ADDITIONAL CONSIDERATIONS OF PERSONAL COOLING

by

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INTRODUCTION

Industrial workers often are required to perform their tasks in a heat stress environment. Examples are found in manual work in deep mines, fire-fighting, maintenance work in boiler rooms, or working near hot steel furnaces. The heat stress is solved partially by the excellent thermoregulatory system of the human body, but additional help is needed to expand the limited period for which the individual can withstand the stress. The additional help may be to cool the hot environment or the individual's body.

Physiologically the human body is a homeotherm as the body temperature is relatively constant over a wide range of environmental and physiological conditions. The body interacts with the environment, trying to minimize the thermal equilibrium upsets or interacting with the thermal equilibrium by increased metabolic activity. Duncan (1975) held that the primary control of 'body temperature' is through feedback control of a 'set temperature' referenced in the hypothalamus of the central nervous system. Thermal receptors in the skin and hypothalamus continually monitor the thermal state at their respective locations and signal the information to the hypothalamus. After integrating all signals, the hypothalamus gives commands to the effector organs (muscles, blood vessels, sweat glands) to function to maintain the body temperature at the desired level. The particular commands given are directed to the three major mechanisms: vasomotor function, sweating, and increase in heat production (by shivering or sympathetic 'chemical' excitation of heat production).

Man's best protection against heat is by using the evaporative cooling resulting from sweating. Sweating is caused by temperature stimuli from both the skin and core. Sweating is not uncomfortable as long as the moisture can evaporate freely from the skin surface. Discomfort occurs when the same rate of sweating requires a larger wetted surface on the skin from which it must evaporate. Sweating at high levels is accompanied by active vasodilation but excessive sweating can cause swelling of the extremities, skin irritation, headaches, and throbbing due to increased heat action.

Active shivering is analogous to sweating but with the opposite effect. Heat generated comes from the increase in metabolic rate in order to compensate for excessive heat loss. Shivering only can occur in cold environments.

Vascular control of the blood flow to and from the skin surface is a method by which the body can change the flow of heat from its central core to the environment. Vasoconstriction usually is associated with a cold stress. Vasodilation always occurs during regulatory sweating.

The above controllers are not sufficient for the human body thermoregulation in excessively severe hot environments (over 40 C) and over prolonged exposures (Dhiman, 1974). Thus supporting thermo-help is needed. Personal cooling is such an approach.

Personal cooling can be done by evaporation of water, convection, and conduction according to Konz et al. (1974). If evaporation of sweat is limited by the person not being able to secrete enough sweat, then other methods of heat reduction must be used. If the condition is environmentally limited, the obvious solution is to increase air velocity, as it is cheaper than reducing the water vapor pressure in the environment.

Water cooling is a powerful means of heat removal as shown by Konz and his associates at Kansas State University (Konz, 1969; Duncan, 1969; Konz and Duncan, 1971). The water cooling concept includes a four portion system for the garment: 1) the tubes and the garment, 2) the source of the water, 3) the lifeline, the connection between the source and the garment, and 4) the control circuit. In space, it was easy to recirculate the water supply by using a back pack unit, but because of the weight, applications on earth cause the source of water to be connected to the garment by the lifeline. This lifeline, acting as a tether, restricts the movement of the worker.

The use of a cooling agent (ice) in the pockets of a garment is the intent of conduction cooling. Water picks up 80 kcal/kg of ice melted when it changes from solid to liquid plus one kcal for each degree Celsius rise in water temperature. Studies at the Human Science Laboratory (Van Rensburg et al., 1970) showed a prefrozen vest, although not as effective as a water cooled jacket, depressed rectal temperature by 1.5 C and heart rate by 20 to 30 beats/minute.

Dry ice sublimation picks up 137 kcal/kg when subliming and 23 kcal/kg as the gas rises to skin temperature. Cooling with dry ice was first reported by Petit et al. (1966) in a Belgian mining journal. In a walking experiment of 20 minutes, heart rate was 17 beats/minute lower, skin temperature was 1.8 C lower, oral temperature was 0.5 C lower and rectal temperature was lowered by 0.2 C. A Japanese experiment (1969) on a mannequin's garment reported the temperature of the mannequin was 10 C lower than the environment. Miura et al. (1971) used a dry ice cooling vest on four subjects doing a step task under three temperatures: 30, 35, and 40 C. Heart rate was 5 to 10 beats/minute lower, skin temperature was 0.6 to 0.8 C lower, and the rectal temperature was 0.3 C lower. The skin and rectal temperatures weren't significantly different at the 30 C condition.

Developing dry ice garments has been a concern of Konz and his associates since 1972. As a result, dry ice cooling jacket Model B1 (which was tested by Duncan (1975) in the field), and dry ice cooling jackets, Models B2 and C, were developed. Techapatanarat (1976) developed Model D by shifting the back vertical pockets of Model C to horizontal positions. These dry ice garments were located over the torso as the torso contributes 22% of the total heat produced during working (Aschoff and Wever, 1958, as cited by Duncan, 1975). The KSU-Stolwijk computer model predicted that the total produced during working by the torso was 30%. Tang (1976) changed the localized concept by using the jumpsuit. Since carbon dioxide is heavier than air and because of the gravitational force, the CO_2 subliming from the pockets around the torso was able to flow to the lower part of the body. Also, when working, the movement of the arms and legs helped to move the CO_2, establishing a more generalized overall individual body cooling situation.

Deshpande (1975) showed that CO_2 cooling created skin cooling with a temperature profile similar to a 'canyon.' Skin temperatures under a slab were about 10 C but rose to 32 C at a distance of 25 mm from the slab edge.

Duncan (1975) used Models B1 and B2 in finding that the sublimation rate of the top compartments (1.9 g/(min-slab)) was significantly faster than that of the lower compartments (1.2). Because of the weight of CO_2 and the elastic edge on the lower part of the jacket, the lower part of the torso was much cooler because of the higher CO_2 concentration. Thus the temperature of the body was divided into three regions; cool, cold, and hot.

Duncan (1975) found that when the dry ice cooling jacket was worn there was a significant increase in oxygen consumption (from a mean of 313 kcal/hr to 387). He believed a 'non-shivering thermogenesis' or 'chemical thermogenesis' had taken place instead of shivering because the subjects didn't report any feeling of shivering.

The Model C dry ice cooling jacket, developed by Konz and Duncan (1975), was made of a quilted nylon outer shell and an inner shell of blended cotton. There were four vertical pockets, two in front and two in back. Each pocket measured 45 cm long, 18 cm wide, and 5 cm thick with the top opening fastened by using Velcro strips. Inside each pocket was a removable plastic bubble liner, inside which was a nylon net divided into three compartments. The arms were made of light, permeable, loose weave nylon. Elastic bands were sewn at the end of the sleeves and the bottom edge of the jacket to prevent the cold CO_2 from escaping. The front of the jacket was fastened by Velcro.

Techapatanarat (1976) modified the Model C dry ice cooling jacket by changing the two pockets on the back from the vertical to horizontal. The jacket, Model D, displayed a more uniform sublimation of dry ice than in the vertical pockets. This implies the subject was more comfortable due to a uniform cooling from the pockets. The dry ice also could last longer due to the more efficient use.

Tang (1976) showed that a dry ice cooling jumpsuit was an efficient means of reducing physiological strain (heart rate, skin and rectal temperatures). An improvement over the previous jackets was evident by the more even cooling of the individual. Tang concluded the oxygen consumption rate was only 1% higher when the subject wore the cooling jumpsuit as compared to a non-cooling condition, and the sublimation rate of the jumpsuit was 3% lower than the jacket.

Esposito (1969) and Audet et al. (1978) introduced a combination system for personal cooling. In these cases, dry ice was used as the coolant but a medium such as water was pumped, in a closed system, to spread this coolness around the body.

Work in the personal cooling area has been followed closely by Konz et al. (1972) with the application of a modified computer program simulation at Kansas State University of the Stolwijk (1970) computer model of human thermoregulation. The KSU-Stolwijk model was modified by Dhiman (1974) and Masud (1975). Konz has validated the model by comparing the model versus experimental data (Konz et al., 1977 and Duncan and Konz, 1978).

OBJECTIVE

The objective of this experiment was to investigate further the dry ice cooling technique as a means of personal cooling. This was done by trying the garments on a different task (step task vs. use of the bicycle ergometer) and determining if this change in task produced different results. Furthermore, the results were compared against an existing simulation model for the previously untried case of the non-steady state working environment. The subject changed conditions during the course of the time period considered. The garments considered were the dry ice cooling jacket (Model D) and Tang's jumpsuit.

The following were measured:

1) heart rate, beats/min
2) oxygen consumption rate, ml/(kg-min)
3) rectal temperature, C
4) torso skin temperatures at five locations, C
5) sublimation rate of dry ice for each slab, g/(min-slab)
6) the results were compared against previous works

METHOD

Task

Each subject performed a Masters step task (step up, step down, turn around, repeat) at a constant rate for a total metabolic rate of 280 Watts. This calculation is defined by vertical displacement, weight of the subject, and rate.

MET = WT x VDISP x RATE

where MET = metabolic rate, W

WT = weight, N (average for the two subjects)

VDISP = vertical displacement, m/step, .254

RATE = rate of stepping, steps/second, 72

The stepping task was performed for 60 minutes in a controlled environment of 34 C dry bulb temperature, 50% rh, and 0.3 m/s air velocity. Then, the subjects walked 30 m to a recovery room and rested for 15 minutes at 25 C and 30% rh. This cycle was repeated three times with the last cycle having a 30 minute recovery time instead of 15 minutes. Thus, the subject spent a total of 180 minutes in the environmental chamber and 60 minutes in the recovery room.

Subjects

Two male subjects were used. Before participating in any session of the experiment they took the Physical Fitness Test from the Health, Physical Education, and Recreation Department at Kansas State University, filled out a past medical record evaluation, and completed a physical examination by a physician. They were each paid $150. See Table 1 for the subjects' characteristics.

Procedure and Measurement

Both subjects were tested at the same time in the six sessions. Each session began with the attachment of three surface electrodes and five skin temperature sensors. The sensors and electrodes were located (see Figure 1) and held in position by surgical tape over 'New Skin' to insure a water-proof seal. This measure of attachment gave a good recording throughout the session, even though the skin was covered with sweat. The rectal thermister was inserted 13 cm.

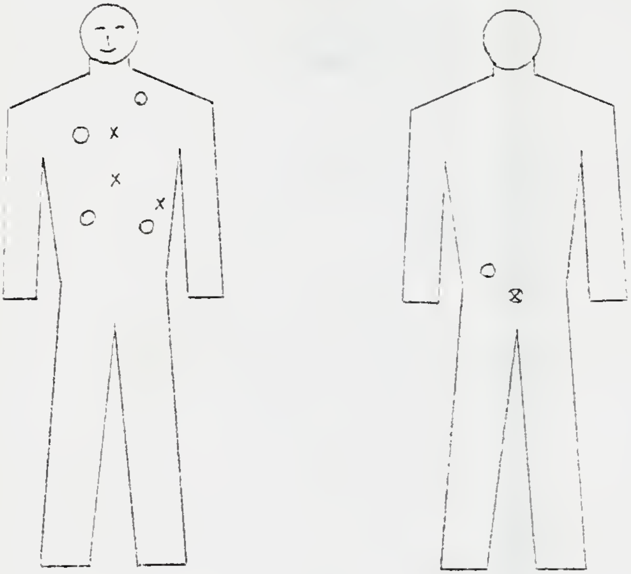
The dry ice was cut and weighed, then placed into the pockets. The cut dry ice measured 10 cm by 10 cm by 2.5 cm. Eight slabs were used in each garment. The subject was placed in the controlled climatic chamber and started stepping after initial measurements were taken of the subject's weight, oxygen consumption rate, heart rate, skin and rectal temperatures, and blood pressure (see Protocol in Appendix A). After 60 minutes, the subject stopped stepping and was taken from the chamber for the simulated rest period. This procedure was repeated three times with the last break allowing the subject's heart rate to return toward 'basal' in using a 30 minute rest period. Then the garment and sensors were removed and the garment weighed.

Table 1. Characteristics of Subjects.

	Subject A	Subject B
Age (years)	21	23
Weight (kg)	72	77
Height (cm)	182	188
Surface Area (m^2)*	2.03	2.12
Skinfold Thickness (mm)		
1 Triceps	10	8.5
2 Pectoral	6	5
3 Abdominal	19	17.5
Percent of Body Fat**	10	9
Resting Blood Pressure (mm Hg)		
Systolic	112	100
Diastolic	78	76
Max VO_2 (ml/(min-kg))	40	32

*Surface Area = $.208 + .945((7.184*10^{-3})(\text{Height, cm})^{.725} \times (\text{Weight, kg})^{.425}$ (Mitchell et al., 1971)

**Health, Physical Education, and Recreation Department, Physical Fitness Exam.



X - Electrode for Heart Rate

O - Skin Temperature Thermisters

Ⓧ - Rectal Temperature Probe

Figure 1. Location of the Sensing Devices on the Subject.

The heart rate was recorded every five minutes starting with an initial reading at time zero. The electrocardiogram was recorded on a Beckman recorder after using a 'hard wire' technique of hooking up the electrodes to the subject. Two electrodes were placed on the centerline of the chest 15 cm apart and a third to the lower left. The placement was important in order to minimize muscle noise. The r waves were recorded for 20 seconds and multiplied by three to give a beats/minute reading.

Oxygen consumption rate was measured every 15 minutes by using a Collins 9-liter respirometer. Readings were taken for one minute intervals. Later the change in volume was computed and standardized for standard pressure and temperature.

Skin temperatures were recorded from the five locations by YSI 709 thermisters. These were connected into a Digitec digital thermometer and a printer which was automatically activated every five minutes. The rectal thermister (YSI) also was recorded every five minutes using the Digitec system.

Blood pressure was taken at 30 minute intervals or when there was a change in conditions. This was done by the registered nurse who was present at all experimental sessions.

Sublimation rate of the dry ice was measured by subtracting the final slab weight from the initial weight and dividing by the time interval between the two weighings. During the experimental sessions a slab of ice from the front upper left pocket was measured every time the subject came into the recovery room.

The subjects were weighed initially and every time a condition change occurred. This and the weighings of the clothing initially and at the end of the session was an attempt to determine the amount of sweat loss.

The subjects were given measured amounts of water at tap temperature at their request when they were in the recovery room.

The subjects were removed from the stepping task also under certain criteria. If the subject's rectal temperature rose 1.1 C from the initial temperature, he was changed from the stepping task and went directly to the 30 minute recovery concluding the experiment. The heart rate exceeding 175 beats/minute was another standard for halting the experiment. Also the nurse had the option to remove the subjects from the experiment as did a request from the subject. Removal of one subject from the experiment for any reason meant the other subject also was removed due to the equipment attachments on the subjects.

Experimental Design

The subjects each participated in six sessions. See Table 2 for the sequence for each individual. The experiment included two sessions where the subject was clothed in slacks and shirt. The four remaining sessions were allocated to two using the dry ice cooling jacket and two using the dry ice cooling jumpsuit. These sessions were further split into using dry ice or not.

Table 2. Experimental Sessions.

Session	Sequence	
	Subject A	Subject B
A. Wearing Slacks and Shirt	1	1
B. Wearing Dry Ice Jacket w/o Ice	2	4
C. Wearing Dry Ice Jacket w/Ice	3	5
D. Wearing Dry Ice Jumpsuit w/o Ice	4	2
E. Wearing Dry Ice Jumpsuit w/Ice	5	3
F. Wearing Slacks and Shirt	6	6

Clothing

On experimental days without a cooling garment, each subject was clothed in socks, boxer shorts, slacks and a long-sleeved, cotton twill shirt. The clothing clo value was measured at 0.49 by Duncan (1975). On days when a cooling jumpsuit was worn, the same clothing was worn plus the jumpsuit but without the long-sleeved shirt and the slacks. The clothing clo value was estimated to be 0.68 clo, Tang (1976). On days when the dry ice cooling jacket was used, the same set of clothing was used but without the long-sleeved shirt. The clothing ensemble with the jacket was measured at 0.90 (Duncan, 1975).

Design of Garments

Tang's jumpsuit with long sleeves was used. There were four pockets in the front and four in back. All of the pockets had the opening on the outer shell of the garment, so the worker could load the dry ice without taking off the garment.

Three kinds of material were used in constructing the jumpsuit. 'Surfline' (50% polyester and 50% cotton) was used to make the sleeves and trousers. 'Satinylquilt' (three layers with the face layer of 100% nylon batting, the middle layer of 100% polyester, and the back layer of 100% nylon durable water repellent finish) was used around the torso. 'SkiDi' (50% Kodel polyester and 50% cotton durable water repellent finish) was used for the inner layer of the torso.

Two insulation layers, air bubble and rubber sheet, were used in the dry ice pockets. All the eight pockets had the same insulation (6 gcal/(sec-C-cm^2 x 10^{-5})). See Figure 2.

The dry ice cooling jacket was made of denim with four pockets, two in the front and two in back. The four pockets were placed in a horizontal position. Each pocket held two slabs of dry ice. The pockets opened only on the inside of the jacket with strips of Velcro. The inner lining of the jacket was made of blended cotton. The jacket was closed by a zipper running on the left side of the jacket. The bottom edge of the jacket was made of an elastic band to seal the CO_2 in. The opening was adjustable by using Velcro strips. The dry ice was placed into nylon netting before pocket insertion.

Computer Simulation

The model of thermoregulation was developed by Stolwijk (1966, 1970) and introduced to Kansas State University by Hsu (1971). It was modified by Dhiman (1974), Masud (1975), Konz and Hwang (1977), and Konz (1979) for studying personal cooling with dry ice. The model has two principal sections, the controller section and the controlled section. The two sections are connected via a negative feedback loop. The controller section receives input from feedback elements (thermoreceptors) located in the skin and hypothalamus. The signals (temperatures) are compared with referenced set points and deviations are then signaled to the controller. The controller activates control elements based on the type of deviation. The

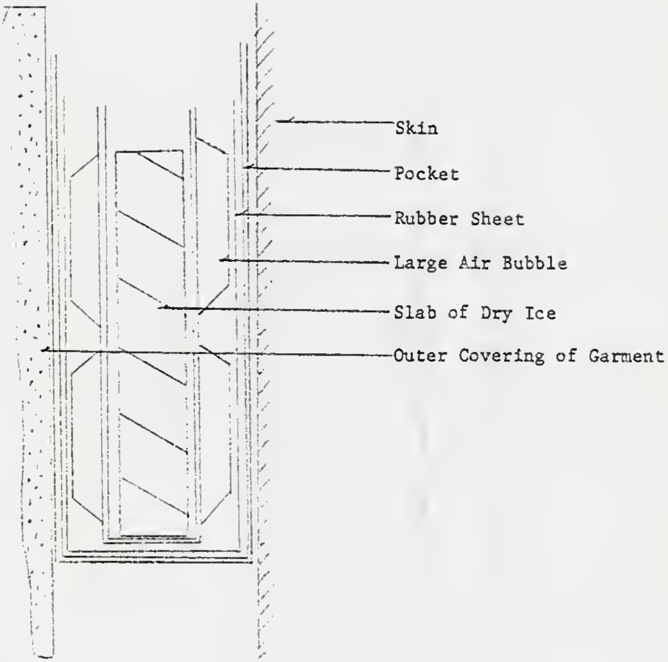


Figure 2. Insulation Inside the Dry Ice Pocket.

control elements then execute the functions required to maintain constant body temperature.

The controlled section of the model has six segments: a spherical head and cylindrical trunk, arms, hands, legs, and feet. Each of these divisions is composed of four layers: core, muscle, fat, and skin. A central blood compartment was created to allow heat flow by way of blood between segments, so the model has 25 compartments.

The basis of the model is the calculation of heat balance in and out of each compartment. Heat is constantly produced by metabolism. This heat is transferred to the skin via convection by blood and conduction through body tissue layers. Heat is lost to the environment by convection, radiation, evaporation, or conduction (when an external cooling device is present). Any excess of what can be transferred is stored in the body, resulting in a higher body temperature.

The computer simulation calculates periodically the error between a temperature and a set temperature for the 25 compartments individually. It then checks the sign of the error or discrepancy in temperature, defining it as warm or cold. The controller actions then are activated: sweating, modifying skin blood flow (dilation or constriction) or shiver in the muscle layer. See Table 3 for a listing of the basis of the simulation.

These commands are transformed into actions according to limits placed upon the model internally or imposed by the environment. The 25 compartments then are compared periodically as to heat balance.

Table 3. Control Equations Acting as the Basis of the Computer Simulation Model.

```
SWEAT = CSW * ERROR(1) + SSW * (WARMS-COLDS) + PSW * ERROR(1)
        * (WARMS-COLDS)

DILAT = CDIL * ERROR(1) + SDIL * (WARMS-COLDS) + PDIL * WARMS
        * WARMS(1)

STRIC = - CCON * ERRCR(1) - SCON * (WARMS-COLDS) + PCON * COLDS
        * COLDS(1)

CHILL = - CCHIL * ERROR(1) - SCHIL * (WARMS-COLDS) + PCHIL
        * ERROR(1) * (WARMS-COLDS)
```

where SWEAT = total efferent sweat command, dimensionless

DILAT = total efferent skin vasodilation command, L/h

STRIC = total efferent skin vasoconstriction command, L/stroke

CHILL = total efferent shivering command, W

ERROR(1) = output from thermoreceptor 1 (head core), C

WARMS = integrated output from the skin warm receptors, C

COLDS = integrated output from skin cold receptors, C

WARMS(1) = warm output from head core, C

COLDS(1) = cold output from head core, C

CSW = sweating coefficient for head core, W/C

CDIL = vasodilation coefficient for head core, L/(h-C)

CCON = vasoconstriction coefficient for head core, W/C

CCHIL = shivering coefficient for head core, W/C

Table 3. Continued

Four coefficients (SSW, SDIL, SCON, SCHIL) assume head and skin signals add. The P coefficients, PSW, PDIL, PCON, and PCHIL, assume the head and skin signals multiply. In the modeling, the P coefficients were equal to zero.

The program has been modified to predict for individuals. This permits comparison against experimental data and leads to a better prediction. The program requires the following input data: age, weight, height, proportion body fat, cardiovascular fitness, acclimatization, clo/segment, job, metabolism, air temperature, air velocity, radiant temperature, relative humidity, and barometric pressure. It is possible to vary the job, clothing, metabolism, air temperature, air velocity, radiant temperature, and relative humidity during the simulation.

The output from the computer simulation 'tells all.' Some of the summary outputs include the subject's comfort vote, the cardiac output, skin blood flow, stroke volume, heart rate, perceived exertion, metabolic heat production, mean skin temperature, evaporative water loss, and salt loss.

RESULTS

Results are given in two sections. The first section discusses the experimental results. The second section compares the experimental results with the KSU-Stolwijk computer simulation model. The experimental results will be interpreted by analyzing the rectal temperature, heart rate, torso skin temperature, oxygen consumption rate, dry ice sublimation, and evaporative sweat loss. The comparison of the model versus the data will include rectal temperature, heart rate, and torso skin temperatures.

The six experimental sessions took place on Thursday and Saturday mornings in March, 1979 at the Institute of Environmental Research, Kansas State University. Due to considerations for human subjects and stopping criteria for halting the experiment, the actual experimental lengths varied. This was in contrast to the planned four hours per experimental session.

Experimental Data

Rectal Temperature

The rectal temperature was measured automatically every five minutes over the length of the session by the Digitec system coupled with the rectal thermister. See Appendix B for the data table.

A computer analysis of variance was used to search for significance among the factors contributing to the rectal temperature.

This program was used only on the first 50 minutes of data as that was the maximum time common to all sessions before a change in conditions due to the stopping criteria. The rectal temperature data were subtracted from the corresponding initial value of the session to make the dependent variable, the change in rectal temperature.

In the analysis of variance, the contributing factors considered were:

$$DRT = SUB + COND + T + T^2 + CONDxT + CONDxT^2$$

where DRT = change in rectal temperature in the first 50 minutes, C
SUB = 1 or 2, denoting the subjects used
COND = 1,2,3,4,5,6, denoting the experimental session condition
T = time in minutes
T^2 = time squared
CONDxT = interaction of condition and time
$CONDxT^2$ = interaction of condition and time squared

Table 4 shows the result of the analysis of variance. The analysis resulted in a model explaining 87.5% of the variance. At alpha = .05, the variables showing significant contribution are subjects, condition, time, and the interaction of time and condition.

With the results of the analysis of variance, Duncan's Multiple Range Test was administered to observe the conditions' differences. See Table 5.

Realizing the subjects contributed individual differences, the two were considered separately. See Tables 6 and 7. In the analysis of variance, the same variables were considered as above but omitting

Table 4. Analysis of Variance for Rectal Temperature.

Source	df	Ss	Ms	F	PR>F
Model	18	11.56	.642	4.83	.0001
Subjects	1	1.11		72.32	.0001
Condition	5	.66		8.61	.0001
Time	1	9.46		616.01	.0001
Time^2	1	.01		.56	.4569
Condition x Time	5	.21		2.77	.0216
Condition x Time^2	5	.11		1.44	.2141
Error	107	1.64	.015		
Total	125	13.21			

R^2 = .875

Mean Rectal Temperature Change = .408

Standard Deviation of Change = .124

Table 5. Duncan's Multiple Range Test for Condition, Change in Rectal Temperature.

alpha level = .05 df = 107 Ms-error = .015

Condition	Condition Mean			
3	.506	A*		
		A		
1	.491	A		
		A		
2	.437	A	B	
			B	
5	.369		B	C
				C
4	.327			C
				C
6	.314			C

*Denotes that means with the same letter are not significantly different.

Table 6. Analysis of Variance for Change in Rectal Temperature, Subject A

Source	df	Ss	Ms	F	PR>F
Model	17	4.248	.250	156.03	.0001
Condition	5	.785		98.05	.0001
Time	1	3.234		2019.29	.0001
Time^2	1	.003		2.07	.1568
Condition x Time	5	.147		18.41	.0001
Condition x Time^2	5	.078		9.76	.0001
Error	45	.072	.0016		
Total	62	4.320			

R^2 = .988

Mean = .314

St. Dev. = .040

Table 7. Analysis of Variance for Change in Rectal Temperature, Subject B

Source	df	Ss	Ms	F	PR>F
Model	17	7.661	.451	174.95	.0001
Condition	5	.713		55.28	.0001
Time	1	6.456		2506.13	.0001
Time^2	1	.020		7.67	.0081
Condition x Time	5	.419		32.53	.0001
Condition x Time^2	5	.053		4.14	.0035
Error	45	.116	.0026		
Total	62	7.777			

$R^2 = .985$

Mean = .502

St. Dev. = .051

the SUB term. The resulting analysis explains 98.8% and 98.5% of the variance respectively. Duncan's test is shown in Tables 8 and 9.

The sum of squares term in Tables 4, 6, and 7 shows that the important predictor is time, in determining the change in rectal temperature. Other variables that are highly significant are subject and condition. Individually, the interactions are also highly significant. Using Duncan's mean separation, the means for Condition 1 and 3 are consistently higher while 4, 5, and 6 are on the low side. Condition 2 varies in relative position. Note the use of dry ice increased rectal temperature for the subjects combined and for Subject B. The two control conditions, 1 and 6, show that an acclimitization occurred as Condition 6 is lower than Condition 1.

Heart Rate

The heart rate was measured every five minutes over the experimental session. See Appendix E for the data tables.

The effects influencing the change in heart rate were determined by the analysis of variance. This computer program used the same variables as those used with rectal temperature with the appropriate substitution of heart rate for rectal temperature. The analysis of variance is presented in Table 10.

Table 11 shows that the significant factors affecting the change in heart rate in the first 50 minutes are time and condition. Duncan's test showed that although not significantly different, the

Table 8. Duncan's Multiple Range Test for Condition, Change in Rectal Temperature for Subject A.

alpha level = .05 df = 45 Ms-error = .0016

Condition	Condition Mean		
2	.438	A	
1	.401	B	
		B	
3	.368	B	C
			C
4	.359		C
5	.203		D
6	.134		E

Table 9. Duncan's Multiple Range Test for Condition,

Change in Rectal Temperature for Subject B.

alpha level = .05 df = 45 Ms-error = .0026

Condition	Condition Mean	
3	.632	A
1	.574	B
		B
5	.553	B
6	.494	C
2	.435	D
4	.292	E

Table 10. Analysis of Variance for Heart Rate.

Source	df	Ss	Ms	F	PR>F
Model	18	5665	314	4.29	.0001
Subjects	1	79		1.08	.3013
Condition	5	1071		2.92	.0165
Time	1	3933		53.68	.0001
Time^2	1	192		2.63	.1078
Condition x Time	5	140		.38	.8591
Condition x Time^2	5	247		.68	.6446
Error	103	7548	73		
Total	121	13213			

$R^2 = .429$

Mean = 27.80

St. Dev. = 8.56

Table 11. Duncan's Multiple Range Test for Heart Rate Conditions.

alpha level = .05 df = 103 Ms-error = 73

Condition	Condition Mean		
6	32.45	A	
		A	
2	29.86	A	B
		A	B
4	28.50	A	B
			B
3	26.14		B
			B
5	24.42		B
			B
1	24.25		B

conditions with ice had a lower increase. The significant conclusion was that the second control condition was higher than the first session. There was no significant difference in heart rate between individuals.

Review of the heart rate comparison figures in Appendix F shows that the heart rate dropped significantly when the subject was breathing oxygen from the respirometer at 15 minute intervals. This was expected as the subjects were standing instead of stepping.

Torso Skin Temperature

The torso skin temperature was measured automatically every five minutes by the Digitec system hooked to five thermisters. The five sensors were located on the upper left chest, right chest, lower right abdomen, middle left abdomen, and lower left back.

The rate of change for the mean torso skin temperature was compared by the same analysis of variance program used above, substituting the change in mean torso skin temperature for the change in rectal temperature. See Table 12 for the analysis. At alpha = .10, all of the variables are highly significant. Duncan's separation shows that the ice caused a lowered increase but not significantly. The significant aspect was that the jumpsuit had a lower rise in mean torso skin temperature than the normal clothing or jacket. See Table 13.

Since the subjects were significant statistically, the two were considered separately. See Table 14 for Subject A and Table 15 for Subject B. The corresponding Duncan's separations are given in Tables 16 and 17.

Table 12. Analysis of Variance for the Change in Mean Torso Skin Temperature.

Source	df	Ss	Ms	F	PR>F
Model	18	109.12	6.06	36.38	.0001
Subject	1	2.20		13.19	.0004
Condition	5	7.50		9.00	.0001
Time	1	63.20		379.13	.0001
Time^2	1	15.05		90.33	.0001
Condition x Time	5	19.31		23.17	.0001
Condition x Time^2	5	1.87		2.24	.0542
Error	119	19.83	.167		
Total	137	128.96			

R^2 = .846

Mean = 1.74

St. Dev. = .408

Table 13. Duncan's Multiple Range Test for Conditions, Change in Mean Torso Skin Temperature.

alpha level = .05 df = 119 Ms-error = .167

Condition	Condition Mean	
2	1.99	A
		A
1	1.89	A
		A
6	1.87	A
		A
3	1.85	A
4	1.47	B
		B
5	1.38	B

Table 14. Analysis of Variance for the Change in Mean Torso Skin Temperature, Subject A.

Source	df	Ss	Ms	F	PR>F
Model	17	78.08	4.59	80.75	.0001
Condition	5	11.98		42.12	.0001
Time	1	44.34		779.50	.0001
Time^2	1	9.25		162.58	.0001
Condition x Time	5	10.72		37.70	.0001
Condition x Time^2	5	1.79		6.31	.0001
Error	52	2.96	.0569		
Total	69	81.03			

R^2 = .963

Mean = 1.867

St. Dev. = .238

Table 15. Analysis of Variance for the Change in Mean Torso Skin Temperature, Subject B.

Source	df	Ss	Ms	F	PR>F
Model	17	43.22	2.54	50.81	.0001
Condition	5	5.79		23.13	.0001
Time	1	21.02		419.97	.0001
Time^2	1	6.00		119.87	.0001
Condition x Time	5	9.78		29.09	.0001
Condition x Time^2	5	.64		2.55	.0391
Error	50	2.50	.050		
Total	67	45.72			

R^2 = .945

Mean = 1.61

St. Dev. = .224

Table 16. Duncan's Multiple Range Test for Condition Means, Mean Torso Skin Temperature for Subject A.

alpha level = .05 df = 52 Ms-error = .0569

Condition	Condition Mean	
2	2.28	A
		A
3	2.27	A
		A
1	2.25	A
4	1.60	B
		B
6	1.53	B
5	1.28	C

Table 17. Duncan's Multiple Range Test for Condition Means, Mean Torso Skin Temperature for Subject B.

alpha level = .05 df = 50 Ms-error = .050

Condition	Condition Mean			
6	2.73	A		
2	1.69	B		
		B		
1	1.53	B	C	
			C	
5	1.49		C	D
			C	D
3	1.43		C	D
				D
4	1.31			D

The variables are highly significant in all cases and the explained variance for the two subjects are .85 and .96 respectively. In the Multiple Range Test for Subject A the ice produced a lower skin temperature which was significant in the jumpsuit comparison. The jumpsuit was statistically significantly lower than the jacket while the second control condition was significantly lower than the first. The condition having the jumpsuit with ice produced the lowest change. In Subject B's case the use of dry ice produced a lower change with the jacket. The jumpsuit did not follow this trend although it was not significantly different. The control conditions were again statistically different with the first session lower.

Although the use of dry ice was significant only in the jumpsuite cases in explaining the change in mean torso skin temperature, its presence was felt in both cases. The average starting temperature for the conditions without the use of dry ice was 33.94 C. The conditions using the coolant started at 31.71 C due to the initial cooling of the skin. Thus the dry ice kept torso skin temperature about 2.2 C lower than without dry ice.

Oxygen Consumption Rate

The oxygen consumption rate was measured every fifteen minutes until the final recovery period on the 9-liter Collins respirometer. See Appendix H for the data.

The data for the heat stress sessions was analyzed by the computer program on analysis of variance similar to the previous cases. See Table 18.

Table 18. Analysis of Variance for the Change in Oxygen Consumption Rate.

Source	df	Ss	Ms	F	PR>F
Model	18	424.1	23.6	1.34	.2145
Subject	1	13.9		.79	.3793
Condition	5	166.8		1.90	.1157
Time	1	4.5		.26	.6151
$Time^2$	1	104.5		5.96	.0192
Condition x Time	5	80.3		.92	.4805
Condition x $Time^2$	5	54.1		.62	.6881
Error	40	701.9	17.5		
Total	58	1126.0			

R^2 = .377

Mean = .573

St. Dev. = 4.189

The analysis showed that at the 10% level of alpha, only time was a significant factor in a model that explained 37% of the total variance.

Although the conditions were not significant, Duncan's test was applied to the condition means with respect to the oxygen consumption rate to determine the trends of the conditions. The results are given in Table 19. The use of the dry ice increased consumption using the jumpsuit, decreased it with the jacket, but without any significance. Although the first control session was lower, the two control sessions were not different statistically.

Dry Ice Sublimation

The sublimation of dry ice was determined by measuring the weight initially and at the end of the last stepping period and dividing by the time expired. The sublimation rate also was predicted for each pocket by a formula presented by Duncan and modified by Techapataranat. This formula is:

$$S = K_1K_2K_3K_4K_5K_6K_7(31.4 + .132\ (IW))$$

where S = sublimation rate/slab, grams/hour

IW = initial weight of the slab, grams, $150 \leq IW \leq 400$

K_1 = thickness factor

= 1.0 for 16 mm thick slab

= .93 for 22 mm thick slab

= 1.39 for 5 mm thick slab

Table 19. Duncan's Multiple Range Test for the Change in Oxygen Consumption Rate Conditions.

alpha level = .05 df = 40 Ms-error = 17.5

Condition	Condition Mean		
5	2.379	A	
		A	
2	1.933	A	
		A	
6	1.635	A	B
		A	B
4	.968	A	B
		A	B
3	-.596	A	B
			B
1	-2.224		B

K_2 = pocket location factor

= 1.00 for top pocket

= .69 for lower pocket

K_3 = jacket vs vest

= 1.00 for jacket

= 1.04 for vest

K_4 = dry bulb environment temperature

= 1.00 for 35 C

= 1.07 for 45 C

K_5 = water vapor in environment

= 1.00 for 33 mm Hg

= 1.04 for 16 mm Hg

K_6 = environment time factor

= 1.085 for time from 0 to 60 minutes

= 1.00 for time from 0 to 120 minutes

= 0.83 for time from 0 to 240 minutes

K_7 = insulation factor

= .94 for low insulation (11 kcal/sec-C-cm^2 x 10^{-2})

= .87 for medium insulation (7 kcal/sec-C-cm^2 x 10^{-2})

= .83 for high insulation (5 kcal/sec-C-cm^2 x 10^{-2})

Tang modified this formula for dry ice jumpsuits. The following changes were made:

K_2 = pocket location factor

= 1.10 for left-back-top and right-back-top pockets

= .95 for other 6 pockets

K_3 = vest vs jumpsuit vs jacket

= 1.04 for vest

= 1.01 for jumpsuit

= 1.00 for jacket

The sublimation rates were calculated for the first heat session of 60 minutes. The values used in this formula are:

$S = (.93)(.95)(1.00)(1.00)(1.04)(1.085)(.85)(31.4 + .132\ (IW))$

(This calculation is for the left-front-top pocket for the jacket. If an upper-back-top pocket was used, 1.10 was substituted for .95. If the jumpsuit was used, 1.01 was substituted for 1.00).

Table 20 shows the difference between experimental and predicted sublimation rates of the eight pockets for the dry ice cooling jacket. Table 21 shows the comparison for the jumpsuit.

Both tables show that the predicted value is significantly less than the actual value for the sublimation rate. For the jacket the predicted value was 38% lower while the jumpsuit's prediction was 39% lower.

Evaporative Sweat Loss

The evaporative sweat loss was measured indirectly at each condition change. The subject was weighed initially and whenever

Table 20. Difference Between Experimental and Predicted Sublimation Rates, Jacket.

Sub	Pocket Location	Experimental Sub. Rate (g/min)	Predicted Sub. Rate (g/min)	Difference	Error (%)
A	Left-Front-Top	1.35	.9398	.4102	30
B	Left-Front-Top	1.65	1.0104	.6396	39
B	Right-Front-Top	1.48	.9142	.5658	38
B	Left-Front-Bottom	1.23	.7787	.4513	37
B	Right-Front-Bottom	1.42	.7421	.5226	37
B	Left-Back-Top	1.68	.9241	.7559	45
B	Right-Back-Top	1.25	.8770	.3730	30
B	Left-Back-Bottom	1.35	.8381	.5119	38
B	Right-Back-Bottom	1.50	.9621	.5379	36
B	Mean	1.45	.8808	.5448	38

Table 21. Difference Between Experimental and Predicted Sublimation Rates, Jumpsuit.

Sub	Pocket Location	Experimental Sub. Rate (g/min)	Predicted Sub. Rate (g/min)	Difference	Error (%)
A	Left-Front-Top	1.83	.9940	.8360	45
A	Right-Front-Top	1.38	.9619	.4181	30
A	Left-Front-Bottom	2.13	1.2651	.8649	40
A	Right-Front-Bottom	2.28	1.2689	1.0111	44
A	Left-Back-Top	1.98	1.5041	.4759	24
A	Right-Back-Top	1.92	1.0380	.8820	46
A	Left-Back-Bottom	1.42	.8396	.5804	41
A	Right-Back-Bottom	1.57	.8960	.6740	43
A	Mean	1.81	1.0960	.7179	39
B	Left-Front-Top	1.75	1.0128	.7372	39

a condition change occurred. He was weighed at the end of the session and a difference in clothing weight was determined. The weight loss was adjusted for the sublimation rate of the dry ice and the water intake. The final result was divided by the surface area of the subject to give evaporative sweat loss, g/(min-m^2). See Table 22.

In focusing on the first cycle of heat stress condition and recovery period, the loss during the heat stress was higher than recovery, 2.54 to 2.18 g/(min-m^2). Weight loss was not affected by the jacket conditions or the jumpsuit with ice. There were no significant differences between subjects.

Experimental Data Versus Computer Simulation Model

For each session, a computer simulation was applied to the actual conditions. These conditions included the length of the session, time for the change in conditions, amount of water intake, and the time when the water was taken by the subject. See Appendix K for the table of input data.

Rectal Temperature

Rectal temperatures from the data and computer simulation model were compared graphically (see figures in Appendix D). Primary concern in this comparison was the difference in the rate of change of the rectal temperature. The computer simulation allowed changes up to 0.3 C per five minute interval while the most change experienced by the subjects was one-half this amount. See Figure 1 in Appendix D.

Table 22. Evaporative Sweat Loss, $g/(min\text{-}m^2)$.

Condition	Subject	Heat 1	Cool 1	Heat 2	Cool 2	Heat 3	Cool 3	Change in Clothing Wt. (g)	Time Expired (min)
1	A	3.7	2.7	3.9	-	5.0	.5	50	225
1	B	3.9	2.6	3.4	.4	4.3	.9	500	225
2	A	1.9	4.9	2.6	4.6	-	-	230	135
2	B	3.1	2.3	3.9	.9	-	-	200	160
3	A	3.0	1.3	2.0	1.2	1.2	3.3	110	240
3	B	2.2	-	-	-	-	-	40	80
4	A	3.0	-	3.7	2.3	-	-	40	160
4	B	.3	1.3	3.6	2.6	-	-	90	135
5	A	1.0	2.1	-	-	-	-	200	80
5	B	2.3	-	2.6	.7	.5	4.1	440	240
6	A	3.0	1.6	-	-	-	-	10	85
6	B	3.1	.8	-	-	-	-	20	85
Mean		2.54	2.18	3.21	1.81	2.75	2.20		
St. Dev.		1.06	1.21	.72	1.48	2.23	1.77		

This comparison carried throughout the session. The maximum range of the subject's actual rectal temperature was 1.1 C. During the same time period, the simulation had climbed 3.0 C from its lowest value. This sharper increase in change allowed the data which had started higher in all cases to remain higher through the first cycle (Figures D-1,2,3,4,5). After this cycle, the increase in the rate of change in the simulation model allowed the predicted value to become and remain higher throughout the remaining time of the session.

A second consideration was the initial difference between the actual and predicted values at time zero. The computer predicted 36.3 C for all non-ice conditions and 36.4 C for those using ice. However, at time zero, the subjects' mean rectal temperature was 37.15 C for the non-ice conditions and 37.42 C for those using ice. Thus, the simulation started about one degree too low.

Heart Rate

Graphical interpretation of the simulation data versus the experimental data is shown in Appendix G.

The simulation model initially allowed a 10 beats/minute discrepancy between the sitting and standing task. The actual data didn't show such a difference. This feature was corrected in the program to equalize the task requirements as to heart rate.

For the non-ice cases the simulation model predicts a rate of 112 beats/minute at 50 minutes. The experimental data had a mean of 118 beats/minute for normal clothing and 125 beats/minute for the dry ice garments without coolant. Thus the prediction was 6 to 13 beats too low. The ice conditions had a predicted mean heart rate of 122 beats/minute and the actual was 132 beats/minute. Thus the prediction was 10 beats too low.

Torso Skin Temperature

The mean torso skin temperature was compared against the torso skin temperature determined by the computer model (see Table 23 and Appendix J).

At time equal 50 minutes, the predicted temperature was lower for all conditions except the jumpsuit with dry ice. For the normal clothing conditions, the predicted temperature was lower by .65 and .55 C. For the jacket and jumpsuit conditions, it was lower by 1.45 and 1.30 C. The jacket with ice was 0.1 C lower. Only the jumpsuit with ice had the data 1.0 C lower than the simulation.

Table 23. Mean Torso Skin Temperature (C), Experimental vs. Simulation at Time Equals 50 Minutes.

Condition	Subject A	Subject B	Mean	Simulation	Mean Diff.
Normal Clothing	36.2	35.3	35.75	35.1	+ .65
Jacket	36.6	36.5	36.55	35.1	+1.45
Jacket w/Ice	35.4	34.4	34.90	34.8	+ .10
Jumpsuit	36.8	36.0	36.40	35.1	+1.30
Jumpsuit w/Ice	33.9	33.7	33.80	34.8	-1.00
Normal Clothing	35.8	35.5	35.65	35.1	+ .55

DISCUSSION

Rectal temperature was found to be a primary concern of the experiment. Five of the six sessions were terminated prematurely after the 1.1 C rise in rectal temperature of one of the subjects. Further consideration with experimentation should adjust the stopping criteria for human protection. Instead of simply a 1.1 C rise in rectal temperature, the criteria may be to stop experimentation when a 1.1 C rise in rectal temperature is reached or the temperature rises past a set temperature, whichever is higher. This would allow flexibility as the subjects initial temperature varied by 0.6 C for Subject A and .5 for Subject B. Such variation caused the experiment to terminate on some days at a temperature that was surpassed in others.

For explanation of the change in rectal temperature, the influencing factors are subjects, conditions, time, and the interaction of condition and time. Individually, the subjects had these factors in common with the addition of the interaction of time squared and condition. For Subject B, time squared became a significant factor. The two subjects, when grouped together, showed by statistical mean separation on conditions that the use of ice caused a higher rise in rectal temperature, though not significant. Individually, Subject B followed this trend on a significant basis. Subject A, on the other hand, contradicted the trend by stating that the use of dry ice in the jacket and jumpsuit was beneficial by causing a lower rise in temperature.

The important benefit, shown by the rectal temperature, was that a periodic rest period in a neutral climate (as opposed to a heat stress condition) allowed the individual to continue under an acceptable physiological criteria longer. The spacing of rest periods provides a challenge for further studies. In the experiment, the initial one hour stepping task was too long in two of the six sessions according to the stopping criteria. On three other occasions the criteria for stopping fell just short during the initial hour period.

For heart rate prediction, major factors to consider are time and condition. The change in heart rate increased with time but decreased with the use of dry ice in the jacket and jumpsuit.

A factor to consider when designing the measuring apparatus for monitoring the experiment is compensation for the time the subject was doing another task such as breathing through the respirometer. Figure F-1 in the Appendix shows that when the subject was occupied with determining the oxygen consumption rate, the heart rate dropped significantly.

The skin temperature was recorded to determine the condition of the body's outer shell under heat stress conditions. The change in skin temperatures was affected by time, subject, condition, and their interactions. Though the dry ice did not produce significantly lower results, it did produce lower temperatures. Also the jumpsuit had a lower rise in torso skin temperature than the jacket. The conditions using the dry ice, furthermore, started 2 C lower, i.e. the ice pre-cooled the skin and kept it 2 C lower.

The placement of the thermisters on the subject's body should be considered representative of the entire area when planning an experiment. Using only five thermisters, the placement was too close to the pockets of dry ice for the thermisters to give the most accurate mean torso skin temperature according to Deshpande's temperature profile.

The oxygen consumption rate was affected by time in the form of time squared, when considering the change over the first 50 minutes. The lack of significant explanation by the factors for the change in oxygen consumption rate, R^2 equals .38, showed that perhaps oxygen consumption was stable over the variables presented. The factors shown to influence oxygen consumption rate are the task and the environmental conditions. For the dry ice used with the jacket, there was a lower consumption rate than without the ice. For the jumpsuit, the dry ice caused an increase in metabolic rate, concuring with studies of Duncan. Thus the design of the jumpsuit overcooled the subject.

The measurement of oxygen presented problems to be overcome in further experiments. The subject was required to stand next to the respirometer for one minute durations for every measurement. This decreased the total walking time and measured the oxygen consumption for standing, not stepping.

Dry ice sublimation for the experiment was higher than the predicted values. This discrepancy may be caused by two effects. The stepping task allowed more movement around the dry ice, in a pumping, bellows motion. The previous experiments used pedaling tasks on the bicycle ergometer. The second consideration was the body fit of the garments. The same garments were used as in the previous experiments. However, the subjects in this experiment were of greater size (72 kg) than those used previously (60 kg). Thus, the body was closer to the dry ice with less air insulation between ice and skin, causing a higher sublimation rate.

The evaporative sweat loss showed a higher rate of sweating during the heat stress condition. Difficulties arose in this measurement due to the conversion of data after not using a scale which was sensitive enough.

In comparison of the computer model with experiment data, the largest discrepancy was in the change of rectal temperature. The computer allowed too large a change per unit time. This says that the simulated body adjusted to a change in temperature faster than the actual body. Appendix D shows the comparison of graphs. In Figure D-1 at 195 minutes, a rise of 1.1 C in rectal temperature is compared with a 3.0 C rise in the simulated rectal temperature.

The actual rectal temperature also exhibited a time lag when changing conditions. In many of the changes of air temperature from 34 to 25 C, the actual minimal rectal temperature was not at the end of the cooling-off period but 15 minutes later (see Appendix D). The simulation model, however, predicted no lag and changed quickly.

The initial rectal temperature would differ for the individual from day to day, often as much as 0.5 C. However, for a given set of conditions the simulation model will predict the same rectal temperature. Thus a confidence interval must be used to help in explaining the differences.

The model's prediction of heart rate was lower than the experimental data. When the dry ice was used as a coolant, the model's prediction was about 10 beats/minute lower.

The model's prediction of mean torso skin temperature was too low except for the dry ice jumpsuit condition. Unlike the rectal temperature's accelerated change in temperature per unit time, the computer model doesn't predict enough of an increase (decrease) for skin temperature. This allows the actual data to increase up to four times the change predicted by the model. See Appendix J.

In conclusion, it was shown that dry ice cooling was better than no cooling using lower torso temperatures and lower heart rates as criteria. If rectal temperature is used as a criterion, the use of dry ice causes a higher rate of change in rectal temperature than without the dry ice for the subjects grouped together. Dry ice lowered the metabolic rate as measured by the consumption of oxygen for the jacket while the jumpsuit overcooled the individual and increased the metabolic rate.

The different task, stepping as opposed to pedaling the bicycle ergometer, allowed more of a pumping action inside the dry ice garment. This combined with a better fit, caused a higher rate of sublimation and more cooling.

The use of rest periods when working in a heat stress environment was beneficial in keeping the individual's physiological system in the acceptable region.

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APPENDIX

Appendix A Protocol

The following is a time chart noting when the various measurements are to be taken. Oxygen consumption is measured for a one minute period. Heart rate is measured in durations of 20 seconds. When taking the heart rate, one subject is measured, then the equipment is switched to the other subject. In the next period, Subject B will be the first one measured. HR denotes heart rate, O_2 denotes oxygen measurement, while Temp indicates measurement of both skin and rectal temperatures.

Time, Min	Task
-20	Hook-up thermisters and sensors, weigh clothing, dressed except for dry ice garment
-5	Weigh dry ice and put into dry ice garment, garment on subject. Measure HR, Temp, blood pressure, and weigh subjects
0	Enter chamber, start task, O_2, HR, and Temp
5	HR, Temp
10	HR, Temp
15	O_2, HR, Temp
20	HR, Temp
25	HR, Temp
30	O_2, HR, Temp, and Blood Pressure
35	HR, Temp
40	HR, Temp
45	HR, Temp, O_2
50	HR, Temp
55	HR, Temp
60	O_2, HR, Temp, Blood Pressure, stop task and leave chamber Weigh subject in cool chamber, weigh slabs of dry ice
65	HR, Temp
70	HR, Temp, start weighing subjects and taking Blood Pressure
75	O_2, HR, Temp, enter chamber and start task
80	HR, Temp
85	HR, Temp
90	HR, Temp, O_2

Time, Min	Task
95	HR, Temp
100	HR, Temp
105	O_2, HR, Temp
110	HR, Temp
115	HR, Temp
120	HR, Temp, O_2
125	HR, Temp
130	HR, Temp
135	HR, Temp, O_2, Blood Pressure, stop task and leave chamber Weigh subjects in cool chamber, weigh slab of ice
140	HR, Temp
145	HR, Temp, start weighing subjects
150	HR, Temp, O_2, Blood Pressure, enter chamber and start task
155	HR, Temp
160	HR, Temp
165	HR, Temp, O_2
170	HR, Temp
175	HR, Temp
180	HR, Temp, O_2, Blood Pressure
185	HR, Temp
190	HR, Temp
195	HR, Temp, O_2
200	HR, Temp
205	HR, Temp

Time, Min	Task
210	HR, Temp, O_2, stop task, Blood Pressure, leave chamber Weigh subjects, ice
215	HR, Temp
220	HR, Temp
225	HR, Temp
230	HR, Temp
235	HR, Temp, start weighing subjects
240	HR, Temp, Blood Pressure, Unhook sensors and weigh clothing

Appendix B Table of Rectal Temperatures for the Experiment

RECTAL TEMPERATURE DATA

TIME	CONDITION 1 NORMAL SUBJ.A	B	CONDITION 2 JACKET-NO ICE A	B	CONDITION 3 JACKET-ICE A	B	CONDITION 4 JUMPSUIT A	B	CONDITION 5 JUMPSUIT-ICE A	B	CONDITION 6 NORMAL A	B
-0.00	37.37	37.84	37.03	36.95	37.26	37.20	37.26	37.33	37.72	37.45	37.10	37.02
0.00	37.37	37.13	37.08	36.97	37.26	37.21	37.21	37.37	37.71	37.49	37.07	37.01
5.00	37.36	37.24	37.07	36.96	37.33	37.22	37.13	37.34	37.65	37.58	37.06	36.58
10.00	37.44	37.26	37.13	37.05	37.39	37.33	37.20	37.17	37.70	37.65	37.02	37.04
15.00	37.54	37.42	37.23	37.18	37.46	37.57	37.25		37.71	37.85	37.02	37.15
20.00	37.66	37.54	37.33	37.34	37.56	37.75	37.44		37.85	37.95	37.08	37.33
25.00	37.75	37.67	37.46	37.48	37.64	37.92	37.56	37.53	37.97	38.11	37.18	37.59
30.00	37.88	37.80	37.50	37.55	37.74	38.02	37.66	37.64	37.97	38.12	37.26	37.68
35.00	37.91	37.81	37.64	37.60	37.73	38.18	37.72	37.73	38.06	38.15	37.34	37.75
40.00	37.94	37.88	37.77	37.74	37.79	38.24	37.82	37.15	38.11	38.31	37.44	37.94
45.00	38.03	37.59	37.89	37.84	37.85	38.32	37.84	37.82	38.12	38.37	37.53	38.02
50.00	38.06	38.03	37.97	37.91	37.87	38.39	37.52	37.93	38.16	38.32	37.64	38.12
55.00	38.12	38.12	38.07	38.00	37.96	38.32	37.55	38.04	38.18	38.34	37.72	38.24
60.00	38.13	38.14	38.12	37.94	38.01	38.25	38.04	38.13	38.16	38.28	37.67	38.24
65.00	38.13	38.05	38.12	37.97	37.98	38.15	38.07	38.02	38.14	38.22	37.71	38.24
70.00	38.11		38.13	37.83	37.94	38.13	37.96	38.03	38.05		37.68	38.21
75.00	38.07		38.13	37.73	37.86	37.98	37.93		38.01		37.63	38.11
80.00	38.04	38.00	38.01	37.74	37.76	37.91	37.92	38.01	37.54		37.60	38.03
85.00	38.06	37.52	37.95	37.76	37.75		37.88	37.33			37.46	37.71
90.00	38.07	37.89	38.02	37.81	37.76		37.54	37.48				
95.00	38.08	37.86	38.06	37.87	37.79		37.56	37.50		37.75		
100.00	38.12	37.87	38.11	37.96	37.82		38.02	38.07		37.80		
105.00	38.18	37.96	38.16	37.95	37.80		38.03	38.16		37.82		
110.00	38.19	37.98	38.16	38.02	38.01		38.04	38.11		37.82		
115.00	38.22	38.03	38.14	38.03	37.92		38.10	38.10		37.88		
120.00	38.27	38.04	38.10	38.08	37.98		38.12	37.85		37.86		
125.00	38.29	38.05	38.01	38.07	37.98		38.13	37.87		38.04		
130.00	38.34	38.11	37.89	38.16	38.07		38.23	37.66		38.13		
135.00	38.37	38.06	37.81	38.07	38.08		38.15	37.51		38.13		
140.00	38.38		37.76	38.02	38.08		38.05	37.38		38.15		
145.00	38.30			37.97	38.01		37.57			38.15		
150.00	38.28			37.82	37.96		37.83			38.03		
155.00	38.26	37.83		37.68	37.86		37.75			37.79		
160.00	38.28	37.89		37.62	37.85		37.76			37.78		
165.00	38.29	37.54			37.67					37.74		
170.00	38.26	37.49			37.91					37.74		
175.00	38.28	38.00			37.94					37.90		
180.00	38.31	38.11			37.52					37.92		
185.00	38.32	38.11			37.97					38.01		
190.00	38.36	38.18			38.00					38.09		
195.00	38.40	38.20			38.01					38.18		
200.00	38.40	38.29			38.07					38.26		
205.00	38.41	38.22			37.83					38.32		
210.00	38.35	38.18			38.07					38.14		
215.00	38.31	38.07										
220.00	38.24	37.59										
225.00	38.11	37.89								38.03		
230.00					37.74					37.92		
235.00					37.72					37.76		
240.00					37.61					37.72		

Appendix C Data Comparison of Rectal Temperatures By Condition

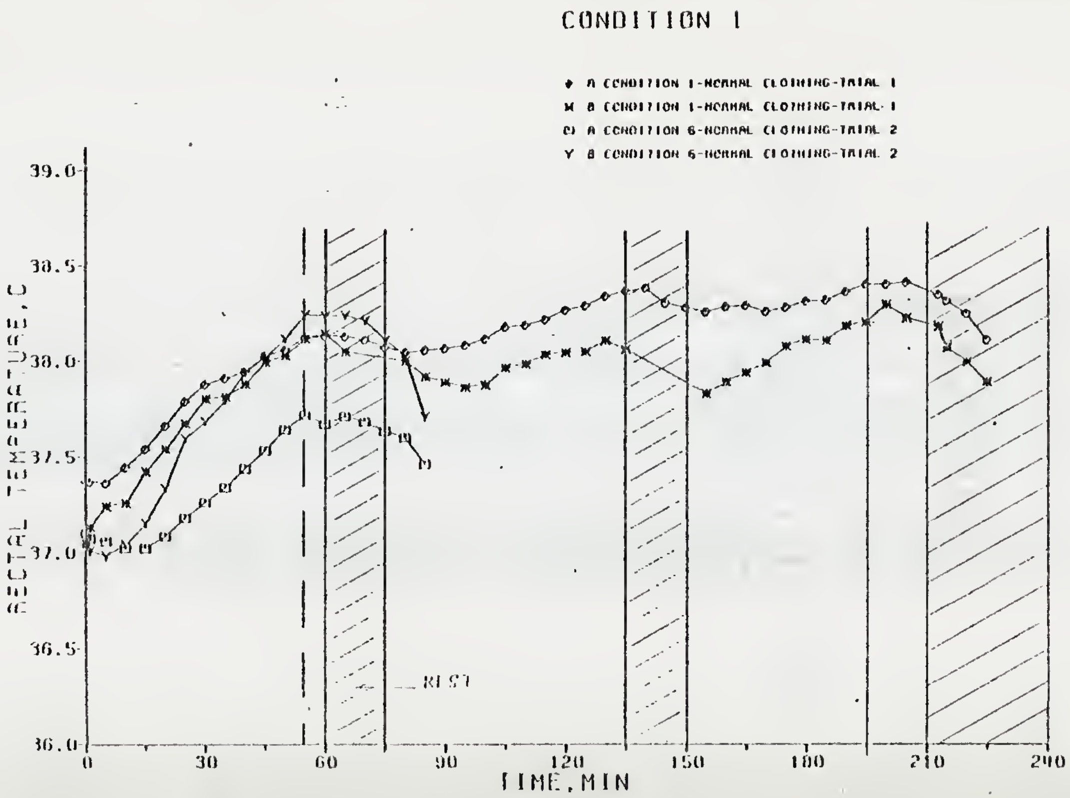

Figure C-1 Comparison of Rectal Temperature for the Normal Clothing Sessions

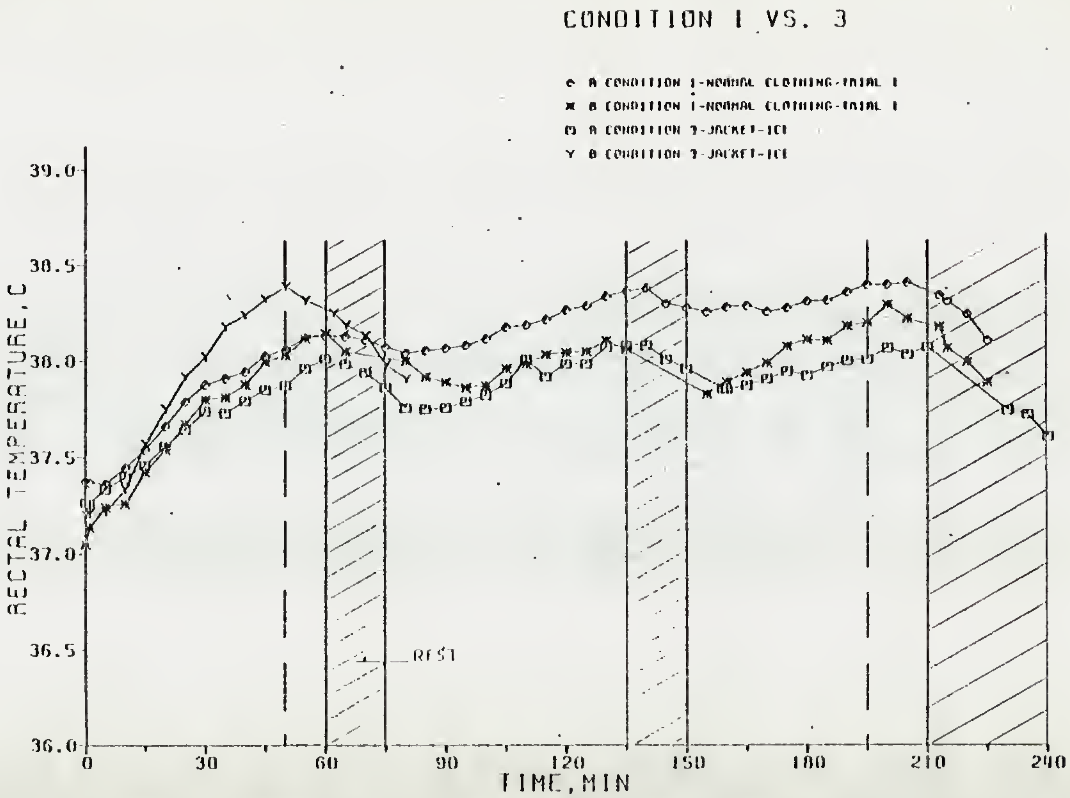

Figure C-2 Comparison of Rectal Temperature for Normal Clothing vs. Jacket with Ice

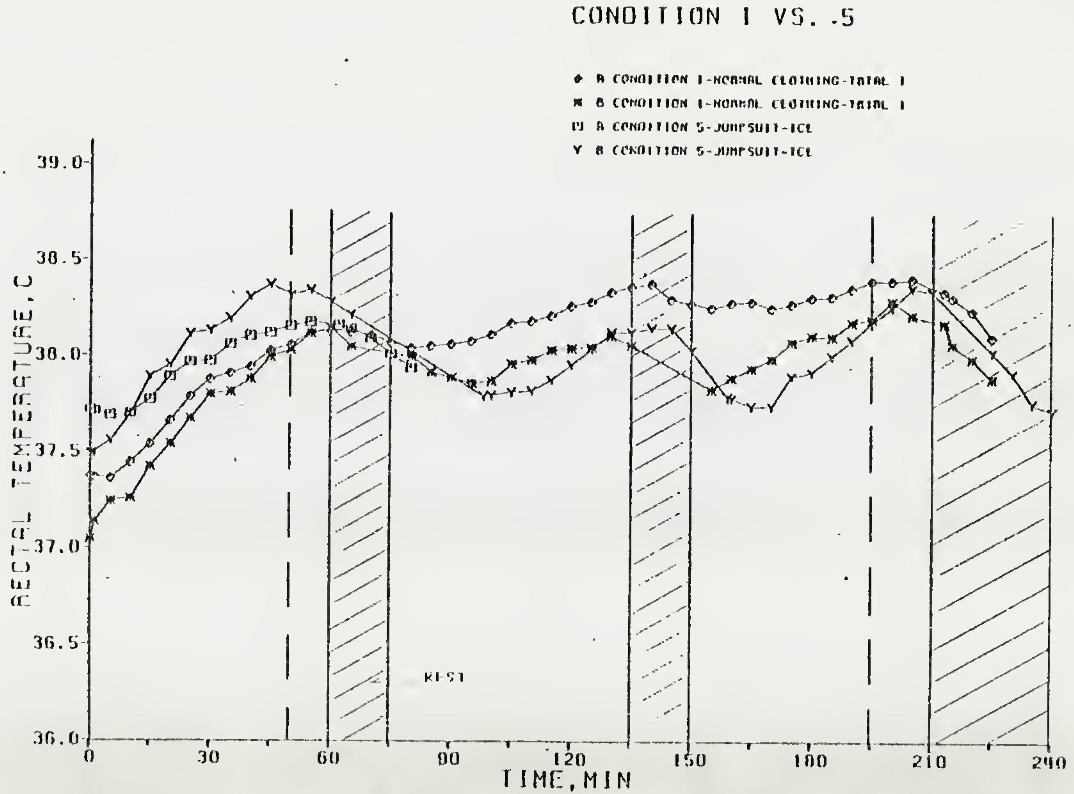

Figure C-3 Comparison of Rectal Temperature for Normal Clothing vs. Jumpsuit with Ice

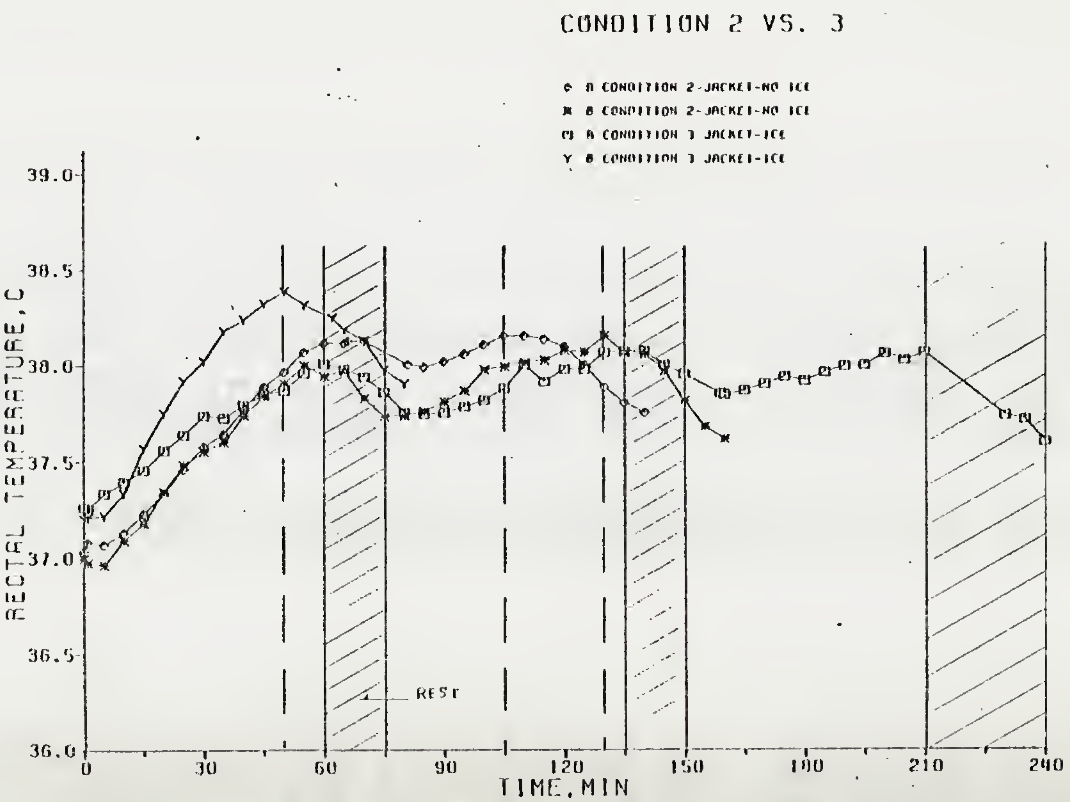

Figure C-4 Comparison of Rectal Temperature for the Dry Ice Jacket, With and Without Ice

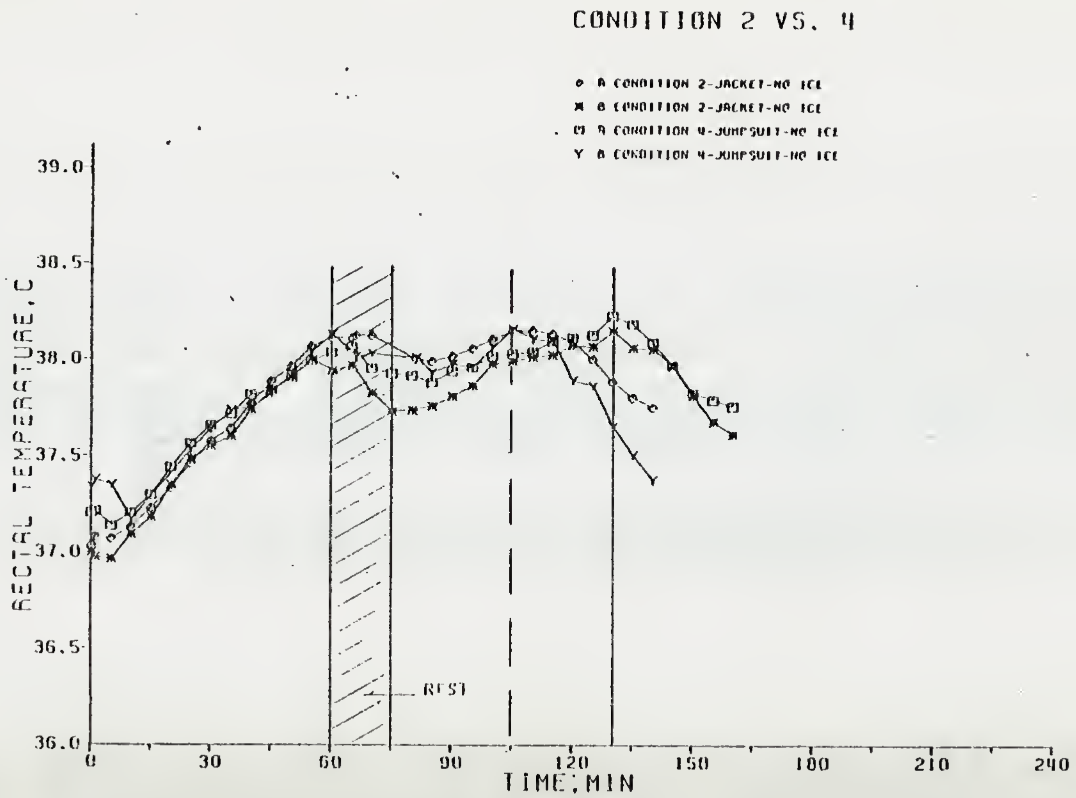

Figure C-5 Comparison of Rectal Temperature for the Dry Ice Garments without Ice

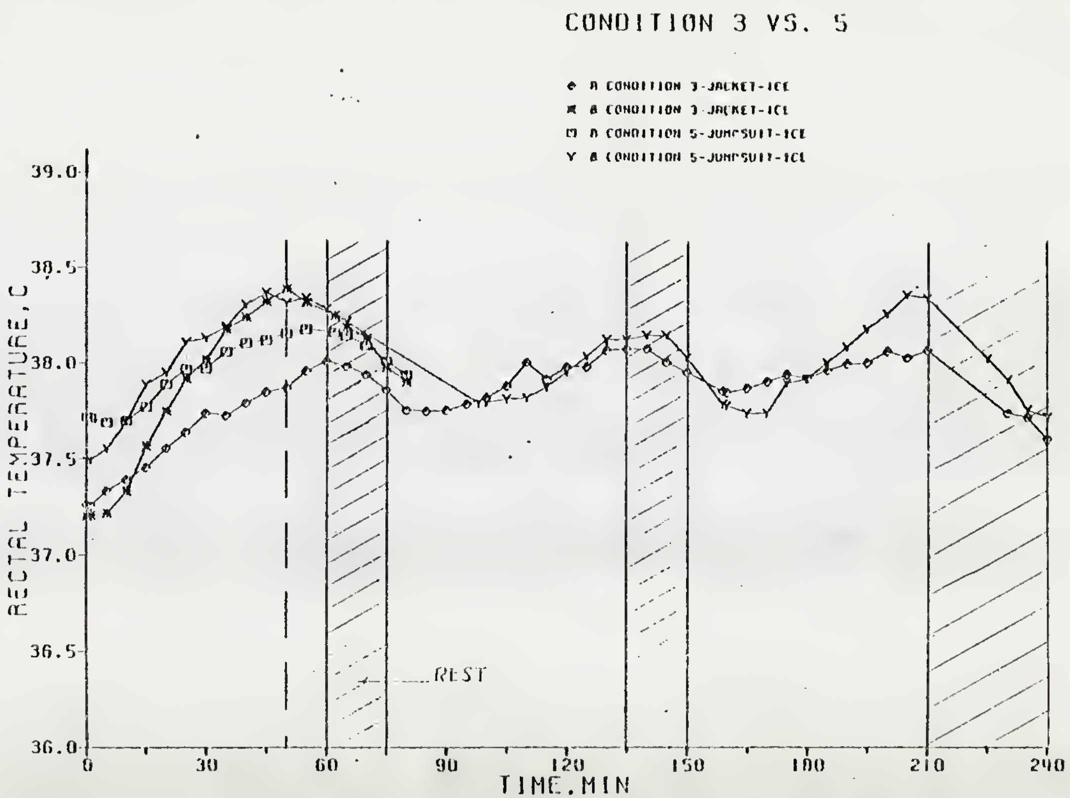

Figure C-6 Comparison of Rectal Temperature for Dry Ice Garments with Ice

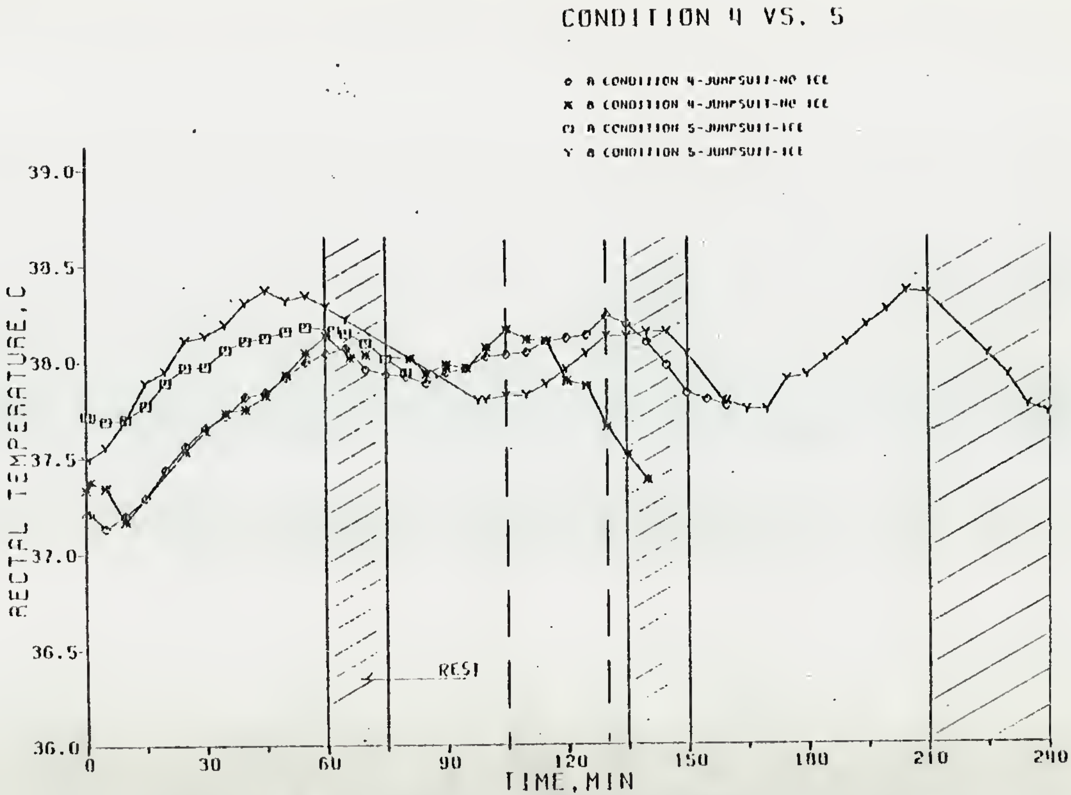

Figure C-7 Comparison of Rectal Temperature for Jumpsuit, With and Without Ice

Appendix D Comparison of Rectal Temperatures
Data vs. Simulation

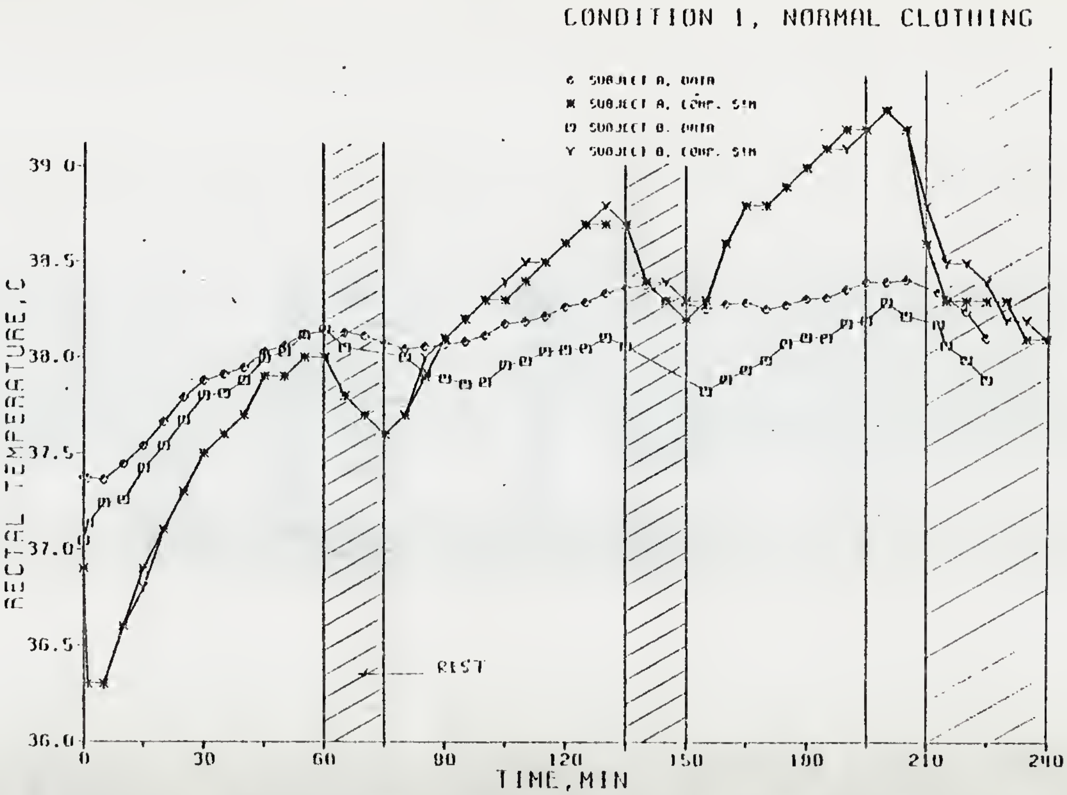

Figure D-1 Comparison of Rectal Temperature for Data vs. Simulation, Normal Clothing

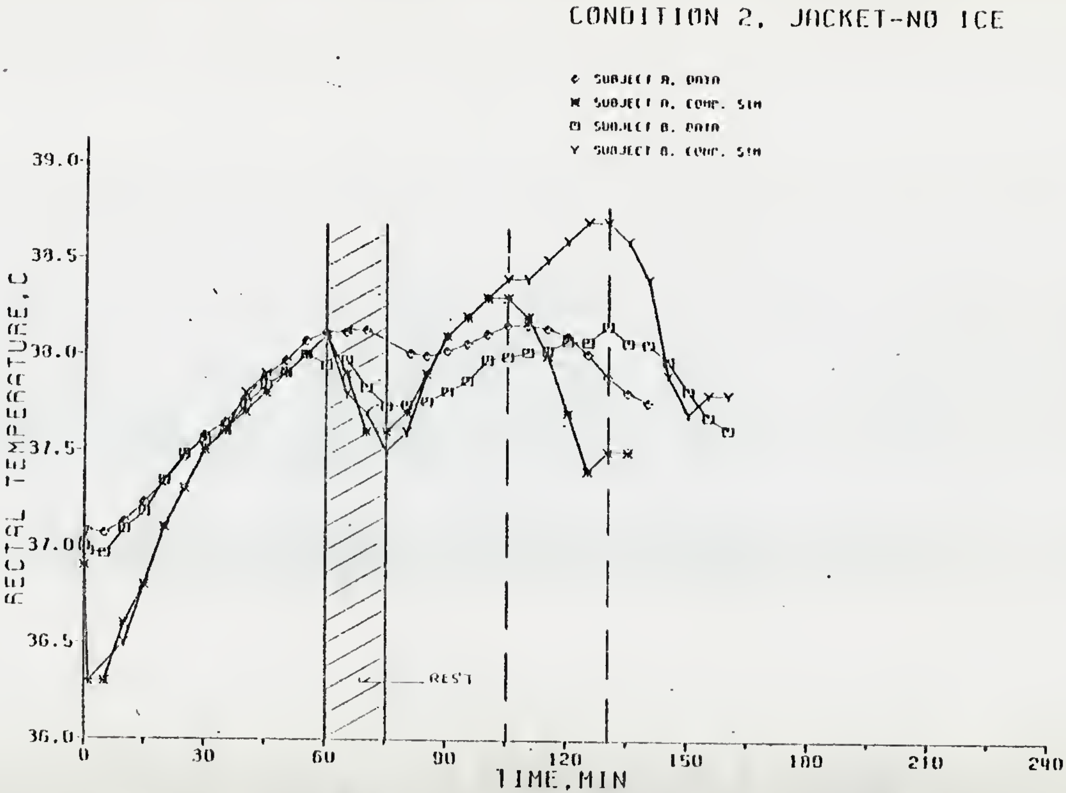

Figure D-2 Comparison of Rectal Temperature for Data vs. Simulation, Jacket without Ice

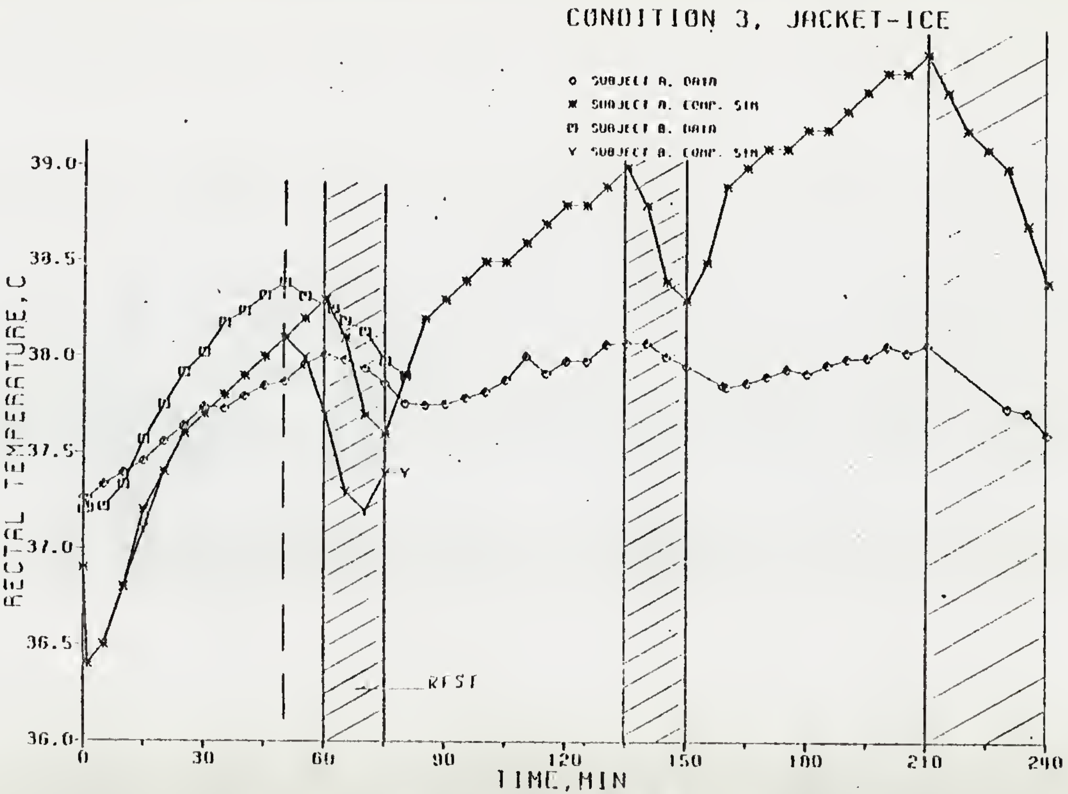

Figure D-3 Comparison of Rectal Temperature for Data vs. Simulation, Jacket with Ice

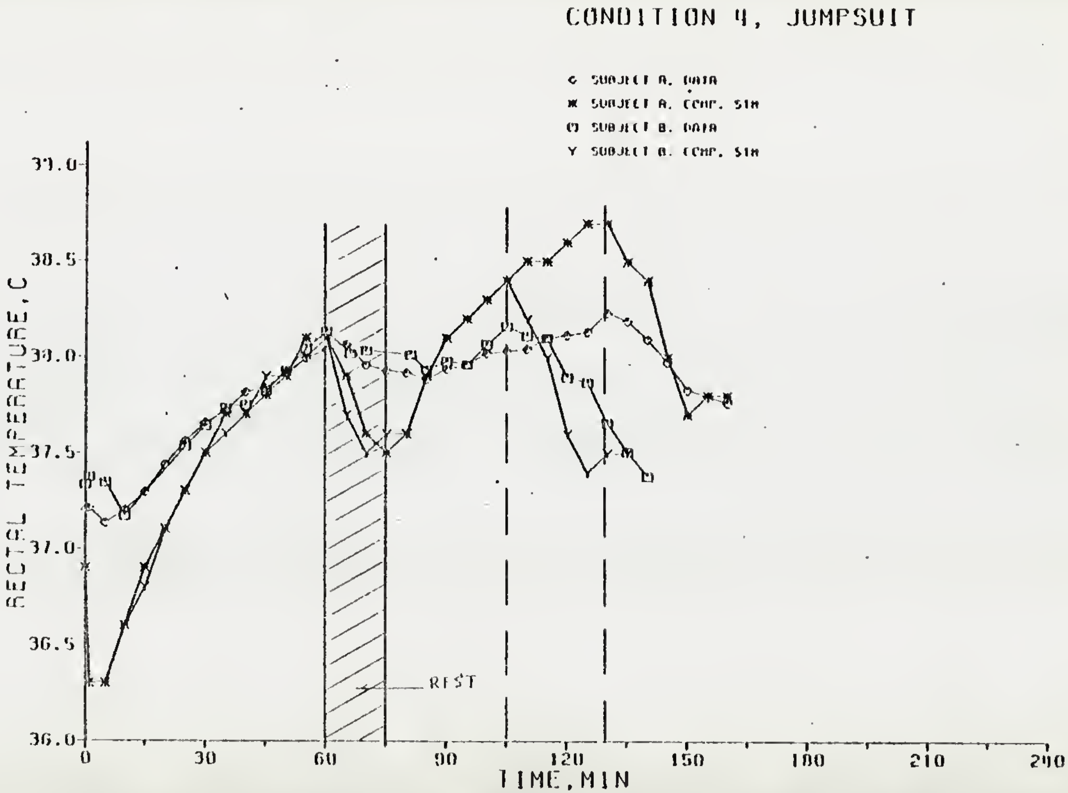

Figure D-4 Comparison of Rectal Temperature for Data vs. Simulation, Jumpsuit without Ice

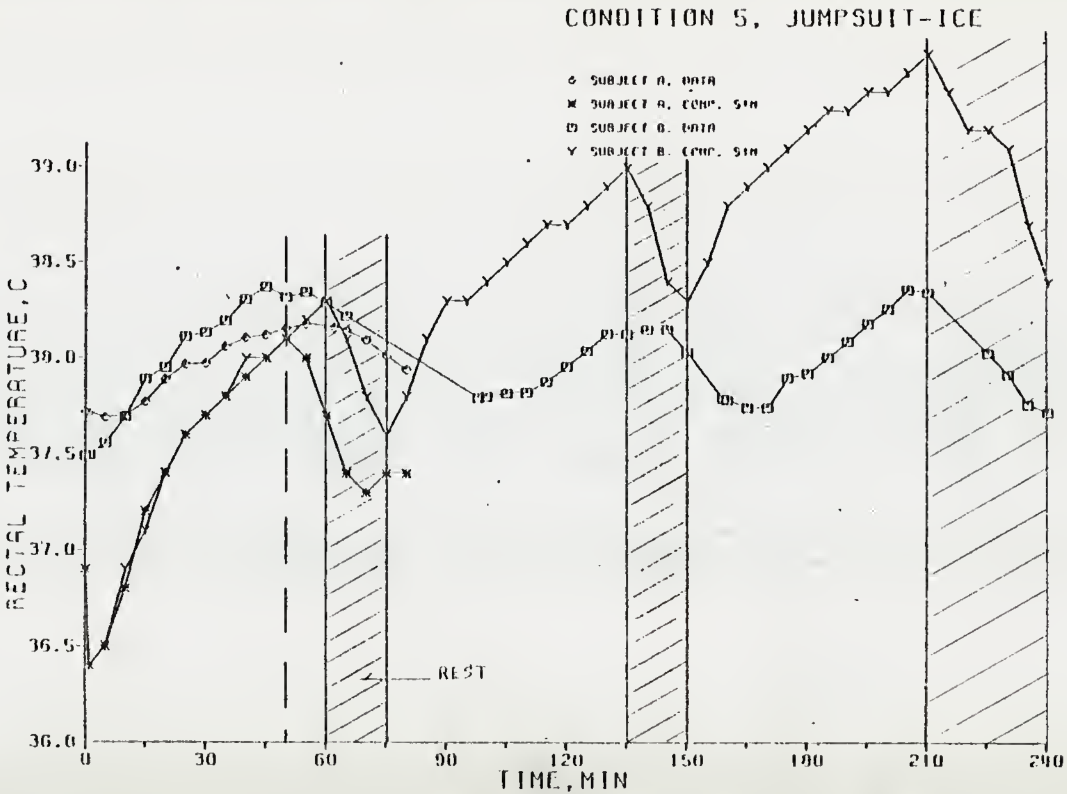

Figure D-5 Comparison of Rectal Temperature for Data vs. Simulation, Jumpsuit with Ice

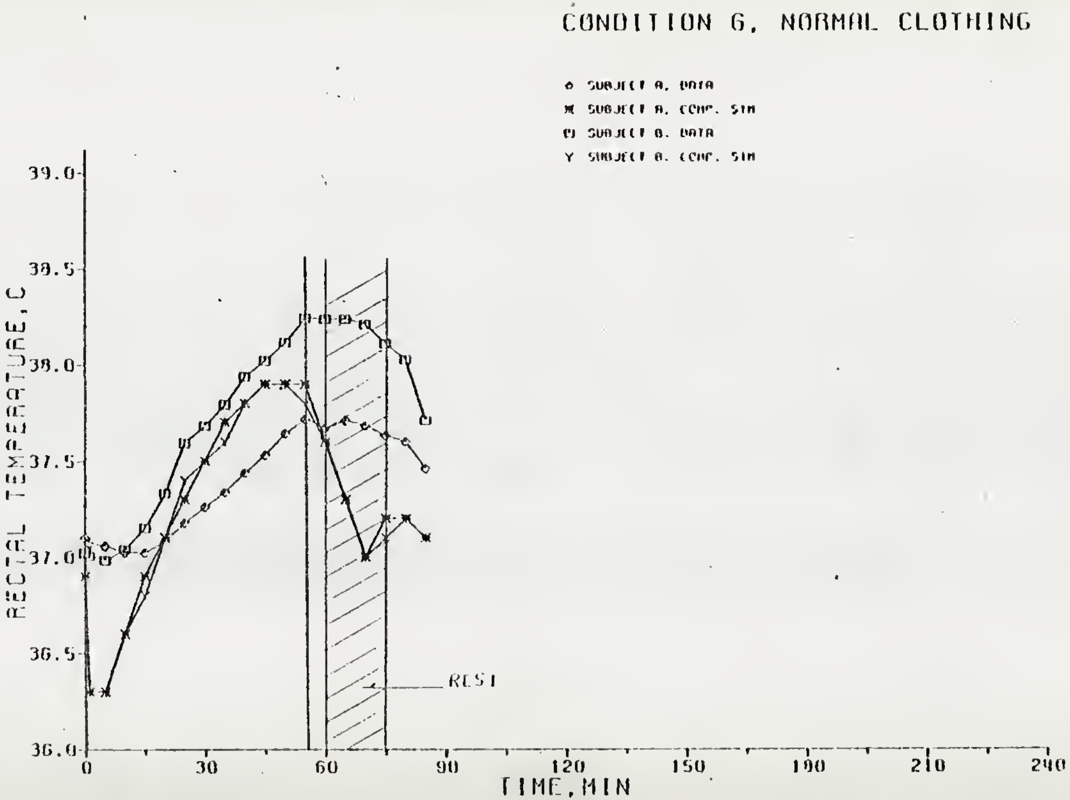

Figure D-6 Comparison of Rectal Temperature for Data vs. Simulation, Normal Clothing

Appendix E Table of Heart Rates for the Experiment

HEART RATE DATA

TIME	CONDITION 1 NORMAL SUBJ.A	B	CONDITION 2 JACKET-NO ICE A	B	CONDITION 3 JACKET-ICE A	B	CONDITION 4 JUMPSUIT A	B	CONDITION 5 JUMPSUIT-ICE A	B	CONDITION 6 NORMAL A	B
-0	84	96	90	81	84	100	81	102	99	105	75	87
0	99	93	90	105	99	129	53	117	102	125	102	108
5	117	111	108	114	111	129	99	123	132	123	90	111
10	120	[illegible]	111	117	93	132	111	125	120	132	102	120
15	[illegible]	[illegible]	105	120	100	120	117	[illegible]	123	111	105	117
20		[illegible]	117	120	111	132	108	108	123	138	102	120
25	[illegible]		117	117	117	130	120	141	126	120	108	126
30	124	99	111	120	105	132	117	120	126	[illegible]	105	126
35	117	126	117	123	114	132	123	117	123	138	111	132
40	123	129	129	[illegible]	111	138	[illegible]	135	126	144	105	129
45	111	120	117	135	120	141	117	153	129	123	108	132
50	111	126	126	123	117	147	123	129	132	132	108	129
55	123	126	105	126	129	111	120	150	114	138	102	96
60	96	90	129	129	117	105	117	126	102	111	81	123
65	84	105	105	93		[illegible]	53	117	[illegible]		87	102
70	84	96	93	90	[illegible]	96	84	102	108		90	84
75	87	108	87	81	[illegible]	93	84	102	99		78	84
80	105	117	102	108	[illegible]	87	108	114	90	[illegible]	78	99
85	129	117	126	123	[illegible]		108	114		[illegible]	75	84
90	93	102	117	126	90		114	126		[illegible]		
95	117	114	123	120	87		111	129		[illegible]		
100	117	123	123	126	81		117	126		120		
105	99	117	111	108	0		111	126		102		
110	117	126	96	129	0		114	100		[illegible]		
115	123	123	92	111	93		114	96		111		
120	114	102	99	120	96		120	88		117		
125	123	123	84	126	84		123	88		135		
130	123	126	76	144	99		132	84		135		
135	117	120	84	90	78		105	84		114		
140	100	100	[illegible]	93	[illegible]		87	[illegible]		[illegible]		
145	93	102		93	90		96			102		
150	96	87		84	84		81			96		
155	102	117		84	105		76			111		
160	117	129		84	105		[illegible]			102		
165	93	123			102					132		
170	117	123			105					117		
175	126	126			102					150		
180	117	111			105					135		
185	126	135			111					144		
190	120	135			114					135		
195	114	123			111					141		
200	108	132			114					144		
205	87	123			114					150		
210	96	96			102					138		
215	87	96			[illegible]							
220	96	96			72					96		
225	67	105			70					102		
230					81					84		
235					87					96		
240					75					[illegible]		

Appendix F Comparison of Heart Rates for Conditions

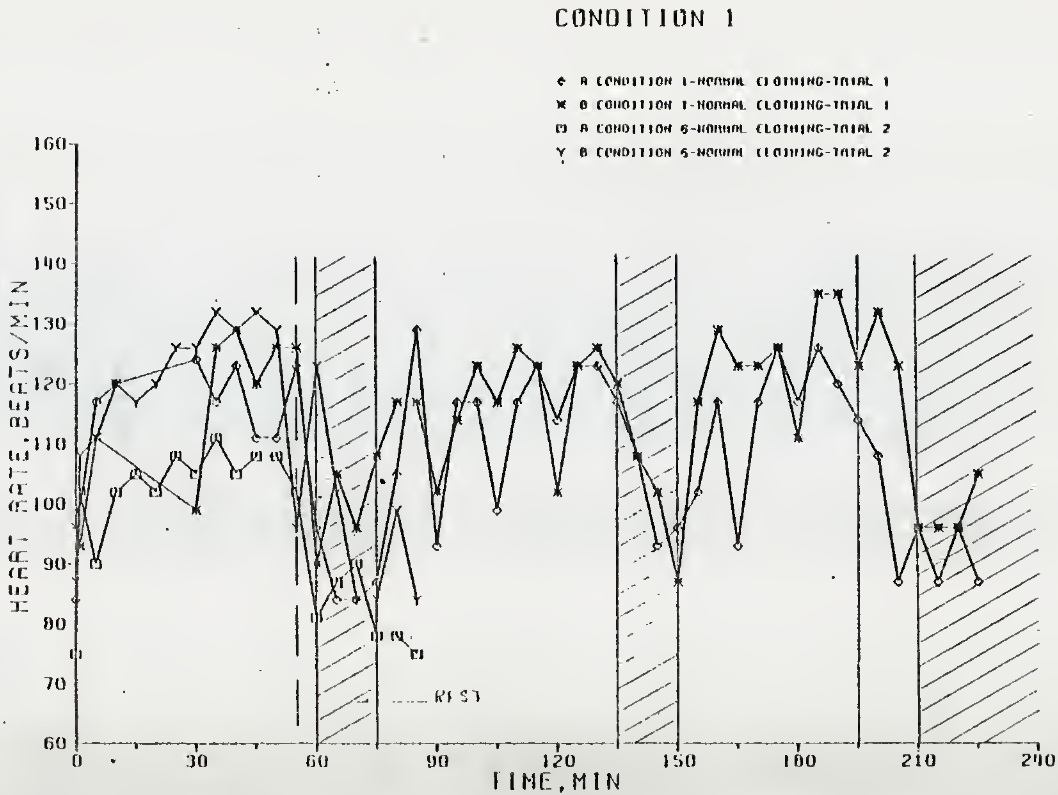

Figure F-1 Comparison of Heart Rates for Normal Clothing Conditions

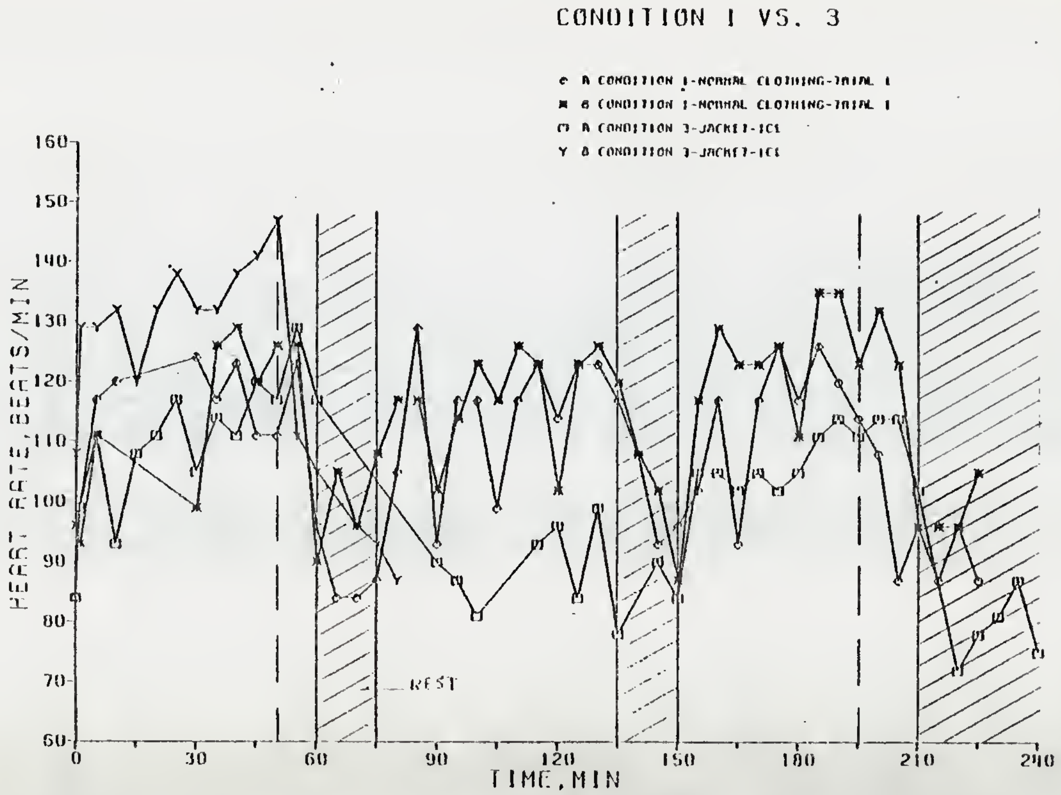

Figure F-2 Comparison of Heart Rates for Normal Clothing and Jacket with Ice

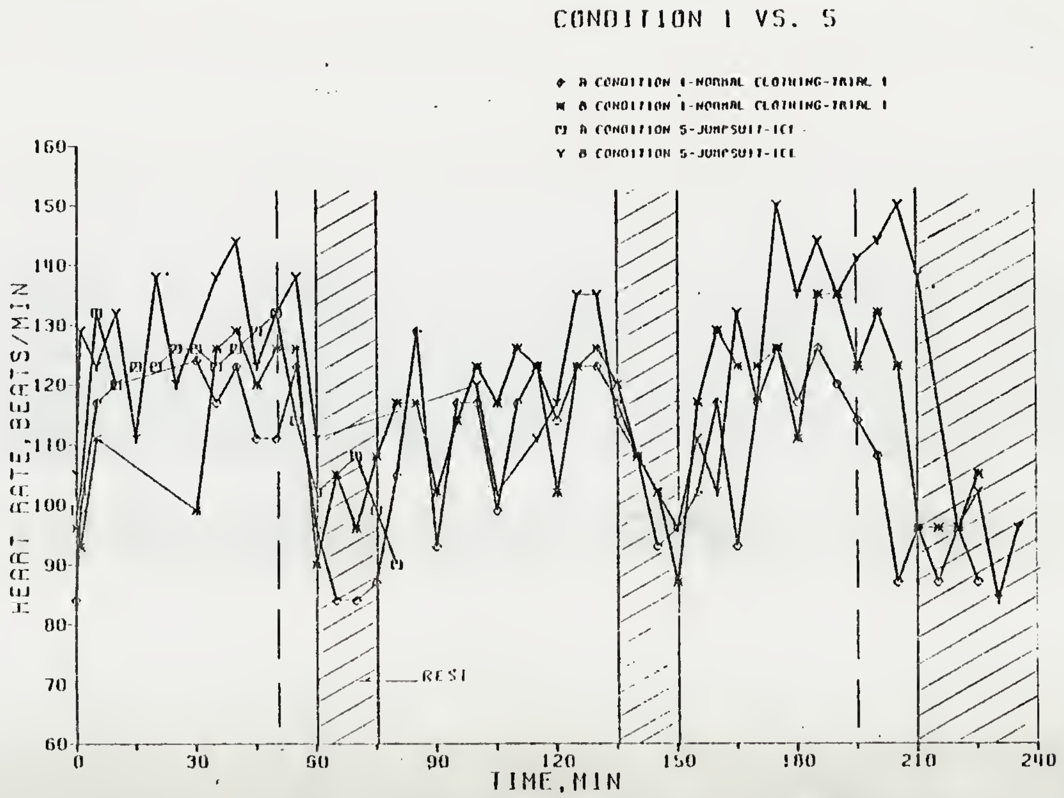

Figure F-3 Comparison of Heart Rates for Normal Clothing and Jumpsuit with Ice

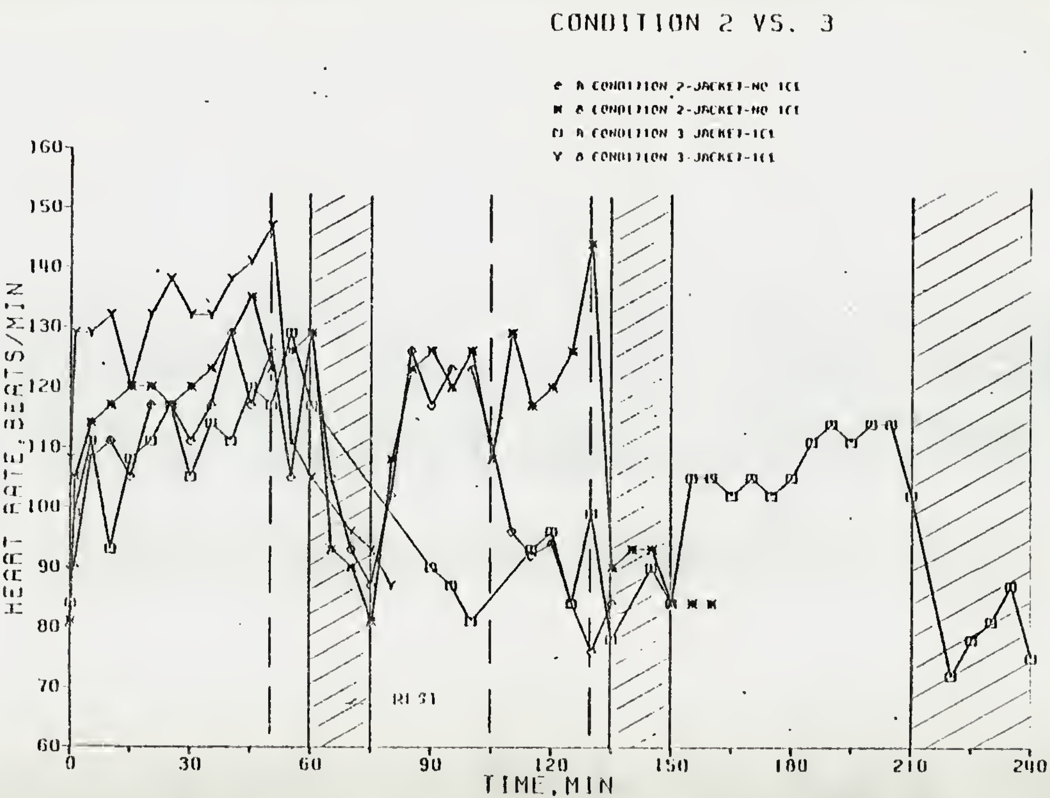

Figure F-4 Comparison of Heart Rates for the Jacket, With and Without Ice

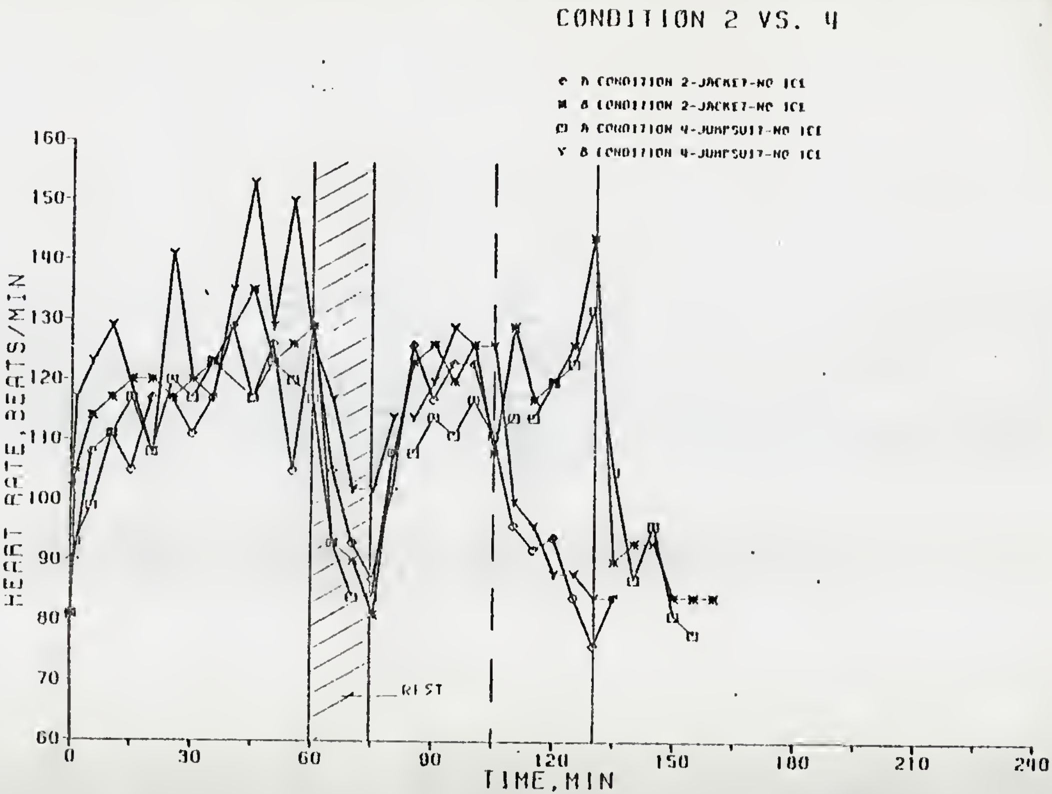

Figure F-5 Comparison of Heart Rates for the Dry Ice Garments without Ice

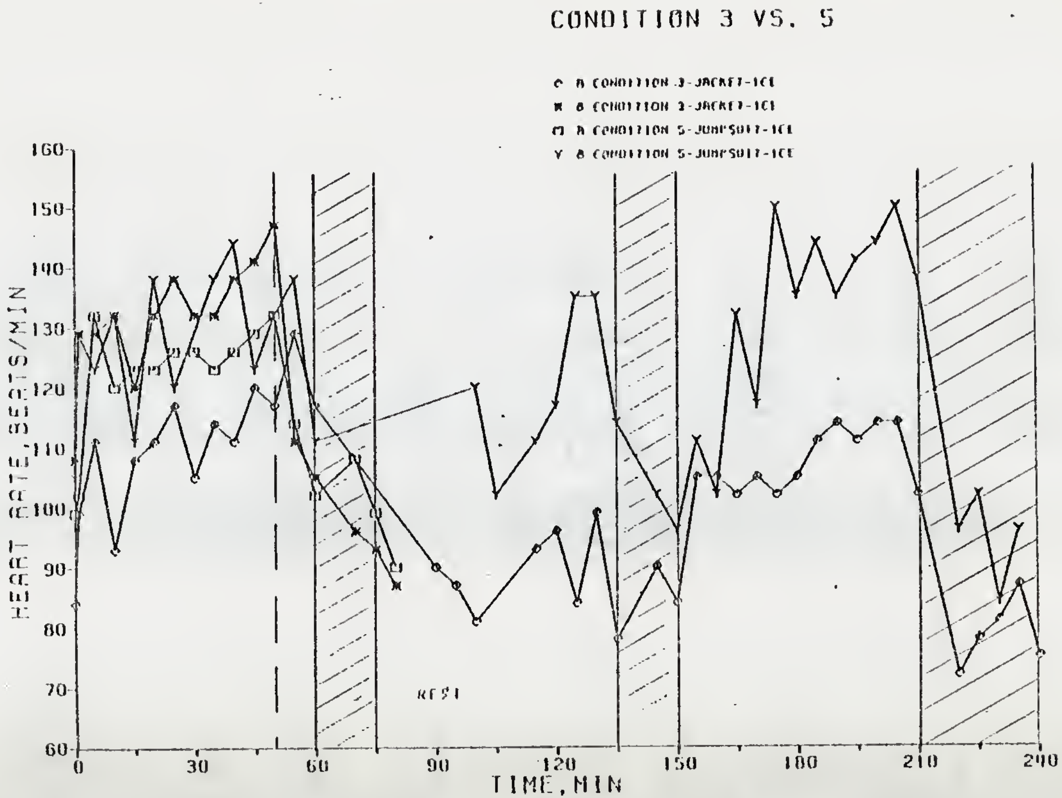

Figure F-6 Comparison of Heart Rates for the Dry Ice Garments with Ice

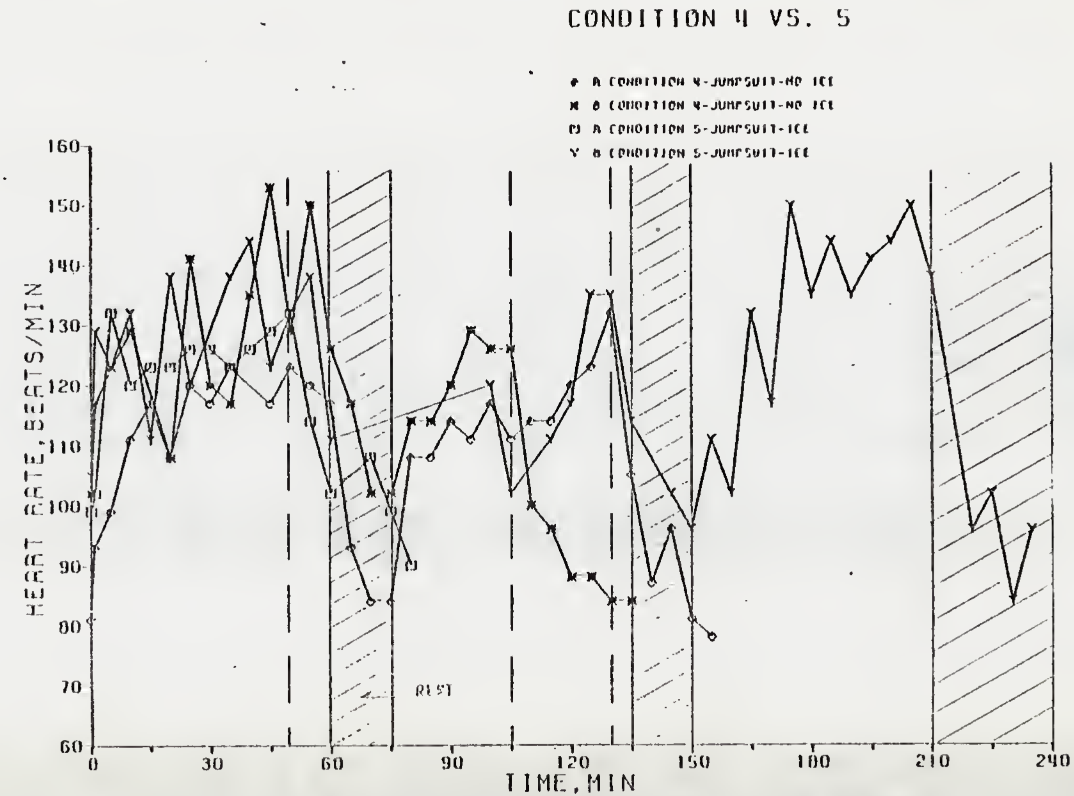

Figure F-7 Comparison of Heart Rates for Dry Ice Jumpsuit, With and Without Ice

Appendix G Comparison of Heart Rates, Data vs. Simulation

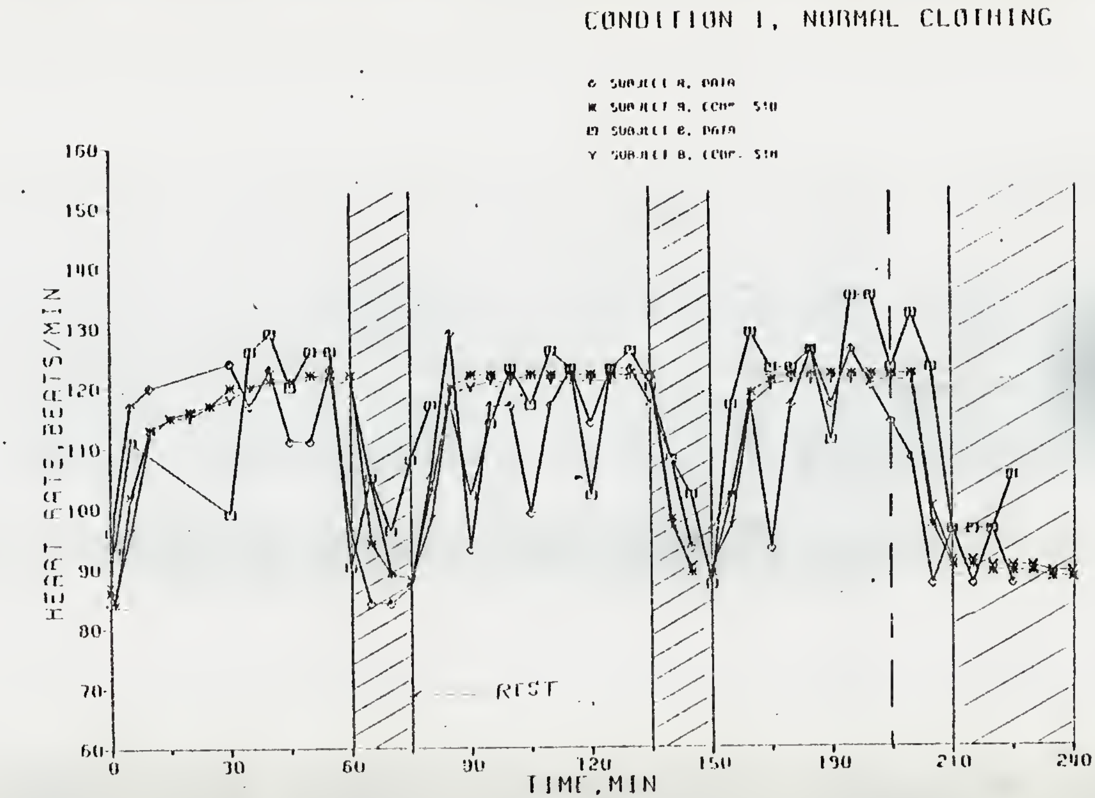

Figure G-1 Comparison of Heart Rates for Data vs. Simulation, Normal Clothing

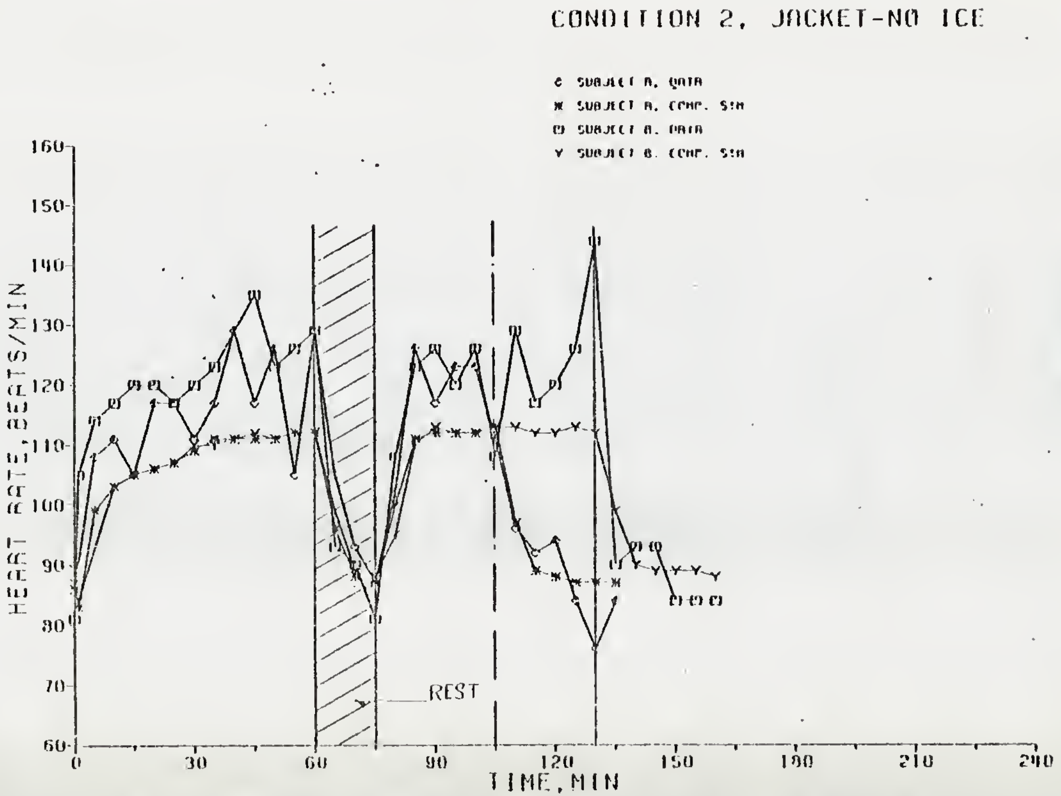

Figure G-2 Comparison of Heart Rates for Data vs. Simulation, Jacket without Ice .

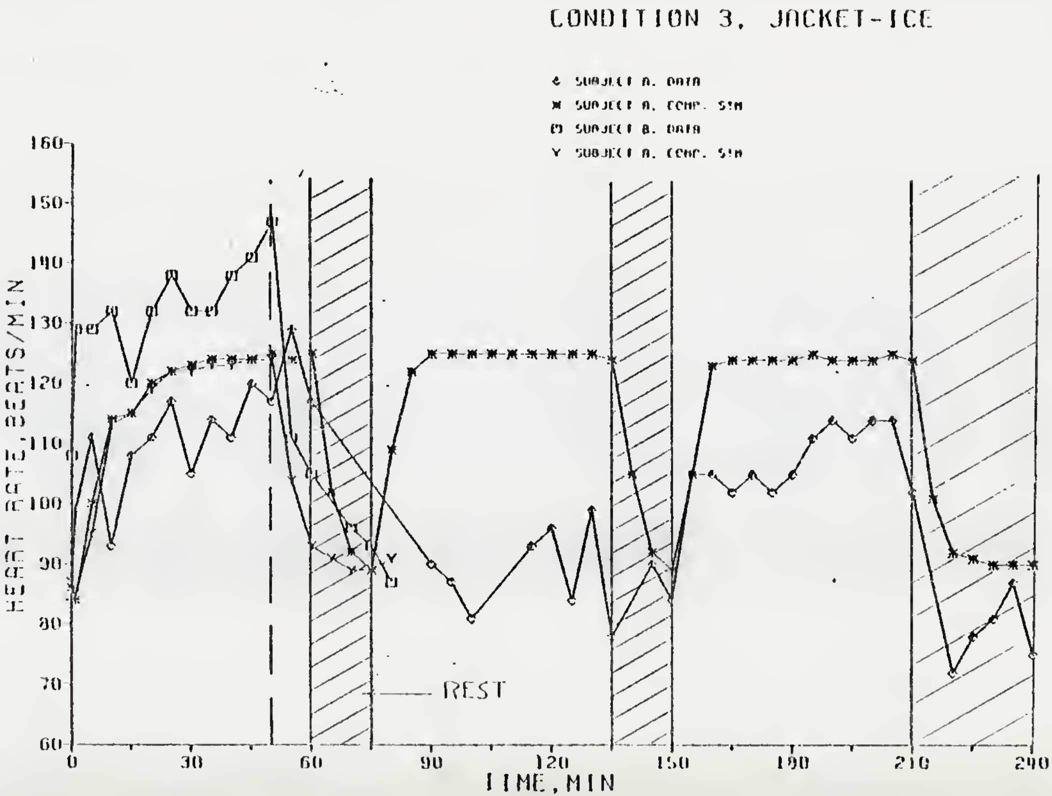

Figure G-3 Comparison of Heart Rates for Data vs. Simulation, Jacket with Ice

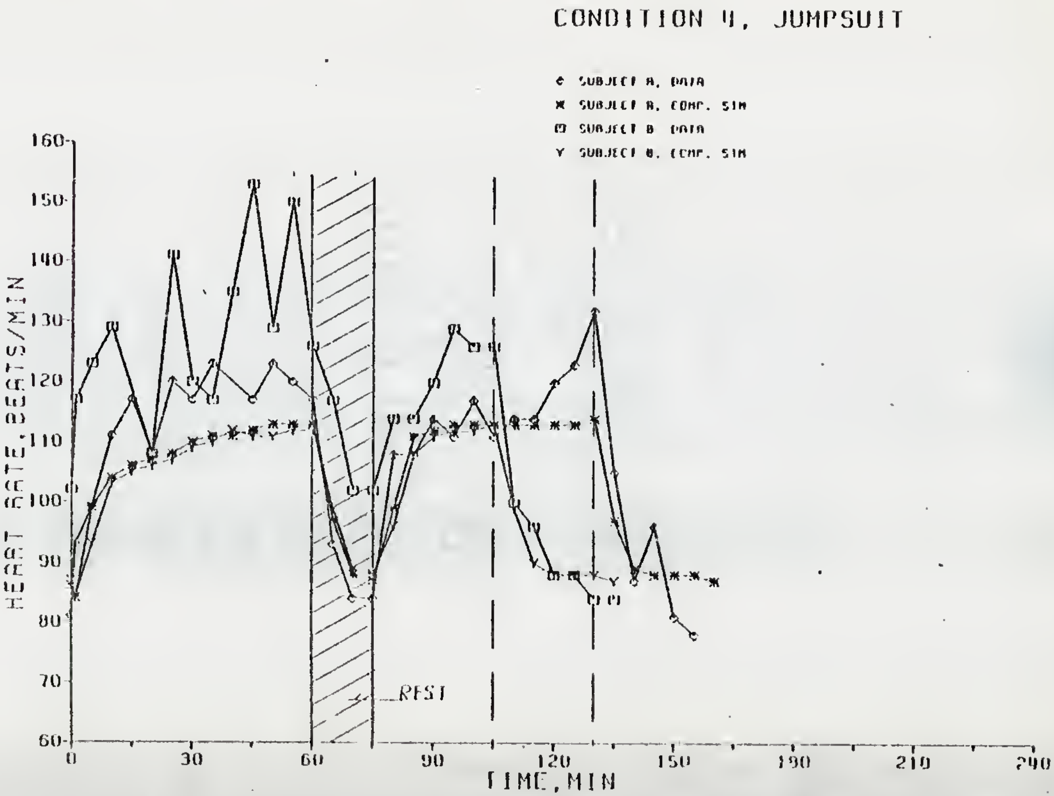

Figure G-4 Comparison of Heart Rates for Data vs. Simulation, Jumpsuit without Ice

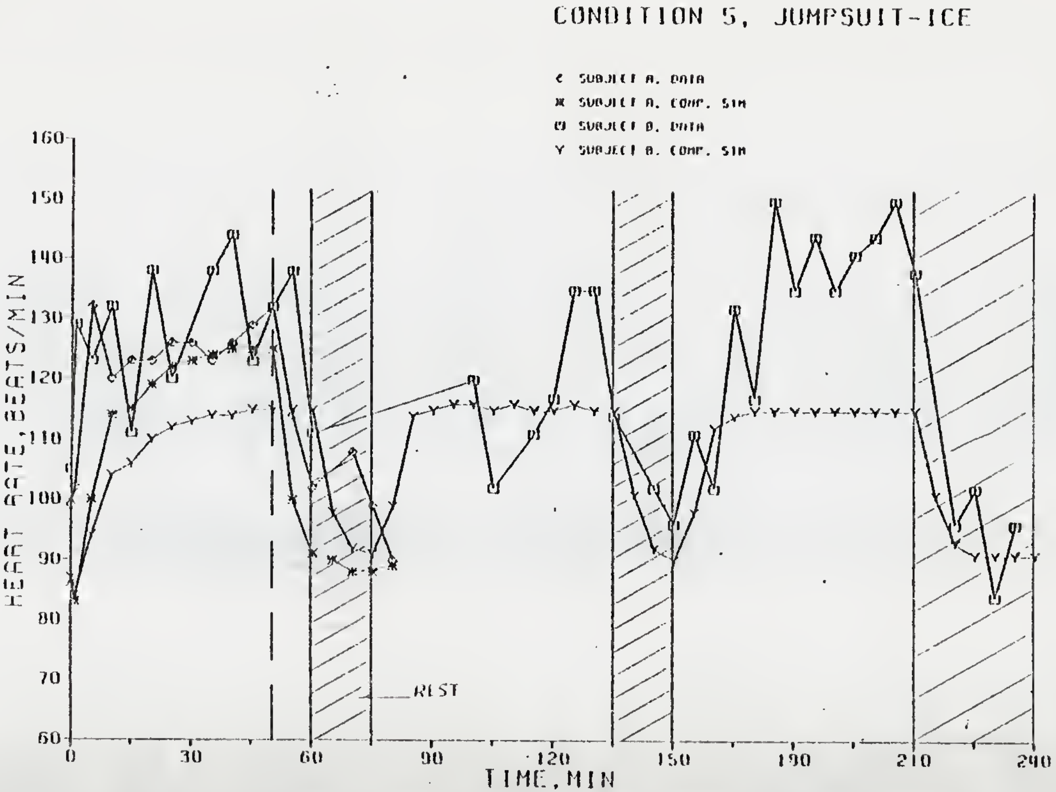

Figure G-5 Comparison of Heart Rates for Data vs. Simulation, Jumpsuit with Ice

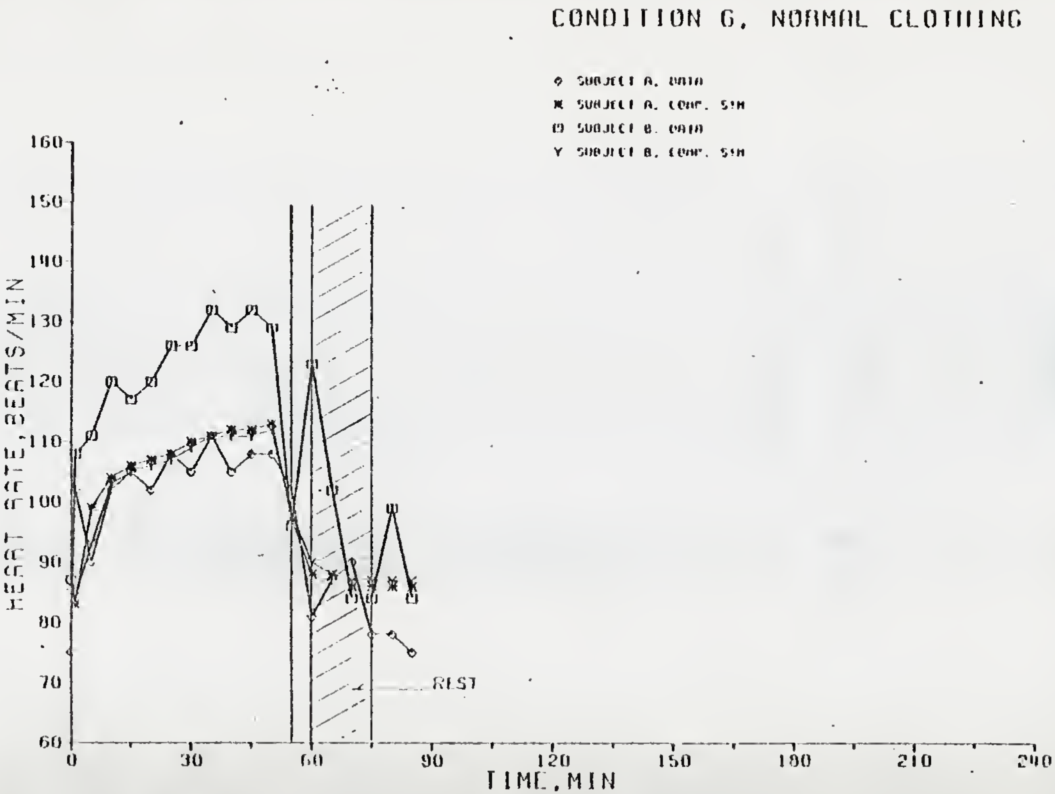

Figure G-6 Comparison of Heart Rates for Data vs. Simulation, Normal Clothing, Trial 2

Appendix H Oxygen Consumption Rate Data for the Experiment

OXYGEN CONSUMPTION RATE, ML/(MIN-KG)

TIME	CONDITION 1 SUBJ.A	B	CONDITION 2 A	B	CONDITION 3 A	B	CONDITION 4 A	B	CONDITION 5 A	B	CONDITION 6 A	B
0.	4.510	4.722	4.536	5.506	5.292	11.130	6.014	4.818	3.361	6.519	4.931	3.377
15.	8.537	7.421	5.214	12,143	8.778	9.104	4.654	7.170	14.431	7.416	5.869	2.805
30.	7.575	8.321	10.674	6.519		11.922	7.458	4.130	9.014	6.284	6.375	10.792
45.	5.298	4.947	10.360	7.416	7.222	5.961	5.292	9.981	7.097	14.159	4.208	8.429
60.	7.215	12.931	3.313	4.156	7.222	4.831	9.014	5.277	2,639	2.247	4.333	3.481
75.	6.253	2.979	5.767	3.377	9.314		5.528	4.733		3.597		
90.	4.569	6.071	6.625	7.532	12.028		5.417	11.931		6.078		
105.	7.044	6.522	12.760	12.260	6.861		10.819	11.243		2.247		
120.	6.293	8.534		6.238	10.347		9.625			6.636		
135.	7.335	12.706		4.494	11.069		5.056			13.939		
150.	10.829	9.453			7.931					4.156		
165.	10.101	6.184			5.778					6.078		
180.	4.813	7.083			8.542					7.649		
195.	7.017	4.947			3.125					14.961		
210.	4.444	4.160			7.931					5.065		

Appendix I Comparison of Oxygen Consumption Rates for Conditions

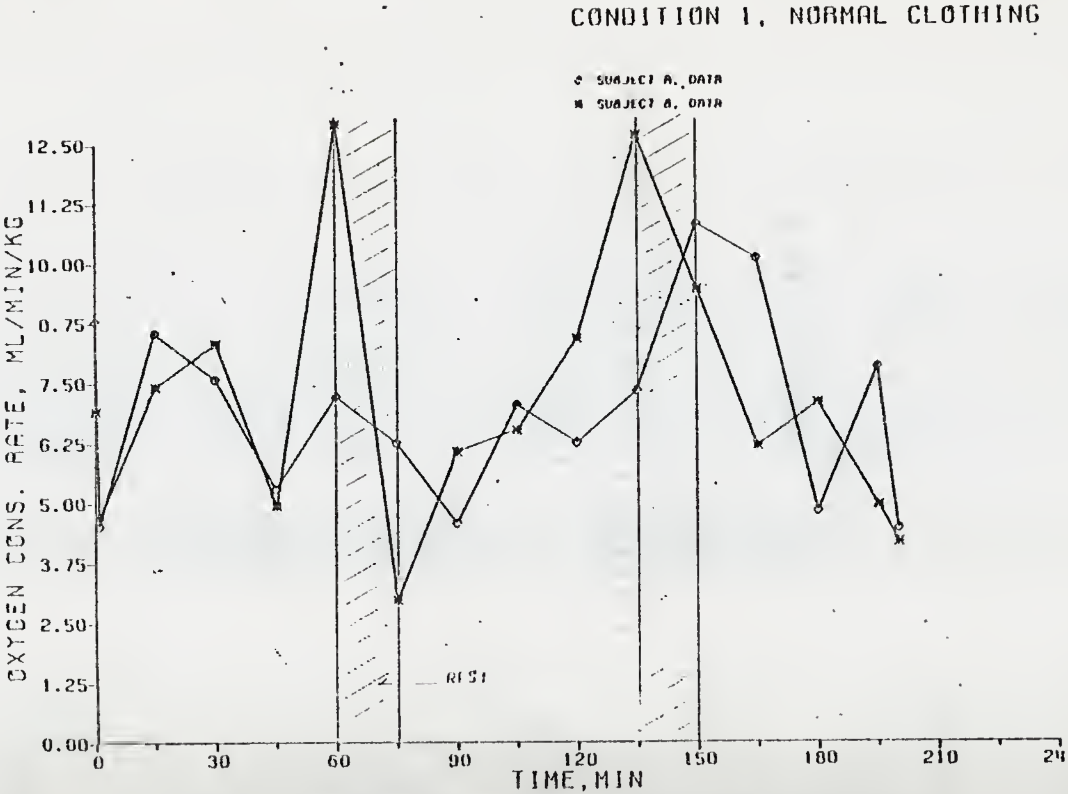

Figure I-1 Comparison of Oxygen Consumption Rates for Normal Clothing

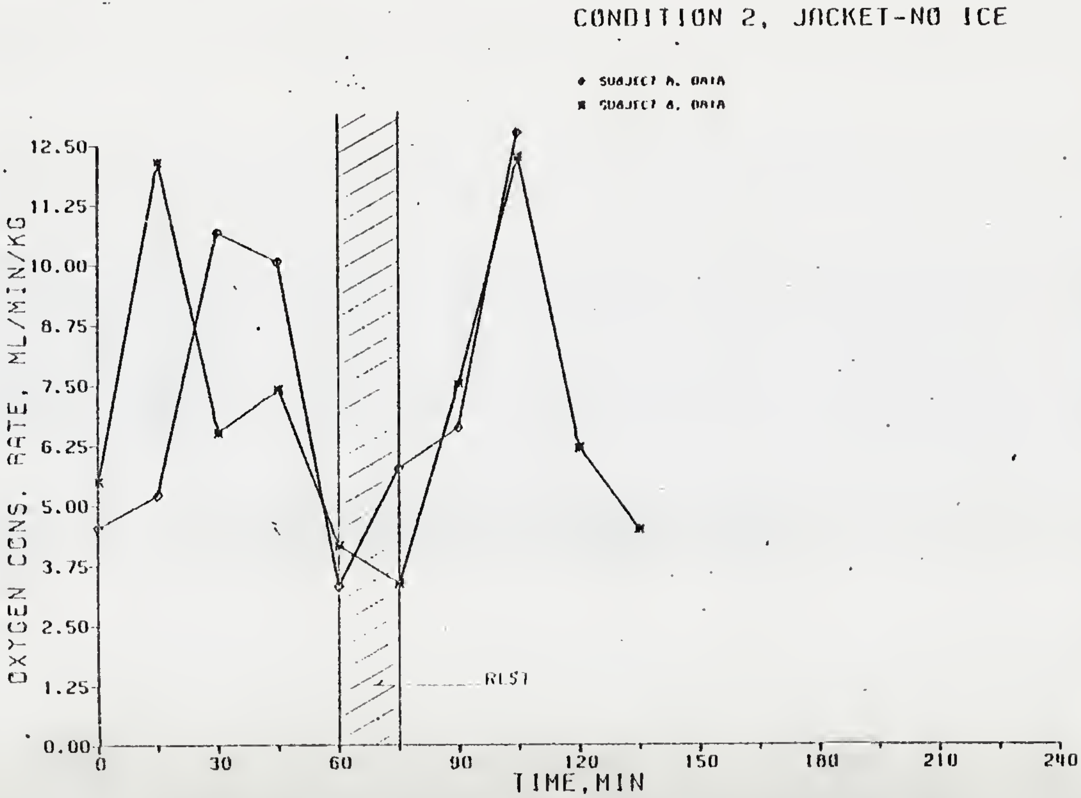

Figure I-2 Comparison of Oxygen Consumption Rates for Jacket without Ice

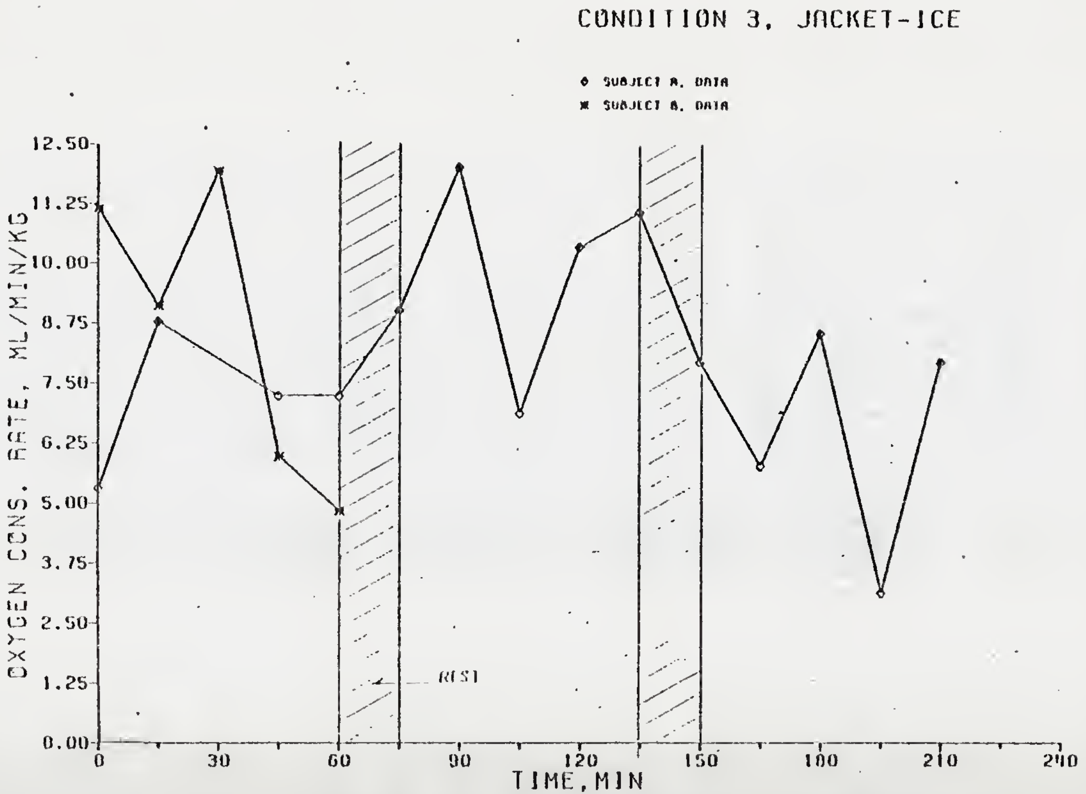

Figure I-3 Comparison of Oxygen Consumption Rates for Jacket with Ice

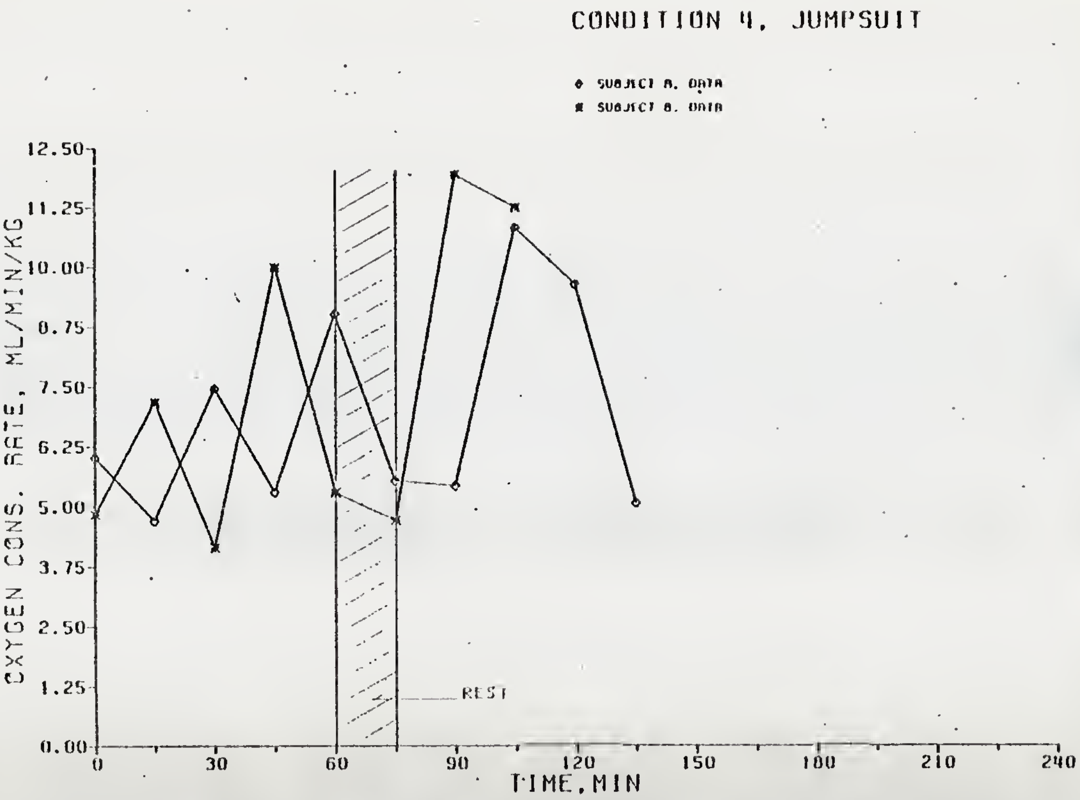

Figure I-4 Comparison of Oxygen Consumption Rates for Jumpsuit without Ice

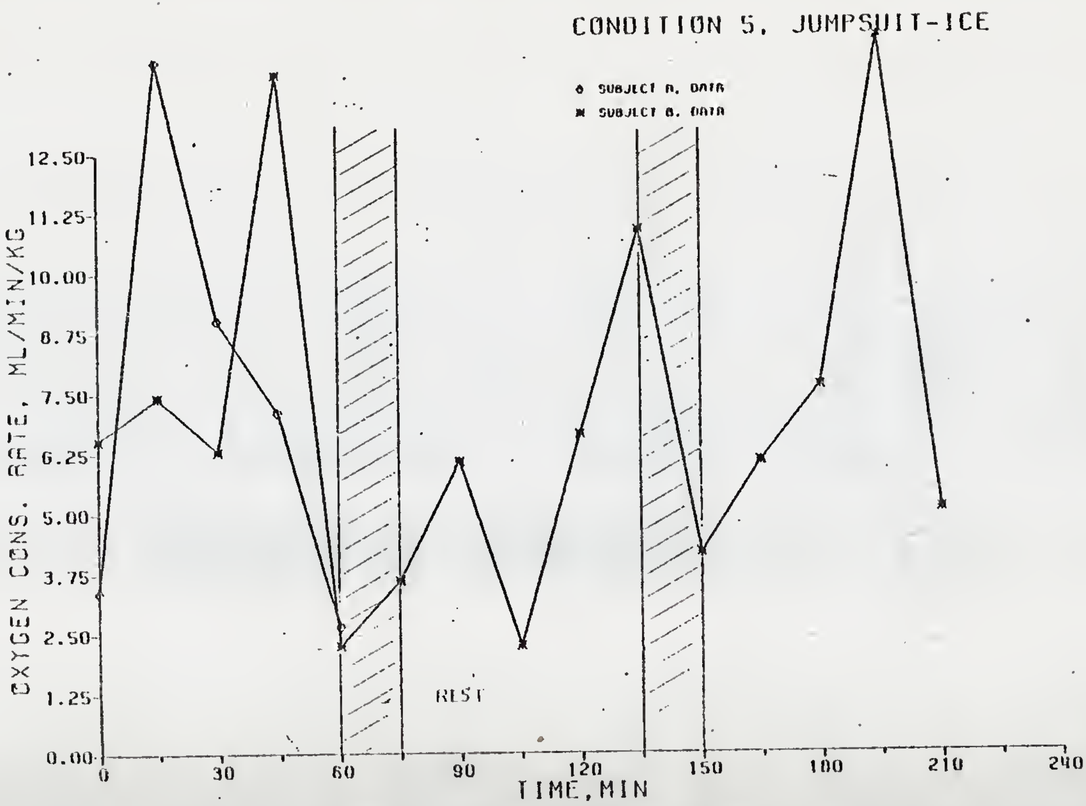

Figure I-5 Comparison of Oxygen Consumption Rates for Jumpsuit with Ice

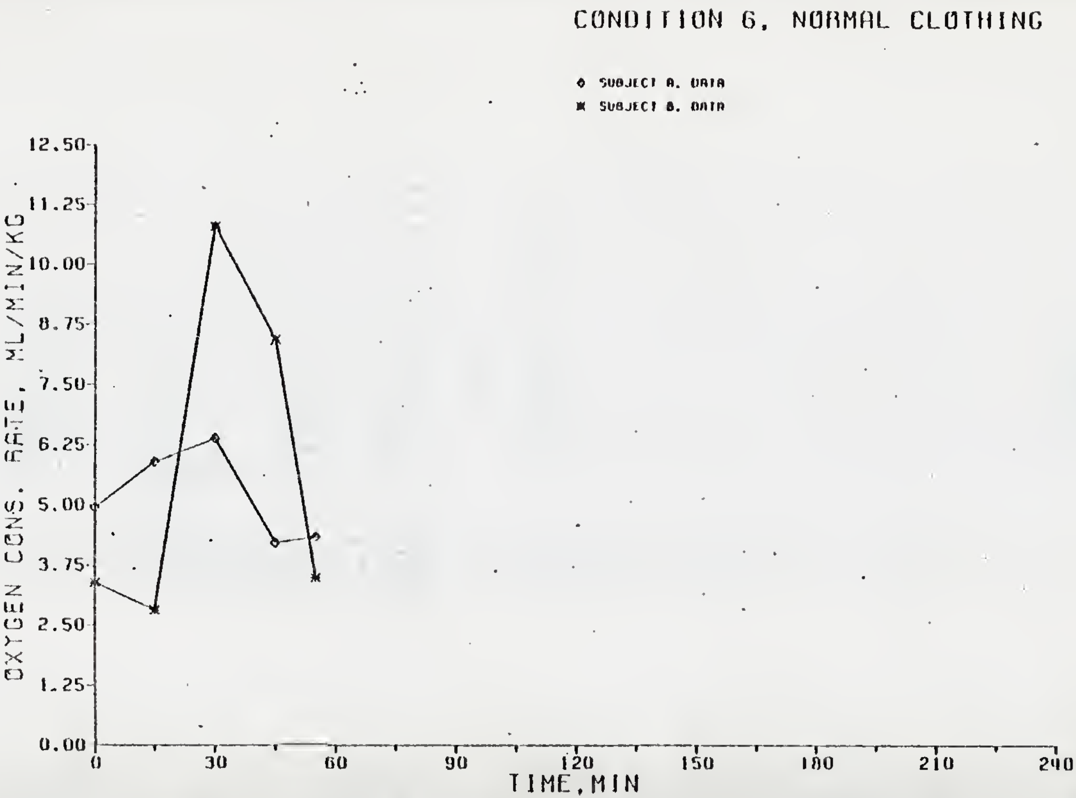

Figure I-6 Comparison of Oxygen Consumption Rates for Normal Clothing, Trial 2

Appendix J Comparison of Mean Torso Skin Temperatures Data vs. Simulation

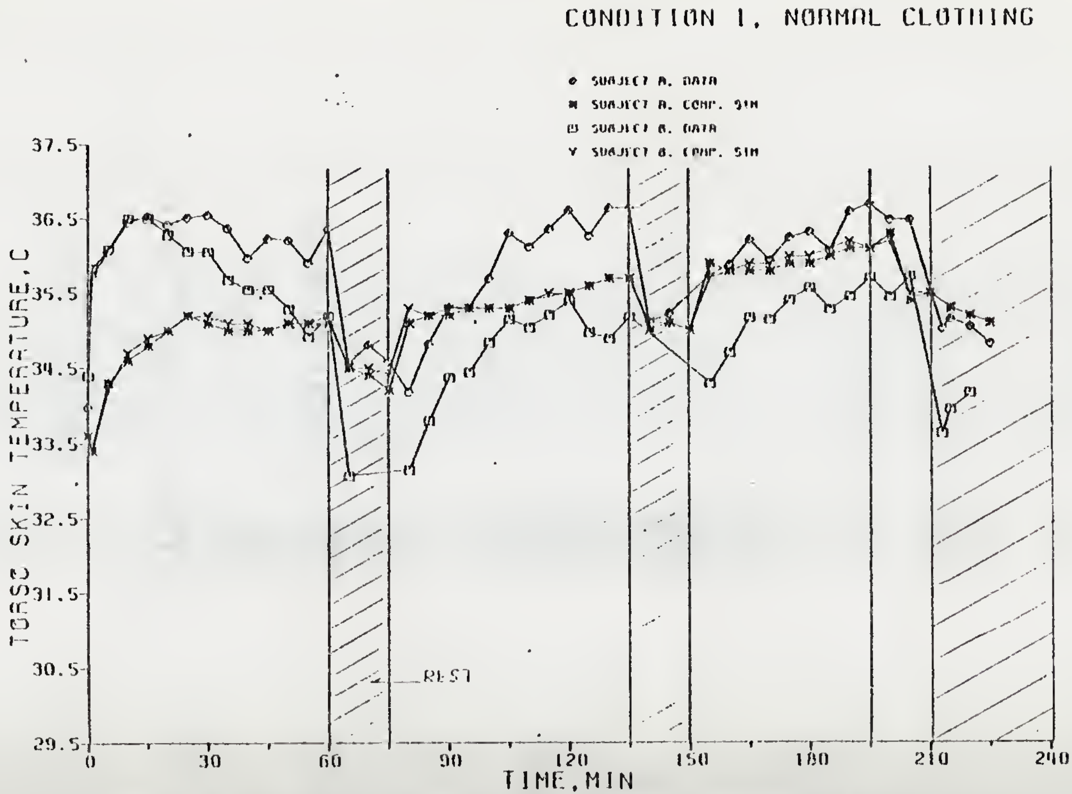

Figure J-1 Mean Torso Skin Temperatures for Data vs. Simulation, Normal Clothing

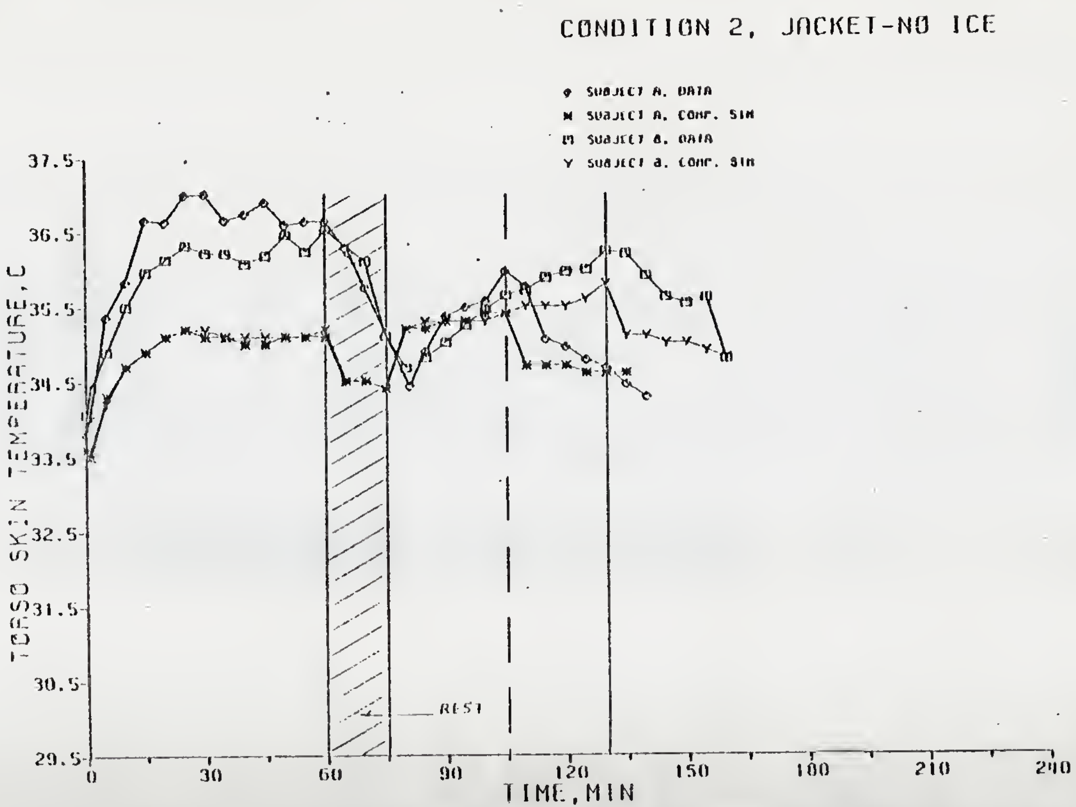

Figure J-2 Mean Torso Skin Temperatures for Data vs. Simulation, Jacket without Ice

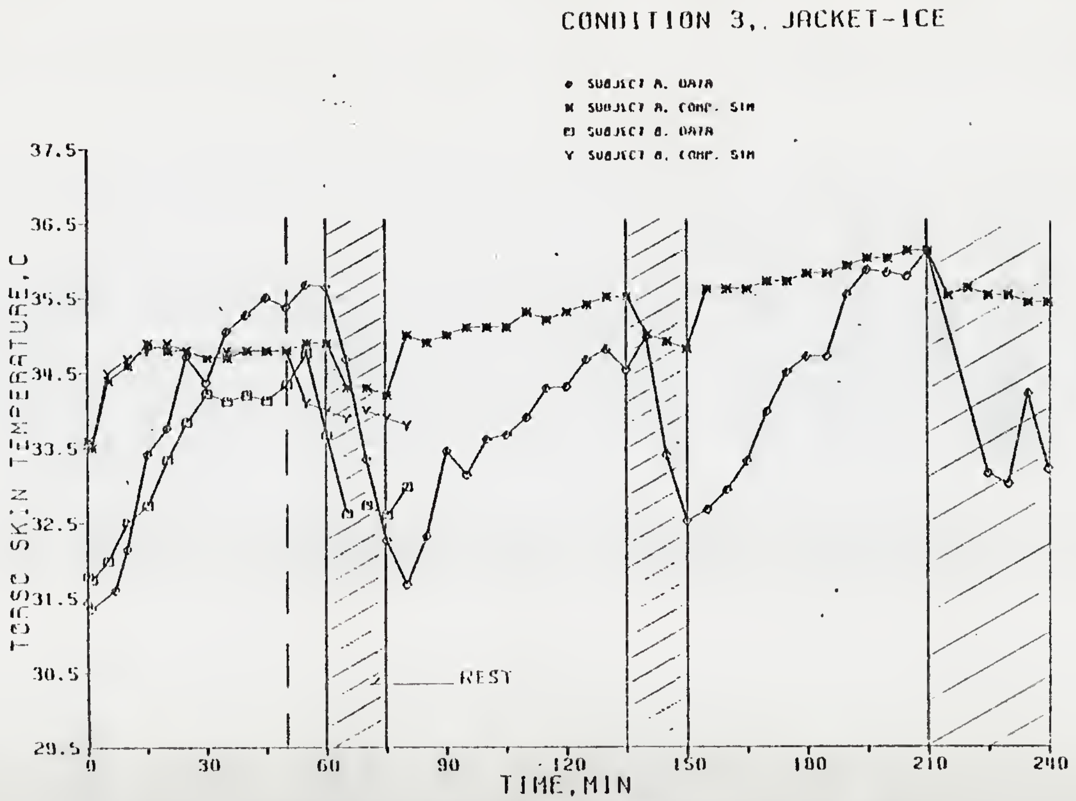

Figure J-3 Mean Torso Skin Temperatures for Data vs. Simulation, Jacket with Ice

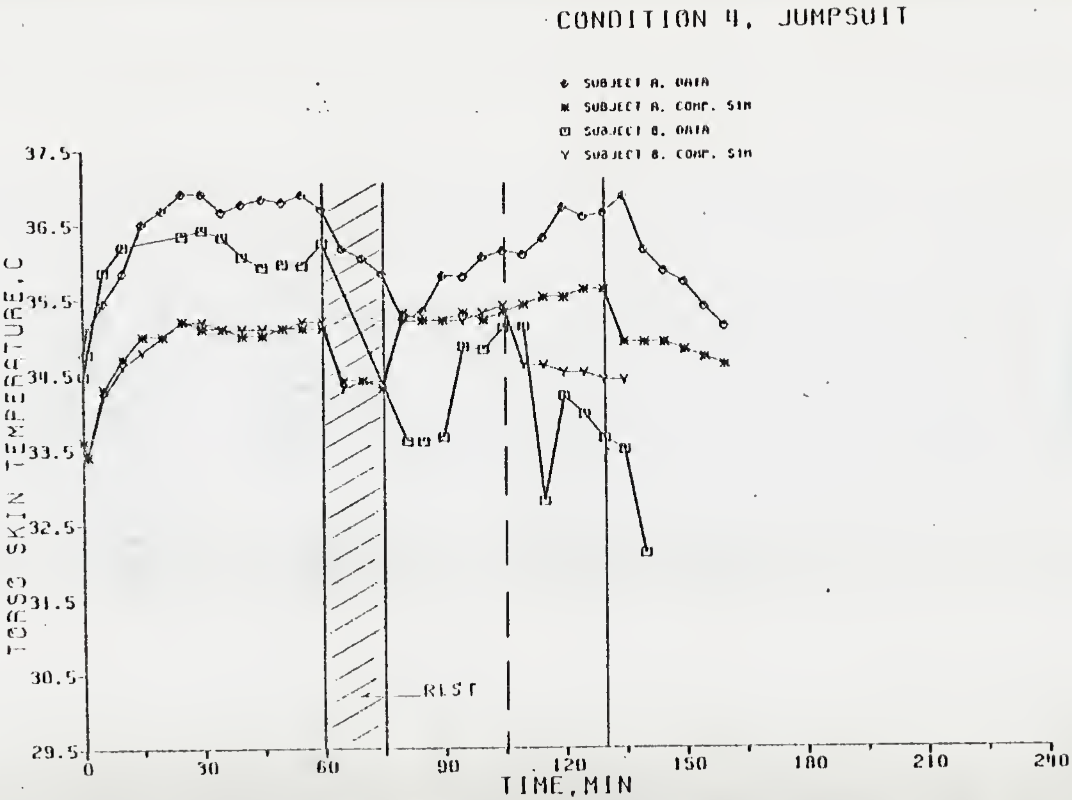

Figure J-4 Mean Torso Skin Temperatures for Data vs. Simulation, Jumpsuit without Ice

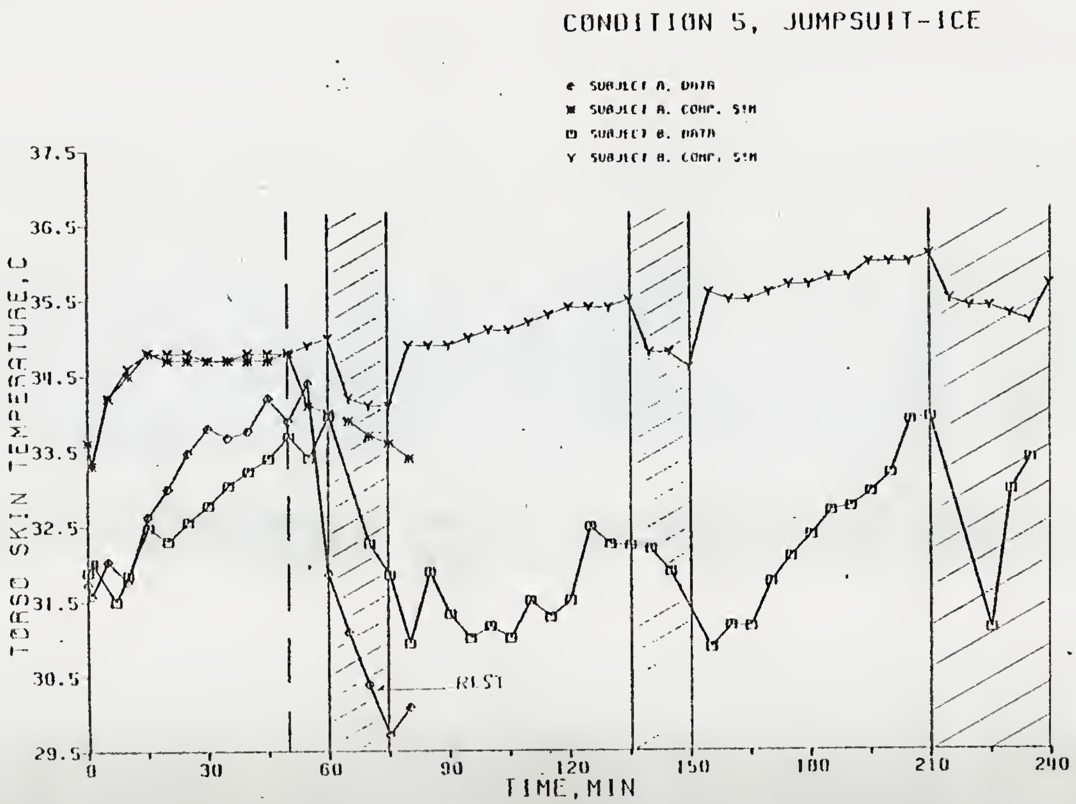

Figure J-5 Mean Torso Skin Temperatures for Data vs. Simulation, Jumpsuit with Ice

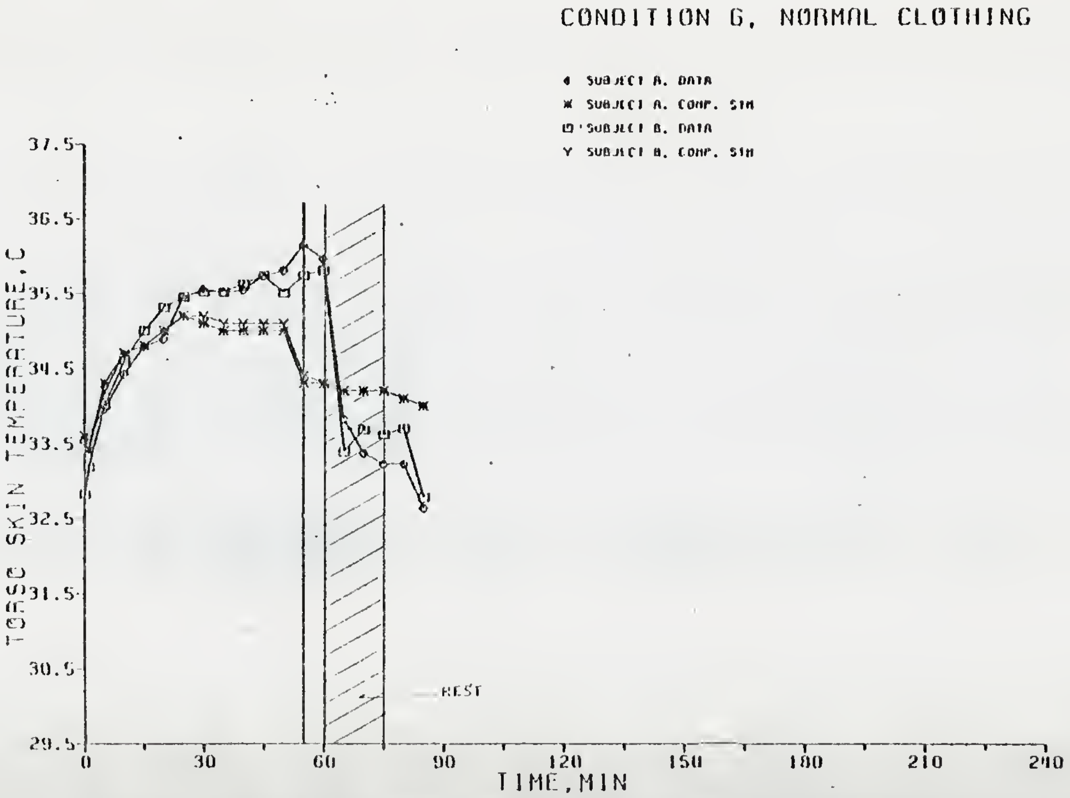

Figure J-6 Mean Torso Skin Temperatures for Data vs. Simulation, Normal Clothing, Trial 2

Appendix K Data for Computer Model

```
  *   *   *  DATA FOR SUBJECT A, CONDITION 1, NORMAL CLOTHING
M                                                                             SEX
21.                                                                           AGE
74.50                                                                         WT
182.                                                                          HT
.10                                                                           IBFYM
0.                                                                            SAF
 3                                                                            SFTNES
0.                                                                            ACCLIM
0.   150. 150. 300.                                                           WW
     65.  140. 215.                                                           WTIME
740.                                                                          BARO
25.  34.  25.  34.  25.  34.  25.  25.                                        TAIRV
     10.  70.  85.  145. 160. 210. 300.                                       WTAIRV
25.  34.  25.  34.  25.  34.  25.  25.                                        TRV
     10.  70.  85.  145. 160. 210. 300.                                       WTIME
.3   .3   .3   .3   .3   .3   .3   .3                                         VV
     10,  70.  85.  145. 160. 210. 300.                                       WVV
.5   .5   .3   .5   .3   .5   .3   .3                                         RHV
     10.  70.  85.  145. 160. 210. 300.                                       WRHV
100. 285. 100. 235. 100. 285. 100. 100.                                       WORKV
     10.  70.  85.  145. 160. 210. 300.                                       WWORKV
                                                                              SUBRAT
.0   .15  .10  .0   .20  .15  .0   .15  .10  .0   .20  .15  .0   .15          CLOV
.10  .00  .20  .15                                                            CLCV
0.0                                                                            WCLOV
25353533                                                                      JOBV
     10.  70.  85.  145. 160. 210. 300.                                       WJOBV
B
250.                                                                          ENDTME
 5.                                                                           INTVAL
```

```
  *   *   *  DATA FOR SUBJECT 8, CONDITICN 1, NORMAL CLOTHING
M                                                                       SEX
25.                                                                     AGE
 74.81                                                                  WT
188.                                                                    HT
.09                                                                     TBFYM
0.                                                                      SAF
 4                                                                      SFINES
0.                                                                      ACCLIM
0.   150. 150. 150.                                                     WW
     65.  140. 215.                                                     WTIME
740.                                                                    BARO
25.  34.  25.  34.  25.  34.  25.  25.                                  TAIRV
     10.  70.  85.  145. 160. 210. 300.                                 WTAIRV
25.  34.  25.  34.  25.  34.  25.  25.                                  TRV
     10.  70.  85.  145. 160. 210. 300.                                 WTRV
.3   .3   .3   .3   .3   .3   .3   .3                                   VV
     10.  70.  85.  145. 160. 210. 300.                                 WVV
.3   .5   .3   .5   .3   .5   .3   .3                                   RHV
     10.  70.  85.  145. 160. 210. 300.                                 WRHV
100. 265. 100. 285. 100. 285. 100. 100.                                 WORKV
     10.  70.  85.  145. 160. 210. 300.                                 WWORKV
                                                                        SUBRAT
.0   .15  .10  .0   .20  .15  .0   .15  .10  .0   .20  .15  .0   .15    CLOV
.10  .00  .20  .15                                                      CLOV
0.0                                                                       WCLOV
25353533                                                                JOBV
     10.  70.  85.  145. 160. 210. 300.                                 WJOBV
8
250.                                                                    ENOTME
 5.                                                                     INTVAL
```

```
  *  *  *  DATA FOR SUBJECT A, CONDITION 2, JACKET W/OUT ICE
M                                                                  SEX
21.                                                                AGE
75.62                                                              WT
182.                                                               HT
.10                                                                TBFYM
0.                                                                 SAF
 3                                                                 SFINES
0.                                                                 ACCLIM
0.    150. 300.                                                    WW
      70.  125.                                                    WTIME
755.                                                               BARO
25.   34.  25.  34.  25.  34.  25.  25.
      10.  70.  85.  115. 160. 220. 300.                           WTAIRV
25.   34.  25.  34.  25.  34.  25.  25.
      10.  70.  85.  115. 160. 220. 300.                           WTRV
.3    .3   .3   .3   .3   .3   .3   .3                             VV
      10.  70.  85.  115. 160. 220. 300.                           WVV
.3    .5   .3   .5   .3   .5   .3   .3                             RHV
      10.  70.  85.  115. 160. 220. 300.                           WRHV
100.  285. 100. 285. 100. 285. 100. 100.                           WORKV
      10.  70.  85.  115. 160. 220. 300.                           WWORKV
                                                                   SUBRAT
.0    .3   .25  .0   .2   .15  .0   .3   .25  .0   .2   .15  .0   .3   CLOV
.25   .0   .2   .15                                                CLOV
0.0                                                                 WCLOV
25353533                                                           JOBV
      10.  70.  85.  115. 160. 220. 300.                           WJOBV
B
145.                                                               ENDTME
5.                                                                 INTVAL
```

```
  *   *   *  DATA FOR SUBJECT 8, CONDITION 2, JACKET W/OUT ICE
M
23.
75.83
188.
.09
0.
 4
0.
0.   150. 300.
0.   75.  150.
740.
25.  34.  25.  34.  25.  25.
0.   10.  70.  85.  140. 300.
25.  34.  25.  34.  25.  25.
0.   10.  70.  85.  140. 300.
.3   .3   .3   .3   .3   .3
0.   10.  70.  85.  140. 300.
.3   .5   .3   .5   .3   .3
0.   10.  70.  85.  140. 300.
100. 285. 100. 285. 100. 100.
0.   10.  70.  85.  140. 300.
0.
.0   .3   .25  .0   .2   .15  .0   .3   .25  .0   .2   .15  .0   .3
.25  .0   .2   .15
0.
253533
0.   10.  70.  85.  140. 300.
8
170.
5.
```

```
  *  *  *  DATA FOR SUBJECT A, CONDITION 3, JACKET W/ICE
M
21.
74.7
132.
.1
800.
 3
0.
     150. 150. 300.
     75.  150. 240.
740.
25.  34.  25.  34.  25.  34.  25.  25.
0.   10.  70.  85.  145. 160. 220. 300.
25.  34.  25.  34.  25.  34.  25.  25.
0.   10.  70.  85.  145. 160. 220. 300.
.3   .3   .3   .3   .3   .3   .3   .3
0.   10.  70.  85.  145. 160. 220. 300.
.3   .5   .3   .5   .3   .5   .3   .3
0.   10.  70.  85.  145. 160. 220. 300.
100. 285. 100. 285. 100. 285. 100. 100.
0.   10.  70.  85.  145. 160. 220. 300.
32.7132.7132.7132.7132.7132.7132.7132.71
.0   .3   .25  .0   .2   .15  .0   .3   .25  .0   .2   .15  .0   .3
.25  .0   .2   .15
0.
25353533
0.   10.  70.  85.  145. 160. 220. 300.
8
 250.
 5.
```

```
  *  *  *  DATA FOR SUBJECT B, CONDITICN 3, JACKET W/ICE
M
23.
75.13
188.
.09
800.
 4
0.
0.   300.
0.   70.
740.
25.  34.  25.  25.
0.   10.  60.  300.
25.  34.  25.  25.
0.   10.  60.  300.
.3   .3   .3   .3
0.   10.  60.  300.
.3   .5   .3   .3
0.   10.  60.  300.
100. 285. 130. 130.
0.   10.  60.  300.
30.0636.0636.0636.0636.0636.0636.0636.06
.3   .3   .25  .0   .2   .15  .0   .3   .25  .0   .2   .15  .0   .3
.25  .0   .2   .15
0.
2533
0.   10.  60.  300.
B
 90.
 5.
```

```
  *   *   *  DATA FOR SUBJECT A, CONDITION 4, JUMPSUIT W/OUT ICE
M
21.
74.11
182.
.10
0.
 3
0.
     150. 300.
0.   75.  150.
740.
25.  34.  25.  34.  25.  25.
0.   10.  70.  85.  140. 300.
25.  34.  25.  34.  25.  25.
0.   10.  70.  85.  140. 300.
.3   .3   .3   .3   .3   .3
0.   10.  70.  85.  140. 300.
.3   .5   .3   .5   .3   .3
0.   10.  70.  85.  140. 300.
100. 285. 100. 285. 100. 100.
0.   10.  70.  85.  140. 300.
0.
.0   .15  .1   .0   .2   .15  .0   .15  .1   .0   .2   .15  .0   .15
.1   .0   .2   .15
0.
253533
0.   10.  70.  85.  140. 300.
6
170.
5.
```

```
    *    *    *   DATA FOR SUBJECT 8, CONDITION 4, JUMPSUIT W/OUT ICE
M                                                                                                               SEX
23.                                                                                                             AGE
75.27                                                                                                           WT
188.                                                                                                            HT
.09                                                                                                             TBFYM
0.                                                                                                              SAF
 4                                                                                                              SFTNES
0.                                                                                                              ACCLIM
0.      150.    300.                                                                                            WW
        70.     125.                                                                                            WTIME
755.                                                                                                            BARO
25.     34.     25.     34.     25.     34.     25.     25.
        10.     70.     85.     115.    160.    220.    300.                                                    WTAIRV
25.     34.     25.     34.     25.     34.     25.     25.
        10.     70.     85.     115.    160.    220.    300.                                                    WTRV
.3      .3      .3      .3      .3      .3      .3      .3                                                      VV
        10.     70.     85.     115.    160.    220.    300.                                                    WVV
.3      .5      .3      .5      .3      .5      .3      .3                                                      RHV
        10.     70.     85.     115.    160.    220.    300.                                                    WRHV
100.    285.    100.    285.    100.    285.    100.    100.                                                    WORKV
        10.     70.     85.     115.    160.    220.    300.                                                    WWORKV
                                                                                                                SUBRAT
0.      .15     .1      .0      .2      .15     .0      .15     .1      .0      .2      .15     .0      .15     CLOV
.1      .0      .2      .15                                                                                     CLOV
0.0                                                                                                              WCLOV
25353533                                                                                                        JOBV
        10.     70.     85.     115.    160.    220.    300.                                                    WJOBV
8
145.                                                                                                            ENDTME
5.                                                                                                              INTVAL
```

```
 *  *  *  DATA FOR SUBJECT A, CONDITION 5, JUMPSUIT W/ICE
M
21.
74.12
132.
.10
600.
 3
0.
0.   275.
0.   70.
740.
25.  34.  25.  25.
0.   10.  60.  300.
25.  34.  25.  25.
0.   10.  60.  300.
.3   .3   .3   .3
0.   10.  60.  300.
.3   .5   .3   .3
0.   10.  60.  300.
100. 285. 100. 100.
0.   10.  60.  300.
46.6646.6646.6646.6646.6646.6646.6646.66
.0   .15  .1   .0   .2   .15  .0   .15  .1   .0   .2   .15  .0   .15
.1   .0   .2   .15
0.
2533
0.   10.  60.  300.
B
 90.
 5.
```

```
  *  *  *  DATA FOR SUBJECT B, CONOITICN 5, JUMPSUIT W/ICE
M
23.
73.01
188.
.09
800.
 4
0.
0.   150. 150. 300.
0.   75.  150. 240.
740.
25.  34.  25.  34.  25.  34.  25.  25.
0.   10.  70.  85.  145. 160. 220. 300.
25.  34.  25.  34.  25.  34.  25.  25.
0.   10.  70.  85.  145. 160. 220. 300.
.3   .3   .3   .3   .3   .3   .3   .3
0.   10.  70.  85.  145. 160. 220. 300.
.3   .5   .3   .5   .3   .5   .3   .3
0.   10.  70.  85.  145. 160. 220. 300.
100. 285. 100. 285. 100. 285. 100. 100.
0.   10.  70.  85.  145. 160. 220. 300.
39.2939.2939.2939.2939.2939.2939.2939.29
.0   .15  .1   .0   .2   .15  .0   .15  .1   .0   .2   .15  .0   .15
.1   .0   .2   .15
0.
25353533
0.   10.  70.  65.  145. 160. 220. 300.
0
250.
5.
```

```
  *   *   *  DATA FOR SUBJECT A, CONDITION 6, NORMAL CLOTHING
M
21.
73.82
162.
.10
0.
 3
0.
0.   300.
0.   70.
740.
25.  34.  25.  25.
0.   10.  60.  300.
25.  34.  25.  25.
0.   10.  60.  300.
.3   .3   .3   .3
0.   10.  60.  300.
.3   .5   .3   .3
0.   10.  60.  300.
100. 265. 100. 100.
0.   10.  60.  300.
0.
0.   .15  .10  .0   .20  .15  .0   .15  .10  .0   .2   .15  .0   .15
.10  .0   .2   .0
0.
2533
0.   10.  60.  300.
8
95.
5.
```

```
  *   *   *  DATA FOR SUBJECT B, CONDITION 6, NORMAL CLOTHING
M
23.
74.49
188.
.09
0.
 4
0.
0.   300.
0.   70.
740.
25.  34.  25.  25.
0.   10.  60.  300.
25.  34.  25.  25.
0.   10.  60.  300.
.3   .3   .3   .3
0.   10.  60.  300.
.3   .5   .3   .3
0.   10.  60.  300.
100. 285. 100. 100.
0.   10.  60.  300.
0.
0.   .15  .1   .0   .2   .15  .0   .15  .1   .0   .2   .15  .0   .15
.1   .0   .2   .15
0.
2533
0.   10.  60.  300.
B
95.
5.
```

Appendix L KSU-Stolwijk Computer Simulation Model

```
      MAIN PROGRAM
      IMPLICIT REAL*8 (A-H,O-Z)
      INTEGER A,B,D,FITNES,G,R,SFTNES,AX
      INTEGER*2 SEX,MA,FE,OUTPUT,FULL,PART,BRIEF
      REAL*8           INCBF,INT,ISET,ITIME,INTVAL
      REAL*8 K1,K2
      REAL*8           LBT,LR,LTH,LTIME
      REAL*8           MAXBF,MAXE,MAXSBY,MAXUPT,MAXVO2,MPR
      REAL*8           MXOSET,MXRBFA,MXRBFO,MVO2ML,NST1,NSTM
      COMMON/X01/CLOV(6,3)
      COMMON/X02/PCT(73),PCTN(73)
      COMMON/X03/OLDBF(25),EVG(25),FILM(25),FILMW(25),CLOWAT(25),EG(25)
      COMMON/X04/NST1(25),C(25),T(25),F(25),HF(25),TSETWS(25),ERROR(25)
      COMMON/X05/RATE(25),COLD(25),WARM(25),TI(25),TSETC(25),TSETWA(25)
      COMMON/X06/DRIP(25)
      COMMON/X07/BFB(24),BF(24),BC(24),SUFA(24)
      COMMON/X08/CMRAD(24),LTH(24),VOL(24),RAD(24),SEGWT(24)
      COMMON/X09/EBPROP(24),PQB(24),PBCO(24),QBQ10(24)
      COMMON/X10/MAXBF(24),TC(24),TO(24),CB(24),Q(24),E(24)
      COMMON/X10A/EB(24)
      COMMON/X11/DELX(18),ARX(18),COND(18),HTSA(18),MPR(18)
      COMMON/X12/SUBRAT(14)
      COMMON/X13/P(20)
      COMMON/X14/JOBV(10),WJOBV(10),RHV(10),WRHV(10),TRV(10),WTRV(10)
      COMMON/X15/TAIRV(10),WTAIRV(10),VV(10),WVV(10),WORKV(10)
      COMMON/X16/WWORKV(10),WW(10),WTIME(10)
      COMMON/X17/SKINO(6),SKINC(6),CHILM(6),PSKIN(6),SWPCP(6)
      COMMON/X17A/WORKM(6)
      COMMON/X18/EVCP(6),EWET(6),PS(6),SWCG(6),NSTM(6)
      COMMON/X19/MAXE(6),HC(6),S(6),HR(6),H(6),EMAX(6),SKINR(6),SKINS(6)
      COMMON/X20/WK1(6),WK2(6),WK3(6),WK4(6),WK5(6),WK6(6),WK7(6)
      COMMON/X21/PAIR(6),HCSL(6),DELTAT(6),CHELL(6),CLO(6),WCLOV(6)
      COMMON/X22/DRY(6),FACL(6),FCL(6),TCL(6),TO(6),TOTALH(6)
      COMMON/X23/DILET(6),FPCL(6),STREC(6)
      COMMON/X24/FSTROV(5),FAVOIF(5),AAVOIF(5),AMVO2R(5)
      COMMON/X25/HEATIM,CWW,RWET,BWT,HP,HFLOW,CT,DTM,RDRY,RSHAPE,EV
      COMMON/X26/CN,ITIME,OT,U,PRSALT,TEVG,STMLKG,SWEAT,CEVG,RH,RECTLT
      COMMON/X27/CUSALT,TS,STROV,SWEAG,WRATE,LTIME,WORKT,CRALT,CO,TB
      COMMON/X28/HEARTR,SFAVDF
      COMMON/X29/WORKAH,LR,TIME,SBF,TBFYM,STVPST,PCTBF,PCHIL
      COMMON/X30/QUAT,ROE,AEWET,PPHG,SVP,PWET,TEMP,HVAPS,HVP,ACRTBF
      COMMON/X31/CSW,SSW,PSW,COIL,SOIL,POIL,CCON,SCON,PCON,CCHIL,SCHIL
      COMMON/X32/HCMIX,HCSEAT,HCWALK,HCSLTB,HCTB
      COMMON/X33/AGE,WT,HT,SHF,SHB,SHT,SHS,SAF,CWLH,LBT,MXRBFA,MXRBFO
      COMMON/X34/SWFSEX,ACCLIM,SWGPSM,BARG,INT,CEFF,TR,VWALK,V,SA,WORKB
      COMMON/X35/WATRES,WATSWT,WATPCY,SR,SUBWAT,TOTWAT,MAXVO2,WEFF
      COMMON/X36/SUBNA,TOTNA,SUBK,TOTK,DILAT,STRIC,CHILL
      COMMON/X37/DIFPSM,DUBOSA,EMAXT,MAXUPT,SPLBFL,SPLBFP,TAIRT,TAIR
      COMMON/X38/CROAD,ASET,ISET,MXOSET,OWORKT,RISET,RRISET,TOTSFB
      COMMON/X39/FITNES(5),A,B,D,G,R,L,NST,JOB
      COMMON/X40/SEX,MA,FE,OUTPUT,FULL,PART,BRIEF
   12 FORMAT(1H0,3X,' HEART RATE, HEARTR= ',F5.0,'  BEATS/MINUTE')
   22 FORMAT(1H0,4X,'SWEAT LOSS EXCEEDS MAX. LIMIT')
  140 FORMAT(1H0,4X,'JOB 1= WALK-RUN')
  141 FORMAT(1H0,4X,'JOB 2= STANDING')
  142 FORMAT(1H0,4X,'JOB 3= SITTING')
  143 FORMAT(1H0,4X,'JOB 4= PEDALING')
  144 FORMAT(1H0,4X,'JOB 5= STEPPING')
  145 FORMAT(1H0,4X,'JOB 6= CART PUSHING')
  146 FORMAT(1H0,4X,'JOB 7= REPETITIVE LIFTING')
```

```
422 FORMAT(1H ,5X,F10.1,' GRAMS OF SODIUM CHLORIDE')
423 FORMAT(1H ,5X,F10.1,' GRAMS OF POTASSIUM CHLORIDE')
424 FORMAT(1H ,5X,F10.1,' GRAMS OF WATER')
425 FORMAT(1H0,4X,'CUMULATIVE LOSSES DURING THE SIMULATION'/
   1       1H ,4X,'THROUGH RESPIRATION AND SWEATING ARE')
940 FORMAT(1H0,///'                TIME=',F8.2,'  MINUTES')
941 FORMAT(1H1,////////'           TIME=',F8.2,'  MINUTES')
945 FORMAT(1H ,6X,'MECHANICAL EFFICIENCY, HEFF=',F6.2/
   1        1H ,6X,'RSHAPE=',1X,F6.3/
   2        1H ,40X,'HEAD',2X,'TRUNK',1X,'ARMS',2X,'HANDS',1X,'LEGS',2
   3X,'FEET'/1H ,4X,'CLO VALUE OF CLOTHING/SEGMENT,CLO=',6F6.2/
   4        1H0,4X,'TOTAL METABOLIC HEAT PRODUCTION,HP=',F5.0,' WATTS')
 950 FORMAT(1H0,4X,'CARDIAC OUTPUT,CD                 =',F4.1,'   LITERS/MIN
   1UTE'/  1H ,6X,'CARDIAC INDEX,CARDI           =',F4.1,'   LITERS/(MIN-
   2SQ M)'/1H ,6X,'SKIN BLOOD FLOWS,SBF          =',F4.1,2X,' LITERS/MINU
   3TE'/   7X,'SPLANCHIC BLOOD FLOW,SPLBFL=',F4.1,2X,' LITERS/MINUTE'/
   4        1H0,4X,'STROKE VOLUME,STROV=',F6.3,' LITERS/STROKE'/
   5        1H0,3X,' HEART RATE, HEARTR= ',F5.0,'  BEATS/MINUTE')
 952 FORMAT(1H ,6X,'TORSO TEMPERATURE, T(8) = ',F9.1,' DEG C')
 953 FORMAT(1H ,6X,'MEAN SKIN TEMPERATURE,TS =',F9.1,' DEG C')
 954 FORMAT(1H0,4X,'MEAN BODY TEMPERATURE,TB   =',F9.1,' DEG C'/
   1        1H ,6X,'RECTAL TEMPERATURE,RECTLT=',F9.1,' DEG C'/
   2        1H ,6X,'ORAL TEMPERATURE,ORALT   =',F9.1,' DEG C'/
   3        1H ,6X,'MEAN SKIN TEMPERATURE,TS =',F9.1,' DEG C'/
   4        1H0,4X,'TOTAL EVAPORATIVE HEAT LOSS,EV=E+RWET =',F5.0,' WAT
   5TS'/   1H ,6X,'TOTAL EVAPORATIVE LOSS, TEVG=EV/EVCP=',F5.0,'  GM/H
   6R'/    1H0,4X,'CUMULATIVE SALT LOSS,CUSALT=',F10.3,'  GM.'/
   7        1H0,4X,'DURING THE LAST',F6.0,' MINUTES OF SIMULATION THE S
   8UBJECT LOST')
  988 FORMAT(1H ,6X,'RECTAL TEMPERATURE,RECTLT=',F9.1,' DEG C')
  989 FORMAT(1H0,4X,'MEAN BODY TEMPERATURE,TB   =',F9.1,' DEG C')
C...........................................................................
           CALL FIRST(M,AX,ENDTME,INTVAL,SFTNES,RWET,RH,
   1WORKT,CO,SFAVDF,LR,TBFYM,PCTBF,AEWET,PPHG,SVP,PWET,TEMP,HVAPS,HVP,
   2AGE,WT,HT,SHF,SHB,SHT,SHS,SAF,LBT,MXRBFA,MXRBFO,ACCLIM,BARO,INT,
   3CEFF,TR,V,SA,WORKB,MAXVO2,DIFPSW,DUBCSA,EMAXT,MAXUPT,TAIRT,TAIR,
   4VWALK,STVPST,SWFSEX,TOTBFB)
C     ... DETERMINE THE ACTUAL NUMBER OF VALID DATA ELEMENTS FOR
C         'SWITCHING' DURING SIMULATION ...
      MAXA   = MAXNUM (TAIRV , WTAIRV, 10)
      MAXR   = MAXNUM (TRV   , WTRV  , 10)
      MAXD   = MAXNUM (VV    , WVV   , 10)
      MAXB   = MAXNUM (RHV   , WRHV  , 10)
      MAXG   = MAXNUM (WORKV , WWORKV, 10)
C
      DO 2000 I = 1, 10
         IJ = 11 - I
         IF (JOBV(IJ).NE.0  .OR.  WJOBV(IJ).NE.0.) GO TO 2005
 2000 CONTINUE
      IJ = 0
 2005 MAXM = IJ
C
      DO 2010 I = 1, 3
         IJ = 4 - I
         IF (CLOV(2,IJ).NE.0.  .OR.  WCLOV(IJ).NE.0.) GO TO 2015
 2010 CONTINUE
      IJ = 0
 2015 MAXAX = IJ
C     ......................................................................
 2100 CONTINUE
```

```
      IF (LTIME.LT.ENDTME) INT = INTVAL
      IF (LTIME.EQ.0      ) INT = 0
C         DETERMINE ENVIRONMENT AT A SPECIFIC TIME
      IF(LTIME.LT.WTAIRV(A))GO TO 2112
      TAIR=TAIRV(A)
      A=A+1
      IF (A.GT.MAXA) A = MAXA
 2112 IF(LTIME.LT.WRHV(B))GO TO 2114
      RH=RHV(B)
      B=B+1
      IF (B.GT.MAXB) B = MAXB
 2114 IF(LTIME.LT.WWORKV(G))GO TO 2126
      WORKT=WORKV(G)
      RISET=0.
      ISET=.0038*(WORKT-OWORKT-WORKB)
      CROAD = 0.0
      IF (WORKT.LT.OWORKT) CROAD=-1.0
      IF (WORKT.GT.OWORKT) CROAD=+1.0
      G=G+1
      IF (G.GT.MAXG) G = MAXG
      OWORKT=WORKT
 2126 IF(LTIME.LT.WVV(D))GO TO 2128
 2127 V=VV(D)
      IF(V.LT.02)V=0.2
      D=D+1
      IF (D.GT.MAXD) D = MAXD
 2128 IF(LTIME.LT.WTRV(R))GO TO 2130
      TR=TRV(R)
      R=R+1
      IF (R.GT.MAXR) R = MAXR
 2130 IF(LTIME.LT.WJOBV(M))GO TO 2132
      JOB=JOBV(M)
      M=M+1
      IF (M.GT.MAXM) M = MAXM
      CALL TASK(V,RELV,WEFF,VWALK,WORKT,HCWALK,RSHAPE,STVPST)
 2132 IF(LTIME.LT.WCLOV(AX))GO TO 2145
      DO 2143 I=1,6
 2143 CLO(I)=CLOV(I,AX)
      AX=AX+1
      IF (AX.GT.MAXAX) AX = MAXAX
 2145 DO 2146 I=1,6
      H(I)=(HR(I)+3.16*HC(I)*V**0.5)*S(I)
      J=(TAIR+35)/5
      PAIR(I)=RH*(P(J)+(P(J+1)-P(J))*((TAIR+35)-5*J)/5.)
 2146 CONTINUE
C     CALCULATION OF RESPIRATORY HEAT LOSS.
      RDRY=0.0014*WORKT*(34.-TAIR)*BARO/760
      RWET=0.0023*WORKT*(44.-PAIR(1))
      WORKAH = 0.0
      IF (WORKT.GT.WORKB) WORKAH = (WORKT-WORKB)*(1.0-WEFF)
      OXUPTK=WORKT/(1.163*60.*4.86)
      MAXUPT =OXUPTK/MAXVO2 *100.0
      RQ = 0.82
      IF(MAXUPT.GT.10.0)  RQ = 0.84
      IF (MAXUPT.GE.50.0) RQ=0.0032*(MAXUPT -50.0) + 0.84
C     ROWELL, PHYSIOLOGICAL REVIEWS, VOL 54,1,75-159,1974
      SPLINT=-1.136*TAIRT+159.36
      SPLBFP=SPLINT-0.99*MAXUPT
      IF(SPLBFP.LT.20.0)SPLBFP=20.0
      IF(SPLBFP.GT.100.0)SPLBFP=100.0
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      SPLBFL=SPLBFP*TOTBF8*0.2/(60*100)                                 HEAT1810
            CALL CONTSG(RWET,DT,SWEAT,SWEAG,SFAVOF,WORKAH,LR,TIME,PCHIL,HEAT1820
     1SAF,CWLH,MXRBFA,MXRBFO,SWFSEX,ACCLIM,SWGPSM,SA,WORKB,OILAT,STRIC, HEAT1830
     2CHILL,EMAXT,SPLBFL,SPLBFP,CROAD,ASET,ISET,MXOSET,RISET,RRISET)    HEAT1840
      CALL HTFLOW(L,CWW,OTM,SAF,CEFF,RORY,ITIME,LTIME,WRATE,HEATIM)     HEAT1850
C               DETERMINE OPTIMUM INTEGRATION STEP                      HEAT1860
      OT=1./60.                                                         HEAT1870
      OO 2171 N=1,25                                                    HEAT1880
      F(N)=HF(N)/C(N)                                                   HEAT1890
      U=OABS(F(N))                                                      HEAT1900
      IF (U*OT.GT.0.2) OT = 0.4/U                                       HEAT1910
 2171 CCNTINUE                                                          HEAT1920
C                  CALCULATE NEW TEMPERATURES                           HEAT1930
      OO 2175 N=1,25                                                    HEAT1940
      T(N)=T(N)+F(N)*OT                                                 HEAT1950
      EVG(N)=EG(N)*OT                                                   HEAT1960
      CEVG=CEVG+EVG(N)                                                  HEAT1970
 2175 CONTINUE                                                          HEAT1980
      BWT=WT+.001*(CWW-CEVG)                                            HEAT1990
      IF(BWT.GE.0.96*WT)GO TO 2181                                      HEAT2000
      WRITE(6,22)                                                       HEAT2010
      GC TO 2280                                                        HEAT2020
 2181 OO 2185 I=1,6                                                     HEAT2030
      FACL(I)=1.+0.20*CLO(I)                                            HEAT2040
      TCL(I)=TO(I)+FCL(I)*(T(4*I)-TO(I))                                HEAT2050
      HR(I)=4*.00000005735*((TCL(I)+TO(I))/2.+273.)**3.*FACL(I)*RSHAPE  HEAT2060
      TOTALH(I)=HR(I)+HC(I)                                             HEAT2070
      FCL(I)=1./(1.+0.155*TOTALH(I)*CLO(I))                             HEAT2080
      TO(I)=(HR(I)*TR+HC(I)*TAIR)/TOTALH(I)                             HEAT2090
      FPCL(I)=1./(1.+.143*HC(I)*CLO(I))                                 HEAT2100
 2185 CONTINUE                                                          HEAT2110
      CALL SALT(OT,EG,INT,SA,SR,SUBK,SUBNA,SUBWAT,TOTK,TOTNA,           HEAT2120
     1TOTWAT,WATPCY,WATRES,WATSWT)                                      HEAT2130
      PRSALT=.002                                                       HEAT2140
      CUSALT=CEVG*PRSALT                                                HEAT2150
      TIME=TIME+DT                                                      HEAT2160
      LTIME=60.*TIME                                                    HEAT2170
      DTM=60.*OT                                                        HEAT2180
      IF(LTIME-INT-ITIME)2100,2100,2190                                 HEAT2190
 2190 CONTINUE                                                          HEAT2200
      ITIME=ITIME+INT                                                   HEAT2210
C                    PREPARE FOR OUTPUT                                 HEAT2220
      CO=0.                                                             HEAT2230
      EV=0.                                                             HEAT2240
      HFLOW=0.                                                          HEAT2250
      HP=0.                                                             HEAT2260
      SBF=0.                                                            HEAT2270
      TB=0.                                                             HEAT2280
      TEVG=0.0                                                          HEAT2290
      TS=0.                                                             HEAT2300
      DO 2200 N=1,24                                                    HEAT2310
      CO=CO+BF(N)/60.                                                   HEAT2320
      CARDI=CO/OUBOSA                                                   HEAT2330
      HP=HP+Q(N)                                                        HEAT2340
      EV=EV+E(N)                                                        HEAT2350
      TEVG=TEVG+EG(N)                                                   HEAT2360
 2200 CONTINUE                                                          HEAT2370
      EV=EV+RWET                                                        HEAT2380
C    *******   CALCULATION HEART RATE,HEARTR, BEAT/MIN                  HEAT2390
C     CALCULATION OF STROKE VOLUME,STRCV,L/STRCKE                       HEAT2400
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      GO TO(2210,2211,2212,2213,2214),SFTNES                            HEAT2410
 2210 STROVM=.135                                                       HEAT2420
      STRVF=1.04                                                        HEAT2430
      GO TO 2215                                                        HEAT2440
 2211 STROVM=.12                                                        HEAT2450
      STRVF=1.03                                                        HEAT2460
      GO TO 2215                                                        HEAT2470
 2212 STROVM=.10                                                        HEAT2480
      STRVF=1.02                                                        HEAT2490
      GO TO 2215                                                        HEAT2500
 2213 STROVM=.09                                                        HEAT2510
      STRVF=1.01                                                        HEAT2520
      GO TO 2215                                                        HEAT2530
 2214 STROVM=.085                                                       HEAT2540
      STRVF=1.00                                                        HEAT2550
      GO TO 2215                                                        HEAT2560
 2215 CONTINUE                                                          HEAT2570
C     BRANDFONBRENER ET AL,CIRCULATION,FIG.3,12,1955                    HEAT2580
      SI=53.45-.194*AGE                                                 HEAT2590
      STRV=(SI*DUBOSA)/1000                                             HEAT2600
      IF (SEX.NE.MA) STRV = 0.9 * STRV                                  HEAT2610
      STROVB=STRV*STRVF*STVPST                                          HEAT2620
      IF(WORKT.LE.500.)STROV=STROVB+(WORKT-WORKB)*.00005*(LBT/60)       HEAT2630
      STROL=STROVB+(500.-WORKB)*.00005*(LBT/60)                         HEAT2640
      IF(WORKT.GT.500.)STROV=STROL+(WORKT-500.)*.000025*(LBT/60)        HEAT2650
      IF(STROV.GT.STROVM)STROV=STROVM                                   HEAT2660
      HEARTR=CO/STROV                                                   HEAT2670
      CT=0                                                              HEAT2680
      DO  2220 I=1,6                                                    HEAT2690
      CT=CT+C(4*I)                                                      HEAT2700
 2220 CONTINUE                                                          HEAT2710
      DO 2230 I=1,6                                                     HEAT2720
      TS=TS+T(4*I)*C(4*I)/CT                                            HEAT2730
      SBF=SBF+BF(4*I)/60.                                               HEAT2740
 2230 CONTINUE                                                          HEAT2750
      CN=0                                                              HEAT2760
      DO 2240 N=1,25                                                    HEAT2770
      CN=CN+C(N)                                                        HEAT2780
 2240 CONTINUE                                                          HEAT2790
      DO 2250 N=1,25                                                    HEAT2800
      TB=TB+T(N)*C(N)/CN                                                HEAT2810
      HFLOW=HFLOW+HF(N)                                                 HEAT2820
 2250 CONTINUE                                                          HEAT2830
C     STRYDOM ORAL/RECTAL TEMP. DIFF.,JAPP.PHYSIO.,20,2,283-287,1965    HEAT2840
      RECTLT=T(5)                                                       HEAT2850
      RLORDF=.253+28.53*OXUPTK/WT                                       HEAT2860
      ORALT=RECTLT-RLORDF                                               HEAT2870
C      WRITE PERIODIC OUTPUT                                            HEAT2880
      IF (OUTPUT.NE.BRIEF) GO TO 2265                                   HEAT2890
      WRITE(6,940)ITIME                                                 HEAT2900
      GO TO 2266                                                        HEAT2910
 2265 WRITE(6,941)ITIME                                                 HEAT2920
 2266 IF (OUTPUT.EQ.FULL) CALL PRPART(AEWET,CHILL,DILAT,EMAXT,QUAT,STRICHEAT2930
     1,SWEAG,SWEAT)                                                     HEAT2940
      T1=T(1)                                                           HEAT2950
      TORSO=T(8)                                                        HEAT2960
      GO TO (2270,2271,2272,2273,2274,2275,2276), JOB                   HEAT2970
 2270 WRITE(6,140)                                                      HEAT2980
      GO TO 2277                                                        HEAT2990
 2271 WRITE(6,141)                                                      HEAT3000
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      GO TO 2277
 2272 WRITE(6,142)
      GO TO 2277
 2273 WRITE(6,143)
      GO TO 2277
 2274 WRITE(6,144)
      GO TO 2277
 2275 WRITE(6,145)
      GO TO 2277
 2276 WRITE(6,146)
 2277 IF (OUTPUT.EQ.BRIEF) GO TO 2278
      WRITE(6,945)WEFF,RSHAPE,(CLO(I),I=1,6),HP
      CALL COMFOT (ACCLIM,AEWET,OUTPUT,OXUPTK,RH,RQ,SA,T1,TEMP,WEFF,
     2WORKT,MAXUPT)
      WRITE(6,950)CC,CAROI,SBF,SPLBFL,STRCV,HEARTR
      CALL PEVOT(HEARTR)
      WRITE(6,954)TB,RECTLT,ORALT,TS,EV,TEVG,CUSALT,INT
      WRITE(6,422)SUBNA
      TOTNA=TOTNA+SUBNA
      SUBNA=0.0
      WRITE(6,423)SUBK
      TOTK=TOTK+SUBK
      SUBK=0.0
      WRITE(6,424)SUBWAT
      TOTWAT=TOTWAT +SUBWAT
      SUBWAT=0.0
      WRITE(6,425)
      WRITE(6,422)TOTNA
      WRITE(6,423)TOTK
      WRITE(6,424)TOTWAT
      IF (OUTPUT.NE.BRIEF) GO TO 2279
 2278 CONTINUE
      WRITE(6,12)HEARTR
      WRITE(6,989)TB
      WRITE(6,988)RECTLT
      WRITE(6,953)TS
      WRITE(6,952)TORSO
 2279 IF (TB.LE.41.0  .AND.  ITIME.LT.ENDTME ) GO TO 2100
 2280 STOP
      END
      FUNCTION MAXNUM (VALUE1, VALUE2, NTOTAL)
C     SUBPROGRAM TO DETERMINE THE ACTUAL NUMBER OF DATA ELEMENTS
C        WHICH CONTROL THE 'SWITCHING' DURING SIMULATION.
C     ... IF THE TRAILING PAIR OF VALUE1 AND VALUE2 ELEMENTS ARE ZERO,
C        THE TOTAL NUMBER OF ELEMENTS IS DECREASED BY 1.  THIS PROCESS
C        IS REPEATED UNTIL ATLEAST ONE OF THE ELEMENTS IN THE PAIR
C        VALUE1 AND VALUE2 IS NONZERO.
C
      REAL*8 VALUE1(NTOTAL), VALUE2(NTOTAL)
      DO 1615 I = 1, NTOTAL
         J = NTOTAL - I + 1
         IF (VALUE1(J).NE.0.  .OR.  VALUE2(J).NE.0. ) GO TO 1616
 1615 CONTINUE
C     ... ERROR SITUATION ...
      J = 0
C     ... RETURN WITH AN APPROPRIATE VALUE FOR MAXNUM ...
 1616      MAXNUM = J
      RETURN
      END
      SUBROUTINE FIRST(M,AX,ENDTME,INTVAL,SFTNES,RWET,RH,
```

```
     1WORKT,CO,SFAVOF,LR,TBFYM,PCTBF,AEWET,PPHG,SVP,PWET,TEMP,HVAPS,HVP,
     2AGE,WT,HT,SHF,SHB,SHT,SHS,SAF,LBT,MXRBFA,MXRBFD,ACCLIM,BARO,INT,
     3CEFF,TR,V,SA,WORKB,MAXVO2,DIFFPSM,DUBCSA,EMAXT,MAXUPT,TAIRT,TAIR,
     4VWALK,STVPST,SWFSEX,TOTBFB)
      IMPLICIT REAL*8 (A-H,O-Z)
      INTEGER A,B,D,FITNES,G,R,SFTNES,AX
      INTEGER*2 SEX,MA,FE,OUTPUT,FULL,PART,BRIEF
      REAL*8                  INT,             INTVAL
      REAL*8            LBT,LR
      REAL*8            MAXE,MAXUPT,MAXVO2
      REAL*8                  MXRBFA,MXRBFD,MVO2ML,NST1,NSTM
      COMMON/X01/CLOV(6,3)
      COMMON/X02/PCT(73),PCTN(73)
      COMMON/X03/DLOBF(25),EVG(25),FILM(25),FILMW(25),CLOWAT(25),EG(25)
      COMMON/X04/NST1(25),C(25),T(25),F(25),HF(25),TSETWS(25),ERROR(25)
      COMMON/X05/RATE(25),COLD(25),WARM(25),TI(25),TSETC(25),TSETWA(25)
      COMMON/X06/DRIP(25)
      COMMON/X09/EBPROP(24),PQB(24),PBCO(24),QBQ10(24)
      COMMON/X10A/EB(24)
      COMMON/X12/SUBRAT(14)
      COMMON/X13/P(20)
      COMMON/X14/JOBV(10),WJOBV(10),RHV(10),WRHV(10),TRV(10),WTRV(10)
      COMMON/X15/TAIRV(10),WTAIRV(10),VV(10),WVV(10),WORKV(10)
      COMMON/X16/WWORKV(10),WW(10),WTIME(10)
      COMMON/X17/SKIND(6),SKINC(6),CHILM(6),PSKIN(6),SWPCP(6)
      COMMON/X18/EVCP(6),EWET(6),PS(6),SWCG(6),NSTM(6)
      COMMON/X19/MAXE(6),HC(6),S(6),HR(6),H(6),EMAX(6),SKINR(6),SKINS(6)
      COMMON/X21/PAIR(6),HCSL(6),DELTAT(6),CHELL(6),CLO(6),WCLOV(6T
      COMMON/X22/DRY(6),FACL(6),FCL(6),TCL(6),TC(6),TOTALH(6)
      COMMON/X24/FSTROV(5),FAVDIF(5),AAVDIF(5),AMVO2R(5)
      COMMON/X39/FITNES(5),A,B,D,G,R,L,NST,JOB
      COMMON/X40/SEX,MA,FE,OUTPUT,FULL,PART,BRIEF
    1 FORMAT(10F5.2)
    2 FORMAT(I1)
    3 FORMAT (10I1)
    6 FORMAT (/4X,'FACTOR TO ADJUST STROKE VOLUME FOR FITNESS,FSTROV: A
     1ND THE PHYSICAL FITNESS FACTOR,FAVDIF:',//3X,'FITNESS',9X,'FSTROV'
     2,9X,'FAVDIF',9X,'ASSUMED A-V DIFF',9X,'ASSUMED MAX. VOL OF OXYGEN'
     3,9X,'MVO2ML',/49X,'ML/100ML',17X,'ML/KG/MIN',24X,'ML/KG/MIN'/3X,I2
     4,'= EXCELLENT ',4X,F4.2,10X,F4.2,16X,F4.1,21X,F4.1,' OR MORE ',17X
     5,'51.6',/3X,I2,'= GOOD ',9X,F4.2,10X,F4.2,16X,F4.1,21X,F4.1,' TO 5
     61.5  ',16X,'47.0',/3X,I2,'= FAIR ',9X,F4.2,10X,F4.2,16X,F4.1,21X
     7,F4.1,' TO 42.5',18X,'38.1',/3X,I2,'= POOR ',9X,F4.2,10X,F4.2,16
     8X,F4.1,21X,F4.1,' TO 33.7',18X,'29.3',/3X,I2,'= VERY POOR ',4X,F4
     9.2,10X,F4.2,16X,F4.1,21X,'25.0',' OR LESS',18X,F4.1)
   52 FORMAT(1H0,4X,'AGE OF THE SUBJECT,AGE=',F6.2,'  YEARS')
   95 FORMAT(18F4.3)
   97 FORMAT(F5.1)
  100 FORMAT(10F5.3)
  101 FORMAT(A1)
  109 FORMAT(1H0,(  T7,'TRV   ',F8.2,4X,' AT TIME  ',F8.0,'  MIN'))
  111 FORMAT(1H0,(  T7,'RHV   ',F8.2,4X,' AT TIME  ',F8.0,'  MIN'))
  112 FORMAT(1H0,(  T7,'WORKV ',F8.0,4X,' AT TIME  ',F8.0,'  MIN'))
  113 FORMAT(1H0,(  T7,'VV    ',F8.2,4X,' AT TIME  ',F8.0,'  MIN'))
  114 FORMAT(1H0,(  T7,'TAIRV ',F8.2,4X,' AT TIME  ',F8.0,'  MIN'))
  115 FORMAT(1H0,(  T7,'JOBV  ',I5,7X,' AT TIME  ',F8.0,'  MIN'))
  116 FORMAT(1H ,(  T7,'CLO ',6(1X,F8.2),'  CLO',(1X,F8.0),'  MIN'))
  162 FORMAT(1H0,4X,'SEX=FEMALE')
  163 FORMAT(1H0,4X,'SEX=MALE')
  500 FORMAT(1H0,4X,'ILLEGAL INPUT DATA:  SFTNES')
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502 FORMAT(1H ,6X,'PERCENT FAT,PCTBF= ',F6.2,' PERCENT')               HEAT4210
503 FORMAT(1H ,6X,'LEAN BODY WEIGHT OF THE SUBJECT,LBT=',1X,F6.2,' KG'HEAT4220
   1)                                                                  HEAT4230
505 FORMAT(1H0,4X,'WEIGHT OF THE SUBJECT,WT',13X,'=',1X,F6.2,' KG')    HEAT4240
509 FORMAT(1H0,4X,'HEIGHT OF THE SUBJECT,HT=',1X,F6.2,' CM')           HEAT4250
510 FORMAT(1H0,4X,'SURFACE AREA OF THE SUBJECT,SA =',1X,F5.2,' SQ M') HEAT4260
514 FORMAT(1H0,4X,'ACCLIMITIZATION OF SUBJECT, ACCLIM=',1X,F4.0,' PERCHEAT4270
   1ENT (0=NONE,100=FULL)')                                            HEAT4280
516 FORMAT(1H ,9X,'DUBOIS SURFACE AREA,DUBOSA=',1X,F5.2,' SQ M')       HEAT4290
519 FORMAT(1H ,6X,'SURFACE AREA OF DRY ICE FACING SKIN,SAF=',1X,F6.2,'HEAT4300
   1 SQ. CM.')                                                         HEAT4310
599 FORMAT(1H ,4X,'BAROMETRIC PRESSURE,BARO=',F6.0,' MM')              HEAT4320
893 FORMAT(1H0,4X,'TIME=0.0 ')                                         HEAT4330
894 FORMAT(1H ,4X,'AIR VELOCITY,V=',F5.2,'  M/SEC    V MUST NOT BE LOWHEAT4340
   1ER THAN 0.2 M/SEC ')                                               HEAT4350
896 FORMAT(1H ,4X,'RELATIVE HUMIDITY,RH=',F5.2)                        HEAT4360
898 FORMAT(1H0,4X,'OUTPUT INTERVAL,INT=',F5.1,' MINUTES')              HEAT4370
911 FORMAT(1H0,4X,'CONSTANT DATA ')                                    HEAT4380
932 FORMAT(1H0,4X,'PHYSICAL FITNESS OF SUBJECT = ',I2,3X,'(SEE TABLE BHEAT4390
   1ELOW FOR EXPLANATION)')                                            HEAT4400
934 FORMAT(1H0,4X,'MAXIMUM VO2 RATE FOR SUBJECT,MAXVO2=',F6.2,' LITERSHEAT4410
   1/MIN')                                                             HEAT4420
942 FORMAT(1H0,4X,'IF USED,DRY ICE JACKET EFFICIENCY,CEFF=',F5.2)      HEAT4430
943 FORMAT(1H ,6X,'SUBLIMATION RATE OF DRY-ICE FOR EACH PERIOD OF 30 MHEAT4440
   1INUTES,GM/HR'/4X,10(F6.1,2X))                                      HEAT4450
944 FORMAT(1H ,6X,'BASAL METABOLISM, WORK3=',F6.0,' WATTS')            HEAT4460
947 FORMAT(1H ,4X,'MEAN RADIANT TEMPERATURE,TR=',F6.2,' C')            HEAT4470
958 FORMAT(1H0,21X,'CORE',22X,'MUSCLE',22X,'FAT',24X,'SKIN'/13X,       HEAT4480
   1'FAT',6X,'BONE',3X,'TISSUE',5X,'FAT',6X,'BONE',3X,'TISSUE',5X,     HEAT4490
   2'FAT',6X,'BONE',3X,'TISSUE',5X,'FAT',6X,'BONE',3X,'TISSUE'/T14,    HEAT4500
   322('_'),T41,22('_'),T63,22('_'),T95,22('_')/3X,'HEAD ',12(3X,F6.2)HEAT4510
   4/3X,'TRUNK',12(3X,F6.2)/3X,'ARMS ',12(3X,F6.2)/3X,'HANDS',         HEAT4520
   512(3X,F6.2)/3X,'LEGS ',12(3X,F6.2)/3X,'FEET ',12(3X,F6.2)/3X,      HEAT4530
   6'CENTRAL BLOOD',1(3X,F6.2),1X,'TISSUE')                            HEAT4540
 976 FORMAT(1H ,4X,'AIR TEMPERATURE,TAIR       =',F6.2,' C')           HEAT4550
 979 FORMAT(1H0,4X,'PCT(J),      % DISTRIBUTION, BY WEIGHT, OF DIFFERENTHEAT4560
   1 TISSUE TYPES FOR STD. MAN WITH BODY FAT=15.11%')                  HEAT4570
 996 FORMAT(1H0,14X,'HEAD',5X,'TRUNK ',3X,'ARMS',4X,'HANDS',5X,'LEGS',5HEAT4580
   1X,'FEET',2X,'UNITS',4X,'AT TIME')                                  HEAT4590
C           READ CONSTANTS FOR CONTROLLED SYSTEM                        HEAT4600
C                    READ INITIAL CONDITION FOR SUBJECT                 HEAT4610
      READ(5,101)SEX                                                    HEAT4620
      READ(5,97)AGE                                                     HEAT4630
      READ(5,97)WT                                                      HEAT4640
      READ(5,97)HT                                                      HEAT4650
      READ(5,97)TBFYM                                                   HEAT4660
      READ(5,97)SAF                                                     HEAT4670
      READ(5,2)SFTNES                                                   HEAT4680
      IF (SFTNES.LT.1) GO TO 2279                                       HEAT4690
      IF (SFTNES.GT.5) GO TO 2279                                       HEAT4700
      READ(5,97)ACCLIM                                                  HEAT4710
      READ(5,100)IWW(J),J=1,4)                                          HEAT4720
      READ(5,100)(WTIME(J),J=1,4)                                       HEAT4730
C         READ ENVIRONMENTAL CONDITIONS                                 HEAT4740
      READ(5,97)BARO                                                    HEAT4750
      READ(5,100)(TAIRV(J),J=1,10)                                      HEAT4760
      READ(5,1)(WTAIRV(J),J=1,10)                                       HEAT4770
      READ(5,100)(TRV(J),J=1,10)                                        HEAT4780
      READ(5,1)(WTRV(J),J=1,10)                                         HEAT4790
      READ(5,100)(VV(J),J=1,10)                                         HEAT4800
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      READ(5,1)(WVV(J),J=1,10)                                          HEAT4810
      READ(5,100)(RHV(J),J=1,10)                                        HEAT4820
      READ(5,1)(WRHV(J),J=1,10)                                         HEAT4830
      READ(5,100)(WORKV(J),J=1,10)                                      HEAT4840
      READ(5,1)(WWORKV(J),J=1,10)                                       HEAT4850
      READ(5,1)(SUBRAT(J),J=1,10)                                       HEAT4860
      READ(5,95)((CLOV(I,J),I=1,6),J=1,3)                               HEAT4870
      READ(5,1)(WCLOV(J),J=1,3)                                         HEAT4880
      READ(5,3)(JOBV(J),J=1,10)                                         HEAT4890
      READ(5,1)(WJOBV(J),J=1,10)                                        HEAT4900
      READ(5,101)OUTPUT                                                 HEAT4910
      READ(5,97)ENDTME                                                  HEAT4920
      READ(5,97)INTVAL                                                  HEAT4930
      AX = 1.0                                                          HEAT4940
C               DEFINE INITIAL VALUES                                   HEAT4950
      INT=INTVAL                                                        HEAT4960
      M=1                                                               HEAT4970
C                 INITIAL CALCULATIONS                                  HEAT4980
      TAIR=TAIRV(A)                                                     HEAT4990
      TR=TRV(R)                                                         HEAT5000
      V=VV(D)                                                           HEAT5010
      RH=RHV(B)                                                         HEAT5020
      WORKT=WORKV(G)                                                    HEAT5030
      WORKB=1.28*WT                                                     HEAT5040
      JOB=JOBV(M)                                                       HEAT5050
      DO 2000 I=1,6                                                     HEAT5060
 2000 CLO(I)=CLOV(I,AX)                                                 HEAT5070
      DO 2001 N=1,25                                                    HEAT5080
      CLOWAT(N)=0.                                                      HEAT5090
      DRIP(N)=0.                                                        HEAT5100
      EG(N)=0                                                           HEAT5110
      FILM(N)=0.                                                        HEAT5120
      FILMW(N)=0.                                                       HEAT5130
      TSETWA(N)=TSETWS(N)                                               HEAT5140
 2001 CONTINUE                                                          HEAT5150
C     BERENSON AND ROBERTSON,BIOASTRONAUTICS DATA BOOK,FIG.3.10,1973    HEAT5160
      DO 2002 I=1,7                                                     HEAT5170
      NJ=(I-1)*4+1                                                      HEAT5180
      TSETWA(NJ)=TSETWA(NJ)+.0038*(WORKT-WORKB)                         HEAT5190
 2002 CONTINUE                                                          HEAT5200
      DO 2003 I=1,6                                                     HEAT5210
      NJ=4*I-2                                                          HEAT5220
      TSETWA(NJ)=TSETWA(NJ)+.0038*(WORKT-WORKB)                         HEAT5230
 2003 CONTINUE                                                          HEAT5240
      GO TO (2013,2014,2015,2016,2017),SFTNES                           HEAT5250
 2013 SFTROV=FSTROV(1)                                                  HEAT5260
      SFAVDF=FAVDIF(1)                                                  HEAT5270
      MVO2ML=51.6                                                       HEAT5280
      MXRBFA=20.                                                        HEAT5290
      MXRBFD=14.                                                        HEAT5300
      GO TO 2018                                                        HEAT5310
 2014 SFTROV=FSTROV(2)                                                  HEAT5320
      SFAVDF=FAVDIF(2)                                                  HEAT5330
      MVO2ML=47.0                                                       HEAT5340
      MXRBFA=18.                                                        HEAT5350
      MXRBFD=13.                                                        HEAT5360
      GO TO 2018                                                        HEAT5370
 2015 SFTROV=FSTROV(3)                                                  HEAT5380
      SFAVDF=FAVDIF(3)                                                  HEAT5390
      MVO2ML=38.1                                                       HEAT5400
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      MXRBFA=16.                                                        HEAT5410
      MXRBFD=12.                                                        HEAT5420
      GO TO 2018                                                        HEAT5430
 2016 SFTROV=FSTROV(4)                                                  HEAT5440
      SFAVDF=FAVDIF(4)                                                  HEAT5450
      MVO2ML=29.3                                                       HEAT5460
      MXRBFA=13.                                                        HEAT5470
      MXRBFD=11.                                                        HEAT5480
      GO TO 2018                                                        HEAT5490
 2017 SFTROV=FSTROV(5)                                                  HEAT5500
      SFAVDF=FAVDIF(5)                                                  HEAT5510
      MVO2ML=25.0                                                       HEAT5520
      MXRBFA=12.                                                        HEAT5530
      MXRBFD=10.                                                        HEAT5540
 2018 CONTINUE                                                          HEAT5550
      MAXVO2=MVO2ML*WT/1000                                             HEAT5560
      OXUPTK=WORKT/(1.163*60.*4.86)                                     HEAT5570
      MAXUPT =OXUPTK/MAXVO2 *100.0                                      HEAT5580
      RQ =0.82                                                          HEAT5590
      IF (MAXUPT.GT.10.0) RQ = 0.84                                     HEAT5600
      IF (MAXUPT.GE.50.0) RQ = 0.0032*(MAXUPT-50.0) + 0.84              HEAT5610
 2033 A=A+1                                                             HEAT5620
      B=B+1                                                             HEAT5630
      D=D+1                                                             HEAT5640
      G=G+1                                                             HEAT5650
      M=M+1                                                             HEAT5660
      R=R+1                                                             HEAT5670
            CALL CONCAL(V,CO,HT,SA,TR,WT,AGE,BARO,LBT,SHB,SHF,SHS,SHT,  HEAT5680
     1TAIR,PCTBF,TBFYM,VWALK,WORKB,WORKT,OIFPSM,OUBOSA,STVPST,SWFSEX)   HEAT5690
      TOTBFB=CO                                                         HEAT5700
      TOTAL=TOTBFB                                                      HEAT5710
      LR=2.2*(760./BARO)                                                HEAT5720
C     CALCULATION OF BASAL EVAPORATIVE LOSS, GM/HR                      HEAT5730
      DO 2050 I=1,6                                                     HEAT5740
      J=(TAIR+35)/5                                                     HEAT5750
      PAIR(I)=RH*(P(J)+(P(J+1)-P(J))*((TAIR+35)-5*J)/5.)                HEAT5760
 2050 CONTINUE                                                          HEAT5770
      DO 2051 N=1,24                                                    HEAT5780
      EB(N)=EBPROP(N)*OIFPSM*DUBOSA*.671                                HEAT5790
 2051 CONTINUE                                                          HEAT5800
      RWET=0.0023*WORKT*(44.-PAIR(1))                                   HEAT5810
      EB(5)=RWET                                                        HEAT5820
      AEWET=0.0                                                         HEAT5830
      EMAXT=0                                                           HEAT5840
      TAIRT=0.0                                                         HEAT5850
      DO 2052 I=1,6                                                     HEAT5860
      TAIRT=TAIRT+TAIR*(S(I)/SA)                                        HEAT5870
      N=4*I-3                                                           HEAT5880
      K=(T(N+3)+35)/5                                                   HEAT5890
      PSKIN(I)=P(K)+(P(K+1)-P(K))*(T(N+3)+35-5*K)/5.                    HEAT5900
      EMAX(I)=(PSKIN(I)-PAIR(I))*LR*(HC(I)*S(I))                        HEAT5910
      EMAXT= EMAXT + EMAX(I)                                            HEAT5920
      EWET(I)=EB(N+3)/EMAX(I)                                           HEAT5930
      AEWET=AEWET+EWET(I)*(S(I)/SA)                                     HEAT5940
      PPHG=PSKIN(I)                                                     HEAT5950
      SVP=EMAX(I)                                                       HEAT5960
      PWET=EWET(I)                                                      HEAT5970
      TEMP=T(N+3)                                                       HEAT5980
      OLDPHS=1                                                          HEAT5990
      CALL SWVP(OLDPHS,PWET,PPHG,SVP,TEMP,HVAPS)                        HEAT6000
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      EVCP(I)=HVAPS
      EG(N+3)=EB(N+3)/EVCP(I)
 2052 CONTINUE
C     FOR EVAPORATION OUE TO RESPIRATION,WE CONSIOER THE RESPIRATORY
C     TRACT AS 100 PERCENT WET AND CALCULATE HVP=EVCP(TRUNK CORE) AS:
      HVP=(2433.95-2.2549*(T(5)-30.))*0.0002778
      EG(5)=EB(5)/HVP
C      WRITE CONSTANT DATA
      WRITE(6,911)
      WRITE(6,893)
      IF (SEX.EQ.MA) WRITE (6,163)
      IF (SEX.NE.MA) WRITE (6,162)
      WRITE (6,52) AGE
      WRITE(6,514)ACCLIM
      WRITE(6,505)WT
      WRITE(6,503)LBT
      WRITE(6,502)PCTBF
      WRITE(6,509)HT
      WRITE(6,510)SA
      WRITE(6,516)OUBCSA
      WRITE(6,932)SFTNES
      WRITE(6,6) (FITNES(I),FSTROV(I),FAVOIF(I),AAVDIF(I),AMVO2R(I),I=1,
     15)
      WRITE(6,934)MAXVO2
      WRITE(6,944)WORKB
      IF (OUTPUT.EQ.BRIEF) GO TO 2060
      WRITE(6,942)CEFF
      WRITE(6,519)SAF
      WRITE(6,943)(SUBRAT(J),J=1,10)
      WRITE(6,979)
      WRITE(6,958)(PCT(J),J=1,73)
      IF (OUTPUT.EQ.FULL) CALL CTPART(JOB,SA,SHB,SHF,SHS,SHT,TOTAL)
      WRITE(6,976)TAIR
      WRITE(6,947)TR
      WRITE(6,894)V
      WRITE(6,896)RH
 2060 WRITE(6,599)BARO
      WRITE(6,114)(TAIRV(J),WTAIRV(J),J=1,10)
      WRITE(6,109)(TRV(J),WTRV(J),J=1,10)
      WRITE(6,113)(VV(J),WVV(J),J=1,10)
      WRITE(6,111)(RHV(J),WRHV(J),J=1,10)
      WRITE(6,112)(WORKV(J),WWORKV(J),J=1,10)
      WRITE(6,115)(JOBV(J),WJOBV(J),J=1,10)
      WRITE(6,996)
      WRITE(6,116)((CLCV(I,J),I=1,6),WCLOV(J),J=1,3)
      WRITE(6,898)INT
      RETURN
 2279 WRITE(6,500)
      STOP
      ENO
      SUBROUTINE PRPART(AEWET,CHILL,DILAT,EMAXT,QUAT,STRIC,SWEAG,SWEAT)
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 MAXBF,MAXE,NST1,NSTM
      COMMON/X03/OLOBF(25),EVG(25),FILM(25),FILMW(25),CLOWAT(25),EG(25)
      COMMON/X04/NST1(25),C(25),T(25),F(25),HF(25),TSETWS(25),ERROR(25)
      COMMON/X05/RATE(25),COLO(25),WARM(25),TI(25),TSETC(25),TSETWA(25)
      COMMON/X06/DRIP(25)
      COMMON/X07/BFB(24),BF(24),BC(24),SUFA(24)
      COMMON/X09/EBPROP(24),PQB(24),PBCO(24),QBC10(24)
      COMMON/X10/MAXBF(24),TC(24),TD(24),QB(24),Q(24),E(24)
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      COMMON/X17/SKINO(6),SKINC(6),CHILM(6),PSKIN(6),SWPCP(6)           HEAT6610
      COMMON/X18/EVCP(6),EWET(6),PS(6),SWCG(6),NSTM(6)                  HEAT6620
      COMMON/X19/MAXE(6),HC(6),S(6),HR(6),H(6),EMAX(6),SKINR(6),SKINS(6)HEAT6630
      COMMON/X21/PAIR(6),HCSL(6),DELTAT(6),CHELL(6),CLO(6),HCLOV(6)     HEAT6640
      COMMON/X23/DILET(6),FPCL(6),STREC(6)                              HEAT6650
  410 FORMAT(1H ,4X,'DILAT(I)',7(1X,F8.3),' VASODILATE COMMAND/SEG,  LITHEAT6660
     1ERS/HOUR')                                                        HEAT6670
  411 FORMAT(1H ,4X,'STRIC(I)',7(1X,F8.3),' VASCONSTRICT COMMAND/SEG,   HEAT6680
     1LITERS/HOUR')                                                     HEAT6690
  412 FORMAT(1H0,4X,'CHILM(I)',7(1X,F8.3),' WATTS')                     HEAT6700
  521 FORMAT(1H0,4X,'PAIR(I) ',6(1X,F8.3),9X,' MM HG  ')                HEAT6710
  679 FORMAT(1H0,4X,'TOTAL OF QBQ10(N)=',F9.3)                          HEAT6720
  680 FORMAT(1H0,4X,'QBQ10(N),     Q10 METABOLIC EFFECT, WATTS')        HEAT6730
  685 FORMAT(1H0,4X,'DRIP(N),   DRIP=EXCESS SWEAT-FILM-CLOWAT,   GM/HR')HEAT6740
  690 FORMAT(1H0,4X,'FILM(N),   FILM FORMED BY OVER-SWEATING,   MICRONS HEAT6750
     1')                                                                HEAT6760
  695 FORMAT(1H0,4X,'CLOWAT(N),   SWEAT THAT SOAKS INTO CLOTHES,   GM/HRHEAT6770
     1')                                                                HEAT6780
  900 FORMAT(1H0,4X,'Q(N),   METABOLIC HEAT PRODUCTION,   WATTS')       HEAT6790
  901 FORMAT(1H0,4X,'BF(N),BLOOD FLOW, LITERS/HOUR')                    HEAT6800
  902 FORMAT(1H0,4X,'BC(N),   CONVECTIVE HEAT TRANSFER BETWEEN CENTRAL BHEAT6810
     1LOOD AND ELEMENTS,   WATTS')                                      HEAT6820
  903 FORMAT(1H0,4X,'TD(N),   CONDUCTIVE HEAT TRANSFER BETWEEN SUCCESSIVHEAT6830
     1E ELEMENTS,   WATTS')                                             HEAT6840
  904 FORMAT(1H0,4X,'HF(N),   RATE OF HEAT FLOW INTO(+) OR FROM(-) AN ELHEAT6850
     1EMENT,   WATTS')                                                  HEAT6860
  905 FORMAT(1H0,4X,'F(N),   RATE OF CHANGE OF TEMPERATURE OF AN ELEMENTHEAT6870
     1,   DEG C/HR')                                                    HEAT6880
  906 FORMAT(1H0,4X,'E(N),   EVAPORATIVE HEAT LOSS,   WATTS')           HEAT6890
  908 FORMAT(1H0,4X,'NST(N),   NON-SHIVERING THERMOGENESIS,   WATTS')   HEAT6900
  931 FORMAT(1H0,4X,'T(N),   TEMPERATURES,   DEG C')                    HEAT6910
  959 FORMAT(1H0,17X,'CORE',9X,'MUSCLE',9X,'FAT',9X,'SKIN'/3X,'HEAD ',4(HEAT6920
     15X,F9.1)/3X,'TRUNK',4(5X,F9.1)/3X,'ARMS ',4(5X,F9.1)/3X,'HANDS',4(HEAT6930
     25X,F9.1)/3X,'LEGS ',4(5X,F9.1)/3X,'FEET ',4(5X,F9.1))             HEAT6940
  960 FORMAT(1H0,17X,'CORE',9X,'MUSCLE',9X,'FAT',9X,'SKIN'/3X,'HEAD ',4(HEAT6950
     15X,F9.1)/3X,'TRUNK',4(5X,F9.1)/3X,'ARMS ',4(5X,F9.1)/3X,'HANDS',4(HEAT6960
     25X,F9.1)/3X,'LEGS ',4(5X,F9.1)/3X,'FEET ',4(5X,F9.1)/3X,'CENTRAL BHEAT6970
     3LOOD')                                                            HEAT6980
  961 FORMAT(1H0,15X,'HEAD',5X,'TRUNK ',3X,'ARMS',5X,'HANDS',4X,'LEGS',6HEAT6990
     1X,'FEET',4X,'TOTAL',2X,'UNITS    ')                               HEAT7000
  962 FORMAT(1H0,4X,'PSKIN(I)',6(1X,F8.3),9X,' MM HG  ')                HEAT7010
  963 FORMAT(1H0,4X,'EMAX(I) ',7(1X,F8.3),' WATTS')                     HEAT7020
  964 FORMAT(1H0,4X,'SWPCP(I)',7(1X,F8.3),' SWEAT,HEAT REMOVAL COMMAND/SHEAT7030
     1KIN SEGMENT,  WATTS')                                             HEAT7040
  965 FORMAT(1H0,4X,'H(I)    ',6(1X,F8.3),9X,' WATTS/DEG C')            HEAT7050
  969 FORMAT(1H0,4X,'EWET(I) ',7(1X,F8.3),' RATIO OF WET/DRY SURFACE')  HEAT7060
  987 FORMAT(1H0,4X,'TSETWA(N),  SET POINT FOR RECEPTORS FOR ACTIVITY WAHEAT7070
     1RM CONDITION,  DEG C ')                                           HEAT7080
  991 FORMAT(1H ,4X,'SWCG    ',7(1X,F8.3),' SWEAT,HEAT REMOVAL COMMAND/SHEAT7090
     1KIN SEGMENT,  GM/HR')                                             HEAT7100
  993 FORMAT(1H0,4X,'EG(N),   EVAPORATIVE HEAT LOSS,   GM/HR')          HEAT7110
      WRITE(6,961)                                                      HEAT7120
      WRITE(6,965)(H(I),I=1,6)                                          HEAT7130
      WRITE(6,521)(PAIR(I),I=1,6)                                       HEAT7140
      WRITE(6,962)(PSKIN(I),I=1,6)                                      HEAT7150
      WRITE(6,963)(EMAX(I),I=1,6),EMAXT                                 HEAT7160
      WRITE(6,964) (SWPCP(I),I=1,6),SWEAT                               HEAT7170
      WRITE(6,991) (SWCG(I),I=1,6),SWEAG                                HEAT7180
      WRITE(6,969) (EWET(I), I=1,6),AEWET                               HEAT7190
      WRITE(6,410)(DILET(I),I=1,6),DILAT                                HEAT7200
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      WRITE(6,411)(STREC(I),I=1,6),STRIC
      WRITE(6,412)(CHELL(I),I=1,6),CHILL
      WRITE(6,901)
      WRITE(6,959)(BF(N),N=1,24)
      WRITE(6,680)
      WRITE(6,959) (Q8Q10(N), N=1,24)
      WRITE(6,679)QUAT
      WRITE(6,900)
      WRITE(6,959)(Q(N),N=1,24)
      WRITE(6,908)
      WRITE(6,959)(NST1(N),N=1,24)
      WRITE(6,906)
      WRITE(6,959)(E(N),N=1,24)
      WRITE(6,993)
      WRITE(6,959)(EG(N),N=1,24)
      WRITE(6,690)
      WRITE(6,959) (FILM(N), N=1,24)
      WRITE(6,685)
      WRITE(6,959) (DRIP(N), N=1,24)
      WRITE(6,695)
      WRITE(6,959) (CLOWAT(N), N=1,24)
      WRITE(6,902)
      WRITE(6,959)(BC(N),N=1,24)
      WRITE(6,903)
      WRITE(6,959)(TD(N),N=1,24)
      WRITE(6,904)
      WRITE(6,960)(HF(N),N=1,25)
      WRITE(6,905)
      WRITE(6,960)(F(N),N=1,25)
      WRITE(6,987)
      WRITE(6,960) (TSETWA(N), N=1,25)
      WRITE(6,931)
      WRITE(6,960)(T(N),N=1,25)
      RETURN
      END
      SUBROUTINE OTPART(JOB,SA,SH8,SHF,SHS,SHT,TOTAL)
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 LTH,MAXBF,MAXE,MPR,NST1,NSTM
      COMMON/X02/PCT(73),PCTN(73)
      COMMON/X04/NST1(25),C(25),T(25),F(25),HF(25),TSETWS(25),ERROR(25)
      COMMON/X05/RATE(25),COLD(25),WARM(25),TI(25),TSETC(25),TSETWA(25)
      COMMON/X07/BFB(24),BF(24),BC(24),SUFA(24)
      COMMON/X08/CMRAD(24),LTH(24),VOL(24),RAD(24),SEGWT(24)
      COMMON/X09/EEPROP(24),PQB(24),PBCO(24),Q8Q10(24)
      COMMON/X10/MAXBF(24),TC(24),TD(24),QB(24),Q(24),E(24)
      COMMON/X10A/EB(24)
      COMMON/X11/DELX(18),ARX(18),COND(18),HTSA(18),MPR(18)
      COMMON/X17/SKIND(6),SKINC(6),CHILM(6),PSKIN(6),SWPCP(6)
      COMMON/X17A/WCRKM(6)
      COMMON/X18/EVCP(6),EWET(6),PS(6),SWCG(6),NSTM(6)
      COMMON/X19/MAXE(6),HC(6),S(6),HR(6),H(6),EMAX(6),SKINR(6),SKINS(6)
      COMMON/X21/PAIR(6),HCSL(6),DELTAT(6),CHELL(6),CLO(6),WCLOV(6)
      COMMON/X32/HCMIX,HCSEAT,HCWALK,HCSLT8,HCT8
   10 FORMAT(1H0,3X,'S(I)= SURFACE AREA OF EACH SEGMENT',/,4X,'HR(I)= LI
     1NEAR RADIANT HEAT TRANSFER COEFFICIENT',/,4X,'HCSL(I)= CONVECTIVE
     2AND CONDUCTIVE HEAT TRANSFER COEFFICIENT - AT SEA LEVEL AND V=0.1M
     3/SEC',/,4X,'HC(I)= CONVECTIVE AND CONDUCTIVE HEAT TRANSFER COEFFIC
     4IENT',/,4X,'SKINR(I)= FRACTION OF ALL SKIN THERMAL RECEPTORS IN EA
     5CH SEGMENT',/,4X,'SKINS(I)= FRACTION OF SWEATING COMMAND APPLICABL
     6E TO EACH SKIN SEGMENT',/,4X,'SKIND(I)= FRACTION OF VASODILATION C
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     7COMMAND APPLICATION TO EACH SKIN SEGMENT',/,4X,'SKINC(I)= FRACTION HEAT7810
     8OF VASOCONSTRICTION COMMAND APPLICATION TO EACH SKIN SEGMENT',/,4XHEAT7820
     9,'WORKM(I)= FRACTION OF TOTAL WORK DONE BY MUSCLE IN EACH SEGMENT'HEAT7830
     X,/,4X,'CHILM(I)= FRACTION OF TOTAL SHIVERING OCCURING IN EACH SEGMHEAT7840
     XENT',/,4X,'NSTM(I)= PROPORTION OF NON-SHIVERING THERMOGENESIS FOR HEAT7850
     XEACH SEGMENT')                                                    HEAT7860
 504 FORMAT(1H ,4X,'SPECIFIC HEAT (THERMAL CAPACITY) OF SKIN,SHS  =',1XHEAT7870
     1,F6.3,' WATT-HR/KG-C')                                            HEAT7880
 506 FORMAT(1H ,4X,'SPECIFIC HEAT (THERMAL CAPACITY) OF FAT,SHF   =',1XHEAT7890
     1,F6.3,' WATT-HR/KG-C')                                            HEAT7900
 507 FORMAT(1H0,4X,'SPECIFIC HEAT (THERMAL CAPACITY) OF BONE,SHB  =',1XHEAT7910
     1,F6.3,' WATT-HR/KG-C')                                            HEAT7920
 508 FORMAT(1H ,4X,'SPECIFIC HEAT (THERMAL CAPACITY) OF TISSUE,SHT=',1XHEAT7930
     1,F6.3,' WATT-HR/KG-C')                                            HEAT7940
 511 FORMAT(1H0,4X,'VOL(N),   VOLUME OF SUBJECT,CUBIC CENTIMETERS')     HEAT7950
 512 FORMAT(1H0,4X,'LTH(N),   LENGTH OF PARTS OF THE BODY,CM ')         HEAT7960
 515 FORMAT(1H0,4X,'RAD(N),   RADIUS OF PARTS OF THE BODY, CM ')        HEAT7970
 524 FORMAT(1H0,3X,'DELX(K),   DELTA X, ABOUT RAD(I),CM ')              HEAT7980
 527 FORMAT(1H0,3X,'COND(K),   CONDUCTIVITY,W/CM C')                    HEAT7990
 531 FORMAT(1H0,4X,'TC(K),  THERMAL CONDUCTANCE BETWEEN ADJACENT ELEMENHEAT8000
     1TS,WATTS/DEG C')                                                  HEAT8010
 550 FORMAT(1H0,12X,'CORE-MUSCLE',4X,'MUSCLE-FAT',7X,'FAT-SKIN'         HEAT8020
     1/3X,'HEAD ',3(6X,F9.1)/3X,'TRUNK',3(6X,F9.1),/3X,'ARMS ',         HEAT8030
     23(6X,F9.1)/3X,'HANDS',3(6X,F9.1)/3X,'LEGS ',3(6X,F9.1)/3X,        HEAT8040
     3'FEET ',3(6X,F9.1))                                               HEAT8050
 560 FORMAT(1H0,11X,'SHAPE',9X,'CORE',9X,'MUSCLE',9X,'FAT',9X,'SKIN'    HEAT8060
     1/3X,'HEAD       SPHERE ',4(5X,F9.1)/3X,'TRUNK    CYLINDER',4(5X,   HEAT8070
     2F9.1)/3X,'ARMS      CYLINDER',4(5X,F9.1)/3X,'HANDS    CYLINDER',   HEAT8080
     34(5X,F9.1)/3X,'LEGS      CYLINDER',4(5X,F9.1)/3X,'FEET     CYLINDERHEAT8090
     4',4(5X,F9.1))                                                     HEAT8100
 585 FORMAT(1H0,19X,'CORE',9X,'MUSCLE',9X,'FAT',9X,'SKIN'/3X,'HEAD      HEAT8110
     1',4(5X,F9.1)/3X,'TRUNK     ',4(5X,F9.1)/3X,'ARMS  (2)',4(5X,F9.1)/ HEAT8120
     23X,'HANDS (2)',4(5X,F9.1)/3X,'LEGS  (2)',4(5X,F9.1)/3X,'FEET  (2)'HEAT8130
     3,4(5X,F9.1))                                                      HEAT8140
 610 FORMAT(1H0,12X,'CORE-MUSCLE',4X,'MUSCLE-FAT',7X,'FAT-SKIN'         HEAT8150
     1/3X,'HEAD ',3(6X,F9.5)/3X,'TRUNK',3(6X,F9.5),/3X,'ARMS ',         HEAT8160
     23(6X,F9.5)/3X,'HANDS',3(6X,F9.5)/3X,'LEGS ',3(6X,F9.5)/3X,        HEAT8170
     3'FEET ',3(6X,F9.5))                                               HEAT8180
 711 FORMAT(1H0,4X,'WORKM(I)',6(1X,F8.3),' (STEPPING)')                 HEAT8190
 712 FORMAT(1H0,4X,'WORKM(I)',6(1X,F8.3),' (CART PUSHING)')             HEAT8200
 713 FORMAT(1H0,4X,'WORKM(I)',6(1X,F8.3),' (REPETITIVE LIFTING)')       HEAT8210
 715 FORMAT(1H0,4X,'TSETC(N),  SET POINT FOR RECEPTORS FOR COLD CONDITIHEAT8220
     1ON,   DEG C ')                                                    HEAT8230
 730 FORMAT(1H0,4X,'WORKM(I)',6(1X,F8.3),' (WALK-RUN)')                 HEAT8240
 731 FORMAT(1H0,4X,'WORKM(I)',6(1X,F8.3),' (STANDING)')                 HEAT8250
 732 FORMAT(1H0,4X,'WORKM(I)',6(1X,F8.3),' (SITTING)')                  HEAT8260
 733 FORMAT(1H0,4X,'WORKM(I)',6(1X,F8.3),' (PEDALING)')                 HEAT8270
 811 FORMAT(1H0,4X,'PQB(N),   PROPORTION OF BASAL METABOLISM')          HEAT8280
 812 FORMAT(1H0,17X,'CORE',9X,'MUSCLE',9X,'FAT',9X,'SKIN'/3X,'HEAD ',4(HEAT8290
     15X,F9.4)/3X,'TRUNK',4(5X,F9.4)/3X,'ARMS ',4(5X,F9.4)/3X,'HANDS',4(HEAT8300
     25X,F9.4)/3X,'LEGS ',4(5X,F9.4)/3X,'FEET ',4(5X,F9.4))             HEAT8310
 813 FORMAT(1H0,4X,'PBCO(N),   PROPORTION OF CARDIAC OUTPUT')           HEAT8320
 850 FORMAT(1H0,4X,'PS(I)',4X,F8.3,1X,F8.3,4(1X,F8.3),5X,'  FRACTION ARHEAT8330
     1EA BY SEGMENT'  )                                                 HEAT8340
 865 FORMAT(1H0,4X,'SEGWT(N),   WEIGHT PER SEGMENT,GM')                 HEAT8350
 867 FORMAT(1H0,4X,'CMRAD(N),   CENTER OF MASS RADIUS, CM')             HEAT8360
 868 FORMAT(1H0,4X,'MPR(K),   MIDPOINT RADIUS,CM')                      HEAT8370
 869 FORMAT(1H0,4X,'HTSA(K),   HEAT TRANSFER OF SURFACE AREA,SQ CM')    HEAT8380
 890 FORMAT(1H0,4X,'T(N),   INITIAL INPUT TEMPERATURES,   DEG C')       HEAT8390
 948 FORMAT(1H ,'****E3(5),RESPIRATORY HEAT LOSS, IS NOT CONSTANT. SO, HEAT8400
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     1IT HAS BEEN INITIALIZED AS ZERO AND LATER CALCULATED BY RWET')      HEAT8410
 949 FORMAT(3X,'TOTAL ',55X,F9.1)                                        HEAT8420
 955 FORMAT(1H0,4X,'CONVECTIVE HEAT TRANSFER COEFFICIENT(MIXED),HCMIX    HEAT8430
    1 =',1X,F6.2,' W/SQ M-C')                                            HEAT8440
 956 FORMAT(1H ,4X,'CONVECTIVE HEAT TRANSFER COEFFICIENT(SEATED),HCSEATHEAT8450
    1 =',1X,F6.2,' W/SQ M-C')                                            HEAT8460
 957 FORMAT(1H ,4X,'CONVECTIVE HEAT TRANSFER COEFFICIENT(WALKING),HCWALHEAT8470
    1K=',1X,F6.2,' W/SQ M-C')                                            HEAT8480
 958 FORMAT(1H0,21X,'CORE',22X,'MUSCLE',22X,'FAT',24X,'SKIN'/13X,        HEAT8490
    1'FAT',6X,'BONE',3X,'TISSUE',5X,'FAT',6X,'BONE',3X,'TISSUE',5X,     HEAT8500
    2'FAT',6X,'BONE',3X,'TISSUE',5X,'FAT',6X,'BONE',3X,'TISSUE'/T14,    HEAT8510
    322('_'),T41,22('_'),T68,22('_'),T95,22('_')/3X,'HEAD ',12(3X,F6.2)HEAT8520
    4/3X,'TRUNK',12(3X,F6.2)/3X,'ARMS ',12(3X,F6.2)/3X,'HANDS',         HEAT8530
    512(3X,F6.2)/3X,'LEGS ',12(3X,F6.2)/3X,'FEET ',12(3X,F6.2)/3X,      HEAT8540
    6'CENTRAL BLOOD',1(3X,F6.2),1X,'TISSUE')                             HEAT8550
 959 FORMAT(1H0,17X,'CORE',9X,'MUSCLE',9X,'FAT',9X,'SKIN'/3X,'HEAD ',4(HEAT8560
    15X,F9.1)/3X,'TRUNK',4(5X,F9.1)/3X,'ARMS ',4(5X,F9.1)/3X,'HANDS',4(HEAT8570
    25X,F9.1)/3X,'LEGS ',4(5X,F9.1)/3X,'FEET ',4(5X,F9.1))               HEAT8580
 960 FORMAT(1H0,17X,'CORE',9X,'MUSCLE',9X,'FAT',9X,'SKIN'/3X,'HEAD ',4(HEAT8590
    15X,F9.1)/3X,'TRUNK',4(5X,F9.1)/3X,'ARMS ',4(5X,F9.1)/3X,'HANDS',4(HEAT8600
    25X,F9.1)/3X,'LEGS ',4(5X,F9.1)/3X,'FEET ',4(5X,F9.1)/3X,'CENTRAL BHEAT8610
    3LOOD')                                                              HEAT8620
 961 FORMAT(1H0,15X,'HEAD',5X,'TRUNK ',3X,'ARMS',5X,'HANDS',4X,'LEGS',6HEAT8630
    1X,'FEET',4X,'TOTAL',2X,'UNITS    ')                                 HEAT8640
 966 FORMAT(1H ,4X,'S(I)     ' ,7(3X,F6.3),    ' SQ. M ')                HEAT8650
 967 FORMAT(1H0,4X,'HR(I)    ',6(1X,F8.3),9X,' WATTS/SQ. M-DEG C')       HEAT8660
 968 FORMAT(1H ,4X,'HC(I)    ',7(1X,F8.3),' WATTS/SQ. M-DEG C')          HEAT8670
 970 FORMAT(1H0,4X,'SKINR(I)',6(1X,F8.3),9X,' PROPORTION')               HEAT8680
 971 FORMAT(1H ,4X,'SKINS(I)',6(1X,F8.3),9X,' PROPORTION')               HEAT8690
 972 FORMAT(1H ,4X,'SKINV(I)',6(1X,F8.3),9X,' PROPORTION')               HEAT8700
 973 FORMAT(1H ,4X,'SKINC(I)',6(1X,F8.3),9X,' PROPORTION')               HEAT8710
 974 FORMAT(1H ,4X,'WSTM(I) ',6(1X,F8.3),9X,' PROPORTION')               HEAT8720
 975 FORMAT(1H ,4X,'CHILM(I)',6(1X,F8.3),9X,' PROPORTION')               HEAT8730
 978 FORMAT(1H ,4X,'HCSL(I) ',7(1X,F8.3),' WATTS/SQ. M-DEG C')           HEAT8740
 980 FORMAT(1H0,4X,'C(N),  HEAT CAPACITANCE,  WATT HR/DEG C')            HEAT8750
 981 FORMAT(1H0,4X,'QB(N),  BASAL METABOLIC HEAT PRODUCTION,WATTS')      HEAT8760
 982 FORMAT(1H0,4X,'EB(N),  BASAL EVAPORATIVE HEAT LOSS (DIFFUSION),WATHEAT8770
     1TS')                                                               HEAT8780
 983 FORMAT(1H0,4X,'BFB(N),  BASAL EFFECTIVE BLOOD FLOW,  LITRES/HR ') HEAT8790
 985 FORMAT(1H0,4X,'TSETHS(N) ,SET POINT FOR RECEPTORS FOR SEDENTARY WAHEAT8800
     1RM CONDITION,  DEG C ')                                            HEAT8810
 986 FORMAT(1H0,4X,'RATE(N), DYNAMIC SENSITIVITY OF THERMORECEPTORS ') HEAT8820
      WRITE(6,958) (PCTN(J), J=1,73)                                     HEAT8830
      WRITE(6,507)SHB                                                    HEAT8840
      WRITE(6,508)SHT                                                    HEAT8850
      WRITE(6,506)SHF                                                    HEAT8860
      WRITE(6,504)SHS                                                    HEAT8870
      WRITE(6,980)                                                       HEAT8880
      WRITE(6,960)(C(N),N=1,25)                                          HEAT8890
      WRITE(6,811)                                                       HEAT8900
      WRITE(6,812)(PWB(N),N=1,24)                                        HEAT8910
      WRITE(6,981)                                                       HEAT8920
      WRITE(6,959)(QB(N),N=1,24)                                         HEAT8930
      WRITE(6,982)                                                       HEAT8940
      WRITE(6,959)(EB(N),N=1,24)                                         HEAT8950
      WRITE(6,948)                                                       HEAT8960
      WRITE(6,813)                                                       HEAT8970
      WRITE(6,812)(PBCO(N),N=1,24)                                       HEAT8980
      WRITE(6,983)                                                       HEAT8990
      WRITE(6,959)(BFB(N),N=1,24)                                        HEAT9000
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      WRITE(6,949)TOTAL
      WRITE(6,865)
      WRITE(6,959) (SEGWT(N), N=1,24)
      WRITE(6,511)
      WRITE(6,580) (VOL(N),N=1,24)
      WRITE(6,512)
      WRITE(6,585) (ETH(N),N=1,24)
      WRITE(6,515)
      WRITE(6,959) (RAD(N),N=1,24)
      WRITE(6,867)
      WRITE(6,959) (CMRAO(N), N=1,24)
      WRITE(6,524)
      WRITE(6,550) (DELX(K), K=1,18)
      WRITE(6,868)
      WRITE(6,550) (MPR(K), K=1,18)
      WRITE(6,869)
      WRITE(6,550) (HTSA(K), K=1,18)
      WRITE(6,527)
      WRITE(6,610) (CCNO(K), K=1,18)
      WRITE(6,531)
      WRITE(6,550) (TC(K), K=1,18)
      WRITE(6,985)
      WRITE(6,960)(TSETWS(N),N=1,25)
      WRITE(6,715)
      WRITE(6,960)(TSETC(N),N=1,25)
      WRITE(6,986)
      WRITE(6,960)(RATE(N),N=1,25)
      WRITE(6,961)
      WRITE(6,850) (PS(I),I=1,6)
      WRITE(6,966)(S(I),I=1,6),SA
      WRITE(6,967)(HR(I),I=1,6)
      WRITE(6,978) (HCSL(I), I=1,6),HCSLTB
      WRITE(6,968)(HC(I),I=1,6),HCTB
      WRITE(6,970)(SKINR(I),I=1,6)
      WRITE(6,971)(SKINS(I),I=I,6)
      WRITE(6,972)(SKIND(I),I=1,6)
      WRITE(6,973)(SKINC(I),I=1,6)
      GO TO (2080,2081,2082,2083,2084,2085,2086), JOB
 2080 WRITE(6,730)(WORKM(I),I=1,6)
      GO TO 2087
 2081 WRITE(6,731)(WORKM(I),I=1,6)
      GO TO 2087
 2082 WRITE(6,732)(WORKM(I),I=1,6)
      GO TO 2087
 2083 WRITE(6,733)(WORKM(I),I=1,6)
      GO TO 2087
 2084 WRITE(6,711)(WORKM(I),I=1,6)
      GO TO 2087
 2085 WRITE(6,712)(WORKM(I),I=1,6)
      GO TO 2087
 2086 WRITE(6,713)(WORKM(I),I=1,6)
 2087 WRITE(6,975)(CHILM(I),I=1,6)
      WRITE(6,974)(NSTM(I),I=1,6)
      WRITE(6,10)
      WRITE(6,955)HCMIX
      WRITE(6,956)HCSEAT
      WRITE(6,957)HCWALK
      WRITE(6,890)
      WRITE(6,960)(T(N),N=1,25)
      RETURN
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      END
      SUBROUTINE CONTSG(RWET,DT,SWEAT,SWEAG,SFAVOF,WORKAH,LR,TIME,PCHIL,
     1SAF,CWLH,MXRBFA,MXRBFO,SWFSEX,ACCLIM,SWGPSM,SA,WORKB,DILAT,STRIC,
     2CHILL,EMAXT,SPLBFL,SPLBFP,CROAD,ASET,ISET,MXOSET,RISET,RRISET)
      IMPLICIT REAL*8 (A-H,O-Z)
      INTEGER A,B,O,FITNES,G,R
      REAL*8            INCBF,     ISET,LR,                     NST1,NSTM
      REAL*8            MAXBF,MAXE,MAXSBY,           MXOSET,MXRBFA,MXRBFO
      COMMON/X03/OLOBF(25),EVG(25),FILM(25),FILMW(25),CLOWAT(25),EG(25)
      COMMON/X04/NST1(25),C(25),T(25),F(25),HF(25),TSETWS(25),ERROR(25)
      COMMON/X05/RATE(25),COLO(25),WARM(25),TI(25),TSETC(25),TSETWA(25)
      COMMON/X06/DRIP(25)
      COMMON/X07/BFB(24),BF(24),BC(24),SUFA(24)
      COMMON/X09/EBPROP(24),PQB(24),PBCO(24),QBQ10(24)
      COMMON/X10/MAXBF(24),TC(24),TD(24),QB(24),Q(24),E(24)
      COMMON/X10A/EB(24)
      COMMON/X13/P(20)
      COMMON/X17/SKINO(6),SKINC(6),CHILM(6),PSKIN(6),SWPCP(6)
      COMMON/X17A/WORKM(6)
      COMMON/X18/EVCP(6),EWET(6),PS(6),SWCG(6),NSTM(6)
      COMMON/X19/MAXE(6),HC(6),S(6),HR(6),H(6),EMAX(6),SKINR(6),SKINS(6)
      COMMON/X21/PAIR(6),HCSL(6),DELTAT(6),CHELL(6),CLO(6),WCLOV(6)
      COMMON/X23/DILET(6),FPCL(6),STREC(6)
      COMMON/X30/QUAT,ROE,AEWET,PPHG,SVP,PWET,TEMP,HVAPS,HVP,ACRTBF
      COMMON/X31/CSW,SSW,PSW,COIL,SOIL,POIL,CCON,SCON,PCON,CCHIL,SCHIL
      COMMON/X39/FITNES(5),A,B,O,G,R,L,NST,JCB
      DO 1502 N=1,25
      COLO(N)=0.
      ERROR(N)=0.
      WARM(N)=0.
      IF(T(N).GT.TSETWA(N))ERROR(N)=T(N)-TSETWA(N)+RATE(N)*F(N)
      IF(T(N).LT.TSETC(N))ERROR(N)=T(N)-TSETC(N)+RATE(N)*F(N)
      IF(ERROR(N))1500,1502,1501
 1500 COLO(N)=-ERROR(N)
      GO TO 1502
 1501 WARM(N)=ERROR(N)
 1502 CONTINUE
C                INTEGRATE PERIPHERAL AFFERENTS
      COLOS=0.0
      WARMS=0.0
      DO 1503 I=1,6
      K=4*I
      WARMS=WARMS+WARM(K)*SKINR(I)
      COLOS=COLOS+COLO(K)*SKINR(I)
 1503 CONTINUE
C                DETERMINE EFFERENT OUTFLOW
      SWEAT=CSW*ERROR(1)+SSW*(WARMS-COLOS)+PSW*ERROR(1)*(WARMS-COLOS)
      DILAT=COIL*ERROR(1)+SOIL*(WARMS-COLOS)+POIL*WARM(1)*WARMS
      STRIC=-CCON*ERROR(1)-SCON*(WARMS-COLOS)+PCON*COLO(1)*COLOS
      CHILL=-CCHIL*ERROR(1)-SCHIL*(WARMS-COLOS)+PCHIL*ERROR(1)*(WARMS-CO
     1LOS)
      IF(SWEAT)1504,1504,1505
 1504 SWEAT=0.0
 1505 CONTINUE
      IF(DILAT)1506,1506,1507
 1506 DILAT=0.0
 1507 CONTINUE
      IF(STRIC)1508,1508,1509
 1508 STRIC=0.0
 1509 CONTINUE
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      IF(CHILL)1510,1510,1511
 1510 CHILL=0.0
C     TIMBAL,MATH MODELS AV. SPACE AND ENV. MED. 47,9,958-64,1976
      IF(CHILL.GT..5*WORKB)CHILL=(5*WORKB)
 1511 CONTINUE
C                 ASSIGN EFFECTOR OUTPUT
 1512 CONTINUE
      DO 1513 N=1,24
      QBQ10(N)=(0.126*(T(N)-TSETWA(N))*QB(N))
 1513 CONTINUE
      QUAT=0.
      DO 1514 N=1,24
      QUAT=QBQ10(N)+QUAT
 1514 CONTINUE
      NST=.067*(SAF)
      DO 1517 N=1,25
      IF(N-6)1515,1516,1515
 1515 NST1(N)=0.
      GO TO 1517
 1516 NST1(N)=NST
 1517 CONTINUE
      EMAXT=0.
      DO 1522 I=1,6
      N=4*I-3
      Q(N)=QB(N)+QBQ10(N)
      E(N)=EB(N)
      E(5)=RWET
      BF(N)=BFB(N)
      IF(N.EQ.5)BF(N)=BFB(N)-(100-SPLBFP)*(SPLBFL)
      Q(N+1)=QB(N+1)+WORKM(I)*WORKAH+CHILM(I)*CHILL+QBQ10(N+1)+NSTM(I)*N
     1ST
      E(N+1)=0
      BF(N+1)=BFB(N+1)+SFAVDF*CHLH*Q(N+1)-CHLH*(QB(N+1)+QBQ10(N+1)+NSTM(
     1I)*NST)
      Q(N+2)=QB(N+2)+QBQ10(N+2)
      E(N+2)=0
      BF(N+2)=BFB(N+2)
      Q(N+3)=QB(N+3)+QBQ10(N+3)
C     STOLWIJK AND NADEL, FEDERATION PROCEEDINGS, VOL.32.5,1607-1613,
C     1973.
      E(N+3)=EB(N+3)+SKINS(I)*SWEAT*2.71828**((T(N+3)-TSETWA(N+3))/10.7)
C     WYNDHAM, MORRISON AND WILLIAMS, J. APP. PHYSIOLOGY, 20, 3, 357-364
      SWFACC=1.0+ACCLIM*0.01*0.75
      MAXSBY=SWGPSH*SA*SWFACC*SWFSEX
C     THESE CARDS ARE PLACED HERE TO LIMIT MAXIMUM SWEAT RATE
      MAXE(I)=MAXSBY*PS(I)*EVCP(I)
      IF(E(N+3).GT.MAXE(I))E(N+3)=MAXE(I)
      BF(N+3)=(BFB(N+3)+SKIND(I)*DILAT)/(1.+SKINC(I)*STRIC)
      DILET(I)=DILAT*SKIND(I)
      STREC(I)=STRIC*SKINC(I)
      CHELL(I)=CHILL*CHILM(I)
      K=(T(N+3)+35)/5
      PSKIN(I)=P(K)+(P(K+1)-P(K))*(T(N+3)+35-5*K)/5.
      EMAX(I)=(PSKIN(I)-PAIR(I))*LR*(H(I)-HR(I)*S(I)*FPCL(I))
      IF(EMAX(I).LE.0.0)EMAX(I)=0.000001
      EMAXT=EMAXT+EMAX(I)
      EWET(I)=E(N+3)/EMAX(I)
      IF(EMAX(I)-E(N+3))1518,1521,1521
C *** SWEAT DRIVE-EVAPORATION=EXTRA WATER(FILM(I)+DRIP(I)+CLOWAT(I))
 1518 ROE=1.0
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      ASET=MXOSET*DT
      IF(CROAD)1544,1570,1554
 1544 CONTINUE
      DO 1545 I=1,7
      NJ=(I-1)*4+1
      TSETHA(NJ)=TSETHA(NJ)-ASET
 1545 CONTINUE
      DO 1546 I=1,6
      NJ=4*I-2
      TSETHA(NJ)=TSETHA(NJ)-ASET
 1546 CONTINUE
      RRISET=RISET+ASET
      IF(RRISET+ISET)1570,1547,1547
 1547 CROAD=0.
 1554 CONTINUE
      DO 1555 I=1,7
      NJ=(I-1)*4+1
      TSETHA(NJ)=TSETHA(NJ)+ASET
 1555 CONTINUE
      DO 1556 I=1,6
      NJ=4*I-2
      TSETHA(NJ)=TSETHA(NJ)+ASET
 1556 CONTINUE
 1560 RRISET=RISET+ASET
      IF(RRISET-ISET)1570,1557,1557
 1557 CROAD=0.
 1570 CONTINUE
      RETURN
      END
      SUBROUTINE HTFLOW(L,CWW,DTM,SAF,CEFF,RDRY,ITIME,LTIME,WRATE,
     2HEATIM)
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 NST1,MAXBF,MAXE,ITIME,LTIME
      COMMON/X04/NST1(25),C(25),T(25),F(25),HF(25),TSETWS(25),ERROR(25)
      COMMON/X07/BFB(24),BF(24),BC(24),SUFA(24)
      COMMON/X10/MAXBF(24),TC(24),TD(24),QB(24),Q(24),E(24)
      COMMON/X12/SUBRAT(14)
      COMMON/X16/WWORKV(10),WW(10),WTIME(10)
      COMMON/X19/MAXE(6),HC(6),S(6),HR(6),H(6),EMAX(6),SKINR(6),SKINS(6)
      COMMON/X22/DRY(6),FACL(6),FCL(6),TCL(6),TO(6),TOTALH(6)
C                    CALCULATE HEAT FLOWS
      DO 1600 I=1,6
      TD(4*I-3)=TC(3*I-2)*(T(4*I-3)-T(4*I-2))
      TD(4*I-2)=TC(3*I-1)*(T(4*I-2)-T(4*I-1))
      TD(4*I-1)=TC(3*I)  *(T(4*I-1)-T(4*I))
      TD(4*I)=0.
 1600 CONTINUE
      CPBLOD=.83
      DO 1601 N=1,24
      BC(N)=BF(N)*(T(N)-T(25))*CPBLOD*1.15
 1601 CONTINUE
      DO 1602 I=1,6
      K=4*I-3
      HF(K)=Q(K)-E(K)-BC(K)-TD(K)
      HF(K+1)=Q(K+1)-BC(K+1)+TD(K)-TD(K+1)
      HF(K+2)=Q(K+2)-BC(K+2)+TD(K+1)-TD(K+2)
      DRY(I)=TOTALH(I)*FCL(I)*(T(4*I)-TO(I))*S(I)
      HF(K+3)=Q(K+3)-BC(K+3)-E(K+3)+TD(K+2)-DRY(I)
 1602 CONTINUE
      HF(5)=HF(5)-RDRY
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      EWET(I)=1.0                                                       HEAT0810
      FILM(N+3)=((E(N+3)-EMAX(I))/EVCP(I))/((S(I)*ROE))                 HEAT0820
C *** THICKNESS IF FILM ON SKIN TO START DRIPPING=35 MICRONS (L. BERGLANHEAT0830
C *** DOCTORATE THESIS 1971)                                            HEAT0840
      IF(FILM(N+3).GT.35.)GO TO 1519                                    HEAT0850
      GO TO 1520                                                        HEAT0860
 1519 FILM(N+3)=35.                                                     HEAT0870
      FILMW(N+3)=S(I)*FILM(N+3)*ROE                                     HEAT0880
      DRIP(N+3)=((E(N+3)-EMAX(I))/EVCP(1))-FILMW(N+3)                   HEAT0890
 1520 E(N+3)=EMAX(I)                                                    HEAT0900
 1521 CONTINUE                                                          HEAT0910
 1522 CONTINUE                                                          HEAT0920
      AEWET=0.0                                                         HEAT0930
      SWEAG=0.0                                                         HEAT0940
      DO 1523 I=1,6                                                     HEAT0950
      N=4*I-3                                                           HEAT0960
      SWPCP(I)=SKINS(I)*SWEAT                                           HEAT0970
      EWET(I)=E(N+3)/EMAX(I)                                            HEAT0980
      AEWET=AEWET+EWET(I)*(S(I)/SA)                                     HEAT0990
      PPHG=PSKIN(I)                                                     HEAT1000
      SVP=EMAX(I)                                                       HEAT1010
      PWET=EWET(I)                                                      HEAT1020
      TEMP=T(N+3)                                                       HEAT1030
      OLDPHS=1                                                          HEAT1040
      CALL SWVP(OLDPHS,PWET,PPHG,SVP,TEMP,HVAPS)                        HEAT1050
      EVCP(I)=HVAPS                                                     HEAT1060
      EG(N+3)=E(N+3)/EVCP(I)+DRIP(N+3)+FILMW(N+3)                       HEAT1070
      SWCG(I)=SWPCP(I)/EVCP(I)                                          HEAT1080
      SWEAG=SWEAG+SWCG(I)                                               HEAT1090
 1523 CONTINUE                                                          HEAT1100
      EG(5)=E(5)/HVP                                                    HEAT1110
      EG(25)=0.0                                                        HEAT1120
C ** THESE CARDS ARE PLACED HERE TO LIMIT MAXIMUM BLOOD FLOW  *****     HEAT1130
      DO 1535 I=1,6                                                     HEAT1140
      MAXBF(4*I-3)=BFB(4*I-3)                                           HEAT1150
      HVP=(2433.95-2.2549*(T(5)-30.))*0.0002778                         HEAT1160
      MAXBF(4*I-2)=BFB(4*I-2)*13.                                       HEAT1170
      MAXBF(4*I-1)=BFB(4*I-1)                                           HEAT1180
      IF(I.EQ.1) GO TO 1534                                             HEAT1190
      MAXBF(4*I)=BFB(4*I)*7.                                            HEAT1200
      GO TO 1535                                                        HEAT1210
C *** FROESE AND BURTON, J. APP PHYSIOLOGY,10,2, 235-241, 1957          HEAT1220
 1534 MAXBF(4*I)=BFB(4*I)                                               HEAT1230
 1535 CONTINUE                                                          HEAT1240
      IF(TIME.NE.0.0) GO TO 1536                                        HEAT1250
      GO TO 1541                                                        HEAT1260
 1536 DO 1537 N=1,24                                                    HEAT1270
 1537 IF(BF(N).GT.MAXBF(N))BF(N)=MAXBF(N)                               HEAT1280
      DO 1540 N=1,24                                                    HEAT1290
      INCBF=(BF(N)-OLDBF(N))/OLDBF(N)                                   HEAT1300
      ACRTBF=INCBF/DT                                                   HEAT1310
      IF(ACRTBF.GT.MXRBFA)GO TO 1538                                    HEAT1320
      IF(ACRTBF.LT.-MXRBFD)GO TO 1539                                   HEAT1330
      GO TO 1540                                                        HEAT1340
 1538 BF(N)=OLDBF(N)*(1+MXRBFA*DT)                                      HEAT1350
      GO TO 1540                                                        HEAT1360
 1539 BF(N)=OLDBF(N)*(1-MXRBFD*DT)                                      HEAT1370
 1540 CONTINUE                                                          HEAT1380
 1541 DO 1542 N=1,24                                                    HEAT1390
 1542 OLDBF(N)=BF(N)                                                    HEAT1400
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      IF(SAF.LE.0.)GO TO 1603
C *** NEXT FOUR CARDS ARE PLACED TO ACCOUNT FOR VARIABLE SUBLIMATION
C     RATE AND COOLING EFFECT OF DRY-ICE.IF MORE THAN 10 PERIODS,CHANGE
C     DIMENSION AND READ STATEMENTS FOR SUBRAT     **********
      PER=DABS((ITIME-0.0001)/30.)
      JPER=PER
      K=JPER+1
      HF(8)=HF(8)-(SUBRAT(K)*.159*CEFF)
C *****  NEXT CARD IS PLACED TO TAKE CARE OF DRINKING WATER
 1603 IF(LTIME.GT.WTIME(L).AND.LTIME.LT.(WTIME(L)+HEATIM)) GO TO 1610
      GO TO 1611
 1610 WRATE =0.06*WW(L)/HEATIM
      TW=11.
      CWW=CWW+WRATE*DTM
      HF(5)=HF(5)-WRATE*(T(5)-TW)*1.163
 1611 HF(25)=0.0
      IF(LTIME.GT.(WTIME(L)+HEATIM).AND.LTIME.LT.(WTIME(L)+HEATIM+DTM))
     1L=L+1
      IF(L.GT.4)L=4
      DO 1612 N=1,24
      HF(25)=HF(25)+BC(N)
 1612 CONTINUE
      RETURN
      END
      SUBROUTINE TASK(V,RELV,WEFF,VWALK,WORKT,HCWALK,RSHAPE,STVPST)
C
      IMPLICIT REAL*8 (A-H,O-Z)
      INTEGER A,B,D,FITNES,G,R
      COMMON/X17A/WORKM(6)
      COMMON/X20/WK1(6),WK2(6),WK3(6),WK4(6),WK5(6),WK6(6),WK7(6)
      COMMON/X39/FITNES(5),A,B,D,G,R,L,NST,JOB
      GO TO (1840,1842,1844,1846,1848,1850,1852),JOB
 1840 DO 1841 I=1,6
      WORKM(I)=WK1(I)
 1841 CONTINUE
C     FANGER, ANGELIUS, KJERULF-JENSEN, ASHRAE TRANSACTIONS, PART 1, 197
C     0. (PAPER 2168)
      VWALK=1.5
      RELV=V+VWALK
      HCWALK=8.6*(RELV**0.53)
      RSHAPE=.740
      STVPST=.8
      WEFF=.00
      GO TO 1854
 1842 DO 1843 I=1,6
      WORKM(I)=WK2(I)
 1843 CONTINUE
      RSHAPE=.725
      STVPST=.8
      WEFF=.00
      GO TO 1854
 1844 DO 1845 I=1,6
      WORKM(I)=WK3(I)
 1845 CONTINUE
      RSHAPE=.696
      STVPST=.8
      WEFF=.00
      GO TO 1854
 1846 DO 1847 I=1,6
C     WEFF FOR PEDAL, STEP, AND CART PUSH FROM WYNDHAM, ERGONOMICS,
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C     9,1,17-29,1966.                                                   HEAT2610
      WORKM(I)=WK4(I)                                                   HEAT2620
 1847 CONTINUE                                                          HEAT2630
      RSHAPE=.750                                                       HEAT2640
      STVPST=0.8                                                        HEAT2650
      WEFF= -.03552 + .00041329*WORKT                                   HEAT2660
      IF(WEFF.GT.0.23)WEFF=.23                                          HEAT2670
      IF(WEFF.LT.0.043)WEFF=.043                                        HEAT2680
      GO TO 1854                                                        HEAT2690
 1848 DO 1849 I=1,6                                                     HEAT2700
      WORKM(I)=WK5(I)                                                   HEAT2710
 1849 CONTINUE                                                          HEAT2720
      RSHAPE=.745                                                       HEAT2730
      STVPST=.8                                                         HEAT2740
      WEFF=0.                                                           HEAT2750
      GO TO 1854                                                        HEAT2760
 1850 DO 1851 I=1,6                                                     HEAT2770
      WORKM(I)=WK6(I)                                                   HEAT2780
 1851 CONTINUE                                                          HEAT2790
      RSHAPE=.735                                                       HEAT2800
      STVPST=.8                                                         HEAT2810
      WEFF=-0.04813+.00039017*WORKT                                     HEAT2820
      IF(WEFF.LT.0.026)WEFF=.026                                        HEAT2830
      IF(WEFF.GT.0.171)WEFF=.171                                        HEAT2840
      GO TO 1854                                                        HEAT2850
 1852 DO 1853 I=1,6                                                     HEAT2860
      WORKM(I)=WK7(I)                                                   HEAT2870
 1853 CONTINUE                                                          HEAT2880
      RSHAPE=.730                                                       HEAT2890
C     JORGENSEN AND POULSEN, COMM. 32, DANISH NAT. ASSOC. FOR INF.      HEAT2900
C     PARALYSIS, 1972.                                                  HEAT2910
      STVPST=.8                                                         HEAT2920
      WEFF=0.061                                                        HEAT2930
 1854 CONTINUE                                                          HEAT2940
      RETURN                                                            HEAT2950
      END                                                               HEAT2960
      SUBROUTINE CONCAL(V,CO,HT,SA,TR,WT,AGE,BARO,LBT,SHB,SHF,SHS,SHT,  HEAT2970
     1TAIR,PCTBF,TBFYM,VWALK,WORK3,WORKT,DIFPSM,DUBOSA,STVPST,SWFSEX)   HEAT2980
      IMPLICIT REAL*8 (A-H,O-Z)                                         HEAT2990
      INTEGER A,B,D,FITNES,G,R                                          HEAT3000
      INTEGER*2 SEX,MA,FE,OUTPUT,FULL,PART,BRIEF                        HEAT3010
      REAL*8          LBT,   LTH,             MAXVO2                    HEAT3020
      REAL*8          MAXBF,MAXE,        MPR,                 NST1,NSTM HEAT3030
      COMMON/X02/PCT(73),PCTN(73)                                       HEAT3040
      COMMON/X04/NST1(25),C(25),T(25),F(25),HF(25),TSETWS(25),ERROR(25) HEAT3050
      COMMON/X07/BFB(24),BF(24),BC(24),SUFA(24)                         HEAT3060
      COMMON/X08/CWRAD(24),LTH(24),VGL(24),RAD(24),SEGWT(24)            HEAT3070
      COMMON/X09/EBPRCP(24),PQB(24),PBCG(24),QBQ10(24)                  HEAT3080
      COMMON/X10/MAXBF(24),TC(24),TD(24),QB(24),Q(24),E(24)             HEAT3090
      COMMON/X11/DELX(18),ARX(18),COND(18),WTSA(18),MPR(18)             HEAT3100
      COMMON/X18/EVCP(6),EWET(6),PS(6),SWCG(6),NSTM(6)                  HEAT3110
      COMMON/X19/MAXE(6),HC(6),S(6),HR(6),H(6),EMAX(6),SKINR(6),SKINS(6)HEAT3120
      COMMON/X21/PAIR(6),HCSL(6),DELTAT(6),CHELL(6),CLO(6),WCLOV(6)     HEAT3130
      COMMON/X22/DRY(6),FACL(6),FCL(6),TCL(6),TC(6),TOTALH(6)           HEAT3140
      COMMON/X23/DILET(6).FPCL(6),STREC(6)                              HEAT3150
      COMMON/X25/HEATIM,CWW,RWET,BWT,HP,HFLOW,CT,DTM,RDRY,RSHAPE,EV     HEAT3160
      COMMON/X32/HCMIX,HCSEAT,HCWALK,HCSLTB,HCTB                        HEAT3170
      COMMON/X35/WATRES,WATSWT,WATPCY,SR,SUBWAT,TOTWAT,MAXVO2,WEFF      HEAT3180
      COMMON/X39/FITNES(5),A,B,D,G,R,L,NST,JGB                          HEAT3190
      COMMON/X40/SEX,MA,FE,OUTPUT,FULL,PART,BRIEF                       HEAT3200
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      DO 1400 I=1,6                                                     HEAT3210
      J=4*I-3                                                           HEAT3220
      K=12*(I-1)+1                                                      HEAT3230
      C(J)=(WT*SHF*PCT(K)+WT*SHB*PCT(K+1)+WT*SHT*PCT(K+2))/100          HEAT3240
      C(J+1)=(WT*SHF*PCT(K+3)+WT*SHB*PCT(K+4)+WT*SHT*PCT(K+5))/100      HEAT3250
      C(J+2)=(WT*SHF*PCT(K+6)+WT*SHB*PCT(K+7)+WT*SHT*PCT(K+8))/100      HEAT3260
      C(J+3)=(WT*SHF*PCT(K+9)+WT*SHB*PCT(K+10)+WT*SHT*PCT(K+11))/100    HEAT3270
 1400 CONTINUE                                                          HEAT3280
      C(J+4)=(WT*SHS*PCT(73))/100                                       HEAT3290
C     SLONIM, ENV. PHYSIOLOGY. P.525                                    HEAT3300
C     MITCHELL, STRYDOM, VAN GRAAN, VAN DER WALT, PFLUGERS ARCH, 325,   HEAT3310
C     188-193, 1971.                                                    HEAT3320
      DUBOSA=.007184*(HT**.725)*(WT**.425)                              HEAT3330
      SA=.208+.945*DUBOSA                                               HEAT3340
      DO 1401 I=1,6                                                     HEAT3350
      S(I)=PS(I)*SA                                                     HEAT3360
 1401 CONTINUE                                                          HEAT3370
      IF(TBFYM-0.)1403,1403,1409                                        HEAT3380
 1403 IF(SEX.EQ.MA) GO TO 1408                                          HEAT3390
      IF(AGE.LE.30.) GO TO 1404                                         HEAT3400
      TBW=8.84+0.331*WT                                                 HEAT3410
      GO TO 1405                                                        HEAT3420
 1404 TBW=11.63+0.318*WT                                                HEAT3430
 1405 BP=WT-(TBW/.73)                                                   HEAT3440
      TBFYM=BP/WT                                                       HEAT3450
      GO TO 1409                                                        HEAT3460
C     SPECIFIC GRAVITY FORMULA VALID ONLY FOR ADULT MALES               HEAT3470
 1408 SPGRV=.162+.8*((HT**.242)/((WT*1000)**.1))                        HEAT3480
C    PIERSON, W. AND EAGLE, W.  AEROSPACE MEDICINE, 40,2,161-164, 1969  HEAT3490
C     TOTAL BODY FAT                                                    HEAT3500
      TBFYM=(5.548/SPGRV)-5.044                                         HEAT3510
 1409 CONTINUE                                                          HEAT3520
C     ADD UP TOTAL OF FAT IN PCT(I) TABLE                               HEAT3530
      TOTF=0.                                                           HEAT3540
      DO 1410 I=1,6                                                     HEAT3550
      TOTF=TOTF+PCT(12*I-5)                                             HEAT3560
 1410 CONTINUE                                                          HEAT3570
      PCTBF=TBFYM*100                                                   HEAT3580
      LBT=WT*((100-PCTBF)/100)                                          HEAT3590
      TMT=0.0                                                           HEAT3600
      DO 1411 I=1,6                                                     HEAT3610
 1411 TMT=TMT+PCT(12*I-6)                                               HEAT3620
      FDIFF=TOTF-PCTBF                                                  HEAT3630
      DO 1412 I=1,73                                                    HEAT3640
 1412 PCTN(I)=PCT(I)                                                    HEAT3650
      DO 1414 I=1,6                                                     HEAT3660
      PCTN(12*I-6)=PCT(12*I-6)*(TMT+FDIFF)/TMT                          HEAT3670
      PCTN(12*I-5)=PCT(12*I-5)*(TOTF-FDIFF)/TOTF                        HEAT3680
 1414 CONTINUE                                                          HEAT3690
C     TEXTBOOK OF PHYSIOLOGY,GUYTON,FIG.47.1                            HEAT3700
      CARDI=4.2866-0.0289*AGE+0.0003*AGE**2                             HEAT3710
      IF(SEX.EQ.MA) GO TO 1416                                          HEAT3720
C     TAYLOR AND PYE, FOUNDATIONS OF NUTRITION, TABLE 2.3               HEAT3730
 1415 BMPSMF=51.101-0.715*AGE+0.006503*(AGE**2)                         HEAT3740
      DIFPSM=10.8                                                       HEAT3750
      SWFSEX=0.67                                                       HEAT3760
      WORKB=BMPSMF*DUBOSA*1.163                                         HEAT3770
      GO TO 1417                                                        HEAT3780
 1416 BMPSMM=55.3851-0.7631*AGE+0.006686*(AGE**2)                       HEAT3790
      CARDI=0.9*CARDI                                                   HEAT3800
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      DIFPSM=15.2
      SWFSEX=1.0
      WORKB=BMPSMM*OUBOSA*1.163
 1417 CG=CAROI*OUBOSA*60.
      DO 1418 N=1,24
      QB(N)=PQB(N)*WORKB
      BFB(N)=PBCO(N)*CG
 1418 CONTINUE
      DO 1420 I=1,6
      SEGWT(4*I-3)=((PCTN(12*I-10)*WT/100)+(PCTN(12*I-9)*WT/100))*1000
      SEGWT(4*I-2)=(PCTN(12*I-6)*WT/100)*1000
      SEGWT(4*I-1)=(PCTN(12*I-5)*WT/100)*1000
      SEGWT(4*I)=PCTN(12*I)*WT*10
 1420 CONTINUE
      DO 1421 I=1,6
      VOL(4*I-3)=SEGWT(4*I-3)
      VOL(4*I-2)=SEGWTI4*I-3)+SEGWT(4*I-2)
      VOL(4*I-1)=SEGWT(4*I-3)+SEGWT(4*I-2)+SEGWT(4*I-1)
      VOL(4*I  )=SEGWT(4*I-3)+SEGWT(4*I-2)+SEGWT(4*I-1)+SEGWT(4*I)
 1421 CONTINUE
      PIE=3.1416
      DO 1422 I=1,4
 1422 LTH(I)=0.0
      DO 1423 I=2,6
      LTH(4*I)=((S(I)*10000)**2)/(4*PIE*VOLI4*I))
      LTH(4*I-3)=LTH(4*I)
      LTH(4*I-2)=LTH(4*I)
      LTH(4*I-1)=LTH(4*I)
 1423 CONTINUE
      DO 1425 I=1,6
      IF(I.EQ.1) GO TO 1424
      RAD(4*I)=2*VOL(4*I)/(S(I)*10000)
      RAD(4*I-1)=((RAD(4*I)**2)-(VOL(4*I)-VOLI4*I-1))/(PIE*LTH(4*I-1)))
     1**(.5)
      RAD(4*I-2)=((RAD(4*I-1)**2)-(VOL(4*I-1)-VOL(4*I-2))/(PIE*LTH(4*I-2
     1)))**(.5)
      RAD(4*I-3)=((RAD(4*I-2)**2)-(VOL(4*I-2)-VOL(4*I-3))/(PIE*LTH(4*I-3
     1)))**(.5)
      GO TO 1425
 1424 RAD(4*I)=3*VOL(4*I)/(S(I)*10000)
      RAD(4*I-1)=((RAD(4*I)**3)-(3*(VOL(4*I)-VOL(4*I-1)))/(4*PIE))
     1**(.333333)
      RAD(4*I-2)=((RAD(4*I-1)**3)-(3*(VOL(4*I-1)-VOL(4*I-2)))/(4*PIE))
     1**(.333333)
      RAD(4*I-3)=((RAD(4*I-2)**3)-(3*(VOL(4*I-2)-VOL(4*I-3)))/(4*PIE))
     1**(.333333)
 1425 CONTINUE
      DO 1426 I=1,6
      CMRAD(4*I-3)=(IRAD(4*I-3)**3)/2)**(.333333)
      CMRAD(4*I-2)=((RAD(4*I-3)**3+RAD(4*I-2) ** 3)/2)**( .333333)
      CMRAD(4*I-1)=((RAD(4*I-2)**3+RAD(4*I-1) ** 3)/2)**( .333333)
      CMRAD(4*I)=((RAD(4*I-1)**3+RAD(4*I)**3)/2)**(.333333)
 1426 CONTINUE
      DO 1427 I=1,6
      DELX(3*I-2)=(CMRAD(4*I-2)-CMRAD(4*I-3))
      DELX(3*I-1)=(CMRAD(4*I-1)-CMRAD(4*I-2))
      DELX(3*I)=(CMRAD(4*I)-CMRADI4*I-1))
 1427 CONTINUE
      DO 1428 I=1,6
      MPR(3*I-2)=CMRAD(4*I-3)+(DELX(3*I-2)/2)
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      MPR(3*I-1)=CMRAD(4*I-2)+(DELX(3*I-1)/2)                           HEAT4410
      MPR(3*I)=CMRAD(4*I-1)+(DELX(3*I)/2)                               HEAT4420
 1428 CONTINUE                                                          HEAT4430
      DO 1430 I=1,6                                                     HEAT4440
      IF(I.EQ.1) GO TO 1429                                             HEAT4450
      HTSA(3*I-2)=2*PIE*LTH(4*I)*MPR(3*I-2)                             HEAT4460
      HTSA(3*I-1)=2*PIE*LTH(4*I)*MPR(3*I-1)                             HEAT4470
      HTSA(3*I)=2*PIE*LTH(4*I)*MPR(3*I)                                 HEAT4480
      GO TO 1430                                                        HEAT4490
 1429 HTSA(3*I-2)=4*PIE*(MPR(3*I-2)**2)                                 HEAT4500
      HTSA(3*I-1)=4*PIE*(MPR(3*I-1)**2)                                 HEAT4510
      HTSA(3*I)=4*PIE*(MPR(3*I)**2)                                     HEAT4520
 1430 CONTINUE                                                          HEAT4530
      DO 1431 K=1,18                                                    HEAT4540
      TC(K)=COND(K)*HTSA(K)/DELX(K)                                     HEAT4550
 1431 CONTINUE                                                          HEAT4560
C     JOB 1=WALK-RUN,2=STAND,3=SIT,4=PEDALING,5=STEPPING,6=CART         HEAT4570
C     PUSHING,7=REPETITIVE LIFTING                                      HEAT4580
      CALL TASK(V,RELV,WEFF,VWALK,WORKT,HCWALK,RSHAPE,STVPST)           HEAT4590
      DO 1460  I=1,6                                                    HEAT4600
      HC(I)=HCSL(I)*(BARO/760)**(.55)                                   HEAT4610
 1460 CONTINUE                                                          HEAT4620
      HCSLTB=0.0                                                        HEAT4630
      DO 1461 I=1,6                                                     HEAT4640
 1461 HCSLTB=HCSLTB+HCSL(I)*S(I)/SA                                     HEAT4650
      HCTB=0.0                                                          HEAT4660
      DO 1462 I=1,6                                                     HEAT4670
 1462 HCTB=HCTB+HC(I)*S(I)/SA                                           HEAT4680
      DO 1463 N=1,25                                                    HEAT4690
      F(N)=0                                                            HEAT4700
 1463 CONTINUE                                                          HEAT4710
      AVDELT=0.0                                                        HEAT4720
      DO 1464 I=1,6                                                     HEAT4730
      DELTAT(I)=DABS(T(4*I)-TAIR)                                       HEAT4740
      AVDELT=AVDELT+DELTAT(I)*S(I)/SA                                   HEAT4750
 1464 CONTINUE                                                          HEAT4760
      HCSEAT=11.6*(V**0.5)                                              HEAT4770
      DO 1465 I=1,6                                                     HEAT4780
      HCMIX=1.26*(AVDELT**0.25)*(1+3.17*(((V**2)/AVDELT)**0.2))         HEAT4790
      TOTALH(I)=HR(I)+HC(I)                                             HEAT4800
      FCL(I)=1./(1.+0.155*TOTALH(I)*CLO(I))                             HEAT4810
      TO(I)=(HR(I)*TR+HC(I)*TAIR)/TOTALH(I)                             HEAT4820
      FPCL(I)=1./(1.+.143*HC(I)*CLO(I))                                 HEAT4830
 1465 CONTINUE                                                          HEAT4840
      RETURN                                                            HEAT4850
      END                                                               HEAT4860
      SUBROUTINE SWVP(OLDPHS,PWET,PPHG,SVP,TEMP,HVAPS)                  HEAT4870
      IMPLICIT REAL*8 (A-H,O-Z)                                         HEAT4880
      REAL*8 K1,K2                                                      HEAT4890
C     SUBROUTINE TO CALCULATE THE HEAT OF VAPORIZATION OF SWEAT         HEAT4900
C     FROM SKIN IN W.H./GM.                                             HEAT4910
      PHIS=PWET+((1.-PWET)*PPHG)/SVP                                    HEAT4920
      IF(DABS(OLDPHS-PHIS).LT.0.02)GO TO 1900                           HEAT4930
      K1=2806.55-762.8*PHIS+390.2*(PHIS**2)                             HEAT4940
      K2=1.1435+1.75*PHIS-0.6386*(PHIS**2)                              HEAT4950
      HVAPS=(K1-K2*(TEMP-30.))*0.0002778                                HEAT4960
      OLDPHS=PHIS                                                       HEAT4970
 1900 RETURN                                                            HEAT4980
      END                                                               HEAT4990
      SUBROUTINE PEVOT(HEARTR)                                          HEAT5000
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      IMPLICIT REAL*8 (A-H,O-Z)                                         HEAT5010
C     ARSTILLA ET AL, COMPARISON OF TWO RATING SCALES, ERGONOMICS,      HEAT5020
C     17,5,577-584,1974.                                                HEAT5030
  720 FORMAT(1H ,6X,'PERCEIVED EXERTION,PEVOT=VERY, VERY HARD')         HEAT5040
  721 FORMAT(1H ,6X,'PERCEIVED EXERTION,PEVOT=VERY, VERY LIGHT')        HEAT5050
  722 FORMAT(1H ,6X,'PERCEIVED EXERTION,PEVOT=VERY LIGHT')              HEAT5060
  723 FORMAT(1H ,6X,'PERCEIVED EXERTION,PEVOT=FAIRLY LIGHT')            HEAT5070
  724 FORMAT(1H ,6X,'PERCEIVED EXERTION,PEVOT=SOMEWHAT HARD')           HEAT5080
  725 FORMAT(1H ,6X,'PERCEIVED EXERTION,PEVOT=HARD')                    HEAT5090
  726 FORMAT(1H ,6X,'PERCEIVED EXERTION,PEVOT=VERY HARD')               HEAT5100
      PEVOTE=.1*HEARTR                                                  HEAT5110
      IF(PEVOTE.LE.8.5) GO TO 1731                                      HEAT5120
      IF(PEVOTE.LE.10.0) GO TO 1732                                     HEAT5130
      IF(PEVOTE.LE.12.0) GO TO 1733                                     HEAT5140
      IF(PEVOTE.LE.14.0) GO TO 1734                                     HEAT5150
      IF(PEVOTE.LE.16.0) GO TO 1735                                     HEAT5160
      IF(PEVOTE.LE.18.0) GO TO 1736                                     HEAT5170
      WRITE (6,720)                                                     HEAT5180
      GO TO 1737                                                        HEAT5190
 1731 WRITE(6,721)                                                      HEAT5200
      GO TO 1737                                                        HEAT5210
 1732 WRITE (6,722)                                                     HEAT5220
      GO TO 1737                                                        HEAT5230
 1733 WRITE(6,723)                                                      HEAT5240
      GO TO 1737                                                        HEAT5250
 1734 WRITE(6,724)                                                      HEAT5260
      GO TO 1737                                                        HEAT5270
 1735 WRITE(6,725)                                                      HEAT5280
      GO TO 1737                                                        HEAT5290
 1736 WRITE(6,726)                                                      HEAT5300
      GO TO 1737                                                        HEAT5310
 1737 RETURN                                                            HEAT5320
      END                                                               HEAT5330
      SUBROUTINE SALT(DT,EG,INT,SA,SR,SUBK,SUBNA,SUBWAT,TOTK,TOTNA,     HEAT5340
     1TOTWAT,WATPCY,WATRES,WATSWT)                                      HEAT5350
      IMPLICIT REAL*8 (A-H,O-Z)                                         HEAT5360
      DIMENSION EG(25)                                                  HEAT5370
      REAL*8INT,KCLG,KCONC,KFAC,KMEQ,NACLG,NAMEQ                        HEAT5380
      SR=0.0                                                            HEAT5390
      WATPCY=0.0                                                        HEAT5400
      WATRES=0.0                                                        HEAT5410
      WATSWT=0.0                                                        HEAT5420
      DO 1860 J=4,24,4                                                  HEAT5430
      SR=SR+EG(J)/(SA*60*10)                                            HEAT5440
      WATSWT=WATSWT + EG(J)*DT                                          HEAT5450
 1860 CONTINUE                                                          HEAT5460
      IF(SR.LE.0.0)SR=0.0                                               HEAT5470
      IF(WATSWT.LE.0.0)WATSWT=0.0                                       HEAT5480
      WATRES=EG(5)*DT                                                   HEAT5490
      WATPCY=WATSWT+WATRES                                              HEAT5500
      SUBWAT=SUBWAT +WATPCY                                             HEAT5510
      SUBNA=0.0                                                         HEAT5520
      NACONC=10.6 + 20*SR                                               HEAT5530
C     CAGE AND DOBSON, J. OF CLINICAL INVEST, 44, M, 1270-74, 1965.     HEAT5540
      CNA=155.                                                          HEAT5550
      IF(NACONC.GE.CNA)NACONC=CNA                                       HEAT5560
      NAMEQ=NACONC*WATSWT*0.001                                         HEAT5570
      NACLG=23.0*NAMEQ*0.001                                            HEAT5580
      SUBNA=SUBNA+NACLG                                                 HEAT5590
      SUBK=0.0                                                          HEAT5600
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      KFAC= 1.0 -.6327*SR
      IF(KFAC.LE..5)KFAC=.5
      KCONC=10.0**KFAC
C     ELIZONDO, BANERJEE AND BULLARD, J APP PHYSIOLOGY, 32, 1, 1-6,1972
      CKE=7.
      CK1=CKE*1.2
C     1.2 FROM GUYTON, TEXT OF MEDICAL PHYSIOLOGY, P.835,1971.
      IF(KCONC.GT.CK1)KCONC=CK1
      KMEQ=KCONC*WATSWT*0.001
      KCLO=36.0*KMEQ*0.001
      SUBK=SUBK+KCLO
      RETURN
      END
      SUBROUTINE COMFCT(ACCLIM,AEWET,OUTPUT,OXUPTK,RH,RQ,SA,T1,TEMP,
     2WEFF,WORKT,MAXUPT)
      IMPLICIT REAL*8 (A-H,O-Z)
      INTEGER*2 PART/'P'/,OUTPUT
      REAL*8 KS,KSMAX,KSO,KSCAZ,KSVCLD,NMET,MAXUPT
  340 FORMAT(1H ,6X,'TOTAL METABOLISM/SQ.M. ,WORKSM =',2X,F4.0,2X,' WATT
     1S/SQ.M.')
  341 FORMAT(1H ,6X,'MET. HEAT INTO BODY,NMET         =',2X,F5.1,'  METS')
  342 FORMAT(1H ,6X,'SKIN WETTEDNESS AT THERMAL NEUTRALITY,WSWO='      ,
     1F8.2,' RATIO')
  343 FORMAT(1H ,6X,'SKIN WETTEDNESS FACTOR  ,EWSW                =',F8.2,'
     1 RATIO')
  344 FORMAT(1H ,4X,'HOT THERMAL SENSATION VOTE,TSHEAT=',F8.2)
  345 FORMAT(1H ,4X,'COLD THERMAL SENSATION VOTE,TSCOLD=',F8.2)
  346 FORMAT(1H ,6X,'SKIN CONDUCTANCE AZER,KSOAZ=',F8.2,' WATTS/SQ.M-C D
     1EG')
  347 FORMAT(1H ,6X,'SKIN CONDUCTANCE VERY COLD,KSVCLD=',F8.2,' WATTS/SQ
     1. M*C DEG')
  350 FORMAT(1H ,6X,'TOTAL METABOLISM, WORKT          =',F6.0,2X,' WATTS')
  354 FORMAT(1H ,6X,'SKIN CONDUCTANCE, KS=',7X,F8.2,' WATTS/SQ.M-C DEG')
  370 FORMAT(1H ,6X,'SUBJECTS COMFORT VOTE=VERY COLD')
  371 FORMAT(1H ,6X,'SUBJECTS COMFORT VOTE=COLD')
  372 FORMAT(1H ,6X,'SUBJECTS COMFORT VOTE=COOL')
  373 FORMAT(1H ,6X,'SUBJECTS COMFORT VOTE=SLIGHTLY COOL')
  374 FORMAT(1H ,6X,'SUBJECTS COMFORT VOTE=NEUTRAL')
  375 FORMAT(1H ,6X,'SUBJECTS COMFORT VOTE=SLIGHTLY WARM')
  376 FORMAT(1H ,6X,'SUBJECTS COMFORT VOTE=WARM')
  377 FORMAT(1H ,6X,'SUBJECTS COMFORT VOTE=HOT')
  378 FORMAT(1H ,6X,'SUBJECTS COMFORT VOTE=VERY HOT')
  400 FORMAT(1H ,6X,'RESPIRATORY QUOTIENT,RQ=',F6.2)
  923 FORMAT(1H ,6X,'PERCENT MAX OX UPTAKE,MAXUPT=',F6.0,' PERCENT')
  933 FORMAT(1H ,6X,'TASK OXYGEN UPTAKE,OXUPTK=',F6.2,' LITERS/MIN')
      WORKSM=WORKT/SA
      NMET=WORKSM*(1.-WEFF)/58.2
      WRITE (6,350) WORKT
      WRITE (6,340) WORKSM
      WRITE(6,341)NMET
      WRITE(6,933)OXUPTK
      WRITE (6,923)MAXUPT
      WRITE(6,400)RQ
      A1=T1-36.98
      IF(A1 .LT. 0.0)A1=0.0
      A2=TEMP-33.8
      IF(A2 .LT. 0.0)A2=0.0
      A3=T1-35.15
      IF(A3 .LT. 0.0)A3=0.0
      A4=32.10-TEMP
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      IF(A4 .LT. 0.0)A4=0.0                                             HEAT6210
      KS=5.3+(6.75+42.45*A1+8.15*A3**.8*A2)/1.0+.4*A4                   HEAT6220
      KSMAX=75 + (ACCLIM/100)*8                                         HEAT6230
      IF(KS.GT.KSMAX)KS=KSMAX                                           HEAT6240
      IF(NMET.LE.1.01)NMET=1.01                                         HEAT6250
      WSWO=.02+.4*(1.0-DEXP(-.6*(NMET-1.)))                             HEAT6260
      EWSW=(AEWET-WSWO)/(1.-WSWO)                                       HEAT6270
      IF(WSWO.GT.AEWET)EWSW=0.                                          HEAT6280
      KSOAZ=12.05*DEXP(.23*(NMET-1.))                                   HEAT6290
      IF (KS.LT.KSCAZ) GO TO 1370                                       HEAT6300
      IF (KS.GT.KSOAZ) GO TO 1386                                       HEAT6310
 1370 KSVCLD=5.3 +.261*(KSCAZ-5.3)                                      HEAT6320
      EVCONS=(KSOAZ-KS)/(KSOAZ-KSVCLD)                                  HEAT6330
      TSCOLD=1.46*EVCONS +3.75*EVCONS**2 -6.19*EVCONS**3                HEAT6340
      IF(TSCOLD.LT.-4.5)TSCOLD=-4.5                                     HEAT6350
      WRITE (6,345)TSCOLD                                               HEAT6360
      IF(TSCOLD.LT.-3.5) GO TO 1380                                     HEAT6370
      IF(TSCOLD.GE.-3.5.AND.TSCOLD.LT.-2.5) GO TO 1381                  HEAT6380
      IF(TSCOLD.GE.-0.5.AND.TSCOLD.LT.1.0) GO TO 1384                   HEAT6390
      IF(TSCOLD.GE.-2.5.AND.TSCOLD.LT.-1.5) GO TO 1382                  HEAT6400
      IF(TSCOLD.GE.-1.5.AND.TSCOLD.LT.-0.5) GO TO 1383                  HEAT6410
 1380 WRITE (6,370)                                                     HEAT6420
      GO TO 1385                                                        HEAT6430
 1381 WRITE (6,371)                                                     HEAT6440
      GO TO 1385                                                        HEAT6450
 1382 WRITE (6,372)                                                     HEAT6460
      GO TO 1385                                                        HEAT6470
 1383 WRITE (6,373)                                                     HEAT6480
      GO TO 1385                                                        HEAT6490
 1384 WRITE (6,374)                                                     HEAT6500
      GO TO 1385                                                        HEAT6510
 1385 WRITE (6,347) KSVCLD                                              HEAT6520
      GO TO 1398                                                        HEAT6530
 1386 TSHEAT=(5.-6.56*(RH-.5))*EWSW                                     HEAT6540
      IF(TSHEAT.GT.4.5)TSHEAT=4.5                                       HEAT6550
      WRITE(6,344)TSHEAT                                                HEAT6560
      IF(TSHEAT.GE.-1..AND.TSHEAT.LT.0.5) GO TO 1393                    HEAT6570
      IF(TSHEAT.GE.0.5.AND.TSHEAT.LT.1.5) GO TO 1394                    HEAT6580
      IF(TSHEAT.GE.1.5.AND.TSHEAT.LT.2.5) GO TO 1395                    HEAT6590
      IF(TSHEAT.GE.2.5.AND.TSHEAT.LT.3.5) GO TO 1396                    HEAT6600
      IF(TSHEAT.GE.3.5) GO TO 1397                                      HEAT6610
 1393 WRITE(6,374)                                                      HEAT6620
      GO TO 1398                                                        HEAT6630
 1394 WRITE (6,375)                                                     HEAT6640
      GO TO 1398                                                        HEAT6650
 1395 WRITE (6,376)                                                     HEAT6660
      GO TO 1398                                                        HEAT6670
 1396 WRITE (6,377)                                                     HEAT6680
      GO TO 1398                                                        HEAT6690
 1397 WRITE (6,378)                                                     HEAT6700
 1398 CONTINUE                                                          HEAT6710
      IF(OUTPUT.EQ.PART)GO TO 1399                                      HEAT6720
      WRITE(6,342) WSWO                                                 HEAT6730
      WRITE(6,343)EWSW                                                  HEAT6740
      WRITE (6,354) KS                                                  HEAT6750
      WRITE (6,346) KSOAZ                                               HEAT6760
 1399 CONTINUE                                                          HEAT6770
      RETURN                                                            HEAT6780
      END                                                               HEAT6790
      BLOCK DATA                                                        HEAT6800
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      IMPLICIT REAL*8 (A-H,O-Z)                                         HEAT6810
      INTEGER A,B,D,FITNES,G,R,SFTNES                                   HEAT6820
      INTEGER*2 SEX,MA,FE,OUTPUT,FULL,PART,BRIEF                        HEAT6830
      REAL*8            INCBF,INT,ISET,ITIME,INTVAL                     HEAT6840
      REAL*8 K1,K2                                                      HEAT6850
      REAL*8            LBT,LR,LTH,LTIME                                HEAT6860
      REAL*8            MAXBF,MAXE,MAXSBY,MAXUPT,MAXVO2,MPR             HEAT6870
      REAL*8            MXOSET,MXRBFA,MXRBFO,MVO2ML,NST1,NSTM           HEAT6880
      COMMON/X01/CLCV(6,3)                                              HEAT6890
      COMMON/X02/PCT(73),PCTN(73)                                       HEAT6900
      COMMON/X03/OLDBF(25),EVG(25),FILM(25),FILMW(25),CLOWAT(25),EG(25) HEAT6910
      COMMON/X04/NST1(25),C(25),T(25),F(25),HF(25),TSETWS(25),ERROR(25) HEAT6920
      COMMON/X05/RATE(25),COLD(25),WARM(25),TI(25),TSETC(25),TSETWA(25) HEAT6930
      COMMON/X06/DRIP(25)                                               HEAT6940
      COMMON/X07/BFB(24),BF(24),BC(24),SUFA(24)                         HEAT6950
      COMMON/X08/CMRAD(24),LTH(24),VOL(24),RAD(24),SEGWT(24)            HEAT6960
      COMMON/X09/EBPRCP(24),PQB(24),PBCO(24),QBQ10(24)                  HEAT6970
      COMMON/X10/MAXBF(24),TC(24),TO(24),QB(24),Q(24),E(24)             HEAT6980
      COMMON/X10A/EB(24)                                                HEAT6990
      COMMON/X11/DELX(18),ARX(18),CONC(18),HTSA(18),MPR(18)             HEAT7000
      COMMON/X12/SUBRAT(14)                                             HEAT7010
      COMMON/X13/P(20)                                                  HEAT7020
      COMMON/X14/JOBV(10),WJOBV(10),RHV(10),WRHV(10),TRV(10),WTRV(10)   HEAT7030
      COMMON/X15/TAIRV(10),WTAIRV(10),VV(10),WVV(10),WORKV(10)          HEAT7040
      COMMON/X16/WWORKV(10),WW(10),WTIME(10)                            HEAT7050
      COMMON/X17/SKINO(6),SKINC(6),CHILM(6),PSKIN(6),SWPCP(6)           HEAT7060
      COMMON/X17A/WORKM(6)                                              HEAT7070
      COMMON/X18/EVCP(6),EWET(6),PS(6),SWCG(6),NSTM(6)                  HEAT7080
      COMMON/X19/MAXE(6),HC(6),S(6),HR(6),H(6),EMAX(6),SKINR(6),SKINS(6)HEAT7090
      COMMON/X20/WK1(6),WK2(6),WK3(6),WK4(6),WK5(6),WK6(6),WK7(6)       HEAT7100
      COMMON/X21/PAIR(6),HCSL(6),DELTAT(6),CHELL(6),CLC(6),WCLOV(6)     HEAT7110
      COMMON/X22/DRY(6),FACL(6),FCL(6),TCL(6),TC(6),TOTALH(6)           HEAT7120
      COMMON/X23/DILET(6),FPCL(6),STREC(6)                              HEAT7130
      COMMON/X24/FSTROV(5),FAVDIF(5),AAVDIF(5),AMVO2R(5)                HEAT7140
      COMMON/X25/HEATIM,CWW,RWET,BWT,HP,HFLOW,CT,DTM,RDRY,RSHAPE,EV     HEAT7150
      COMMON/X26/CN,ITIME,DT,U,PRSALT,TEVG,STMLKG,SWEAT,CEVG,RH,RECTLT  HEAT7160
      COMMON/X27/CUSALT,TS,STROV,SWEAG,WRATE,LTIME,WORKT,CRALT,CO,TB    HEAT7170
      COMMON/X28/HEARTR,SFAVDF                                          HEAT7180
      COMMON/X29/WORKAH,LR,TIME,SBF,TBFYM,STVPST,PCTBF,PCHIL            HEAT7190
      COMMON/X30/QUAT,ROE,AEWET,PPHG,SVP,PWET,TEMP,HVAPS,HVP,ACRTBF     HEAT7200
      COMMON/X31/CSW,SSW,PSW,COIL,SOIL,POIL,CCON,SCON,PCON,CCHIL,SCHIL  HEAT7210
      COMMON/X32/HCMIX,HCSEAT,HCWALK,HCSLTB,HCTB                        HEAT7220
      COMMON/X33/AGE,WT,HT,SHF,SHB,SHT,SHS,SAF,CWLH,LBT,MXRBFA,MXRBFO   HEAT7230
      COMMON/X34/SWFSEX,ACCLIM,SWGPSM,BARO,INT,CEFF,TR,VWALK,V,SA,WORKB HEAT7240
      COMMON/X35/WATRES,WATSWT,WATPCY,SR,SUBWAT,TOTWAT,MAXVO2,WEFF      HEAT7250
      COMMON/X36/SUBNA,TOTNA,SUBK,TOTK,DILAT,STRIC,CHILL                HEAT7260
      COMMON/X37/DIFPSM,DUBOSA,EMAXT,MAXUPT,SPLBFL,SPLBFP,TAIRT,TAIR    HEAT7270
      COMMON/X38/CROAD,ASET,ISET,MXOSET,OWORKT,RISET,RRISET,TOTBFB      HEAT7280
      COMMON/X39/FITNES(5),A,B,D,G,R,L,NST,JOB                          HEAT7290
      COMMON/X40/SEX,MA,FE,OUTPUT,FULL,PART,BRIEF                       HEAT7300
      DATA AAVDIF/16.00,15.00,14.00,13.00,12.00/                        HEAT7310
      DATA A,B,D,G,L,R/1,1,1,1,1,1/                                     HEAT7320
      DATA AMVO2R/51.600,42.600,33.800,25.000,25.000/                   HEAT7330
      DATA BRIEF/'B'/                                                   HEAT7340
      DATA CCHIL/13.00/, CCON/10.800/, COIL/136.00/                     HEAT7350
      DATA CEFF/0.5500/, CEVG/0.00/, CROAD/0.00/, CSW/372.00/           HEAT7360
      DATA CHILM/.0200,.8500,.0500,.0000,.0700,.0000/                   HEAT7370
      DATA COND/.0041900,.0027800,.0020500,.0041900,.0033500,.0020500,  HEAT7380
     2.0041900,.0033500,.0020500,.0041900,.0027800,.0020500,.0041900,   HEAT7390
     3.0033500,.0020500,.0041900,.0027800,.0020500/                     HEAT7400
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      DATA CWLH/1.1500/, CHW/0.00/, DT/0.000/, DTM/0.00/
      DATA EBPROP /.00000,.00000,.00000,.08000,.00000,.00000,.00000,
     2.34700,.00000,.00000,.00000,.14000,.00000,.00000,.00000,.05300,
     3.00000,.00000,.00000,.30700,.00000,.00000,.00000,.07300/
      DATA FAVOIF/0.8700,0.9400,1.0000,1.0300,1.1700/
      DATA FE/'F'/,FITNES/1,2,3,4,5/
      DATA FSTROV/1.1000,1.0500,1.0000,.9500,.9000/
      DATA FULL/'F'/
      DATA HCSL/3.0000,2.1000,2.1000,4.0000,2.1000,4.0000/
      DATA HEATIM/10.00/
      DATA HR/4.8000,4.8000,4.2000,3.6000,4.2000,4.0000/
      DATA ITIME/0.00/
      DATA LTIME/0.00/
      DATA MA/'M'/,MXDSET/1.00/
      DATA NSTM/0.0000,1.0000,0.0000,0.0000,0.0000,0.0000/
      DATA CWORKT/0.00/
      DATA P/.2800,.4700,.7700,1.2400,1.9500,3.0100,4.5800,
     1       6.5400,9.2000,12.7900,17.5300,23.7500,31.8200,42.1800,
     255.3400,71.3900,92.5500,118.1100,149.4500,187.6000/
      DATA PART/'P'/
      DATA PBCC/.107600,.005900,.001300,.008700,.502100,.139700,
     2.034800,.012700,.002000,.026700,.004800,.003000,.000200,.000600,
     3.000700,.012100,.006400,.081100,.011700,.017200,.000400,.000600
     4,.001100,.018200/
      DATA PCT/0.0000,2.1400,2.1300,0.0000,0.0000,0.5100,0.5000,0.0000
     2,0.0000,0.0000,0.0000,0.3600,0.0000,3.3000,12.9800,0.0000,0.0000
     3,24.3500,9.6000,0.0000,0.0000,0.0000,0.0000,1.8200,0.0000,
     42.0200,1.0000,0.0000,0.0000,4.5800,1.3000,0.0000,0.0000,
     50.0000,0.0000,0.6500,0.0000,0.3100,0.0400,0.0000,0.0000,0.1000,
     60.1900,0.0000,0.0000,0.0000,0.0000,0.2600,0.0000,6.7300,2.6400,
     70.0000,0.0000,13.8200,3.2300,0.0000,0.0000,0.0000,0.0000,
     81.6200,0.0000,0.5000,0.0700,0.0000,0.0000,0.1100,0.2900,0.0000,
     90.0000,0.0000,0.0000,0.3400,3.3700/
      DATA PQB/.172900,.001400,.001500,.001000,.608600,.067200,
     2.028800,.005400,.009500,.012800,.002300,.001700,.001000,.002700,
     3.000300,.000700,.030000,.038400,.005800,.004300,.001700,
     4.000200,.006000,.000900/
      DATA PCHIL/0.00/, PCON/0.00/, POIL/0.00/, PSW/0.00/
      DATA PS/.08500,.37500,.13000,.05100,.29800,.06100/
      DATA RATE/0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,
     20.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00
     3,0.00,0.00/
      DATA S/.173100,.763800,.268400,.100200,.601200,.129900/
      DATA SCHIL/0.400/, SCON/10.800/, SOIL/17.00/, SHB/0.58200/
      DATA SHF/0.6400/, SHS/0.69600/, SHT/1.05800/, SR/0.00/
      DATA SSW/33.700/, SUBK/0.00/, SUBNA/0.00/, SUBWAT/0.00/
      DATA SKINC/.0100,.0500,.1900,.2000,.2000,.3500/
      DATA SKINR/.2100,.4200,.1000,.0400,.2000,.0300/
      DATA SKINS/.08100,.48100,.15400,.03100,.21800,.03500/
      DATA SKINU/.13200,.32200,.09500,.12100,.23000,.10000/
      DATA SWGPSM/400.00/
      DATA T/37.000,35.100,34.800,34.800,36.900,36.300,34.500,
     233.600,35.500,34.100,33.600,33.200,35.400,35.400,35.300,35.200,
     335.800,35.500,35.300,34.100,35.100,35.100,35.100,35.000,36.700/
      DATA TOTWAT/0.00/, TIME/0.000/, TOTK/0.00/, TOTNA/0.00/
      DATA TSETC/36.900,35.000,34.700,34.500,36.800,35.200,34.400,
     233.500,35.400,34.000,33.500,33.100,35.300,35.300,35.200,35.100,
     335.700,35.400,35.200,34.000,35.000,35.000,35.000,34.900,36.600/
      DATA TSETWS/37.000,35.100,34.800,34.600,36.900,36.300,34.500,
     233.600,35.500,34.100,33.600,33.200,35.400,35.400,35.300,35.200,
```

```
335.800,35.500,35.300,34.100,35.100,35.100,35.100,35.000,36.700/   HEAT8010
 DATA WK1/.01100,.33300,.15000,.00200,.50000,.00400/                HEAT8020
 DATA WK2/.01100,.59200,.10500,.00200,.35000,.00300/                HEAT8030
 DATA WK3/.01100,.56000,.10500,.00200,.31800,.00300/                HEAT8040
 DATA WK4/.01100,.33300,.10500,.00200,.54600,.00300/                HEAT8050
 DATA WK5/.01100,.56000,.10500,.00200,.31800,.00300/                HEAT8060
 DATA WK6/.01100,.31700,.17500,.00300,.50000,.00400/                HEAT8070
 DATA WK7/.0100,.3000,.1600,.0300,.4200,.0800/                      HEAT8080
 DATA WATSHT/0.00/, WRATE/0.00/, WATPCY/0.00/, WATRES/0.00/         HEAT8090
 END                                                                HEAT8100
```

ADDITIONAL CONSIDERATIONS OF PERSONAL COOLING

by

RANDELL GENE WAGNER

B.S.I.E., Kansas State University, 1977

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering

KANSAS STATE UNIVERSITY
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1979

ABSTRACT

Personal cooling was studied in a non-steady heat stress environmental condition at Kansas State University. Comparison was done with a dry ice cooling jacket and jumpsuit, with and without dry ice, and normal clothing for two male subjects doing a step task. After stepping for one hour in 34 C and 50% rh, the subjects rested 15 minutes in 25 C and 30% rh. A session contained three cycles.

Time and condition were the major factors shown to influence the subjects. The use of dry ice was beneficial for lower skin temperature and heart rate. The dry ice precooled the initial skin temperature by 2 C. Due to the task and its bellowing effect, dry ice sublimation was 40% faster than predicted.

The rest periods were shown to be beneficial in keeping the individual in the heat stress condition longer under acceptable physiological criteria.

The data were compared against the KSU-Stolwijk computer simulation model to validate the model for these conditions. The model's rectal temperature did not change rapidly enough. The predicted heart rates were about 10 beats/minute too low.