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A COMPUTER PROGRAM TO PREDICT ENERGY COST, RECTAL TEMPERATURE, AND HEART RATE RESPONSE TO WORK, CLOTHING, AND ENVIRONMENT

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Edgewood Arsenal

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A COMPUTER PROGRAM TO PREDICT ENERGY COST, RECTAL TEMPERATURE, AND HEART RATE RESPONSE TO WORK, CLOTHING, AND ENVIRONMENT

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by

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As a result of many years of thermal stress studies, a computer program was developed at USARIEM, Natick, Massachusetts, to predict rectal temperature and heart rate response to work, environment, and clothing. This report defines the mathematical basis of the program and presents a brief guide for its use with the HP9810A programmable calculator.

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PREFACE

The work described in this report was authorized under Task 1W762710A09506, Individual Protection Studies. The work was begun in February 1975 and completed in May 1975.

CONTENTS

A COMPUTER PROGRAM TO PREDICT ENERGY COST, RECTAL TEMPERATURE, AND HEART RATE RESPONSE TO WORK, CLOTHING, AND ENVIRONMENT

I. INTRODUCTION.

Over the years, Dr. Ralph F. Goldman and his many coworkers in the Military Ergonomics Laboratory of the US Army Research Institute of Environmental Medicine, Natick, Massachusetts, have developed a series of predictive equations for body temperature and heart rate response to various environmental factors. As part of their work, a computer program was developed for use with the HP9810A programmable calculator. Since no single reference in the open literature fully describes the mathematical basis and the computer usage, this publication will attempt to fill this void.

Unless otherwise stated, all terminology, subscripted variables, and units follow the usage recommended by the International System of Units (SI)[1] and the International Union of Physiological Sciences.[2]

II. MATHEMATICAL BASIS.

A. Energy Cost

The total metabolic rate (M) can be determined[3] for any conditions of total mass (m_t, kg), speed of walking (v, m/s), % grade (G), and nature of terrain (η) so that

$$M = \eta m_t \left\{ [2.7 + 3.2(v-0.7)^{1.65}] + G\,[0.23 + 0.29(v-0.7)] \right\} \qquad (1)$$

At rest, a constant value of 105W is assumed, and for running,[3] a suggested adjustment for equation 1 is:

$$M(\text{running}) = [M + 0.47(900-M)]\,(1 + G/100) \qquad (2)$$

Otherwise, the total metabolic rate for various activities can be obtained from published tables.[4]

The total surface skin area A for a given human subject of weight (Wt, kg) and height (Ht, cm) is calculated from the Du Bois formula[5] as

$$A = (71.84 \times 10^{-4}) Wt^{0.425}\, Ht^{0.725}, \; m^2 \qquad (3)$$

B. Environmental Factors

The numerical values for the effective clothing insulation coefficient, clo, and the effective permeability index ratio, i_m/clo, where i_m is the clothing permeability coefficient, are adjusted as a function of the air speed corrected for movement of the wearer.[6] The effective air speed can be estimated as:

$$v_{eff} = v_{air} + 0.004\,(M-105), \; m/s \qquad (4)$$

Preceding page blank

The effective clothing insulation coefficient is

$$\text{clo}^* = \text{clo}\ (v_{eff})^{-\gamma} \tag{5}$$

and the effective permeability index ratio is

$$\left(\frac{i_m}{\text{clo}}\right)^* = \frac{i_m}{\text{clo}}\ (v_{eff})^{\gamma} \tag{6}$$

where γ is a velocity modifier (see Appendix C).

The required evaporative cooling E_{req} is the total heat load (metabolic rate minus external work) plus the environmental heat load (radiation plus convection)

$$E_{req} = M_{net} + E_{R+C} \tag{7}$$

where

$$M_{net} = M - 0.98 m_t vG,\ W$$

and

$$E_{R+C} = \frac{6.47A}{\text{clo}^*}(T_a - T_s),\ W \tag{8}$$

so that

$$E_{req} = M - 0.098 m_t vG + \frac{6.47A}{\text{clo}^*}(T_a - T_s),\ W \tag{9}$$

where

T_a = ambient dry bulb temperature, °C

T_s = estimated equilibrium skin temperature, °C

The maximum evaporative capacity from the skin through the clothing and trapped air layers to the environment[b] is expressed as

$$E_{max} = (14.2A)\left(\frac{i_m}{\text{clo}}\right)^*(44 - \phi_a P_w),\ W \tag{10}$$

where

44 = the water (sweat) vapor pressure, in mm Hg, at a skin temperature of 36°C

ϕ_a = percentage saturation of the ambient air (relative humidity)

P_w = saturated vapor pressure of water at ambient air temperature, mm Hg.

Although values for P_w are tabularized as a function of ambient temperature, P_w can be computed by[7] the relation

$$\log_{10} \frac{P_c}{P_w} = \frac{x}{T} \left[\frac{a + bx + cx^3}{1 + dx} \right] \tag{11}$$

where

P_w = saturated vapor pressure of water at ambient air temperature, in atmospheres (atm)

P_c = 218.167 atm

T = ambient temperature, °K

$\quad = T_a + 273.16$

$x = 647.27 - T$

$a = 3.2437814$

$b = 5.86826 \times 10^{-3}$

$c = 1.1702379 \times 10^{-8}$

$d = 2.1878462 \times 10^{-3}$

over the temperature range from 10°C to 150°C.

C. Rectal Temperature Predictive Equations.

The combined effect of metabolic and environmental heat stress on rectal temperature of acclimatized men is evaluated[6] by the final equilibrium rectal temperature

$$T_{ref} = 36.75 + T_{re}(M) + T_{re}(R+C) + T_{re}(E) \tag{12}$$

Equation 12 is comprised of four components:

(1) basal metabolic rate temperature (36.75°C)

(2) added temperature due to metabolic load,

$$T_{re}(M) = 0.004 \ (M \quad 0.098 m_t v G), \ ^\circ C \tag{13}$$

(3) change (+ or −) in temperature due to radiation and convection of the environment.

$$T_{re}(R+C) = \left(\frac{0.014A}{clo^*} \right) (T_a - T_s) \tag{14}$$

and

(4) added temperature due to evaporation

$$T_{re}(E) = 0.8 \exp[0.0047(E_{req} - E_{max})] \tag{15}$$

The difference in the initial rectal temperature between nonacclimatized and fully acclimatized men was estimated[8] to be -0.5°C and has been assumed to decrease exponentially[8] as:

$$\Delta T_{reo} = 0.5\exp(-0.3N) \tag{16}$$

where

N = days with previous exposure to work in heat

and

$$\exp(u) = 2.718^{(u)}$$

When the acclimatization process is interupted, some loss in acclimatization occurs, and Givoni estimated that, with each day of nonexercise in the heat, an equivalent of 1/2 day is lost.[8]

The differences between nonacclimatized and partially acclimatized subjects as an exponential function of the elevation of the equilibrium temperature above the predicted initial level for acclimatized subjects at rest (T_{reo} = 37.15°C) was studied by Givoni and Goldman.[6,8] The empirical expression obtained for the change, ΔT_{ref} in the equilibrium rectal temperature, beyond the initial difference is

$$\Delta T_{ref} = 1.2\left\{1 - \exp[0.5(T_{reo} - T_{ref})]\right\} \tag{17}$$

Accounting for days of work in the heat, equation 17 becomes

$$\Delta T_{ref}(accl) = \exp(-0.3N)\,[0.5 + \Delta T_{ref}] \tag{18}$$

In addition, the above difference can be modified by the evaporative capacity of the environment, so that the total change of equation 18 will be

$$\Delta T_{ref}(accl) = \exp(-0.3N)\,[0.5 + \Delta T_{ref}]\,[1 - \exp(-0.005 E_{max})] \tag{19}$$

At rest, the time pattern of the rectal temperature is formulated by[6]

$$T_{re}(t, rest) = T_{rei} + \Delta T_{re}\,(0.1)^{0.4(t-0.5)} \tag{20}$$

where

T_{rei} = initial rectal temperature, °C

ΔT_{re} = $(T_{ref} - T_{rei})$

t = time, hr

It should be noted that when t is allowed to approach infinity, in equation 20, $T_{re}(t, rest)$ equals T_{ref} of equation 12.

The time pattern of rectal temperature during work was described[6] in the form

$$T_{re}(t, work) = T_{rei} + \Delta T_{re} \left\{1 - \exp[\tau(t_d - t)]\right\} \quad (21)$$

where

t_d = initial time lag, hr

= 58/M

τ = time constant, °C/hr

= $2 - 0.5(\Delta T_{re})^{1/2}$*

During the interval $0 \leq t < t_d$, the rectal temperature response continues to follow the resting pattern, so that

$$T_{re}(t, work) = \begin{cases} \text{equation 20}, & 0 \leq t < t_d \\ \text{equation 21}, & t \geq t_d \end{cases} \quad (22)$$

During recovery, the metabolic rate is relatively constant, and equals the resting rate (105 W). Although the rate of recovery depends on the level of T_{re} reached at the end of work, the inertia of T_{re} may continue to rise during the initial phase of recovery. The pattern of recovery has been described[6] as

$$T_{re}(t, recovery) = T_{re}(W) - [T_{re}(W) - T_{re}(R)] \left\{1 - \exp[\alpha(t_{drec} - t)]\right\} \quad (23)$$

where

$T_{re}(W)$ = rectal temperature at the beginning of decrease, °C

$T_{re}(R)$ = equilibrium resting rectal temperature, °C

α = recovery time constant, hr

= $1.5[1 - \exp(-1.5\ CP)]$

t_{drec} = recovery time lag, hr

= $0.25 \exp(-0.5\ CP)$

and CP is the cooling power of the environment (see equation 31).

It should be noted that $T_{re}(W)$ is not necessarily equal to T_{re} at the end of work, since the body temperature continues to rise, but at a lower rate than during work. It has been assumed that this rate of rise is one-half of the rise predicted by equation 23.[6]

* In the computer program, τ has been modified to be equal to $0.5 + 1.5 \exp[-0.3\ \Delta T_{re}]$.

D. Heart Rate Predictive Equations

Givoni and Goldman[8] assumed that (a) the equilibrium heart rate decreased exponentially with the duration of the acclimatization process, and that (b) the nonacclimatized heart rate decreased according to the relationship.

$$1 - \exp(0.005E_{max}) \tag{24}$$

Based upon these two assumptions, the equilibrium heart rate for partially acclimatized subjects is given as

$$HR_{f(N)} = HR_f + \Delta HR_{(accl)} \exp(-0.3N), \text{ bpm} \tag{25}$$

where

HR_f = equilibrium heart rate for fully acclimatized subjects due to heart rate index

The term $\Delta HR_{(accl)}$, due to the acclimatization process, is given by[8]

$$\Delta HR_{(accl)} = 40 \left\{1 - \exp[0.04(HR_i - HR_f)]\right\} \left\{1 - \exp(-0.005\,E_{max})\right\} \tag{26}$$

where

HR_i = initial heart rate, bpm

The term HR_f is computed according to the heart rate index,[9] I_{HR}:

$$I_{HR} = 0.4M + \left(\frac{1.39A}{clo^*}\right)(T_a - T_s) + 80 \exp\left\{0.0047(E_{req} - E_{max})\right\} \tag{27}$$

HR_f is then computed from the level of I_{HR} from equation 27 as:

$$HR_f = \begin{cases} 65 + 0.35\,(I_{HR} - 25), & 0 \leq I_{HR} \leq 225 \\ 135 + 42\left\{1 - \exp(225 - I_{HR})\right\}, & I_{HR} > 225 \end{cases} \tag{28}$$

The time pattern of the heart rate at rest is given by[9]

$$HR(t)_{rest} = HR_i + \Delta HR[1 - \exp(-3t)] \tag{29}$$

where

$\Delta HR = HR_{f(N)} - HR_i$

t = exposure time, hr

During work, or other physical activity, the time pattern of the heart rate is given by[9]

$$HR(t)_{work} = HR_{iw} + \Delta HR \left\{1-0.8\exp[-(6-0.03\Delta HR)t]\right\} \tag{30}$$

where

HR_{iw} = initial heart rate at the beginning of work.

The time pattern of the decrease in the heart rate during a recovery phase depends on the effective cooling power CP of the environment[9] by dry heat exchange and evaporation, given by

$$CP = 0.15A\left(\frac{i_m}{clo}\right)^{*} (44-\phi_a P_w) + \left(\frac{0.097A}{clo^{*}}\right)(T_s-T_a)-1.57 \tag{31}$$

Therefore,

$$HR(t)_{recovery} = HR_w-(HR_w-HR_f)\,[1-\exp(-kbt)] \tag{32}$$

where

HR_w = heart rate at the end of the work period

HR_f = equilibrium heart rate for resting at the given climatic and clothing conditions (by equation 28)

$k = 2-0.01(HR_w-HR_f)$

$b = 2 + 12\,[1-\exp(-0.3CP)]$

III. COMPUTER PROGRAM.

A. Introduction.

The computer program for the HP-9810A programmable calculator has been written in a conversational mode of questions and answers. The following discussion assumes that the user is familar with the operation of the HP-9810A, the plotter, and cassette memory, using the "MATH PACK" ROM. The procedure for data entry, and program execution is described below.

B. Data Entry.

1. Standard Data?

This program has provisions for entering typical values for the input parameters.

If standard data (yes) is to be used,
press.

SET FLAG then CONTINUE

If standard data (no) is not used,
press:

CONTINUE

2. Skip Input List?

If yes, press:

SET FLAG then CONTINUE

If no, press:

CONTINUE

3. Input Parameters.

Standard values will be displayed: metric units in the X-register, and equivalent English unit in the Y-register. A standard value may be changed:

a. If in metric units, enter value in the X-register and then press:

CONTINUE

b. If in English units, enter value in the X-register and press:

SET FLAG then CONTINUE

Each parameter has an integer which corresponds to its memory-storage register location.

Thus:

<u>Location Parameter.</u>

10–HEIGHT, CM

11–WEIGHT, KG

12–TOTAL SKIN AREA, SQ M

Calculated by Equation 3.

13–EFFECTIVE (EFF) SKIN AREA, SQ M

The effective skin area is the total skin area less the areas of impermeable surfaces.

14–INITIAL (INT) RECTAL TEMPERATURE, °C

The initial rectal temperature which has equilibrated with resting.

15–INT HEART RATE, BPM

16–SKIN TEMPERATURE, °C

Usually equilibrium skin temperature is estimated to be 36°C for a clothed, fully sweat wetted man, and 35°C for a nude man.

17–DAYS IN HEAT

Acclimatization factor; subtract 1/2 day for each day skipped.[8]

18–LOAD, KG

This is the total weight carried (clothing, equipment, etc).

19–WALK SPEED, M/S

20–% GRADE

21–TERRAIN FACTOR

See Appendix A.

Location Parameter.

22 -METABOLIC (METAB) LOAD, WORK 1

This is the metabolic load, in watts, for the first work period, according to equation 1. If the work load does not consist of walking, ignore items 18, 19, 20, and 21, and enter metabolic load directly.[4]

23 METAB LOAD, WORK 2

24 CLO COEFFICIENT

Use clo value which is uncorrected for air speed and metabolic load – See Appendix B.

25 IM/CLO COEFFICIENT (UNCORRECTED) - See Appendix B.

26 VELOCITY MODIFIER

The value of the exponent of equations 5, 6. See Appendix C.

27 WIND SPEED, M/S (UNCORRECTED)

28 DRY BULB TEMPERATURE, °C

Use ambient temperature.

29 RELATIVE HUMIDITY

The relative humidity of the ambient air.

30 INITIAL REST

Time of the initial rest period in minutes.

31 1ST WORK

Time of the first work period in minutes.

32 1ST RECOVERY

Time of the first recovery period in minutes.

33 2ND WORK

34 2ND RECOVERY

35 TIME INTERVAL OF PRINTOUT

99 OUTPUT MASK

0 or 1 to indicate no or yes respectively A 4 digit number is used to select desired outputs of calculated values.

1st digit = time series of heart rate and rectal temperature?

2nd digit = final values of intermediate equations?

3rd digit = plot of rectal temperature only?

4th digit = plot of heart rate only?

For example, if all options are desired, the output mask = 1111.

If only the plots of heart rate and rectal temperature are desired, output mask = 0011.

4. CHANGES?

If there are any changes desired, enter the parameter number in the Y-register and the new value (metric units only!) in the X-register, press:

then

If no changes, press:

5. Calculated Values.

If this option of the output mask is desired, the values of the following parameters will be printed for each phase of activity:

a. WINDSPEED (UNCORRECTED), M/SEC.

b. DRY BULB TEMPERATURE, °C.

c. % RELATIVE HUMIDITY.

d. METABOLIC RATE, WATTS – Equation 1.

e. TRE(M) – Equation 13.

f. TRE(R+C) – Equation 14.

g. TRE(E) – Equation 15.

h. TRE(F) – Equation 12.

i. TRE(F,ACCL) – Equation 19.

j. I(HR) – Equation 27.

k. HR(F) – Equilibrium heart rate, Equation 25.

l. E(REQ) – Equation 9.

m. E(MAX) – Equation 10.

n. WET SKIN, % – Equal to E(REQ)/E(MAX)

o. COOLING POWER – Equation 31.

p. CLO – Effective clo value, Equation 5.

q. IM/CLO – Effective i_m/clo value, Equation 6.

6. RESET INITIAL T(RE) AND HR?

7. DRAW AXES?

If yes, will draw axes for plotting; if no, will plot only rectal temperature and heart rate curves, depending on the output mask.

8. REPEAT SAME MAN?

IV. SUMMARY.

The mathematical basis for predicting heart rate and rectal temperature response to work, environment, and clothing has been presented. In addition, a brief guide for the use of this computer program for the HP-9810A programmable calculater is also discussed, complemented by a sample computer run.

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APPENDIX A

TERRAIN COEFFICIENT (η)

Soule and Goldman* give recommended values for η (in equation 1) for use when moderate loads of 10 to 40 kg are carried.

Terrain	η
Treadmill	1.0
Blacktop surface	1.0
Dirt road	1.1
Light brush	1.2
Heavy brush	1.5
Swampy bog	1.8
Loose sand	2.1

* Soule, R. G., and Goldman, R. F. Terrain Coefficients for Energy Cost Prediction. *J. Appl. Physiol. 32*, 706-708 (1972).

APPENDIX B

CLOTHING INSULATION AND EVAPORATIVE IMPEDANCE

A representative list of clothing insulation (clo) and evaporative impedance (i_m/clo) values for military uniforms and CB ensembles have been tabulated by Goldman,* as derived from studies on a "sweating copper man."

Uniform	clo	i_m/clo
None	0.78	0.75
Coveralls. lightweight, standard cotton	1.29	0.39
Jacket and trousers (fatigues)	1.33	0.37
Old utility uniform (8.5 oz)	1.56	0.31
New utility uniform (8.2 oz)	1.40	0.34
Combat, tropical	1.43	0.34
CB overgarment, alone	1.64	0.27
CB liner, standard	1.65	0.26
CB overgarment, over combat tropical	2.11	0.23
CB overgarment, over utility ensemble (8.2 oz)	2.07	0.22
CB overgarment, over CB liner ensemble	2.15	0.22
1/4 length plastic raincoat,over fatigues	1.45	0.28
1/2 length plastic raincoat, over fatigues	1.48	0.24
3/4 length plastic raincoat, over fatigues	1.62	0.20
Full length plastic raincoat, over fatigues	1.70	0.16
Standard poncho, over fatigues	1.83	0.11
Add for protective,mask, hood and gloves	+0.25	-0.07
Add for armored vest:	+0.15	-0.04
Add for protective mask, hood, gloves and armored vest	+0.40	-0.11

* Goldman, R. F. Systematic Evaluation of Thermal Aspects of Air Crew Protective Systems. AGARD Conference Proceedings No. 25, Behavioral Problems in Aerospace Medicine, October, 1967, Rhode-Saint-Genese, Belgium.

APPENDIX C

VELOCITY MODIFIER (γ)

The velocity modifier, γ, corrects clo and i_m/clo values for the effective wind velocity, i.e. equations 5,6. For clo values, γ is negative, but is positive for i_m/clo values. The magnitude of γ ranges from 0.2 to 0.3 depending on clothing permeability and surface characteristics. Theoretically, if the clothing is tight fitting $\gamma \rightarrow 0.20$; otherwise, for high permeability types, $\gamma \rightarrow 0.30$ (see reference 6). An average value of 0.25 will not affect the final results dramatically unless the wind speed is unusually high.

APPENDIX D

SAMPLE COMPUTER PRINTOUT

I. INTRODUCTION.

The following sample printout was based on a hypothetical situation of first testing a nude man and subjecting him to a two-cycle work and recovery test following an initial rest period and at specified environmental conditions. For each test phase, the numerical results of the intermediate equations are printed, the axes drawn, and the resultant time pattern of rectal temperature, denoted by triangles, and heart rate (solid line), shown in figure D-1. Since the output mask = 1111, the values of temperature and heart rate at 5 minute intervals are also printed.

It was then desired to repeat the same "man" wearing standard fatigues, but with a single work and recovery cycle, different from the first case. The output mask has been changed to only plot the temperature and heart rate curves (figure D-2). In this run, it can be seen that both curves exceeded the maximum scale limits of 170 bpm and 40°C.

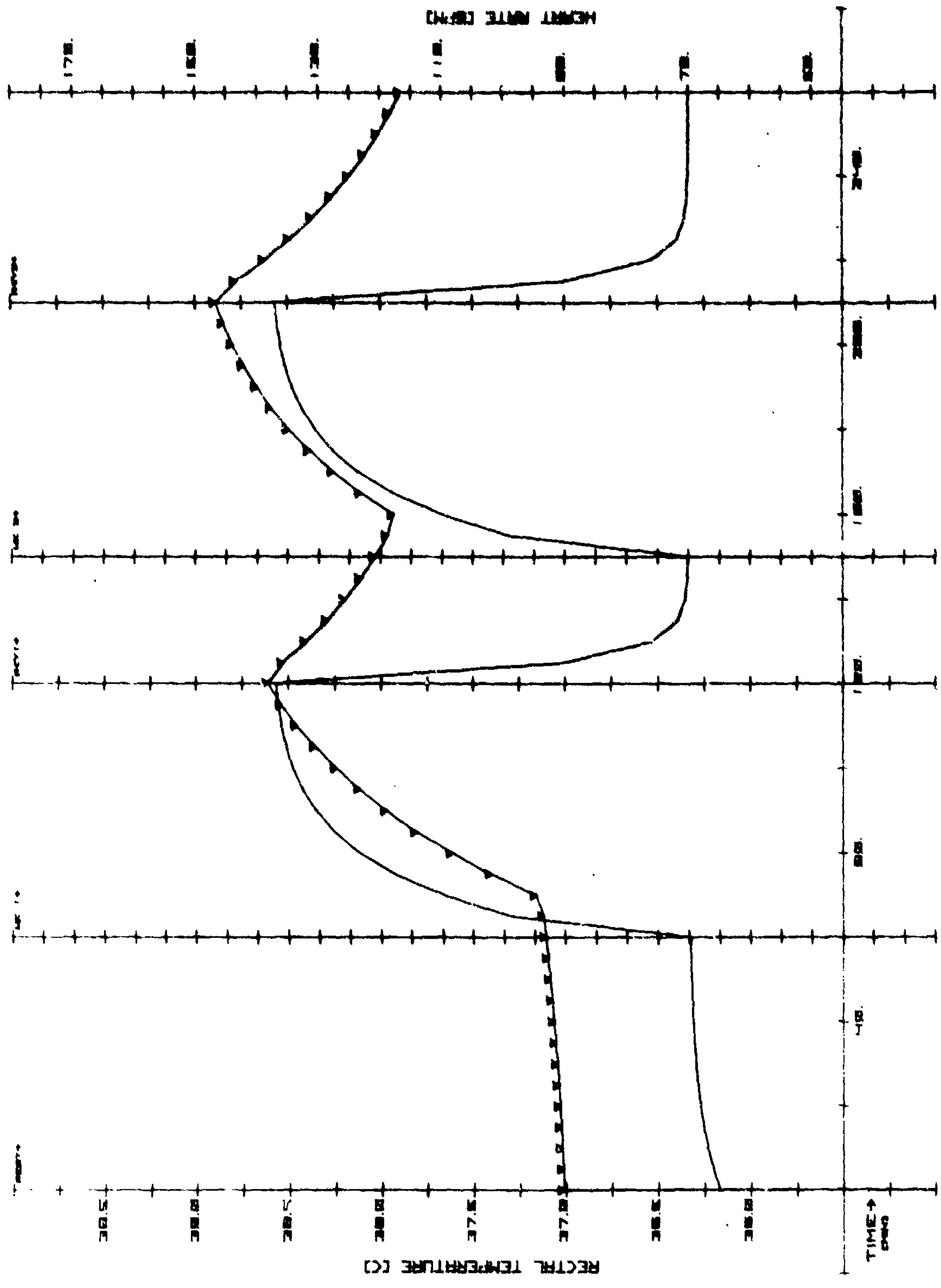

Figure D-1. Heart Rate and Rectal Temperature against Time, Unclothed Man, Two-Cycle Work and Recovery Test

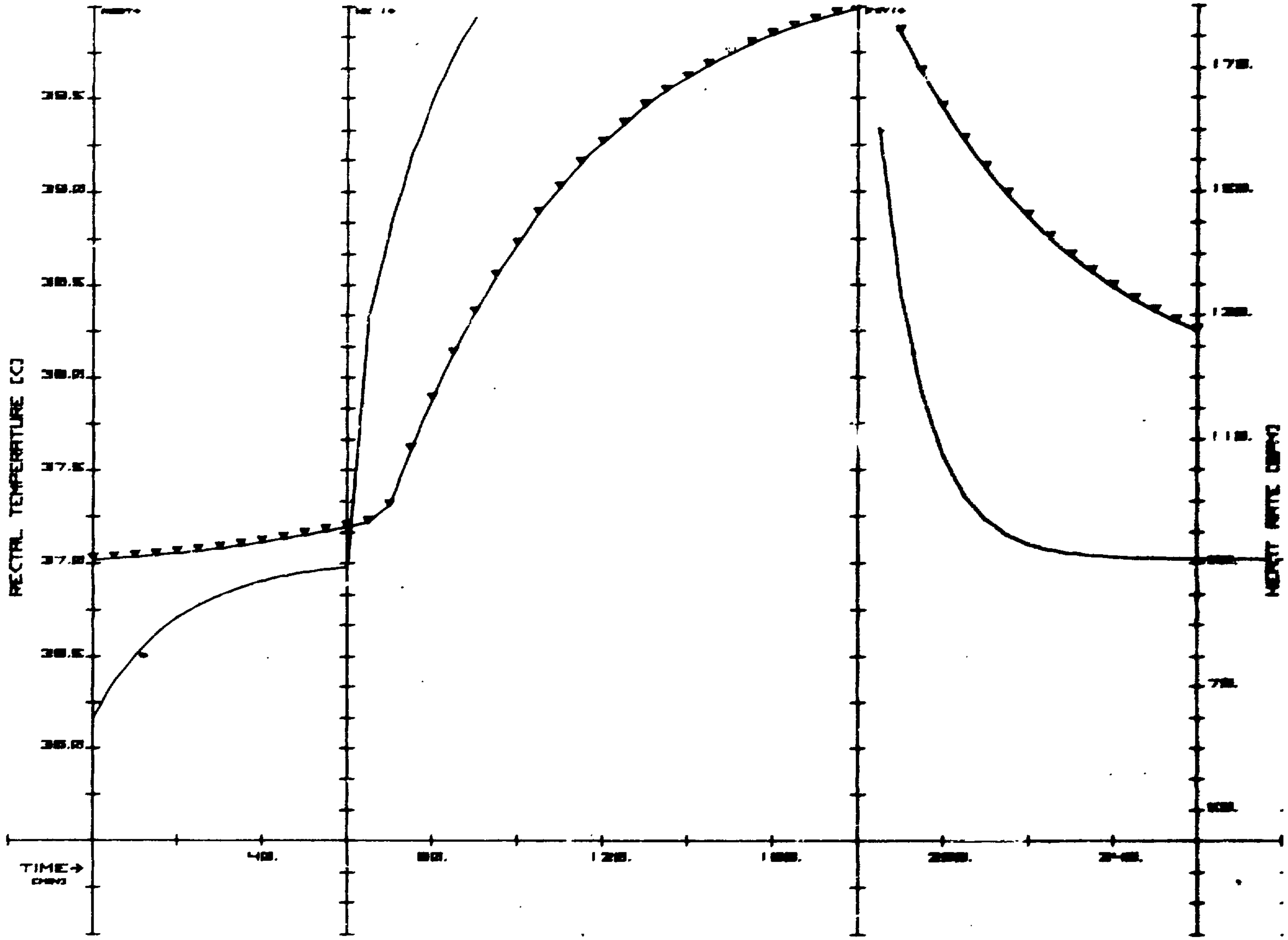

Figure D-2. Man in Standard Fatigues, Single Work and Recovery Cycle: Heart Rate and Rectal Temperature against Time

II. THE PRINTOUTS.

```
STANDARD DATA ?

SKIP INPUT LIST?

READY

10→ HEIGHT, CM
        171.45

11→ WEIGHT, KG
        68.04

12→ TOTAL SKIN
    AREA, SQ M
        1.80

13→ EFF. SKIN
    AREA, SQ M
        1.80

14→ INT. RECTAL
    TEMP., DEG. C
        37.00

15→ INT. HEART
    RATE, BPM
        65.00

16→ SKIN TEMP
    DEG. C
        36.00

17→ DAYS IN HEAT
        0.00

18→ LOAD, KG
        0.00

19 →WALK SPD, M/S
        1.50

20→ % GRADE
        0.00

21→ TERR. FACTOR
        1.10

22→ METAB. LOAD
    WORK 1, WATTS
        367.81

23→ METAB. LOAD
    WORK 2, WATTS
        367.81

24→ CLO COEFF.
        0.78

25→ IM/CLO COEFF.
        0.75

26→ VEL. MODIFIER
        0.25

27→ WIND SPD, M/S
        1.50

28→ DRY BULB TEMP
    DEG. C
        30.00

29→ REL. HUMIDITY
        75.

DURATION OF TIME
PERIODS, MINUTES

30→ INITIAL REST
        60.

31→ 1ST. WORK
        60.

32→ 1ST. RECOVERY
        30.

33→ 2ND. WORK
        60.

34→ 2ND. RECOVERY
        50.

35→ TIME INTERVAL
    OF PRINTOUT
        5.

99 → OUTPUT MASK
        1111.

ENTRIES COMPLETE
```

REST	WORK 1	RECOVERY 1
CHANGES ?	CHANGES ?	CHANGES ?
WIND SPEED, M/S	WIND SPEED, M/S	WIND SPEED, M/S
1.50	1.50	1.50
DRY BULB TEMP, C	DRY BULB TEMP, C	DRY BULB TEMP, C
30.0	30.0	30.0
% REL. HUMIDITY	% REL. HUMIDITY	% REL. HUMIDITY
75.	75.	75.
METAB RATE, WATT	METAB RATE, WATT	METAB RATE, WATT
105.	368.	105.
TRE (M)	TRE (M)	TRE (M)
0.42	1.47	0.42
TRE (R+C)	TRE (R+C)	TRE (R+C)
-0.21	-0.24	-0.21
TRE (E)	TRE (E)	TRE (E)
0.10	0.25	0.10
TRE (F)	TRE (F)	TRE (F)
37.06	38.23	37.06
TRE (F.ACCL)	TRE (F. ACCL)	TRE (F. ACCL)
0.40	0.92	0.40
I (HR)	I (HR)	I (HR)
31.07	147.84	31.07
HR (F)	HR (F)	HR (F)
70.	138.	70.
E (REQ)	E (REQ)	E (REQ)
6.	255.	6.
E (MAX)	E (MAX)	E (MAX)
439.	501.	439.
% WET SKIN	% WET SKIN	% WET SKIN
1.	51.	1.
COOLING POWER	COOLING POWER	COOLING POWER
4.52	5.38	4.52
CLO	CLO	CLO
0.70	0.62	0.70
IM/CLO	IM/CLO	IM/CLO
0.83	0.95	0.83
++*+*+*+*+*+*+	*+*+*+*+*+*+*+*+	*+*+*+*+*+*+*+*+

WORK 2

CHANGES ?

WIND SPEED, M/S
1.50
DRY BULB TEMP, C
30.0
% REL HUMIDITY
75.
METAB RATE, WATT
368.
TRE(M)
1.47
TRE (R+C)
-0.24
TRE (E)
0.25
TRE (F)
38.23
TRE (F. ACCL)
0.92
I (HR)
147.84
HR (F)
138.
E (REQ)
255.
E (MAX)
501.
% WET SKIN
51.
COOLING POWER
5.38
CLO
0.62
IM/CLO
0.95
++*+*+*+*+*+*+

RECOVERY 2

CHANGES ?

WIND SPEED, M/S
1.50
DRY BULB TEMP, C
30.0
% REL HUMIDITY
75.
METAB RATE, WATT
105.
TRE(M)
0.42
TRE (R+C)
-0.21
TRE (E)
0.10
TRE (F)
37.06
TRE (F. ACCL)
0.40
I (HR)
31.07
HR (F)
70.
E (REQ)
6.
E (MAX)
439.
% WET SKIN
1.
COOLING POWER
4.52
CLO
0.70
IM/CLO
0.83
++*+*+*+*+*+*+

RESET INITIAL
T (RE) AND HR ?

DRAW AXES ?

REST PERIOD

TIME
RECTAL TEMP
HEART RATE

0. *
37.01
65.

5.
37.02
66.

10.
37.02
67.

15.
37.03
68.

20.
37.03
68.

25.
37.04
69.

30.
37.05
69.

35.
37.05
69.

40.
37.06
69.

45.
37.07
69.

50.
37.08
70.

55.
37.09
70.

60.
37.11
70.

1ST WORK PERIOD			1ST RCY PERIOD			2ND WORK PERIOD		
TIME	RECTAL TEMP	HEART RATE	TIME	RECTAL TEMP	HEART RATE	TIME	RECTAL TEMP	HEART RATE
0.	37.11	70.	0.	38.61	137.	0.	38.03	70.
5.	37.12	99.	5.	38.53	90.	5.	37.96	99.
10.	37.16	110.	10.	38.40	76.	10.	37.93	110.
15.	37.40	118.	15.	38.29	72.	15.	38.11	118.
20.	37.62	123.	20.	38.19	71.	20.	38.25	124.
25.	37.81	128.	25.	38.11	70.	25.	38.38	128.
30.	37.97	131.	30.	38.03	70.	30.	38.49	131.
35.	38.12	133.				35.	38.59	133.
40.	38.24	134.				40.	38.67	134.
45.	38.35	135.				45.	38.74	135.
50.	38.45	136.				50.	38.80	136.
55.	38.54	137.				55.	38.85	137.
60.	38.61	137.				60.	38.89	137.

2ND RCY PERIOD

TIME
RECTAL TEMP
HEART RATE

0.
38.89
137.

5.
38.78
90.

10.
38.62
76.

15.
38.49
72.

20.
38.36
71.

25.
38.26
70.

30.
38 16
70.

35.
38.08
70.

40.
38.01
70.

45.
37.94
70.

50.
37.89
70.

REPEAT SAME
MAN ?

REST

CHANGES ?

PARAMETER NUMBER
18.
WAS CHANGED FROM
0.000
TO
5.000

COMPUTED METAB.
RATE IS NOW
394.837
PARAMETER
22 AND/OR 23
MUST BE CHANGED
IF, APPROPIATE.

CHANGES ?

PARAMETER NUMBER
22.
WAS CHANGED FROM
367.808
TO
394.837

CHANGES ?

PARAMETER NUMBER
31.
WAS CHANGED FROM
60.000
TO
120.000

CHANGES ?

PARAMETER NUMBER
32.
WAS CHANGED FROM
30.000
TO
140.000

CHANGES ?

PARAMETER NUMBER
33.
WAS CHANGED FROM
60.000
TO
0.000

CHANGES ?

PARAMETER NUMBER
34.
WAS CHANGED FROM
50.000
TO
0.000

CHANGES ?

PARAMETER NUMBER
99.
WAS CHANGED FROM
1111.000
TO
11.000

CHANGES ?

PARAMETER NUMBER
24.
WAS CHANGED FROM
0.780
TO
1.330

CHANGES ?

PARAMETER NUMBER
25.
WAS CHANGED FROM
0.750
TO
0.370

CHANGES ?
WORK 1

CHANGES ?

RECOVERY 1

CHANGES ?
RESET INITIAL
T (RE) AND HR ?

DRAW AXES ?

REST PERIOD
1ST WORK PERIOD
1ST RCY PERIOD

REPEAT SAME
MAN ?