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ON OF BRITISH AND CANADIAN CONDUCTIVE
FOR HEATING ELEMENTS FOR HANDWEAR:
PRELIMINARY REPORT

by

R.W. Nolan and S.W. Cattroll

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EVALUATION OF BRITISH AND CANADIAN CONDUCTIVE RUBBER HEATING ELEMENTS FOR HANDWEAR: PRELIMINARY REPORT

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ABSTRACT

A physiological evaluation of British and Canadian conductive rubber heating elements for use in electrically-heated handwear was carried out in the DREO cold room at -40°C. It was found that the difference between the mean hand temperatures of test subjects wearing either type of handwear was not significant.

RÉSUMÉ

Le CRDO a effectué des essais en chambre froide, à -40°C, sur les effets physiologiques de deus types de gants comportant des éléments chauffants en caoutchouc conducteur, l'un de fabrication britannique et l'autre de fabrication canadienne. Les essais ont montré qu'il n'y a pas de différence significative entre les températures moyennes des mains d'un sujet qui porte un type de gant différent dans chaque main.

INTRODUCTION

The Canadian Forces have a continuing requirement to equip Service personnel with hand covering which will provide optimum cold weather protection and permit maximum dexterity. Research at DREO has been directed to the provision of warmth by means of conducting rubber, supported by a thermostatic control unit designed to provide intermittent power action, and evaluation experiments have been carried out using gloves as a test vehicle (1). At the 11th Commonwealth Defence Conference on Operational Clothing and Combat Equipment it was agreed that Canada would undertake a comparative evaluation of the Canadian experimental method of providing auxiliary heating to the hands and a British system designed to achieve the same objective.

Six pairs of electrically-heated mittens of British design were forwarded to DREO. These consisted of a thin conductive rubber heating element encased in a shell made of blue-coloured nylon laminated to a thin (~ 1 mm) urethane foam backing (Figure 1). A slit, 5 cm long, through which the index finger could be extended was incorporated in the design of the mitten. No outer mitten nor information on the type of outer mitten used (if any) was supplied with the British mitten. Previous work at DREO had been carried out using a conductive rubber heating element encased in a 6-mm-thick urethane foam liner inside a specially designed outer glove of black leather cowhide. It was obvious that the British "system" as received could not be compared meaningfully to the Canadian "system".

Since the British conductive rubber heating element could not be modified to fit inside a glove, it was decided to manufacture mitten shells of British design and insert the Canadian heating elements into these. Because additional quantities of the British shell material were not available, a similar material (nylon-tricot fabric laminated to urethane foam) was obtained and used to manufacture 12 pairs of mitten shells of British design into which the British and Canadian heating elements were inserted. Additional British electrical connecting plugs were also not available and these were replaced with plugs readily available in Canada. The modified mitten is shown in Figure 2.

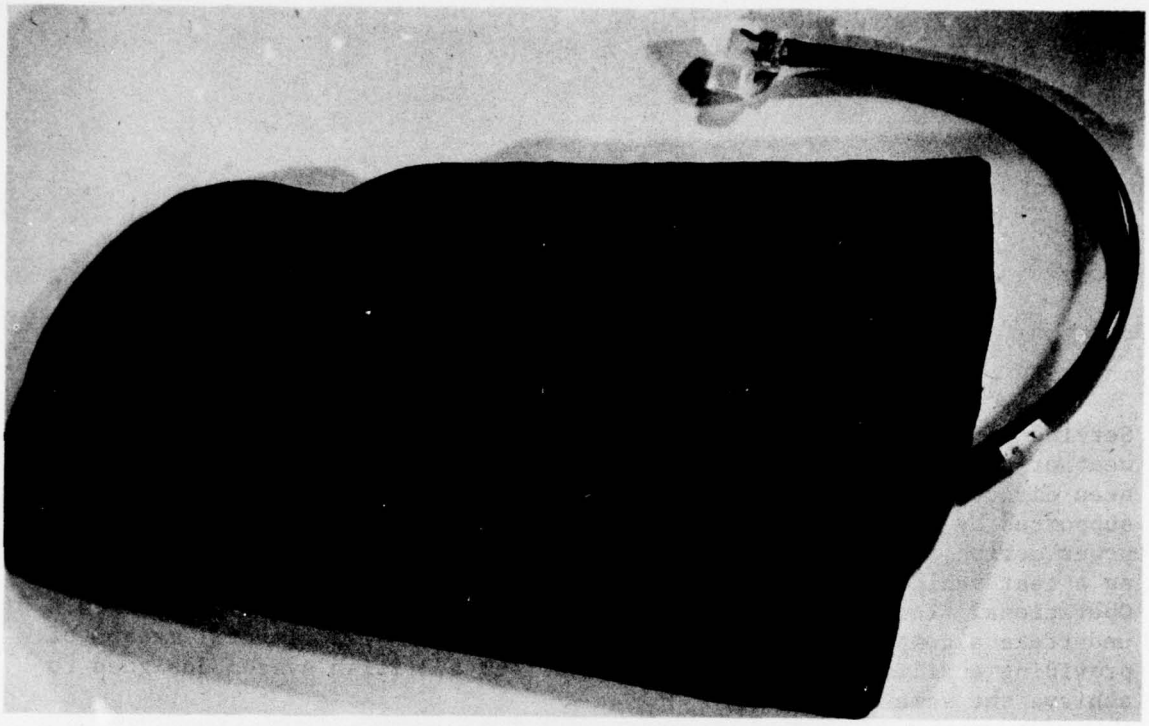

Figure 1. The British Electrically-Heated mitten.

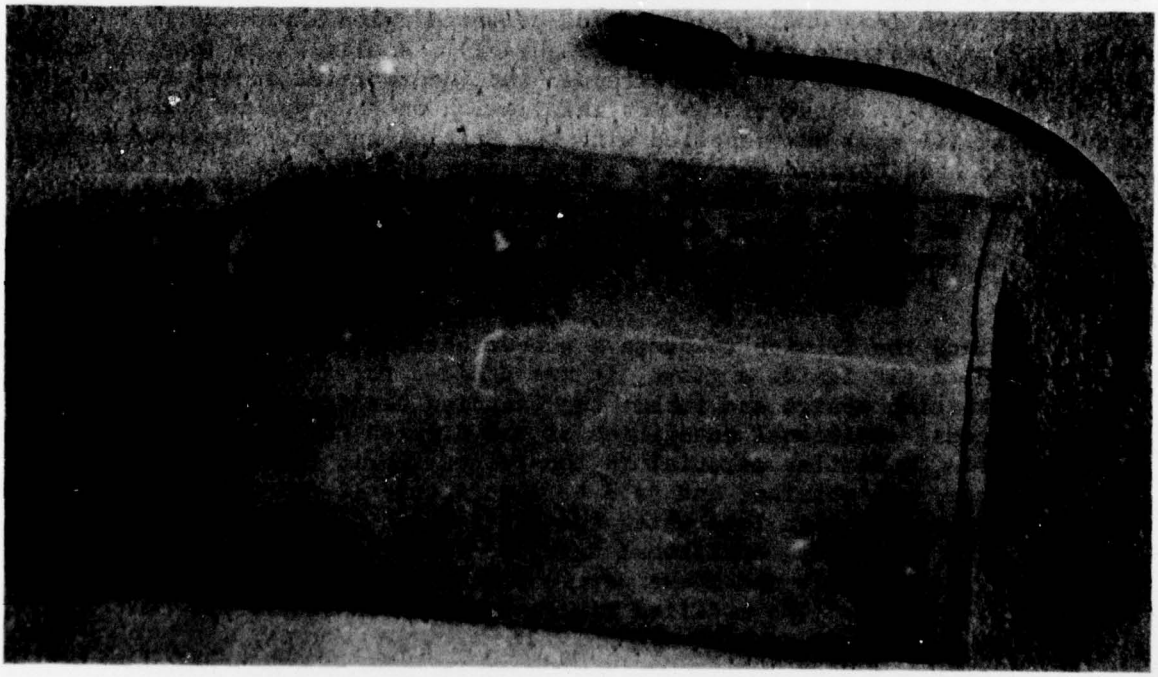

Figure 2. Modified Electrically-Heated Mitten

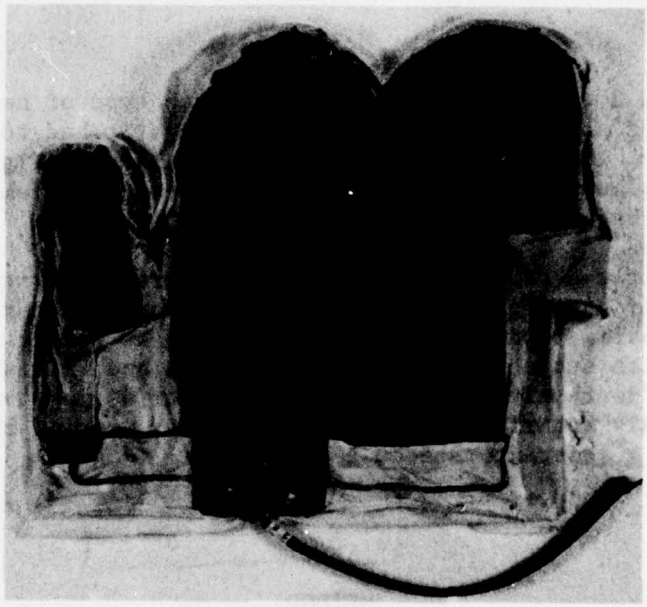

Figure 3. British Heating Element.

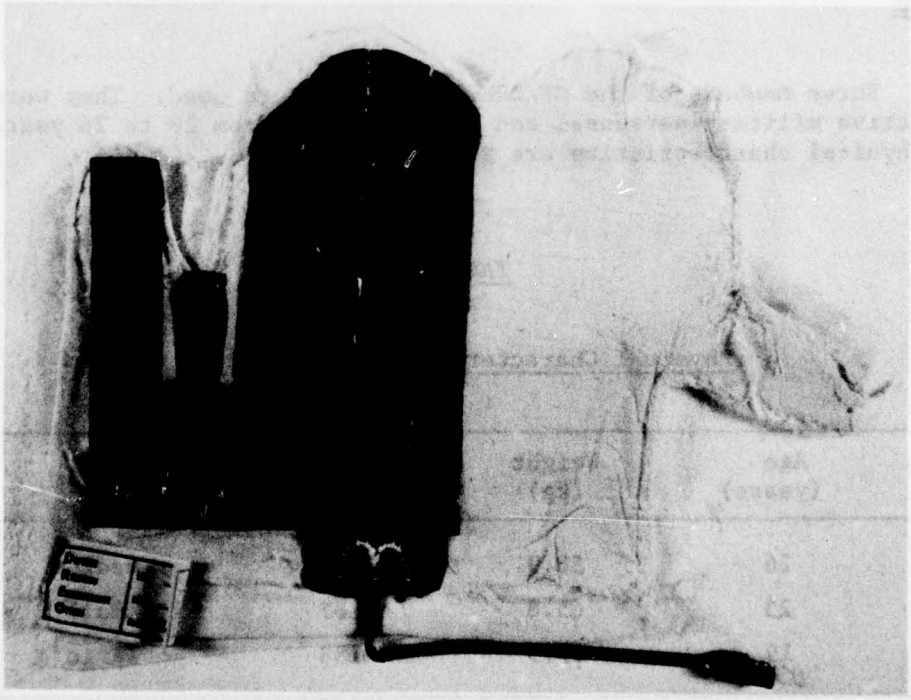

Figure 4. Canadian Heating Element.

Figures 3 and 4 are photographs of each type of heating element placed inside the shell material prior to being stitched to form the complete mitten. It is noted that the British element (Figure 3) is such that it envelops most of the hand whereas the Canadian element (Figure 4) covers only the back of the hand.

Since it was of prime interest to compare the British and Canadian conductive rubber heating elements, it was decided that during the preliminary investigation no outer mittens would be worn. All testing was conducted with subjects wearing the Canadian and British electrically-heated mittens "as received". Also, to eliminate as many variables as possible, the only activity performed by subjects wearing the mittens was marching at a constant rate on a treadmill.

METHOD

Subjects

Three members of the CF/DREO Test Team were used. They were young, male, active military personnel and ranged in age from 19 to 26 years. Their physical characteristics are given in Table I.

TABLE I

Physical Characteristics of Subjects

Subject No.	Age (years)	Weight (kg)	Height (cm)	Hand Size
1	26	58.9	163	medium
2	23	65.8	167	small
3	19	89.5	188	large

Experimental

The resistance of each of the heating elements at 20°C was measured and the power consumption at 12 volts was calculated. It was observed that the resistance of each type of element varied substantially from mitten to mitten. At 12 volts the average power consumption of the British element was found to be 1.1 watts and that of the Canadian element was found to be 12 watts.

The comparative evaluation of the British and Canadian heating elements was conducted in the DREO cold chamber at a temperature of -40°C. Test subjects dressed in Canadian Forces Arctic clothing and wearing a pair of either type of mitten, walked 1.6 ms^{-1} on a treadmill for a period of one hour facing a 4.5-ms^{-1} wind. During the test period, subjects grasped a 5-cm diameter iron handrail with the right hand to assist balance and to simulate the heat sink presented by large hand tools. Skin temperatures were measured using thermistors taped at three different positions (tip of third finger, point at which second and third fingers join palm, back of hand) on the right hand of each subject and were recorded at two-minute intervals.

Power was provided to the heating elements using a 12-volt dc power supply. A relay device in the circuit to each of the Canadian mittens activated electrical timers so that the total power consumption of each of the mittens during a test run could be measured as the thermostats switched on and off. The British mittens are not equipped with thermostats.

Because of the subject-to-subject and day-to-day variation in test results observed during preliminary investigations it was decided that a number of "control" runs should be conducted with test subjects wearing standard handwear. This would serve to acclimatize the subjects to the test conditions and to provide basic information regarding the extent of variation in hand temperature that might be expected. It was found that the hand temperatures of subjects wearing the Canadian Forces GP glove (a general purpose leather glove) with wool liner at -40°C were similar to those measured when the heated mittens were worn. Thus the GP glove with wool liner was selected as the "control" handwear. A total of fifteen one-hour test runs was conducted.

During the comparative evaluation of the Canadian and British mittens, the three subjects each wore one pair of three different types of handwear (Canadian, British, GP) on a rotating basis as follows:

Run No.	Subject No. 1	2	3
1	Canadian	British	GP
2	GP	Canadian	British
3	British	GP	Canadian

After completing one sequence of three test runs, each subject had worn each of the three types of handwear once. This sequence was repeated seven times for total of 21 one-hour test runs.

For each test run, the following procedure was used. Each subject dressed in his Arctic clothing excepting the parka. Thermistor probes were then taped to the right hand and the handwear was donned. The parka was then donned (with handwear cuffs inside the parka sleeve) and the subjects entered the cold room. The two subjects wearing heated mittens marched on the treadmill for a period of one hour and their hand temperatures were recorded at two-minute intervals. The other subject remained inactive in the cold chamber until his hand became uncomfortably cold (<10°C). He was then permitted to leave. Temperature data from the inactive subject was not used in the comparison of the electrically-heated handwear.

Throughout the trial, observations regarding handwear durability and the personal opinions of subjects were noted.

RESULTS AND DISCUSSION

Durability

Initially, difficulties were experienced with the power leads to both types of handwear due to the insulation cracking near the cuffs of the mittens when flexed in the cold. This problem was resolved by having the subjects wear the leads inside the sleeves of their parkas.

Both the British and Canadian conductive rubber heating elements functioned satisfactorily for the duration of the evaluation (at least 21 hours per mitten).

Manual Dexterity

Manual dexterity was not measured formally during this investigation, although it was noted that the subjects experienced difficulty in closing the buttons and fasteners on their parkas when the mittens were worn. Since the design and the outer shell material of the mitten was the same for both the British and Canadian heating element, it is expected that formal measurements of manual dexterity would yield similar results for each type of handwear. Previous work at DREO on the effect of different types of Canadian gloves on manual dexterity has indicated that manual performance is affected to about the same degree by all of the gloves tested (2, 3).

Hand Temperature

After each test, the average hand temperature of each subject at two-minute intervals was determined by calculating the arithmetic mean of the skin temperature at three points on the hand. When all testing was completed these results were combined to produce tables of the change in mean hand temperature as a function of time for each type of handwear for each subject.

A summary of results is presented in Table II. The change in the overall mean hand temperature of all three subjects as a function of time for each type of handwear is given. Each entry in the second and third column of the table represents the average of 63 individual temperature measurements (3 temperatures per subject x 3 subjects x 7 test runs). Similar information for the GP glove and wool liner is given in the fourth column of the table where each entry represents the average of 90 temperature measurements (2 subjects, 15 test runs). These data are presented graphically in Figure 5.

A comparison of the average hand temperatures of subjects wearing the British and Canadian mittens at -40°C is made in Table III, where data for individual subjects are given. Mean hand temperatures observed after exposure in the cold chamber at -40°C for 20, 40 and 60 minutes during each of the test runs are presented. These data were analyzed statistically using the t-Test; it was found that there was no significant difference between the hand temperatures of subjects wearing either type of

TABLE II

Mean Hand Temperatures of Subjects Wearing Various Types of Handwear at -40°C

Time (minutes)	Mean Hand Temperature (°C)		
	Canadian* Mitt	British* Mitt	GP** Glove
0	30.7	31.7	32.9
4	27.5	27.6	27.1
8	26.6	26.4	24.5
12	26.9	26.1	23.4
16	27.1	25.9	23.3
20	27.4	26.4	23.5
24	26.7	25.8	23.6
28	26.3	26.0	23.6
32	26.3	26.2	22.9
36	26.5	25.9	22.6
40	26.7	26.1	22.3
44	25.5	26.8	22.1
48	25.6	26.6	21.6
52	26.2	26.4	21.1
56	26.6	26.0	20.8
60	26.6	25.6	20.9

* 21 test runs

** 15 test runs

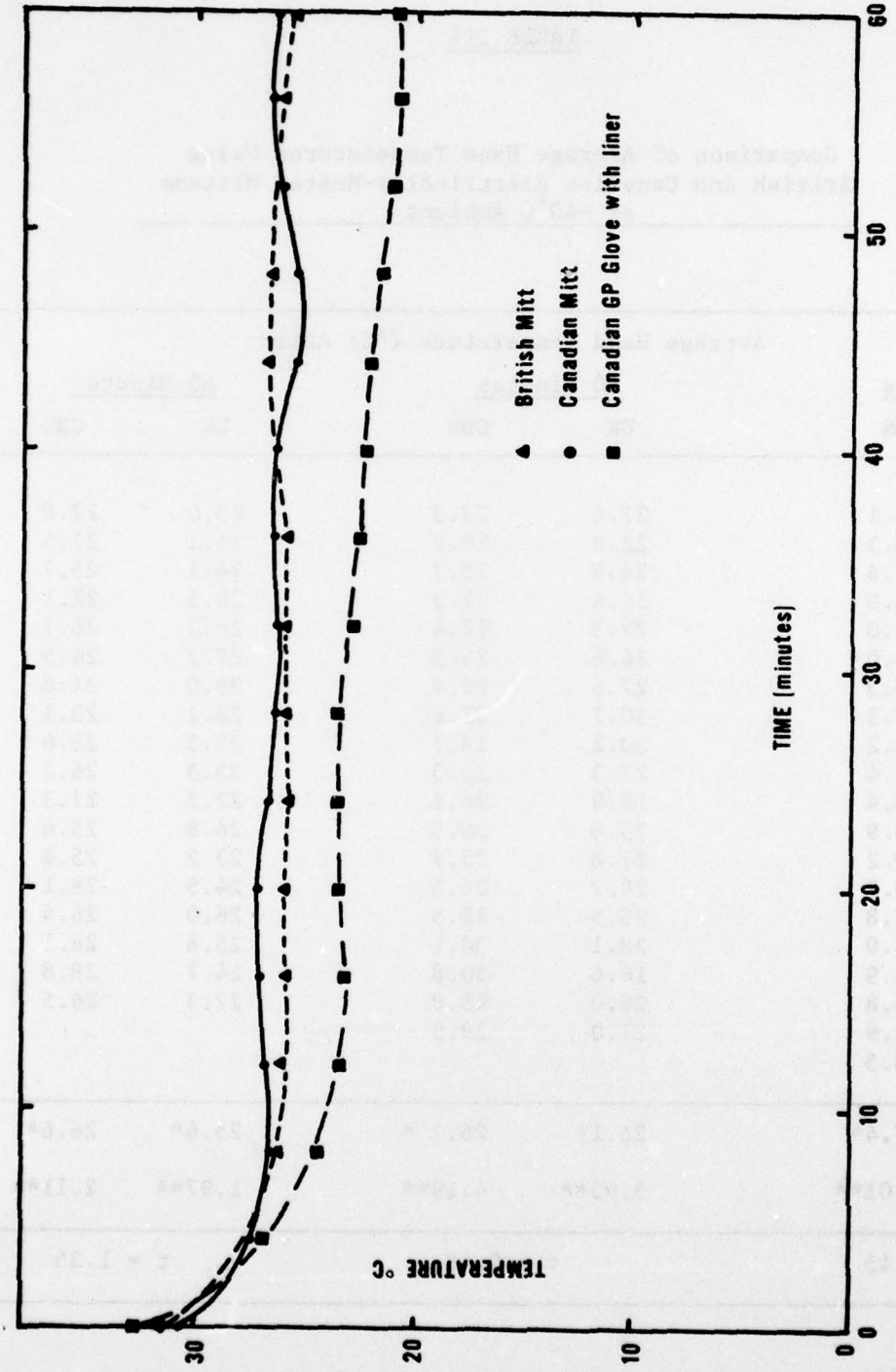

Figure 5. Summary of results: Mean hand temperatures of test subjects wearing various handwear systems at -40°C.

TABLE III

Comparison of Average Hand Temperatures Using British and Canadian Electrically-Heated Mittens at -40°C Ambient

Average Hand Temperature (°C) After					
20 Minutes		40 Minutes		60 Minutes	
UK	CDN	UK	CDN	UK	CDN
18.9	26.1	27.6	23.3	23.0	27.8
18.6	18.3	22.9	16.2	25.1	27.5
22.7	22.6	24.6	25.7	24.1	25.7
26.9	29.0	26.4	29.3	28.5	22.1
27.4	26.0	27.5	22.4	26.2	26.1
28.0	25.0	26.6	24.5	27.7	26.5
29.9	30.3	27.5	29.4	29.0	31.8
30.7	28.3	30.7	31.8	28.1	23.1
30.3	29.2	30.2	18.7	25.3	25.6
25.9	27.4	27.3	29.3	23.3	26.2
28.2	30.4	15.9	26.8	22.7	27.3
18.3	26.9	25.8	30.5	26.8	25.6
27.7	30.2	27.8	25.9	23.2	25.8
24.5	26.7	29.7	26.5	24.5	28.1
29.9	27.8	25.5	28.5	26.0	26.4
28.4	29.0	28.1	30.1	25.6	28.1
26.0	26.9	16.6	30.8	24.7	28.8
27.3	26.8	28.0	28.8	27.3	26.5
29.0	31.9	27.0	29.5		
29.6	28.5				
26.4*	27.4*	26.1*	26.7 *	25.6*	26.6*
3.90**	3.01**	3.93**	4.19**	1.97**	2.11**
t = 1.45		t = 0.48		t = 1.36	

* Mean
** Std. Dev.

electrically-heated mitten. Under the stated test conditions, the hand is maintained at approximately 26°C when mittens of either type are worn. This temperature is approximately 5°C warmer than when the GP glove with wool liner is worn under the same conditions.

Throughout the test period, hand temperatures were such that the thermostat on the Canadian mittens did not function (i.e. power was supplied continuously to both the British and Canadian mitten). In spite of the fact that more than ten times as much power was supplied to each Canadian mitten than to each British mitten (12 watts versus 1 watt), hand temperatures inside each type of mitten were approximately the same. This is probably due in part to the different shapes of the conductive rubber heating elements. The Canadian heating element was designed to fit inside a glove along the back of the hand where blood flow is nearest the skin surface and potential heat losses are the greatest whereas the British heating element envelops the palm and back of the hand. During the present evaluation, subjects grasped a 5-cm diameter iron handrail at -40°C, presenting a substantial heat sink to the palm of the hand. The heating element between the palm of the hand and this heat sink in the British mitten insulates the hand and provides enhanced heat retention.

The slit in the mitten near the index finger opened as the subjects grasped the handrail and tended to remain open after repeated wear. Subjects felt that their fingers would have been warmer if the slit was not present. It is felt that the slit serves no useful purpose since at ambient temperatures where electrically-heated handwear is necessary, exposing the bare finger and contacting cold metal (e.g. to pull a trigger) would result in frostbite.

It is felt that neither the British nor modified Canadian handwear as used under the conditions of this evaluation is satisfactory in providing optimum cold weather protection and maximum manual dexterity. Additional insulation is required in each case to maintain the hands at a comfortable temperature (usually considered to be about 30°C). If the experimental handwear had been worn in the cold by inactive subjects it is expected that much lower hand temperatures would have been recorded.

As has been suggested by others previously (1), it is felt that a more practical means of heating the hands and allowing manual dexterity would be through the use of a combination of a well-insulated electrically heated outer mitten with a very thin inner glove. This system would enable personnel to work in the cold on tasks requiring manual dexterity for short periods of time wearing the light glove. The electrically-heated mitten would serve to rewarm the hands quickly when required.

CONCLUSIONS

Under the test conditions described above, the results indicate the following:

(i) There is no significant difference in the mean hand temperature of subjects wearing electrically-heated handwear with either the British or Canadian conductive rubber heating elements.

(ii) Each type of heating element is capable of maintaining the hand at approximately 26°C, a temperature approximately 5°C warmer than when the Canadian GP glove and wool liner are worn.

(iii) Manual dexterity is affected by each type of handwear. Subjects experienced difficulty in closing buttons and fasteners on their parkas when the mittens were worn.

(iv) The Canadian heating element consumes approximately ten times more power than the British heating element.

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3. Vittorio, P.V., R.W. Nolan and S.W. Cattroll, "Dexterity Afforded by Experimental CW Protective Gloves", DREO Technical Note No. 76-2, February 1976.

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A physiological evaluation of British and Canadian conductive rubber heating elements for use in electrically-heated handwear was carried out in the DREO cold room at -40°C. It was found that the difference between the mean hand temperatures of test subjects wearing either type of handwear was not significant.

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