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REPORT NO. T2/86

**PHYSIOLOGICAL TESTING OF EXPERIMENTAL  
CHEMICAL WARFARE AGENT PROTECTIVE  
PATIENT WRAPS**

**US ARMY RESEARCH INSTITUTE OF  
ENVIRONMENTAL MEDICINE  
Natick, Massachusetts**

**OCTOBER 1985**

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results showed that  $O_2$  depletion and  $CO_2$  accumulation after 2 h of encapsulation was less in the patient wrap made of a Nyco twill shell and 3M melt-blown polypropylene core and the patient wrap made of a Nyco Oxford shell and Lanton Mark IV core than the patient wrap made of a Nyco twill shell and a Von Blucker Saratoga shell. There were no significant differences in final core temperature or sweating rate during 2 h of encapsulation among the six prototypes. Further testing in a hot environment ( $T_{db} = 49.14 (\pm 0.43)$ ,  $T_{dp} = 17.02 (\pm 0.26)$  °C) revealed that there was less  $O_2$  depletion in one patient wrap (Nyco twill/3M polypropylene) than in the wrap composed of a Nyco oxford shell and Bondina Mark IV core, although the two wraps were not different in a cold environment ( $T_{db} = -38.83 (\pm 0.74)$  °C). Keywords:

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TECHNICAL REPORT  
NO. T2/86

PHYSIOLOGICAL TESTING OF EXPERIMENTAL CHEMICAL WARFARE AGENT  
PROTECTIVE PATIENT WRAPS.

by  
Lou A. Stephenson, Bruce S. Cadarette  
and Karen L. Speckman

Project Reference:  
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## TABLE OF CONTENTS

	<u>Page</u>
List of Figures	iv
List of Tables	v
Abstract	vi
Introduction	1
Materials and Methods	1
Results and Discussion	6
Conclusions	14
References	15
Appendix 1	16
Appendix 2	17
Distribution List	18

## LIST OF FIGURES

		<u>Page</u>
Figure 1.	The mean oxygen concentration during the first 48 min of encapsulation in Wrap 3 and Wrap 7.	9
Figure 2.	The mean carbon dioxide concentration during the first 48 min of encapsulation in Wrap 3 and Wrap 7.	9

## LIST OF TABLES

		<u>Page</u>
Table 1.	Description of chemical warfare agent protective patient wraps.	2
Table 2.	Individual characteristics of the subjects.	3
Table 3.	Mean ( $\pm$ S.D.) increase in core temperature ( $\Delta T_{re}$ ) during encapsulation, the $\Delta T_{re}$ predicted after 6 hours of encapsulation, and final heart rate (HR) during encapsulation.	6
Table 4.	Mean ( $\pm$ S.D.) sweating rate during encapsulation and the predicted weight loss, based on sweating rate, after 6 hours of encapsulation.	7
Table 5.	Mean ( $\pm$ S.D.) oxygen (O <sub>2</sub> ) and carbon dioxide (CO <sub>2</sub> ) concentration within the patient wraps while subjects were encapsulated for the initial 48 min. The critical difference from Tukey's test (C.D.) is also presented.	10
Table 6.	Mean ( $\pm$ S.D.) oxygen and carbon dioxide concentration within the patient wraps after 2 hours of encapsulation. The critical difference from Tukey's test (C.D.) is also presented.	11
Table 7.	Mean ( $\pm$ S.D.) predicted rectal temperature ( $T_{re}$ ) and finger temperature ( $T_{finger}$ ) during encapsulation in -40°C (n=5).	14

### Abstract

A physiological comparison of subject responses during 2 hours of encapsulation in the chemical warfare agent protective patient wrap currently being procured, six prototypes developed by the United States and a newly developed United Kingdom patient wrap was done in a warm environment ( $T_{db} = 29.90 (\pm 0.46) ^\circ\text{C}$ ,  $T_{dp} = 6.89 (\pm 2.14) ^\circ\text{C}$ ). Core temperature (rectal) and  $\text{O}_2$  and  $\text{CO}_2$  concentration within the wrap were measured every minute. Heart rate was measured every 5 minutes. Weight loss was measured before and after each experiment. The results showed that  $\text{O}_2$  depletion and  $\text{CO}_2$  accumulation after 2 h of encapsulation was less in the patient wrap made of a Nyco twill shell and 3M melt-blown polypropylene core and the patient wrap made of a Nyco Oxford shell and Lanton Mark IV core than the patient wrap made of a Nyco twill shell and a Von Blucker Saratoga shell. There were no significant differences in final core temperature or sweating rate during 2 h of encapsulation among the six prototypes. Further testing in a hot environment ( $T_{db} = 49.14 (\pm 0.43)$ ,  $T_{dp} = 17.02 (\pm 0.26) ^\circ\text{C}$ ) revealed that there was less  $\text{O}_2$  depletion in one patient wrap (Nyco twill/3M polypropylene) than in the wrap composed of a Nyco oxford shell and Bondina Mark IV core, although the two wraps were not different in a cold environment ( $T_{db} = -38.83 (\pm 0.74) ^\circ\text{C}$ ).

## INTRODUCTION

In the event of a military conflict in which chemical warfare agents are deployed, it would be necessary to protect casualties transported through such an area. To be prepared for such a situation, six chemical warfare agent protective patient wraps, each having the same general design, but composed of different materials have been developed. In order to evaluate which patient wrap causes the least physiological strain, human subjects were encapsulated in each of the six newly developed patient wraps. Oxygen (O<sub>2</sub>) depletion and carbon dioxide (CO<sub>2</sub>) accumulation in the patient wrap, and core temperature of the subject were measured. The six patient wraps were compared with each other, as well as to the old standard United Kingdom (U.K.) wrap and a new U.K. wrap.

After the initial experiments, two of the six experimental wraps were chosen for further evaluation in two extreme environments. The second series of experiments also provided preliminary data about safe exposure time during encapsulation in the two extreme environments.

## MATERIALS AND METHODS

Eight chemical warfare agent protective patient wraps were tested: six experimental wraps, the standard U.K. wrap and a new U.K. wrap. The experimental wraps were composed of an impermeable ground sheet and an upper blanket of chemical protective, laminated cloth. There was a clear window in the upper blanket where the soldier's head was positioned. Each experimental prototype utilized the same materials for the window and ground sheet. The

window was a tri-laminated nylon/saran/polyethylene film. The ground sheet was Loretex and nylon. The shell and carbon based core materials of each experimental prototype varied (Table 1).

Table 1. Description of chemical warfare agent protective patient wraps.

<u>SHELL</u>	<u>CORE (CARBON BASED)</u>
1. NONE (Standard United Kingdom)	Bondina Mark IV
2. Fire resistant cotton/Tyvek (New United Kingdom)	Modified Mark IV
3. Nyco Twill	3M Melt Blown PF
4. Von Blucher "Hylla"	Von Blucher Saratoga
5. Nyco Oxford	Bondina Mark IV
6. Nyco Twill	50 ml Polyurethane Foam
7. Nyco Twill	Von Blucher Saratoga
8. Nyco Oxford	Lantor Mark IV

Table 2. Individual characteristics of the subjects.

	Weight (kg)	Height (cm)	A <sub>D</sub> (m <sup>2</sup> )	Age	Resting Metabolic Rate (ml O <sub>2</sub> ·kg <sup>-1</sup> ·min <sup>-1</sup> )
1.	66.4	179.9	1.84	23	4.5
2.	75.5	175.4	1.91	21	4.0
3.	86.9	169.2	1.98	26	3.5
4.	67.3	171.8	1.79	22	4.5
5.	62.5	170.4	1.73	18	5.3
6.	79.0	179.7	1.98	19	4.7
7.	67.0	170.1	1.78	26	4.5
8.	92.3	177.6	2.10	27	4.1
$\bar{X}$ + S.D.	74.6 (10.8)	174.3 (4.4)	1.89 (0.13)	22.8 (3.4)	4.4 (0.5)

Eight men (Table 2) volunteered to be tested. Resting metabolic rate was measured with an MMC Horizon System (Beckman) by standard procedures (1) while the supine subject was in a fasted state. Prior to the first experiment, each subject was familiarized with the patient wrap and the experimental protocol. The experimental design was a counterbalanced repeated measures design, so that familiarity to encapsulation would not affect data analysis. The counter balanced repeated measures design is the research design of choice any time there is reason to suspect systematic differences between successive measurements because experiments are planned so that each treatment is given first, second, ... to an equal number of subjects (2). With this extra control, any systematic effect of the order of treatment will not bias the comparison of

treatment means. The repeated measures design also decreases intra-treatment variability (3), which will increase the power of the experimental design while minimizing subject number.

The experimental protocol for choosing the best patient wrap from a physiological basis was the same for each experiment. The experiments were conducted in an environmental chamber where  $T_{db}$  was  $29.90 (\pm 0.46) ^\circ\text{C}$  and  $T_{dp}$  was  $6.89 (\pm 2.14) ^\circ\text{C}$ . The subject was dressed in battle dress uniform and boots. He inserted a YSI rectal temperature thermistor 10 cm past the anal sphincter for the measurement of core temperature ( $T_{re}$ ). ECG electrodes and leads were attached for heart rate (HR) measurement. The subject was then weighed. A small diameter polyethylene tube, which was attached to a pump so that a continuous air sample could be drawn from within the wrap, was then positioned at the bridge of the nose. The  $\text{O}_2$  concentration of this sample of air was analyzed by an Applied Electrochemistry S-3A Analyzer. The  $\text{CO}_2$  concentration was measured by a Beckman LB-2  $\text{CO}_2$  Analyzer. A dew point sensor (4) was attached within the patient wrap so that the dew point temperature ( $T_{dp}$ ) within the wrap could be measured. He lay quietly for at least 30 min on the bottom layer of the patient wrap, ensuring that  $T_{re}$  was stable before the experiment began. The subject was then encapsulated in the wrap.  $\text{O}_2$  concentration,  $\text{CO}_2$  concentration,  $T_{re}$  and  $T_{dp}$  were measured every minute. Heart rate was measured every 5 minutes. Subjects were encapsulated in the wrap for two hours if  $\text{O}_2$  concentration did not fall below 16%. In some cases,  $\text{O}_2$  concentration fell below 16%, and the experiment was terminated. After the two hours of encapsulation, an impermeable film was fastened over the experimental patient wrap.  $\text{O}_2$  and  $\text{CO}_2$  concentration,  $T_{re}$  and  $T_{dp}$  were monitored every 30 sec and HR was measured every min after the film was

attached. The film was removed when the O<sub>2</sub> concentration fell to 16% (range = 1.5-21.1 minutes). The subject remained in the wrap for 20 min after the film was removed. Subjects were weighed after the experiment.

A one-way analysis of variance with repeated measures was used to determine differences between the wraps for change in T<sub>re</sub>, sweating rate, and predicted T<sub>re</sub> and weight loss after 6 h of encapsulation (P < 0.05). A two-way analysis of variance with repeated measures (wrap x time) was used to reject the null hypothesis for O<sub>2</sub> and CO<sub>2</sub> accumulation, T<sub>re</sub>, T<sub>dp</sub> and heart rate (P < 0.05). Tukey's test of critical differences was used where appropriate (5).

Two wraps were chosen for further testing in the two extreme environmental conditions. Six men were studied during two hours of encapsulation (no film attached) in hot (HOT/DRY, 49.1(± 0.43)°C, T<sub>db</sub>; 17.0 (± 0.26)°C, T<sub>dp</sub>) and in cold (COLD/DRY, T<sub>db</sub> = -38.83 (± 0.74) °C) environments. The mean (± S.D.) age, height, weight, DuBois body surface area (A<sub>D</sub>) and resting metabolic rate of the subjects was 25.8 ± 5.7 years, 174.9 ± 4.8 cm, 74.9 ± 9.5 kg, 1.90 ± 0.11 m<sup>2</sup> and 0.27 ± 0.03 l·min<sup>-1</sup> respectively.

In the hot experiments tropical uniforms were worn. A sample of air was drawn continuously from within the wrap as explained for the initial experiments. CO<sub>2</sub> and O<sub>2</sub> concentration, T<sub>re</sub>, HR and weight loss were measured as described above. The experiment was terminated if O<sub>2</sub> fell below 16%, T<sub>re</sub> reached 39.2°C or if the subject felt incapable of remaining in the environment.

The subjects wore the full COLD/DRY ensemble (clo = 4.30 (6)) during the cold exposure. T<sub>re</sub> and the index finger temperature (T<sub>finger</sub>) were measured continuously. The experiment was terminated if T<sub>finger</sub> fell below 10°C or if the subject felt too cold to remain encapsulated.

A one way analysis of variance with repeated measures was used to determine differences between the two wraps for the final  $T_{re}$  and  $O_2$  and  $CO_2$  concentration in the HOT/DRY environments, and for the final  $T_{re}$  and  $T_{finger}$  in the cold environment.

### RESULTS AND DISCUSSION

Generally the subjects remained encapsulated for 2 hours, however, in a few cases the experiments were terminated before that time because  $O_2$  concentration decreased below 16%. All subjects were encapsulated for 48 min at least, therefore time analyses of the data were done for that period of time.

Core temperature ( $T_{re}$ ) increased as a function of time in all wraps. Wrap 1 (Table 1) was superior to all wraps in that it was most conducive to heat dissipation (Table 3 and Appendix 1). However, the increase in core temperature

Table 3. Mean (+ S.D.) increase in core temperature ( $\Delta T_{re}$ ) during encapsulation, the  $\Delta T_{re}$  predicted after 6 hours of encapsulation, and final heart rate (HR) during encapsulation.

	Wrap 1	Wrap 2	Wrap 3	Wrap 4	Wrap 5	Wrap 6	Wrap 7	Wrap 8
$\Delta T_{re}$	0.07 (0.05)	0.21 (0.06)	0.21 (0.16)	0.30 (0.14)	0.21 (0.11)	0.25 (0.09)	0.22 (0.12)	0.25 (0.12)
Predicted $\Delta T_{re}$ after 6h	0.17 (0.10)	0.60 (0.31)	0.49 (0.34)	0.74 (0.29)	0.50 (0.23)	0.60 (0.20)	0.56 (0.29)	0.59 (0.27)
HR	71 (10.2)	81 (4.1)	79 (6.7)	82 (8.8)	84 (10.1)	80 (10.5)	78 (13.8)	73 (6.8)

during encapsulation was not significantly different among the prototypes (Table 3). The predicted increase in core temperature over a six- hour period in the

warm environment based on the measurements made in this study was also not significantly different. In this environmental condition (no solar load), subjects could be encapsulated in any of the wraps for up to six hours provided that the subjects were adequately hydrated (Table 4). It is critical to note that the subjects in these experiments were normally hydrated and were not sedated. Dehydration would result in decreased evaporation and elevated  $T_{re}$  (7) and would invalidate the 6-hr  $T_{re}$  prediction. Also, some types of analgesia could impair thermoregulation, so casualties to whom those types of analgesic agents have been administered would be less able to remain encapsulated in the wrap for long periods of time. Furthermore, any changes in the ambient conditions such as solar radiation, higher ambient temperature and higher relative humidity would invalidate the predicted change in  $T_{re}$  over a 6-h period of encapsulation. Any of these conditions would result in a higher  $T_{re}$  than predicted.

Table 4. Mean ( $\pm$  S.D.) sweating rate during encapsulation and the predicted weight loss, based on this sweating rate, after 6 hours of encapsulation.

	Wrap 1	Wrap 2	Wrap 3	Wrap 4	Wrap 5	Wrap 6	Wrap 7	Wrap 8
Sweating Rate ( $g \cdot min^{-1}$ )	2.20 (1.37)	2.11 (0.86)	3.03 (1.20)	2.36 (1.57)	2.56 (1.33)	2.00 (1.06)	2.60 (1.31)	2.69 (1.24)
Predicted Weight loss after 6 h (kg)	0.79 (0.49)	0.77 (0.31)	1.09 (0.43)	0.85 (0.56)	0.92 (0.48)	0.72 (0.38)	0.94 (0.48)	0.97 (0.45)

The heart rate was not different among the experimental patient wraps, although the HR averaged  $84 (\pm 10)$  beats $\cdot$ min $^{-1}$  in Wrap 5 which was statistically greater than Wrap 1 which averaged  $71 (\pm 10)$  b $\cdot$ min $^{-1}$  (Table 3 and Appendix 1).

Sweating rate was not different among the patient wraps (Table 4 and Appendix 1). The predicted weight loss after six hours of encapsulation was not different among the various wraps (Table 4), although encapsulation for that length of time could result in moderate dehydration (in some cases up to 1.5% of body weight). Atropine results in approximately a 65% reduction in sweating rate in various environmental conditions (3). If casualties have been previously treated with atropine,  $T_{re}$  will rise much more rapidly than in untreated casualties, again invalidating the prediction of  $T_{re}$  after six hours of encapsulation.

Oxygen and carbon dioxide concentrations within the wrap were generally stabilized during the first twenty five minutes of encapsulation (Figs. 1 and 2). When the  $O_2$  concentration was analyzed by a two-way analysis with repeated measures, including all subjects during the first 48 min of encapsulation (Subject 2 was removed from Wrap 5 at 48 min), Wrap 7 was less permeable to oxygen than Wraps 1,3 and 8. However, Tukey's test of critical differences revealed that oxygen concentration within Wrap 7 was not different from  $O_2$  concentration in Wraps 2,4,5, and 6; and Wrap 5 was not different from Wraps 1,3 and 8 (Table 5). Therefore only Wrap 7 can be judged truly less permeable to  $O_2$  as assessed by  $O_2$  depletion encapsulation than the Wraps 1, 3 and 8. Even though the analyses show Wrap 7 to be less permeable to  $O_2$  than wraps 1,3 and 8, the mean  $O_2$  concentration was greater than 18% during the initial 48 min of encapsulation (Fig. 1). However, in three cases, the experiment had to be stopped due to  $O_2$  concentrations less than 16% during encapsulation within Wrap 7.

Figure 1. The mean oxygen concentration during the first 48 min of encapsulation in Wrap 3 (▲) and Wrap 7 (■).

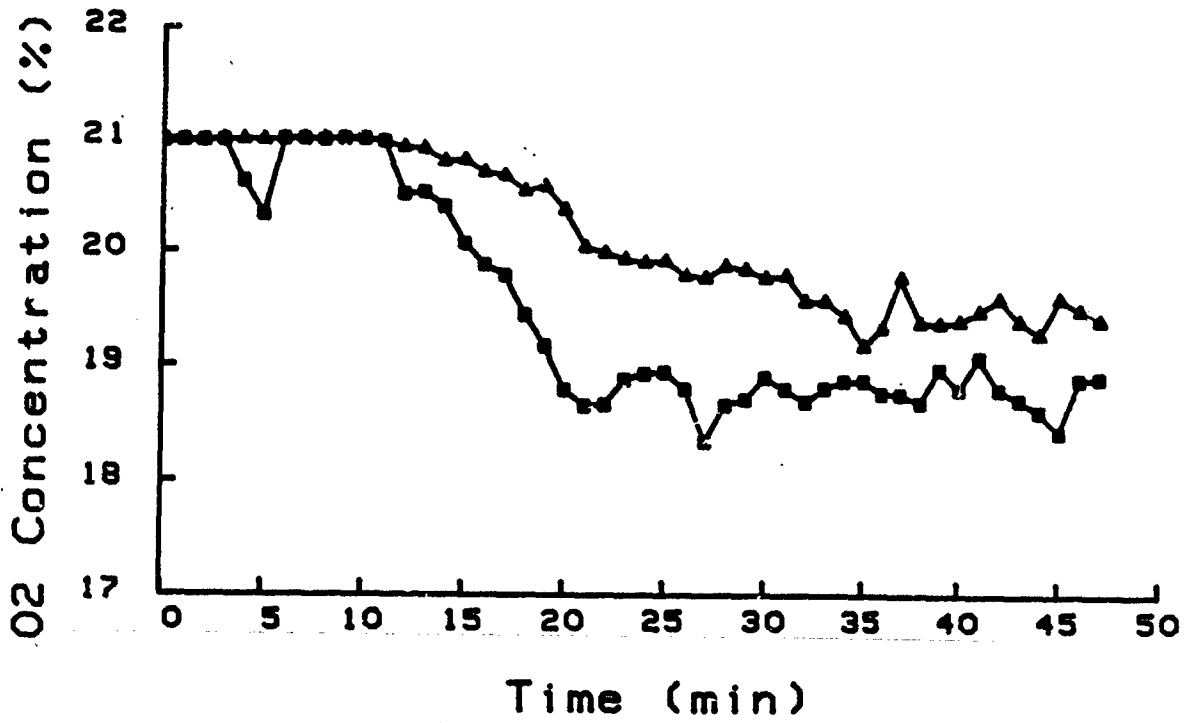


Figure 2. The mean carbon dioxide concentration during the first 48 min of encapsulation in Wrap 3 (▲) and Wrap 7 (■).

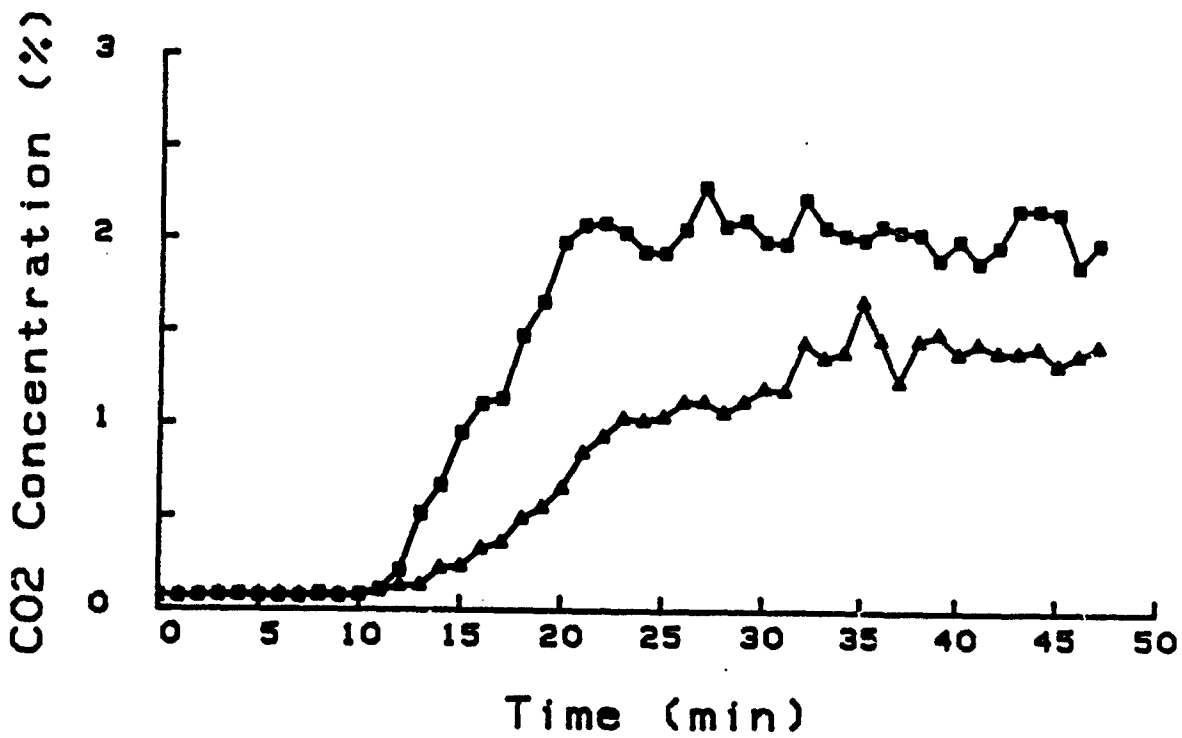


Table 5. Mean ( $\pm$  S.D.) oxygen (O<sub>2</sub>) and carbon dioxide (CO<sub>2</sub>) concentration within the patient wraps while subjects were encapsulated for the initial 48 min. The critical difference from Tukey's test (C.D.) is also presented.

	Wrap 1	Wrap 2	Wrap 3	Wrap 4	Wrap 5	Wrap 6	Wrap 7	Wrap 8
O <sub>2</sub> (%)	20.09 (0.8)	19.29 (0.9)	19.63 (0.9)	19.23 (1.0)	19.46 (1.0)	19.15 (0.9)	18.84 (1.2)	19.77 (0.7)
C.D. = 0.68								
CO <sub>2</sub> (%)	0.92 (0.6)	1.56 (0.8)	1.24 (0.8)	1.64 (0.8)	1.42 (0.8)	1.71 (0.7)	1.93 (0.9)	1.18 (0.6)
C.D. = 0.56								

CO<sub>2</sub> accumulation during the initial 48 min was less in Wraps 1,3, and 8 than Wrap 7 (Table 5). Wraps 2,4,5 and 6 were not statistically significantly different in CO<sub>2</sub> permeability from Wrap 7. However, the CO<sub>2</sub> concentration within Wrap 7 was considerably less than 3% during the initial 48 min of encapsulation (Figure 2 and Table 5). Based on the analyses of the initial 48 min of encapsulation, all the wraps would meet the letter requirement (O<sub>2</sub> concentration  $\geq$  18%, CO<sub>2</sub> concentration  $\leq$  3%) However, O<sub>2</sub> concentration decreased further over the entire two hours of encapsulation (prior to the placement of the impermeable film). Although in five cases, the experiment was terminated before two hours of encapsulation, a comparison of the O<sub>2</sub> and CO<sub>2</sub> concentrations within the wraps after two hours would be informative. Therefore in those cases in which the experiment was terminated, the last O<sub>2</sub> or CO<sub>2</sub> concentration measured was used as the 2 h value. The O<sub>2</sub> concentration was not different between Wraps 1,3,4,5,6 and 8 after 2 h of encapsulation, but O<sub>2</sub> concentration was clearly lower in Wrap 7 than in Wraps 1,3 and 8 (Table 6). Similar results were observed in CO<sub>2</sub> concentration after 2 h of encapsulation. Wraps 1,3,4,5,6 and 8 had a lower CO<sub>2</sub> concentration than Wraps 2 and 7 (Table 6); but Wraps 4,5 and 6 were not significantly different from Wrap 7. CO<sub>2</sub>

accumulation was greater during encapsulation in Wraps 2 and 7 than Wraps 1 and 3. Also CO<sub>2</sub> accumulation was greater in Wrap 7 than Wrap 8. Thus, after 2 hours of encapsulation, Wrap 7 was less permeable to O<sub>2</sub> and CO<sub>2</sub> than Wraps 1,3 and 8.

Table 6. Mean ( $\pm$  S.D.) oxygen and carbon dioxide concentration within the patient wraps after 2 hours of encapsulation. The critical difference from Tukey's test (C.D.) is also presented.

	Wrap 1	Wrap 2	Wrap 3	Wrap 4	Wrap 5	Wrap 6	Wrap 7	Wrap 8
O <sub>2</sub> (%)	19.54	18.03	19.32	18.53	18.80	18.41	17.62	19.17
	(0.9)	(1.6)	(0.6)	(0.9)	(1.4)	(0.6)	(1.2)	(0.5)
C.D. = 1.27								
CO <sub>2</sub> (%)	0.98	2.31	1.18	1.90	1.62	1.95	2.61	1.43
	(0.6)	(1.2)	(0.5)	(0.8)	(1.2)	(0.7)	(1.1)	(0.5)
C.D. = 1.06								

During a 2 h encapsulation period in the environment in which the experiments were conducted, all of the experimental wraps were adequate according to the letter requirement except Wrap 7 (Table 6). Further testing was conducted on 2 prototype wraps in more extreme hot and cold environments. Wraps 3 and 5 were chosen because encapsulation in those wraps resulted in a lower  $T_{re}$  than the other prototypes (Table 3), although these differences were not statistically significant. Another consideration in choosing these two prototypes was that the production cost was estimated to be lower than some of the other prototypes.

Those experiments indicated that there were slight differences between Wraps 3 and 5. In the HOT/DRY environment, the majority of the subjects requested to be removed from both wraps before the end of the experiment. One subject's rectal temperature reached 39.2°C in both wraps and consequently was removed. The mean ( $\pm$  S.D.) time of encapsulation in Wrap 3 was 92.3 ( $\pm$ 26.5) min and 94.6 ( $\pm$  27.9) min in Wrap 5, which was not different between wraps

(Appendix 2). The final O<sub>2</sub> concentration during encapsulation was greater in Wrap 3 (Appendix 2). Although the final CO<sub>2</sub> concentration was not significantly different between wraps, there was a very strong trend toward significant differences ( $p = 0.051$ ), with Wrap 3 being less than 5. The concentration of O<sub>2</sub> in Wrap 5 did not fall below 18% and was only a 0.5% lower than in Wrap 3, although in higher altitudes this difference would become more important. Final  $T_{re}$  was not different between wraps. The predicted increase in  $T_{re}$  for 3 h of encapsulation in Wrap 3 was 2.2 ( $\pm 0.6$ )°C and 2.1 ( $\pm 0.6$ )°C for Wrap 5, and was also not different between wraps (Appendix 2). There was no difference in weight loss between the wraps. The average weight loss was 1.2 ( $\pm 0.7$ ) kg in Wrap 3 and 1.3 ( $\pm 0.3$ ) kg in Wrap 5. The predicted weight loss after 3 h was 2.2 ( $\pm 0.9$ ) kg in Wrap 3 and 2.5 ( $\pm 0.6$ ) kg in Wrap 5. There was no difference in heart rate between the wraps (Appendix 2).

The predicted  $T_{re}$  and weight loss during encapsulation in the HOT/DRY environment represent a substantial physiological strain (Appendix 2). An increase in core temperature which averages 2.2°C (3 h) could result in some heat injury casualties, even in men who were normally hydrated. In a field situation, the soldier would be further stressed by the combat situation and injury, as well as the environment. Proper hydration may be impossible in such a situation and would further increase the physiological strain. Encapsulation in the field for a longer time than the experimental subjects tolerated (~90 min) in these environmental conditions is contraindicated. If a technique for rehydrating the encapsulated patient is available, time of encapsulation without heat injury could be prolonged. Whenever sedatives, pain killers, atropine or other drugs used for protection against chemical warfare agents have been administered in the field, the time of encapsulation without heat injury would be reduced.

Furthermore, in these experiments it was observed that  $O_2$  could be depleted to less than 16% in the area near the face during encapsulation when the subject lay with his face positioned upright such that the impermeable window of the wrap was pressed against the face. If the subject turned his head, the  $O_2$  concentration would increase immediately. An unconscious or sedated patient would be more likely to suffocate, while a conscious patient who was able to turn his head would have little possibility of suffocation.

In the  $-40^{\circ}\text{C}$  environment there were no differences between wraps (Appendix 2). The time of encapsulation averaged 76.5 ( $\pm 10.6$ ) min in Wrap 3 and 68.6 ( $\pm 10.3$ ) min in Wrap 5.  $T_{re}$  decreased  $0.65$  ( $\pm 0.4$ ) $^{\circ}\text{C}$  in Wrap 3 and  $0.46$  ( $\pm 0.2$ ) $^{\circ}\text{C}$  in Wrap 5.  $T_{\text{finger}}$  decreased  $16.4$  ( $\pm 5.2$ )  $^{\circ}\text{C}$  to  $14.45$  ( $\pm 5.0$ ) $^{\circ}\text{C}$  in Wrap 3 and  $14.2$  ( $\pm 4.2$ )  $^{\circ}\text{C}$  to  $14.8$  ( $\pm 5.2$ ) $^{\circ}\text{C}$  in Wrap 5. Weight loss was negligible in both wraps, and heart rate was not different between wraps. Predicted  $T_{re}$  at 3 h, where differences between the two wraps would be maximized, were not significantly different.  $T_{re}$  was predicted to decrease  $1.49$  ( $\pm 0.7$ ) $^{\circ}\text{C}$  in Wrap 3 and  $1.27$  ( $\pm 0.6$ ) $^{\circ}\text{C}$  in Wrap 5 (Appendix 2). Predicted finger temperatures after 3 h were not different between wraps. In both, the fingers would suffer cold injury. Table 7 shows the mean predicted core and finger temperatures for 90, 120 and 180 min during encapsulation. It must be kept in mind that these predictions are for nonstressed subjects dressed in the full Arctic ensemble, which included 3 layers of insulation ( $clo = 2.18$  (6)) for the hands. After 90 min of encapsulation in a  $-40^{\circ}\text{C}$  environment, a small portion of the population could suffer cold injury to the phalanges. The instances of cold injury would increase with 2 h of encapsulation.

Table 7. Mean (+ S.D.) predicted rectal temperature ( $T_{re}$ ) and finger temperature ( $T_{finger}$ ) during encapsulation in  $-40^{\circ}\text{C}$  ( $n = 5$ ).

	90 min		120 min		180 min	
	Wrap 3	Wrap 5	Wrap 3	Wrap 5	Wrap 3	Wrap 5
$T_{re}$ (S.D.)	-0.75 (0.4)	-0.64 (0.3)	-0.99 (0.5)	-0.85 (0.4)	-1.49 (0.7)	-1.27 (0.6)
$T_{finger}$ (S.D.)	-19.38 (7.6)	-20.13 (7.2)	-25.84 (10.1)	-26.84 (9.6)	-38.76 (15.1)	-40.26 (14.5)

### CONCLUSIONS

All the prototype patient wraps exceeded the letter requirement for  $\text{O}_2$  depletion,  $\text{CO}_2$  accumulation and core temperature during a 2 h encapsulation period in a warm environment except for the wrap made of Nyco twill shell and a Von Blucher Saratoga core (Wrap 7). By 2 h of encapsulation mean  $\text{O}_2$  concentration within this wrap had decreased to less than 18%. Both  $\text{O}_2$  depletion and  $\text{CO}_2$  accumulation was statistically different in Wrap 7 than Wraps 1, 3 and 8. In the HOT/DRY environment,  $\text{O}_2$  depletion was significantly less in the patient wrap composed of a Nyco twill shell and 3M melt blown polypropylene core than a wrap made of a Nyco oxford shell and Bondina Mark IV core. There were no significant differences in core temperature and finger temperature between the two patient wraps when tested in the  $-40^{\circ}\text{C}$  environment.

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### Appendix 1

The statistical table for one-way analysis of variance with repeated measures. The F-value (F), the F probability (F-prob) and critical differences (C.D.) are listed for sweating rate, predicted 6h weight loss (6h  $\Delta$ Wt) final changes in  $T_{re}$  ( $\Delta T_{re}$ ), predicted 6h  $T_{re}$  (6h  $T_{re}$ ), final  $O_2$  concentration ( $O_2$ ) and the final carbon dioxide concentration ( $CO_2$ ).

	SR	6h $\Delta$ WT	$\Delta T_{re}$	6h $T_{re}$	$O_2$	$CO_2$	HR
F	0.740	0.729	3.452	3.484	5.524	5.601	2.463
F-prob	0.640	0.648	0.0044	0.0042	0.0001	0.0001	0.0301
C.D.	-	-	0.162	0.396	1.269	1.059	13.0

## Appendix 2

The statistical table for one-way analysis of variance with repeated measures for both the HOT/DRY and COLD environments. The mean data for Wrap 3 (W3) and Wrap 5 (W5), the F-values (F), the F probability (F-prob) and critical difference (C.D.) are listed for weight change ( $\Delta wt$ ), final change in  $T_{re}$  ( $\Delta T_{re}$ ), predicted 3 h  $T_{re}$  (3 h  $T_{re}$ ), final  $O_2$  concentration ( $O_2$ ), final  $CO_2$  concentration ( $CO_2$ ) and time of encapsulation (time) in the HOT/DRY environment, and weight change ( $\Delta wt$ ), final change in  $T_{re}$  ( $\Delta T_{re}$ ), predicted 3 h  $T_{re}$  (3 h  $T_{re}$ ), final change in finger temperature ( $\Delta T_{finger}$ ), predicted 3 h  $T_{finger}$  (3 h  $T_{finger}$ ) and time of encapsulation (time) in the COLD environment.

	HOT/DRY					
	$\Delta WT$	$\Delta T_{re}$	3 h $T_{re}$	$O_2$	$CO_2$	Time
W3	-1.20	1.17	2.19	19.07	0.95	92.25
W5	-1.27	1.14	2.09	18.57	1.44	94.58
F	0.20	0.05	0.26	13.98	6.53	0.20
F-prob	0.67	0.82	0.63	0.01	0.051	0.68
C.D.	-	-	-	0.34	-	-

	Cold					
	$\Delta WT$	$\Delta T_{re}$	3 h $T_{re}$	$\Delta T_{finger}$	3 h $T_{finger}$	time
W3	-0.23	-0.66	-1.49	-16.36	-38.76	76.50
W5	-0.13	-0.46	-1.27	-14.23	-40.26	68.58
F	1.67	4.39	4.77	1.41	0.07	1.43
F-prob	0.25	0.10	0.09	0.30	0.80	0.29
C.D.	-	-	-	-	-	-

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5-86