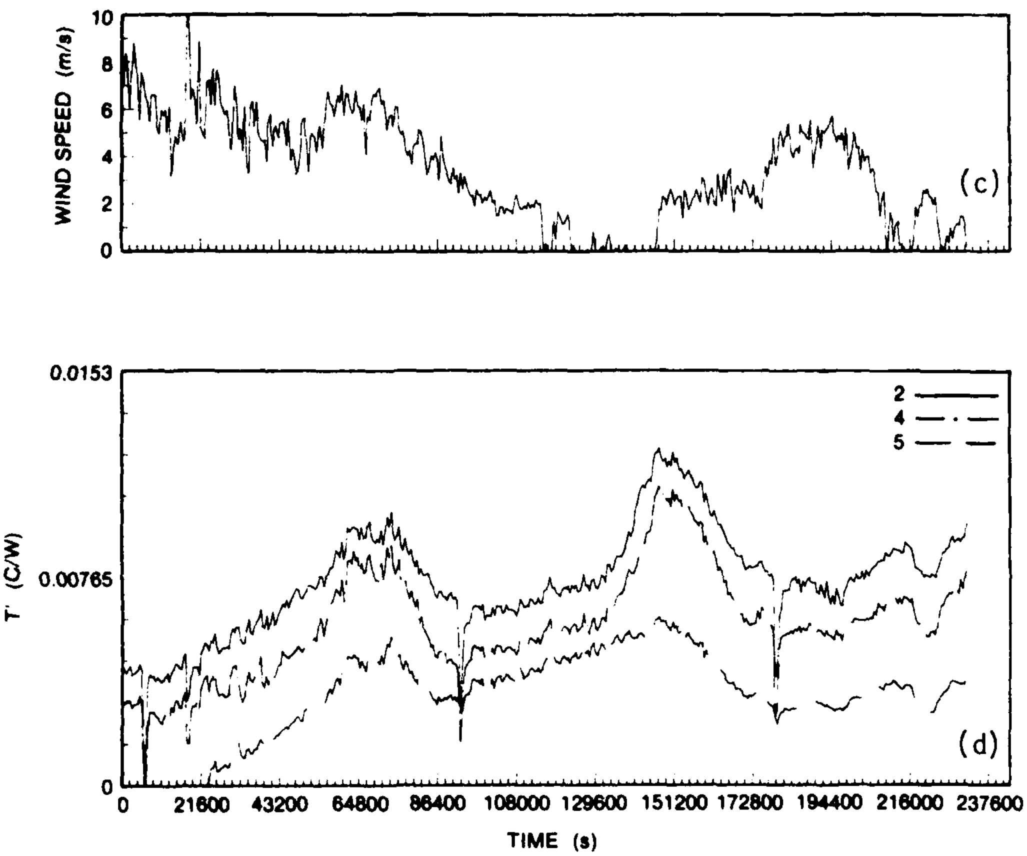


Figure 2: Typical Data Plots of

(c) Wind Speed vs Time.
(d) Tent Temperature Rise per Watt of Heat Input vs Time.

Heat was continuously being transferred both to or from the tent by conduction, convection and radiation. During one period (0 to 48600 s) a light rain was falling which provided an additional heat loss mechanism, evaporative heat transfer.

It can be observed that a changing ambient temperature (0 to 156600 s) caused changes in the relative temperature and that there was considerable lag between "cause" and "effect" due to the "thermal inertia" of the tent. Changes in the radiative heat transfer to the tent due to sunshine (140400 to 166320 s) also cause sizeable changes in the relative temperature. The effect of wind speed on heat transfer from the tent and the tent temperature appears to be slight but noticeable (172800 to 216000 s).

Figure 2d is a plot of Ti' as calculated using the data of Figure 2a versus time. The relative changes in the curves during each time interval are the same for both Figures 2a and 2d. It is apparent that the relative temperature per watt of heat input is a valid alternative method for presenting the data, and it will be seen that it is a useful form for comparing tents which have been heated at different rates of energy input.

The results quoted in tabular form in succeeding sections of text were obtained from observations made during more stable weather conditions than those relating to Figure 2. The results given in this text reveal the relative importance of each weather variable to the heating of tents.

4.2 Effect of Lining A Tent

The relative temperature increase measured in heated 10-Man Arctic tents (both with and without liners) is presented in Table 2. The addition of a tent liner to a tent has a significant effect on the Ti' of an unlined tent. The addition of a liner causes an increase in the value of Ti' of 60% to 100%. This means that a tent with a single layer liner will have a relative temperature which can be as much as twice as large as the same tent without a liner.

The details of the role of tent liners in insulating a tent will be discussed in a forthcoming report. As previously noted, it is hypothesized that the boundary layers of air which form at the liner surface are responsible for most of the insulation and the thermal resistance of the liner itself is negligible for typical fabric thicknesses [5].

Table 2. Relative Temperature Increases In Heated Tents In Which dTa Is Constant.

Exper. No.	Time Interval (s)	Wind Speed (m/s)	dTa (C)	Ti' (lined) (C/W)	Ti' (unlined) (C/W)
5	21600 43200	0	2		0.00577 *
6	16200 43200	0	2.75	0.00895 *	0.00516 *
7	29700 44280	2	1.4	0.01074 *	0.00517
8	5400 54000	1.2	2.4	0.00874	0.00515
8	91800 145800	0.8	2.4	0.00709	0.00443
9	16200 27000	2.25	0.25	0.00700	0.00504
10	37800 48600	1	-1.5		0.00486
11	1080 10800	4.25	0.50	0.00700	0.00474
12	27000 43200	2	-11		0.00706
15	24300 40500	4.4	1	0.00898	
20	26460	0	2.7	0.00702	
21	10800 48600	2.25	0.25	0.00672 ** 0.00698	

(A * denotes 1300W heat input, otherwise 3900W)
(A ** denotes an experimental tent liner)

5.0 CONCLUSION

The heat transfer to and from tents is a complicated function of conductive, convective, radiative and evaporative heat transfer as well as the ventilation rate. These variables often change simultaneously, making quantitative assessment of tentage difficult. In order to make accurate quantitative assessments, much more data are required than are presently available with stable weather conditions. When the additional data are available, they will be used to separate the effects of each variable on the overall heat transfer from a tent.

Relative temperature, Ti, and relative temperature per watt, Ti', are both useful forms for presenting data, however Ti' is more versatile as it eliminates the need to specify the power of the heater used. Thus two tents heated with differently sized heaters may be compared and assessed with common parameters more conveniently.

The addition of a single liner to an unlined tent can significantly improve the tent's thermal resistance. From the data presented here, the thermal resistance of a lined tent is 60% to 100% greater than the thermal resistance of an unlined tent. The single comparison of two different tent liners (Evolution 3 and Nomex) indicates that the liner material is probably inconsequential for textile materials of comparable thicknesses.

The equilibration time of the tents following a step increase in heating was found to be quite long (4000 to 6500 s). The transient response of the tent can be interpolated quite well by an exponential function given a characteristic time constant. Unlined tents had a characateristic time of 1000 seconds while the lined tents had a characteristic time of 1800 seconds. The electrical analogy given in the text indicates that the lined tent should have a longer time constant as both the thermal resistance and the heat capacity of the lined tent are greater.

It was found that the tent temperatures varied with the rate of change of ambient and globe temperatures. This transient response to external change is not as well defined as the transient response to internal change. It was found that the rates of change of the tent temperature was one-half the rate of change of ambient temperature for the rates observed. It was also found that the Ti' varied linearly with the effective rate of change of the globe temperature at approximately 7×10^{-4} [1/W]. These values provide guidelines, subject to accuracy requirements, which can be used with measurements of the ambient and globe temperatures to specify whether the tent is near equilibrium or if the tent immediately above the ground. This would result in a natural convective heat transfer thereby warming the tent. If the ground is colder than the air, the temperature gradient causes a stable condition in which heat could be lost to the ground from the air by conduction only (assuming no forced convection due to ventilation). Heat transfer rates for a cooled lower surface are approximately one order of magnitude lower than for a heated lower surface [7].

4.7 Effect of Wind Speed

Figure 11 shows a slight decrease of Ti' for increasing wind speed for the unlined tent, however, the data for a lined tent was too scattered to form any reliable conclusion. The scatter in the data make the assessment difficult and it should be noted that the velocity is small, covering only 0 to 4 m/s. It appears that there is no sizable effect of the wind speed on the convective heat transfer from the tent for wind speeds less than 4 m/s.

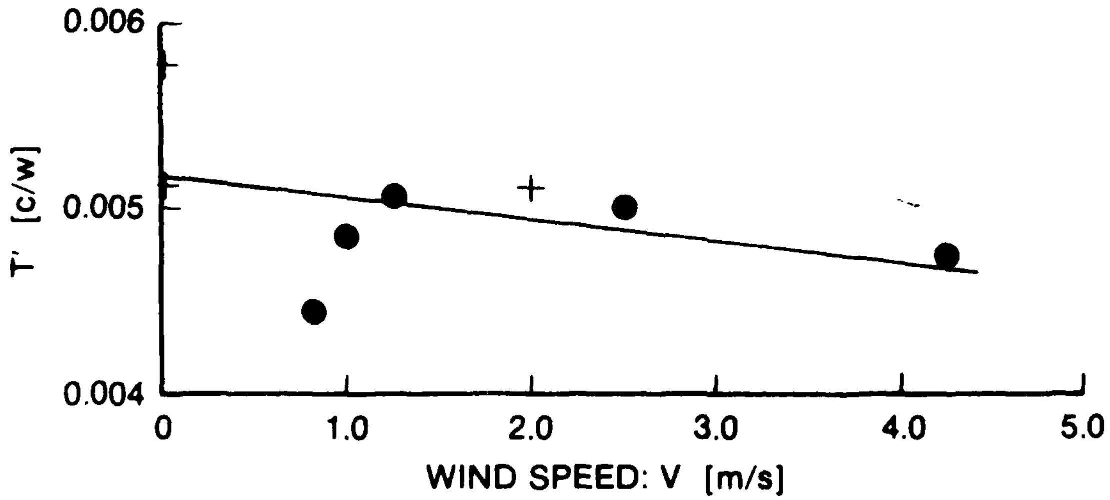


Figure 11: Relative Temperature Per Watt for Various Wind Speeds.

- $1.5 \leq \Delta T_a \leq 2.75$ (C)
- ● 3 Heaters/Tent
- + 1 Heater/Tent

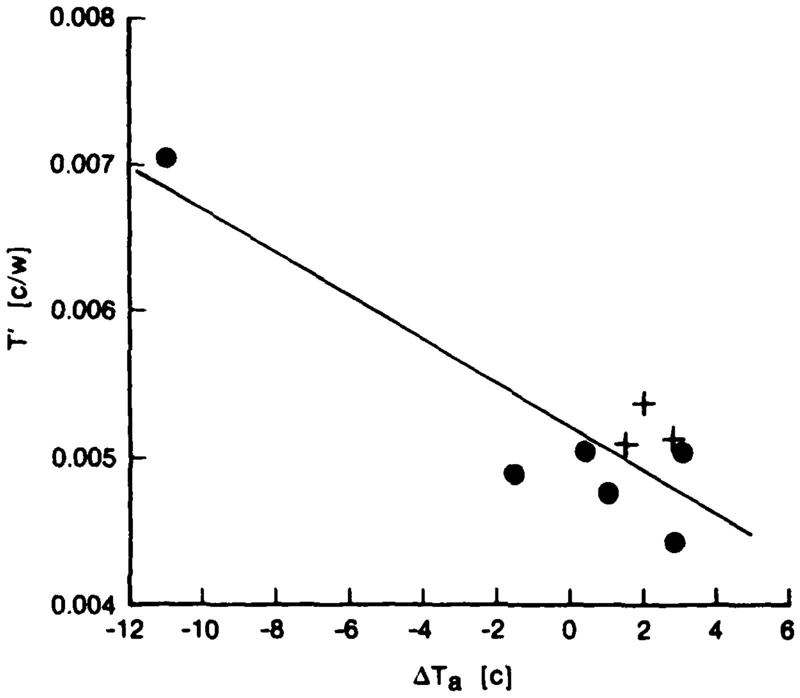


Figure 10: Relative Temperature Per Watt for Various Differences Between the Ambient and Globe Temperatures in an Unlined Tent.

Wind Speed ≤ 4.25 (m/s)
• 3 Heaters/Tents
+ 1 Heater/Tent

Knowing the thermal properties of any particular tent allows one to calculate the maximum acceptable rate of change of the ambient or globe temperature which will still provide useful data. This will depend upon the accuracy with which Ti' or the tent temperatures must be known.

4.6 Effect of Thermal Radiation

Data are usually gathered at night in order to minimize any variations in the radiant heat transfer rate to the tent. Thus, the data available for values of dTa which differ significantly from zero are limited. The information that is available is presented here to provide an estimate of the importance of the rate of thermal radiative heat transfer to a tent.

The time intervals in Table 2 were chosen such that dTa remained approximately constant during each interval. Thus, since the relative tent temperature is independent of any constant ambient temperature, different values of dTa correspond to different magnitudes of radiative heat transfer to the tent. A large radiative heat transfer to the tent results in a large globe temperature which results in a small dTa. This additional heat transfer to the tent causes an increase in the tent temperature, however, it is not included in the definition of the heat input to the tent. This causes an elevated Ti' which makes the tent appear to have a better thermal resistance than would otherwise be determined. The magnitude of the change in Ti' shown in Figure 10 indicates that the tent performance can be significantly influenced by the rate of radiant heat transfer to the tent under common climatic conditions.

In most experiments, the initial tent temperatures (prior to heating) were less than the ambient temperature. This was probably due to radiant heat loss from the tent as the globe temperature was less than the ambient temperature indicating a radiant heat loss from the globe. In one instance, however, the tent temperatures were slightly greater than the ambient temperature. Three possible explanations for this phenomena are:

(1) Errors in measurement of the tent temperatures, which are generally thought to be no greater than 0.2°C.

(2) Differences in radiant heat transfer from the tent and the ambient temperature thermistor.

(3) Natural convective heat transfer from the ground to the air in the tent.

The third explanation may be of importance when the ground is warmer than the air causing an unstable temperature gradient in the air

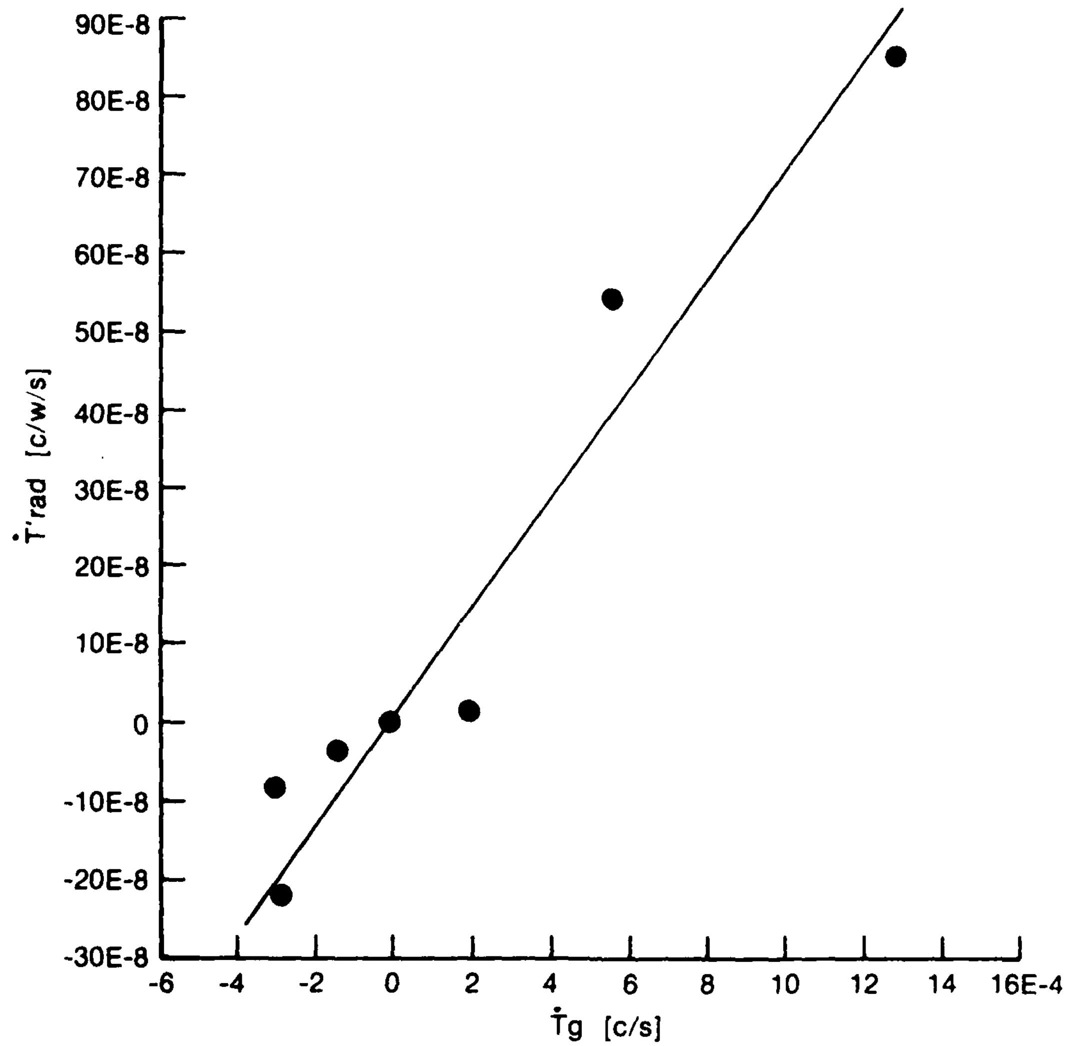


Figure 9: Rate of Change of the Relative Temperature Per Watt for Various Rates of Change of the Effective Globe Temperature in an Unlined Tent.

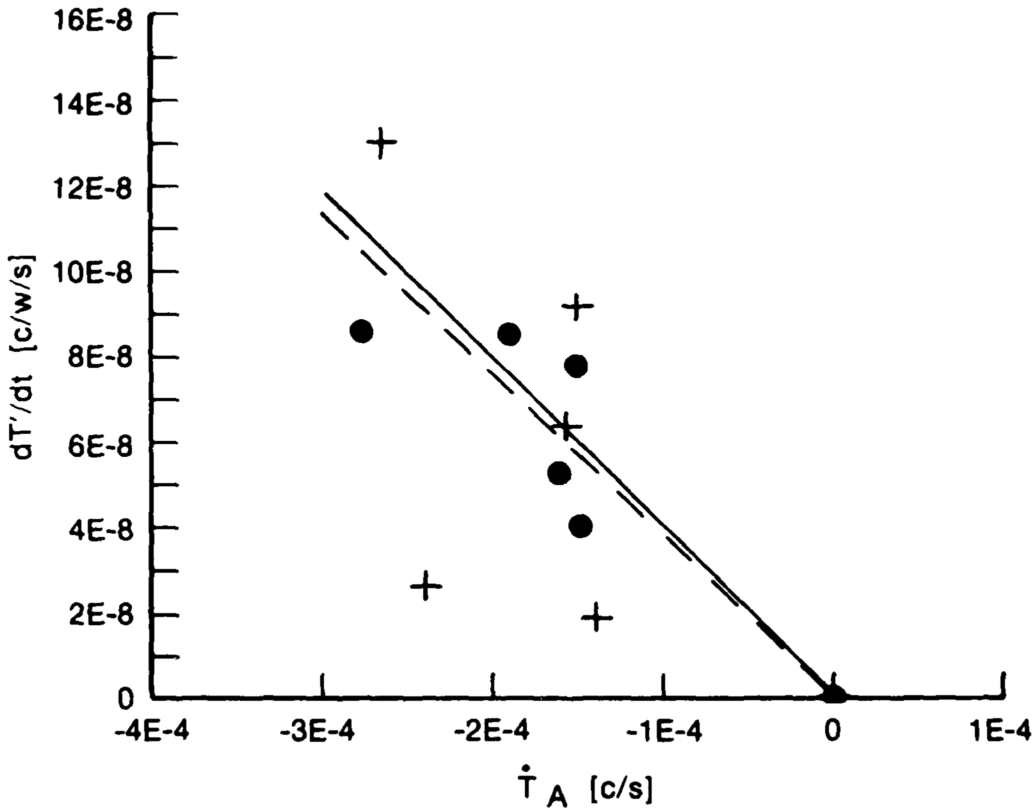


Figure 8: Rate of Change of the Temperature Per Watt for Various Rates of Change of the Ambient Temperature.

●,----- Unlined Tent
+,——— Lined Tent

If it is assumed that the thermal capacitance and resistance of the floor can be neglected [3], the thermal capacitance of the tent may be estimated. Using typical values for the heat capacity of fabrics [6], average tent dimensions and the density of air at 0°C, the thermal capacities of the air, tent membrane and tent liner are:

$$C_{air} = 2.8 \times 10^{4} \text{ J/C}$$
$$C_{mem} = 7.8 \times 10^{3} \text{ J/C}$$
$$C_{lin} = 4.5 \times 10^{3} \text{ J/C}$$

Using these values and the ratio of the time constant for a lined tent versus an unlined tent (1.8), it is found that the thermal resistance of a lined tent is approximately 60% greater than the thermal resistance of an unlined tent which is within the range of values for Ti' cited in Table 2. Note that Ti' is similar to an equivalent thermal resistance, however, it is not a true property of the tent.

4.5 Effects of Time Varying Ambient and Globe Temperatures

It was found, as expected, that for varying ambient or globe temperature, that the internal tent temperature changed. It was also found that the tent temperature did not change at the same rate as the rate of change of the ambient or globe temperatures due to the thermal inertia of the tent and the air in the tent. It is important to realize that if either the ambient temperature or the globe temperature are changing at significant rates, the measured values of the tent temperatures will not be representative of a steady state condition. For example, the rate of change of T' was plotted against the rate of change of the ambient temperature (Figure 8). It was found that the tent temperatures lagged the changing ambient temperature. A linear interpolation of the data was made, and it was found that the tent temperatures changed at approximately half the rate at which the ambient temperature changed for the rates observed.

Using this information, the rate of change of Ti' with changing globe temperature was estimated. It was assumed that the net rate of change of the globe temperature was equal to the measured rate of change of globe temperature minus the rate of change of the ambient temperature (as the globe temperature appears to change on a one to one basis with changing ambient temperature). The rate of change of Ti' due to the changing globe temperature was assumed to be equal to the measured rate of change of Ti' minus the rate of change of Ti' due to the changing ambient temperature (estimated from Figure 8). These values were found to be linearly related also (Figure 9).

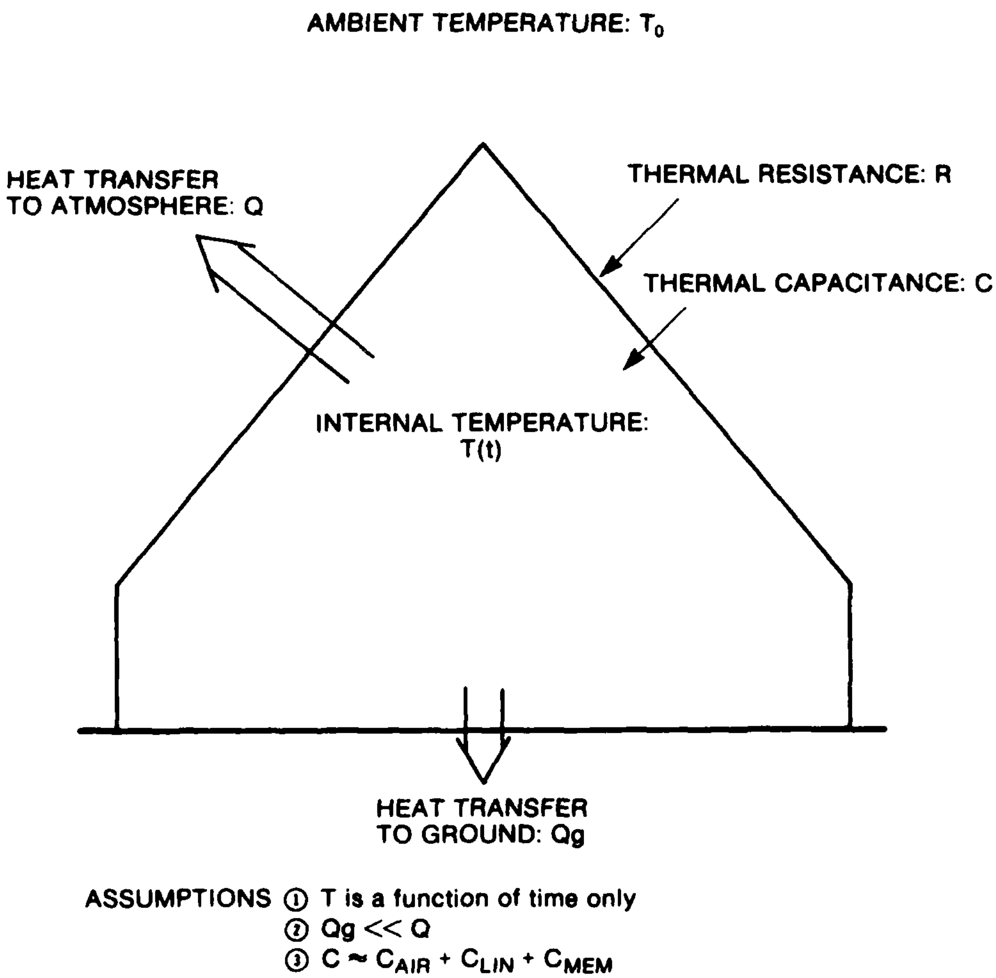


Figure 7: Lumped Parameter Analysis of the Transient Temperature Response of an Idealized 10 Man Tent.

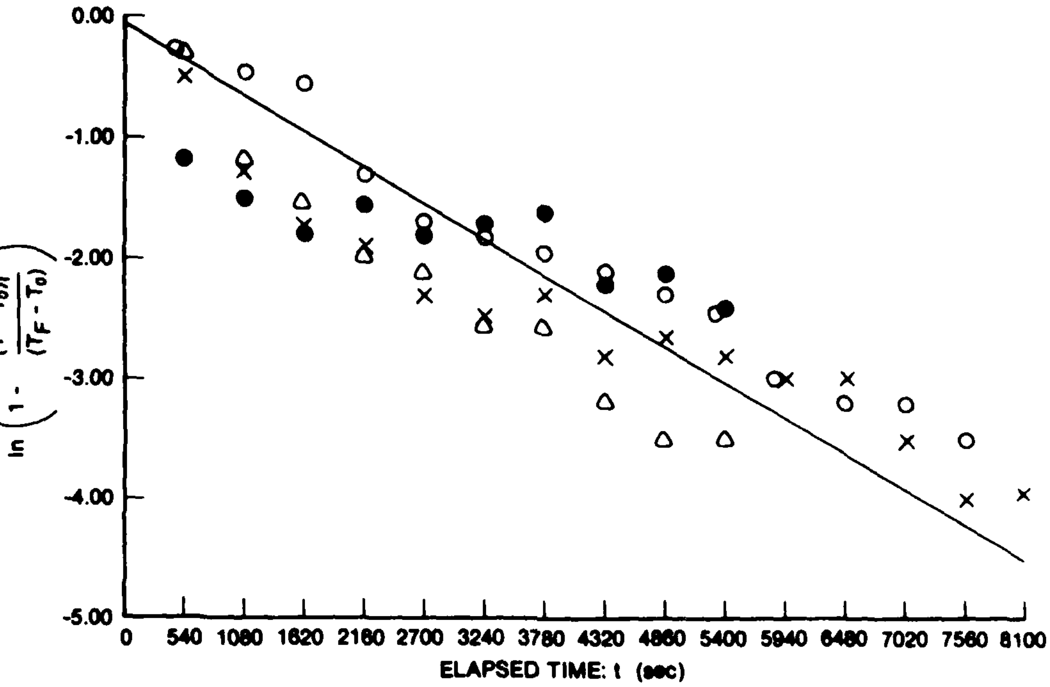


Figure 6: Logarithmic Function of the Relative Temperature for [illegible] Versus Elapsed Time After a Step Increase in the Heat Input to a Lined Tent.

$-1/t' = -5.55E-4$

- ● - *Nomex liner*
- Δ - *Nomex liner*
- x - *Nomex liner*
- o - *Evolution [illegible] liner*

Equation 6 was rearranged to give:

$$\ln\left(1 - \frac{T_i - T_o}{T_F - T_o}\right) = -\left(\frac{1}{t'}\right)t \qquad (7)$$

which was used to plot the data in Figure 6. The time constant, t', was obtained by evaluating the slope of the linear interpolation which best fit the data plotted in Figure 5.

As can be seen from Figure 5, the exponential function of Equation 6 is a good approximation to the observed tent response to a step heat input. A time constant of 1000 second was found to be representative of an unlined tent, and similarly a time constant of 1800 seconds was found representative of the lined tents. This means that the unlined tent reaches steady state more quickly than does the lined tent. This fact is also shown in elapsed times to steady state. This is not unexpected if the tent is modeled and examined using a lumped parameter analysis as shown in Figure 7.

It is assumed that the air in the tent is well stirred and has a uniform temperature (T) which will vary with time only. The tent and the air inside the tent have a thermal capacitance (C) and a thermal resistance (R). The rate at which heat is put into the tent is (Q). The air outside the tent is assumed to be at a constant temperature. The governing differential equation for this lumped parameter model is:

$$C\frac{dT}{dt} - \frac{(T - T_0)}{R} = Q \qquad (8)$$

Solving this differential equation gives rise to a solution composed of a transient and a steady-state component:

$$T(t) = A \times e^{\left(-\frac{t}{RC}\right)} + B \qquad (9)$$

where A and B are constants which are determined by the initial and final conditions.

The transient portion of the solution involves a time constant equal to "RC". Any increase of the tent's thermal resistance or thermal capacitance will increase the tent's time constant. The addition of a liner will increase both of these quantities.

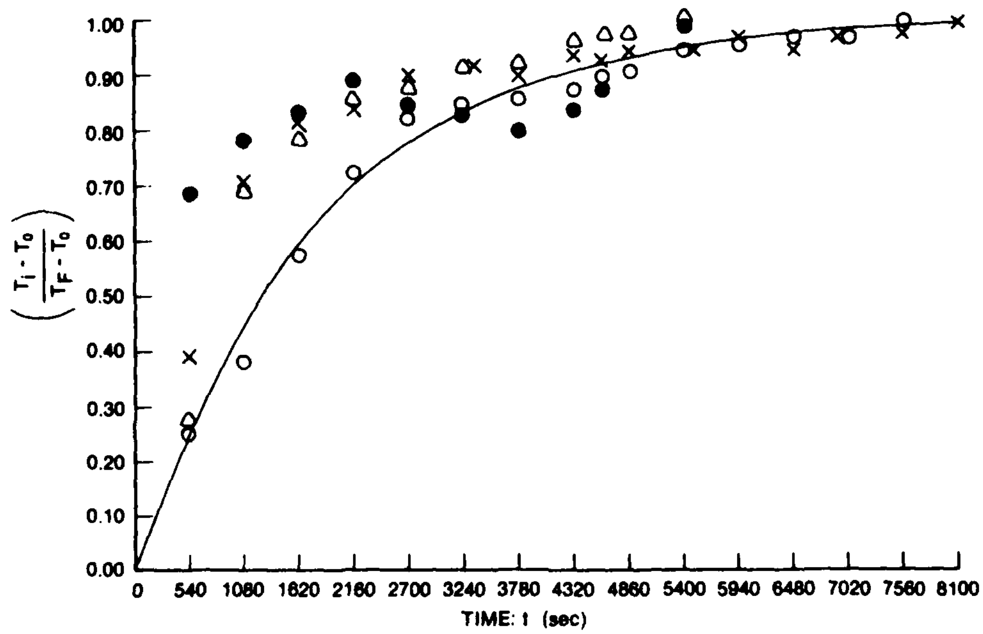


Figure 5: Response of the Relative Temperature Per Watt to a Step Increase of the Heat Input for a Lined Tent.

- ● *Nomex liner*
- △ *Nomex liner*
- ○ *Nomex liner*
- x *Evolution 3 liner*
- ——— *Interpolating Curve, Equation 6,* t' = 1800.

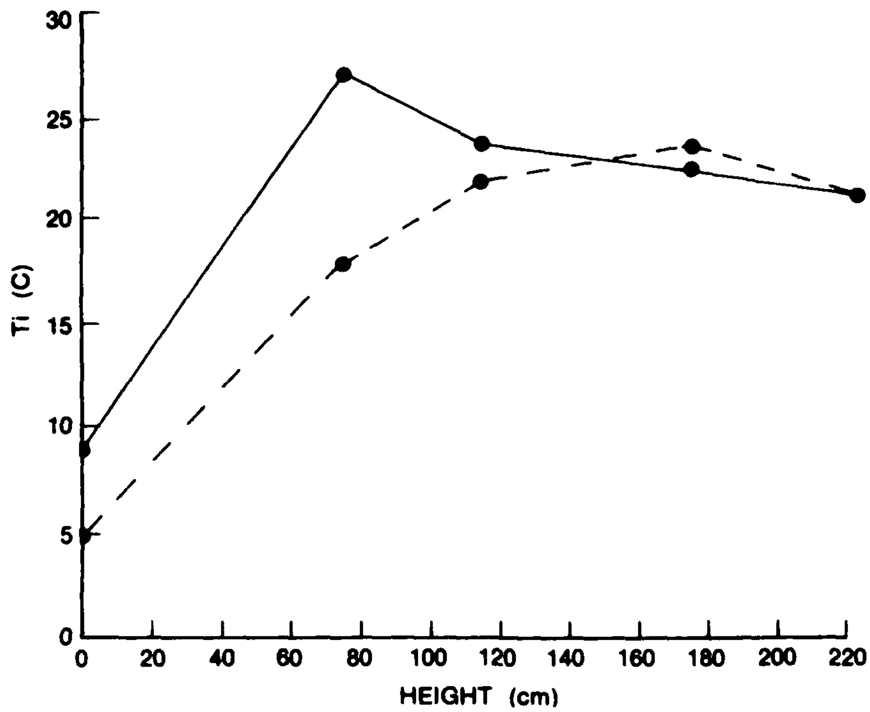


Figure 3: Typical Vertical Temperature Distribution Along the Pole of a Ten Man Arctic Tent.
For: ———— Heater at the Foot of the Pole.
- - - - - - Heater at the Stove Hole.
Experiment #9.

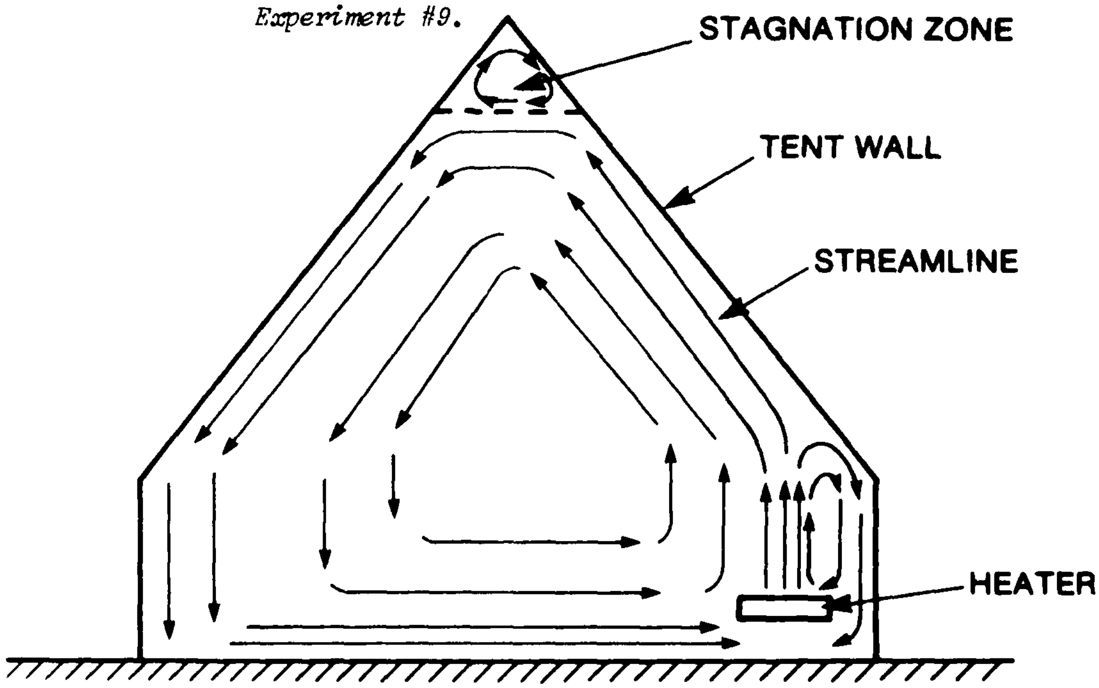


Figure 4: Hypothetical Air Flow Pattern in a 10 Man Arctic Tent with the Heater at the Stove Hole Position.

When the heaters are arranged around the pole, the hottest air temperature along the pole would occur immediately above the heater (Figure 3). As the plume of hot air rises, it entrains cooler air and thus decreases in temperature until it reaches the peak.

When the heaters are placed away from the pole, one would expect the pole temperatures to increase with increasing height and reach a maximum at the peak as the pole is no longer in the plume. Instead, it has been observed that the hottest temperature occurs some 20 cm below the peak of the 10-Man Arctic Tent.

Figure 4 shows a hypothetical air-flow pattern in the tent which is caused both by buoyancy and the forced convection of the heater. It is hypothesized that the plume of hot air, rising from the heater, stagnates at the peak of the tent. This creates a volume of air which is somewhat separate from the general flow field. This air then loses heat through the tent walls thereby increasing its density. As the cooled air subsides, it is held up by the rising plume and a local equilibrium between the buoyancy force and the stagnation pressure of the plume occurs.

The stagnation zone is not entirely separate from the main flow. Turbulent mixing at the interface between the stagnation zone and the main flow will cause an exchange of air and mixing in the stagnation zone. The stagnation zone may also be penetrated by the plume if a parcel of air from the plume has sufficient momentum to displace air in the stagnation zone.

4.4 Time Response to a Step Change in Heat Input

In several experiments, the tent was initially at steady state with no heat input. The heaters were then turned on and the tents' temperatures were allowed to rise to new steady state values. The mean response times of the tents were then calculated, using the total change in Ti, $(T_F - T_0)$, to normalize the value of Ti at time "t".

Figure 5 shows the average response of Ti of a lined tent immediately after the heaters have been turned on. The result is similar to other exponential decaying transients which are modelled by assuming a constant steady state value and a transient term as shown in Equation 6:

$$Ti = (T_F - T_0) \times (1 - e^{-\frac{t}{t'}}) + T_0 \qquad (6)$$

where, t' is the characteristic response time or time constant.

4.3 Air Circulation

A phenomenon was observed which gives some insight into the circulation of air within the tent. It has been found that the highest temperature of the tent does not always occur at the peak of the tent, but at some distance below the peak. This was observed both when the heaters were arranged around the pole (Table 3a) and when the heaters were placed at the stove hole, near the wall of the tent (Table 3b). This phenomenon has also been reported in two other investigations [4,5].

Table 3a. Steady-State Pole Temperatures with the Heaters Positioned at the Pole. (Degrees Celsius)

Exper. No.	Time (s)	T1 (Peak)	T2	T3	T4	T5 (Floor)
9	21600	21	23	24	27	9
10	43200	19	22	22	23	6
11	5400	18	21	20	24	10
	27000	19	21	19	24	9
12	10800	23	26	26	28	15
15	0	36	41	43	46	22
20	0	32	38	40	42	17
21	27000	26	31	29	33	10
	27000	25	30	31	33	14

Table 3b. Steady-State Pole Temperature with the Heaters Positions at the Stove Hole. (Degrees Celsius)

Exper. No.	Time (s)	T1 (Peak)	T2	T3	T4	T5 (Floor)
5	0	8	9	9	7	3
6	27000	7	9	9	6	3
7	21600	6	8	7	5	2
	21600	10	14	12	10	6
8	118800	6	8	8	5	0
9	37800	21	24	22	18	5
10	21600	19	21	20	16	6
12	32400	29	32	32	27	14

temperature is changing too rapidly to assume steady state conditions.

The calculation of Ti' does not implicitly include heat transfer by radiation. Thus variations in the radiant heat transfer to the tent cause variations in Ti' by changing the tent temperature. Different radiative heat transfer rates are reflected in the difference between the ambient and globe temperatures, dTa, for a constant ambient temperature. Based on the available data, it was found that Ti' varied approximately linearly with dTa by a proportionality constant of -1.4×10^{-4} [1/W].

The effect of low wind speed (V<5 m/s) on Ti' appears to be small (< 10%). Although the data were scattered, it indicated a mild negative relationship between Ti' and the wind speed. It is expected that, when enough data are obtained, over a large velocity range, Ti' will be found to decrease with increasing wind speed as convective heat transfer from the tent and wind penetration of the tent walls increase.

6.0 ACKNOWLEDGEMENT

This study was sponsored by DCGEM through DCGEM Task # 36.

7.0 REFERENCES

[1] White, F.M. Viscous Fluid Flow, McGraw-Hill, New York, 1974.

[2] Kuehn, L.A. Response of the Globe Thermometer, DCIEM Report No. 859. Defence and Civil Institute of Environmental Medicine, Downsview, Ontario, January 1973.

[3] Nykvist, W. Heat-Driven Fan for Tent Habitability Improvement, Technical Report: Natick/TR-83/015, Unclassified, United States Army Natick Research and Development Laboratories, Natick, Massachusetts, November 1982.

[4] Pang, S.H.H., Constantine, L.R. Private Communication.

[5] Farnworth, B., Private Communication.

[6] Handbook of Tables for Applied Engineering Science, The Chemical Rubber Co., Cleveland, Ohio, 1970.

[7] Ozisik, M.N. Basic Heat Transfer, McGraw-Hill, New York, 1977.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1 ORIGINATING ACTIVITY Defence Research Establishment Ottawa Department of National Defence Ottawa, Ontario, CANADA K1A 0Z4	2a DOCUMENT SECURITY CLASSIFICATION UNCLASSIFIED 2b GROUP

3 DOCUMENT TITLE

An Initial Investigation Of The Heating Properties Of Conical Tents

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

TECHNICAL NOTE

5 AUTHOR(S) (Last name, first name, middle initial)

CAIN, Brad

6 DOCUMENT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
JUNE 1984	25	7

8a PROJECT OR GRANT NO	9a ORIGINATOR'S DOCUMENT NUMBER(S) DREO TECHNICAL NOTE NO. 83-32
8b CONTRACT NO	9b OTHER DOCUMENT NO (S) (Any other numbers that may be assigned this document)

10 DISTRIBUTION STATEMENT

UNLIMITED DISTRIBUTION

11 SUPPLEMENTARY NOTES	12 SPONSORING ACTIVITY DCGEM

13 ABSTRACT

The following aspects of the heating of the CF 10-Man Arctic Tent were examined: the effect of lining the tent; the time response of the internal tent temperature to a step increase in heat transfer to the tent; radiative heat transfer to the tent and convective heat loss from the tent. The internal tent temperatures were found to be significantly affected by the provision of a tent liner which increased the relative temperature per unit of heat input by 60% to 100%. Change in the radiative heat transfer to the tent also changed the internal tent temperature significantly. A hypothesis on the circulation pattern within the tent was proposed to explain the temperature distribution within the tent. The thermal response of these tents was found to be exponential with time constants of 1000 s and 1800 s for unlined and lined tents respectively. Internal tent temperatures of heated tents were found to remain approximately constant for wind velocities less than 5 m/s.

DSIS

UNCLASSIFIED
Security Classification

KEY WORDS

Tents
Heating
Liner
Circulation
Time response
Radiative heat transfer
Wind
Temperature
Insulation

INSTRUCTIONS

[illegible] Enter the name and address of the [illegible] the document.

[illegible] Enter the overall [illegible] including special warning [illegible]

[illegible] group number. The three [illegible] Security Regulations.

[illegible] document title in all [illegible] be unclassified. [illegible] without classi- [illegible] capital letter [illegible] following the title.

[illegible] NOTES: Enter the category of document, e.g., [illegible] report, technical note or technical letter. If appropri- [illegible] the type of document, e.g., interim, progress, [illegible] final. Give the [illegible] dates when a [illegible] period is covered.

AUTHOR(S): Enter the name(s) of author(s) as shown on or in the document. Enter last name, first name, middle initial. If military, show rank. The name of the principal author is an [illegible] requirement.

[illegible] DATE: Enter the date (month, year) of [illegible] approval for publication of the document.

7a. [illegible] NUMBER OF PAGES: The total page count should [illegible] pagination procedures, [illegible] enter the number [illegible]

[illegible] REFERENCES: [illegible] total number of [illegible] the document.

[illegible] GRANT NUMBER: [illegible] appropriate, enter the [illegible] research and development project or grant number [illegible]

[illegible] the applicable [illegible]

[illegible] Enter the [illegible] document will be [illegible] activity. [illegible]

9b. OTHER DOCUMENT NUMBER(S): If the document has been assigned any other document numbers (either by the originator or by the sponsor), also enter this number(s).

10. DISTRIBUTION STATEMENT: Enter any limitations on further dissemination of the document, other than those imposed by security classification, using standard statements such as:

(1) *"Qualified requesters may obtain copies of this document from their defence documentation center."*

(2) *"Announcement and dissemination of this document is not authorized without prior approval from originating activity."*

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document, even though it may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall end with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (TS), (S), (C), (R), or (U).

The length of the abstract should be limited to 20 single-spaced standard typewritten lines, 7½ inches long.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a document and could be helpful in cataloging the document. Key words should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context.

END

FILMED

4-85

DTIC