Research Repo.

Physiological System Integrations with Emphasis on the Respiratory - Cardiovascular System

by

R. R. Gallagher, Ph.D.
Department of Electrical Engineering
Kansas State University
Manhattan, Kansas

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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 \( V_0 \) reflecting shifts due to autonomic 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 \((\text{Ca}(\text{HbO}_2))\) 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 \(\text{Ca}(\text{HbO}_2)\). 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 thermoregulatory 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 thermoregulatory 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 CO₂ and O₂ 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 O₂ 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 CO₂ and O₂ tensions are passed to the cardiovascular system with the idea that they will be utilized in an implementation of CO₂ and O₂ forcing for a cardiac output formulation.

In order to fulfill the demands of the forementioned mechanism, the resting O₂ 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

\[
\begin{align*}
\text{ROUT}(1) &= \text{AVO2DM}/1000 \\
\text{ROUT}(2) &= \text{FREQ} \\
\text{ROUT}(3) &= \text{C}(11) \\
\text{ROUT}(4) &= \text{F}(7) \\
\text{ROUT}(5) &= \text{F}(1)
\end{align*}
\]  

(4.1)

where

\[
\begin{align*}
\text{AVO2DM} &= \text{a-v } \text{O}_2 \text{ difference, } \text{ml} \text{O}_2/\text{min}, \\
\text{FREQ} &= \text{respiratory frequency, } \text{bpm}, \\
\text{C}(11) &= \text{cerebral blood flow, } \text{l/min}, \\
\text{F}(7) &= \text{Pa}(\text{CO}_2), \text{ mmHg}, \text{ and} \\
\text{F}(1) &= \text{Pa}(\text{O}_2), \text{ mmHg}.
\end{align*}
\]

Likewise, the input variables are indicated as

\[
\begin{align*}
\text{C}(10) &= \text{CIN}(1) \\
\text{VO2DT} &= \text{CIN}(2) \\
\text{VO2RDT} &= \text{CIN}(3)
\end{align*}
\]  

(4.2)

where

\[
\begin{align*}
\text{C}(10) &= \text{cardiac output, } \text{l/min}, \\
\text{VO2DT} &= \text{oxygen required for particular work load, } \text{lO}_2/\text{min}, \text{ and} \\
\text{VO2RDT} &= \text{oxygen required for resting state, } \text{lO}_2/\text{min}.
\end{align*}
\]

In the SS02W(X) Subroutine of the respiratory system, the following modification has been performed. The former subroutine statements were replaced by

\[
\begin{align*}
\text{COMMON/RINTR/ROUT}(10) \text{, CIN}(10) \\
\text{VO2RDT} &= \text{CIN}(3) \\
\text{SS02W}(X) &= \text{VO2RDT} - .0500 + (.0004850815 \times 6.12 \times X)/.25
\end{align*}
\]  

(4.3)

(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.

\[
\begin{align*}
\text{IF (WORK.LE.0.0 .AND. NWREST.LT.1) RMT(2) = CIN(3)-C(26)} \\
\text{AVO2DM} &= (\text{F}(9)\times\text{C}(10)-\text{F}(13)\times(\text{C}(10)-\text{C}(11))-\text{F}(12)\times\text{C}(11))\times1000. \\
\text{AVO2DF} &= \text{AVO2DM}/\text{C}(10) \\
\text{ROUT}(1) &= \text{AVO2DM}/1000. \\
\text{IF(WORK.GT.0.0) ROUT(1) = RMT(2)+C(26)}
\end{align*}
\]
The transfer of cardiac output from the cardiovascular to the respiratory system was handled in the main program, GRODIN, \( C(10) = C\text{IN}(1) \). 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 O₂ 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

\[ FREQ = 8.1 + 7.815 \times (RMT(2) + C(26)) \]  

with

\[ RMT(2) = O_2 \text{ metabolic rate of tissue} \]
\[ C(26) = O_2 \text{ metabolic rate of brain}. \]

Thus, Equation 5.1 didn't respond to any forcing other than O₂ demand. This formulation was replaced by

\[ FREQ = \left( \frac{1 + 32 \left( \frac{1 + a}{a} \right) R C \frac{V_A}{DSVOL}}{16 \left( \frac{1 + a}{a} \right)^{1/2} R C} \right)^{1/2} - 1 \]  

with

\[ R C = 0.015 \text{ min}, \]
\[ V_{A} \approx V_{E} = \text{expired ventilation,} \]
\[ a = 1.95 = \frac{\text{inspiratory elastance}}{\text{expiratory elastance}} = \frac{K_I}{K_E}, \text{ and} \]
\[ DSVOL = \text{dead space volume.} \]  

Upon substituting the constants, FREQ is given by

\[ FREQ = \left( (1. + (.726 \times V_E)/DSVOL)^{0.5} - 1. \right)/.363 \]  

with

\[ DSVOL = 0.140 + 0.002 \times V_E \]  

Dead space ventilation, originally defined as

\[ \text{DEADVT} = .1107 \times FREQ + .0785 \times V_E \]
is now given by
\[
\text{DEADVT} = 1 + 0.098 \times \text{VE}.
\] (3.6)

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,
\[
\text{AVO2DF} = \frac{\text{AVO2DM}}{C(10)}
\] (5.7)

where
\[
C(10) = \text{cardiac output and}
\]
\[
\text{AVO2DM} = (F(9) \times C(10) - F(13) \times (C(10) - C(11)) - F(12) \times C(11)) \times 1000
\]
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 O₂ (0.1 lO₂/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 ≈ 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 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 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.
DA6=GO3H32*TPFS*EXEC

COMMON/X/XO/XMH/CXT

COMMON/STATE/X(497)+T

1 IF(CX<T/60) CALL GROOIN

2 IF(CX<T/60) 60 TO 9

RETURN

END

-- GROOIN --
SUBROUTINE GRODIN

DIMENSION C(10), AX(10,2), SV(10,3), VTRAN(10), RK(14,4),
- SC(14), OR(14), Y(15), D(20), VOL(10), RMT(2),
- BC(4), QF(6), TAU(5), CC(3), CB(3), CH(4), CPH(3),
- D0(4), C14(10), C142, C143, C144, C145, C146, C147, C148, C149,
- C1410, C1411, C1412, C1413, C1414, C1415, C1416, C1417, C1418,
- C1419, C1420, C1421, C1422, C1423, C1424, C1425, C1426, C1427,
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- C14356, C14357, C14358, C14359, C14360, C14361, C14362, C14363,
- C14364, C14365, C14366, C14367, C14368, C14369, C14370, C14371,
- C14372, C14373, C14374, C14375, C14376, C14377, C14378, C14379,
BAROMETRIC PRESSURE.

"VOL-FRACTION OF INSPIRED GAS" "VOL-FRACTION OF ALVEOLAR VENTILATION"

"INITIAL TIME"

"COMPUTER TIME STEP"

"CONTROLLER EQUATION CONSTANTS MAINTAINS RESTING PA(CO2) APPROX. 40 (mm Hg)"

"VALUES FOR RESTING ALVEOLAR VENTILATION"

"OUTPUT PRINT INCREMENTS (ALSO PRINTS AT 0.5 TIME INCREMENTS)"

"ARTERIAL M+ CONCENTRATIONS"

"ARTERIAL O2 TENSION"

"TOTAL GAS CONCENTRATIONS AT BRAIN EXIT"

"TOTAL GAS CONCENTRATIONS AT TISSUE EXIT"

"VENOUS GAS CONCENTRATIONS AT LUNG EXIT"

"VENOUS GAS CONCENTRATIONS AT BRAIN EXIT"

"VENOUS GAS CONCENTRATIONS AT TISSUE EXIT"

"CARDIAC OUTPUT"

"TISSUE BLOOD FLOW"

"TISSUE BLOOD FLOW"

"ARTERIAL O2 TENSION"

"TOTAL GAS CONCENTRATIONS AT TISSUE EXIT"

"ARTERIAL O2 TENSION"

"VENOUS GAS CONCENTRATIONS AT TISSUE EXIT"

"TOTAL GAS CONCENTRATIONS AT ALVEOLAR EXIT"

"TOTAL GAS CONCENTRATIONS AT TISSUE EXIT"

"VENOUS GAS CONCENTRATIONS AT TISSUE EXIT"

"VENOUS GAS CONCENTRATIONS AT TISSUE EXIT"

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"ARTERIAL O2 TENSION"

"TOTAL GAS CONCENTRATIONS AT TISSUE EXIT"

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**ARTERIAL GAS CONCENTRATIONS AT BRAIN ENTRANCE**

- $\text{CAB(CO}_2) = \text{CA(CO}_2)(T - TAB)$
- $\text{CAB(O}_2) = \text{CA(O}_2)(T - TAB)$
- $\text{CAB(N}_2) = \text{CA(N}_2)(T - TAB)$

**VENOUS BRAIN GAS CONCENTRATION AT LUNG ENTRANCE**

- $\text{CVB(CO}_2)(T - TVB)$
- $\text{CVB(O}_2)(T - TVB)$
- $\text{CVB(N}_2)(T - TVB)$

**VENOUS TISSUE GAS CONCENTRATION AT LUNG ENTRANCE**

- $\text{CVT(CO}_2)(T - TVT)$
- $\text{CVT(O}_2)(T - TVT)$
- $\text{CVT(N}_2)(T - TVT)$

**ARTERIAL GAS CONCENTRATIONS AT TISSUE ENTRANCE**

- $\text{CAT(CO}_2) = \text{CA(CO}_2)(T - TAT)$
- $\text{CAT(O}_2) = \text{CA(O}_2)(T - TAT)$
- $\text{CAT(N}_2) = \text{CA(N}_2)(T - TAT)$

**ARTERIAL H+ CONCENTRATION AT CAROTID BODIES* SITE**

- $\text{Ca(H+)} = \text{CA(H+)}(T - TAO)$

**ARTERIAL O2 TENSION AT CAROTID BODIES* SITE**

- $\text{PA(O}_2) = \text{PA(O}_2)(T - TAO)$

**ARTERIAL H+ CONCENTRATION AT BRAIN ENTRANCE**

- $\text{CA(H+)} = \text{CA(H+)}(T - TAT)$

**TOTAL GAS CONCENTRATION FROM BRAIN AT LUNG ENTRANCE**

- $\text{CVB(CO}_2) + \text{CVB(N}_2) + \text{CVB(O}_2)(T - TVB)$

**TOTAL GAS CONCENTRATION FROM TISSUE AT LUNG ENTRANCE**

- $\text{CVT(CO}_2) + \text{CVT(N}_2) + \text{CVT(O}_2)(T - TVT)$

**COMPUTATIONAL THERMODYNAMIC AND TISSUE ROUGH-HEMP**

- $\text{PCO}_2$
- $\text{PO}_2$
- $\text{PN}_2$
- $\text{pH}

**COMPARTMENTAL GAS TENSIONS AND CONCENTRATIONS**

- $\text{PA(O}_2)$
- $\text{PA(CO}_2)$
- $\text{PA(N}_2)$
PRODUCT OF DIFFUSION COEFFS. AND GAS DIFFERENTIALS ACROSS BLOOD-BRAIN BARRIER.

DIMENSION XNB(14,2), DJH(N), IDJ(12)

COMMON /X,Z,C,XH,SY,TTRAN, RK, SC, OC, A, D, P, VOLT, HMT, BC, QE,

1 TAU, CC, CH, CH, CPW, DQ, VE, VI, CPB, CPT, CADK, X, DI,

2 IRK, LOC, ITERX, INDEX, J, M, N

COMMON/R/XNS,XMX,CXT,WORK1,DUM1,DUM2,DUM3,WORK2,HMTB,HMTB2,TIMEOF

REAL ITTY

IF (CAT.GT.0.) GO TO A0

WRITE (6,5)

FORMAT (A4)

IF (ITTY .NE. ITTY) ITTY = 0

WRITE (6,90)

90 FORMAT (I11,1x,37HRESPIRATORY CHEMOSTAT -- INPUT DATA/)

C DATA FOR INITIAL CONDITIONS

DO 10 I = 1,10

10 CONTINUE

C MODEL RUN IN SAME COMPUTER RUN.

READ (5,90) ITTY

90 FORMAT (I11,1x,37HRESPIRATORY CHEMOSTAT -- INPUT DATA/)

C DATA FOR INITIAL CONDITIONS

C DO IO I = 1,10

C DETERMINE END OF RUN (NO CAPABILITY TO START ANOTHER)

C ESTABLISH COMPUTER STEP INDEPENDENT OF INPUT DATA.

C(13) = 78125E-2

190 FORMAT (5X,F15.0,5X,2A)
READ (5,190) HC(I), XN(I,J), J = 1,2
229 CONTINUE
230 DO 30 I = 1,2
231 READ (5,190) RMT(I), XN(I,J), J = 1,2
232 CONTINUE
30 CONTINUE
234 DO 40 I = 1,2
235 READ (5,190) DJ(I), XN(I,J), J = 1,2
236 CONTINUE
40 CONTINUE
C OUTPUT INPUT DATA
238 J = 1
241 DO 75 I = 1,8
242 JX = J + 4
243 WRITE (6,92) J, C(12), T2, JX
244 92 FORMAT (2,1X,2I5,F9.4)
245 CONTINUE
75 CONTINUE
247 WRITE (6,92) J, C(12), T2, JX
248 J = 45
249 WRITE (6,92) J, RMT(I), RMT(12), DJ(I), DJ(1)
250 IF ITTY I/O MAX TIME WILL COME FROM WORK CARD.
251 IF (ITYI .NE. 0) C(16) = 9999999999.
253 F1(CO2)
254 DUM1 = C(31)
255 F1(CO2)
256 DUM2 = C(32)
257 F1(CO2)
258 DUM3 = C(33)
259 WORK = 0
260 WORK2 = 0
261 C METABOLIC RATE OF O2 CONSUMPTION IN TISSUE.
262 RMTB2 = CIN(3) - C(26)
264 B = RMTB2 = CIN(3) - C(26)
265 TINEOF = 0
266 XSO = 0
267 AMH = 0, C(36)/G, CDC8125
269 MAM = 0
270 CONTINUE
271 XSO = XSO + AMH
272 IFS(MAM .LE. 1) XSO = XSO + C(36)
273 MAM = 1
274 C(35) = 0
275 C(40) = 0
276 C INITIAL GUESSES FOR ITERATIVE LOOPS
278 C ARTERIAL CONCENTRATION OF CO2.
279 C C(1) = 0.6
280 C BRAIN CONCENTRATION OF CO2.
281 C C(2) = C(4)
282 C TISSUE CONCENTRATION OF CO2.
283 C C(3) = C(7)
284 C BRAIN CO2 TENSION.
CpB = 50.0

CPT = 90.0

IF (CO2GTXMH) GOTO207

C SETS VARIOUS CONSTANTS AND AGGREGATES OF CONSTANTS

C THX

C(15) = C(15) + .0001

C PRINT ALL TIME

C C(39) = C(39) + .0001

C FACTOR OF 1 = 7 MULTIPLYING DIFFUSION COEFFICIENTS

DO 200 I = 27,29

C(1) = C(1) * 1.E-7

200 CONTINUE

202 CONTINUE

IRK = 1

M = 14

N = 3

IOJ(1) = 0

C SOLUBILITY COEFFICIENTS

A(1) = (ALPHA)C02 - A(2) - (ALPHA)O2, A(3) = (ALPHA)N2

A(4) = (ALPHA)C02, 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/MMG CONVERSION FACTOR

SK = 0.00132

C CARBONIC ACID DISSOCIATION CONSTANT

CADK = 795.0

VOL(1) = VOL(10) = VOLUMES-USED IN CALCULATION OF VARIABLE TIME DELAYS

VOL(1) = 0.035

VOL(2) = 1.042

VOL(3) = 0.168

VOL(4) = 0.000

VOL(5) = 0.168

VOL(6) = 2.955

VOL(7) = 0.725

VOL(8) = 1.062

VOL(9) = 0.008

VOL(10) = 1.042

C METABOLIC RATE OF CO2 IN BRAIN = TISSUE / SAME FOR O2

QF(6) = (C(25) + RMT(11) + C(26) + RMT(2))

B = 47

U(I) = C(I) = 47

DO 210 I = 2,4

C PRODUCTS OF CONVERSION FACTORS AND SOLUBILITY COEFFICIENTS

D(I) = SK*A(I-1)

D(I+1) = SK*A(I+2)

D(I+3) = D(I+1)*D(I)

210 CONTINUE

C FACTOR USED IN ESTABLISHING CA(CO2)

D(1) = 0.14 - 2.3*C(I+1)

C
CALL RC3
CALL RC10
CALL RC12
GO TO 60
50 CALL RC15
CALL RC16
CALL RC13
CALL RC12

C

IF(C(35) .GE. XNH) GO TO 201

C

IF (C(35) .GT. C(15)) GOTO 80
IF(CAT .GT. C(15)) GOTO 80
70 CALL RC14

UU = AMOD(C(35), D(14))
IF (UU .LT. 0.0001 .OR. UU .GT. D(15)) GOTO 80

RETURN
GO TO 60

80 WRITE(*,76) 78 FOR FINAL VALUES FOR FOLLOWING VARIABLES

IF (C(37) .GT. 1.0E-5) GO TO 250

220 CTERM = 0.0

IF (VTRAN .EQ. 104.0) 230, 240, 290

230 CTERM = (23.6E9)+(16940.0-VTRAN)**4.9

290 C(37) = (C(20)+C(16)+VTRAN)+1.0-C(16)+C(16)+C(16)+C(16)

1 + C(12)-VTRAN*CTERM = VI

I = 37
WRITE(*,192) I, C(1), (XN, J), J = 1, 2

250 DO 260 I = 1, 14
WRITE(*,192) I, C(1), (XN, J), J = 1, 2

260 CONTINUE
WRITE(*,194)
WRITE(*,192) (XN, J), J = 1, 2

830 FORMAT(*NORMAL TERMINATION*)
301 CONTINUE

STOP

C 90 FORMAT (1H14X37H=RESPIRATORY CHEMOSTAT = INPUT DATA///)
C 92 FORMAT (142X13,10F10.4,1DX2A6)
SUBROUTINE RC12

DIMENSION C(40), XH(40), SV(16), TITAN(1A), RK(14),
SC(16), DC(14), A(16), D(16), F(20), VOL1(10), RMT1(2),
C(31), CH(2), CH(14), CPH(3),
DC(14), FClO), VOL(10), RMT(2),
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COMMON/XH, SC, SV, RK, DC, A, D, F, VOL, RMT, DC, SC,
COMMON/XH, SC, SV, RK, DC, A, D, F, VOL, RMT, DC, SC,
COMMON/XH, SC, SV, RK, DC, A, D, F, VOL, RMT, DC, SC,
COMMON/XH, SC, SV, RK, DC, A, D, F, VOL, RMT, DC, SC,
COMMON/XH, SC, SV, RK, DC, A, D, F, VOL, RMT, DC, SC,
COMMON/XH, SC, SV, RK, DC, A, D, F, VOL, RMT, DC, SC,
COMMON/XH, SC, SV, RK, DC, A, D, F, VOL, RMT, DC, SC,
171 610 IF (W .NE. 4) GO TO 1770
172   H = 0
173   WRITE (6,1805)
174 1220 N = N + 1
175   WRITE (6,1810) CXT, N, W(5)
176   WRITE (6,1815) - C(1), I = 1, J, (OC(1), I = 1, J), F(7), F(11)
177   IF (14.0 .GT. 0)
178   WRITE (6,1820) CC(1), F(1), F(10), F(11), F(14), CM(1), CM(2)
179   IF (14.0 .LT. 0)
180   WRITE (6,1825) CC(1), F(1), F(10), F(11), F(14), CM(1), CM(2)
181   IF (14.0 .EQ. 0)
182   WRITE (6,1830) CC(1), F(1), F(10), F(11), F(14), CM(1), CM(2)
183   IF (14.0 .LE. 0)
184   WRITE (6,1835) CC(1), F(1), F(10), F(11), F(14), CM(1), CM(2)
185   IF (14.0 .GE. 0)
186   WRITE (6,1840) CC(1), F(1), F(10), F(11), F(14), CM(1), CM(2)
187   IF (14.0 .NE. 0)
188   WRITE (6,1845) CC(1), F(1), F(10), F(11), F(14), CM(1), CM(2)
189   IF (14.0 .EQ. 0)
190   WRITE (6,1850) CC(1), F(1), F(10), F(11), F(14), CM(1), CM(2)
191   IF (14.0 .LE. 0)
192   WRITE (6,1855) FREQ, TUNIT, READING, RATE, AVO2DF, DSVOL
193   IF (14.0 .GE. 0)
194   WRITE (6,1860) FREQ, TUNIT, READING, RATE, AVO2DF, DSVOL
195   RETURN
196   1230 FORMAT (EH XXXX.X7X.FL0.4)
197   1272 FORMAT (6F10.4)
198   1805 FORMAT (1H1)
199   1810 FORMAT (100.0aX.II8H4F10.4, .7X.E4X.LV R=.F10.4, .3X.HM8Q DIFF=F8.9)
200   16X3UCURX2Zm2Zar2Xm22XH1D0 .R I V V T E SYX3HtRCC20X
201   2010 FORMAT (3H0273m3hP273m4hVH273m5hP273m6hVH273m7hP273m8hVH)
202   2020 FORMAT (13A8H, LEAKC8F10.9)
203   1820 FORMAT (13A8H, LEAKC8F10.9)
204   1825 FORMAT (13A8H, LEAKC8F10.9)
205   1830 FORMAT (13A8H, LEAKC8F10.9)
206   1835 FORMAT (13A8H, LEAKC8F10.9)
207   1840 FORMAT (13A8H, LEAKC8F10.9)
208   1845 FORMAT (13A8H, LEAKC8F10.9)
209   1850 FORMAT (13A8H, LEAKC8F10.9)
210   1855 FORMAT (13A8H, LEAKC8F10.9)
211   1860 FORMAT (13A8H, LEAKC8F10.9)
212   1865 FORMAT (13A8H, LEAKC8F10.9)
213   1900 FORMAT (13A8H, LEAKC8F10.9)
214   1905 FORMAT (13A8H, LEAKC8F10.9)
215   1910 FORMAT (13A8H, LEAKC8F10.9)
216   1915 FORMAT (13A8H, LEAKC8F10.9)
217   1920 FORMAT (13A8H, LEAKC8F10.9)
218   1925 FORMAT (13A8H, LEAKC8F10.9)
219   1930 FORMAT (13A8H, LEAKC8F10.9)
220   1935 FORMAT (13A8H, LEAKC8F10.9)
221   1940 FORMAT (13A8H, LEAKC8F10.9)
222   1945 FORMAT (13A8H, LEAKC8F10.9)
223   1950 FORMAT (13A8H, LEAKC8F10.9)
224   1955 FORMAT (13A8H, LEAKC8F10.9)
225   1960 FORMAT (13A8H, LEAKC8F10.9)
226   1965 FORMAT (13A8H, LEAKC8F10.9)
227   1970 FORMAT (13A8H, LEAKC8F10.9)
228   1975 FORMAT (13A8H, LEAKC8F10.9)
229   1980 FORMAT (13A8H, LEAKC8F10.9)
230   1985 FORMAT (13A8H, LEAKC8F10.9)
231   1990 FORMAT (13A8H, LEAKC8F10.9)
C SYSTEM RESPONSES: TIME CONSTANTS FOR WORK LOADS AND TISSUE O2

C METABOLIC RATE.

C DECREASING WORK LOADS:

IF (WORK2 < 60) THEN WORK = WORK2

C TISSUE O2 METABOLIC RATE:

C TISSUE CO2 METABOLIC RATE:

C TERM USED IN V1 THAT IS A COMPONENT OF TRANSIENT RESPONSE RELATED

C TIME USED IN V1 TIME ON:

C END OF PROGRAM
FUNCTION S5O2A(X)
C Calculation of steady-state oxygen requirements for various levels
C of work load (X=NULLS),

COMMON/RINTRA/ROLT(10), C(10)

V02ROT=C(10)

S5O2A=V02ROT*05001+.0044503156*10^X/25

RETURN
END

S5O2A
DB6:G03432.TPS.TERG

---

COMMON/STATE/X(50),IDNT(G0)

STATE/LA,OPV,OPA,UPC,OPV,GA,AR,CLAA,WUTA,WTTA,QUADA,

SUIC,CLILL,CLUAA,CLGAR,ULCAP,CLV,E,ULSV,FFEY,UAUC,UTHCV,CSFPC,

LOC,UPC,OPC,SRV,OMD,ORD,CSMA,INA,CSMV,OPV,INHV.

SUIC,CLILL,CLUAA,CLGAR,ULCAP,CLV,E,ULSV,FFEY,UAUC,UTHCV,CSFPC,

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STATE/ACPA,CPV,CLV,CPA,CPFC,CPV,CA,CA,CLAA,CTAA,CLA,CA,

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57 \[ X(18) = x(13) + \text{DIFF} + a \]
58 \[ X(19) = x(19) + \text{DIFF} + b \]
59 \[ SY = SY \]
60 \[ PDY = OY \]
61 \[ CALL X10 \]
62 \[ PD(10) = C + \]
63 \[ CALL CTRL \]
64 \[ TEMP = TEMP + 0.2 \]
65 \[ IF (TEMP + T) > 110 \]
66 \[ CONTINUE \]
67 \[ CALL EXEC \]
68 \[ SY = +f. \]
69 \[ CSOCO. \]
70 \[ TEMP = TEMP + 0.2 \]
71 \[ IF (T - LT + 0.1) > 41 \]
72 \[ GO TO 10 \]
73 \[ DO 10 i = 1, 32 \]
74 \[ PG(I) = SIN(\Theta) \]
75 \[ TILT = TILT + 0.1 \]
76 \[ IF (ABS(\Theta)) < 1E-5 \]
77 \[ GO TO 30 \]
78 \[ DO 20 I = 1, 32 \]
79 \[ PG(I) = 0 \]
80 \[ TILT = TILT \]
81 \[ IF (ABS(\Theta)) < 1E-5 \]
82 \[ TILT = TILT \]
83 \[ IF (ABS(\Theta)) < 1E-5 \]
84 \[ TILT = TILT \]
85 \[ IF (ABS(\Theta)) < 1E-5 \]
86 \[ TILT = TILT \]
87 \[ VLEG = VLEG + V(I, 1) \]
88 \[ DO 201 I = 1, 20 \]
89 \[ VLEG = VLEG + V(I, 1) \]
90 \[ DO 201 I = 1, 20 \]
91 \[ VLEG = VLEG + V(I, 1) \]
92 \[ TEMP = TEMP + \text{DIFF} + U(I) \]
93 \[ DO 16 I = 1, 32 \]
94 \[ TEMP = TEMP + \text{DIFF} + U(I) \]
95 \[ SPACE(3) = V(50) = VLEG + TEMP + V(I, 1) + V(I, 1) + V(I, 2) \]
96 \[ + V(I, 1) + V(16) + V(I, 17) \]
97 \[ 1002 CONTINUE \]
98 \[ IF (T - TAS) < 1.2 \]
99 \[ SAS = SIN(13 + 13 + TT/TAS) \]
100 \[ E(1) = 0.05 + 0.35 + SAS + SF \]
101 \[ E(3) = 0.12 + 0.14 + SAS + SF \]
102 \[ NPIVC = (20 + SAS + 0.1732 + 104 \]
103 \[ NPIVC = (10 + SAS + 0.1732 + 105 \]
104 \[ GO TO 3 \]
105 \[ 2 E(1) = 0.05 \]
106 \[ E(3) = 0.12 \]
107 \[ RSPVC = 0.1501 \]
108 \[ HTMVC = 0.075075 \]
109 \[ 3 TV = TT + 0 \]
110 \[ IF (TV > LT) > 0 \]
111 \[ IF (TV = TV + 0.5) \]
112 \[ IF (TV = TV + 0.5) \]
113 \[ IF (TV + TV + 4.5) \]
114 \( E(2) = 0.175 + 3Y + SF + SV \)
115 \( E(4) = 0.02 + 1.50 + SF + SV \)
116 GO TO 6
117 \( E(2) = 0 \) 1175
118 \( E(4) = 0.02 \)
119 \( \text{CONTINUE} \)
120 \( \text{GO TO 6} \)
121 \( \text{CONTINUE} \)
122 \( \text{IF} \left( X(4) - \text{LT} - 0 \right) \text{OR} \left( X(4) = 0.0 \right) \)
123 \( \text{COMPUTE VOLUMES} \)
124 \( V(50) = 0.0 \)
125 \( \text{GO TO 6} \)
126 \( V(1) = V(1) + X(1) \)
127 \( \text{IF} \left( X(4) - \text{LT} - 0 \right) \text{OR} \left( X(4) = 0.0 \right) \)
128 \( \text{V(50)} \)
129 \( \text{IF} \left( \text{THETA} = 45 + 1.50 + 0.0 \right) \text{RTM} = 2.5 \)
130 \( \text{RESPIRATORY PUMPS} \)
131 \( \text{IF} \left( \text{PEX} = 0.0 \right) \text{GO TO 116} \)
132 \( \text{IF} \left( \text{PIT} = 45 + 0.0 \right) \text{OR} \left( \text{THETA} = 45 + 1.50 \right) \text{GO TO 115} \)
133 \( \text{COMPUTE VOLUMES} \)
134 \( \text{IF} \left( E(3) = 0.0 \right) \text{GO TO 116} \)
135 \( \text{IF} \left( E(4) = 0.0 \right) \text{GO TO 115} \)
136 \( \text{PIT} = 2.5 + 19.704 + 56 + 497 + 51 + 479 + 409 + 16 + 802 + T \)
137 \( \text{DEPTH} = 470 + 1.5 \)
138 \( \text{IF} \left( \text{DEPTH} = 5 + 1 \right) \text{DEPTH} = 5 \)
139 \( \text{PIT} = 4 + \text{DEPTH} \)
140 \( \text{IF} \left( \text{DEPTH} = 5 + 1 \right) \text{DEPTH} = 1.5 \)
141 \( \text{CONTINUE} \)
142 \( \text{GO TO 115} \)
143 \( \text{CONTINUE} \)
144 \( \text{PEX} = 0.0 \)
145 \( \text{PEX} = 0.0 \)
146 \( \text{PEX} = 0.0 \)
147 \( \text{PEX} = 0.0 \)
148 \( \text{PEX} = 0.0 \)
149 \( \text{PEX} = 0.0 \)
150 \( \text{PEX} = 0.0 \)
151 \( \text{MUSCLE PUMP} \)
152 \( \text{CONTINUE} \)
153 \( \text{IF} \left( \text{THETA} = 45 + 1.50 \right) \text{THP} = 0 \)
154 \( \text{SMP} = 5 + 1 + 2 + 3 + 4 + 12 + 15 + 16 + 17 \)
155 \( \text{PMP} = 9 + 3 + 3 \)
156 \( \text{IF} \left( \text{THETA} = 45 + 1.50 \right) \text{PMP} = 0 \)
157 \( \text{IF} \left( \text{SMP} = 45 + 1.50 \right) \text{PMP} = 0 \)
158 \( \text{IF} \left( \text{PEX} = 0.0 \right) \text{PMP} = 0 \)
159 \( \text{DO 44} \)
160 \( \text{CONTINUE} \)
161 \( \text{GO TO 115} \)
162 \( \text{GO TO 115} \)
163 \( \text{GO TO 115} \)
164 \( \text{PIT} = 2 \)
165 \( \text{PIT} = 2 \)
166 \( \text{DO 12} \)
167 \( \text{DO 12} \)
168 \( \text{DO 12} \)
169 \( \text{DO 12} \)
170 \( \text{DO 12} \)
```plaintext
171 TOT=0.300+D0P
172 HR=60./TOT
173 CONTROLLED COMPLIANCES
174 LRC=(PRN-PHC)><7.
175 SUM=0.
176 00 90 1*1.44
177 F3(I)*F3(I+1)
178 90 SUM=F3(I)-SUM
179 F3(I+5)=MEC
180 ERC=(SUM+ERC)/45.
181 IF (ERC<.0.1.0) GO TO 7
182 IF (ECL<.0.1.EFC=1.90.)
183 CLGVE=3.956*(1.0+D3.0*ERC)
184 CLGVS=3.135+(1.0+D3.0*ERC)
185 CONTINUE
186 C RESPIRATION
187 IF (THETA<.0.T+. AND. T.>40.) RESTO2=.37
188 C FREQ=V0Z00T*.0.24+50*2
189 IF (FREQ<.0.1.0) FREQ=37.
190 TA=60./FREQ
191 XDOT(1)=((V0Z00T+T+.0.)*4/1000.
192 IF (PEX.0.0.0=1.0) XDOT(1)=1.0/300.
193 IF (ACCMT.0.0.0=1.0) XDOT(1)=0.0
194 C OXYGEN DEFICIT FUNCTION 002
195 CALL DELAY(O02,5.0.0Z00T,Y0200,1)
196 XDOT(6)=1.0-V0Z00T*PEX*V0Z00T*0.31/40.
197 IF (O02.0.0.0=1.0) XDOT(6)=O.
198 UO 31 IMHC.99
200 31 X(T)=X(T)+C.1*(XDOT(1)+SAVE(1-39))
201 RETURN
202 END
```

QPRT,S ALGO


SUBROUTINE ALG0(T)
C INTEGRATION ALGORITHM
COMMON STATE/ X(50),XDOT(50)
DIMENSION XDS(50)
DO 3 I=1,34
3 XDS(I)=XDOT(I)
M=0.0D0
IF(T.GT.11.DM.0D0) THEN
CALL CVS
DO 4 I=1,34
4 X(I)=X(I)/2.+(XDOT(I)*XDS(I))*X(I)
RETURN
END

GPRT.S X10
GO TO 90

59 NA(3)=NAB

60 GO TO 90

105 N(4)=1

106 N(5)=1

107 N(6)=1

108 N(7)=NAB

200 CONTINUE

210 WRITE (6,205) Nm(N(1),I=1,6)

205 FORMAT (//,599*' ***',/599*' ***',/599*' ***',//)

215 DO 220 I=1,9

220 A(I,0)=A(I,1)+A(I,2)+A(I,3)+A(I,4)+A(I,5)+A(I,6)

300 FORMAT (7X,'L16.6,'A16.6')

305 WRITE (6,305)PT,(A(I,1),I=1,6)

400 FORMAT (7X,'L16.6,'A16.6')

500 FORMAT (7X,'L16.6,'A16.6')

600 FORMAT (7X,'L16.6,'A16.6')

700 FORMAT (7X,'L16.6,'A16.6')

800 FORMAT (7X,'L16.6,'A16.6')

900 FORMAT (7X,'L16.6,'A16.6')

100 FORMAT (7X,'L16.6,'A16.6')

110 RETURN

END
C operator

10 DATA COMMON/STATE/A(100)
11 DATA COMMON/STATE/B(50)
12 DATA COMMON/STATE/C(50)
13 DATA COMMON/STATE/D(50)
14 DATA COMMON/STATE/E(50)
15 DATA COMMON/STATE/F(201)
16 DATA COMMON/STATE/G(293)
17 DATA COMMON/STATE/H(50)
18 DATA COMMON/STATE/I(50)
19 DATA COMMON/STATE/J(50)
20 DATA COMMON/STATE/K(50)
21 DATA COMMON/STATE/L(50)
22 DATA COMMON/STATE/M(50)
23 DATA COMMON/STATE/N(50)
24 DATA COMMON/STATE/O(50)
25 DATA COMMON/STATE/P(50)
26 DATA COMMON/STATE/Q(50)
27 DATA COMMON/STATE/R(50)
28 DATA COMMON/STATE/S(50)
29 DATA COMMON/STATE/T(50)
30 DATA COMMON/STATE/U(50)
31 DATA COMMON/STATE/V(50)
32 DATA COMMON/STATE/W(50)
33 DATA COMMON/STATE/X(50)
34 DATA COMMON/STATE/Y(50)
35 DATA COMMON/STATE/Z(50)
36 DATA COMMON/STATE/A0(50)
37 DATA COMMON/STATE/B0(50)
38 DATA COMMON/STATE/C0(50)
39 DATA COMMON/STATE/D0(50)
40 DATA COMMON/STATE/E0(50)
41 DATA COMMON/STATE/F0(50)
42 DATA COMMON/STATE/G0(50)
43 DATA COMMON/STATE/H0(50)
44 DATA COMMON/STATE/I0(50)
45 DATA COMMON/STATE/J0(50)
46 DATA COMMON/STATE/K0(50)
47 DATA COMMON/STATE/L0(50)
48 DATA COMMON/STATE/M0(50)
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57 DATA COMMON/STATE/V0(50)
58 DATA COMMON/STATE/W0(50)
59 DATA COMMON/STATE/X0(50)
60 DATA COMMON/STATE/Y0(50)
61 DATA COMMON/STATE/Z0(50)
62 DATA COMMON/STATE/A1(50)
63 DATA COMMON/STATE/B1(50)
64 DATA COMMON/STATE/C1(50)
65 DATA COMMON/STATE/D1(50)
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67 DATA COMMON/STATE/F1(50)
68 DATA COMMON/STATE/G1(50)
69 DATA COMMON/STATE/H1(50)
70 DATA COMMON/STATE/I1(50)
71 DATA COMMON/STATE/J1(50)
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78 DATA COMMON/STATE/Q1(50)
79 DATA COMMON/STATE/R1(50)
80 DATA COMMON/STATE/S1(50)
81 DATA COMMON/STATE/T1(50)
82 DATA COMMON/STATE/U1(50)
83 DATA COMMON/STATE/V1(50)
84 DATA COMMON/STATE/W1(50)
85 DATA COMMON/STATE/X1(50)
86 DATA COMMON/STATE/Y1(50)
87 DATA COMMON/STATE/Z1(50)
88 DATA COMMON/STATE/A2(50)
89 DATA COMMON/STATE/B2(50)
90 DATA COMMON/STATE/C2(50)
91 DATA COMMON/STATE/D2(50)
92 DATA COMMON/STATE/E2(50)
93 DATA COMMON/STATE/F2(50)
94 DATA COMMON/STATE/G2(50)
95 DATA COMMON/STATE/H2(50)
96 DATA COMMON/STATE/I2(50)
97 DATA COMMON/STATE/J2(50)
98 DATA COMMON/STATE/K2(50)
99 DATA COMMON/STATE/L2(50)
00 DATA COMMON/STATE/M2(50)
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02 DATA COMMON/STATE/O2(50)
03 DATA COMMON/STATE/P2(50)
04 DATA COMMON/STATE/Q2(50)
05 DATA COMMON/STATE/R2(50)
06 DATA COMMON/STATE/S2(50)
07 DATA COMMON/STATE/T2(50)
08 DATA COMMON/STATE/U2(50)
09 DATA COMMON/STATE/V2(50)
10 DATA COMMON/STATE/W2(50)
11 DATA COMMON/STATE/X2(50)
12 DATA COMMON/STATE/Y2(50)
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8. BIBLIOGRAPHY


