(NASA-CR-160220) USER'S INSTRUCTIONS FOR THE 41-NODE THERMOREGULATORY MODEL (STEADY STATE VERSION) (General Electric Co.) 33 p HC A03/MF A01 CSCL 06P

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PROGRAM DESCRIPTION GUIDE

A. IDENTIFICATION

Program Name - 41-Node Thermoregulatory Model (Steady State Version)

Programmer and Bioengineer Contact - J. I. Leonard, GE/TSS, Houston

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B. GENERAL DESCRIPTION

A mathematical model of the human thermoregulatory system, previously developed (References 1-9), has been further modified (Reference 10) to give it greater user flexibility and to provide a more accurate description of evaporative water losses due to respiration, skin diffusion and sweating. This is a steady state version of the more general transient model (Reference 11) and is capable of giving rapid predictions of the behavior of the human thermostat at equilibrium (i.e., a zero heat storage rate) in response to a wide range of environmental conditions, postures and metabolic expenditures.

The version presented here has been modified to operate in conversational mode using a remote terminal. Values for input parameters are entered prior to execution and the user has the capability of choosing among a large number of variables for output. An emphasis has been placed on printing out those variables directly concerned with evaporative loss rate. An additional flexibility has been incorporated to provide for ease of performing parameter estimation studies. These and other modifications which have been made to the previous steady state version have been documented in Reference 10.

C. USAGE AND RESTRICTIONS

Machine, Operating System, and Compiler Required - Univac 1106, EXEC 8, FORTRAN V

Peripheral Equipment Required - Time-Sharing Terminal

D. PARTICULAR DESCRIPTION

The model in its present form is the result of many years of development, modifications, and revisions by several institutions including the John B. Pierce Foundation, Lockheed Electronics Division, General Electric/Houston, and NASA-JSC. The equations used, their derivations and assumptions can be found in the following documents (listed in chronological order):

Reference 1 and 2: Descriptive papers by Dr. Stolwijk on the basic formulation of the model. Includes comparison of model behavior with some experimental data.

Reference 3: A complete computer program documentation of the Lockheed version of the Stolwijk model modified for use with space suits and liquid cooled garments. This version contains improved equations for convection, radiation and evaporation.

References 4-7: Brief documentations of the General Electric modifications to the Lockheed version. This version excludes all logic and data not pertaining to the shirtsleeve mode. Includes improved equations for the convective heat transfer coefficient and evaporative loss coefficient through clothing. A brief description of the steady state algorithm is found in Reference 7.

Reference 8 and 9: User's instructions for the General Electric version of both the steady state and transient models for use on the Xerox Sigma 3 and Univac 1110. Includes complete program listings and sample runs.

Reference 10: Detailed descriptions of modifications to the steady state version. A companion report to the present document. Includes validation of the respiratory and diffusion water loss segments.

A software block diagram of the updated steady state version is given in Figure 1. The transient version is similar with the exclusion of Subroutine CONVRG.

E. DESCRIPTION OF INPUT

1) The program prompts the user to specify the output lists and values for the input parameters. Sample runs are shown in Appendix 2. The program will first prompt the user to designate the output lists desired. The user can choose from one or more of six output lists (see Section F) and designates the choice by typing a "Y" under the numbers 1, 2, 3, 4, 5, or 6. This prompt occurs only on the first run of a series of runs. If the user wishes to modify the output list after this, the run must be aborted either normally (Section G) or with "@@X TIO" and re-executed with "@XQT".

2) The second prompt will be a question asking if a listing of input parameters is desired. User responds "Y" or "N". This list will contain the parameter name, the index number (1-13) and the internally stored value. This prompt only occurs during the first run of a series.

3) The third prompt will be instruction to change any of the 20 input parameters. Each parameter is designated by an index number and a variable name as shown in Table I. The pre-set internally stored values are given in parenthesis. Parameters can be modified by typing the index number of the parameter followed by the value. After all changes are made, the user types "-1" and this will be followed by a printout of the first 13 parameters. Parameters 14-20 will not be printed unless one of them has been changed from its internally stored value. This prompt will occur after each run. Any changes in input data will be carried over to subsequent runs automatically.

   If certain data is needed frequently to initialize any of the twenty input parameters they can be entered rapidly by placing them in file element "SSDATA" according to the format shown in Appendix 1. The user then simply types "@ADD SSDATA" following the prompt for input data.

4) If the model does not converge a message "CONVERGENCE NOT OBTAINED" will be printed. This will occur very infrequently. If it does, refer to Reference 10, Section 3 for instructions to obtain a satisfactory solution.

F. DESCRIPTION OF OUTPUT

The user can choose from one or more of six output lists. These are given in Table II where the FORTRAN name for each variable is given in place of a numeric value. Samples of actual runs are given in Appendix 2.

G. INTERNAL CHECKS AND EXITS

Program echoes back each input parameter value after it is typed. Program checks for invalid input and prompts user to re-enter the value if format is incorrect. On occasion a "READ ERROR" message will be printed even though data was entered correctly. The user should merely repeat the entry. Entry does not have to conform to numerical order of index number.

Program insures that values for VCAB must be greater than 0.0 and that values of POS are either 1.0, 2.0, or 3.0.

A normal exit is obtained after any run by typing "N" following the question "DO YOU WISH TO START NEW RUN?"

H. INDEPENDENT SUBROUTINES

All subroutines for this program (including source and relocatable elements) are stored in the file "THERM".

ELEMENT NAME	SUBROUTINE NAME	DESCRIPTION
THERMAL		Main program containing I/O commands
SHIRTS	SHIRT	Calculation of insensible heat losses
MANS	MAN	Thermoregulatory control section, calculation of evaporative water loss, blood flows, heat flows and temperatures
VPPSS	VPPS	Algorithm to compute water vapor pressure from saturation temperature
CONVRG	CONVRG	Convergence algorithm consisting of successive substitution and half-interval methods
SSDATA		Initialization data

I. COMPUTER PROGRAM LISTING AND EXAMPLE OUTPUT

Appendix 1 - Listing of main program, subroutines and data files

Appendix 2 - Sample runs

FIGURE 1

SOFTWARE BLOCK DIAGRAM

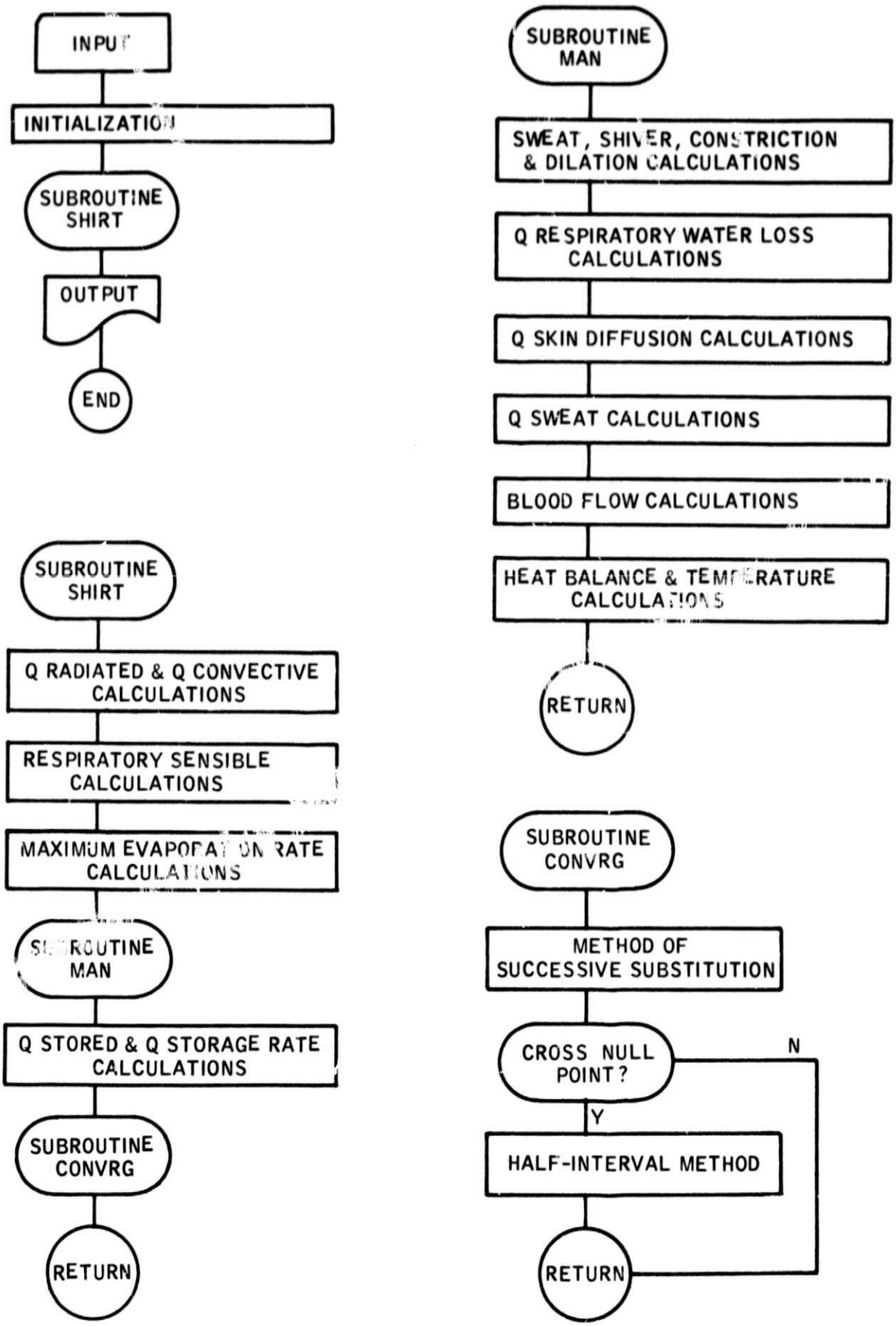

TABLE I

INPUT PARAMETERS

INDEX NO.	PARAMETER NAME	DESCRIPTION
1	RM	Metabolic rate, BTU/hr
2	QBASAL	Basal metabolic rate, BTU/hr
3	UEFF	Useful work efficiency, percent
4	POS*	*Position of subject (Standing = 1.0, Sitting = 2.0, Prone = 3.0)
5	TCAB	Cabin temperature, ^{o}F
6	TW	Temperature of walls, ^{o}F
7	TDEWC	Cabin dewpoint temperature, ^{o}F
8	VCAB	Cabin Free-stream velocity, ft/min
9	PCAB	Cabin pressure, psi
10	G	Gravity (Earth = 1.0, Moon = .167, Space = 0.0)
11	CLOV	Clothing resistance (clo units)
12	EUG	Emissivity of undergarment
13	CPG	Specific heat of gas, BTU/lb-^{o}F
14	EPSI	**Error criteria for convergence, BTU/hr (0.25)
15	NMAX	**Maximum number of iterations allowed (500)
16	DEBUG	**Switch for debugging routine (Off = 0.0, On = 1.0) (Normally off)
17	R1	**Sweat reabsorption parameter, BTU/hr (0.0)
18	R2	**Multiplier of sweat control parameters (1.0)
19	P1	**Multiplier of convection coefficients (1.0)
20	P2	**Multiplier of radiation coefficient (1.0)

* The body surface areas for convection and radiation are internally set to the following values according to the input value of POS:

POS	CONVECTIVE AREA(ft^2)	RADIATIVE AREA(ft^2)
1.0	19.5	15.5
2.0	15.5	11.5
3.0	12.5	9.5

** Normal values for these parameters are given in parenthesis. Printout of these parameters occurs only when their values are changed from normal

TABLE II

OUTPUT LISTS

EVAPORATIVE LOSS RATE AT STEADY STATE (GMS/HR)

LIST #1

RESPIRATION:	WRESP		
SKIN DIFFUSION:	WDIFF	DIFF MAX:	DMAX
SWEAT:	WSWEAT		
TOTAL INSENSIBLE LOSS:	WINSEN		
TOTAL SKIN LOSS:	WSKIN	SKIN EVAP. MAX:	EMAXTL
TOTAL EVAP. LOSS:	WEVAP		
WETTED AREA(%) FOR			
SKIN DIFF:	DIFWET		
SWEAT:	SWTWET		
SWEAT + DIFF:	WET		
DRIP:	DRIP		

LIST #2

TEMPERATURES - DEG F		BLOOD FLOW - L/MIN	
HEAD CORE:	T(1)	SKIN:	TSBF
TRUNK CORE:	T(5)	MUSCLE:	TMBF
CENTRAL BLOOD:	T(41)	TOTAL:	CO
AVG MUSCLE:	T(43)		
AVG SKIN:	T(42)		

LIST #3

HEAT BALANCE (BTU/HR)

QBASAL:	QBASAL	QSENS:	SQUG	QSTOR(BTU):	QSTOR
QWORK:	WORK	QEVAP:	QEVAP		
QSHIV:	QSHIV	STORAT:	STORAT		

LIST #4

CONTROLLER SIGNALS

SWEAT:	SWEAT	WARM(1):	WARM(1)
QSHIV:	QSHIV	COLD(1):	COLD(1)
DILAT:	DILAT	WARMS:	WARMS
STRIC:	STRIC	COLDS:	COLDS

LIST #5

BODY SURFACE TEMPERATURES - DEG F

	HEAD	TRUNK	ARMS	LEGS	HANDS	FEET
SKIN:	T(4)	T(8)	T(16)	T(20)	T(32)	T(40)
CLOTHING:	TUG(1)	TUG(2)	TUG(4)	TUG(6)	TUG(8)	TUG(10)

LIST #6

HEAT TRANSFER COEFFICIENTS

CONDUCTION:	
TOTAL BODY(BTU/HR):	SQUGW
FORCED CONVECTION COEF.,HC:	HC
NATURAL CONVECTION COEF.,HC1:	HC1
RADIATION:	
TOTAL BODY(BTU/HR):	SQUGA
RADIATION COEF.,HR:	HR
MAXIMUM EVAPORATION:	
TOTAL BODY(BTU/HR):	QMAXTL
FORCED CONVECTION COEF.,HE:	HE
NATURAL CONVECTION COEF.,HE1:	HE1
CLOTHING COEF.,HECL:	HECL
COMBINED COEF.,HEVAP:	HEVAP

TABLE III

GLOSSARY OF NEW TERMS

The following is a list of definitions of output terms that have been added to the original program. All definitions refer to total body effects rather than individual elements or segments.

CO = Cardiac output, liters/min
= TBF*0.454/60.0

DIFWET = Wetted skin area due to skin diffusion, percent WDIFF/EMAXTL*100.

DMAX = Maximum rate of water loss allowed for skin diffusion, gm/hr
= 0.06*EMAXTL

DRIP = Rate of water secretion due to sweating + diffusion that is greater than the maximum evaporation rate, gm/hr
= (WET/100.0 - 1.0)*EMAXTL

EMAXTL = Maximum evaporation possible from body surface, gm/hr
= GMAXTL*454.0/1040.0

QMAXTL = Maximum evaporation possible from body surface, BTU/hr
= 10
= $\sum_{I=1}$ EMAX(I)

SWTWET = Wetted skin area due to sweating, percent
WSWEAT/EMAXTL*100.0

WDIFF = Rate of water loss due to skin diffusion, gm/hr
= QD*454.0/1040.0

WET = Wetted skin area due to sweating and skin diffusion, percent
= (WDIFF + WSWEAT)/EMAXTL*100.0

WEVAP = Total evaporative loss due to respiration, diffusion and sweating, gm/hr
= WRESP + WDIFF + WSWEAT

WINSEN = Total insensible water loss (respiration + diffusion), gm/hr
= WRESP + WDIFF

WRESP = Water loss due to respiration, gm/hr
= QR*454.0/1040.0

WSKIN = Evaporative loss rate from skin surface, gm/hr
= WDIFF + WSWEAT

WSWEAT = Evaporative loss rate due to sweating, gm/hr
= QSWEAT*454.0/1040.0

REFERENCES

1. Stolwijk, J.A.J. 1970. Mathematical Model of Thermoregulation, Chapter 48 in "Physiological and Behavioral Temperature Regulation", Hardy, J.D., Gagge, A.P., and Stolwijk, J.A.J. (Ed), Charles C. Thomas, Springfield, Ill.

2. Stolwijk, J.A.J. 1971. "A Mathematical Model of Physiological Temperature Regulation in Man", National Aeronautics and Space Administration Contract NAS9-9531-Final Report.

3. Morgan, L.W., Collett, G., and Cook, D.W. "Computer Program Documentation: 41-Node Transient Metabolic Man Program", LEC/672-23-030031, NASA Contract NAS9-5384, Lockheed Electronics Company, Houston Aerospace Systems Division.

4. Smith, S.M. 1972. Simplification of 1108 Lockheed Version of Stolwijk Model and Incorporation of Improved Convective Heat Transfer Coefficient, TIR 750-MED-2004, General Electric Company, Space Division, Houston Programs.

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6. Smith, S.M. 1972. "Incorporation of Clothing Logic Contained in Stolwijk Amoeba Program into Simplified Lockheed Version of Stolwijk Model", TIR 750-MED-2006, General Electric Company, Space Division, Houston Programs.

7. Smith, S.M. 1972. Sigma 3 Steady State Version of Lockheed Program, TIR 741-MED-2011, General Electric Company, Space Division, Houston Programs.

8. Smith, S.M. 1973. Simplified 41-Node Stolwijk Metabolic Man Model (1108 Version), TIR 741-MED-3011, General Electric Company, Space Division, Houston Programs.

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10. Leonard, J.I. 1974. "Modifications to the Steady State 41-Node Thermoregulatory Model Including Validation of the Respiratory and Diffusional Water Loss Equations", TIR 741-MED-4014. General Electric Company, Space Division, Houston Operations.

11. Grounds, D.J. 1974. "Transient Thermoregulatory Model with Graphics Output", TIR 741-MED-4011. General Electric Company, Space Division, Houston Operations.

APPENDIX 1

FORTRAN PROGRAM LISTING OF MAIN PROGRAM

AND ALL SUBROUTINES

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6-G03432*TPFS*THERMAL
  1       CJOB  41-NODE THERMOREGULATORY STEADY STATE MODEL
  2             COMMON  T(43),TUG(10),ACE(10),ARE(10),PCAB,TCAB,RM,VPPCAB,
  3            *QSHIV,DILAT,STRIC,TOTL,QLCG,C(41),TSET(43),ERROR(41),
  4            *QEVAP,WORK,QBASAL,TBF,QRSTOL,TSBF,TMBF,QDIF(10),QSWEAT,
  5            *QRLEON,VRESP,HUMIN,HUMEXP,DEBUG,EPSI,NMAX,
  6            *TW,EUG,CLO,CPG,G,SQUG,QSTOR,TUGAV,U,VCAB,STORAT,
  7            *EMAX(10),QRSEN1,QRSEN2,QRSEN3,QRSEN5,QRSEN6,
  8            *QSEN(10),QRAD(10),HEVAP,HE,HE1,HECL,HR,HC,HC1,
  9            *WARMS,COLDS,SWEAT,QR,QD,QMAXTL,HCSAVE,HESAVE,
 10            *QVAP1,QVAP2,QVAP,WARM(41),COLD(41),NCOUNT,TOTAL,TSTEP,FLAG,
 11            *TN(40),SQUGA,SQUGW,R1,R2,P1,P2
 12             DIMENSION PCA(10)
 13             NAMELIST/OPTION/DEBUG,EPSI,NMAX
 14             NAMELIST/PARAM/R1,R2,P1,P2
 15             DATA R1,R2,P1,P2/0.0,1.0,1.0,1.0
 16             DATA DEBUG,EPSI,NMAX/0.0,0.25,500
 17             DATA PCA/.07,.3602,.06705,.06705,.1587,.1587,.025,.025,2*.0343/
 18             DATA TSET/98.53,95.13,94.66,94.24, 98.40,97.30,94.15,92.52,
 19            *          95.95,93.42,92.46,91.85, 95.95,93.42,92.46,91.85,
 20            *          96.46,95.54,95.56,93.38, 96.46,95.54,95.56,93.38,
 21            *          95.74,95.68,95.54,95.40, 95.74,95.68,95.54,95.40,
 22            *          95.25,95.05,95.20,95.07, 95.25,95.05,95.20,95.07,
 23            *          98.4,0.0,0.0,0.0/
 24             DATA C/4.89,0.727,0.485,0.529, 26.59,35.57,9.36,2.67,
 25            *       1.56,3.35,0.635,0.474, 1.56,3.35,0.635,0.474,
 26            *       4.67,10.10,1.58,1.19, 4.67,10.10,1.58,1.19,
 27            *       0.154,0.066,0.099,0.187, 0.154,0.066,0.099,0.187,
 28            *       0.254,0.0660,0.143,0.243, 0.254,0.0660,0.143,0.243,
 29            *       4.96/
 30       C
 31       C  DEFINITION OF BODY SEGMENT TEMPERATURE SUBSCRIPTS
 32       C  T(1)  = HEAD CORE          T(2)  = HEAD MUSCLE      T(3)  = HEAD FAT
 33       C  T(4)  = HEAD SKIN          T(5)  = TRUNK CORE       T(6)  = TRUNK MUSC
 34       C  T(7)  = TRUNK FAT          T(8)  = TRUNK SKIN       T(9)  = RIGHT ARM
 35       C  T(10) = RIGHT ARM MUSCLE   T(11) = RIGHT ARM FAT    T(12) = RIGHT ARM
 36       C  T(13) = LEFT ARM CORE      T(14) = LEFT ARM MUSCLE  T(15) = LEFT ARM F
 37       C  T(16) = LEFT ARM SKIN      T(17) = RIGHT LEG CORE   T(18) = RIGHT LEG
 38       C  T(19) = RIGHT LEG FAT      T(20) = RIGHT LEG SKIN   T(21) = LEFT LEG C
 39       C  T(22) = LEFT LEG MUSCLE    T(23) = LEFT LEG FAT     T(24) = LEFT LEG S
 40       C  T(25) = RIGHT HAND CORE    T(26) = RIGHT HAND MUSCLET(27) = RIGHT HANC
 41       C  T(28) = RIGHT HAND SKIN    T(29) = LEFT HAND CORE   T(30) = LEFT HAND
 42       C  T(31) = LEFT HAND FAT      T(32) = LEFT HAND SKIN   T(33) = RIGHT FOOT
 43       C  T(34) = RIGHT FOOT MUSCLE  T(35) = RIGHT FOOT FAT   T(36) = RIGHT FOOT
 44       C  T(37) = LEFT FOOT CORE     T(38) = LEFT FOOT MUSCLE T(39) = LEFT FOOT
 45       C  T(40) = LEFT FOOT SKIN     T(41) = CENTRAL BLOOD    T(42) = AVERAGE SK
 46       C  T(43) = AVERAGE MUSCLE
 47       C
 48       C
 49             DATA RM,QBASAL,UEFF,POS,TCAB,TW,TDEWC,VCAB,
 50            *PCAB,G,CLOV,EUG,CPG/
 51            *283.00,283.00,22.0,2.0,75.0,75.0,52.0,30.0,
 52            *14.7,1.00,0.30,0.95,0.220/
 53             DATA KY,KX/1HN,1HY/
 54             DATA K1,K2,K3,K4,K5,K6/1HN,1HN,1HN,1HN,1HN,1HN/
 55             WRITE (6,40)
 56        40 FORMAT (////'   41-NODE THERMOREGULATORY STEADY STATE MODEL'/
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```
     *  '   REFER TO GE-AGS USER GUIDE TIR 741-MED-4015'//)
C*****************************************************************
C
C     READ INPUT DATA
C
C*****************************************************************
      WRITE(6,45)
   45 FORMAT(//'0TO OBTAIN OUTPUT LISTS 1 - 6 WRITE "Y" ',
     * 'UNDER APPROPIATE NUMBER, THEN CR'/' 1 2 3 4 5 6 ')
      GO TO 49
   48 WRITE(6,92)
   49 READ(5,50,ERR=48) K1,K2,K3,K4,K5,K6
   50 FORMAT(6A2)
      WRITE(6,56)
   56 FORMAT(//,'0DO YOU WISH A LISTING OF INPUT PARAMETERS?
     *  (Y/N)  CR')
      READ(5,57) KK
   57 FORMAT(1A3)
      IF (KK .EQ. KY) GO TO 85
      WRITE(6,70)  RM,QBASAL,UEFF,POS,TCAB,TW,TDEWC,VCAB,
     *PCAB,G,CLOV,EUG,CPG
   70 FORMAT(//,'0INPUT PARAMETERS SET TO FOLLOWING VALUES:'/,
     *//'0INDEX', 4X, 'NAME', 5X, 'VALUE'/
     *  '  1',7X,'RM    =',F10.3/'  2',7X,'QBASAL=',F10.3/
     *'  3',7X,'UEFF  =',F10.3/'  4',7X,'POS   =',F10.3,5X,
     *'/'  5',7X,'TCAB  =',F10.3/
     *'  6',7X,'TW    =',F10.3/'  7',7X,'TDEWC =',F10.3/
     *'  8',7X,'VCAB  =',F10.3/
     *'  9',7X,'PCAB  =',F10.3/'  10',6X,'G     =',F10.3/
     *'  11',6X,'CLOV  =',F10.3/'  12',6X,'EUG   =',F10.3/
     *'  13',6X,'CPG   =',F10.3/)
   85 WRITE(6,90)
   90 FORMAT('0TO CHANGE INPUT,ENTER INDEX NO.(1-15), VALUE  ',
     * '(I2,E15.5)'/,
     *'0****WHEN LIST IS COMPLETED TYPE "-1", THEN CR****')
      GO TO 93
   89 CONTINUE
      WRITE(6,95)  I,VALNEW
   95 FORMAT(4X,3H***,I4,F10.4)
      GO TO 93
   91 WRITE(6,92)
   92 FORMAT('***READ ERROR***PLEASE TRY AGAIN***')
   93 READ(5,94,ERR=91)  I,VALNEW
   94 FORMAT(I2,E15.5)
      IF(I .LT. 0) GO TO 96
      IF(I .LT. 1 .OR. I .GT. 20) GO TO 91
      GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20), I
    1 RM = VALNEW
      GO TO 89
    2 QBASAL = VALNEW
      GO TO 89
    3 UEFF = VALNEW
      GO TO 89
    4 POS = VALNEW
      IF(POS .GT. 3.0 .OR. POS .LT. 1.0) GO TO 91
      GO TO 89
    5 TCAB = VALNEW
```

```
      GO TO 89
    6 TW = VALNEW
      GO TO 89
    7 TDEWC = VALNEW
      GO TO 89
    8 VCAB = VALNEW
      IF(VCAB .EQ. 0.0) GO TO 31
      GO TO 89
   31 VCAB = 1.0
      WRITE(6,32)
   32 FORMAT('0******VCAB NOT PERMITTED TO BE ZERO******')
      GO TO 89
    9 PCAB = VALNEW
      GO TO 89
   10 G = VALNEW
      GO TO 89
   11 CLOV = VALNEW
      GO TO 89
   12 EUG = VALNEW
      GO TO 89
   13 CPG = VALNEW
      GO TO 89
   14 EPSI = VALNEW
      GO TO 89
   15 NMAX = VALNEW
      GO TO 89
   16 DEBUG = VALNEW
      GO TO 89
   17 R1 = VALNEW
      GO TO 89
   18 R2 = VALNEW
      GO TO 89
   19 P1 = VALNEW
      GO TO 89
   20 P2 = VALNEW
      GO TO 89
   96 WRITE(6,70)   RM,QBASAL,UFFF,POS,TCAB,TW,TDEWC,VCAB,
     *PCAB,G,CLOV,EUG,CPG
      IF(DEBUG.NE.0.0.OR.EPSI.NE.0.25.OR.NMAX.NE.500)
     * WRITE(6,OPTION)
      IF(R1.NE.0.0 .OR. R2.NE.1.0 .OR. P1.NE.1.0 .OR. P2.NE.1.0)
     * WRITE(6,PARAM)
      CONTINUE
C*************************************************************
C
C     INITIALIZATION
C
C*************************************************************
      DO 100 I=1,43
  100 T(I)=TSET(I)
      DO 110 I=1,10
      J=4*I
  110 TUG(I)=T(J)
      IF(POS .EQ. 1.0) GO TO 120
      GO TO 125
  120 AC = 19.5
      AR = 15.5
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171             GO TO 150
172         125 IF(POS .EQ. 2.0) GO TO 130
173             GO TO 135
174         130 AC = 15.5
175             AR = 11.5
176             GO TO 150
177         135 IF(POS .EQ. 3.0) GO TO 140
178             WRITE(6,80)
179          80 FORMAT('0POSITION PARAMETER ENTERED INCORRECTLY - ABORT RUN')
180             CALL EXIT
181         140 AC = 12.5
182             AR = 9.5
183         150 CONTINUE
184             DO 160 I=1,10
185             J=4*I
186             ACE(I)=PCA(I)*AC
187             ARE(I)=PCA(I)*AR
188         160 CONTINUE
189             U=UEFF/100.*(RM-QBASAL)
190             WORK=RM-QBASAL-U
191             VPPCAB=VPP(TDEWC)
192             CLO = 0.88 * CLOV
193       C*****************************************************************
194       C
195       C     MAIN LOOP FOR SHIRTSLEEVE CASE
196       C
197             CALL SHIRT
198       C
199       C*****************************************************************
200       C
201       C     COMPUTE EVAPORATIVE LOSSES IN GM/HR AND PREPARE
202       C                    FOR OUTPUT
203       C
204       C*****************************************************************
205             WRESP = QR*454./1040.
206             WDIFF = QD*454./1040.
207             WSWEAT = QSWEAT*454./1040.
208             WINSEN = WRESP + WDIFF
209             WSKIN = WDIFF + WSWEAT
210             WEVAP = WRESP + WDIFF + WSWEAT
211             EMAXTL = QMAXTL*454./1040.
212             DMAX = 0.06*EMAXTL
213             DIFWET = WDIFF/EMAXTL*100.
214             SWTWET = WSWEAT/EMAXTL*100.
215             WET = ((WDIFF + WSWEAT)/EMAXTL)*100.
216             DRIP = (WET/100. - 1.0)*EMAXTL
217             IF(DRIP .LT. 0.0) DRIP = 0.0
218             IF(SWEAT .NE. 0.0) PHI = SWTWET/SWEAT
219             IF(SWEAT .EQ. 0.00) PHI = 1.0E+05
220             CO = TBF*0.454/60.
221             TSBF = TSBF*0.454/60.
222             TMBF = TMBF*0.454/60.
223             IF(K1 .NE. KX) GO TO 325
224             WRITE(6,310)
225         310 FORMAT(///,17X,'EVAPORATIVE LOSS RATE AT STEADY STATE'/
226            *30X,'(GMS/HR)')
227             WRITE(6,320) WRESP,WDIFF,DMAX,WSWEAT,WINSEN,WSKIN,
```

```
228          •EMAXTL,WEVAP,DIFWET,SWTWET,WET,DRIP,PHI
229         320 FORMAT(/12X,'RESPIRATION:',F10.2/9X,
230          •'SKIN DIFFUSION:',F10.2,10X,'DIFF MAX:',F8.2/
231          •18X,'SWEAT:',F10.2//2X,'TOTAL INSENSIBLE LOSS:',F10.2/
232          •8X,'TOTAL SKIN LOSS:',F10.2,4X,'SKIN EVAP. MAX:',
233          •F8.2/7X,'TOTAL EVAP. LOSS:',F10.2//5X,'WETTED AREA(S) FOR',/
234          •14X,'SKIN DIFF:',F10.2/18X,'SWEAT:',F10.2/11X,'SWEAT +',
235          •' DIFF:',F10.2//19X,'DRIP:',F10.2,5X,'WETNESS/DRIVE:',F8.4)
236         325 CONTINUE
237             IF(K2 .NE. KX) GO TO 335
238             WRITE(6,330) T(1),TSBF,T(5),TMBF,T(41),CO,T(43),T(42)
239         330 FORMAT(//,7X,'TEMPERATURES - DEG F',8X,'BLOOD FLOW - L/MIN',
240          •/5X,'HEAD CORE:',5X,F7.2,10X,'SKIN:',5X,F6.2,/4X,'TRUNK CORE:',
241          •5X,F7.2,8X,'MUSCLE:',5X,F6.2/' CENTRAL BLOOD:',5X,F7.2,9X,
242          •'TOTAL:',5X,F6.2/4X,'AVG MUSCLE:',5X,F7.2/6X,'AVG SKIN:',5X,F7.2)
243         335 CONTINUE
244             IF(K3 .NE. KX) GO TO 345
245             WRITE(6,340) QBASAL,SQUG,QSTOR,WORK,EVAP,QSHIV,STORAT
246         340 FORMAT(//22X,'HEAT BALANCE (BTU/HR)'/5X,'QBASAL:',F8.2,
247          •6X,'QSENS:',F8.2,5X,'QSTOR(BTU):',F8.2/6X,'QWORK:',
248          •F8.2,6X,'QEVAP:',F8.2/6X,'QSHIV:',F8.2,5X,'STORAT:',F8.2)
249         345 CONTINUE
250             IF(K4 .NE. KX) GO TO 355
251             WRITE(6,350) SWEAT,WARM(1),QSHIV,COLD(1),DILAT,
252          • WARMS,STRIC,COLDS
253         350 FORMAT(//23X,'CONTROLLER SIGNALS'/10X,'SWEAT:',F9.2,12X,
254          •'WARM(1):',F9.2/10X,'QSHIV:',F9.2,12X,'COLD(1):',
255          •F9.2/10X,'DILAT:',F9.2,14X,'WARMS:',F9.2/10X,
256          •'STRIC:',F9.2,14X,'COLDS:',F9.2)
257         355 CONTINUE
258             IF(K5 .NE. KX) GO TO 365
259             WRITE(6,360) T(4),T(8),T(12),T(24),T(32),T(40),
260          •TUG(1),TUG(2),TUG(4),TUG(6),TUG(8),TUG(10)
261         360 FORMAT(//17X,'BODY SURFACE TEMPERATURES - DEG F',/
262          •12X,'HEAD',5X,'TRUNK',5X,'ARMS',4X,'LEGS',5X,
263          •'HANDS',4X,'FEET'/5X,'SKIN:',F7.2,5F9.2//
264          •' CLOTHING:',F7.2,5F9.2)
265         365 CONTINUE
266             IF(K6 .NE. KX) GO TO 375
267             WRITE(6,370) SQUGA,HCSAVE,HC1,SQUGW,HR,QMAXTL,HESAVE,HE1,
268          •HECL,HEVAP
269         370 FORMAT(//20X,'HEAT TRANSFER COEFFICIENTS'/10X,'CONDUCTION:'/
270          •13X,'TOTAL BODY(BTU/HR):',11X,F7.2/13X,'FORCED ',
271          •'CONVECTION COEF.,HC:',3X,F7.2/13X,'NATURAL CONVECTION'
272          •' COEF.,HC1:',1X,F7.2//10X,'RADIATION:'/13X,
273          •'TOTAL BODY(BTU/HR):',11X,F7.2/13X,'RADIATION COEF.,'
274          •'HR:',11X,F7.2//10X,'MAXIMUM EVAPORATION:'/13X,
275          •'TOTAL BODY(BTU/HR):',11X,F7.2/13X,'FORCED CONVECTION ',
276          •' COEF,HE:',3X,F7.2/13X,'NATURAL CONVECTION COEF.,HE1:',
277          •1X,F7.2/13X,'CLOTHING COEF.,HECL:',10X,F7.2/
278          •13X,'COMBINED COEF.,HEVAP:',9X,F7.2)
279         375 CONTINUE
280             WRITE(6,300)
281         300 FORMAT(////'DO YOU WISH TO START NEW RUN? (Y/N) CR')
282             READ(5,57) KKK
283             IF(KKK .NE. KY) GO TO 85
284             CALL EXIT
285             END
```

```
603432*TPF$.SHIRTS
 1            SUBROUTINE SHIRT
 2            COMMON  T(43),TUG(10),ACE(10),ARE(10),PCAB,TCAB,RM,VPPCAB,
 3           *QSHIV,DILAT,STRIC,TOTL,QLCG,C(41),TSET(43),ERROR(41),
 4           *QEVAP,WORK,QBASAL,TBF,QRSTOL,TSBF,TMBF,QDIF(10),QSWEAT,
 5           *QRLEON,VRESP,HUMIN,HUMEXP,DEBUG,EPSI,NMAX,
 6           *TW,EUG,CLO,CPG,G,SQUG,QSTOR,TUGAV,U,VCAB,STORAT,
 7           *EMAX(10),QRSEN1,QRSEN2,QRSEN3,QRSEN5,QRSEN6,
 8           *QSEN(10),QRAD(10),HEVAP,HE,HE1,HECL,HR,HC,HC1,
 9           *WARMS,COLDS,SWEAT,QR,QD,QMAXTL,HCSAVE,HESAVE,
10           *QVAP1,QVAP2,QVAP,WARM(41),COLD(41),NCOUNT,TOTAL,TSTEP,FLAG,
11           *TN(40),SQUGA,SQUGW,R1,R2,P1,P2
12            DIMENSION H(10)
13            DATA H/.033,.026,2*.036,2*.033,2*.04,2*.036/
14            FLAG = 0.0
15            NCOUNT=0
16          1 NCOUNT=NCOUNT+1
17            TWR=TW+460.
18            SQUGA=0.0
19            SQUGW=0.
20      C*****************************************************************
21      C
22      C  CALCULATION OF Q-RADIATED(QRAD) AND Q-SENSIBLE(QSEN)
23      C
24      C*****************************************************************
25            DO 60 I=1,10
26            J=4*I
27            TUGR=TUG(I)+460.
28            HC=H(I)*ACE(I)*SQRT(PCAB*VCAB)*P1
29            HCSAVE = HC
30            HC1=(0.06*ACE(I)*(PCAB**2*G*ABS(TUG(I)-TCAB))**.25)*P1
31            IF( HC1 .GT. HC) HC=HC1
32            HR=0.1713E-8*ARE(I)*EUG*(TUGR**3+TUGR*TUGR*TWR+TUGR*TWR*TWR+
33           *TWR**3)*P2
34            IF(CLO .LT. 0.01) GO TO 20
35            IF(I .LT. 2 .OR. I .GT. 6) GO TO 20
36            TUG(I)=(HR*TW+HC*TCAB+ACE(I)/CLO*T(J))/(HR+HC+ACE(I)/CLO)
37            GO TO 40
38         20 TUG(I)=T(J)
39         40 QUGW=HR*(TUG(I)-TW)
40            QUGA=HC*(TUG(I)-TCAB)
41            SQUGW=SQUGW+QUGW
42            SQUGA=SQUGA+QUGA
43            QSEN(I)=QUGA
44            QRAD(I)=QUGW
45         60 CONTINUE
46      C*****************************************************************
47      C
48      C   CALCULATION OF RESPIRATORY SENSIBLE
49      C
50      C*****************************************************************
51            QRSEN1=0.5*0.0418*PCAB*144.0/(48.3*(TCAB+459.69))*RM*CPG*((0.385*
52           *T(1)+0.086*T(2)+0.0287*T(3)+0.238*T(5)+0.2615*T(6))-TCAB)
53           *      *(1.0 - 0.33*(14.7 - PCAB))
54            QRSEN2 = 0.172 * QRSEN1
55            QRSEN3 = 0.0574 * QRSEN1
56            QRSEN6 = 0.523 * QRSEN1
```

```
      QRSEN5 = 0.476 * QRSEN1
      QRSEN1=0.771*QRSEN1
C
C
      SQUG = SQUGA + SQUGW + QRSEN1 + QRSEN5 + QRSEN2 + QRSEN3 +
     .QRSEN6
C*****************************************************************
C
C     CALCULATE MAXIMUM EVAPORATION RATE
C
C*****************************************************************
      DO 80 I=1,10
      J=4*I
      VPTUG=VPP(TUG(I))
      HE=0.126*ACE(I)*(TCAB+460.)**1.04*VEFF/100.*SQRT(VCAB/PCAB)
      HESAVE = HE
      HE1=1.32*ACE(I)*(TCAB+460.)/PCAB*(PCAB*G*(ABS(.005*PCAB*(TUG(I)-
     *    TCAB))+1.02*(VPTUG-VPPCAB)))**.25
      IF(HE1 .GT. HE) HE=HE1
      IF(I .LT. 2 .OR. I .GT. 6) GO TO 70
      IF(CLO .LT. .01) GO TO 70
      HECL=22.36*ACE(I)*(T(J)+460.)**0.81/(CLO*PCAB)
      HEVAP = (HE*HECL)/(HE+HECL)
      EMAX(I)=HEVAP*(VPP(T(J))-VPPCAB)
      GO TO 75
   70 EMAX(I)=HE*(VPP(T(J))-VPDEW)
   75 IF(EMAX(I) .LT. 0.0) EMAX(I)=0.0
   80 CONTINUE
      QMAXTL = 0.0
      DO 90 I = 1,10
      QMAXTL = QMAXTL + EMAX(I)
   90 CONTINUE
C-----------------------------------------------------------------
C
      CALL MAN
C
C-----------------------------------------------------------------
      QSTOR=0.
      DO 100 I=1,41
      QSTOR=QSTOR+C(I)*(T(I)-TSET(I))
  100 CONTINUE
C*****************************************************************
C
C     CRITERIA FOR CONVERGENCE
C
C*****************************************************************
      STORAT = QBASAL + WORK + QSHIV - QEVAP - SQUG
      IF(DEBUG .EQ. 0.0) GO TO 120
      WRITE(6,110) NCOUNT, STORAT, T(1)
  110 FORMAT(I4,5X,'STORAT =',F8.2,5X,'T(1) =',F8.4)
  120 CONTINUE
C-----------------------------------------------------------------
C
      CALL CONVRG(T,TN,STORAT,NCOUNT,FLAG,EPSI,NMAX)
C
C-----------------------------------------------------------------
      IF(FLAG .EQ. 0.0) GO TO 1
      IF(FLAG .EQ. 1.0) GO TO 1
      IF(FLAG .EQ. 2.0) GO TO 11
   11 RETURN
      END
```

```
086-G03432*TPFS*MANS
      1            SUBROUTINE MAN
      2            COMMON  T(43),TUG(10),ACE(10),ARE(10),PCAB,TCAB,RM,VPPCAB,
      3           *QSHIV,DILAT,STRIC,TOTL,QLCG,C(41),TSET(43),ERROR(41),
      4           *QEVAP,WORK,QBASAL,TBF,QRSTOL,TSBF,TMBF,QDIF(10),QSWEAT,
      5           *QRLEON,VRESP,HUMIN,HUMEXP,DEBUG,EPSI,NMAX,
      6           *TW,EUG,CLO,CPG,G,SQUG,QSTOR,TUGAV,U,VCAB,STORAT,
      7           *EMAX(10),QRSEN1,QRSEN2,QRSEN3,QRSEN5,QRSEN6,
      8           *QSEN(10),QRAD(10),HEVAP,HE,HE1,HECL,HR,HC,HC1,
      9           *WARMS,COLDS,SWEAT,QR,QD,QMAXTL,HCSAVE,HESAVE,
     10           *QVAP1,QVAP2,QVAP,WARM(41),COLD(41),NCOUNT,TOTAL,TSTEP,FLAG,
     11           *TN(40),SQUGA,SQUGW,R1,R2,P1,P2
     12            DIMENSION BF(40),QMET(40),QLAT(10),QSWT(10),WTAREA(10)
     13            DIMENSION   FACTOR(40)
     14            DIMENSION BFB(40),QB(40),WORKM(10),CHILM(10),SKINV(10),SKINC(10),
     15           .          SKINS(10),QB1000(40),SKINR(10)
     16            DATA CSW,SSW,PSW,CDIL,SDIL,PDIL,CCON,SCON,PCON,CCHIL,SCHIL,PCHIL
     17           .  /705.0,63.9,0.0,143.,9.20,0.0,2.78,2.78,0.0,0.0,0.0,0.0,25.7/
     18            DATA BFB/99.3,0.265,0.287,3.18, 463.0,13.2,5.65,4.63,
     19           .         0.925,1.26,0.221,0.550,0.925,1.26,0.221,0.550,
     20           .         2.97,3.79,0.575,3.15, 2.97,3.79,0.575,3.15,
     21           .         0.111,0.265,0.0442,2.21, 0.111, .265, .0442,2.21,
     22           .         0.177, .0221, .055, 3.31,  .177, .0221, .055, 3.31/
     23            DATA QB1000/172.0,1.34,1.48,1.08, 610.,67.2,28.6,5.37,
     24           .           4.70,6.40,1.14,0.875,4.70,6.40,1.14,.875,
     25           .           15.0,19.2,2.89,2.15, 15.0,19.2,2.89,2.15,
     26           .           0.54,1.34,0.202,0.336,.54,1.34,.202,.336,
     27           .           .875,.135,.268,.470, .875,.135,.268,.470/
     28            DATA WORKM/0.0,0.3,0.04,0.04,0.3,0.3,0.005,0.005,0.005,0.005/
     29            DATA CHILM/0.02,0.85,0.025,0.025,0.035,0.035,4*0.0/
     30            DATA SKINR/0.0695,0.4935,2*0.0343,2*0.07525,2*0.09225,2*0.0167/
     31            DATA SKINV/0.132,0.322,0.0475,0.0475,0.115,0.115,0.061,0.061,
     32           .           0.05,0.05/
     33            DATA SKINC/0.05,0.15,0.025,0.025,0.025,0.025,0.175,0.175,0.175,
     34           .           0.175/
     35            DATA SKINS/0.081,0.482,2*0.077,2*0.1095,2*0.0155,2*0.0175/
     36            DATA FACTOR/3.04,25.14,30.43,0.0,3.02,10.48,43.67,0.0,
     37           .           1.32,9.82,28.89,0.0,1.32,9.82,28.89,0.0,
     38           .           9.93,13.68,70.57,0.0,9.93,13.68,70.57,0.0,
     39           .           6.07,10.64,10.92,0.0,6.07,10.64,10.92,0.0,
     40           .           15.44,19.52,15.55,0.0,15.44,19.52,15.55,0.0/
     41      C*****************************************************************
     42      C
     43      C  SWEAT,SHIVER,CONSTRICTION,DILATION CALCULATIONS
     44      C
     45      C*****************************************************************
     46      C
     47      C         ESTABLISH THERMORECEPTOR OUTPUT
     48      C
     49            DO 80 I=1,40
     50            ERROR(I) = T(I) - TSET(I)
     51            WARM(I) = 0.0
     52            COLD(I) = 0.0
     53            IF(ERROR(I)) 20,40,60
     54         20 COLD(I) = ERROR(I)
     55         40 GO TO 80
     56         60 WARM(I) = ERROR(I)
```

```
      80 CONTINUE
C
C       INTEGRATE PEIPHERAL AFFFRENTS
C
          WARMS = 0.0
          COLDS = 0.0
          DO 90 I=1,10
          K = 4*I
          WARMS = WARMS + WARM(K)*SKINR(I)
          COLDS = COLDS + COLD(K)*SKINR(I)
      90 CONTINUE
C
C       DETEMINE EFFERENT OUTFLOW
C
          SWEAT=(CSW*ERROR(1)+SSW*(WARMS-COLDS)+PSW*WARM(1)*WARMS)*R2
          DILAT=CDIL*ERROR(1)+SDIL*(WARMS-COLDS)+PDIL*WARM(1)*WARMS
          STRIC=-CCON*ERROR(1)-SCON*(WARMS-COLDS)+PCON*COLD(1)*COLDS
          QSHIV=-CCHIL*ERROR(1)-SCHIL*(WARMS-COLDS)+PCHIL*COLD(1)*COLDS
C
C       ENSURE EFFERENT COMMANDS ARE POSITIVE
C
          IF(SWEAT) 91,92,92
      91  SWEAT= 0.0
      92  IF(DILAT) 93,94,94
      93  DILAT = 0.0
      94  IF(STRIC) 95,96,96
      95  STRIC = 0.0
      96  IF(QSHIV) 97,98,98
      97  QSHIV = 0.0
      98  CONTINUE
C*****************************************************************
C
C  CALCULATION OF RESPIRATORY EVAPORATIVE LOSS
C
C*****************************************************************
          VPIN = VPPCAB
          HUMIN = 0.622*VPIN/(PCAB-VPIN)
          TEXP = 86.9 + 0.066*TCAB + 57.4*HUMIN
          VPEXP = VPP(TEXP)
          HUMEXP = 0.622*0.8*VPEXP/(PCAB-0.8*VPEXP)
          VRESP = (0.0415*PCAB*144.*30.)/(1544.*(TCAB+460.))
     *          *(1.0 - 0.000*(14.7 - PCAB))*RM
          QR = VRESP*(HUMEXP-HUMIN)*1040.
          QLAT1 = 0.3860*QR
          QLAT2 = 0.0860*QR
          QLAT3 = 0.0287*QR
          QLAT5 = 0.2380*QR
          QLAT6 = 0.2630*QR
C*****************************************************************
C
C  CALCULATION OF SWEAT EVAPORATIVE LOSS
C
C*****************************************************************
          QSWEAT = 0.0
          BULL = 18.0
          DO 100 I=1,10
          J=4*I
```

```
114             QSWT(I) = SKINS(I)*(SWEAT*EXP(ERROR(J)/BULL) - R1)*1.0
115             IF(QSWT(I) .LT. 0.0) QSWT(I) = 0.0
116             QSWEAT = QSWEAT + QSWT(I)
117             WTAREA(I) = QSWT(I)/EMAX(I)
118             IF(WTAREA(I) .GT. 1.00) WTAREA(I) = 1.000
119           100 CONTINUE
120     C*************************************************************
121     C
122     C       CALCULATION OF SKIN DIFFUSION EVAPORATIVE LOSS
123     C
124     C*************************************************************
125             QD = 0.0
126             DO 120 I=1,10
127             QDIF(I) = 2.8*ACE(I)*(VPP(TUG(I))-VPPCAB)
128            .          *((VCAB/PCAB)**0.15)*(1.0 - WTAREA(I))
129             IF(QDIF(I) .GT. 0.06*EMAX(I)) QDIF(I) = 0.06*EMAX(I)
130             QD = QD + QDIF(I)
131           120 CONTINUE
132     C*************************************************************
133     C
134     C       CALCULATION OF TOTAL EVAPORATIVE LOSSES
135     C
136     C*************************************************************
137             DO 130 I=1,10
138             QLAT(I) = QDIF(I) + QSWT(I)
139             IF(QLAT(I) .GT. EMAX(I)) QLAT(I) = EMAX(I)
140           130 CONTINUE
141             QEVAP = QR + QD + QSWEAT
142     C*************************************************************
143     C
144     C  BLOOD FLOW CALCULATIONS
145     C
146     C*************************************************************
147             DO 190 I=1,40
148           190 QB(I) = QB1000(I)/1000.0
149             DO 200 I=1,10
150             N=4*I-3
151             BF(N)=BFB(N)
152             QMET(N)=QB(N)*QBASAL
153             QMET(N+1)=QB(N+1)*QBASAL+WORKM(I)*WORK+CHILM(I)*QSHIV
154             BF(N+1)=BFB(N+1)+(QMET(N+1)-QB(N+1)*QBASAL)/1.3
155             QMET(N+2)=QB(N+2)*QBASAL
156             BF(N+2)=BFB(N+2)
157             QMET(N+3)=QB(N+3)*QBASAL
158             BF(N+3)=((BFB(N+3)+SKINV(I)*DILAT)/(1.0+SKINC(I)*STRIC))
159            .          *EXP(ERROR(N+3)/18.0)*1.0
160           200 CONTINUE
161             TSBF=BF(4)+BF(8)+BF(12)+BF(16)+BF(20)+BF(24)+BF(28)+BF(32)+BF(36)
162            .          +BF(40)
163             TMBF=BF(2)+BF(6)+BF(10)+BF(14)+BF(18)+BF(22)+BF(26)+BF(30)
164            .+BF(34)+BF(38)
165     C-------------------------------------------------------------
166     C  CHECK FOR NEGATIVE BLOOD FLOW
167     C-------------------------------------------------------------
168             DO 220 I=1,40
169           220 IF(BF(I).LT.0.0)BF(I)=0.0
170     C*************************************************************
```

```
      C
            IF(FLAG .EQ. 1.0) GO TO 350
      C
      C  CALCULATE NEW TEMPERATURES FROM STEADY STATE HEAT BALANCE
      C
      C*************************************************************
      C-------------------------------------------------------------
      C  CALCULATE TEMP OF HEAD CORE,T(1), AND TRUNK CORE,T(5),
      C-------------------------------------------------------------
            TN(1)=(QMET(1)-QLAT1-QRSEN1+BF(1)*T(41)+FACTOR(1)*T(2))/
           *      (BF(1)+FACTOR(1))
            TSTEP=TN(1) - T(1)
            TN(5)=(QMET(5)-QLAT5-QRSEN5+BF(5)*T(41)+FACTOR(5)*T(6))/
           *      (BF(5)+FACTOR(5))
      C-------------------------------------------------------------
      C  CALCULATE TEMPERATURES OF REMAINING CORES --ARM(9-13),LEG(17-21),
      C                    HAND(25-29),AND FOOT(33-37)
      C-------------------------------------------------------------
            DO 260 I=9,37,4
            TN(I)=(QMET(I)+BF(I)*T(41)+FACTOR(I)*T(I+1))/(BF(I)+FACTOR(I))
        260 CONTINUE
      C-------------------------------------------------------------
      C  CALCULATE THE TEMPERATURES OF THE MUSCLE --HEAD(2),TRUNK(6),ARM(10-
      C                14),LEG(18-22),HAND(26-30),FOOT(34-38)
      C-------------------------------------------------------------
            TN(2)=(QMET(2)-QLAT2-QRSEN2+FACTOR(1)*T(1)+FACTOR(2)*T(3)+
           *      BF(2)*T(41))/(BF(2)+FACTOR(1)+FACTOR(2))
            TN(6)=(QMET(6)-QLAT6-QRSEN6+FACTOR(5)*T(5)+FACTOR(6)*T(7)+
           *      BF(6)*T(41))/(BF(6)+FACTOR(5)+FACTOR(6))
            DO 280 I=10,38,4
            TN(I)=(QMET(I)+FACTOR(I-1)*T(I-1)+FACTOR(I)*T(I+1)+
           *      BF(I)*T(41))/(BF(I)+FACTOR(I-1)+FACTOR(I))
        280 CONTINUE
      C-------------------------------------------------------------
      C  CALCULATE TEMPERATURES OF THE FAT LAYER --HEAD(3),TRUNK(7),ARM(11-15),
      C             LEG(19-23),HAND(27-31),FOOT(35-39)
      C-------------------------------------------------------------
            TN(3)=(QMET(3)-QLAT3-QRSEN3+FACTOR(2)*T(2)+FACTOR(3)*T(4)+
           *      BF(3)*T(41))/(BF(3)+FACTOR(2)+FACTOR(3))
            DO 300 I=7,39,4
            TN(I)=(QMET(I)+FACTOR(I-1)*T(I-1)+FACTOR(I)*T(I+1)+
           *      BF(I)*T(41))/(BF(I)+FACTOR(I-1)+FACTOR(I))
        300 CONTINUE
      C-------------------------------------------------------------
      C  CALCULATE TEMPERATURES OF THE SKIN --HEAD(4),TRUNK(8),ARM(12-16),
      C             LEG(20-24),HAND(28-32),FOOT(36-40)
      C-------------------------------------------------------------
            DO 320 I=4,40,4
            J=I/4
            TN(I)=(QMET(I)-QLAT(J)-QSEN(J)-QRAD(J)+FACTOR(I-1)*T(I-1)+
           *      BF(I)*T(41))/(BF(I)+FACTOR(I-1))
        320 CONTINUE
      C-------------------------------------------------------------
      C  CALCULATE TEMP OF CENTRAL BLOOD --(41)
      C-------------------------------------------------------------
        350 SQCONV = 0.0
            TBF=0.0
```

```
      DO 340 I=1,40
      SQCONV=SQCONV+BF(I)*T(I)
      TBF=TBF+BF(I)
  340 CONTINUE
      T(41)=SQCONV/TBF
C-----------------------------------------------------------------------
C     CALCULATE AVERAGE SKIN TEMPERATURE(42) BASED ON PERCENTAGE OF
C  TOTAL SKIN AREA FOR EACH SKIN NODE * THAT NODES TEMPERATURE
C-----------------------------------------------------------------------
      T(42)=0.07*T(4)+0.3602*T(8)+0.06705*T(12)+0.06705*T(16)+0.1587*
     .      T(20)+0.1587*T(24)+0.025*T(28)+0.025*T(32)+0.0343*T(36)+
     .      0.0343*T(40)
      T(43)=0.02325*T(2)+0.549*T(6)+0.0527*T(10)+0.0527*T(14)+0.1592*
     .      T(18)+0.1592*T(22)+0.00115*T(26)+0.00115*T(30)+0.00115*
     .      T(34)+0.00115*T(38)
      RETURN
      END
```

```
D86-G03432*TPFS*CONVRG
      1            SUBROUTINE CONVRG(T,TN,STORAT,NCOUNT,FLAG,EPSI,NMAX)
      2            DIMENSION TLOW(41),TLOW1(41),TLOW2(41),THIGH(41),THALF(41),
      3           *          T(41),TN(40)
      4      C*****************************************************************
      5      C
      6      C     CONVERGENCE OF THERMAL MODEL TO STEADY STATE
      7      C     BY METHOD OF SUCCESSIVE SUBSTITION OF TEMP
      8      C     FOLLOWED BY HALF-INTERVAL CONVERGENCE METHOD
      9      C
     10      C          FLAG = 0.0   SUCCESSIVE SUBSTITUTION METHOD
     11      C          FLAG = 1.0   HALF-INTERVAL METHOD
     12      C          FLAG = 2.0   CONVERGENCE OBTAINED
     13      C                       RETURN TO MAIN PROGRAM
     14      C
     15      C*****************************************************************
     16      C
     17      C      INITIALIZATION
     18      C
     19            IF(NCOUNT .GT. 1) GO TO 2
     20            DO 1 I=1,41
     21            TLOW(I) = 0.0
     22            TLOW1(I) = 0.0
     23            TLOW2(I) = 0.0
     24            THIGH(I) = 0.0
     25            THALF(I) = 0.0
     26          1 CONTINUE
     27          2 IF(ABS(STORAT) .LT. EPSI) GO TO 110
     28            IF(FLAG .EQ. 1.0) GO TO 75
     29            IF(NCOUNT .EQ. NMAX) GO TO 100
     30      C
     31      C     DETERMINE IF NCOUNT IS ODD OR EVEN
     32      C     IF NC = 0,  NCOUNT IS EVEN
     33      C
     34            NC = (NCOUNT/2)*2 - NCOUNT
     35      C
     36      C     DETERMINE IF STORAT HAS CHANGED SIGN
     37      C
     38            IF(NCOUNT .EQ. 1) STLOW = 0.0
     39            IF(STLOW*STORAT .LT. 0.0) GO TO 30
     40            STLOW = STORAT
     41      C
     42      C   SAVE PREVIOUS VALUES OF T AND STORAT FOR LAST TWO ITERATIONS
     43      C
     44            IF(NC .EQ. 0) GO TO 10
     45            DO 5 I=1,41
     46          5 TLOW1(I) = T(I)
     47            STLOW1 = STORAT
     48            GO TO 25
     49         10 DO 20 I=1,41
     50         20 TLOW2(I) = T(I)
     51            STLOW2 = STORAT
     52            GO TO 25
     53      C
     54      C     METHOD OF SUCCESSIVE SUBSTITUTION
     55      C
     56         25 DO 28 I=1,40
```

```
      28 T(I) = TN(I)
         GO TO 95
C
C     INITIALIZATION OF HALF-INTERVAL CONVERGENCE METHOD
C
      30 ICOUNT = 0
         DO 35 I=1,41
      35 THIGH(I) = T(I)
         IF(NC .EQ. 0) GO TO 45
         DO 40 I=1,41
         TLOW(I) = TLOW1(I)
         STLOW = STLOW1
         IF(TLOW(I) .NE. 0.0) GO TO 40
         TLOW(I) = T(I)
         STLOW = STORAT
      40 CONTINUE
         GO TO 55
      45 DO 50 I=1,41
         TLOW(I) = TLOW2(I)
         STLOW = STLOW2
         IF(TLOW(I) .NE. 0.0) GO TO 50
         TLOW(I) = TLOW1(I)
         STLOW = STLOW1
      50 CONTINUE
      55 ITER = ALOG(ABS(STLOW-STORAT)/EPSI)/ALOG(2.0) + 3.0
C
C     HALF-INTERVAL ITERATION
C
      60 ICOUNT = ICOUNT + 1
         IF(ICOUNT .GT. ITER) GO TO 100
         DO 65 I=1,41
      65 THALF(I) = (THIGH(I) + TLOW(I))/2.0
         DO 70 I=1,41
      70 T(I) = THALF(I)
         GO TO 98
      75 IF(STLOW*STORAT .LT. 0.0) GO TO 85
         DO 80 I=1,41
      80 TLOW(I) = THALF(I)
         STLOW = STORAT
         GO TO 60
      85 DO 90 I=1,41
      90 THIGH(I) = THALF(I)
         GO TO 60
C
C     RETURN COMMANDS
C
      95 FLAG = 0.0
         RETURN
      98 FLAG = 1.0
         RETURN
     100 FLAG = 2.0
         WRITE(6,105) NCOUNT, STORAT
     105 FORMAT('*****CONVERGENCE NOT OBTAINED.****',4X,'NCOUNT =',
        . I4,4X,'STORAT =',F8.2)
         RETURN
     110 FLAG = 2.0
         WRITE(6,115) NCOUNT, STORAT
```

```
      115 FORMAT(//'!!!!!CONVERGENCE!!!!!      NCOUNT =',
     *I4,4X,'STORAT =',F6.2)
          RETURN
          END
```

```
-G03432*TPFS.VPPS
          FUNCTION VPP(T)
C**************************************************************************
C
C         FUNCTION TO CALCULATE VAPOR PRESSURE OF WATER AT T
C         T=TEMP DEG F
C         VPP=VAPOR OF WATER PSIA
C
C**************************************************************************
          X=647.27-(T+460.)/1.8
          TEMP=X*1.8/(T+460.)*(3.244+5.868E-3*X+1.170E-8*X**3)/(1.+2.188E-3*
         *X)
          VPP=3207./10.**TEMP
          RETURN
          END
```

```
-G03432*TPFS.SSDATA
1 360.
2 283.
3 0.0
4 2.0
5 75.
6 75.
7 52.
8 17.5
9 14.7
10 1.0
11  .9
12 .9
13 .22
```

SAMPLE RUN #1

```
>@PREP
FURPUR 0026-07/16-09:24
>@MAP THERM
MAP 0026-07/16-09:25 -(0,)

START=014606, PROG SIZE(I/D)=6593/3863
SYS$*RLIB$. LEVEL 69
END OF COLLECTION - TIME 4.134 SECONDS
>@XQT



   41-NODE THERMOREGULATORY STEADY STATE MODEL
   REFER TO GE-AGS USER GUIDE TIR 741-MED-4015



 TO OBTAIN OUTPUT LISTS 1 - 6 WRITE "Y" UNDER APPROPIATE NUMBER, THEN CR
 1 2 3 4 5 6
>Y Y Y Y Y Y


 DO YOU WISH A LISTING OF INPUT PARAMETERS?                (Y/N)  CR
>Y


 INPUT PARAMETERS SET TO FOLLOWING VALUES:


 INDEX     NAME       VALUE
  1        RM     =    283.000
  2        QBASAL=    283.000
  3        UEFF   =     22.000
  4        POS    =      2.000
  5        TCAB   =     75.000
  6        TW     =     75.000
  7        TDEWC  =     52.000
  8        VCAB   =     30.000
  9        PCAB   =     14.700
  10       G      =      1.000
  11       CLOV   =       .300
  12       EUG    =       .950
  13       CPG    =       .220
```

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APPENDIX 2

SAMPLE RUNS

SAMPLE RUN #1: The following features are illustrated: a) Use of the "@PREP", "@MAP THERM", and "@XQT" commands in order to collect compiled elements and execute prog am, b) Internally stored input parameter values are listed following second prompt, c) The response to change the first and fourth input parameters (note the "READ ERROR" that occurred when a value of 4. was entered which was outside the allowable range), and d) Output lists #1-6 corresponds to those specified following first prompt.

SAMPLE RUN #2: The following features are illustrated: a) Use of the "@ADD SSDATA" command following third prompt to enter a string of data from an external element, b) Input parameters may still be changed after the initial input, and c) Output lists #2 and 4 correspond to those specified following first prompt.

SAMPLE RUN #1 - continued

```
 TO CHANGE INPUT,ENTER INDEX NO.(1-15), VALUE  (I2,E15.5)
 ♦♦♦WHEN LIST IS COMPLETED TYPE "-1", THEN CR♦♦♦♦
> 1 1200.
    ♦♦♦    1 1200.0000
> 4 4.
 ♦♦READ ERROR♦♦♦PLEASE TRY AGAIN♦♦♦
> 4 1.
    ♦♦♦    4    1.0000
>-1


 INPUT PARAMETERS SET TO FOLLOWING VALUES:


 INDEX     NAME      VALUE
  1        RM    =  1200.000
  2        QBASAL=   283.000
  3        UEFF  =    22.000
  4        POS   =     1.000
  5        TCAB  =    75.000
  6        TW    =    75.000
  7        TDEWC =    52.000
  8        VCAB  =    30.000
  9        PCAB  =    14.700
  10       G     =     1.000
  11       CLOV  =      .300
  12       EUG   =      .950
  13       CPG   =      .220


 !!!!CONVERGENCE!!!!!     NCOUNT =  73    STORAT =    .24


                EVAPORATIVE LOSS RATE AT STEADY STATE
                          (GMS/HR)

          RESPIRATION:     32.07
       SKIN DIFFUSION:      8.16          DIFF MAX:   31.99
                SWEAT:    199.54

 TOTAL INSENSIBLE LOSS:     40.24
       TOTAL SKIN LOSS:    207.70    SKIN EVAP. MAX:  533.20
     TOTAL EVAP. LOSS:    239.78

    WETTED AREA(%) FOR
            SKIN DIFF:      1.53
                SWEAT:     37.42
         SWEAT + DIFF:     38.95

                 DRIP:       .00     WETNESS/DRIVE:    .0817
```

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SAMPLE RUN #1 - continued

```
      TEMPERATURES - DEG F          BLOOD FLOW - L/MIN
     HEAD CORE:        99.07          SKIN:        .90
    TRUNK CORE:        99.41        MUSCLE:       4.35
 CENTRAL BLOOD:        99.08         TOTAL:       9.62
    AVG MUSCLE:        93.76
      AVG SKIN:        99.41

                    HEAT BALANCE (BTU/HR)
    QBASAL:  283.00      QSENS:  448.75     QSTOR(BTU):  307.48
     QWORK:  715.26      QEVAP:  549.27
     QSHIV:     .00     STORAT:     .24

                    CONTROLLER SIGNALS
          SWEAT:   457.83            WARM(1):      .54
          QSHIV:      .00            COLD(1):      .00
          DILAT:    88.34              WARMS:      .70
          STRIC:      .00              COLDS:     -.51

              BODY SURFACE TEMPERATURES - DEG F
            HEAD     TRUNK     ARMS     LEGS     HANDS     FEET
     SKIN:  94.18     91.50    94.04    94.99    96.83    96.33

 CLOTHING:  94.18     87.13    88.44    89.27    96.83    96.33

                HEAT TRANSFER COEFFICIENTS
          CONDUCTION:
             TOTAL BODY(BTU/HR):              191.88
             FORCED CONVECTION COEF.,HC:         .51
             NATURAL CONVECTION COEF.,HC1:       .33

          RADIATION:
             TOTAL BODY(BTU/HR):              235.37
             RADIATION COEF.,HR:                 .56

          MAXIMUM EVAPORATION:
             TOTAL BODY(BTU/HR):             1221.42
             FORCED CONVECTION  COEF,HE:        .00
             NATURAL CONVECTION COEF.,HE1:    77.01
             CLOTHING COEF.,HECL:           2978.74
             COMBINED COEF.,HEVAP:           293.06



 DO YOU WISH TO START NEW RUN? (Y/N) CR
>N
```

SAMPLE RUN #2

```
   41-NODE THERMOREGULATORY STEADY STATE MODEL
   REFER TO GE-AGS USER GUIDE TIR 741-MED-4015


 TO OBTAIN OUTPUT LISTS 1 - 6 WRITE "Y" UNDER APPROPIATE NUMBER, THEN CR
 1 2 3 4 5 6
>N Y N Y N N


 DO YOU WISH A LISTING OF INPUT PARAMETERS?                (Y/N)  CR
>N
 TO CHANGE INPUT,ENTER INDEX NO.(1-15), VALUE  (I2,E15.5)
 ♦♦♦WHEN LIST IS COMPLETED TYPE "-1", THEN CR♦♦♦♦
>@ADD SSDATA
    ♦♦♦    1  360.0000
    ♦♦♦    2  283.0000
    ♦♦♦    3     .0000
    ♦♦♦    4    2.0000
    ♦♦♦    5   75.0000
    ♦♦♦    6   75.0000
    ♦♦♦    7   52.0000
    ♦♦♦    8   17.5000
    ♦♦♦    9   14.7000
    ♦♦♦   10    1.0000
    ♦♦♦   11     .9000
    ♦♦♦   12     .9000
    ♦♦♦   13     .2200
> 1 500.
    ♦♦♦    1  500.0000
> 3 22.
    ♦♦♦    3   22.0000
>11 0.5
    ♦♦♦   11     .5000
>-1
```

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SAMPLE RUN #2 - continued

```
INPUT PARAMETERS SET TO FOLLOWING VALUES:


INDEX     NAME      VALUE
 1        RM     =   500.000
 2        QBASAL=    283.000
 3        UEFF   =     22.000
 4        POS    =      2.000
 5        TCAB   =     75.000
 6        TW     =     75.000
 7        TDEWC  =     52.000
 8        VCAB   =     17.500
 9        PCAB   =     14.700
 10       G      =      1.000
 11       CLOV   =       .500
 12       EUG    =       .900
 13       CPG    =       .220


!!!!CONVERGENCE!!!!!      NCOUNT =  16     STORAT =  -.23

      TEMPERATURES - DEG F          BLOOD FLOW - L/MIN
    HEAD CORE:        98.59           SKIN:        .38
   TRUNK CORE:        98.73         MUSCLE:       1.17
CENTRAL BLOOD:        98.39          TOTAL:       5.92
   AVG MUSCLE:        94.66
     AVG SKIN:        98.73

                    CONTROLLER SIGNALS
          SWEAT:   127.03             WARM(1):      .06
          QSHIV:      .00             COLD(1):      .00
          DILAT:    20.90               WARMS:     1.17
          STRIC:      .00               COLDS:     -.12


DO YOU WISH TO START NEW RUN? (Y/N) CR
>N
```