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Produced by the NASA Center for Aerospace Information (CASI)
This model is a combined, steady-state cardiovascular and thermal model. It was originally developed for interactive use by Dr. R. F. Walters, Department of Human Physiology, School of Medicine, University of California, Davis, California. The model has been converted to batch mode simulation for the Sigma 3 computer. The purpose of the model is to compute steady-state circulatory and thermal variables in response to exercise workloads and environmental factors. During a computer simulation run, several selected variables are printed at each time step. End conditions are also printed at the completion of the run.

R. C. Croston, Ph.D.
PROGRAM DESCRIPTION

A. IDENTIFICATION

Program Name - WALTERS
Programmer - R. C. Croston, GE/MSC, Houston
Date of Issue - April 6, 1972

B. GENERAL DESCRIPTION

This model is a combined, steady-state cardiovascular and thermal model. It was originally developed for interactive use by Dr. R. F. Walters, Department of Human Physiology, School of Medicine, University of California, Davis, California. The model has been converted to batch mode simulation for the Sigma 3 computer.

C. USAGE AND RESTRICTIONS

Machine and Compiler Required - XDS Sigma 3 and ANSI FORTRAN
Peripheral Equipment Required - Card reader and line printer
Approximate amount of memory required - 2,465 hexadecimal

D. PARTICULAR DESCRIPTION

Equations Used and Derivations - See final report of Contract NAS9-11657, Modification 2C.

Definition of Terms Used - Terms are defined in the referenced math model and in the following descriptions of input and output variables.

Detailed Description - The mathematical model is summarized here by a functional block diagram, Figure 1. The purpose of the model is to compute steady-state circulatory and thermal variables in response to exercise work loads and environmental factors. During a computer simulation run, several selected variables are printed at each time step. End conditions are also printed at the completion of the run.

E. DESCRIPTION OF INPUT

Control and Program Cards - (begin in card column 1)

;JOB
;ASSIGN SI=14 (026 Keypunch Code)
;ASSIGN F:5=3
;ASSIGN F:6=4
;FORTRAN
COMBINED STEADY-STATE CIRCULATORY AND THERMAL MODELS

WALTERS MODEL FUNCTIONAL BLOCK DIAGRAM

FIGURE 1.
(SOURCE DECK)

LOAD
$ROUT 256,0
$MP
END
XEQ

(DATA DECK)

END

Program Cards - Listed at the end of this document.

Data Cards — (Card columns, format, name definitions)

Columns 1-10, 11-20, etc., 8 parameters per card for a 8F10.0 format of the following list of required input data:

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<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
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</thead>
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<td>RESTING A-V DIFF, &quot;OTHER&quot;</td>
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Col. 1-10, 21-30, 41-50, 61-70  8F10.0  Time to change work rate (sec)
11-20, 31-40, 51-60, 71-80  8F10.0  Work rate in KPM/min

(Seven of the above cards are required for a complete schedule.)

Time (seconds), oxygen uptake (ml/min), ventilation (ml/min), heart rate (beats/min), cardiac output (ml/min), body temperature (°C), and skin temperature (°C).

**F. DESCRIPTION OF OUTPUT**

The following variables are printed on the line printer. A sample printout is shown in Figure 2.
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**SUMMARY OF CONDITIONS AT TIME OF STOP**

- **ENVIRONMENT**
- **TAIR = 23**
- **HUMIDITY = 0.5 PCT**
- **ATM PRESS = 760**
- **AIR SPEED = 0.2**
- **LEG HOOK = 33.5 mL O2/MIN**
- **ARM HOOK = 13.4**

- **BODY STATUS**
- **BODY TEMP = 34.35°C**
- **SKIN TEMP = 32.7**
- **VENTILATION = 6166.2**
- **O2 UPTAKE = 246.6**
- **CARDIAC OUTPUT = 4945.7**
- **HEART RATE = 59.3**

- **OXYGEN DEBTs**
- **CORRIMARY = 0.4**
- **LEG = 11.4**
- **ARM = 0.1**
- **LEG RATE = 2,386 ML O2/MIN**
- **ARM RATE = 0.0**
C. INTERNAL CHECKS AND EXITS

Exit - A normal exit gives end conditions and a stop.

H. INDEPENDENT SUBROUTINES

None

I. SYSTEM SUBROUTINES

No special subroutines.

J. COMPLETION OR FINAL CHECKOUT DATE

April 6, 1972.

K. PROGRAM LISTING
C****
C000 WRITE (3) PRVAL
C NRECS=NRECS+1
C**** FIRST CHECK TO SEE IF STOP, PRINT, OR OTHER HALT PRINTS REACHED
C IF (ISTART+NE0) GO TO 4001
C WRITE (6)*1144) (PRNAM.(IPR1),I*1,JPR)
1144 FORMAT (1H,,3X6(AA,4X))
C WRITE (6,601)
C 601 FORMAT (1H TIME V02 V HR CA TB)
C * 'TSKN')
C READ(S*10)PRNT
C READ(S*21)W
C 27 FORMAT ((BF10.4),2F10.4)
C START=1
C001 IF (TIME.LT.STRPTH) GO TO 4010
C WRITE (6)*002)
C002 FORMAT ('* STOP TIME EXCEEDED, DO YOU WISH PLOT (Y/N)')
C READ (5,900) A(1)
C IF (A(1).EQ.0) GO TO 4005
C WRITE (6)*004)
C004 FORMAT ('* DO YOU WISH TO RESTART (Y/N)')
C READ (5,900) A(1)
C IF (A(1).EQ.0) GO TO 526
C GO TO 10000
C C4005 REMOVED PLOTTING ROUTINE
C 4010 IF (TIME.LT.PRPTH) GO TO 4020
C PRPTH=TIME+PRNT
C START=1
C IF (START-1) GO TO 4010
C WRITE (6)*1144) (PRNAM.(IPR1),I*1,JPR)
C START=1
C0105 WRITE (6)*012) (PRVAL(IPR1),I*1,JPR)
C CHANGED VARIABLE OUTPUT
C0105 WRITE(6,012)TIME,SP2,T,*VHR,CA, TB,TSKN
C012 FORMAT (1H,FR,16F9.1)
C**** TEMPORARY CONTINUE OPTION
C IPT=0
C CALL TREAD(A,ALFA,FP,IND,IPT)
C IF (IND*NE0) GO TO 1006
C**** END OF TEMPORARY SECTION
C C REMOVED VARIABLE INCREMENTING SECTION
C 0200 TIME**020
C IF (TIME-100) 26, 29, 29
C 26 CONTINUE
C**** START EXECUTION LOOP
C**** RESPIRATION RATE
C 0500 WRITE(IPR1)TS,SP2,IPR1
C WRITE (6)*111) V
C 11 FORMAT (1V,W*1,F10.1)
C**** BRAIN
C 0263*R263TS
C HBR = HBR + 000825
C**** INACTIVE MUSCLE
C 233
4085 HTARM=HTARM+(1*EFARMX*20+ARMX+2ARMX+0.75+1/2ARMX*EFARMX
+2ARMX)*0.3+1.05/25+1.285*TS

C00 SK = 0.832K + 15

4090 HTSK=32SK * 0.0+425

C00 RESPIRATORY COMPARTMENT

C00 CALCULATE TOTAL NON-RSPEQ O2 CONSUMPTION

PCWSP = (M2BR+2ARMX+2ARMX+2ARMX+2ARMX+2ARMX+2ARMX+2ARMX+2ARMX+2ARMX)

IF (PCWSP = EQ.2XPREF) GO TO 4100

PCRSD = 1+XRSPV/VMAX=4.5

IF (PCRSD - LE-01 PCRSD = 0.1)

PCRSD = PCWSD + PCRNS + 0.01

ORSP = 0.8XRSP / (1+PCRSD)

ORSP = ORSP/10

IF (ORSP/TS+LT>ORSPR) ORSP=ORSPR+TS

HTSP = 0.2RSP+0.04825

BFSP = BFRSP*(0.2RSP/TS)/ORSP+AVPSMX

ORSP=02RSP

4100 V = (2RT+TS/VUPTE)

C00 WRITE (6+10) M2LEG.20ARM.20COR.20RSP.1.0

C00 IF (VLT+VMAX) GO TO 4110

WRITE (6+102) V

4102 FORMAT (4 V EXCEEDS MAXIMUM ALLOWABLE VENTILATION RATE NOW."

4103 GO TO 1000

C00 SUM TOTAL BLOOD FLOW * * *

C00 IF (C0 = 0.25FLEG.20ARM.20COR.20RSP.BFRSP.BRSP)

C00 1 FORMAT (1 02/LEG.20ARM.20COR.20RSP.TOT/72/1.45/85)

HR=80/VS

C00 IF (HR+LT+VMAX) GO TO 4120

WRITE (6+112) HR

4112 FORMAT (1 HEART RATE "PROF.8.1", EXCEEDS MAXIMUM ""

4113 GO TO 1000

C00 HEAT BALANCE PORTION OF MODEL

4120 CONTINUE

C00 WRITE (6+14) HTOT,HTBR,HTARM,HTCOR,HTSKN,HTRSP,HTIM,HTOTH

C00 1 FORMAT (1 HT PROD (TOTO,HTBR,HTARM,HTCOR,HTSKN,HTRSP,HTIM,HTOTH)

C00 ' 1.510.5/" /61.50"

C00 CALCULATE VAPOR PRESSURE AT BODY TEMP

HWEX = 10**(-6.4051 - (2365/178 + 2373 + 1.11) + PRESS/101.3

HLS=0.84 + (0.242*WVEXP/VI + 2.182/1782 + 0.23 + 0.23 + TS

HTNET=HTTOT+HLS

C00 HEAT LOSS FROM SKIN BLOOD FLOW * * *

HLSKIN = 17.1 +A1*TSKN+TAIR+TS*0.8584/60.

C00 WRITE (6+93) TSKN,EFUN

C00 93 FORMAT (1 TSKN, EFSKIN/1,2F8.1)

C00 NOTE: OTHER WAYS TO CALCULATE SKIN T IS THIS BEST ***

WSMN = 10**(-6.4051 - (2365/178 + 2373 + 1.11) + PRESS/101.3

C00 CALCULATE HEAT LOSS THROUGH SWEATING * * *

IF (HR+LT+TSBW) GO TO 4150

IF (TSKIN+LT+29+0.1) GO TO 4150

HLSN = 2.4 + (178+TSBW)

HLSN = 11.70 + (VAIR+0.37) *(WVSKN+H) * AD * 0.8584/60

DTB=TSBW

IF (DTB=0.7+1) DTB=3.
BFSKIN=BFSKNR=BFSKW=0165=0.7/3
IF (THL=0.16+HL=0.8) GO TO 4158
THL=THL+X
IF (SKW) GO TO 4160
WRITE (6,*144) TIME
4146 FORMAT (1X, 'TIME IS', FD, 5:3, ' HEAT LOSS BY SWEATING NAR ',
AT MAX RATE ', 1, 1, 1
SHW=TRUE
GO TO 4160
4150 HLSW=0
BFSKIN=BFSKNR
OETHW=0
IF (NOT. SHW) GO TO 4160
WRITE (6,*141) TIME
4161 FORMAT (1X, 'TIME IS', FD, 5:3, ' HEAT LOSS BY SWEATING NAR 0.1',
BELONG MAX RATE ', 1, 1, 1
SHW=FALSE
GO TO 4160
4158 IF (NOT SHW) GO TO 4160
WRITE (6,*159) TIME
4159 FORMAT (1X, 'TIME IS', FD, 5:3, ' HEAT LOSS BELONG MAX RATE ',
1, 1, 1
SHW=FALSE
C**** CALCULATE NET HEAT BALANCE, NEW BODY TEMP = *
4160 TB = (HTVET + HLSW + HLSKIN) / (WGT + X) + TR
HTVET = HTVET + HLSKIN
IF (TATR + TMAX) GO TO 4170
WRITE (6,*162) TB
4162 FORMAT (1X, 'BODY TEMP (NOW ', FD, 5:3, ') EXCEEDS MAXIMUM!
GO TO 1000
C**** SUMMARIZE CHANGES; MOVE TO NEXT TIME STEP
4170 TIME = TIME + TB
C**** WRITE (6,*15) HLSW=FLWSKIN=FLSKIN
C 15 FORMAT (1X, 'HT LOSS ', FL, 16:3)
GO TO 4000
C**** SYSTEM HAS FAILED FOR ONE OF SEVERAL REASONS.
C**** PRINT OUT FINAL VALUES = *
10000 WRITE (6,*10002) TIME, T, R, M, PRESS, V, AIR, PR, E, R, L, ARM
10002 FORMAT (1X, 'SUMMARY OF CONDITIONS AT TIME OF STOP = ', FD, 16:3,
ENVIRONMENT / / TAIL = ', FD, 16:3, ' HUMIDITY = ', FD, 16:3, ' PCT ',
/ / ATM PRESS = ', FD, 16:3, ' AIR SPEED = ', FD, 16:3, ' LEG WORK = ', FD, 16:3
/ / M/02/IN/1 ARM WORK = ', FD, 16:3,
WRITE (6,*10004) TB, HLSW, HLSKIN, STMR, TOT/SH, SHR
10004 FORMAT (1X, 'BODY STATUS / / BODY TEMP = ', FD, 16:3, ' SKIN T',
/ / TEMP = ', FD, 16:3, ' VENTILATION = ', FD, 16:3, ' O2 UPTAKE = ',
/ / CARDIAC OUTPUT = ', FD, 16:3, ' HEART RATE = ', FD, 16:3,
WRITE (6,*10006) DBCD, DBLEG, DBARM, DDBL, DODBAR
10006 FORMAT (1X, 'OXYGEN DEBTS / / CORONARY = ', FD, 16:3
/ / LEG = ', FD, 16:3, ' ARM = ', FD, 16:3, ' LEG RATE = ', FD, 16:3
/ / M/02/IN/1 ARM RATE = ', FD, 16:3
C WRITE (6,*1161)
C HEAD(5,*400) = 0
C IFA(1:*NE*YES) GO TO 10019
C WRITE (3) PRAL
C VRECS = NRECS = 1
C GO TO 4000
C REPLACE STATEMENT NUMBERS 10019 AND 10020
C0019 WRITE (6,10020)
C0020 FORMAT (1X, 'DO YOU WISH TO RESTART MODEL (Y/N)'
C READ (5,900) A(1)