Research Repo.

Physiological System Integrations with Emphasis on the Respiratory - Cardiovascular System

by

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PHYSIOLOGICAL SYSTEM INTEGRATIONS
WITH EMPHASIS ON THE
RESPIRATORY-CARDIOVASCULAR SYSTEM

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1. INTRODUCTION

This report deals with the integration of two types of physiological system simulations. These types are classified as long-term and short-term. The long-term model is a circulatory system model which simulates long-term blood flow variations and compartmental fluid shifts. (1) The short-term models simulate transient phenomena of the respiratory, thermoregulatory, and pulsatile cardiovascular systems as they respond to stimuli such as LBNP, exercise, and environmental gaseous variations. (2-4) An overview of the interfacing approach is described in Section 2. Detailed descriptions of the variable interface for long-term to short-term and between the three short-term models are given in succeeding sections of this report.

In order to fulfill the objectives of the study each system was carefully analyzed. Types of inputs and simulation forcing functions were evaluated. When an identical physiological variable was calculated by more than one model, the calculation which was most physiologically based was retained as an interfacing variable.

The major emphasis of this component of the study concentrated on the respiratory-pulsatile cardiovascular system with exercise playing the role of a major stimulus. Studies of simulations involving this integrated system and its response to altered environmental gaseous concentrations (O_2, CO_2) are being conducted.

2. OVERALL INTEGRATED SIMULATION

For implementation of the simulation of an experiment which might encompass hours, days, and even weeks it is mandatory that two interfacing segments be considered. One of these would handle the transfer of variable and parameter values during short-term simulations when all short-term transient models are functioning. The other interface would allow transfer of information in an initialization or reinitialization mode. These two interfacing segments are illustrated in Figure 1. The interface between the short-term transient models and the long-term model is also utilized as the input for the experimental protocol.

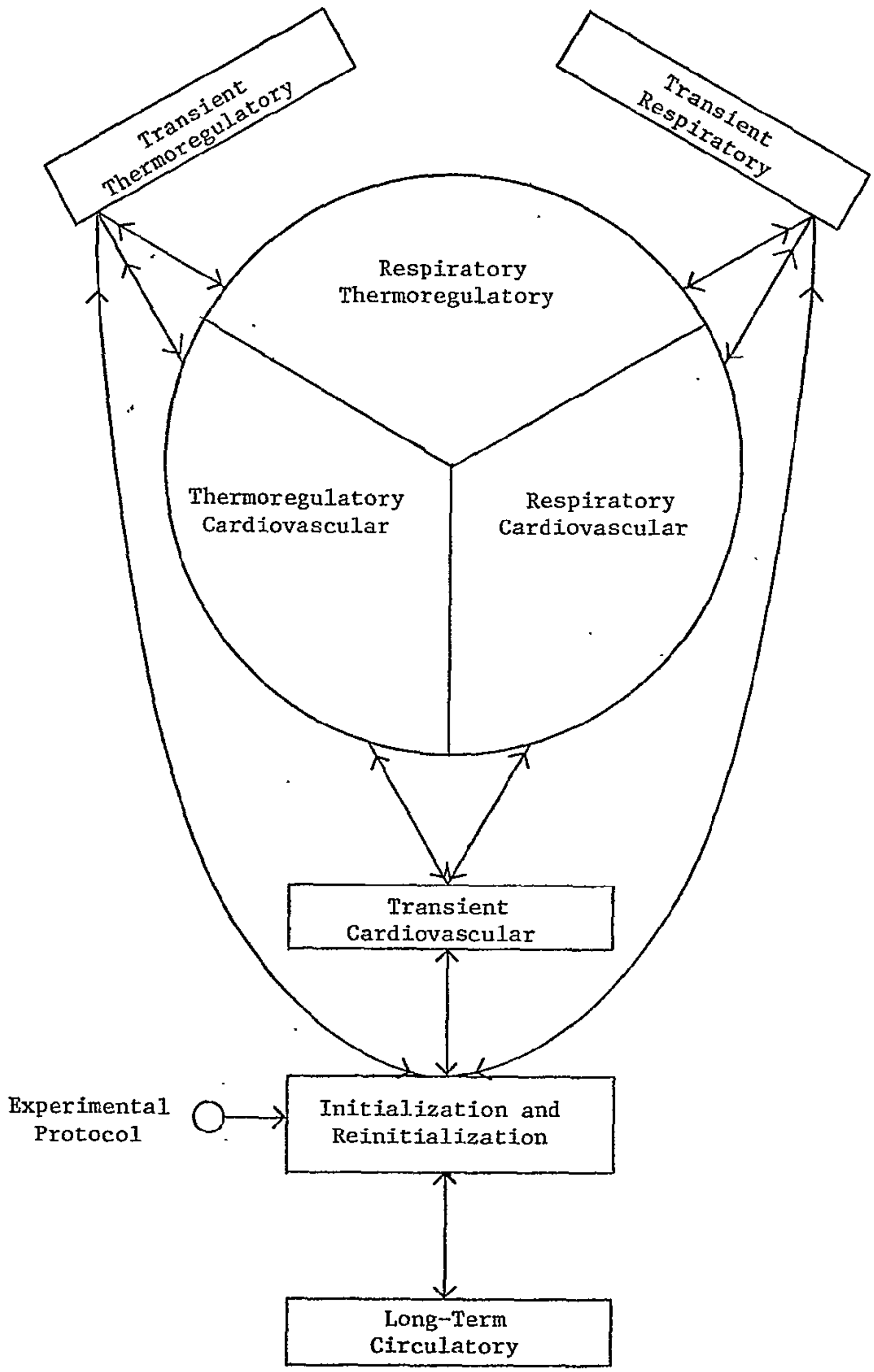

Figure 1. Overall interfacing schemes of transient and long-term physiological system models.

3. INITIALIZATION AND REINITIALIZATION INTERFACE

In the following Sections brief descriptions of the salient interfacing features are presented. Since the interface is not individualized with regard to specific system types, much of the initialization of variables is common to all the systems.

3.1 Circulatory to Cardiovascular

Establishment of blood volumes after long-term simulations is important. In particular, the unstressed volume (V_o) reflecting shifts due to antonomic stimulation needs to be transferred along with total blood volume. Changes in the resistance flow segments, such as in the renal component, play important roles in transient simulations of exercise. Whether implemented as alterations in peripheral resistance or by some other mechanism a cardiac output influence is necessary.

3.2 Circulatory to Thermoregulatory

Skin blood flow is a variable that contributes to the particular compartmentalization of the thermoregulatory system, thus it is necessary that long-term shifts in this variable be realized. No other variables are strictly inherent between these two systems. That is, other thermoregulatory system variables are available for reinitialization through the cardiovascular and respiratory system components.

3.3 Circulatory to Respiratory

A cardiac output update is obtained from the circulatory system via the cardiovascular system. This transfer of variable seems logical since the cardiac output component is removed from the respiratory system and total blood flow is generated for all three short-term models by the cardiovascular system.

Long-term changes in metabolic rates must be transferred to the respiratory system. In addition, the blood hemoglobin (Hb) level variations are necessary for establishing arterial hemoglobin concentrations ($Ca_{(HbO_2)}$) in the respiratory system.

3.4 Short-term to Long-term Transfer of Information

Necessary initialization data from the thermoregulatory system include skin blood flow and a water loss variable. Skin blood flow reflects the short-term thermal environmental changes as well as related physiological changes. Since the long-term circulatory system model does not formulate evaporative loss, the evaporative water loss from the thermoregulatory system would be utilized as an increased water loss. Consequently, the circulatory system would not further distinguish the total water loss and the evaporative loss. Details of these variable flows will be pursued in a future study.

Presently, the significant variable transfer from the respiratory to circulatory system is the variation in $Ca_{(HbO_2)}$. The cardiac output influence is the dominant contributor from the cardiovascular to circulatory system. As the integrated system is further developed and refined, it is likely that other variables will be added to this initialization and reinitialization component.

4. SHORT-TERM MODEL INTERFACES

In the top portion of Figure 1 the short-term model interfaces are displayed. A closer look at the particular variables involved is given here. Greater emphasis is placed upon the respiratory-cardiovascular system interface since the immediate study concentrates on this phase.

4.1 Respiratory-Thermoregulatory System Interface

Only the variable which describes respiratory minute volume is directly transferred to the thermoregulatory system. It is an input used in describing water loss and heat loss formulation. Other variables of the thermoregulatory system which are influenced by the respiratory system are transferred by the cardiovascular system. These include cerebral blood flow and metabolic rates. No variables are passed directly from the thermoregulatroy to the respiratory system.

4.2 Cardiovascular-Thermoregulatory System Interface

There are several variables passed from the cardiovascular to the thermoregulatory system. Blood flows including total cardiac output, muscle blood flow due to exercise, and cerebral blood flow are passed to the thermoregulatroy system. It should be noted that the cerebral blood flow formulation originates in the respiratory system. In a similar manner metabolic rates are transferred to the thermoregulatory system via the cardiovascular system. Body attitude (standing, sitting, prone) as it relates to shunted blood flow due to physiological stress and peripheral resistance is transferred in a manner useful to the thermoregulatory system.

The reverse transfer of information yields skin blood flow, a cardiac output influence, and a blood shunting influence due to thermal environmental contributions. These are then used to update or augment existing formulations in the cardiovascular system.

4.3 Respiratory-Cardiovascular System Interface

Cerebral blood flow, described as a function of arterial CO_2 and O_2 gas tensions in the respiratory system is passed to the cardiovascular system. The variable, respiratory frequency, is transferred to the cardiovascular system. Refer to Section 5 for a description of the modified version of this expression. Instead of passing an a-v O_2 difference term and having total oxygen uptake calculated in the cardiovascular system, the entire development of oxygen demand is retained in the respiratory system. Oxygen demand is then passed to the cardiovascular system. Although not completely developed, arterial CO_2 and O_2 tensions are passed to the cardiovascular system with the idea that they will be utilized in an implementation of CO_2 and O_2 forcing for a cardiac output formulation.

In order to fulfill the demands of the forementioned mechanism, the resting O_2 requirement (VO2RDT) and total metabolic rate (VO2DT) for a given exercise level is transferred to the respiratory system. The cardiac output subroutine is deleted from the respiratory system with cardiac output requirements fulfilled by a transfer from the cardiovascular system.

Interface modifications are established in the following manner. The block diagram for controlling metabolic rate which existed in the cardiovascular system is modified to the one which appears in Figure 2. A common interface has been established as

```
COMMON/RINTR/ROUT(10), CIN(10).
```

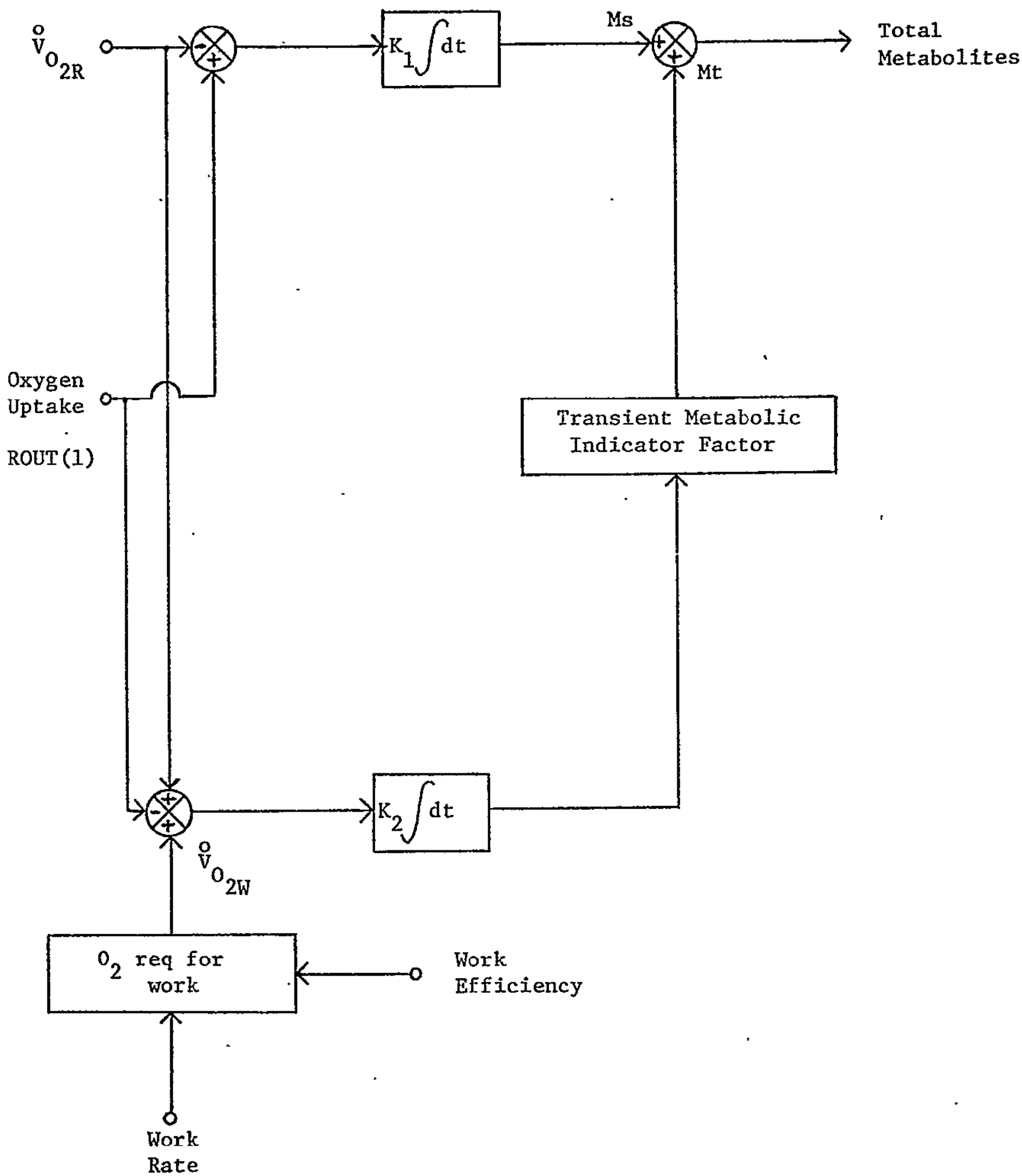

Figure 2. Revised block diagram for controlling metabolic rate in the cardiovascular system. Variable ROUT(1) is obtained from the respiratory system.

In the respiratory model, Subroutine RC12, the output variables are indicated as

```
ROUT(1) = AVO2DM/1000
ROUT(2) = FREQ
ROUT(3) = C(11)
ROUT(4) = F(7)
ROUT(5) = F(1)                                      (4.1)
```

where

AVO2DM = a-v O_2 difference,mlO_2/min,
FREQ = respiratory frequency, bpm,
C(11) = cerebral blood flow, l/min,
F(7) = Pa(CO_2), mmHg, and
F(1) = Pa(O_2), mmHg.

Likewise, the input variables are indicated as

```
C(10)  = CIN(1)
VO2DT  = CIN(2)
VO2RDT = CIN(3)                                     (4.2)
```

where

C(10) = cardiac output, l/min,
VO2DT = oxygen required for particular work load, lO_2/min, and
VO2RDT = oxygen required for resting state, lO_2/min.

In the SSO2W(X) Subroutine of the respiratory system, the following modification has been performed. The former subroutine statements were replaced by

```
COMMON/RINTR/ROUT(10), CIN(10)
VO2RDT = CIN(3)                                                    (4.3)
SSO2W(X) = VO2RDT - .0500 + (.0004850815 * 6.12 * X)/.25           (4.4)
```

where X = work load in watts and the other terms are as previously defined.

In Subroutine RC12 the following statements were added such that they appear in both the increasing and decreasing work load paths.

```
IF (WORK.LE.0.0 .AND. NWREST.LT.1) RMT(2) = CIN(3)-C(26)
AVO2DM = (F(9)*C(10)-F(13)*(C(10)-C(11))-F(12)*C(11))*1000.
AVO2DF = AVO2DM/C(10)
ROUT(1) = AVO2DM/1000.
IF(WORK.GT.0.0) ROUT(1) = RMT(2)+C(26)
```

```
ROUT(2) = FREQ
ROUT(3) = C(11)
ROUT(4) = F(7)
ROUT(5) = F(1)
```

The transfer of cardiac output from the cardiovascular to the respiratory system was handled in the main program, GRODIN, C(10) = CIN(1). Additions to COMMON/R/ in RC 12 include RMTM and TCT.

Refer to Appendix 7.1 for the program listing illustrating the implementation of these statements in Section 4.3 and the corresponding changes in the cardiovascular system.

5. MODIFICATION OF INDIVIDUAL RESPIRATORY SYSTEM

Improvement in the individual respiratory model was suggested in a previous research report. (5) These modifications were made and presently exist in the latest version of the respiratory system model. (6) In addition, a-v O_2 difference (AVO2DF) and dead space volume (DSVOL) have been added to the output routines.

These modifications are summarized here. In the original model respiratory frequency (FREQ) was given by

$$FREQ = 8.1 + 7.815 * (RMT(2) + C(26)) \qquad (5.1)$$

with

RMT(2) = O_2 metabolic rate of tissue and

C(26) = O_2 metabolic rate of brain.

Thus, Equation 5.1 didn't respond to any forcing other than O_2 demand. This formulation was replaced by

$$FREQ = \frac{\left(\left(1 + 32\left(\frac{1 + a}{a}\right)\frac{RC\ \mathring{V}_A}{DSVOL}\right)^{1/2} - 1\right)}{16\left(\frac{1 + a}{a}\right) RC} \qquad (5.2)$$

with

RC = 0.015 min,

$\mathring{V}_A \approx V_E$ = expired ventilation,

$a = 1.95 = \frac{\text{inspiratory elastance}}{\text{expiratory elastance}} = \frac{K_I}{K_E}$, and

DSVOL = dead space volume. (5)

Upon substituting the constants, FREQ is given by

FREQ = ((1. + (.726 * VE)/DSVOL)**.5 - 1.)/.363 (5.3)

with

DSVOL = 0.140 + 0.002 * VE (5.4)

Dead space ventilation, originally defined as

DEADVT = .1107 * FREQ + .0785 * VE (5.5) is now given by

DEADVT = 1 + .098 * VE. (5.6)

The representation for minute volume (TVNT) remains unchanged.

The a-v O_2 difference expression that is necessary for the integrated system to function is added to RC12. Here,

AVO2DF = AVO2DM/C(10) (5.7)

where

C(10) = cardiac output and

AVO2DM = (F(9) * C(10) - F(13) * (C(10) - C(11)) - F(12) * C(11)) * 1000

as defined in Section 4.

The terms in AVO2DM are defined in exactly the same way as in the original respiratory system model. See Appendix D of the listed reference. (7) Also, in comparison of the original respiratory program and the latest modified version there are additions to the output statements of RC12. (5-7) Statement #'s 218, 219, and 220 have been modified to include AVO2DF and DSVOL. In a similar manner statement #'s 246, 263, 264, and 265 now include these new output variables.

Before leaving the discussion of the calculation of a-v O_2 difference the significance of transport delays should be considered. Slight errors exist in the present formulation. Blood flow transport delay times are not considered in the calculation of venous blood concentrations. See Equation 5.7. Actually the concentrations and compartmental blood flows should correspond to the same time. This means that an additional bookkeeping operation should be implemented such that the concentration at the lung entrance reflects the delay times and their corresponding contributions.

6. EVALUATION OF INTEGRATED RESPIRATORY-CARDIOVASCULAR SYSTEM

The evaluation of the integrated respiratory-cardiovascular system proved quite encouraging. Several types of simulations were tried. A 200-watt exercise level of 5 minute duration was used as the stimulus. In this section two systems are compared. The basic difference between the two systems involves the formulation of metabolic requirements. System A is shown in Figure 3 and System B is shown in Figure 4. Selected responses for these two systems are illustrated in Figures 5-14.

The major variations in the responses can be summarized as follows. System B doesn't allow for the rapid increase in heart rate that occurs with System A. Since the cardiac output doesn't vary appreciably between the two systems, the over response in heart rate of System A is accompanied by a decrease in stroke volume. System B is a slightly more efficient system since a lesser amount of O_2 (0.1 lO_2/min) is required to sustain the simulation at this steady-state exercise level. The differences in the pre-exercise variable levels are related to the differences of basal conditions for the respiratory system and resting conditions for the cardiovascular system. This feature is coupled with the fact that the cardiac output settles to $\approx$ 6.8 l/min compared to the 6 l/min for the original respiratory system. After considering all of the variables' responses and the control of regulation involved with each one, System B seems to perform in a more satisfying manner. Therefore, the system shown in Figure 4 is recommended as the integrated system for exercise simulations.

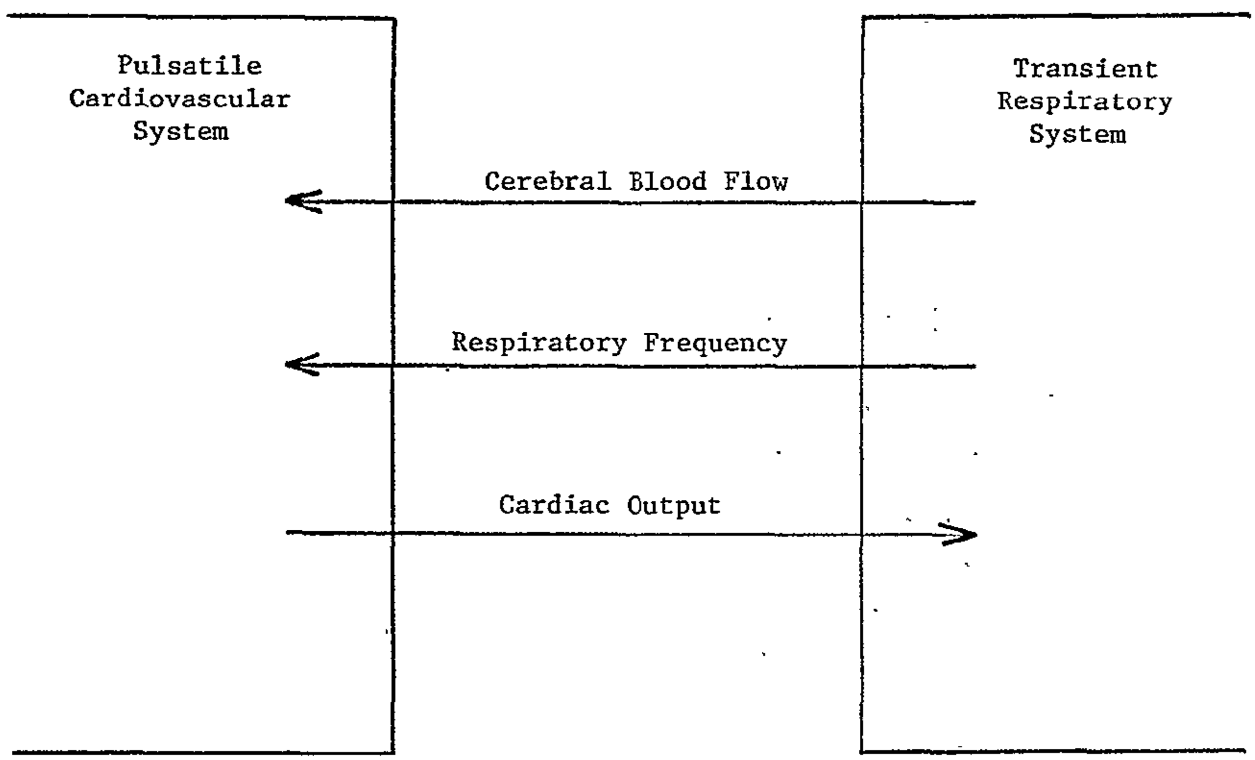

Figure 3. Respiratory-cardiovascular system interface which retains the metabolic formulation in each model during exercise stimulation

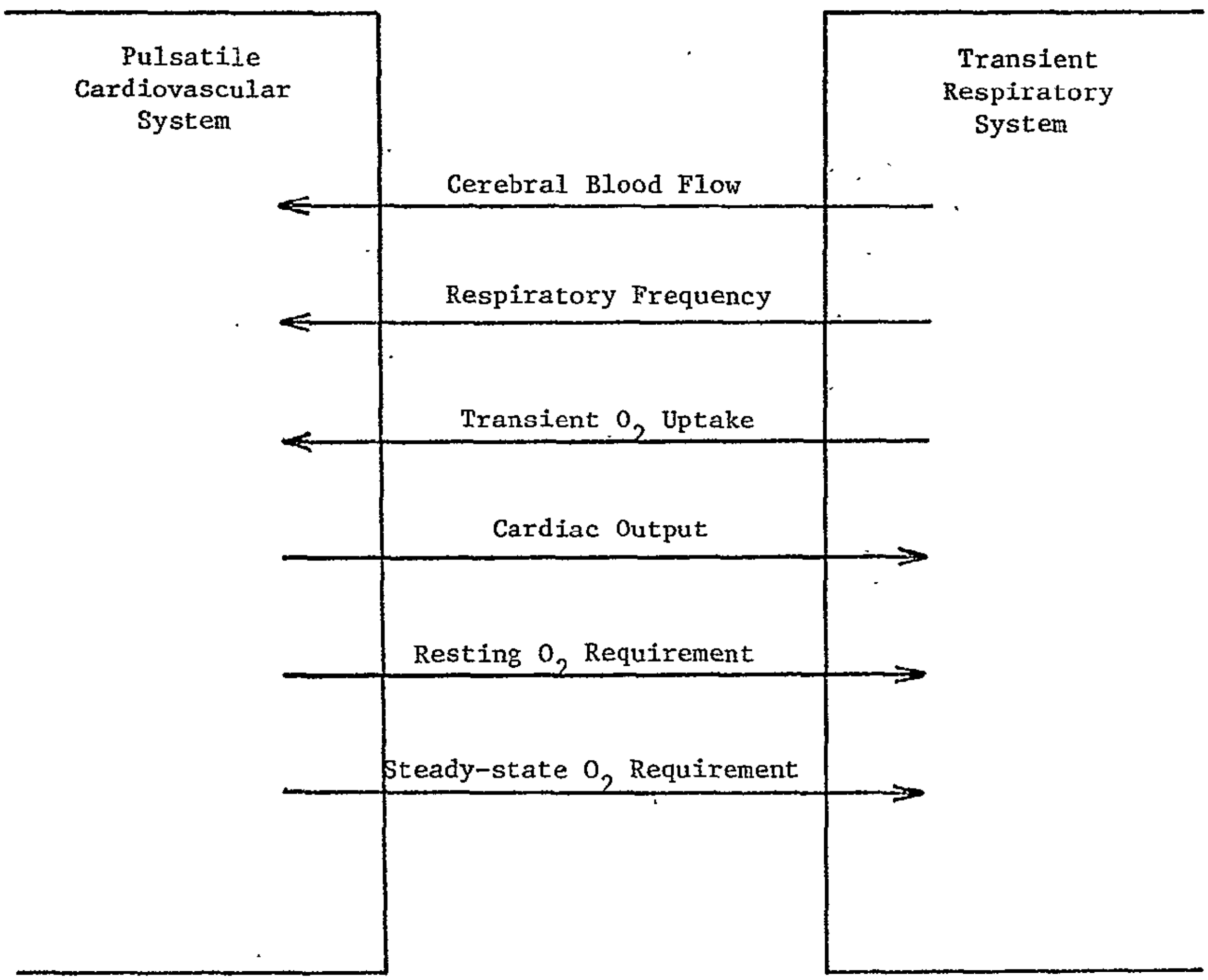

Figure 4. Respiratory-cardiovascular system interface which utilizes the metabolic formulation of the respiratory system during exercise stimulation.

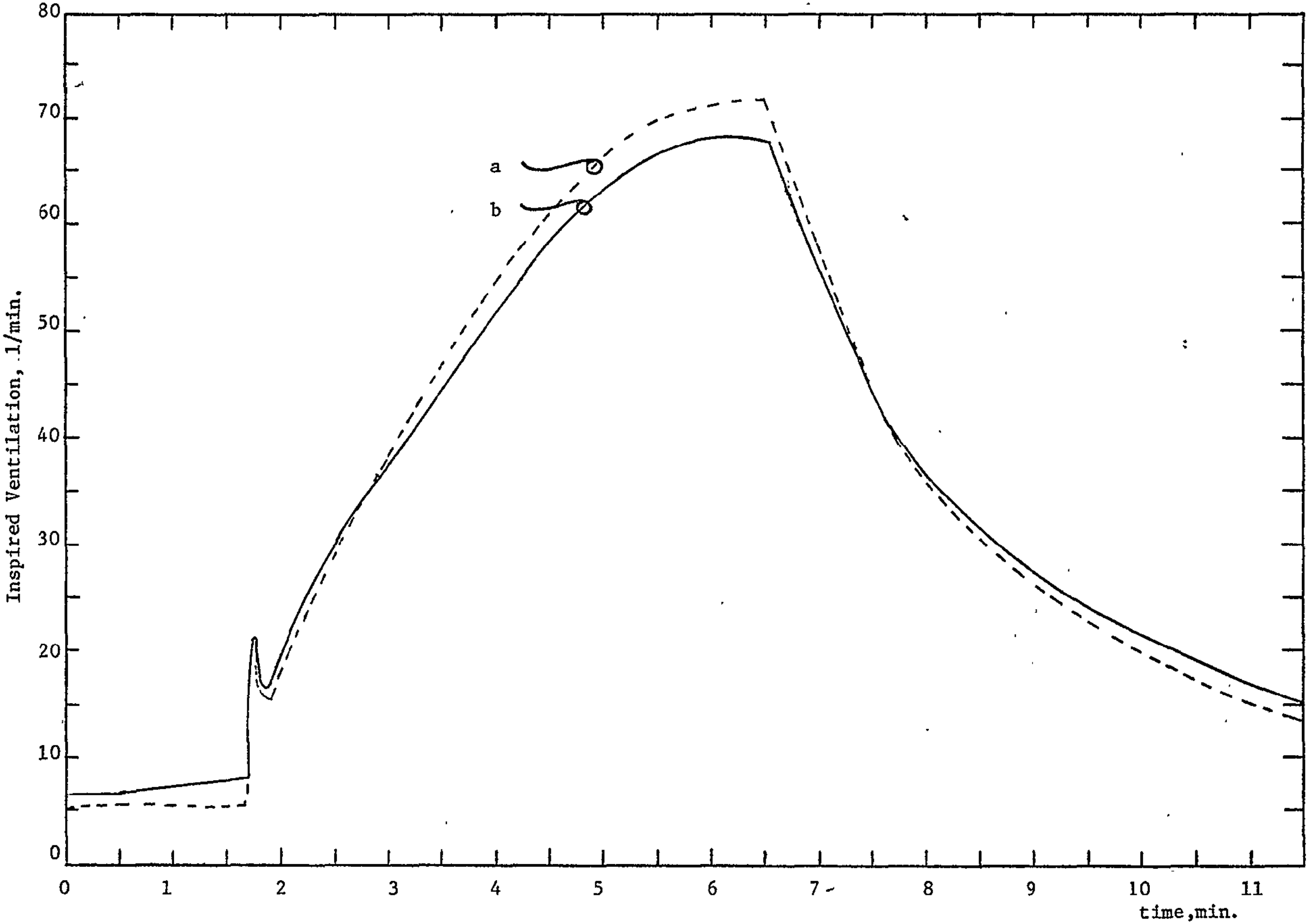

Figure 5. Inspired ventilation versus time for five minutes of 200 watt exercise stimulation and corresponding off-transient response. (a) Individual cardiovascular and respiratory system simulations of metabolic requirements. (b) Metabolic requirements controlled by respiratory system model.

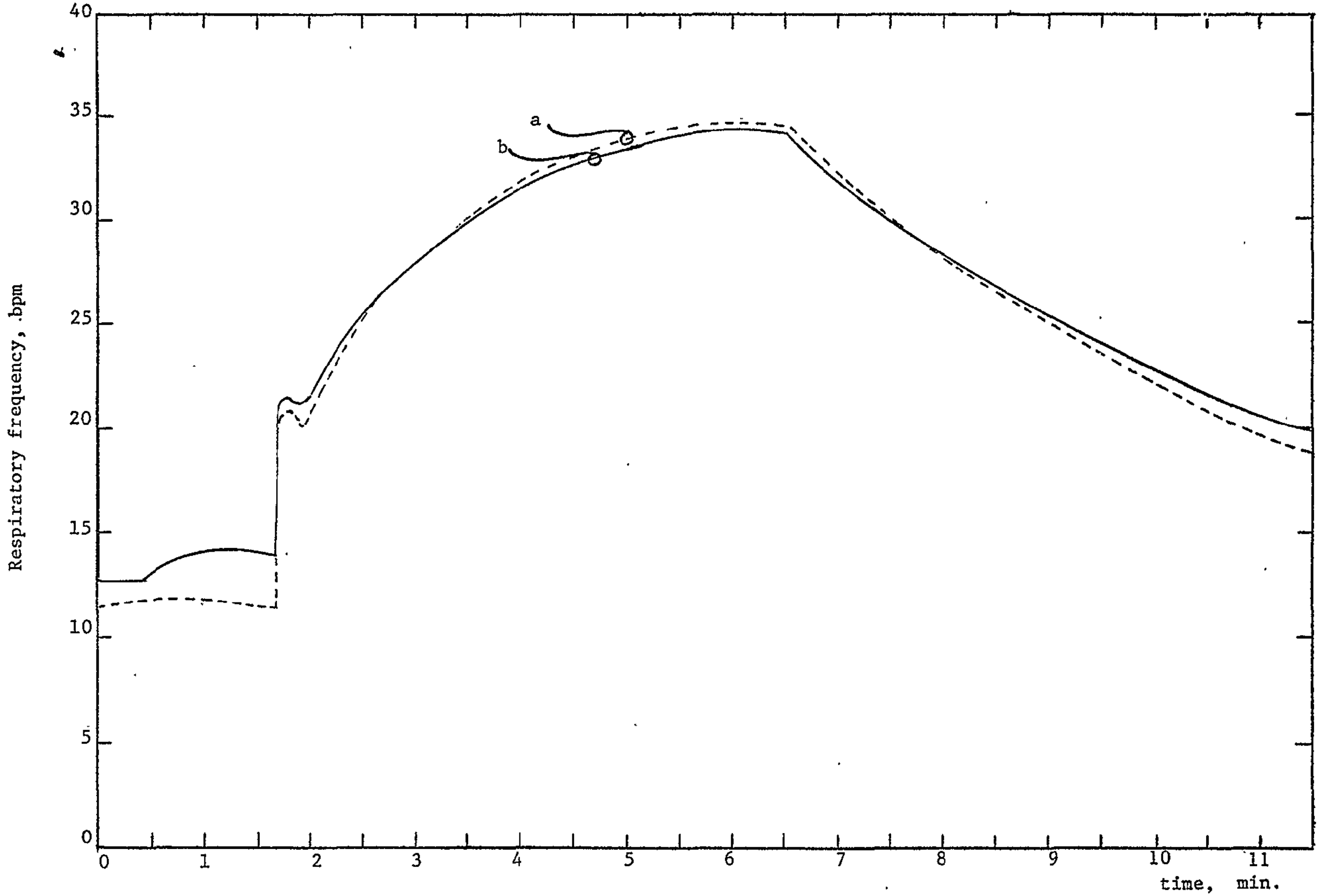

Figure 6. Respiratory frequency versus time for five minutes of 200 watt exercise stimultion and corresponding off-transient response. (a) Individual cardiovascular and respiratory system simulations of metabolic requirements. (b) Metabolic requirements controlled by respiratory system model.

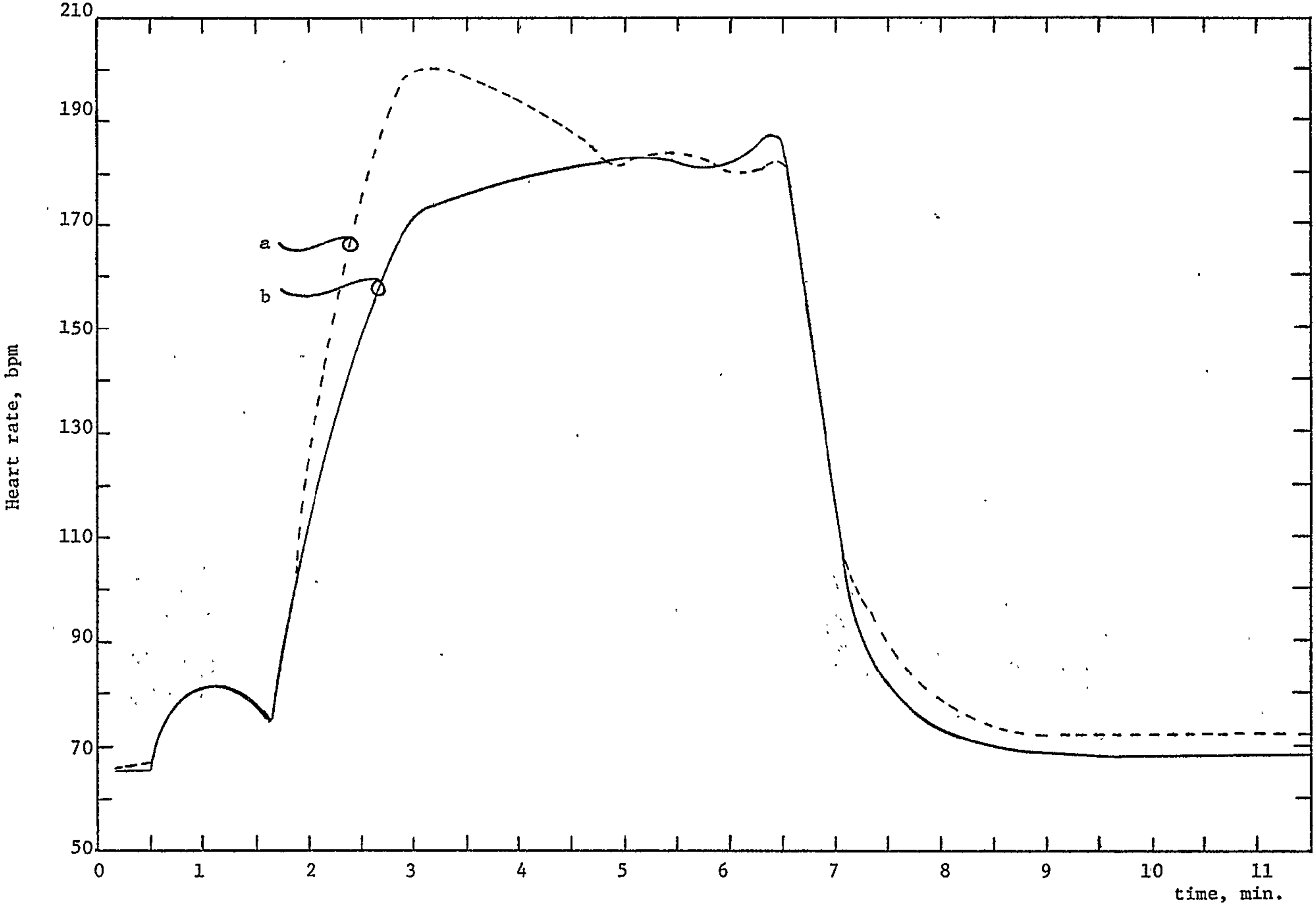

Figure 7. Heart rate versus time for five minutes of 200 watt exercise stimulation and corresponding off-transient response. (a) Individual cardiovascular and respiratory system simulations of metabolic requirements. (b) Metabolic requirements controlled by respiratory system model.

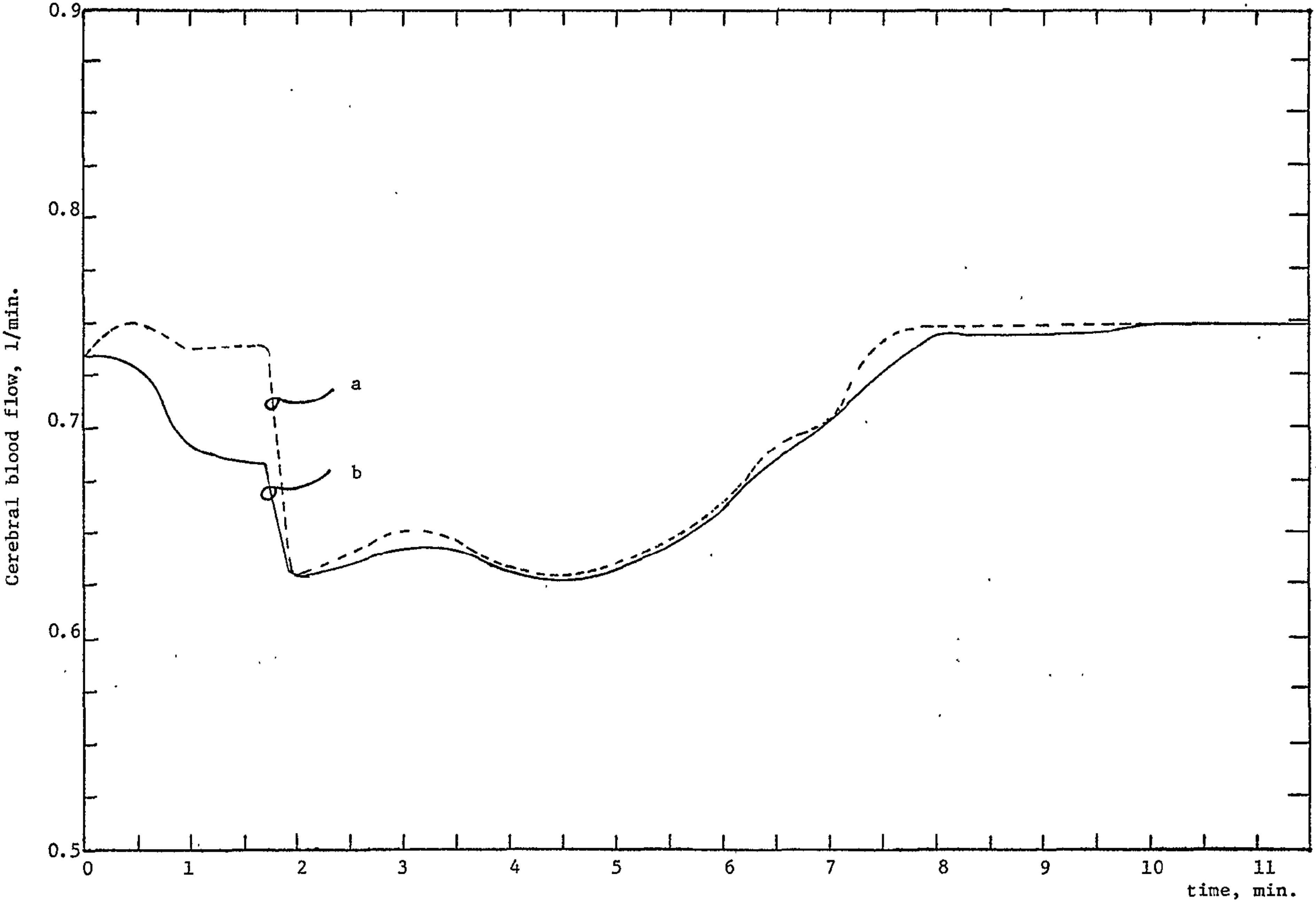

Figure 8. Cerebral blood flow versus time for five minutes of 200 watt exercise stimulation and corresponding off-transient response. (a) Individual cardiovascular and respiratory system simulations of metabolic requirements. (b) Metabolic requirements controlled by respiratory system model.

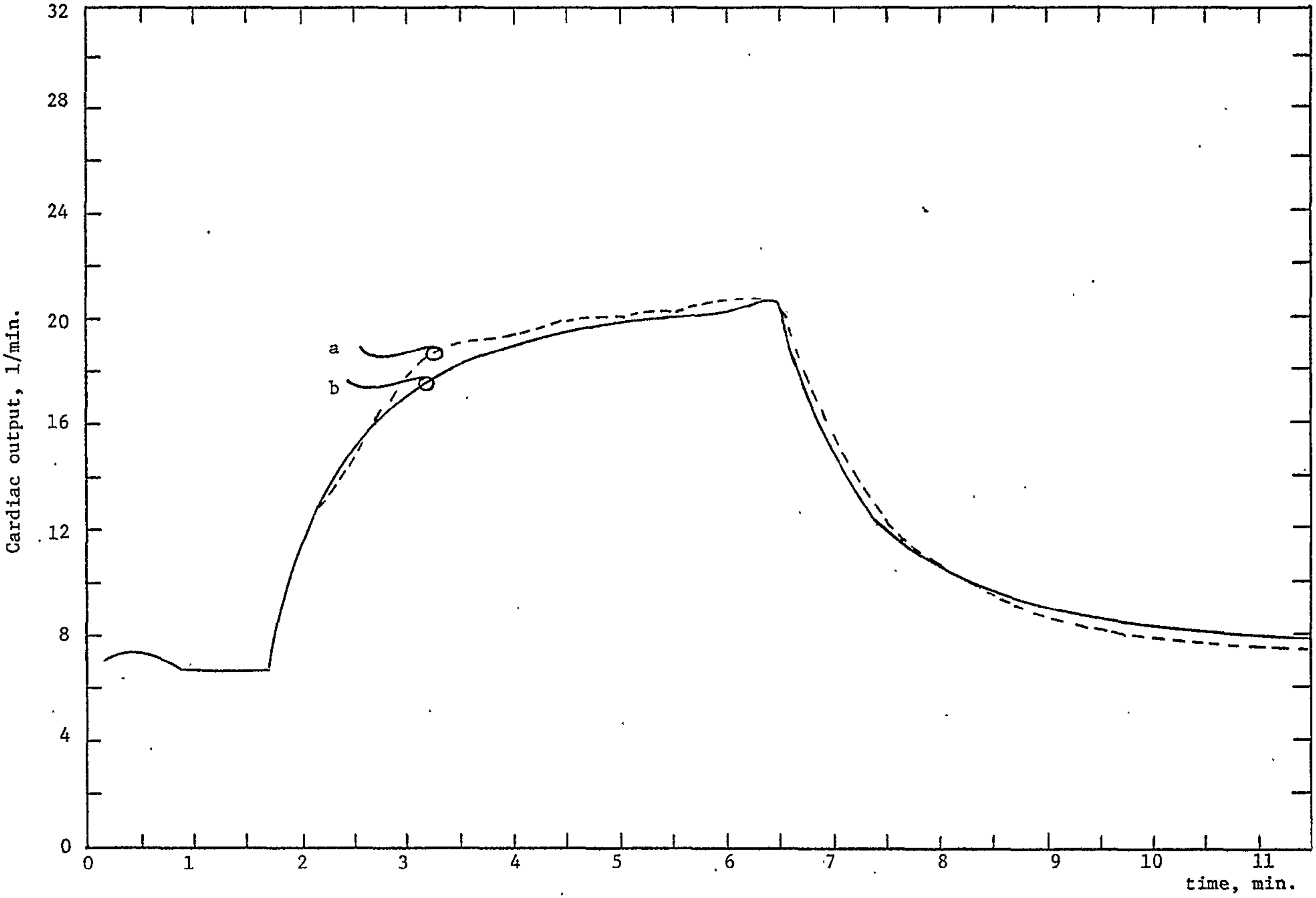

Figure 9. Cardiac output versus time for five minutes of 200 watt exercise stimulation and corresponding off-transient response. (a) Individual cardiovascular and respiratory system simulations of metabolic requirements. (b) Metabolic requirements controlled by respiratory system model

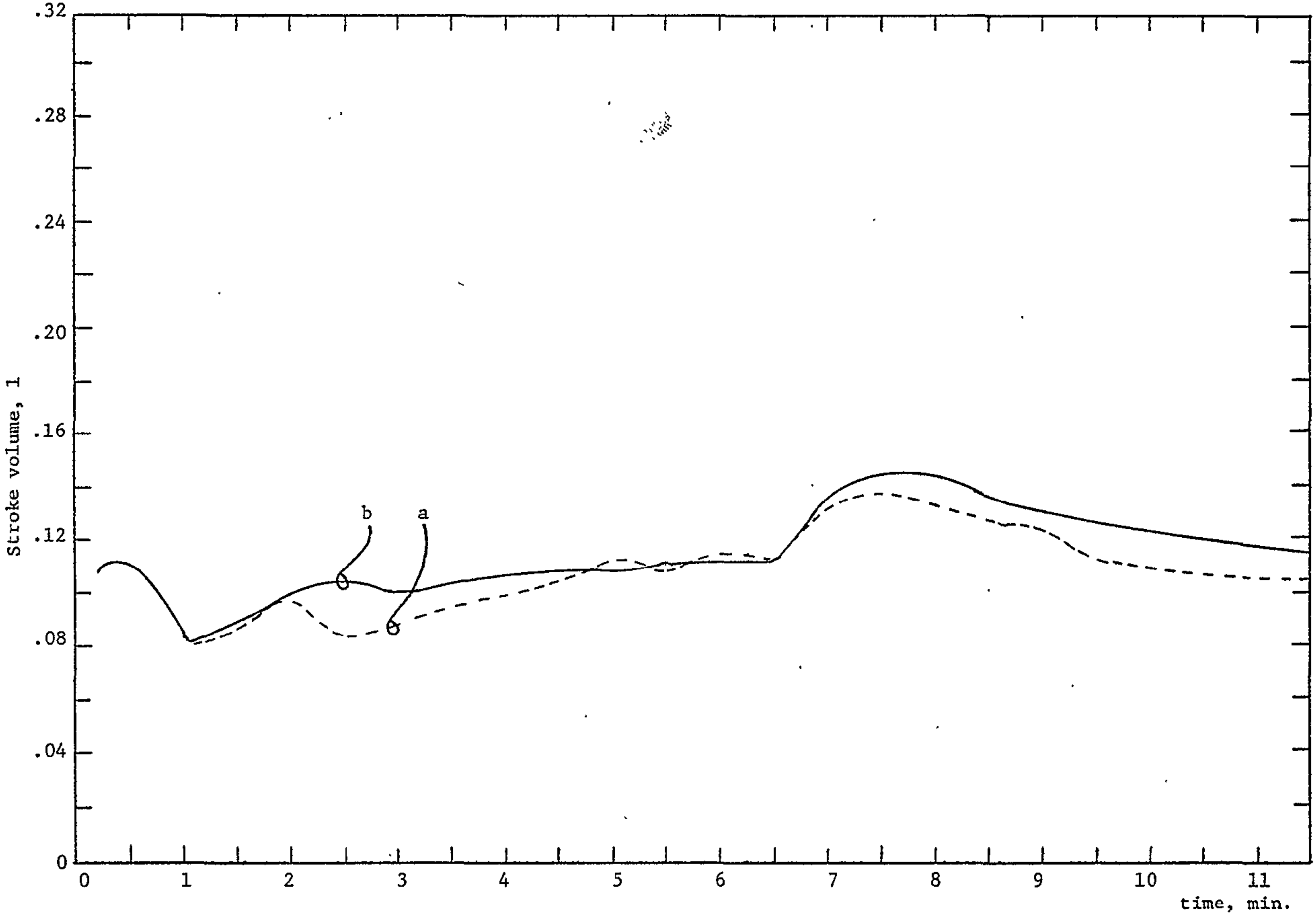

Figure 10. Stroke volume versus time for five minutes of 200 watt exercise stimulation and corresponding off-transient response. (a) Individual cardiovascular and respiratory system simulations of metabolic requirements. (b) Metabolic requirements controlled by respiratory system model.

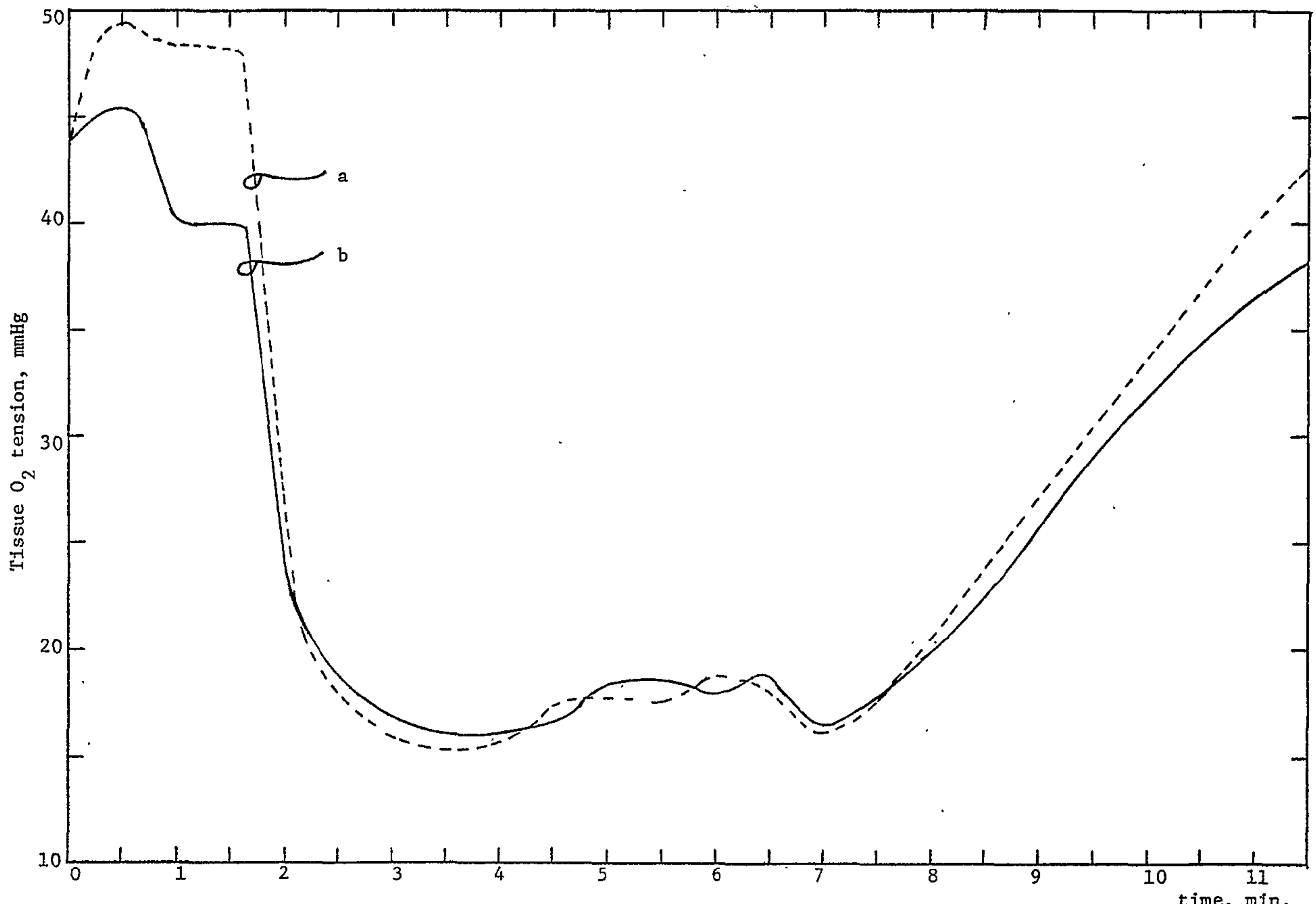

Figure 11. Tissue O_2 tension versus time for five minutes of 200 watt exercise stimulation and corresponding off-transient response. (a) Individual cardiovascular and respiratory system simulations of metabolic requirements. (b) Metabolic requirements controlled by respiratory system model

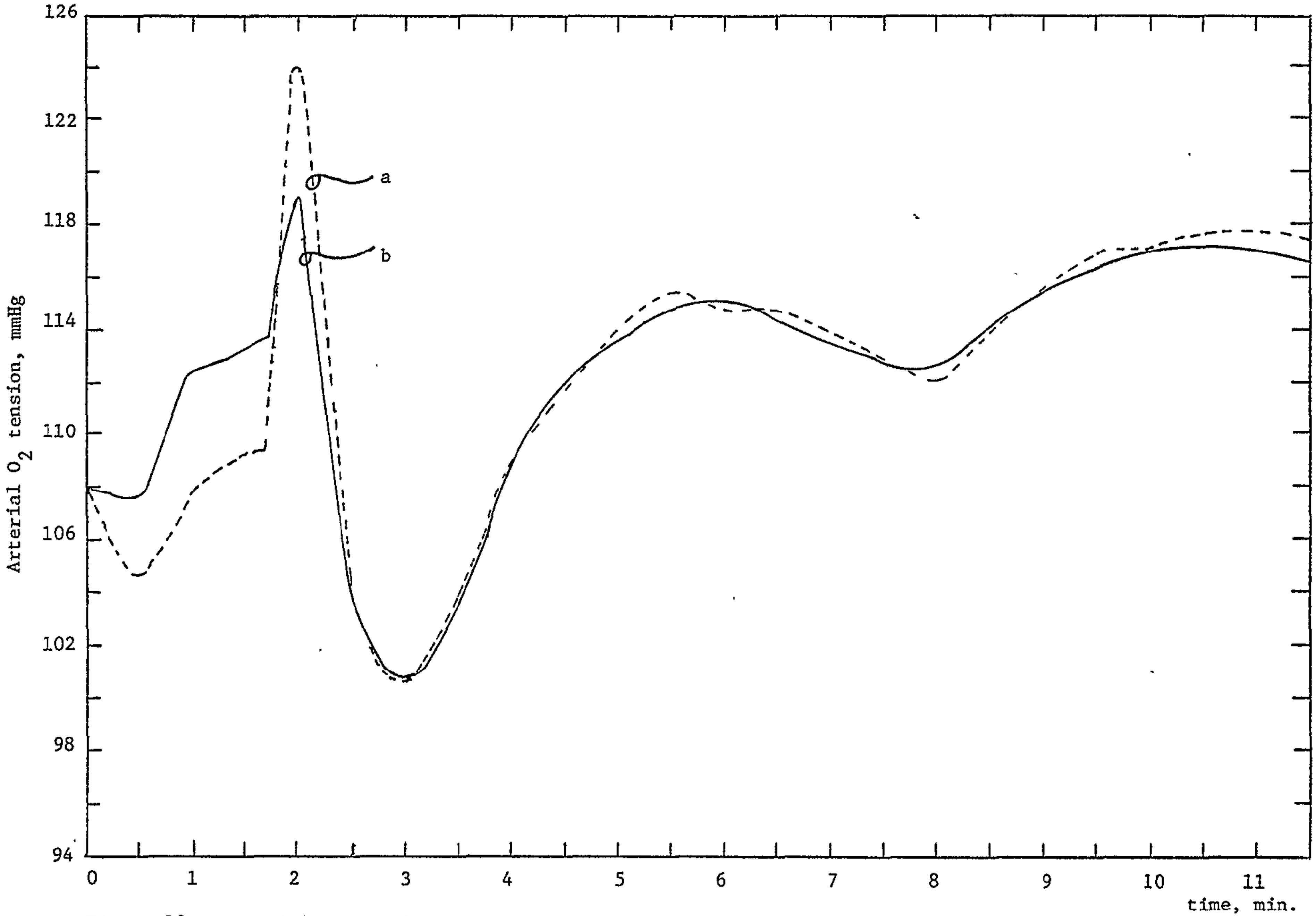

Figure 12. Arterial O_2 tension versus time for five minutes of 200 watt exercise stimulation and corresponding off-transient response. (a) Individual cardiovascular and respiratory system simulations of metabolic requirements. (b) Metabolic requirements controlled by respiratory system model.

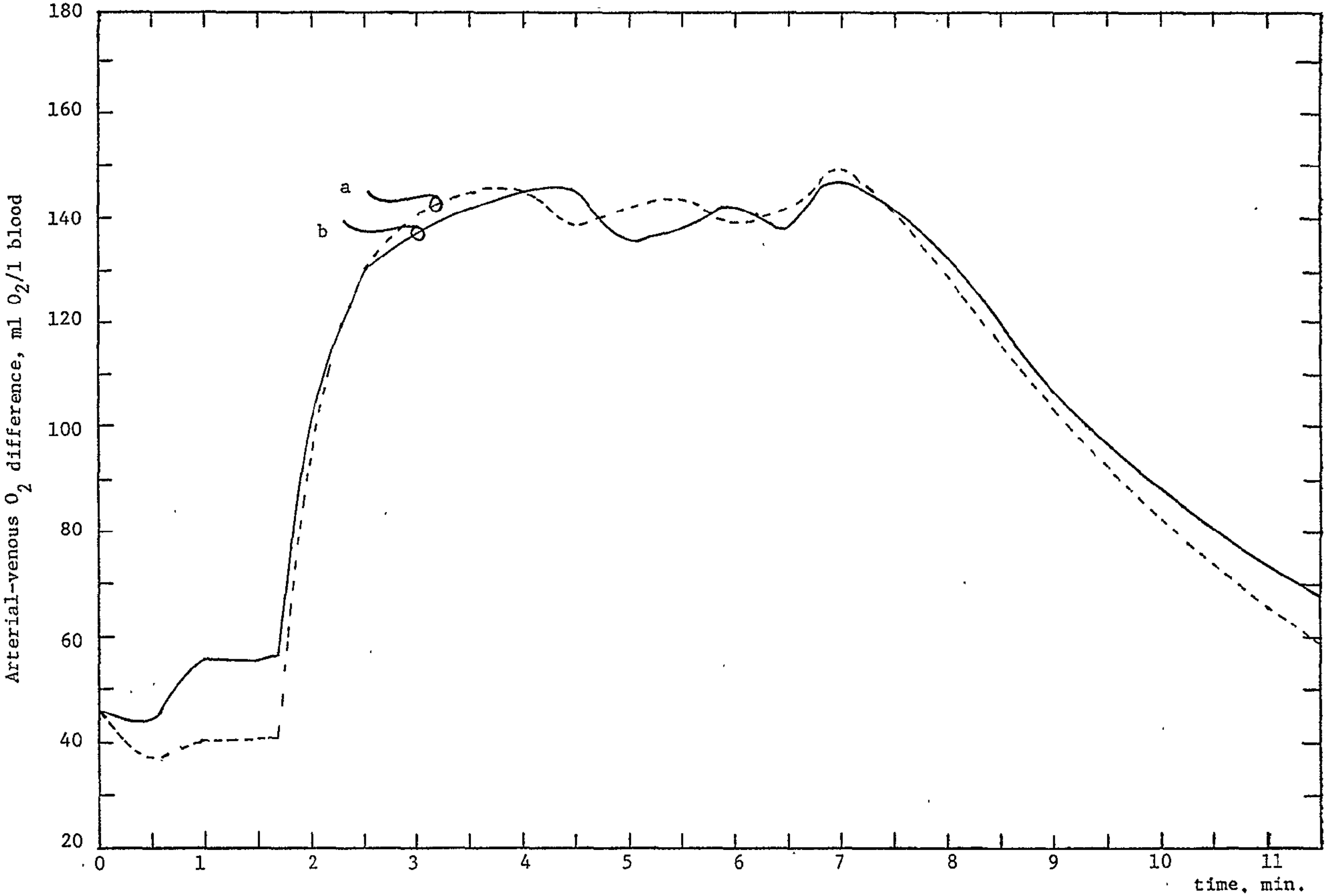

Figure 13. Arterial-venous O_2 difference versus time for five minutes of 200 watt exercise stimulation and corresponding off-transient response. (a) Individual cardiovascular and respiratory system simulations of metabolic requirements. (b) Metabolic requirements controlled by respiratory system model.

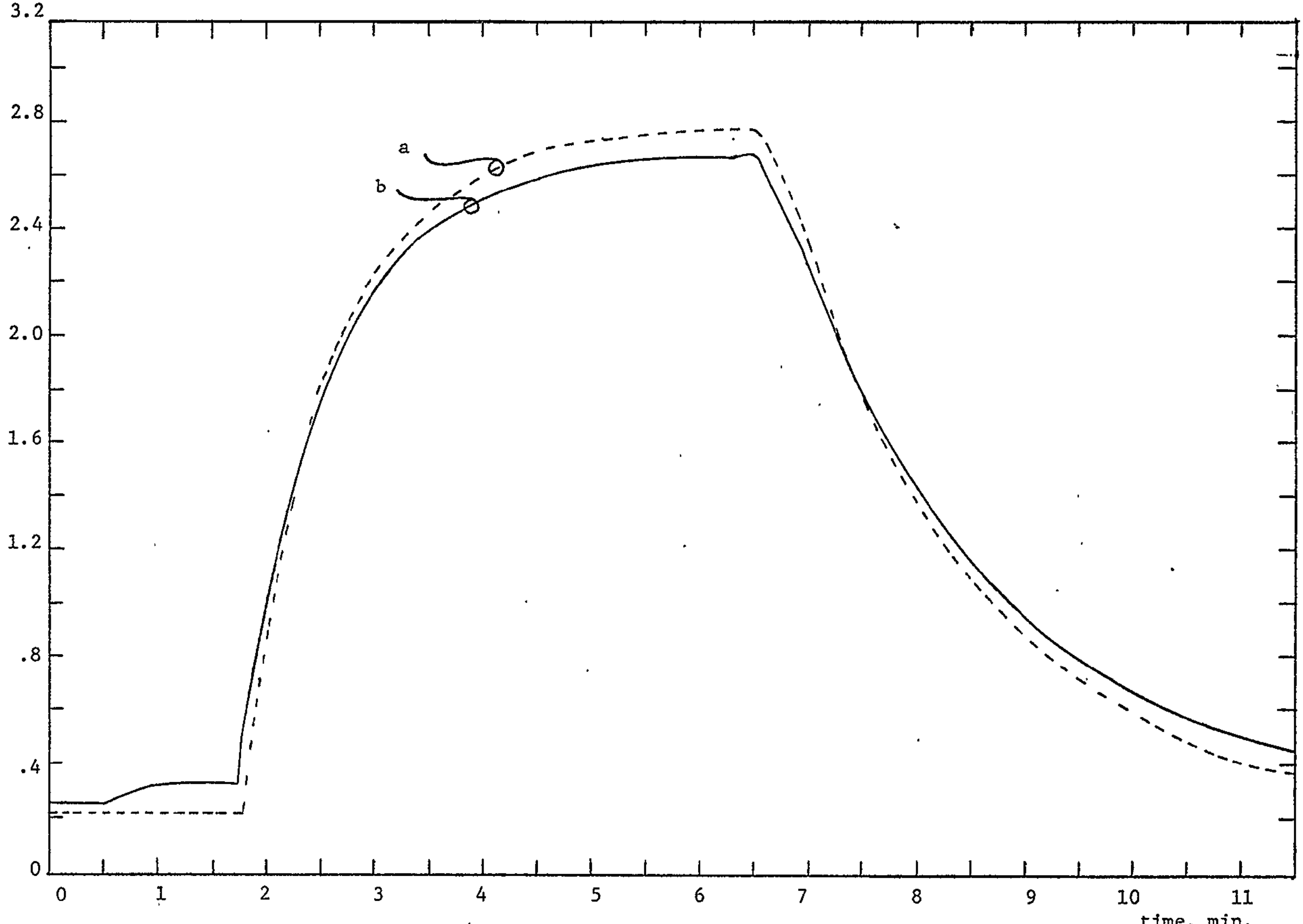

Figure 14. Tissue O_2 metabolic rate versus time for five minutes of 200 watt exercise stimulation and corresponding off-transient response. (a) Individual cardiovascular and respiratory system simulations of metabolic requirements. (b) Metabolic requirements controlled by respiratory system model.

7. APPENDIX

7.1 Program Listing of Particular Subroutines

Computer Program Listing of the subroutines of the respiratory system and pulsatile cardiovascular system models which were modified for the integration of the two systems.

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PART1

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```
D66-G03432*TPFS*#BA
       1              CALL TERG
       2              END
```

```
@PRT,S EXEC
```

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```
DB6-GD3432*TPFS.EXEC
      SUBROUTINE EXEC
      COMMON/R/XOS,XMH,CXT
      COMMON/STATE/X(597),T
    9 IF(CXT.LT.T/60.)CALL GRODIN
      IF(CXT.LT.T/60.)GO TO 9
      RETURN
      END
```

@PRT,S GRODIN

```
      SUBROUTINE GRODIN
      DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
     1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
     2          BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
     3          DQ(4)
      COMMON/RINTR/ROUT(10),CIN(10)
C     C(40)
C  ALVEOLAR VOL GAS FUNCTIONS
C       1    FA(CO2)
C       2    FA( O2)
C       3    FA(N2)
C
C  GAS CONCENTRATIONS IN BRAIN.
C       4    CB(CO2)
C       5    CB(O2)
C       6    CB(N2)
C
C  GAS CONCENTRATIONS IN TISSUE.
C       7    CT(CO2)
C       8    CT(O2)
C       9    CT(N2)
C  CARDIAC OUTPUT.
C       10   Q
C  CEREBRAL BLOOD FLOW.
C       11   QB
C  GAS TENSION IN CSF.
C       12   PCSF(CO2)
C       13   PCSF(O2)
C       14   PCSF(N2)
C
C  LENGTH OF SIMULATION RUN.
C  (THIS IS NOT USED IN TTY MODE. IN BATCH,A WORK CARD WITH 0 TIME WILL
C   ALSO STOP RUN).
C       15   TMAX
C  WEIGHTING OF H+CONC IN CSF VERSUS VENOUS BLOOD OF BRAIN.
C       16   CENTRAL SENSITIVITY PARTITION
C  BLOOD OXYGEN CAPACITY
C       17   (HB)
C  TIME CONSTANTS IN CARDIAC OUTPUT AND CEREBRAL BLOOD FLOW RESPONSES.
C       18   R1
C       19   R2
C
C  CONTROLLER EQUATION SENSITIVITY WEIGHTINGS.
C       20   CENTRAL SENSITIVITY COEFFICIENT
C       21   CAROTID BODY SENSITIVITY COEFFICIENT
C
C  VOLUMES OF LUNG,BRAIN,AND TISSUE
C       22   KL
C       23   KB
C       24   KT
C
C  BRAIN METABOLIC RATE OF CO2 PRODUCTION.
C       25   MRB(CO2)
C  BRAIN METABOLIC RATE OF O2 CONSUMPTION.
C       26   MRB(O2)
C  GAS DIFFUSION COEFF.FOR BLOOD-BRAIN BARRIER.
```

```
C      27    DCO2
C      28    DO2
C      29    DN2
C
C   BAROMETRIC PRESSURE.
C      30    B
C   VOL.FRACTION OF INSPIRED GAS.
C      31    FI(CO2)
C      32    FI(O2)
C      33    FI(N2)
C
C   VOL.OF CSF.
C      34    KCSF
C   INITIAL TIME
C      35    T
C   COMPUTER TIME STEP.
C      36    H
C   CONTROLLER EQUATION CONSTANT(MAINTAINS RESTING PA(CO2) APPROX.40).
C      37    VI(N)
C   VALUE FOR RESTING ALVEOLAR VENTILATION.
C      38    VI(SS)
C   OUTPUT PRINT INCREMENTS (ALSO PRINTS AT .5MIN.INCRIMENTS).
C      39    PRINT-ALL TIME
C
C      SV(18,50)
C   ARTERIAL GAS CONCENTRATIONS AT LUNG EXIT.
C       1    CA(CO2)
C       2    CA(O2)
C       3    CA(N2)
C
C   VENOUS GAS CONCENTRATIONS AT BRAIN EXIT.
C       4    CVB(CO2)
C       5    CVB(O2)
C       6    CVB(N2)
C
C   VENOUS GAS CONCENTRATIONS AT TISSUE EXIT.
C       7    CVT(CO2)
C       8    CVT(O2)
C       9    CVT(N2)
C
C   CARDIAC OUTPUT.
C      10    Q
C   CEREBRAL BLOOD FLOW.
C      11    QB
C   TISSUE BLOOD FLOW.
C      12    QT
C   ARTERIAL H+ CONCENTRATION.
C      13    CA(H+)
C   ARTERIAL O2 TENSION.
C      14    PA(O2)
C
C      15    --
C   TOTAL GAS CONCENTRATIONS AT BRAIN EXIT.
C      16    CVB(CO2) + CVB(O2) + CVB(N2)
C   TOTAL GAS CONCENTRATIONS AT TISSUE EXIT.
C      17    CVT(CO2) + CVT(O2) + CVT(N2)
C   TIME.
```

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```
C       18   T
C
C      VTRAN(18)
C  ARTERIAL GAS CONCENTRATIONS AT BRAIN ENTRANCE.
C        1    CAB(CO2) = CA(CO2)(T - TAB)
C        2    CAB(O2) = CA(O2)(T - TAB)
C        3    CAB(N2) = CA(N2)(T - TAB)
C
C  VENOUS BRAIN GAS CONCENTRATION AT LUNG ENTRANCE.
C        4    CVB(CO2)(T - TVB)
C        5    CVB(O2)(T - TVB)
C        6    CVB(N2)(T - TVB)
C
C  VENOUS TISSUE GAS CONCENTRATION AT LUNG ENTRANCE.
C        7    CVT(CO2)(T - TVT)
C        8    CVT(O2)(T - TVT)
C        9    CVT(N2)(T - TVT)
C
C  ARTERIAL GAS CONCENTRATIONS AT TISSUE ENTRANCE.
C       10    CAT(CO2) = CA(CO2)(T - TAT)
C       11    CAT(O2) = CA(O2)(T - TAT)
C       12    CAT(N2) = CA(N2)(T - TAT)
C
C  ARTERIAL H+ CONCENTRATION AT CAROTID BODIES'SITE.
C       13    CAO(H+) = CA(H+)(T - TAO)
C  ARTERIAL O2 TENSION AT CAROTID BODIES'SITE.
C       14    PAO(O2) = PA(O2)(T - TAO)
C  ARTERIAL H+ CONCENTRATION AT BRAIN ENTRANCE.
C       15    CAB(H+) = CA(H+)(T - TAB)
C  TOTAL GAS CONCENTRATION FROM BRAIN AT LUNG ENTRANCE.
C       16    (CVB(CO2) + CVB(O2) + CVB(N2))(T - TVB)
C  TOTAL GAS CONCENTRATION FROM TISSUE AT LUNG ENTRANCE.
C       17    (CVT(CO2) + CVT(O2) + CVT(N2))(T - TVT)
C
C      D(15)
C   FOR D(15) THE SYMBOLS B=BAROMETRIC PRESSURE, 47=WATER VAPOR PRESS.,
C  K=CONVERSION FACTOR FOR ATM TO MMHG, A=SOLUBILITY COEFF.OF GASES,
C  H=COMPUTER TIME-STEP, HB=BLOOD OXYGEN CAPACITY
C        1    B - 47
C        2    K ACO2
C        3    K AO2
C        4    K AN2
C        5    K AN2 (B - 47)
C        6    K AO2 (B - 47)
C        7    K AN2 (B - 47)
C        8    0.16 + 2.3(HB)
C        9    863/(B - 47)
C       10    0.62
C       11    K ACSF(CO2)
C       12    K ACSF(O2)
C       13    K ACSF(N2)
C       14    2*H
C       15    1.99*H
C      F(20)
C  COMPARTMENTAL GAS TENSIONS AND CONCENTRATIONS.
C        1    PA(O2)
C        2    K ACO2 PA(CO2)
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C     3   PB(O2)
C     4   K ACO2 PB(CO2)
C     5   PT(O2)
C     6   K ACO2 PT(CO2)
C     7   PA(CO2)
C     8   PA(O2)
C     9   CA(O2)
C    10   CA(N2)
C    11   CA(CO2) + CA(O2) + CA(N2)
C    12   CVB(O2)
C    13   CVT(O2)
C
C  PRODUCT OF DIFFUSION COEFFS.AND GAS DIFFERENTIALS ACROSS BLOOD-BRAIN
C  BARRIER.
C    14   DCO2 (PB(CO2) - PCSF(CO2))
C    15   DO2 (PB(O2) - PCSF(O2))
C    16   DN2 (PB(N2) - PCSF(N2))
C
C    17   PB(O2)
C    18   PB(N2)
      DIMENSION XNB(4,2), DJ(4), IDJ(2)
      COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
     1         TAU, CC, CHB, CH, CPH, DQ, VE, VI, CPB, CPT, CADK, X, DT,
     2         IRK, LOC, ITERX, INDEX, I, J, M, N
      COMMON/R/ XDS,XMH,CXT,WORK,DUM1,DUM2,DUM3,WORK2,RMTB,RMTB2,TIMEOF
     1  ,RMLIN,ITTY
C  ITTY =FLG FOR TTY MODE.
C     O= OUTPUT TO PRINTER (BATCH MODE).
C     'TTY '= TTY I/O AND 1ST TIME TO SUBROUTINE RC12.
C     1 = TTY I/O AND NOT 1ST TIME TO RC12.
      DATA ITTTY/'TTY '/
C     DATA FOR INITIAL CONDITIONS
      C(10)=CIN(1)
      IF (CXT.GT.O.) GO TO 40
      WRITE (6,5)
    5 FORMAT (/' - GRODINS' RESPIRATORY CONTROL MODEL'//)
  300 CONTINUE
      WRITE(6,483)
  483 FORMAT('0ADD DATA...')
C  READ INDICATION OC BATCH OR TTY MODE.
      READ(5,480) ITTY
  480 FORMAT(A4)
      IF(ITTY .NE. ITTTY) ITTY = 0
      WRITE(6,90)
   90 FORMAT (1H1,1X,37H*RESPIRATORY CHEMOSTAT -- INPUT DATA*/)
C   - DATA FOR INITIAL CONDITIONS
      DO 10 I = 1,40
C  1106 HAS PROBLEM WITH END= , SO THIS ISNT USED TO
C   DETERMINE END OF RUN(NOD CAPABILITY TO START ANOTHER
C   MODEL RUN IN SAME COMPUTER RUN).
      READ(5,190,END=301) C(I),(XN(I,J),J=1,2)
   10 CONTINUE
C   ESTABLISH COMPUTER STEP INDEPENDENT OF INPUT DATA.
      C(36)=.78125E-2
  190 FORMAT (5X,F15.0,5X,2A4)
      DO 20 I = 1,4
      IP40 = I + 40
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      READ   (5,190) BC(I), (XNB(I,J), J = 1,2)
   20 CONTINUE
      DO 30 I = 1,2
      READ   (5,190) RMT(I), (XNB(I,J), J = 1,2)
      IP40 = I + 44
   30 CONTINUE
      DO 40 I = 1,2
      READ   (5,190) DJ(I), (XNB(I,J), J = 1,2)
      IP40 = I + 46
   40 CONTINUE
C
C  OUTPUT INPUT DATA.
      J = 1
      DO 75 I = 1,8
      JX = J + 4
      WRITE(6,92) J,(C(I2),I2=J,JX)
   92 FORMAT(' ',I2,2X,5(F9.4))
      J = J + 5
   75 CONTINUE
      WRITE(6,92) J,(BC(I),I=1,4)
      J = 45
      WRITE(6,92) J,RMT(1),RMT(2),DJ(1),DJ(2)
C
C  IF TTY I/O MAX.TIME WILL COME FROM WORK CARD.
      IF(ITTY .NE. 0) C(15) = 9999999999.
C
C  FI(CO2)
      DUM1=C(31)
C  FI(O2)
      DUM2=C(32)
C  FI(N2)
      DUM3=C(33)
      WORK=0.
      WORK2=0.
C  METABOLIC RATE OF O2 CONSUMPTION IN TISSUE.
      RMTB=CIN(3)-C(26)
      RMTB2=CIN(3)-C(26)
C
      TIMEOF=0.
      XDS=0.
      XMH=10.*C(36)/0.0078125
      MMM=0
  201 CONTINUE
      XDS=XDS+XMH
      IF(MMM.EQ.1)XDS=XDS+C(36)
      MMM=1
      C(35)=0.
      C(40)=0.
C
C     INITIAL GUESSES FOR ITERATIVE LOOPS
C  ARTERIAL CONCENTRATION OF CO2.
      CC(1) = 0.6
C  BRAIN CONCENTRATION OF CO2.
      CC(2) = C(4)
C  TISSUE CONCENTRATION OF CO2.
      CC(3) = C(7)
C  BRAIN CO2 TENSION.
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      CPB = 50.0
C   TISSUE CO2 TENSION.
      CPT = 50.0
      IF(XDS.GT.XHH) GOTO202
C     SETS VARIOUS CONSTANTS AND AGGREGATES OF CONSTANTS
C   THAX.
      C(15) = C(15) + .0001
C   PRINT ALL-TIME.
C     C(39) = C(39) + .0001
C   FACTOR OF 1-E-7 MULTIPLYING DIFFUSION COEFFICIENTS.
      DO 200 I = 27,29
      C(I) = C(I) * 1.E-7
  200 CONTINUE
  202 CONTINUE
      IRK = 1
      M = 14
      N = 5
      IDJ(1) = 0
C      SOLUBILITY COEFFICIENTS.
C   A(1)= (ALPHA)CO2, A(2)= (ALPHA)O2, A(3)= (ALPHA)N2.
C   A(4)= (ALPHA)CO2, A(5)= (ALPHA)O2, A(6)= (ALPHA)N2
      A(1) = 0.51
      A(2) = 0.024
      A(3) = 0.013
      A(4) = 0.51
      A(5) = 0.024
      A(6) = 0.013
C   ATM/MMHG CONVERSION FACTOR.
      SK = 0.00132
C   CARBONIC ACID DISSOCIATION CONSTANT.
      CADK = 795.0
C   VOL(1)-VOL(10)= VOLUMES USED IN CALCULATION OF VARIABLE TIME DELAYS.
      VOL(1) = 0.015
      VOL(2) = 1.062
      VOL(3) = 0.188
      VOL(4) = 0.06
      VOL(5) = 0.188
      VOL(6) = 2.94
      VOL(7) = 0.735
      VOL(8) = 1.062
      VOL(9) = 0.008
      VOL(10)= 1.062
C
C   (METABOLIC RATE OF CO2 IN BRAIN + TISSUE.) / SAME FOR O2
      QF(6) = (C(25) + RMT(1))/(C(26) + RMT(2))
C   B-47
      D(1)=C(30)-47.
      DO 210 I = 2,4
C   PRODUCTS OF CONVERSION FACTORS AND SOLUBILITY COEFFICIENTS.
      D(I) = SK*A(I-1)
      D(I+9) = SK*A(I+2)
C
      D(I+3) = D(I)*D(I)
  210 CONTINUE
C   FACTOR USED IN ESTABLISHING CA(CO2)
      D(8) = 0.16 * 2.3*C(17)
C
```

```
      D(9) = 863.0/D(1)
C--FACTOR USED IN ESTABLISHING CB(CO2).
      D(10) = 0.62
C -MANIPULATION OF COMPUTER TIME STEP.
      D(14) = C(36)*2.0
      D(15) = D(14) - .01*C(36)
C
      CALL RC3
      CALL RC4
      CALL RC5 (CPB, F(4), C(4), BC(2))
      CALL RC21 (CHB(2), F(3), F(4), C(4), CH(2), CPH(2))
      CALL RC19 (CPB, CHB(2), CC(2), BC(1), F(4))
      CALL RC5 (CPT, F(6), C(7), BC(3))
      CALL RC21 (CHB(3), F(5), F(6), C(7), CH(3), CPH(3))
      CALL RC19 (CPT, CHB(3), CC(3), BC(1), F(6))
      CALL RC20
      CALL RC7
      CALL RC8
      CALL RC9
      CALL RC10
      CALL RC11
      CALL RC12
      GO TO 60
   50 CALL RC15
      CALL RC16
   60 CALL RC13
      CALL RC12
C
      IF(C(35).GE.XMH) GO TO 201
C
      IF (C(35) .GT. C(15)) GOTO80
      IF(CXT.GT.C(15)) GOTO 80
   70 CALL RC14
      UU = AMOD(C(35), D(14))
      IF (UU .LT. .0001 .OR. UU .GT. D(15))   GOTO50
      RETURN
C      GO TO 60
   80 WRITE(6,78)
   78 FORMAT('1 FINAL VALUES FOR FOLLOWING VARIABLES.')
      IF (C(37) .GT. 1.0E-5)     GO TO 250
  220 CTERM = 0.0
      IF (VTRAN(14) - 104.0)      230, 240, 240
  230 CTERM = (23.6E-9)*((104.0 - VTRAN(14))**4.9)
  240 C(37) = C(20)*(C(16)*VTRAN(15) + (1.0 - C(16))*CH(4))
     1       + C(21)*VTRAN(13) + CTERM - VI
      I = 37
      WRITE(6,192)I,C(I), (XN(I,J), J = 1,2)
  250 DO 260 I = 1,14
      WRITE(6,192)I,C(I), (XN(I,J), J = 1,2)
  260 CONTINUE
      WRITE (6,194)
      WRITE(6,830)
  830 FORMAT('ONORMAL TERMATION')
  301 CONTINUE
      STOP
C  90 FORMAT (1H148X37H-RESPIRATORY CHEMOSTAT -- INPUT DATA-///)
C  92 FORMAT (42XI3,10AF10.4,10X2A6)
```

```
      C 190 FORMAT (5XF15.0,5XZA6)
        192 FORMAT('-',I3,2X,F15.4,2X,2A4)
        194 FORMAT (1H1)
            END
```

QPRT,S RC,2

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D86-G03432*TPFS.RC12

```
      SUBROUTINE RC12
      COMMON/RINTR/ROUT(10),CIN(10)
      DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
     1          SC(14,5), DC(14), A(8), D(15), F(20), VOL(10), RMT(2),
     2          BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
     3          DQ(4)
      COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
     1          TAU, CC, CHB, CH, CPH, DQ, VE, VI, CPB, CPT, CADK, X, DT,
     2          IRK, LOC, ITERX, INDEX, I, J, M, N
      COMMON/R/ XDS,XMH,CXT,WORK,DUM1,DUM2,DUM3,WORK2,RMTB,RMTB2,TIMEOF
     1  ,RMLIN,ITTY,ITTYOT,ITTYIN,WRKTTY(50,3),LEXEC,MARKER,NWREST
     2  ,RMTM,TCT
      DATA IRUN/'RUN '/,ISTOP/'STOP'/,MORE/'MORE'/
      DATA IBACK/'BACK'/
C     DIMENSION WRKTTY(50,3)
C6969                 FORMAT(1H 8HSUB RC12)
C     OUTPUT -- PUNCHED CARDS AND PRINTED
      CXT=C(35)+XDS-10.
      IF(CXT.LE.0.)CXT=+0.
C  DEAD SPACE VOLUME
      DSVOL=0.140+0.002*VE
C  RESPIRATORY FREQUENCY.
      FREQ=((1.+(.726*VE)/DSVOL)**.5-1.)/.363
C  DEAD SPACE VENTILATION
      DEADVT=1.+.098*VE
C     C(31)=(DEADVT*C(1)+VE*DUM1)/(DEADVT+VE)
C     C(32)=(DEADVT*C(2)+VE*DUM2)/(DEADVT+VE)
C     C(33)=(DEADVT*C(3)+VE*DUM3)/(DEADVT+VE)
C  MINUTE VOLUME.
      TVNT=DEADVT+(VE+VI)/2.
C  HEART RATE.
      HRATE=43.8*(RMT(2)+C(26))+54.5
C
C
      IF(CXT .LT. TIMEOF) GO TO 203
C
C  HERE IF NEED TO READ A NEW WORK LOAD CARD.
C          BRANCH IF IN BATCH MODE.
      IF(ITTY .EQ. 0) GO TO 500
C
C
C   HERE IF TTY MODE..................
      IF(ITTY .EQ. 1) GO TO 550
C  HERE IF TTY MODE, AND 1ST TIME THIS ROUTINE CALLED.
      ITTY = 1
      WRITE(6,505)
  505 FORMAT('0INPUT WORK CARDS...'/)
C    1 ' WORK= WORK LOAD(WATTS)...'/
C    2 ' MINS= TIME FOR WORK LOAD...'/
C    3 ' PRINT= TIME INCRIMENT(MINS)FOR PRINTOUT...'/
C    4 ' EXEC...'/
C    5 '  MORE= INPUT MORE BEFORE EXEC...'/
C    6 '  RUN = EXEC.WITH ABOVE,THEN CAN INPUT AGAIN...'/
C    7 '  STOP= EXEC.WITH ABOVE THEN STOP...'/
C    8 '  BACK= ERASE PREVIOUS WORK RECORD...')
  504 ITTYIN = 0
```

```
      ITTYOT = 1
C
  501 IF(ITTYIN .LT. 50) GO TO 506
C  HERE IF BUFFER FOR WORK LOAD CARDS IS FULL.
      WRITE(6,511)
  511 FORMAT('0BUFFER FOR WORK LOAD RECORDS FULL.'/
     1 ' WILL USE EXEC= RUN.')
      LEXEC = IRUN
      GO TO 551
C
  506 ITTYIN = ITTYIN + 1
  509 WRITE(6,507)
  507 FORMAT(' WORK   MINS   PRINT  EXEC  ',
     1 '(F6.2,1X,F6.2,1X,F6.2,1X,A4)...')
      READ(5,502,ERR=509) (WRKTTY(ITTYIN,J),J=1,3),LEXEC
  502 FORMAT(F6.2,1X,F6.2,1X,F6.2,1X,A4)
      WRITE(6,503) (WRKTTY(ITTYIN,J),J=1,3),LEXEC
  503 FORMAT(3(' ',F6.2),A4)
      IF(LEXEC .NE. IBACK) GO TO 518
      ITTYIN = ITTYIN - 1
      IF(ITTYIN .LT. 1) ITTYIN = 1
      GO TO 509
C
  518 IF(LEXEC .EQ. IRUN .OR. LEXEC .EQ. ISTOP) GO TO 551
      IF(LEXEC .EQ. MORE) GO TO 501
      WRITE(6,510)
  510 FORMAT(' EXEC.PARAMETER WRONG. TRY AGAIN.')
      GO TO 509
C
C  HERE IF 1ST TIME THIS ROUTINE CALLED.
C SEE IF MORE WORK CARDS IN BUFFER(WRKTTY(500,3))
  550 IF(ITTYOT .LE. ITTYIN) GO TO 551
C  HERE IF EXAUSTED WORK CARD BUFFER (WRKTTY(500,3)).
      IF(LEXEC .EQ. IRUN) GO TO 504
C  FORCE END OF COMPUTER RUN WHEN LEXEC= 'STOP'.
      C(15) = 0.
      GO TO 1210
C
  551 WORK2 = WRKTTY(ITTYOT,1)
      DURAT = WRKTTY(ITTYOT,2)
      C(39) = WRKTTY(ITTYOT,3)
      ITTYOT = ITTYOT + 1
      GO TO 606
C
C
C
  203 IF(MARKER.EQ.0) GOTO101
    1 WORK=WORK2
      MARKER=1
C SYSTEM RESPONSES: TIME CONSTANTS FOR WORK LOAD LEVELS(INCREASING).
      IF(WORK.LE.0.)GOTO2
      IF(WORK.GE.50.) TCT=2.3/(2.*WORK/200.)
      IF(WORK.LT.50)TCT=4.6
C  TISSUE O2 METABOLIC RATE.
      RMT(2)=SSO2W(WORK)-(SSO2W(WORK)-RMTB2)*EXP(-TCT*(CXT   -TIMEON))
      VTIME=1.1-1.1*EXP(-TCT*(CXT-TIMEON)/1.92)
C  TERM USED IN VI THAT IS A COMPONENT OF TRANSIENT RESPONSE RELATED
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      C  TO WORK LOAD.
           RMLIN =SS02W(WORK)-(SS02W(WORK)-RMT(2))*(1.-VTIME)
           IF(VTIME.GE.1.) RMLIN=SS02W(WORK)
      C  TISSUE CO2 METABOLIC RATE.
           RMT(1)=.88*RMT(2)
           IF(TVNT.GT.37.) RMT(1)=(TVNT+40.77)*RMT(2)/88.5
           IF(C(35).LT.C(40)) GOTO2
           WRITE (6,333) RMT(1),RMT(2)
       333 FORMAT( '0',1X,25HCHANGE IN METABOLIC RATES,5X,7HMRCO2= ,F10.4,
          1  5X,6HMRO2= ,F10.4,/)
      C
      C
         2 CONTINUE
           IF (WORK.LE.0.0 .AND. NWREST.LT.1) RMT(2)=CIN(3)-C(26)
           AVO2DM=(F(9)*C(10)-F(13)*(C(10)-C(11))-F(12)*C(11))*1000.
           AVO2DF=AVO2DM/C(10)
           ROUT(1)=AVO2DM/1000.    IF(WORK.GT.0.0) ROUT(1)=RMT(2)+C(26)
           ROUT(2)=FREQ
           ROUT(3)=C(11)
           ROUT(4)=F(7)
           ROUT(5)=F(1)
      C    U = AMOD(C(35), 0.5)
      C    IF (U .LT. 1.0E-5 .OR. U .GT. .4999)       GO TO 1210
           IF(C(35).LT.C(40))GOTO1230
           C(40)=C(40)+C(39)
      C  ARTERIAL N2 TENSION.
      1210 PAN2 = D(1)*C(3)
      C  TISSUE O2 TENSION.
           PTO2 = C(8)/D(3)
      C  TISSUE N2 TENSION.
           PTN2 = C(9)/D(4)
      C  CEREBROSPINAL FLUID PH , EQUATION 6.2 .
           PHCSF = 9. - RCF1(CH(4))
      C  VENOUS BRAIN H+ CONCENTRATION , EQUATION 4.7 .
           HVB   = CADK*F(4)/(CC(2) - F(4))
      C  VENOUS BRAIN PH , EQUATION 4.6 .
           PHVB  = 9. - RCF1(HVB)
      C  VENOUS TISSUE H+ CONCENTRATION , EQUATION 5.7 .
           HVT   = CADK*F(6)/(CC(3) - F(6))
      C  VENOUS TISSUE PH , EQUATION 5.6 .
           PHVT  = 9. - RCF1(HVT)
      C  RESPIRATORY QUOTIENT (ALVEOLAR).
           RQ = ((C(11)*VTRAN(4) + GF(1)*VTRAN(7))/C(10) - CC(1))/
          1     (F(9) - (C(11)*VTRAN(5) + GF(1)*VTRAN(8))/C(10))
           GF(5) = GF(6) - RQ
      C
      C
      C  HERE WHEN READY TO PRINT.
      C         SEE IF TTY MODE.
           IF(ITTY .EQ. 0) GO TO 610
      C
      C  HERE IF TTY OUTPUT.
           WRITE (6,700) CXT,CC(1),CC(2),CC(3),F(9),F(12),F(13),
          &  CH(4),F(7),CPB,CPT,F(1),F(17),PTO2,VI,VE,C(11),
          &  FREQ,TVNT,AVO2DF,RMT(2),C(10)
       700 FORMAT(7F9.4)
           RETURN
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```
  610 IF (N .NE. 4)     GO TO 1220
      N = 0
      WRITE (6,1805)
 1220 N = N + 1
C
      WRITE (6,1810) CXT, RQ, QF(5)
C
      WRITE (6,1815) (C(I), I = 1,3), (DC(I), I = 1,3), F(7), F(1),
     1       PAN2
      WRITE (6,1820)    CC(1), F(9), F(10), F(7), F(1), PAN2, CH(1),
     1       CPH(1), CHB(1)
      WRITE (6,1825)    (C(I), I = 4,6), (DC(I), I = 4,6), CPB, F(17),
     1       F(18), CH(2), CPH(2)
      WRITE (6,1830)    (C(I), I = 7,9), (DC(I), I = 7,9), CPT, PTO2,
     1       PTN2, CH(3), CPH(3)
      WRITE (6,1835)    (DC(I), I = 12,14), (C(I), I = 12,14), CH(4),
     1       PHCSF
      WRITE (6,1840)    CC(2), F(12), C(6), CPB, F(17), F(18), HVB,
     1       PHVB, CHB(2)
      WRITE (6,1845)    CC(3), F(13), C(9), CPT, PTO2, PTN2, HVT,
     1       PHVT, CHB(3)
      WRITE (6,1850)    (TAU(I), I = 1,5), VI, VE, C(10), C(11), DC(10),
     1       DC(11)
      WRITE (6,1855) FREQ,TVNT,DEADVT,HRATE,AVO2DF,DSVOL
 1230 RETURN
 1290 FORMAT (5H XXXX5X7F10.4)
 1292 FORMAT (8F10.4)
 1805 FORMAT (1H1)
 1810 FORMAT (1H0,X4HTIME,F10.4,7X,6HALV RQ,F10.4,3X7HRQ DIFF,F8.4/
     1       16X3HCO28X2HO28X2HN27X21HD E R I V A T I V E S9X4HPCO26X
     2       3HPO27X3HPN27X4H(H+)7X2HPH5X4HHBO2)
 1815 FORMAT (3X8HALVEOLAR9F10.4)
 1820 FORMAT (3X8HARTERIAL3F10.4,30X,5F10.4,F8.4)
 1825 FORMAT (6X5HBRAIN11F10.4)
 1830 FORMAT (5X6HTISSUE11F10.4)
 1835 FORMAT (8X3HCSF30X8F10.4)
 1840 FORMAT (4X7HV BRAIN3F10.4,30X,5F10.4,F8.4)
 1845 FORMAT (3X8HV TISSUE3F10.4,30X,5F10.4,F8.4)
 1850 FORMAT (5X18HTRANSPORT TIMES --4X2HAB6X2HVB8X2HVT8X2HAT8X2HAC2X
     1  2H**4X2HVI8X2HVE8X1HQ9X2HFB7X11HDERIVATIVES/21X,10F10.4,F8.4)
 1855 FORMAT(3X,9HRESP FREQ,F8.4,2X,13HMINUTE VOLUME,F8.4,
     1  2X,8HD S VENT,F8.4,2X,10HHEART RATE,F8.4,
     2  2X,7HAVO2DF,F8.4,2X,5HDSVOL,F8.4)
C   BATCH MODE WORK CARD READ...
C
C      WILL USE WORK CARD WITH TIME=0 AS INDICATION
C      OF END OF RUN BECAUSE 1106 HAS PROBLEM
C      WITH END= ON READ.
  500  READ(5,300,END=2) WORK2,DURAT
  300  FORMAT(F6.2,3X,F6.2)
C
       IF(DURAT .GT. 0.) GO TO 606
C  HERE IF READ INDICATION OF END OF RUN IN BATCH MODE.
       C(15) = 0.
       GO TO 1210
C
  606 WRITE (6,305) WORK2,DURAT,CXT
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      305 FORMAT('0',43('*')/
         1 ' WORK LOAD CHG.(',F6.2,'WATTS FOR',
         2 F8.2,'MINS) AT',F9.4,'MINS')
      607 TIMEOF=DURAT+CXT
          TIMEON=CXT
C  SYSTEM RESPONSES: TIME CONSTANTS FOR WORK LOADS AND TISSUE O2
C  METABOLIC RATE.
          IF(WORK2.GE.WORK)RMTB2=RMT(2)
C  DECREASING WORK LOADS.
          IF(WORK2.LT.WORK) RMTH=RMT(2)
          IF(WORK2.LT.WORK)RMTB=SSO2*(WORK2)
          IF((WORK2.LT.WORK).AND.(WORK.GE.50.))    TCT=2.3/(2.*WORK/200.)
          IF((WORK2.LT.WORK).AND.(WORK.LT.50.))TCT=4.6
          IF(WORK2.NE.WORK) GOTO1
      101 WORK=WORK2
          MARKER=0
          NREST=2
C  TISSUE O2 METABOLIC RATE.
          RMT(2)=RMTB-(RMTB-RMTM)*EXP(-TCT*(CXT-TIMEON)*.50)
          VTIME=1.1-1.1*EXP(-TCT*(CXT-TIMEON)/3.84)
C  TERM USED IN VI THAT IS A COMPONENT OF TRANSIENT RESPONSE RELATED
C  TO WORK LOAD.
          RMLIN =RMTB-(RMTB-RMTM)*(1.-VTIME)
          IF(VTIME.GE.1.) RMLIN=RMTB
C  TISSUE CO2 METABOLIC RATE.
          RMT(1)=.88*RMT(2)
          IF(TVNT.GT.37.) RMT(1)=(TVNT+40.77)*RMT(2)/88.5
          IF(C(35).LT.C(40)) GOTO2
          WRITE (6,333) RMT(1),RMT(2)
          GOTO2
          END
```

@PRT,S SSO2*

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```
DB6-G03432*TPFS.SS02W
      FUNCTION SS02W(X)
C  CALCULATION OF STEADY-STATE OXYGEN REQUIREMENTS FOR VARIOUS LEVELS
C  OF WORK LOAD (X=WATTS).
      COMMON/RINTR/ROUT(10),CIN(10)
      VO2RDT=CIN(3)
      SS02W=VO2RDT-.0500+(.00049508l5*6.12*X)/.25
      RETURN
      END

@PRT,S TERG
```

DB6-G03432*TPFS.TERG

```
      SUBROUTINE TERG
C***   GE CARDIOVASCULAR LBNP MODEL 10/23/73
       COMMON/STATE/X(50),XDOT(50)
      2/STATE/QRA,QRV,QLA,QLV,QPA,QPC,QPV,QAA,QARC,QLAA,QUTA,QLTA,QUABA,
      3QLABA,QCILL,QLGSA,QLGAR,QLGCAP,QLGVE,QLGSV,QFEV,QABVC,QTHVC,QSPVC,
      4QLOC,QUPC,QHCAP,QHSV,QJV,QCOR,QCSMA,QIMA,QCSMV,QPOV,QIMV,
      5QRENA,QRALE,QRENV,QRET,QD(10),QSKB
      6/STATE/CRA,CRV,CLA,CLV,CPA,CPC,CPV,CAA,CARC,CLAA,CUTA,CLTA,CUABA,
      7CLABA,CCILL,CLGSA,CLGAR,CLGVE,CLGSV,CFEV,CABVC,CTHVC,CSPVC,
      8CLOC,CUPC,CHSV,CJV,CCSMV,CIMV,CPOV,
      9CRENA,CRENV,CD(18)
      A/STATE/PRA,PRV,PLA,PLV,PPA,PPC,PPV,PAA,PARC,PLAA,PUTA,PLTA,PUABA,
      BPLABA,PCILL,PLGSA,PLGAR,PLGVE,PLGSV,PFEV,PABVC,PTHVC,PSPVC,
      CPLOC,PUPC,PHSV,PJV,PCSMV,PIMV,PPOV,
      DPRENA,PRENV,PD(16),PM,PMC
       COMMON/STATE/
      ERPA,RRV,RMV,RAV,RPA,RPC,RPV,RARC,RLAA,RUTA,RLTA,RUABA,
      FRLABA,RCILL,RLGSA,RLGAR,RLGCAP,RLGVE,RLGSV,RFEV,RABVC,
      GRTHVC,RSPVC,RLOC,RUPC,RHCAP,RHSV,RJV,RCOR,RCSMA,RIMA,RCSMV,
      HRPOV,RIMV,RRENA,RRALE,RREFF,RRENV,RD(11),RSKB
      I/STATE/FLPA,FLAA,FLARC,FLLAA,FLUTA,FLLTA,FLUABA,
      JFLLABA,FLCILL,FLCSMA,FLIMA,FLRENA,FLDM(8)
      K/STATE/V(50),VU(50),PG(34),PEXT(32),E(4)
      *,PRN,ABIAS,TBIAS,TTHAZ,TMODEL,SPACE(5)
      L,Z(40),WK(20),HR,SV,CO,RT,PEX,W,PSYS,PDYS,FREQ
      M,VO2DOT,AVD,PIAB,PITH,PMP,THETA,SF
      N,TTOT,TAS,TVS,C1,C2,GNEW,PEXIN,TR
      *,DUMMY(13),T,DPRT,VLEG
       CALL XIC
       CALL CONTRL
       CALL CVS
     1 CALL ALGO(T)
       IF (T.GT.TTHAZ) THETA=0.
       IF (T.LT.WK(20)) GO TO 1
       CALL EXEC
       RETURN
       END
```

@PRT,S CVS

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D86-603432*TPFS.CVS

```
      SUBROUTINE CVS
C              GE CARDIOVASCULAR LBNP MODEL
C                             CONTROLLED SYSTEM
      COMMON/RINTR/RIN(10),ROUT(10)
      COMMON/STATE/X(50),XDOT(50)
     2/STATE/QRA,QRV,QLA,QLV,QPA,QPC,QPV,QAA,QARC,QLAA,QUTA,QLTA,QUABA,
     3QLABA,QCILL,QLGSA,QLGAR,QLGCAP,QLGVE,QLGSV,QFEV,QABVC,QTHVC,QSPVC,
     4QLOC,QUPC,QMCAP,QHSV,QJV,QCOR,QCSMA,QIMA,QCSMV,QPOV,QIMV,
     5QRENA,QHALE,QRENV,QRET,QD(10),QSKB
     6/STATE/CRA,CRV,CLA,CLV,CPA,CPC,CPV,CAA,CARC,CLAA,CUTA,CLTA,CUABA,
     7CLABA,CCILL,CLGSA,CLGAR,CLGVE,CLGSV,CFEV,CABVC,CTHVC,CSPVC,
     8CLOC,CUPC,CHSV,CJV,CCSMV,CIMV,CPOV,
     9CRENA,CRENV,CD(18)
     A/STATE/PRA,PRV,PLA,PLV,PPA,PPC,PPV,PAA,PARC,PLAA,PUTA,PLTA,PUABA,
     BPLABA,PCILL,PLGSA,PLGAR,PLGVE,PLGSV,PFEV,PABVC,PTHVC,PSPVC,
     CPLOC,PUPC,PHSV,PJV,PCSMV,PIMV,PPOV,
     DPRENA,PRENV,PD(16),PM,PMC
      COMMON/STATE/
     ERRA,RRV,RMV,RAV,RPA,RPC,RPV,RARC,RLAA,RUTA,RLTA,RUABA,
     FRLABA,RCILL,RLGSA,RLGAR,RLGCAP,RLGVE,RLGSV,RFEV,RABVC,
     GRTHVC,RSPVC,RLOC,RUPC,RHCAP,RHSV,RJV,RCOR,RCSMA,RIMA,RCSMV,
     HRPOV,RIMV,RRENA,RHALE,RREFF,RRENV,RD(11),RSKB
     I/STATE/FLPA,FLAA,FLARC,FLLAA,FLUTA,FLLTA,FLUABA,
     JFLLABA,FLCILL,FLCSMA,FLIMA,FLRENA,FLDM(3)
     K/STATE/V(50),VU(50),PG(34),PEXT(32),E(4)
     *,PRN,ABIAS,TBIAS,TTHA7,TMODEL,SPACE(5)
     L,Z(40),WK(20),HR,SV,CO,RT,PEX,N,PSYS,PDYS,FREQ
     M,VO2DOT,AVD,PIAB,PITH,PMP,THETA,SF
     N,TTOT,TAS,TVS,C1,C2,GNEW,PEXIN,TR
     *,DUMMY(13),T,DPRT,VLEG
      DIMENSION PRS(1),CMP(32),RSO(50),FINR(12)
      EQUIVALENCE (PRS,PRA),(CMP(1),CRA),(RSO(1),RRA),(FINR(1),FLPA)
     & ,(PD(3),TT),(PD(4),TSVE),(PD(5),TRSP),(PD(6),TMP)
     & ,(PD(7),TPS),(PD(8),P2)
C              T IS ELAPSED TIME
C              TT IS A CLOCK FOR ONE BEAT
      TT=T-TSVE
      IF (TT-TTOT) 1002,1001,1001
 1001 TSVE=T
C....
      DPMD=1700.+4600./3.*(VO2DOT-.5)
      DPER=DPMD-PD(10)
      IF(DPER.LT.-50.)PD(11)=PD(11)-.001
      IF(DPER.GT.50.)PD(11)=PD(11)+.001
      IF(VO2DOT.LT..5)PD(11)=0.
      CO=X(33)/TTOT*.06
      X(33)=0.0
      PM=X(10)/TTOT
      X(10)=0.0
      PMC=X(13)/TTOT
      X(13)=0.0
      PD(1)=X(34)/TTOT
      X(34)=0.0
      SV=TTOT/60.*CO
      RT=PD(1)/CO
      DIFF=-V(50)+V(49)
```

```
      X(18)=X(18)+DIFF*0.6
      X(19)=X(19)+DIFF*0.4
      PSYS=SYS
      PDYS=DYS
      CALL XIO
      PD(10)=0.
  110 CALL CONTRL
      TEMP=TEMP+0.2
      IF (TEMP-T) 110,111,111
  111 CONTINUE
      CALL EXEC
      SYS=0.0
      DYS=1000.
      TTOT=60./HR
      TAS=0.10+0.09*TTOT
      TVS=0.16+0.20*TTOT
      IF (T.LT.41. .OR. T.GT.43.) GO TO 20
      DO 10 I=1,32
   10 PG(I)=SIN(THETA/57.2958)*Z(I)*1.05*980./1332.
      TILT=THETA
   20 CONTINUE
      IF (TMODEL.GT.0.) GO TO 26
      GO TO 30
C  26 IF (ABS(THETA).LT.1.E-5 .OR. T.LT.40.) GO TO 30
   26 IF (ABS(THETA).GT.1.E-5) TILTD=1.
      IF (ABS(THETA).GT.1.E-5) GO TO 30
      IF (TILTD.GT.2.) GO TO 30
      DO 28 I=1,32
   28 PG(I)=0.
      TILTD=3.
   30 CONTINUE
      VLEG=0.
      DO 201 I=15,20
      VLEG=VLEG+V(I)
  201 CONTINUE
      VLEG=VLEG-VU(18)-VU(19)-VU(20)
      TEMPV=0.
      DO 16 I=1,32
   16 TEMPV=TEMPV+VU(I)
      SPACE(3)=V(50)-VLEG-TEMPV+VU(18)+VU(19)+VU(20)
     6 +VU(15)+VU(16)+VU(17)
 1002 CONTINUE
      IF(TT-TAS)1,2,2
    1 SAS=SIN(3.1416*TT/TAS)
      E(1)=0.05+0.05*SAS*SF
      E(3)=0.12+0.14*SAS*SF
      RSPVC=(20.+SAS*40.)/1332.
      RTHVC=(10.+SAS*20.)/1332.
      GO TO 3
    2 E(1)=0.05
      E(3)=0.12
      RSPVC=.015015
      RTHVC=.0075075
    3 TV=TT-0.1
      IF(TV.LT.0.0)TV=0.0
      IF(TV-TVS)4,5,5
    4 SVS=SIN(3.1416*TV/TVS)
```

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      E(2)=0.0175+.39*SF*SVS
      E(4)=0.02+1.50*SF*SVS
      GO TO 6
    5 E(2)=0.0175
      E(4)=0.02
    6 CONTINUE
      DO 11 I=1,4
   11 CMP(I)=1./E(I)
      IF(X(4).LT.0.0)X(4)=0.0
C                COMPUTE VOLUMES
      V(50)=0.0
      DO 55 I=1,32
      V(I)=VU(I)+X(I)
   55 V(50)=V(50)+V(I)
      V(50)=V(50)-V(9)-V(11)-V(13)-V(10)-VU(18)-VU(19)-VU(20)
      IF (THETA.GT.45.AND.T.GT.40.) PITH=-2.5
C                RESPIRATORY PUMPS
      IF (PEX.EQ.0.0) GO TO 115
      IF(T.LE.40.0 .OR. THETA.LT.45.)GO TO 115
      TRSP=TRSP+T-TPS
      IF(TRSP.GT.TR)TRSP=0.0
      TI=TRSP/TR
      PITH=-2.67-19.704*TI+56.409*TI**2-53.479*TI**3+16.602*TI**4
      DEPTH=(VO2DOT-1.)/2.
      IF(DEPTH.LT.0.)DEPTH=0.
      IF(DEPTH.GT.1.5)DEPTH=1.5
      PITH=PITH-DEPTH
      PIAB=-PITH/2.
  115 CONTINUE
      DO 71 I=1,12
   71 PEXT(I)=PITH
      PEXT(22)=PITH
      PEXT(23)=PITH
      DO 72 I=28,32
   72 PEXT(I)=PIAB
      PEXT(14)=PIAB
      PEXT(21)=PIAB
C                MUSCLE  PUMP
      TMP=TMP+T-TPS
      TPS=T
      IF (TMP.GE.1.) TMP=0.
      SMP=SIN(2.*3.1416*TMP)
      PMP=40.*SMP
      IF(THETA.LT.15.)PMP=10.*SMP
      IF (SMP.LT.0.) PMP=0.
      IF (PEX.LT.1.) PMP=0.
      DO 44 I=16,19
   44 PEXT(I)=PMP
C                COMPUTE PRESSURES
      P1=P2
      P2=PLV
      DO 12 I=1,7
   12 PRS(I)=X(I)/CMP(I)+PEXT(I)
      DPDT=(PLV-P1)/(2.*.002)
      IF(DPDT.GT.PD(10))PD(10)=DPDT
      DO 13 I=15,17
   13 PRS(I)=X(I)/CMP(I)+PEXT(I)
```

```
      PTIS=SPACE(4)
      PGBIAS=SPACE(5)
      DO 15 I=18,20
      PRS(I)=X(I)/VU(I)*2.+PEXT(I)+PTIS+PGBIAS-2.
   15 IF(X(I).GT.VU(I))PRS(I)=
     & (X(I)-VU(I))/CMP(I)+PEXT(I)+PTIS+PGBIAS
      DO 14 I=24,32
   14 PRS(I)=X(I)/CMP(I)+PEXT(I)
      PAA=X(8)/CAA+PITH
      PUTA=X(29)/CUTA+PITH
      PLTA=X(12)/CLTA+PITH
      IF(PUTA.GT.SYS)SYS=PUTA
      IF(PUTA.LT.DYS)DYS=PUTA
      PLABA=PIAB-11.826+0.062265*V(14)+0.0097734*V(14)*V(14)
      PLABA=X(14)/CLABA+PIAB
C**** ABDOMINAL VENA CAVA
      PABVC=-5.4996+0.082408*V(21)-0.00033598*V(21)*V(21)
     .+0.00000045026*V(21)*V(21)*V(21)
      IF (X(21).GT.200. .AND. X(21).LT.350.)
     . PABVC=.34/150.*(X(21)-200.)+1.15
C**** THORACIC VENA CAVA
      PTHVC=-5.5006+0.1154*V(22)-0.00065673*V(22)*V(22)
     .+0.000001236*V(22)*V(22)*V(22)
      IF (X(22).GT.150. .AND. X(22).LT.250.)
     . PTHVC=.3/100. * (X(22)-150.) + 1.16
      PSPVC=-3.4999+0.92409*X(23)-0.042246*X(23)*X(23)
     .+0.00063465*X(23)*X(23)*X(23)
      PTHVC=PTHVC+PEXT(22)+TBIAS
      PABVC=PABVC+PEXT(21)+ABIAS
      PSPVC=PSPVC+PEXT(23)
      QRA=(PRA-PRV)/RRA
C                 HEART MODEL
      IF(PRA.LT.PRV)QRA=0.0
      QRV=X(09)/FLPA
      IF(QRV.LT.0.0)QRV=0.0
      XDOT(09)=PRV-PPA-RRV*QRV
      IF(XDOT(09).LT.0.0.AND.QRV.EQ.0.0)XDOT(09)=0.0
      QLA=(PLA-PLV)/RRV
      IF(PLA.LT.PLV)QLA=0.0
      QLV=X(11)/FLAA
      IF(QLV.LT.0.0)QLV=0.0
      XDOT(11)=PLV-PAA+PG(8)-RAV*QLV
      IF(XDOT(11).LT.0.0.AND.QLV.EQ.0.0)XDOT(11)=0.0
C                 PULMONARY CIRCULATION
      QPA=(PPA-PPC)/RPA
      QPC=(PPC-PPV)/RPC
      QPV=(PPV-PLA)/RPV
C                 ARTERIAL MODEL
      QAA=(PAA-PUTA+PG(12))/RUTA
      QUTA=(PUTA-PLTA+PG(13))/RLTA
      QLTA=(PLTA-PLABA+PG(14))/RLABA
      QLABA=(PLABA-PCILL+PG(15))/RCILL
C                 LEGS
      QCILL=(PCILL+PG(16)-PLGSA)/RLGSA
      QLGSA=(PLGSA-PLGAR)/RLGAR
      QLGCAP=(PLGAR-PLGVE)/RLGCAP
      RLGVE=.05
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```
      IF(QLGVE.LT.0.0)RLGVE=67.567567
      QLGVE=(PLGVE-PLGSV)/RLGVE
      RLGSV=.05
      IF(QLGSV.LT.0.0)RLGSV=67.567567
      QLGSV=(PLGSV-PG(19)-PFEV)/RLGSV
C                VENOUS MODEL
      RFEV=.021
      IF(QFEV.LT.0.0)RFEV=67.567567
      QFEV=(PFEV-PG(20)-PABVC)/RFEV
      QABVC=(PABVC-PG(21)-PTHVC)/RABVC
      QTHVC=(PTHVC-PG(22)-PRA)/RTHVC
      QSPVC=(PSPVC-PG(23)-PRA)/RSPVC
C                HEAD+ARMS
      QLOC=(PAA+PG(24)-PLOC)/RLOC
      QUPC=(PLOC-PUPC)/RUPC
      QBRAIN=RIN(3)*1000./60.
      QARM=17.25
      QHCAP=QBRAIN+QARM
C      QHCAP=(PUPC-PHSV)/RHCAP
      QHSV=(PHSV-PJV)/RHSV
      RJV=.004301
      IF(QJV.LT.0.0)RJV=67.567567
      QJV=(PJV-PG(27)-PSPVC)/RJV
C                CORONARY CIRCULATION
      QCOR=(PAA-PRA)/RCOR
C                CONTINUITY FOR VENOUS RETURN
      QRET=QSPVC+QTHVC+QCOR
C                HEPATIC-SPLANCHNIC CIRCULATION
      QCSMA=(PLTA-PCSMV)/RCSMA
      QCSMV=(PCSMV-PPOV)/RCSMV
      QPOV=(PPOV-PTHVC)/RPOV
C                RENAL CIRCULATION
      QRENA=(PLABA-PRENA)/RRENA
      QRALE=(PRENA-PRENV)/(RRALE+RREFF)
      QRENV=(PRENV-PABVC)/RRENV
C                SKELTON,BONE MARROW,AND OTHER
      QSKB=(PLABA-PABVC)/RSKB
C                STATE VARIABLE DERIVATIVES
      XDOT(1)=QRET-QRA
      XDOT(2)=QRA-QRV
      XDOT(3)=QPV-QLA
      XDOT(4)=QLA-QLV
      XDOT(5)=QRV-QPA
      XDOT(6)=QPA-QPC
      XDOT(7)=QPC-QPV
      XDOT(8)=QLV-QAA-QCOR-QLOC
      XDOT(10)=PAA
      XDOT(12)=QUTA-QLTA-QCSMA
      XDOT(14)=QLTA-QLABA-QRENA-QSKB
      XDOT(15)=QLABA-QCILL
      XDOT(16)=QCILL-QLGSA
      XDOT(17)=QLGSA-QLGCAP
      XDOT(18)=QLGCAP-QLGVE
      XDOT(19)=QLGVE-QLGSV
      XDOT(20)=QLGSV-QFEV
      XDOT(21)=QFEV-QABVC+QRENV+QSKB
      XDOT(22)=QABVC+QPOV-QTHVC
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      XDOT(23)=QJV-QSPVC
      XDOT(24)=QLOC-QUPC
      XDOT(25)=QUPC-QHCAP
      XDOT(26)=QHCAP-QHSV
      XDOT(27)=QHSV-QJV
      XDOT(28)=QCSMA-QCSMV
      XDOT(29)=QAA-QUTA
      XDOT(30)=QCSMV-QPOV
      XDOT(31)=QRENA-QRALE
      XDOT(32)=QRALE-QRENV
      XDOT(33)=QLV
      XDOT(13)=PLOC
      XDOT(34)=PUTA
      RETURN
      END

@PRT,S CONTRL
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D86-G03432*TPFS.CONTRL

```
      SUBROUTINE CONTRL
      COMMON/STATE/X(50),XDOT(50)
     2/STATE/QRA,QRV,QLA,QLV,QPA,QPC,QPV,QAA,QARC,QLAA,QUTA,QLTA,QUABA,
     3QLABA,QCILL,QLGSA,QLGAR,QLGCAP,QLGVE,QLGSV,QFEV,QABVC,QTHVC,QSPVC,
     4QLOC,QUPC,QHCAP,QHSV,QJV,QCUR,QCSMA,QIMA,QCSMV,QPOV,QIMV,
     5QRENA,QRALE,QRENV,QRET,QD(10),QSKB
     6/STATE/CRA,CRV,CLA,CLV,CPA,CPC,CPV,CAA,CARC,CLAA,CUTA,CLTA,CUABA,
     7CLABA,CCILL,CLGSA,CLGAR,CLGVE,CLGSV,CFEV,CABVC,CTHVC,CSPVC,
     8CLOC,CUPC,CHSV,CJV,CCSMV,CIMV,CPOV,
     9CRENA,CRENV,CD(18)
     A/STATE/PRA,PRV,PLA,PLV,PPA,PPC,PPV,PAA,PARC,PLAA,PUTA,PLTA,PUABA,
     BPLABA,PCILL,PLGSA,PLGAR,PLGVE,PLGSV,PFEV,PABVC,PTHVC,PSPVC,
     CPLOC,PUPC,PHSV,PJV,PCSMV,PIMV,PPOV,
     DPRENA,PRENV,PD(16),PM,PHC
     . COMMON/STATE/
     ERRA,RRV,RLV,RAV,RPA,RPC,RPV,RARC,RLAA,RUTA,RLTA,RUABA,
     FRLABA,RCILL,RLGSA,RLGAR,RLGCAP,RLGVE,RLGSV,RFEV,RABVC,
     GRTHVC,RSPVC,RLOC,RUPC,RHCAP,RHSV,RJV,RCUR,RCSMA,RIMA,RCSMV,
     HRPOV,RIMV,RRENA,RRALE,RREFF,RRENV,RD(11),RSKB
     I/STATE/FLPA,FLAA,FLARC,FLLAA,FLUTA,FLLTA,FLUABA,
     JFLLABA,FLCILL,FLCSMA,FLIMA,FLRENA,FLDM(8)
     K/STATE/V(50),VU(50),PG(34),PEXT(32),E(4)
     *,PRN,ABIAS,TBIAS,TTHA7,TMODEL,SPACE(5)
     L,Z(40),WK(20),HR,SV,CO,RT,PEX,W,PSYS,PDYS,FREQ
     M,VO2DOT,AVD,PIAB,PITH,PHP,THETA,SF
     N,TTOT,TAS,TVS,C1,C2,GNEA,PEXIN,TR
     *,DUMMY(13),T,DPRT,VLEG
CC      CVS-RESP. INTERFACE
C     BLOCK DATA FOR INTERFACE IN & OUT
      COMMON/RINTR/RIN(10),ROUT(10)
C     INPUT FROM RESP.
      VO2DOT=RIN(1)
      FREW=RIN(2)
C     QBRAIN=RIN(3)*1000./60.
      PCO2=RIN(4)
      PO2=RIN(5)
      DPCO2=PCO2-37.5751
      DPO2=PO2-107.9482
      RVACT=1.+((DPCO2+DPO2)*0.01273)
C      RVACT=1.
C     OUTPUT TO RESP.
      ROUT(1)=CO
      ROUT(2)=VO2DOT
      ROUT(3)=RESTO2
C     CVS MODEL
      REAL   NUM9DI,NUM90
      EQUIVALENCE
     2 (ACCHET,X(41)),(XN4,X(43)),(DA,X(44)),(DL,X(45)),
     3(DO2,X(48)),(XN3,X(49)),(PD(2),FLAG),(PD(9),DTS),(PD(12),DMS)
      COMMON/DELAYC/ AVDTS(50),VO2TS(50),SAVE(10),F1(15),F2(15),F3(45)
     &   ,ANF,TDN,FNS,RESTO2
C          SAVE OLD XDOT(41-49)
      DO 10 I=40,49
   10 SAVE(I-39)=XDOT(I)
C                                          W= WORK RATE KG-M/MIN
      DO 25 I=1,17,2
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```
      IF(T-WK(I)) 26,25,25
   25 W=WK(I+1)
   26 IF(W) 27,27,28
   27 PEX=0.0
      GO TO 29
   28 PEX=1.0
   29 CONTINUE
C                         -OXYGEN REQUIREMENT FUNCTION-VO2WDT----
      IF(DO2.LT.0.0)DO2=0.0
      VO2WDT=.0004850815*W/.25
      PSW=-1.5+DO2
      DT1=DO2
      DT2=(2.*DO2-1.275)/1.15
      DT3=DA+DL
      DTIN=SWIN(PSW,DT1,DT2)
      DT=FCNSW(PEX,DT3,DT3,DTIN)
C                          ALACTIC OXYGEN DEBT DA
      DAIH=.15*(DT-1.5)+1.5
      DAI=SWIN(PSW,DO2,DAIH)
      DAO=FCNSW(PEX,0.0,0.0,DAI)
      T8=FCNSW(PEX,0.0,300.,2.)
      XDOT(44)=(DAO-DA)/T8
C                          LACTIC OXYGEN DEBT DL
      DLIH=.85*(DT-1.5)
      DLI=SWIN(PSW,0.0,DLIH)
      DLO=FCNSW(PEX,0.0,0.0,DLI)
      T7=FCNSW(PEX,0.0,300.,10.)
      XDOT(45)=(DLO-DL)/T8
C                          ARTERIAL-VENOUS OXYGEN DIFFERENCE AVD
      NUM9DI=.038*DO2
      CALL DELAY(0.0.05,NUM9DI,AVDTS,NUM9D,1)
      AVD=VO2DOT/CO
      XDOT(46)=(NUM9D-X(46))/5.
      IF(PEX.EQ.0.0)FLAG=0.0
      IF(FLAG.EQ.1.0)GO TO 60
      IF(PEX)60,60,61
   61 ANF=1.0
      TON=T+20.
      FLAG=1.0
   60 IF(T.GT.TON)ANF=0.0
      TAN=FCNSW(ANF,3.,36.,3.)
      XDOT(49)=(11.00*ANF-XN3)/TAN
      XDOT(43)=(5.5*PEX-XN4)/6.
      DMMX=2.0
      DM=DO2*25./22.
      IF(PEX.GT.0.0)DTS=DT
      IF(PEX.GT.0.0)DMS=DM
      IF(PEX.LT.1.)DM=DMS/DTS*DT
      CHEMON=DO2/0.8
      IF(CHEMON.GT.0.5)CHEMON=0.5
      FN=2.*XN4+XN3
      IF(FN.GT.11.)FN=11.
      IF(PEX.GT.0.)FNS=FN
      IF(PEX.LT.1.)FN=FNS/DTS*DT
C               CONTROLLED RESISTANCES
C     LEGS
      RMET=150.-ACCMET*50.
```

```
      IF(RMET.LT.15.)RMET=15.
      RDM=450.-450.*DM/DMMX
      IF(RDM.LT.15.)RDM=15.
      RLGCAP=(RMET+RDM)/1332.
      RLGARM=RMET+RDM
      RLGARN=-FN*5400./11.
      RLGAR=(RLGARM+RLGARN+5400.)/1332.*RVACT
C     OTHER BRANCHES
      RHCAP=3570./1332.
      RCOR=(20500.-9395.*DM/DMMX)/1332.
      RSKB=(7640.+6000.*DL)/1332.
      RRALE=(5000.-1600.*DL)/1332.
      RDMR=DM/DMMX
      IF(RDMR.GT.1.)RDMR=1.
      RCSMA=(5000.+1070.*(FN/11./2.+RDMR/2.))/1332.*RVACT
      SUM=0.
      DO 92 I=1,14
      F1(I)=F1(I+1)
   92 SUM=F1(I)+SUM
      F1(15)=CO
      COT=(SUM+CO)/15.
      IF(COT.GT.25.)COT=25.
      RPA=.0175-.0075/21. * COT
      RPC=.0595-.0245/21. * COT
      RPV=RPA
      RREFF=0.
      IF (THETA.GT.15. .AND. T.GT.40.) GO TO 600
      RCSMA=(2490.+(4770.-4130.)*(FN/11./2.+DM/DMMX/2.))/1332.*RVACT
      RLGAR=(6000.-600.*PEA+RLGARN+RLGARM)/1332.*RVACT
      RRALE=(3600.+(8020.-5140.)*DL/0.9)/1332.
  600 CONTINUE
      SF=.67+.374*(X(40)-.9)
      IF(SF.GT.1.135)SF=1.135+.86*(X(40)-2.143)
      XDOT(40)=(VO2DOT-X(40))/T7
      IF(SF.LT.0.67)SF=.67
      IF(SF.GT.3.)SF=3.
      IF (PEX.LT.1. .AND. THETA.LT.45.) SF=.48
      IF(THETA.GT.15..AND.T.LT.40.)SF=.48
      SF=SF+PD(11)
  610 CONTINUE
C                                   PRESSURE REFERENCE FUNCTION PR
      PRN=86.+C1*DO2+C2*ACCMET
      EN=PRN-PM/2.-PMC/2.+XN3+3.*XN4+FN/2.
      SUM=0.
      DO 91 I=1,14
      F2(I)=F2(I+1)
   91 SUM=F2(I)+SUM
      F2(15)=EN
      ER=(SUM+EN)/15.
      PAVG=PD(1)
      IF (PAVG.LT.95. .AND. PAVG.GT.69.) GAIN=
     6 (4.1-3.77/6.*(PAVG-69.))*GNEW
      IF (PAVG.LE.69.) GAIN=4.1*GNEW
      IF (PAVG.GT.95.) GAIN=.33*GNEW
      IF(PEX.GT.0.)GAIN=.33*GNEW
      DDP=0.533*(ER*GAIN)
      IF(DDP.LT.0.0)DDP=0.0
```

```
      TOT=0.300+DDP
      HR=60./TOT
C                CONTROLLED COMPLIANCES
      ERC=(PRN-PMC)*.7
      SUM=0.
      DO 90 I=1,44
      F3(I)=F3(I+1)
   90 SUM=F3(I)+SUM
      F3(45)=ERC
      ERC=(SUM+ERC)/45.
      IF(ERC.LT.0.0)GO TO 7
      IF(ERC.GT.80.)ERC=80.
      CLGVE=3.956*(1.0-.0083*ERC)
      CLGSV=3.1435*(1.0-.0083*ERC)
    7 CONTINUE
C                RESPIRATION
      RESTO2=.313
      IF (THETA.GT.15. .AND. T.GT.40.) RESTO2=.37
C      FREQ=VO2DOT*6.24+5.28
      IF(FREQ.GT.30.)FREQ=30.
      TR=60./FREQ
      XDOT(41)=(VO2DOT-0.38)*.4/300.
      IF(PEX.EQ.0.0)XDOT(41)=-1./300.
      IF(ACCMET.LE.0.0.AND.PEX.EQ.0.0)XDOT(41)=0.0
C                                    OXYGEN DEFICIT FUNCTION DO2
      CALL DELAY(0.0,5,VO2DOT,VO2TS,VO2DD,1)
      XDOT(48)=(-VO2DD+PEX*VO2WDT+0.33)/60.
      IF(DO2.LE.0.0.AND.PEX.EQ.0.0)XDOT(48)=0.0
      DO 31 I=40,49
   31 X(I)=X(I)+0.1*(XDOT(I)+SAVE(I-39))
      RETURN
      END
```

@PRT,S ALGO

```
D86-GD3432*TPFS.ALGO
      SUBROUTINE ALGO(T)
C              INTEGRATION ALGORITHM
      COMMON /STATE/ X(50),XDOT(50)
      DIMENSION XDS(50)
      DO 3 I=1,34
    3 XDS(I)=XDOT(I)
      H=0.001
      IF(T.GT.11.)H=.002
      T=T+H
      CALL CVS
      DO 4 I=1,34
    4   X(I)=H/2.*(XDOT(I)+XDS(I))+X(I)
      RETURN
      END

@PRT,S XIO
```

DB6-GO3432*TPFS.XIO

```
      SUBROUTINE XIO
      COMMON/STATE/X(600)
      COMMON/XIOD/N(9),NW(8),INIT,A(9,6)
      DATA KY,NWTL/1HN,6H  TILT/
      T=X(598)
      IF (INIT.GT.0) GO TO 200
      INIT=1
      CALL CDATE(MD)
      CALL CTIME(MT)
      WRITE(6,5)MD,MT
    5 FORMAT(/'   CARDIOVASCULAR TILT ERGOMETRY MODEL',6X,A6,' AT ',A6/
     * '   REFER TO GE-AGS USER GUIDE TIR 741-MED-*****'//)
C    * '/TO SIMULATE TILT EXPERIMENT ENTER 1.')
      X(495)=1.
C      READ (5,6) X(495)
C    6 FORMAT (F5.0)
    9 WRITE (  6,10)
   10 FORMAT('0DO YOU WISH TO CHANGE INITIALIZED DATA? (Y/N)')
      READ (  5,20) K
   20 FORMAT(1A1)
      IF (K.EQ.KY) GO TO 60
      WRITE (  6,30)
   30 FORMAT('0PLEASE ENTER INDEX(1-600), VALUE; CR: (I3,E12.6)')
      GO TO 40
   35 WRITE (6,86)
   40 READ (5,50,ERR=35) I,VALNEW
   50 FORMAT(I3,E12.6)
      WRITE (6,55) I,VALNEW
   55 FORMAT(4X,3H***,I4,F10.4)
      IF (I.LT.1 .OR. I.GT.600) GO TO 60
      X(I) = VALNEW
      GO TO 40
   60 WRITE (  6,70)
   70 FORMAT('0DO YOU WISH TO MODIFY THE OUTPUT LIST? (Y/N)')
      READ (  5,20) K
      IF (K.EQ.KY) GO TO 200
      WRITE (  6,80)
   80 FORMAT ('0PLEASE ENTER POSITION(2-9), INDEX(1-600),'
     & ' LABEL, CR:  (I1,I4,A6)')
      GO TO 90
   85 WRITE (6,86)
   86 FORMAT (' *READ ERROR.')
   90 READ (5,100,ERR=85) IP,I,NAB
  100 FORMAT(I1,I4,A6)
      WRITE (6,101) IP,I,NAB
  101 FORMAT(4X,3H***,I2,I4,1X,A6)
      IF (IP.EQ.0) GO TO 200
      IF (IP.EQ.1) GO TO 9
      IF (IP.LT.2 .OR. IP.GT.9) GO TO 85
      IF (I.LT.1 .OR. I.GT.600) GO TO 85
      GO TO (90,102,103,104,105,106,107,108,109),IP
  102 N(1)=I
      NW(1)=NAB
      GO TO 90
  103 N(2)=I
      NW(2)=NAB
```

```
      GO TO 90
  104 N(3)=I
      NW(3)=NWB
      GO TO 90
  105 N(4)=I
      NW(4)=NWB
      GO TO 90
  106 N(5)=I
      NW(5)=NWB
      GO TO 90
  107 N(6)=I
      NW(6)=NWB
      GO TO 90
  108 N(7)=I
      NW(7)=NWB
      GO TO 90
  109 N(8)=I
      NW(8)=NWB
      GO TO 90
  200 CONTINUE
      IF (T.GT.0.001) GO TO 215
      IF (X(495).LT.0.5) GO TO 210
      IF (N(7).NE.469) GO TO 210
      NW(7)=NWTL
      N(7)=575
  210 WRITE (6,205) NW,(N(I),I=1,8)
  205 FORMAT(///'    SECS',8(2X,A6)/'     599',6I8/'  ******',
     *  8('   ******'))
  215 DO 220 I=1,9
      K=N(I)
      A(I,5)=X(K)
  220 A(I,6)=(A(I,1)+A(I,2)+A(I,3)+A(I,4)+A(I,5))/5.0
      X(570)=A(9,6)
      IF (N(7).EQ.575 .AND. T.LT.41.) A(7,6)=0.
C      WRITE(6,300)T,(A(I,5),I=1,8)
      IF ((T-PT).LT.1.1 .OR. AMOD(T,ABS(X(599))).GT.1.) GO TO 310
      LP=T
      PT=LP
      WRITE(6,300)PT,(A(I,6),I=1,8)
  300 FORMAT (F7.1,8F8.3)
      IF (X(599).GT.0.) GO TO 310
      DIMENSION NXP(24),RNXP(24)
      DATA NXP/45,48,564,491,571,124,123,134,138,150,121,
     & 201,203,227,221,233,249,250,41,576,130,44,242,205/
      DO 301 I=1,24
      J=NXP(I)
  301 RNXP(I)=X(J)
      WRITE (6,305) RNXP
C      WRITE (6,305) (X(I),I=1,32)
  305 FORMAT (7X,4E16.6)
  310 DO 320 J=1,4
      DO 320 I=1,9
  320 A(I,J)=A(I,J+1)
      RETURN
      END
```

PRT.S BLKDAT

```
086-603432*TPFS.BLKDAT
               BLOCK DATA
               COMMON/STATE/A(100)
               COMMON/STATE/B(50)
               COMMON/STATE/C(50)
               COMMON/STATE/D(50)
               COMMON/STATE/E(50)
               COMMON/STATE/F(20)
               COMMON/STATE/G(280)
          C** STATE
               DATA A/89.9,215.8,38.7,218.0,7.7,10.6,27.4,6.5,0.,0.,              1- 10
              1 0.,3.25,0.,13.6,52.3,62.4,4.1,126.0,205.,2.5,                     11- 20
              2 355.2,253.5,36.4,23.5,31.2,63.4,3.1,254.2,3.2,120.7,              21- 30
              3 17.1,43.7,5*0.,0.0,17*0.,50*0./                                   31-100
          C** FLOW
               DATA B/39*0.,204.,224.,208.,211.,212.,214.,215.,231.,0.,0.,0./    101-150
          C** COMP
               DATA C/4*0.,1.2,1.7,5.3,.25,2*0.,2*.2,0.,.21,.2,.8,.3,3.96,3*14.,.6 151-170
              1 .3*0.,.12,.3996,5.3,.9058,9.59,1.505,6.047,                      171-180
              2 .2224,2.517,5*0.,.3,12*0./                                       181-200
          C** PRES
               DATA D/40*0.,0.001,7*0.,2*90./                                    201-250
          C** RES
               DATA E/3*.007508,.004,.01502,.05255,.015022,2*0.,.01200,          251-260
              1 .0400,0.,.0340000,.0340,.03003,4.505,.4505,.07508,.07508,.02102, 261-270
              2.00738,.007508,.01502,.1,.03378,3.431,.3754,.004302,15.39,2.35    271-280
              3 .34.5345,.2252,.5255,.3003,.01502,.45045,2.744,.6494,0.,0.,      281-290
              4 9*0.,5,15/                                                       291-300
          C** INRT
               DATA F/.0007508,.002,2*0.,.004,.004,0.,.004,.00626,11*0./         301-320
          C** MISC
               DATA G/48*0.,5000.,5000.,30.,0.,30.,0.,85.,15.,400.,61.6,2*0.,    321-380
              1 0.,90.5,0.,43.5,5.194,30.,30.,100.,188.,40.,                     381-390
              2 3*0.,50.,50.,509.,28.,562.,0.0,375.,                              391-400
              3 50.,150.,18*0.,                                                  401-420
              * 34*0.,32*0.,4*0.,88.,2.55,3.60,9999.,0.,                         421-495
              * 0.,0.0,0.2.,0.,7*0.,-7.,2*0.,                                    496-510
              4 0.,10.,10.,16.,6.,16.,2*0.,16.,14.,                              511-520
              5 14.,2.,-7.,-14.,0.,0.,-14.,13*0.,                                521-540
              * 0.,0.,100.,600.,400.,0.,13*-1.,401.,                             541-560
              6 72.,.09,6.7,5*0.,8.3,0.,                                         561-570
              7 .0550,0.,-1.5,0.,90.,.48,.633,.19,.36,46.,                       571-580
              8 10.,-.015,88.,14*0.,0.00,10.,0./                                 581-600
               COMMON/X(OD/N(9),NN(8),INIT
               DATA INIT/0/
               DATA NN/'    HR','    CO','    SV','VO2DOT',
              * '  SYST','  DIAS','  TILT','  LEGV'/
               DATA N/561,563,562,570,567,568,575,600,570/
               COMMON/RINTR/RIN(10),ROUT(10)
               DATA RIN(2)/12.8/
               END

@PRT,T GE.

086-603432*GE
```

```
FOR  RC4(0)
REL  RC4
FOR  RC5(0)
REL  RC5
FOR  RC6(0)
REL  RC6
FOR  RC7(0)
REL  RC7
FOR  RC8(0)
REL  RC8
FOR  RC9(0)
REL  RC9
FOR  RC10(0)
REL  RC10
FOR  RC11(0)
REL  RC11
FOR  RC14(0)
REL  RC14
FOR  RC15(0)
REL  RC15
FOR  RC16(0)
REL  RC16
FOR  RC17(0)
REL  RC17
FOR  RC19(0)
REL  RC19
FOR  RC20(0)
REL  RC20
FOR  RC21(0)
REL  RC21
FOR  RCF1(0)
REL  RCF1
FOR  RCF2(0)
REL  RCF2
FOR  RCF3(0)
REL  RCF3
FOR  SSVENT(0)
REL  SSVENT
ELT  SEADAT(0)
ELT  CO2DAT(0)
ELT  GRODAT(0)
FOR  DELAY(0)
REL  DELAY
FOR  FCNSW(0)
REL  FCNSW
FOR  SWIN(0)
REL  SWIN
ELT  WBA(0)
REL  WBA
FOR  RC3(0)
REL  RC3
FOR  XIO(0)
REL  XIO
FOR  BLKDAT(0)
REL  BLKDAT
REL  EXEC
ELT  EXEC(0)
```

```
FOR  CVS(0)
REL  CVS
FOR  RC13(0)
REL  RC13
FOR  RC13/SIMP(0)
FOR  GRODIN/SA(0)
FOR  RC12/SA(0)
FOR  SSO2W/SA(0)
ELT  RUNG(U)
FOR  TERG/SA(0)
FOR  CVS/SA(0)
FOR  CONTRL/SA(0)
ELT  RUNEX(0)
ELT  RUNOL(0)
ELT  RUN(0)
FOR  ALGO(0)
REL  ALGO
FOR  SSO2W(0)
REL  SSO2W
ELT  LIST(0)
FOR  CONTRL/OL(0)
FOR  CVS/OL(0)
FOR  GRODIN/OL(0)
FOR  TERG(0)
REL  TERG
FOR  CONTRL(0)
REL  CONTRL
REL  RC12
FOR  RC12(0)
FOR  GRODIN(0)
REL  GRODIN
ABS  RUN

@BRKPT-PRINTS
```

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