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Aerospace Medical Research Laboratory
Wright-Patterson Air Force Base, Ohio

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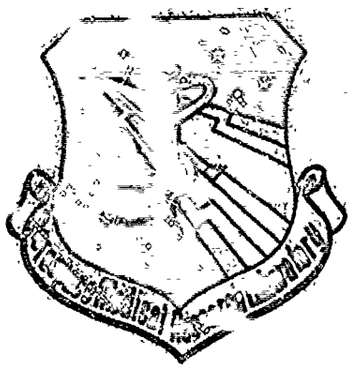

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NOVEMBER 1972

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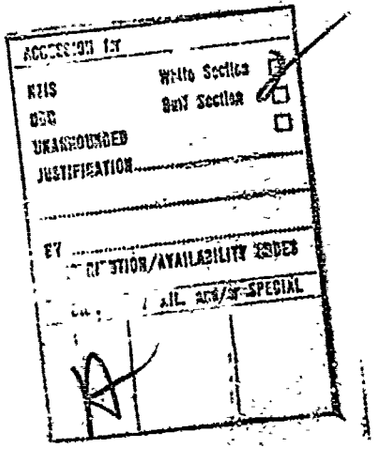

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13. ABSTRACT

Two 24-hour cold water immersion - life raft exposures were conducted in our laboratory test facility involving three subjects in each exposure. Physiologic data were obtained during these exposures to discern the better cold water protective capabilities of two environmental marine diving suits. The Swedish Unisuit proved thermally superior to the Dunlop suit. Several recommendations are made.

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Cold Water Immersion						
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FOREWORD

This research was conducted by personnel in the Aerospace Medical Research Laboratory, Aerospace Medical Division, in support of require-- ments for Headquarters Aerospace Rescue and Recovery Service, Scott AFB, Illinois, and the Life Support Systems Program Office, Aeronautical Systems Division, Wright-Patterson AFB, Ohio.

This technical report has been reviewed and is approved.

CLYDE R. REPLOGLE, PHD
Chief
Environmental Medicine Division
Aerospace Medical Research Laboratory

SECTION I
INTRODUCTION

Preliminary physiologic data collected at Eglin Air Force Base, Florida, indicated that the cold water survival clothing for the Skylab program needed future testing. The two dry suits were the Dunlop (NATO) and the Swedish Unisuit assemblies. The contingency requirement for the Skylab program is to provide pararescue personnel with the capability to withstand 2 hours of cold water immersion with a subsequent 72 hours in a life raft exposed to conditions found in northern latitudes.

Therefore, two 24-hour exposures were planned in the laboratory test facility involving three subjects in each exposure. Careful metabolic, heart rate, and thermal data were to be collected during this exposure in an effort to discern the better of the two clothing assemblies.

SECTION II

EXPERIMENTAL METHOD

Six volunteer test subjects were used in the two programmed 24-hour cold water immersion - life raft exposures. Three subjects all wearing identical outer dry suits participated in each exposure. The underlying clothing was varied only with the Dunlop suit. The specific clothing and insulative values are listed in table 1. The water temperature was maintained at 0C while the air temperature was -4C with 30 to 60m/minute wind velocity.

An ECG harness was affixed and the subjects were dressed in thermistor underwear. The sensors in this underwear monitored 17 skin temperatures as well as rectal temperature. In both exposures, some physiologic data were telemetered. After control readings, the subjects walked into the environmental chamber and jumped into a large swimming pool filled with cold water and ice. A seven man insulated Navy raft was afloat in the pool. A realistic exposure called for one man to stay in the water 45 minutes before being joined by the other two subjects. At the end of a 2 hour water immersion for the first subject, all three clamored aboard the large life raft. The exposures were terminated upon the subject's request or at the monitor's discretion. Table 2 shows the physical conditions during each test.

The telemetry equipment was fabricated by Dr. Marko of the Laboratory and yielded accurate temperature and ECG data. Three units were built each with a total of seven channels: 4 for skin temperatures, 1 for rectal temperature, 1 for calibration and 1 for the ECG signal. A major effort was devoted to antenna modification so that it could be placed under the hood of this clothing. For the first time, reliable metabolic data were obtained by means of a new $\dot{V}_{02}$ sensor developed by our laboratory group. This technique represents a major advance in predicting tolerance times during cold water immersion or cold water immersion - raft exposures.

TABLE 1

CLOTHING ASSEMBLIES

Subject	Test No.	Clothing Worn (Inside and Outside)	Clo Value	Clo Value Under Clothing (Alone)
A	1	Thermistor Underwear, 1 pr. Waffle Weave Underwear, Unisuit Liner, 2 pr. socks, wool gloves, Unisuit	1.78	1 pr. Waffle Weave Underwear + Unisuit Liner 1.32
B	1	Thermistor Underwear, 1 pr. Waffle Weave Underwear, Unisuit Liner, 2 pr. socks, wool gloves, Unisuit	1.78	1 pr. Waffle Weave Underwear + Unisuit Liner 1.32
C	1	Thermistor Underwear, 1 pr. Waffle Weave Underwear, Unisuit Liner, 2 pr. socks, wool gloves, Unisuit	1.78	1 pr. Waffle Weave Underwear + Unisuit Liner 1.32
D	2	Thermistor Underwear, 1 pr. Waffle Weave Underwear, Ventile Spacer, 2 pr. wool socks, wool gloves, 2 pc. Dunlop Suit	1.00	1 pr. Waffle Weave Underwear + Spacer Liner 1.1
E	2	Thermistor Underwear, 2 pr. Waffle Weave Underwear, 2 pr. socks, wool gloves, 2 pc. Dunlop Suit	0.98	2 pr. Waffle Weave Underwear 0.81
F	2	Thermistor Underwear, 1 pr. Waffle Weave Underwear, 1 Unisuit Liner, 2 pr. socks, wool gloves, 2 pc. Dunlop Suit	1.19	1 pr. Waffle Weave Underwear, Unisuit 1.32

TABLE 2

PHYSICAL TEST CONDITIONS, CLOTHING AND TEST DURATION

Test Date/ Subject	Air Temp T_A (C)	Water Temp Tw (C)	Wind Velocity Wv (M/min)	Divers Suit Worn	Time In Water	(Minutes) In Raft	Total
8 Dec 71							
A			30-60		120	935	1055
				Unisuit			
B	-4.0	0			75	928	1003
C					75	935	1010
14 Dec 71							
D			30-60		120	442	562
E	-4.0	0		Dunlop	75	1020	1095
F					75	1020	1095

SECTION III
RESULTS

Individual skin, core temperature, and heart rate changes during the exposures are plotted in figures 1-6. No data were available during the water immersion portion of the Unisuit test because of failure of prototype telemetry equipment. None of the physiologic data indicated thermal difficulty. The three subjects in the Unisuit tests maintained rectal temperatures above 36.6C, well above the critical level of 35.0C. These core temperatures stabilized after the first hour in the raft. With this same clothing, no serious temperature levels of the extremities were reached with the lowest value of 14.3C recorded for the feet.

Temperature changes during the Dunlop tests were somewhat more serious. Subject D asked to be removed after only 442 minutes in the raft because of discomfort resulting from the extreme cold. His rectal temperature of 35.3C verifies his subjective feelings. There was no problem with his extremity temperatures. The other two subjects were able to go on and asked to be removed after 1020 minutes in the raft because of intolerable cold. At the end of the test, their core temperatures had dropped to 35.3C and 35.7C. Extremity temperatures were maintained above 13.0C. Heart rates in all cases were within normal limits for sedentary, resting individuals. Metabolic data are presented in figures 7 and 8. There is a marked difference between the metabolic rates of subjects dressed in the Unisuits and Dunlop suits during the cold water immersion phase. The average values of an exercising man in water wearing the Unisuit is about 65 to 75 Kcal/m^2 hr - a moderate level - compared to the 90 to 140 Kcal/m^2 hr levels of the subjects wearing the Dunlop suits. Note Subject F's response. In the raft, the metabolic levels of subjects dressed in the Dunlop assemblies were somewhat higher on the average than those wearing the Unisuits. All levels were below 80 Kcal/m^2 hr and usually below 70 Kcal/m^2 hr.

Air temperatures within the raft varied from 10 to 20C higher than ambient air temperatures. A physical analysis of the insulation afforded by the life raft is shown in table 3. The functional insulative value of this raft, checked by two techniques, was 1.67 clo. Figure 9 presents a theoretical calculation of total insulation for comfort with various numbers of occupants in this raft at various air temperatures.

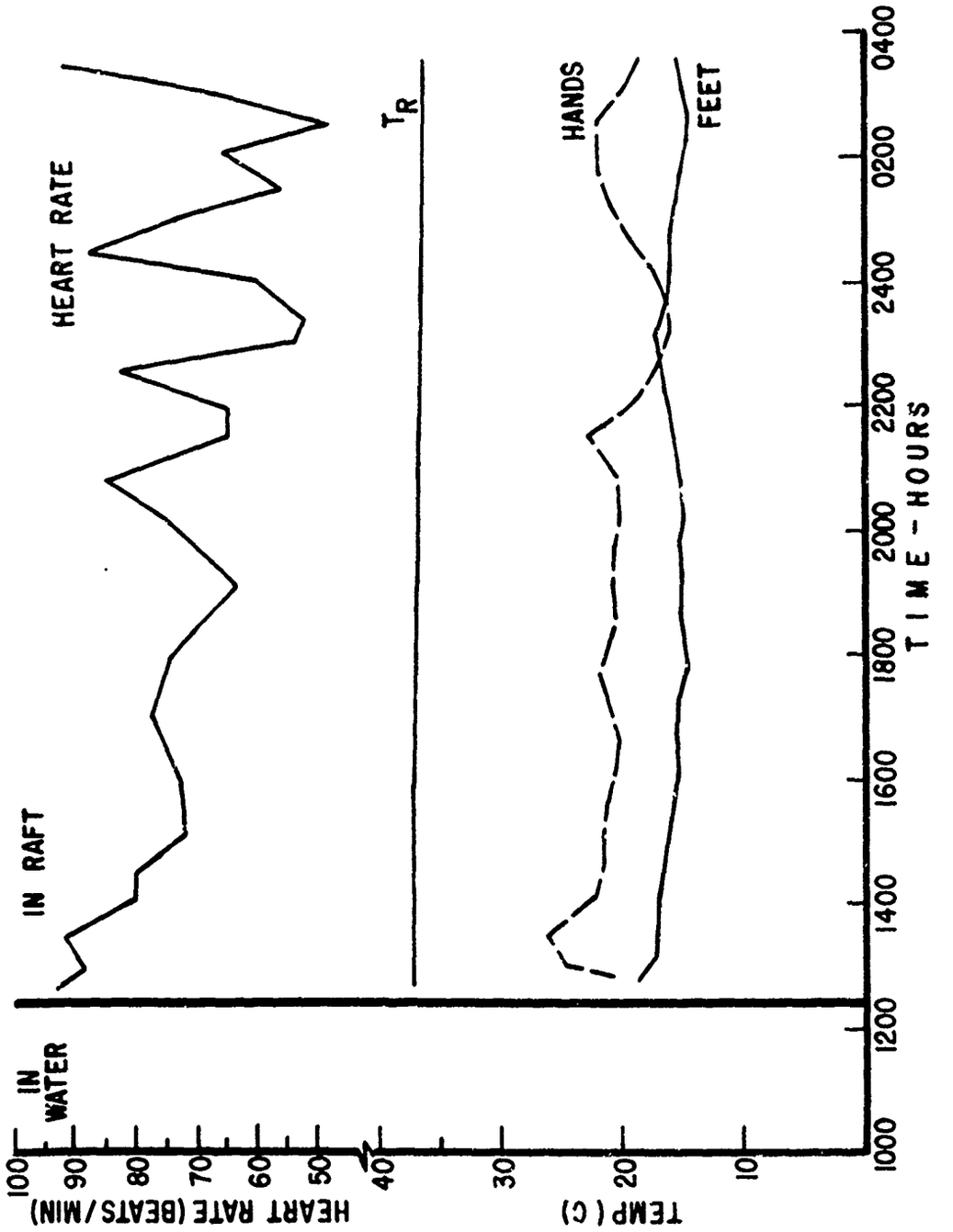

FIGURE 1. PHYSIOLOGICAL RESPONSES OF SUBJECT A WHILE WEARING THE UNISUIT WITH A UNISUIT LINER

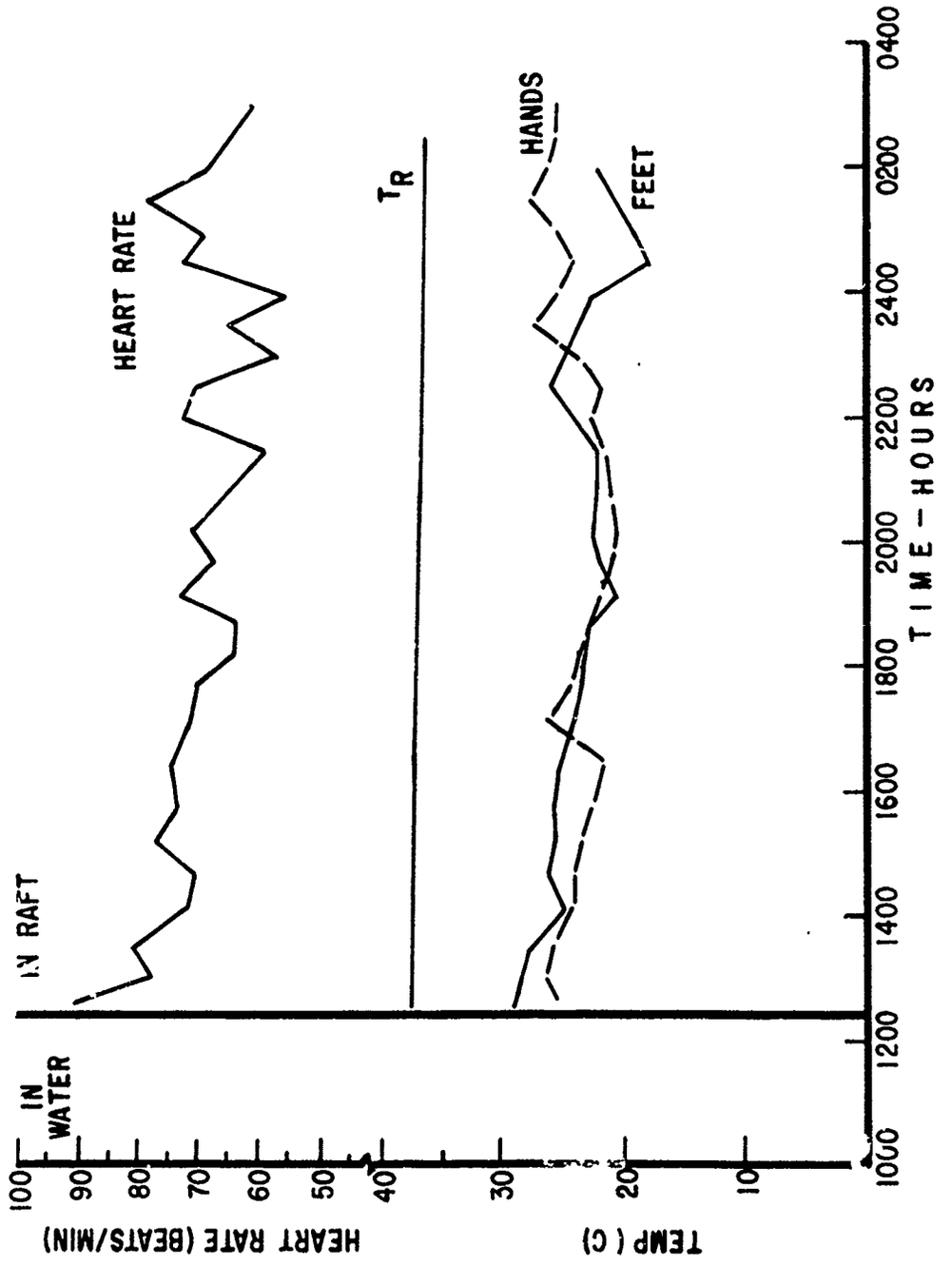

FIGURE 2. PHYSIOLOGICAL RESPONSES OF SUBJECT B WHILE WEARING THE UNISUIT WITH A UNISUIT LINER

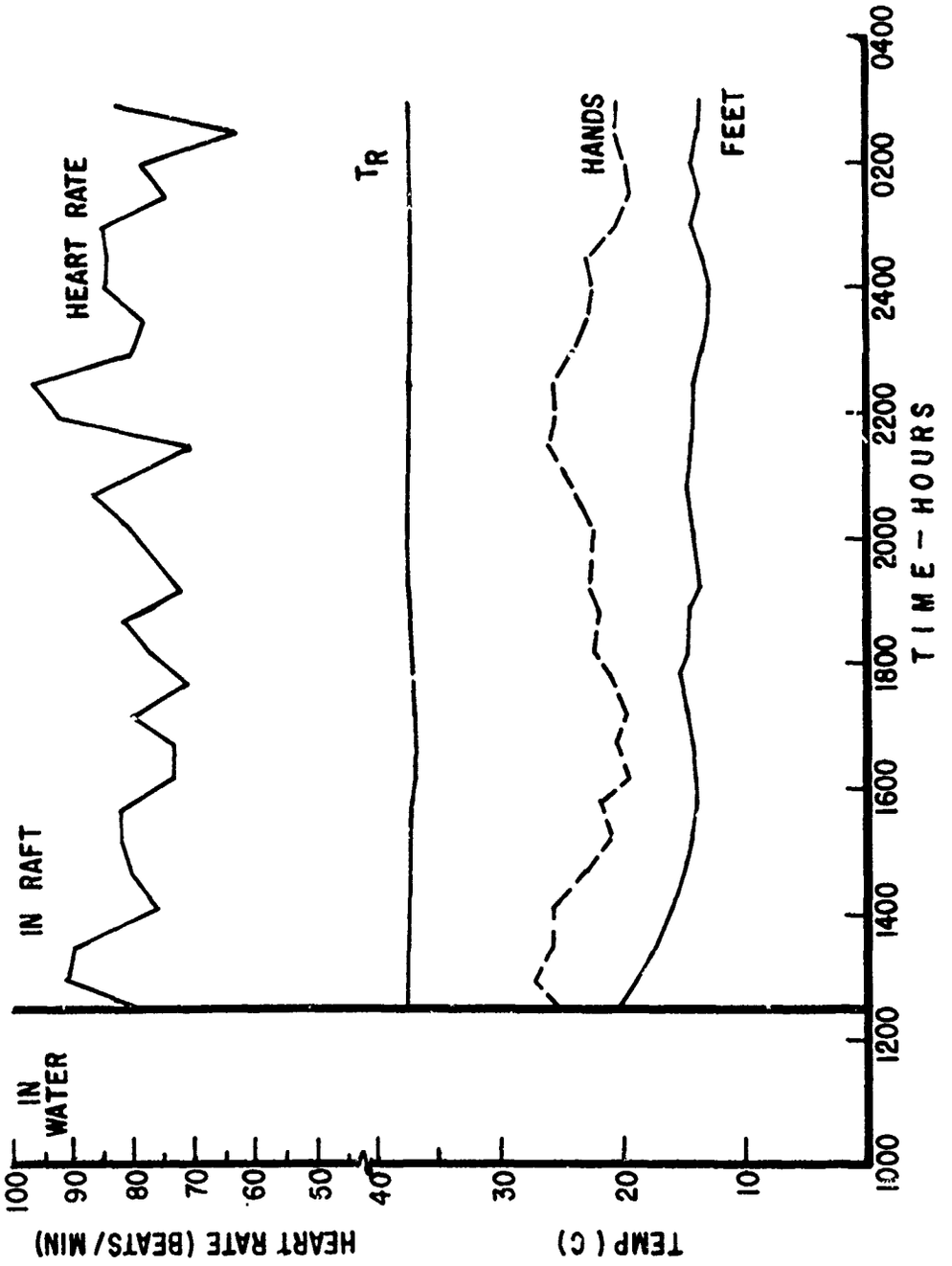

FIGURE 3. PHYSIOLOGICAL RESPONSES OF SUBJECT C WHILE WEARING THE UNISUIT WITH A UNISUIT LINER

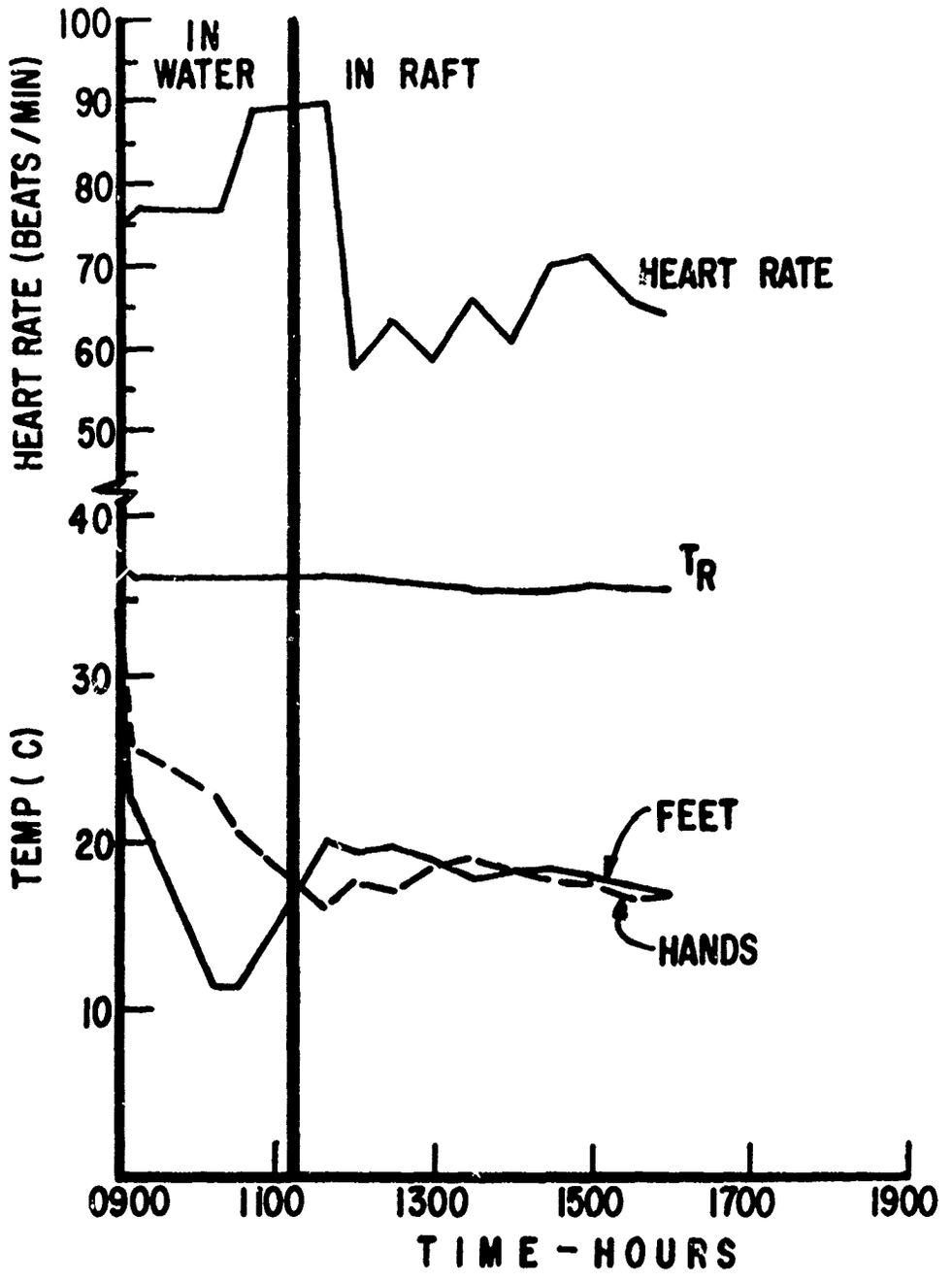

FIGURE 4. PHYSIOLOGICAL RESPONSES OF SUBJECT D WHILE WEARING THE DUNLOP SUIT WITH 1 PAIR WAFFLE WEAVE UNDERWEAR AND AN EXPERIMENTAL SPACER LINER

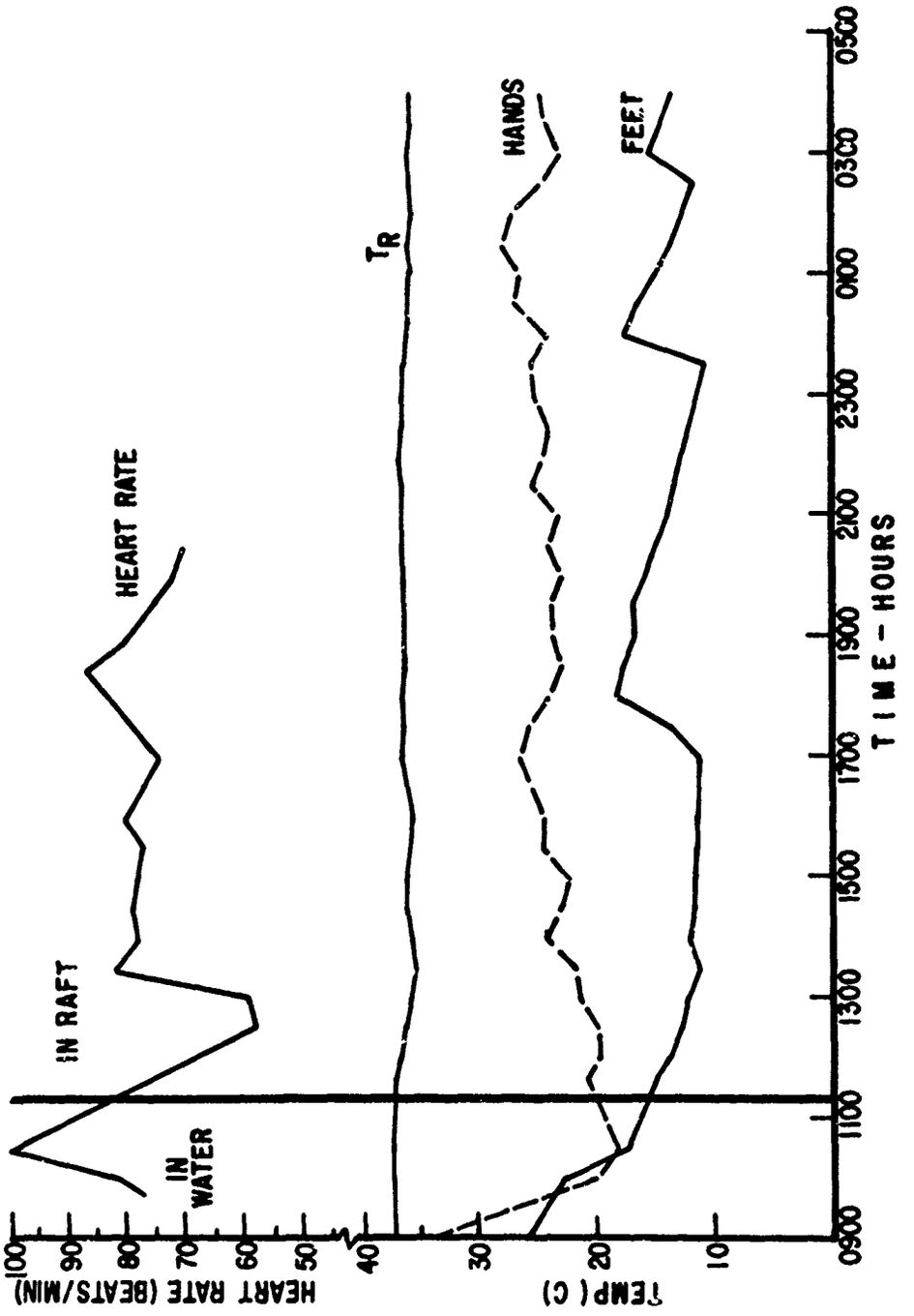

FIGURE 5. PHYSIOLOGICAL RESPONSES OF SUBJECT E WHILE WEARING THE DUNLOP SUIT AND 2 PAIR OF WAFFLE WEAVE UNDERWEAR

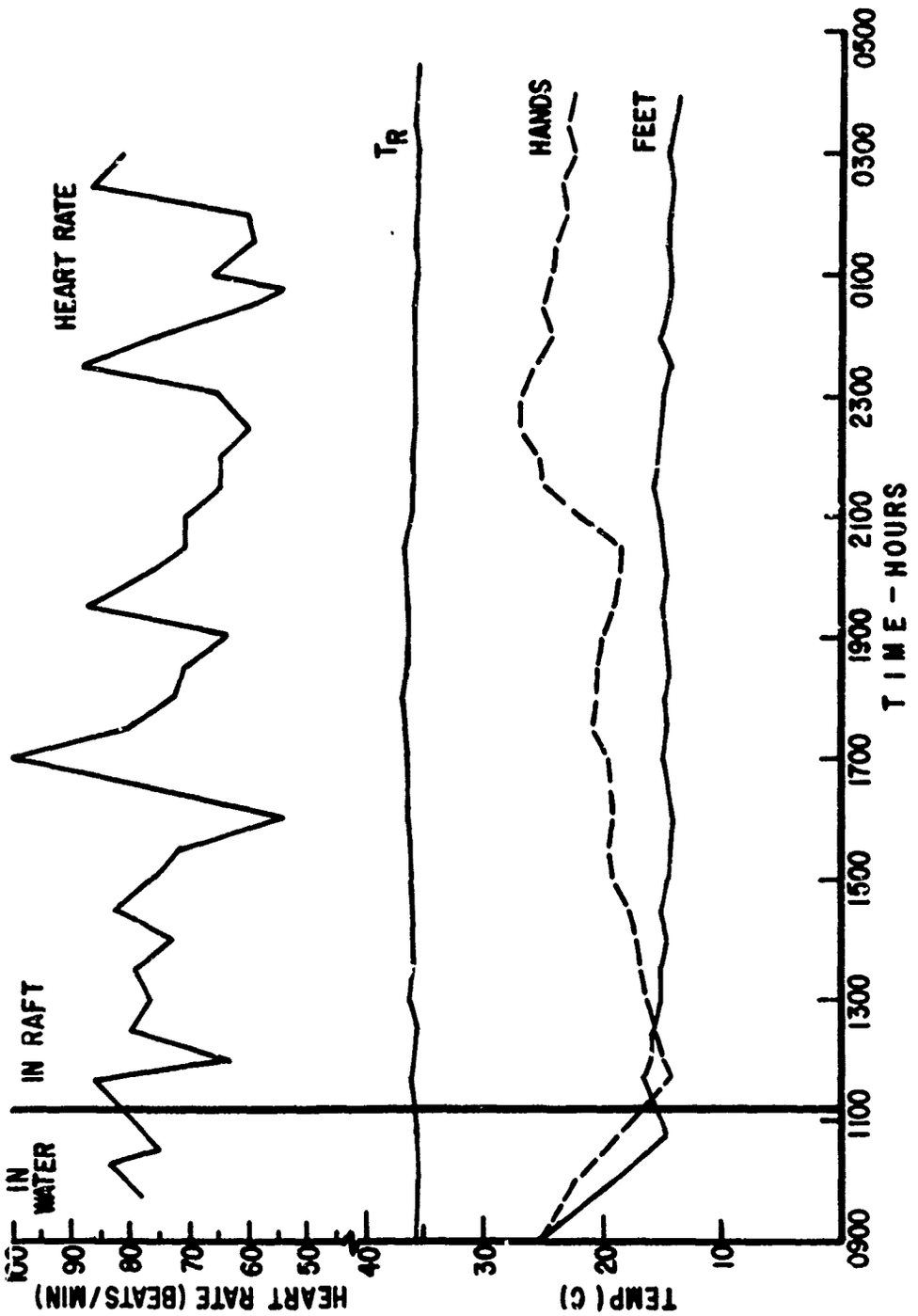

FIGURE 6. PHYSIOLOGICAL RESPONSES OF SUBJECT F WHILE WEARING THE DUNLOP SUIT WITH 1 PAIR OF WAFFLE WEAVE UNDERWEAR AND THE UNISUIT LINER

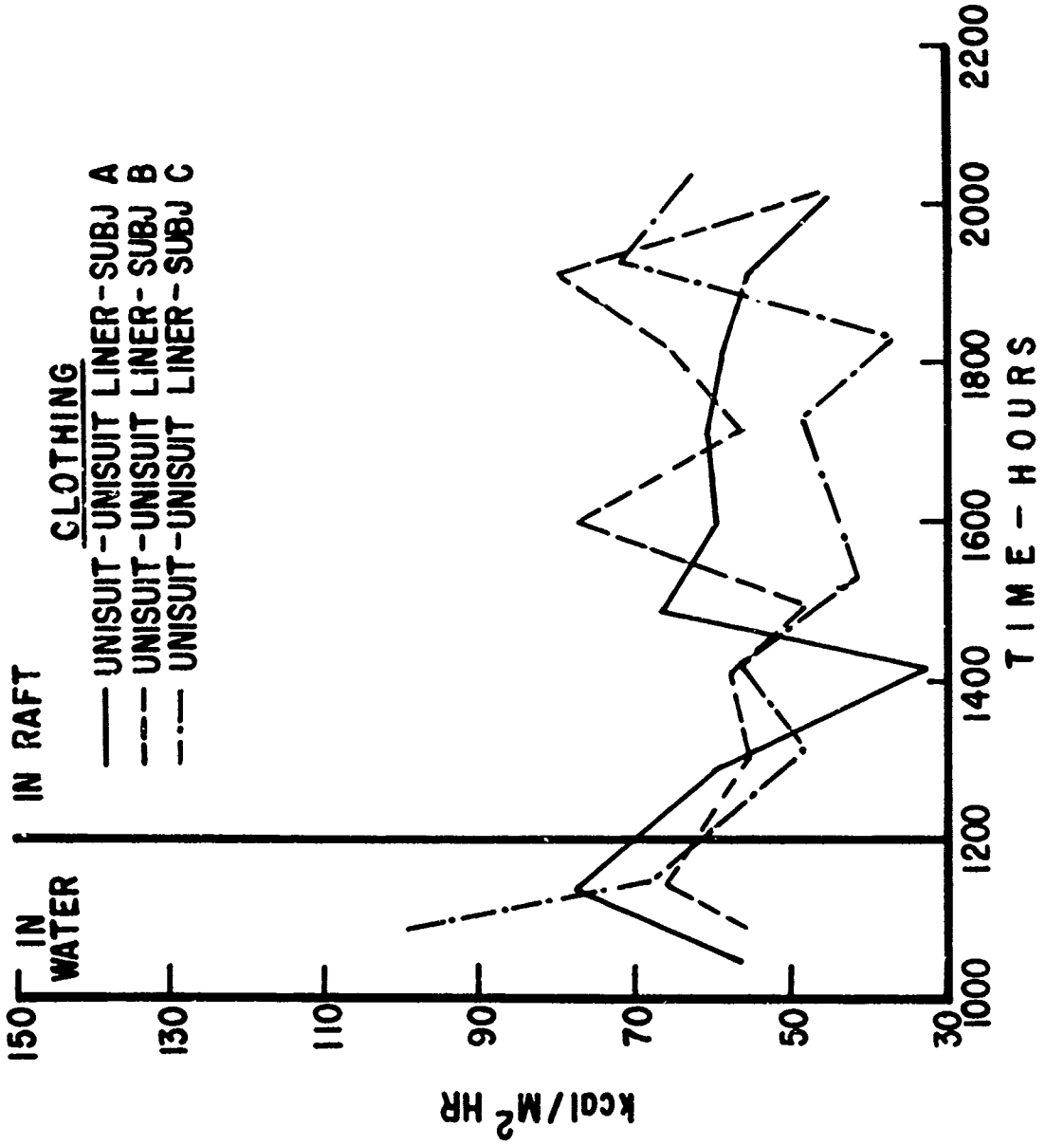

FIGURE 7. THE METABOLIC RESPONSE OF SUBJECTS WEARING THE UNISUIT ASSEMBLIES

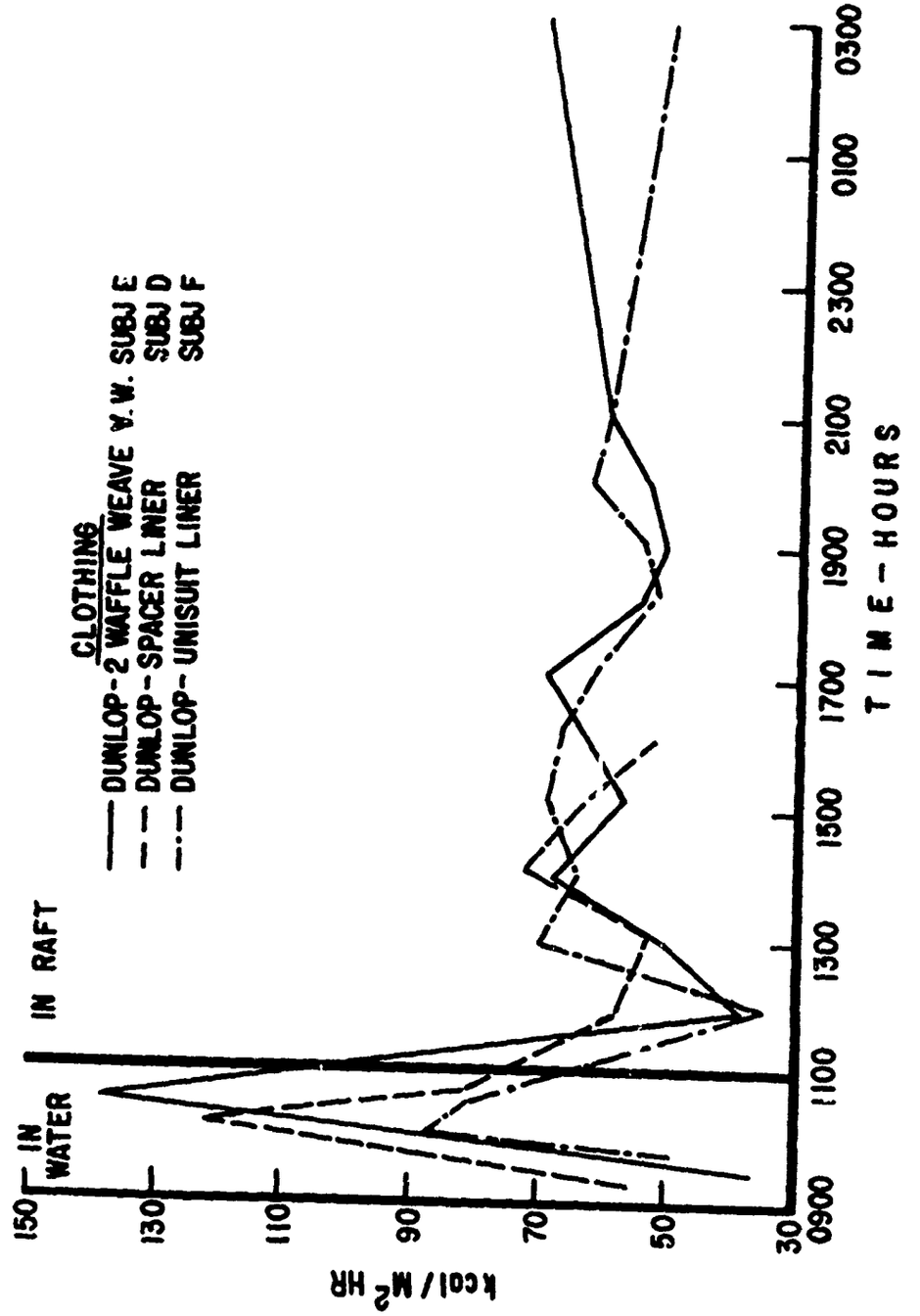

FIGURE 8. THE METABOLIC RESPONSE OF SUBJECTS WEARING THE DUNLOP ASSEMBLIES

TABLE 3

Insulation Values for the 7-man Navy Insulated Life Raft

Procedure			Mean Manikin Temp (C)	Mean Ambient Temp (C)	Thermal Insulation - Clo Total (I)	(Ig)	$I_{Raft_{Total}}$
Method 1 Use of Copper Manikin	TEST	1	40.6	3.7	2.44	1.10	1.34
		2	39.7	3.8	2.33	1.10	1.23
					MEAN	=	1.29

$$I_{TOTAL} = I_{garment} + Ia_{raft} + I_{raft} + Ia$$

$$I_{RAFT_{TOTAL}} + I_{Total} - I_{garment}$$

Method 2 Use of Heaters in Raft	Conductances Kcal/m^2hrC		Insulative Values Clo = $\frac{1}{k \times 0.18}$ Clo value	
	1. Floor -	9.80	1. Floor	0.55
	2. Ceiling -	3.05	2. Ceiling	1.55
	3. Side walls -	4.39	3. Side walls	1.27
	4. End walls -	6.00	4. End walls	0.90
	5. Inside air to outside air -	3.34	5. Inside air to outside air (effective insulation)	1.67
	6. Inside wall to outside wall -	5.13	6. Inside wall to outside wall (Insulation of raft per se)	1.08

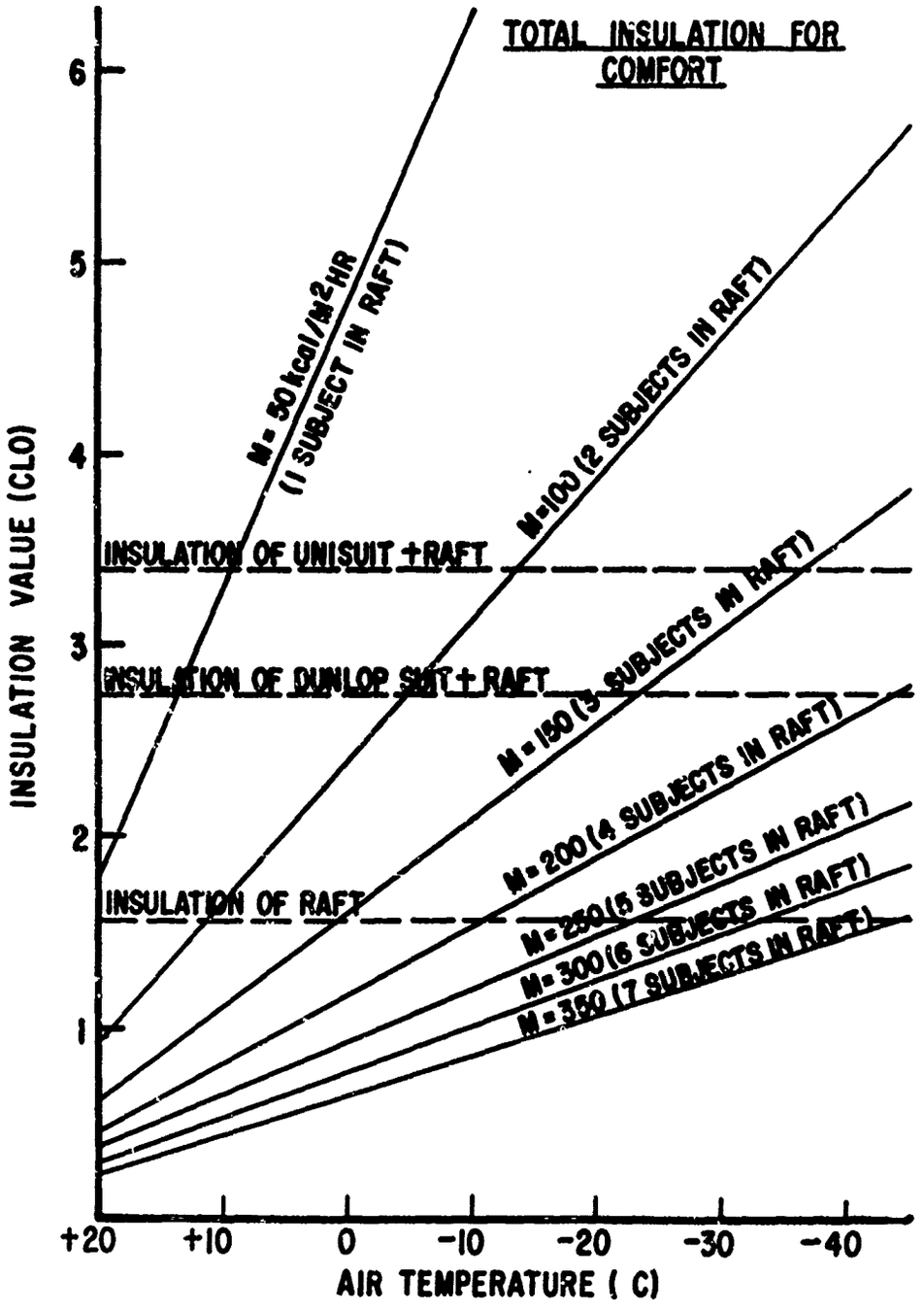

FIGURE 9. PREDICTIVE CLO VALUES REQUIRED FOR COMFORT IN A 7-MAN LIFE RAFT. THE AVERAGE METABOLIC RATE OF 50 Kcal/M^2HR IS BASED ON DATA OBTAINED IN THIS STUDY.

DISCUSSION

These test data indicate the Unisuit is thermally superior to that of the Dunlop suit. The use of the Unisuit liner greatly enhances thermal equilibrium. Subject F wearing this liner under the Dunlop suit showed a marked reduction in metabolic rate during cold water immersion. This is supported by the clo value of this assembly shown in table 1. Most subjects requested to be removed from the exposure because of long term shivering, discomfort, and boredom. Thermally, all of the persons wearing the Unisuit could tolerate longer exposures without serious physiological problems. Those subjects wearing the Dunlop suit reached tolerable limits.

Heater pads were given to the subjects wearing the Dunlop suits with favorable response. Perceptible heat is generated for approximately 10 minutes.

Subjective comments concerning the Unisuit were favorable with slight bouts of shivering reported with the most discomfort relating to tight booties and face seals. In the actual case, these suits would be tailor fitted and constrictive spots could be alleviated by cutting the outer material. Booties were cut in the Dunlop suit exposure to alleviate constriction.

Subjects wearing the Dunlop suit complained of water leakage at the wrists and cold feet during water immersion. The feet did not rewarm while in the raft. Fingers were also cold and numb during cold water immersion. The Unisuit mittens afforded better protection.

SECTION IV
CONCLUSIONS

1. Thermally, the Unisuit is superior to the Dunlop suit when identical underclothing is worn.

2. The ventile spacer garment is a detriment, thermally, and should be discarded.

3. Pararescue personnel wearing the Unisuit with appropriate underclothing could tolerate 2 hours of cold water exposure and subsequently several days in an insulated raft. Cold sea survival training is necessary.

4. A telemetry system has been fabricated to obtain limited physiologic data in field environments.

SECTION V
RECOMMENDATIONS

The Unisuit should be modified to meet the pararescue requirements, i.e., opening parachute shock. Physiologic data can be obtained during the final field testing of the modified suit to provide a broader data base.

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