AN ANALYSIS OF A RESPIRATORY CONTROL MODEL UNDER EXERCISE CONDITIONS

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

I. INTRODUCTION

Physiological systems are made up of many interrelated variables. This inherent complexity makes these systems very difficult to study directly; therefore, other means must be employed for their analysis.

Investigators of complex systems often try to counter this complexity by formulating models which are based upon experimental fact and/or physiologically sound assumptions. At the start, these models are usually a verbal conception. The model comprises statements of actual or presumed relationships among the variables. As the statements become refined, the models expand and become complex, sometimes approaching the complexity of the system being modelled. At this point, the model becomes too complex to be handled by verbal statements.

It now becomes advantageous to redevelop the model in terms of symbolic relationships. This form will allow it to be manipulated by mathematical techniques; therefore, allowing the use of computational devices, i.e., digital, analog, and hybrid computers. Now the model can be experimented on by an orderly variation of parameters. The results obtained from the model are then compared to the results obtained by performing the same variation on the actual system, the experimental components of the research. It is then up to the modeler to determine, from these results whether the model simulates the real system with a satisfactory degree of faithfulness.

At the present time most physiological system models are in the transition phase, from the verbal to the mathematical model (1). The problems in making these transitions lie in obtaining suitable mathematical relationships. This means that more experiments must be performed which give quantitative rather than qualitative results.

There are some physiological systems which are more readily quantized than others. The respiratory system is one. This is due to the fact that the physiochemical description of gases lends itself very nicely to the respiratory system. Also, the understanding of the control mechanism for this physiological system has progressed to the quantification stages. It is for these reasons that there have been many proposed models of the respiratory system (2,3,4,5,6).

The engineer's role in such a research effort is first associated with the quantification and mathematical description of the system's functioning. After a model is formulated, many engineering techniques can be employed to verify the model and to suggest logical changes that may better represent the system. Such is the purpose of this paper. Grodins et al. (2) developed a model that will simulate the respiratory system at rest under different sea level ambient conditions. This model, however, is incomplete for it does not include the effects of exercise on the respiratory system. Therefore Weissman (7) modified Grodins' model to include the effects of exercise. With this modification the model can be used as a prediction of the respiratory responses of the important respiratory system stimuli. An extension of the model's capabilities to altered environments has not been thoroughly evaluated. One of the goals of the following study is to evaluate the simulation's response to variations in exercise levels at a specific environment (one-third atmosphere, 70% O_2, 28.08% N_2, and 1.92% CO_2).

This study discusses the exercise modification and its relationship to respiratory control so that the desired responses are obtained for various exercise stimuli and the corresponding transition between stimuli levels. Oxygen uptake and carbon dioxide production by the active tissues are utilized to interface the effects of exercise in the system equation. The controller subroutine is modified to include a component relating to a neurohumoral response for alveolar ventilation during exercise.

This study will also include the analysis of some simulation runs to determine the validity of the response and the interaction of the different variables used in the modification. Possible changes will then be suggested to improve the flexibility of the model in addition to an improvement in the fidelity of the model's responses compared to known physiological data.

This paper will begin with a brief discussion of the physiology involved in making the modification to Grodins' model. A detailed explanation of the modification follows utilizing flow charts and plots obtained from the programming of important functions on the Nova 1200 Minicomputer.

Following the explanation of the exercise subroutines is a description of several total system simulations of various exercise levels and the responses corresponding to these. Based upon these simulations conclusions and recommendations for further system modifications are presented.

II. THE CONTROL OF RESPIRATION DURING MUSCULAR EXERCISE

Muscular exercise causes a great change in the energy metabolism and gas exchange of the body. Respiration must therefore change to maintain the integrity of the internal environment of the body.

The way in which the respiratory system reacts to exercise depends on three variables:

1) the intensity of the exercise: the greater the intensity, the greater the response.
2) the type of exercise: bicycle riding will produce a different response than weight lifting.
3) environmental conditions: the respiratory response is quite different at various altitudes.

What is the mechanism that allows the respiratory system to respond to the needs of the body under these different conditions? The search for the answer is still underway.

The initial approach to the study of the problem of control of respiration was confined for a long time to the analysis of simple mechanisms. The control of respiration during exercise was dealt with in terms of a decrease of arterial oxygen or an increase of carbon dioxide. A great deal of time was then spent deciding whether the stimulation of the respiratory system was due to the CO_2 or the H^+ concentration released by the hydrated form of CO_2, carbonic acid (H_2CO_3) (8). The chemical reaction is defined as

$$CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows H^+ + HCO_3^- \quad . \qquad (1)$$

This simple mechanism for the control of exercise hyperpnea was unsatisfactory to many investigators. Neither CO_2 or anoxia (low oxygen concentration), even when combined, leads to the magnitude of the ventilation response observed during exercise. In addition to the chemical stimuli, the possibility that there are other stimuli of a different nature originating from the active muscles has now become an area of investigation and will be discussed below.

A. Humoral Theories

The chemical substances transported by the blood that may be responsible for exercise hypernea are:

1. Carbon Dioxide Tension, P_{CO_2}

The CO_2 production is greatly increased in muscular exercise. This should lead to an increased concentration of CO_2 in the blood sufficient to stimulate the respiratory center. The hyperventilation that follows would lead to a decreased blood CO_2 content, so that the whole process of the regulation of respiration could be considered as a simple feedback system. However, the blood CO_2 increases very little during exercise, and this increase is not enough to explain the change in ventilation that is observed.

2. Oxygen Tension, P_{O_2}

The possibility of a decrease of actual P_{O_2} during exercise may be present. However, this decrease would not amount to more than a few mm Hg, since the saturation of the arterial blood with O_2 is not appreciably affected in exercise. It would take a P_{O_2} of approximately 60 mm Hg to affect any sizable stimulus from the chemoreceptors in the aortic arch and carotid bodies (9).

3. H^+ Concentration

The increase in H^+ ion concentration of the arterial blood due to CO_2 accumulation has never been observed in mild exercise. Only during severe exercise does the H^+ concentration of the arterial blood increase. This increase is caused by large amounts of lactic acid produced by the exercising muscles during severe exercise when anaerobic metabolism accounts for the majority of energy.

4. Unknown Substances

The possibility of a release of substances formed in the muscles during exercise which affect respiration has been postulated (10). Such substances have never been identified.

All the humoral mechanisms postulated above, even if considered to be functioning at the same time, cannot explain the regulation of respiration during exercise. Steady state ventilation increases linearly with oxygen uptake, within the bounds of aerobic metabolism, independent of any chemical change in the blood.

B. Neurogenic Theories

Krogh and Lindhard (11) were the first to interpret the sudden increase of ventilation at the beginning of exercise on a neural basis. They postulated that impulses from the motor cortex of the brain were sent to the respiratory center to effect a change in ventilation. It was experimentally shown that the passive movements of the limbs elicited a ventilatory response (1). It was thought that impulses from mechanoreceptors in the muscles, tendons and joints transmitted to the respiratory center were the cause of the response. Comroe and Schmidt (12) found that the mechanoreceptors involved were limited only to the joints.

While performing cross circulation experiments on dogs, Kao (13) showed that the hyperventilation accompanying muscular activity is limited to the exercising neural dog. The humoral dog whose head was perfused by blood coming from the active limbs of the neural dog showed no change in ventilation. The increased ventilation of the neural dog was not due to the chemical stimulus of the respiratory center, since there were no changes in the blood of the humoral dog.

It is a well known fact that at the onset of exercise, pulmonary ventilation increases abruptly in a much shorter time than the circulation time; that is before chemical substances formed by the exercising muscles can reach the respiratory center (14).

Neurogenic controls alone are inadequate to maintain the delicate chemical balance of the blood during exercise at the same level as when the body is at rest. Therefore both humoral and neurogenic mechanisms are involved for the most effective control of respiration during muscular exercise.

C. Neurohumoral Theory

Dejours (15) recorded ventilation and arterial CO_2 tension, P_{aCO_2}, on a single breath basis to detect the very fast changes in ventilation at the start and end of exercise. The ventilation increases abruptly at the beginning of exercise, causing a fall in P_{aCO_2}. The ventilation then increases more slowly and reaches a steady state level in a few minutes. Simultaneously, the P_{aCO_2} increases and returns to the pre-exercise level. Corresponding changes take place at the end of exercise. A sudden decrease in ventilation causes an increase in P_{aCO_2} followed by a slow decrease in P_{aCO_2} to the resting value.

Since the neurohumoral theory seems to be adequately justified by experimental results, it has been utilized in the description of exercise hyperpnea. Weissman based his modification of Grodins' model completely the neurohumoral theory. Figure 1 shows the time relationship of ventilation during exercise and Figure 2 is a block diagram of the respiratory control model. Although it is the accepted theory of many researchers, some do not agree with the fast changes that occur in both the on- and off-transient responses (16).

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPAIRED TO THE REST OF THE INFORMATION ON THE PAGE.

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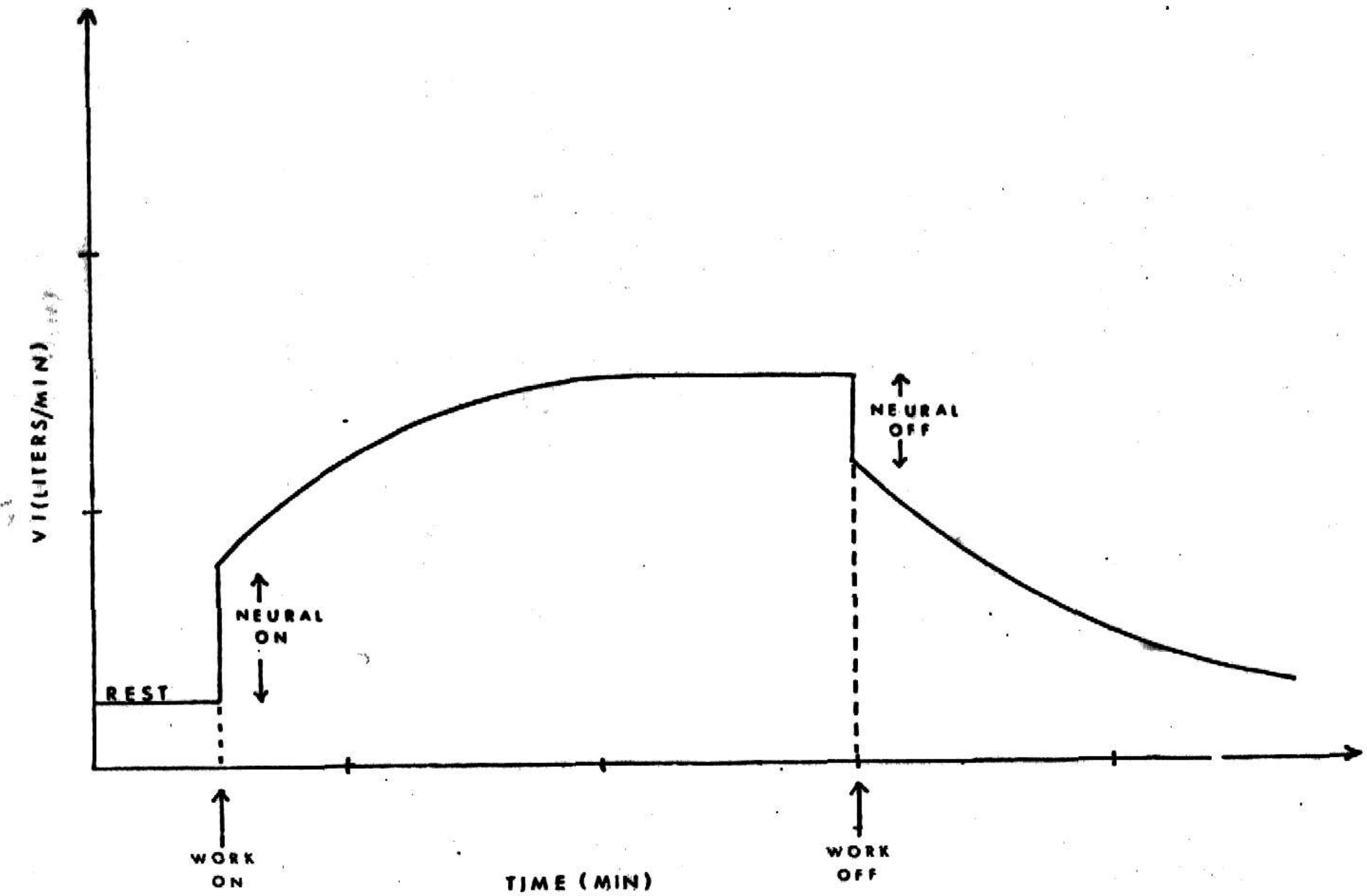


FIGURE 1. Time course of ventilation during exercise

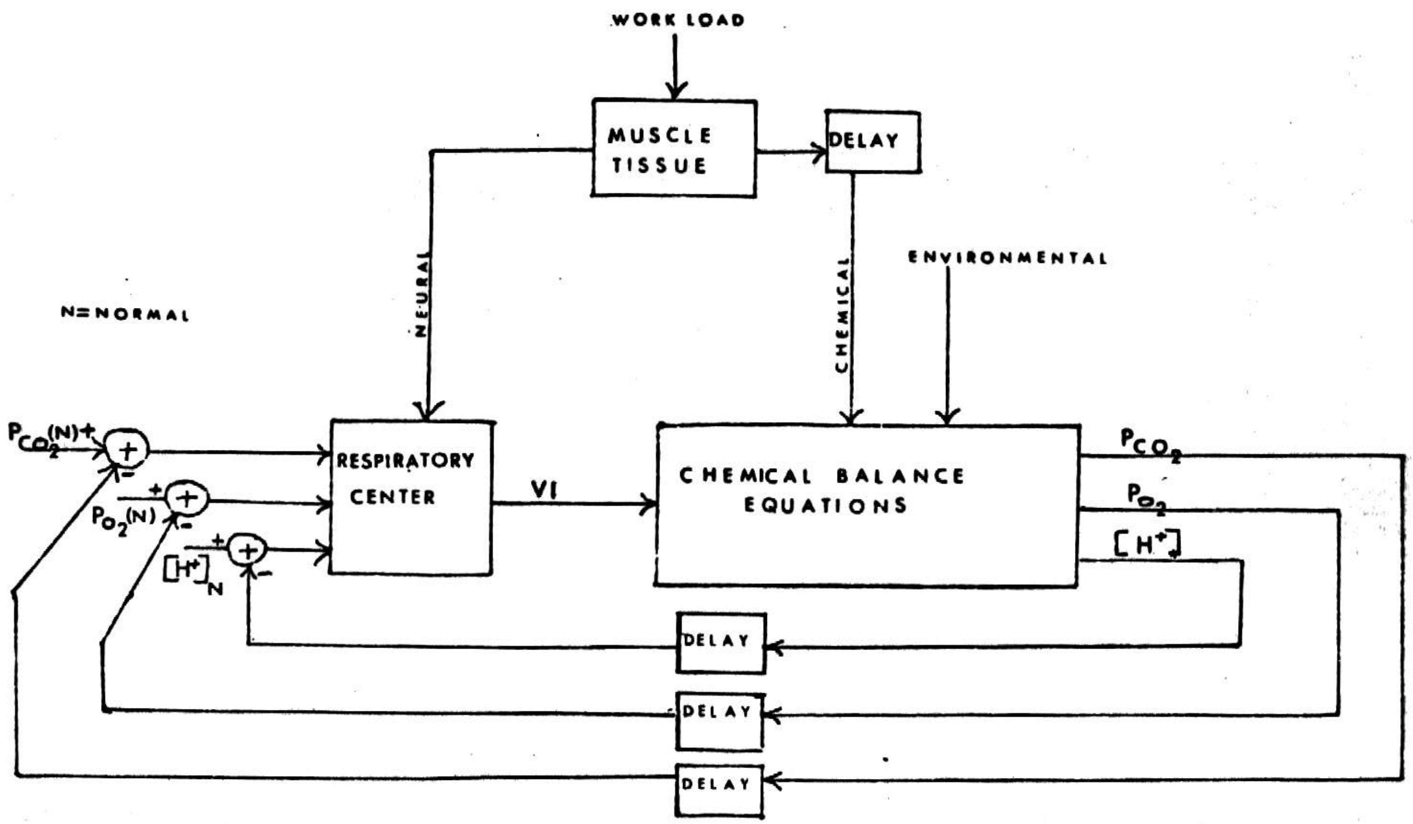


FIGURE 2. Block diagram of respiration control model

III. DETAILS OF THE MODIFICATION

Weissman's modification of Grodins' model was analyzed with very little documentation on hand. Very few comment statements were available in the program listing. Therefore, an understanding of how this modification coincided with the rest of the program was necessary. Grodins' entire program is partitioned into subroutines to facilitate any possible changes. See Appendix B. The modification in question is contained in subroutine RC12. The block diagram in Figure 3 shows RC12's relationship to the other subroutines in the program. As shown, RC12 fits into a loop that establishes and solves the system equations. The controller subroutine, RC17, is also a part of the loop. It is called before the system equations are calculated in RC11. This is needed because inspiratory ventilation rate (VI) and expiratory ventilation rate (VE) are both needed in the calculation of the system equations. RC17 will be discussed later.

The exercise subroutine is then scrutinized, with the initial step being the construction of a flow chart (Figure 4). This gives an insight into the functioning of this routine. In this subroutine, the tissue metabolic rates of oxygen, RMT(2), and carbon dioxide, RMT(1), are calculated along with the heart rate (HRATE), respiration frequency (FREQ), minute volume (TVNT), and dead space (DEADVT). The metabolic rates are the variables that interface this subroutine with the rest of the program. Both metabolic rates are used in the system equations.

The subroutine reads in a work load (WORK2) and duration (DURAT) from the input data cards. A decision of the work load is then made, depending upon its absolute magnitude and its magnitude relative to the previous work

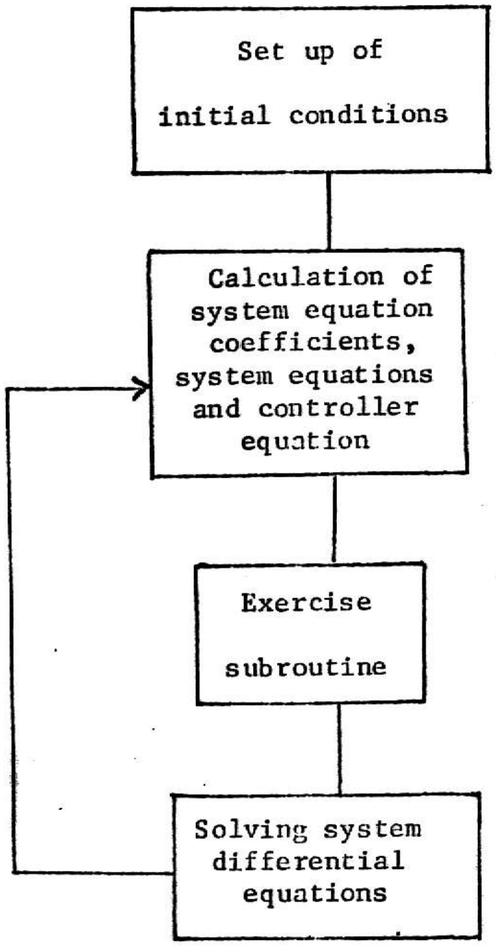
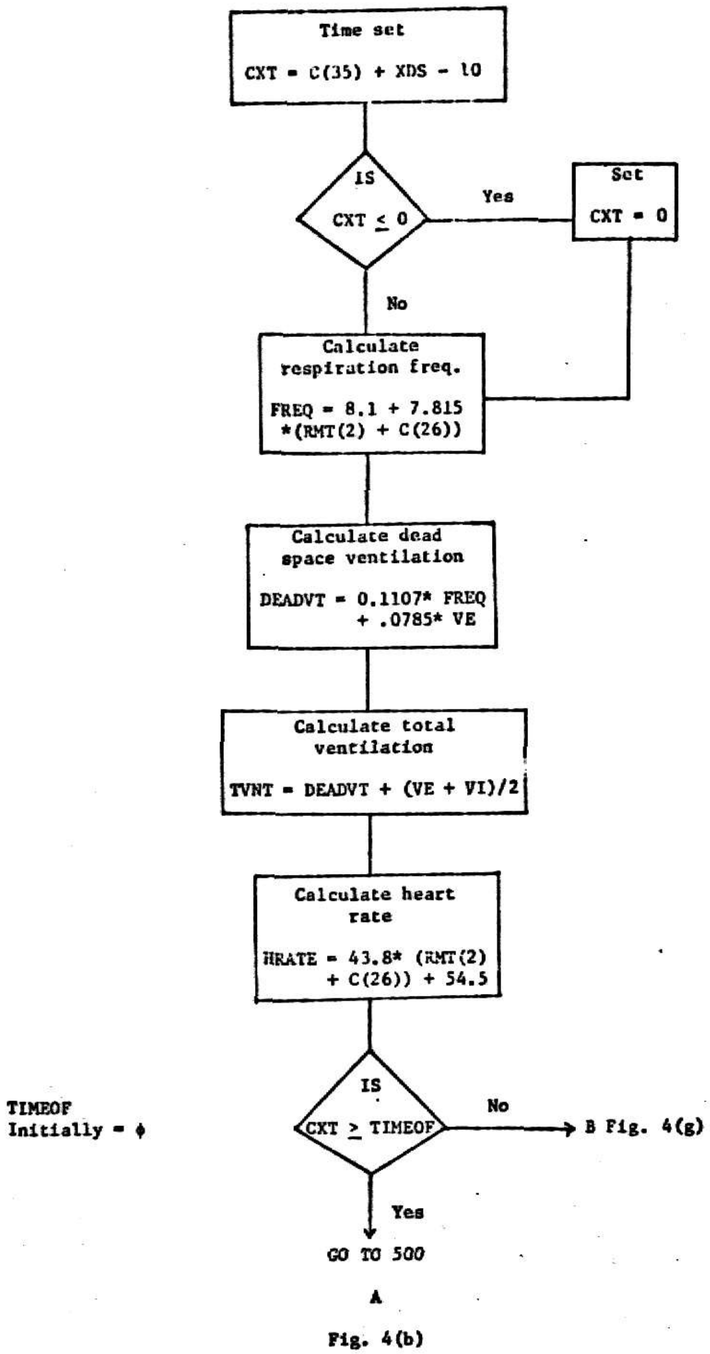


FIGURE 3. RC12's relationship to the other program subroutines



(a)

FIGURE 4. Flow chart for RC12

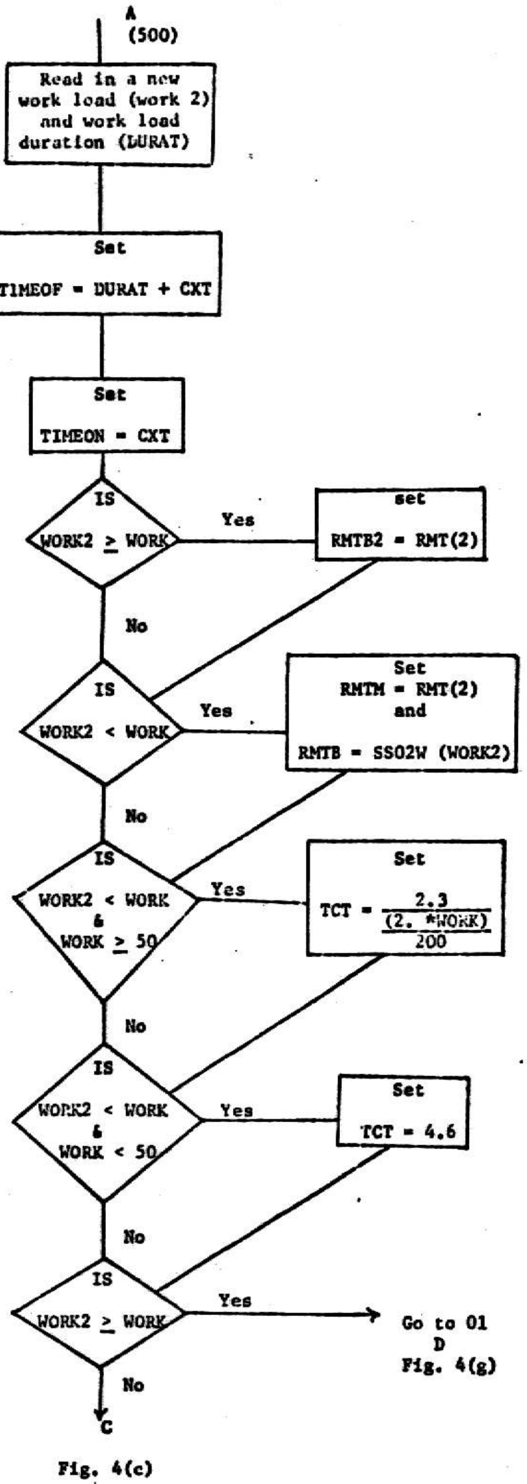

A
(500)
Read in a new work load (work 2) and work load duration (DURAT)
Set
TIMEOF = DURAT + CXT
Set
TIMEON = CXT
IS
WORK2 ≥ WORK
Yes
set
RMTB2 = RMT(2)
No
IS
WORK2 < WORK
Yes
Set
RMTM = RMT(2)
and
RMTB = SSO2W (WORK2)
No
IS
WORK2 < WORK
&
WORK ≥ 50
Yes
Set
TCT = 2.3 / ((2. *WORK) / 200)
No
IS
WORK2 < WORK
&
WORK < 50
Yes
Set
TCT = 4.6
No
IS
WORK2 ≥ WORK
Yes
Go to 01
D
Fig. 4(g)
No
C
Fig. 4(c)

FIGURE 4(b).

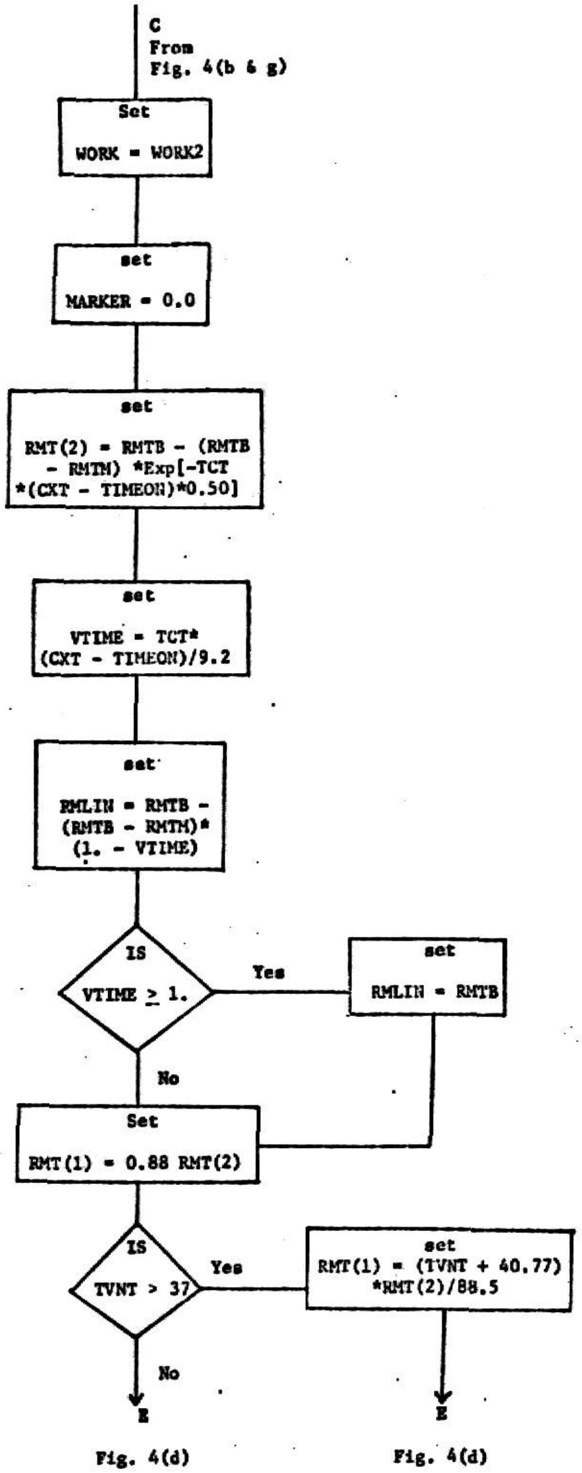

C
From
Fig. 4(b & g)
Set
WORK = WORK2
set
MARKER = 0.0
set
RMT(2) = RMTB - (RMTB - RMTM) *Exp[-TCT *(CXT - TIMEON)*0.50]
set
VTIME = TCT* (CXT - TIMEON)/9.2
set
RMLIN = RMTB - (RMTB - RMTM)* (1. - VTIME)
IS
VTIME ≥ 1.
Yes
set
RMLIN = RMTB
No
Set
RMT(1) = 0.88 RMT(2)
IS
TVNT > 37
Yes
set
RMT(1) = (TVNT + 40.77) *RMT(2)/88.5
No
E
Fig. 4(d)
E
Fig. 4(d)

FIGURE 4 (c).

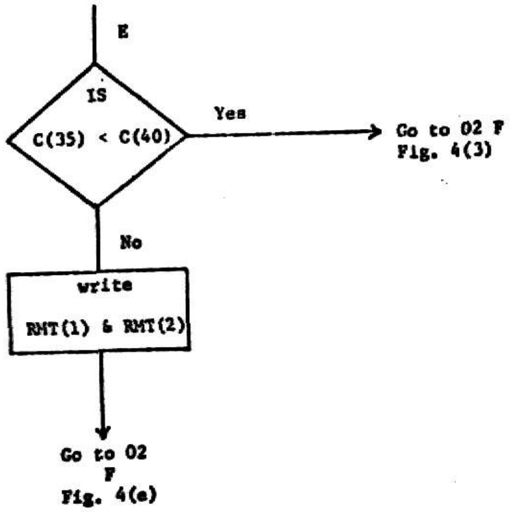

E
IS
C(35) < C(40)
Yes
Go to 02 F
Fig. 4(3)
No
write
RMT(1) & RMT(2)
Go to 02
F
Fig. 4(e)

FIGURE 4(d).

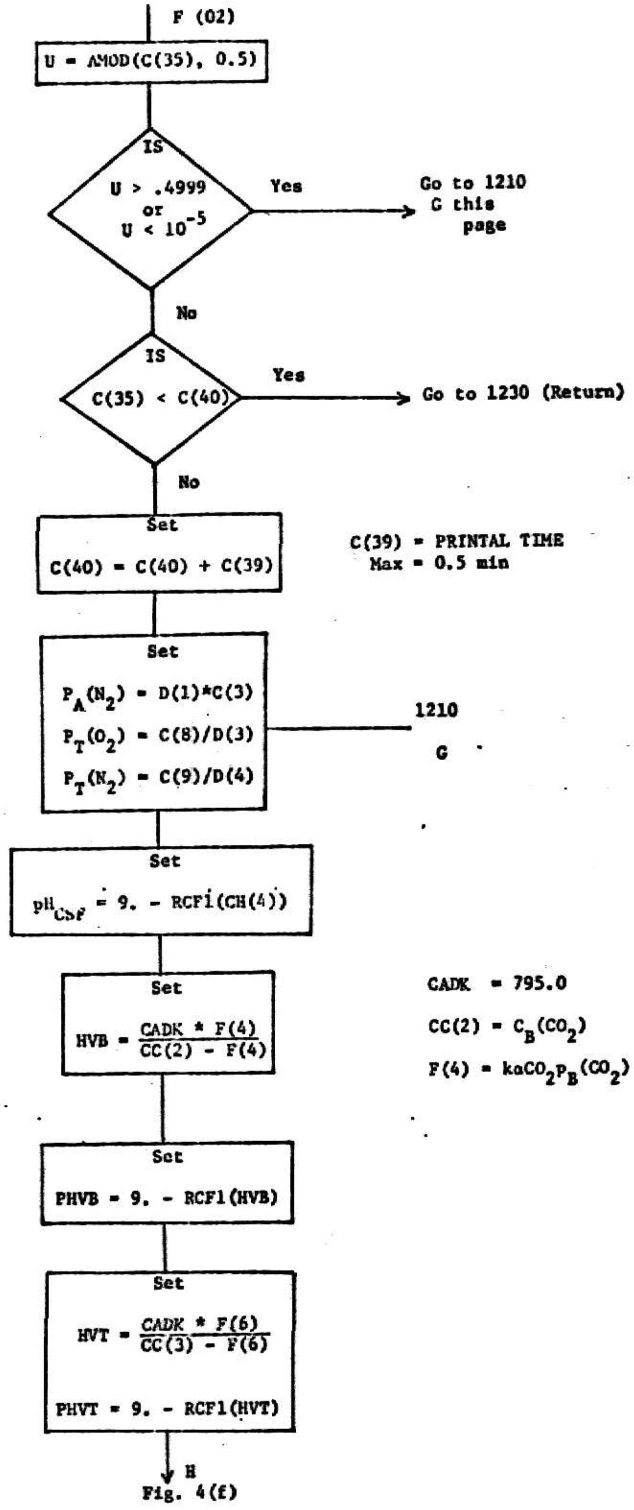

F (02)
U = AMOD(C(35), 0.5)
IS
U > .4999
or
U < 10^-5
Yes
Go to 1210
G this
page
No
IS
C(35) < C(40)
Yes
Go to 1230 (Return)
No
Set
C(40) = C(40) + C(39)
C(39) = PRINTAL TIME
Max = 0.5 min
Set
P_A(N_2) = D(1)*C(3)
P_T(O_2) = C(8)/D(3)
P_T(N_2) = C(9)/D(4)
1210
G
Set
pH_CSF = 9. - RCF1(CH(4))
Set
HVB = CADK * F(4) / CC(2) - F(4)
CADK = 795.0
CC(2) = C_B(CO_2)
F(4) = kaCO_2P_B(CO_2)
Set
PHVB = 9. - RCF1(HVB)
Set
HVT = CADK * F(6) / CC(3) - F(6)
PHVT = 9. - RCF1(HVT)
H
Fig. 4(f)

FIGURE 4(e).

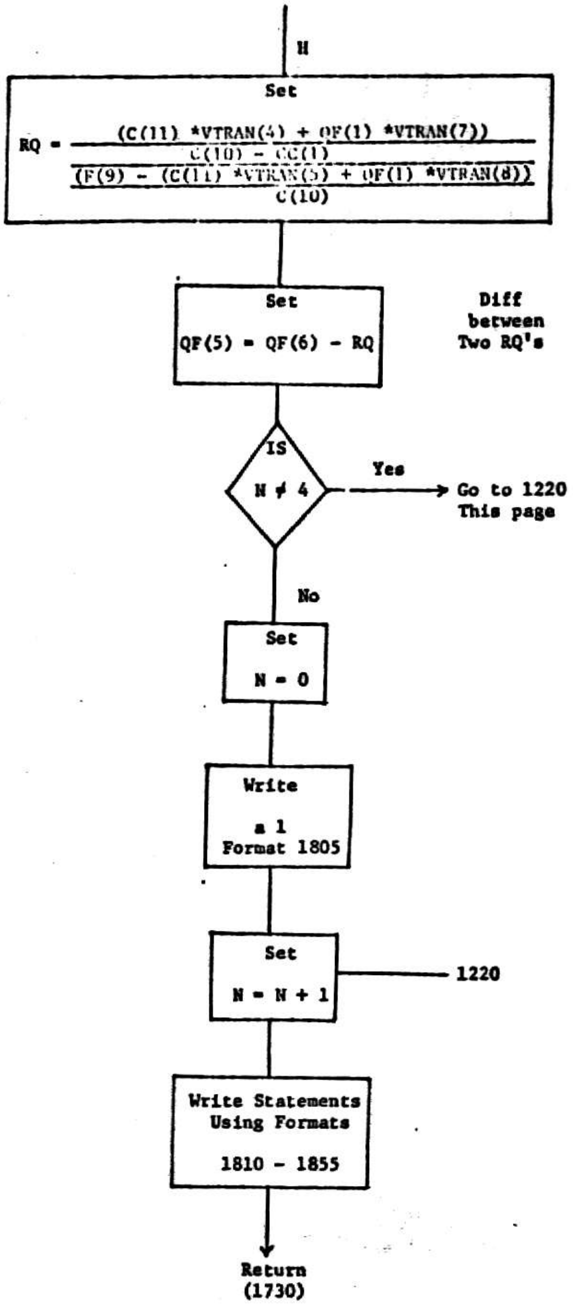

H
Set
RQ = (C(11) *VTRAN(4) + QF(1) *VTRAN(7)) / C(10) - CC(1) / (F(9) - (C(11) *VTRAN(5) + QF(1) *VTRAN(8)) / C(10)
Set
QF(5) = QF(6) - RQ
Diff between Two RQ's
IS
N ≠ 4
Yes
Go to 1220 This page
No
Set
N = 0
Write
a 1
Format 1805
Set
N = N + 1
1220
Write Statements Using Formats
1810 - 1855
Return (1730)

FIGURE 4(f).

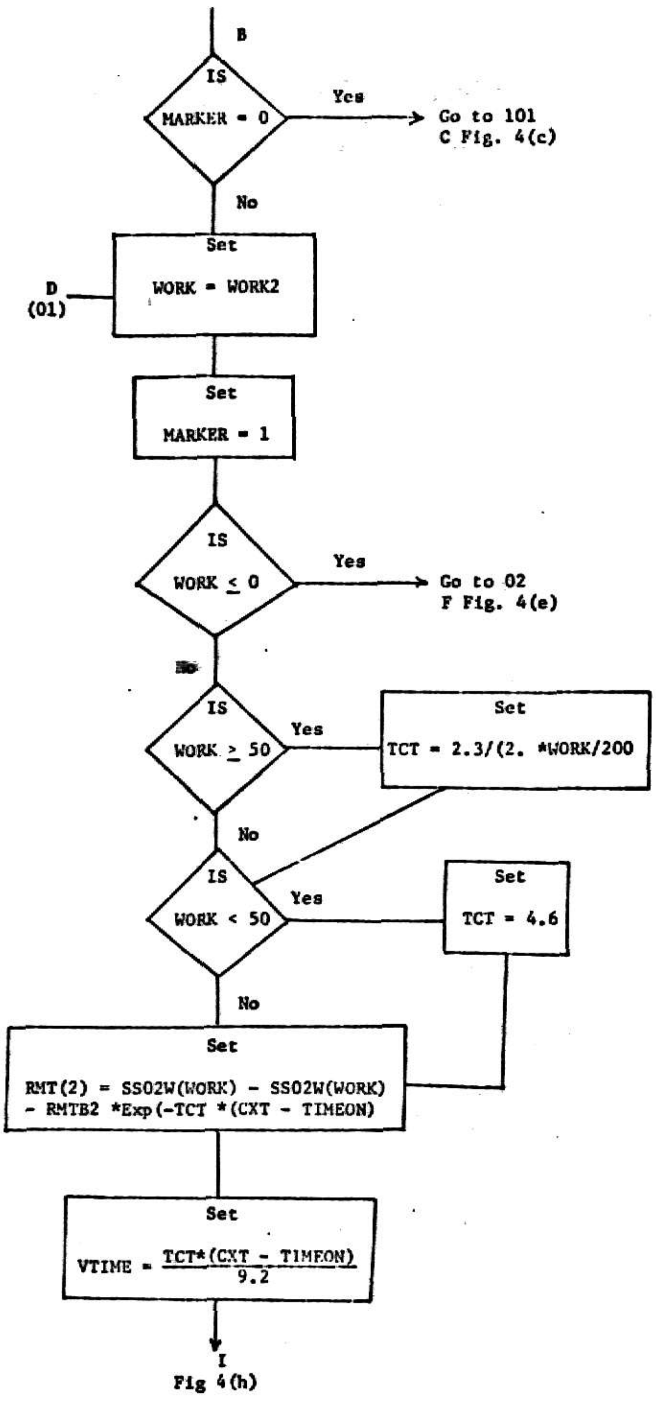

B
IS
MARKER = 0
Yes
Go to 101
C Fig. 4(c)
No
Set
WORK = WORK2
D
(01)
Set
MARKER = 1
IS
WORK ≤ 0
Yes
Go to 02
F Fig. 4(e)
IS
WORK ≥ 50
Yes
Set
TCT = 2.3/(2. *WORK/200
No
IS
WORK < 50
Yes
Set
TCT = 4.6
No
Set
RMT(2) = SSO2W(WORK) - SSO2W(WORK)
- RMTB2 *Exp(-TCT *(CXT - TIMEON)
Set
VTIME = TCT*(CXT - TIMEON) / 9.2
I
Fig 4(h)

FIGURE 4(g).

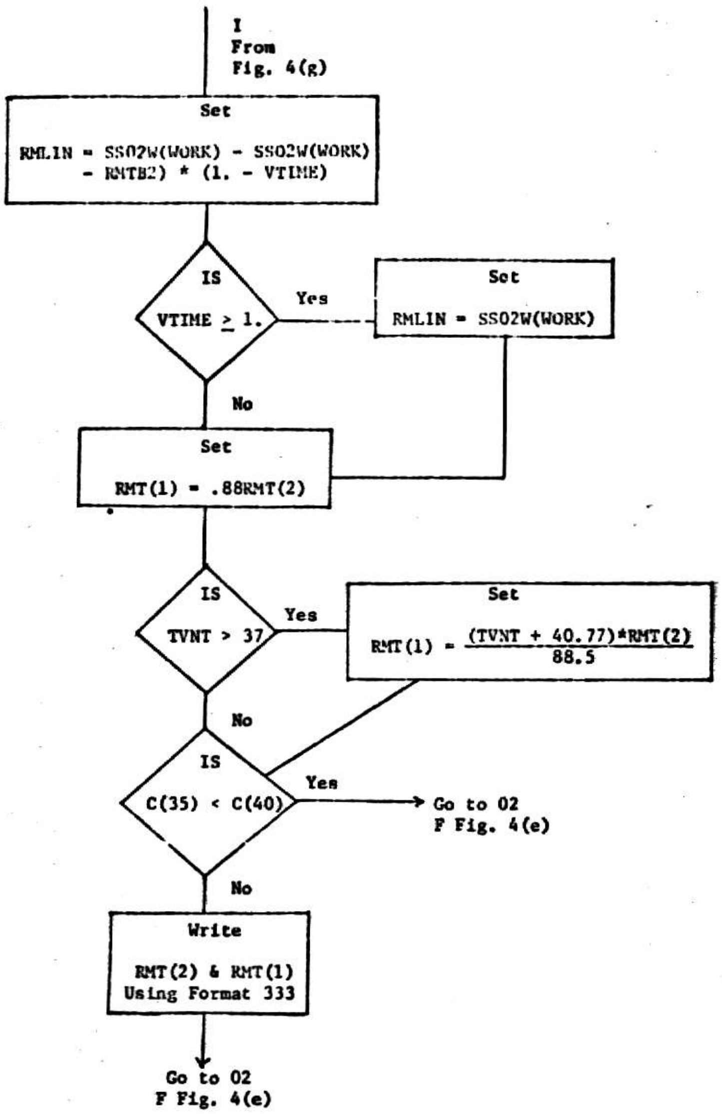

I
From
Fig. 4(g)
Set
RMLIN = SS02W(WORK) - SS02W(WORK)
- RMTB2) * (1. - VTIME)
IS
VTIME ≥ 1.
Yes
Set
RMLIN = SS02W(WORK)
No
Set
RMT(1) = .88RMT(2)
IS
TVNT > 37
Yes
Set
RMT(1) = (TVNT + 40.77)*RMT(2) / 88.5
No
IS
C(35) < C(40)
Yes
Go to 02
F Fig. 4(e)
No
Write
RMT(2) & RMT(1)
Using Format 333
Go to 02
F Fig. 4(e)

FIGURE 4(h).

load (WORK). This decision is needed since there are two different equations that calculate the metabolic rate of oxygen. One is for WORK2 less than WORK, and one is for WORK2 greater than or equal to WORK. To make sure that the program knows where it is at all times, a flag is set depending on the relative magnitude of the new work load. If WORK2 is less than WORK, MARKER is set equal to zero (MARKER = 0). If it is larger than or equal to WORK, MARKER is set equal to one (MARKER = 1). This flag is necessary because the program is continually calling RC12. The flag makes it possible for the program to return to the same set of equations until a new work load is read in. This will occur whenever the simulation time, C(35), is greater than TIMEOF. TIMEOF is set equal to the duration time plus the simulation time, CXT, when the work load is read in:

$$\text{TIMEOF} = \text{CXT} + \text{DURAT} \qquad (2)$$

Physiological studies show that oxygen uptake is a good indicator for the amount of work that is being performed (17). This is why all other physiological parameters are always related to oxygen uptake. As mentioned before, the modification under discussion for this program is based mainly on two expressions for oxygen uptake; one for when the work loads are increasing, and one for when the work loads are decreasing. These two expressions are discussed in the following material.

A. Increasing Work Loads

For this case the subroutine utilizes the expression

$$\text{RMT}(2) = \text{SS02W}(\text{WORK}) - (\text{SS02W}(\text{WORK}) - \text{RMTB2})* \\ \text{EXP}(-\text{TCT}(\text{CXT} - \text{TIMEON})) \qquad (3)$$

where:

SS02W(WORK) is the tissue steady state oxygen consumption for a particular work load. Oxygen consumption varies linearly with work load as shown in Figure 5. However, the relationship between oxygen consumption and work load in this program is a piecewise linear relationship, as illustrated by Figure 6. Figures 5 and 6 illustrate a maximum value for the oxygen consumption. At this point there is no further increase in oxygen consumption for an increase in work load. This point is known as the maximum oxygen uptake (MAX O_2). It is a measure of one's physical fitness. In the average male the MAX O_2 is about 3.5 liters per minute at a work load of 250 watts. MAX O_2 is higher in the more fit individual. For example, some long distance runners have a MAX O_2 of between 5 and 6 liters per minute (17). The dotted line in Figure 6 is a suggested change that would eliminate the discontinuity at 250 watts.

RMTB2 is the oxygen consumption at the time the work load is initiated. If the work load is started from rest, this value is 0.215 liters per minute.

TCT is the inverse of the time constant. It determines the rise time of the exponential components. TCT is related to the work load by the following expressions:

$$\text{TCT} = \begin{cases} 4.6 & \text{for work} \leq 50 \text{ watts} \\ 2.3/2*\text{WORK}/200 & \text{for work} > 50 \text{ watts} \end{cases} \qquad (4)$$

This function is plotted in Figure 7. From this plot it is seen that, as the work load is increased, TCT becomes smaller. This

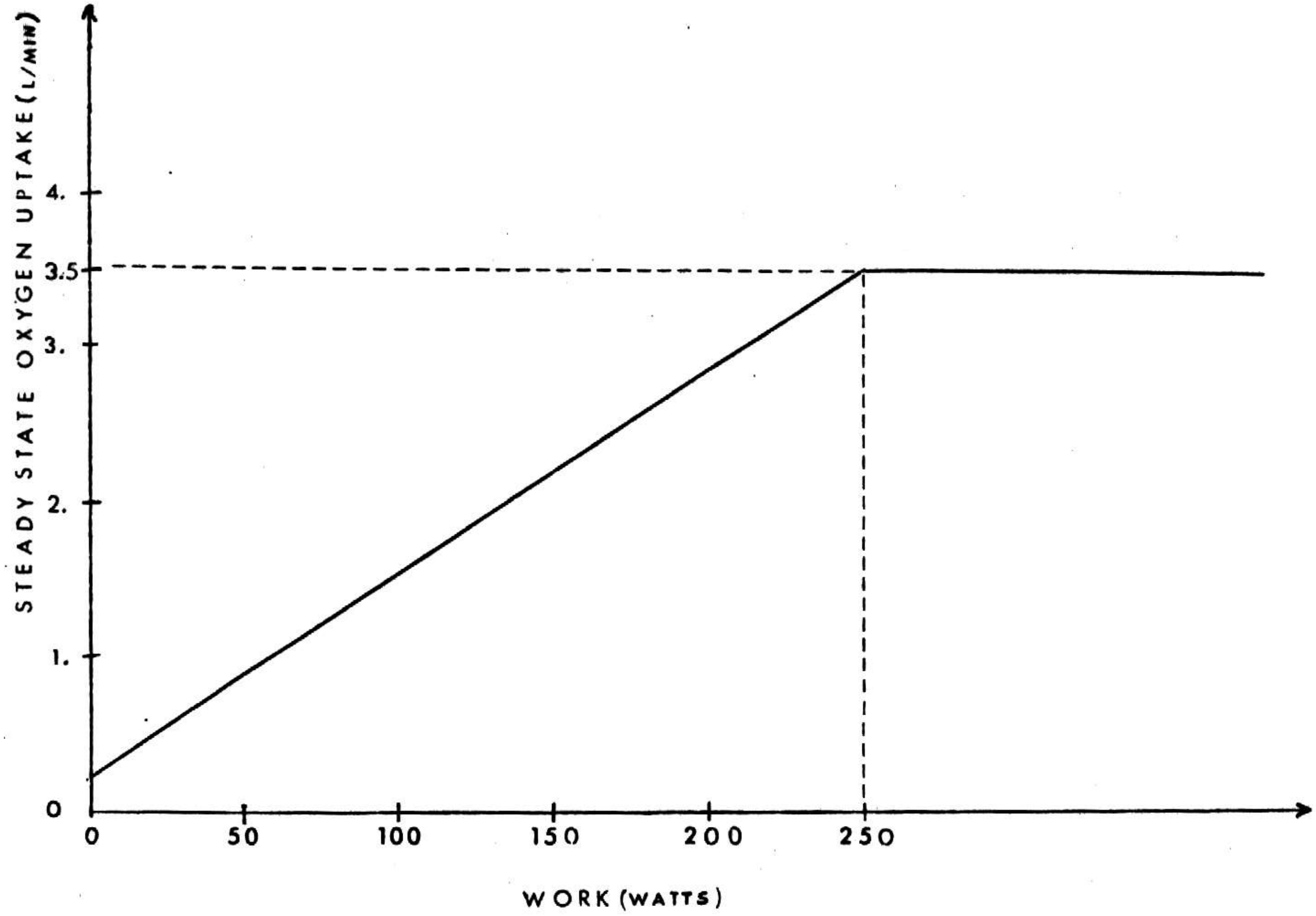


FIGURE 5. Classical relationship between steady state oxygen uptake and work load

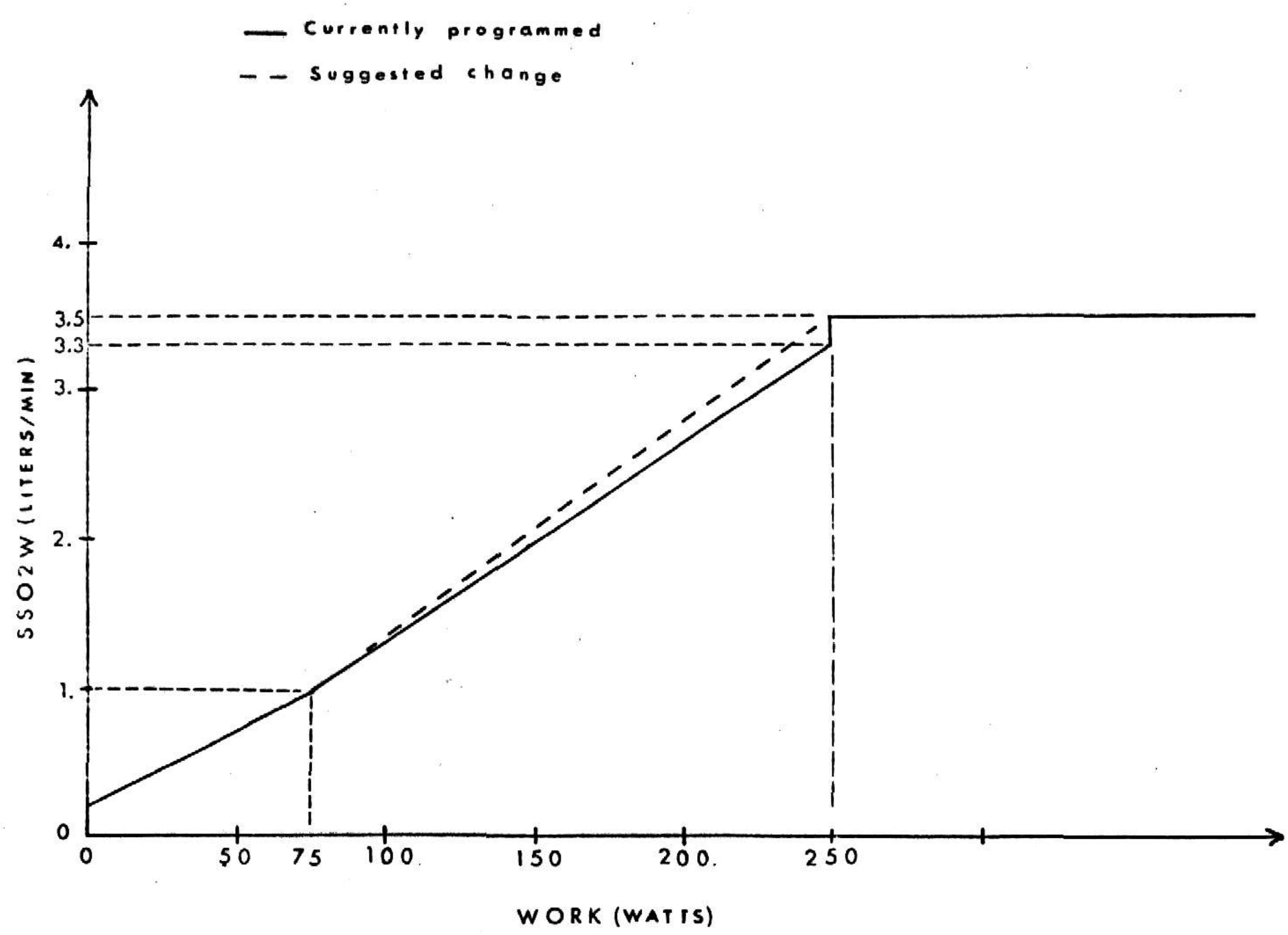


FIGURE 6. Piecewise linear relationship of steady state oxygen uptake and work load used in model

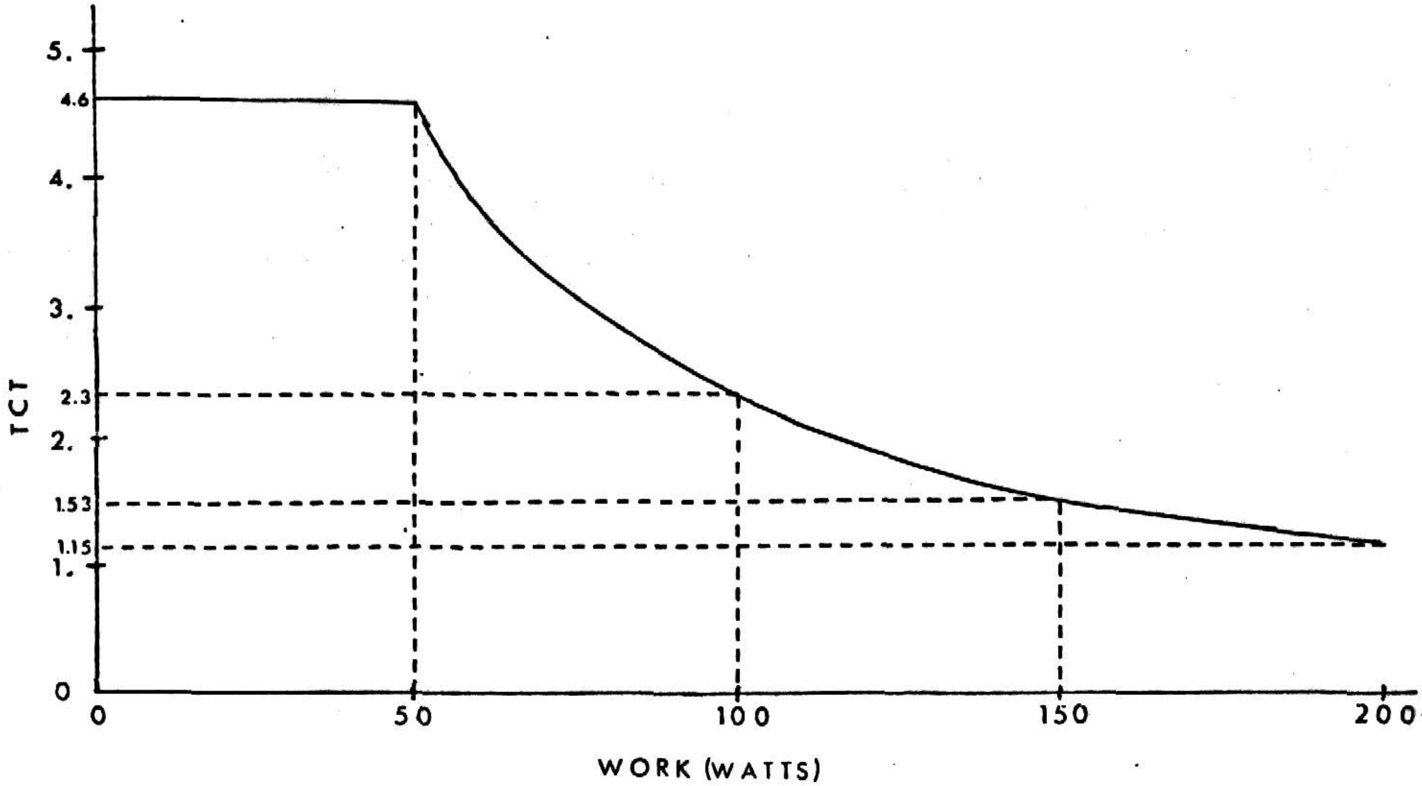


FIGURE 7. Inverse time constant versus work

means that as the work load increases, more time is required to reach steady state.

CXT is equal to the simulation time C(35).

TIMEON is the time when the work load is started. After the work load is read in, the subroutine sets TIMEON = CXT. Thus CXT - TIMEON is elapsed time of the work load at any time C(35).

With the aid of the NOVA 1200 minicomputer (see Appendix A) plots of RMT(2) for different work loads were obtained. The first plot, Figure 8, illustrates how RMT(2) changes from rest to steady state for five different work loads. Figure 9 describes the time course of RMT(2) if the work loads change without returning to rest. Notice that in both plots it takes more time to reach steady state as the work loads increase.

B. Decreasing Work Loads

For decreasing work loads RC12 utilizes an oxygen consumption expression that is a decaying exponential. It has a time constant that is twice as long as the time constant used in the expression for increasing work loads. The expression is written as

RMT(2) = RMTB - (RMTB-RMTM) * EXP(-TCT*(CXT-TIMEON)* 0.5)   (5)

where:

RMTB is the steady state oxygen consumption at the new, lower work load.

CXT, TCT, and TIMEON are as stated before. However, it is important to notice that TCT is determined not by the new work load but by

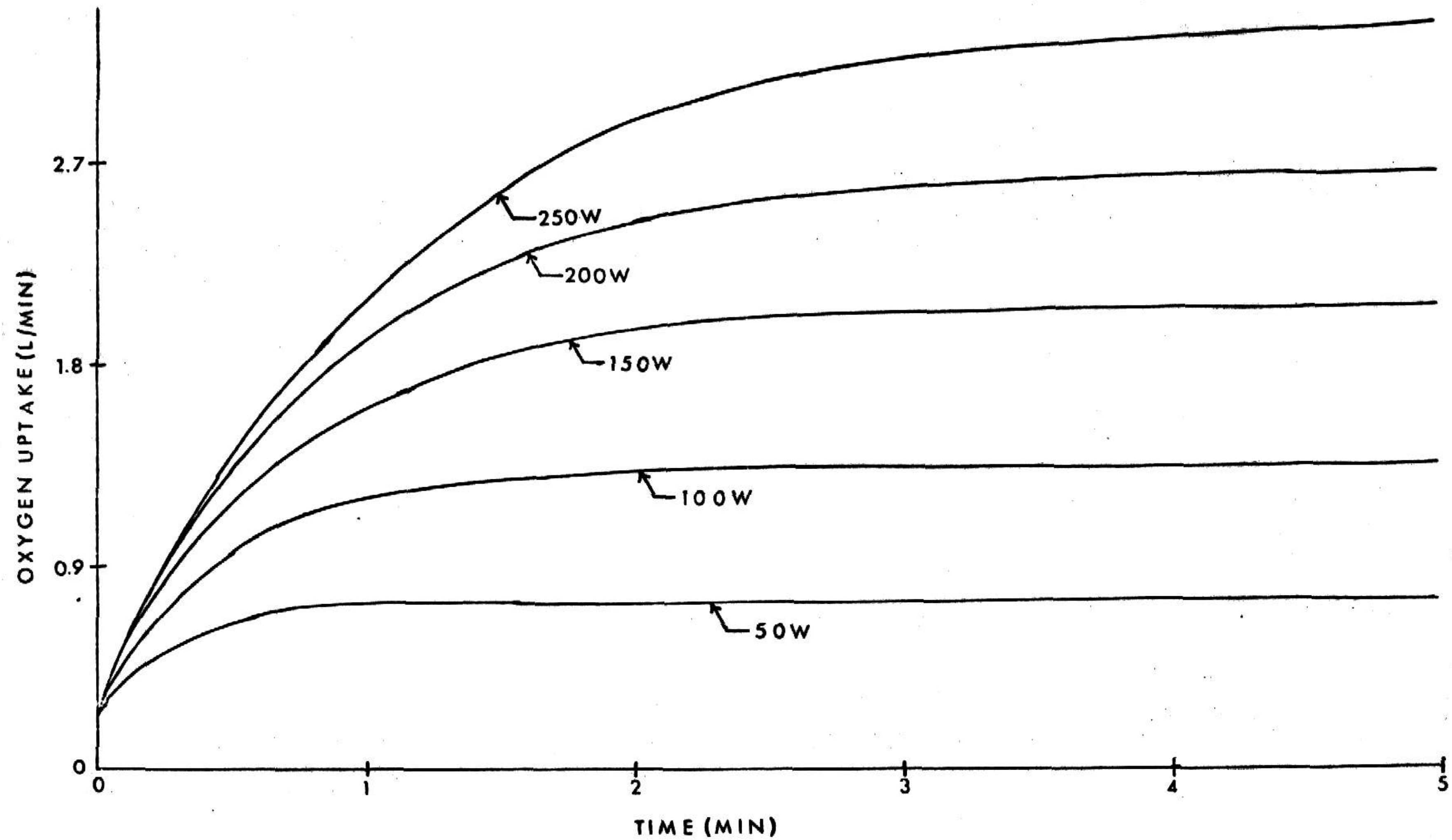


FIGURE 8. Uptake of oxygen from resting conditions

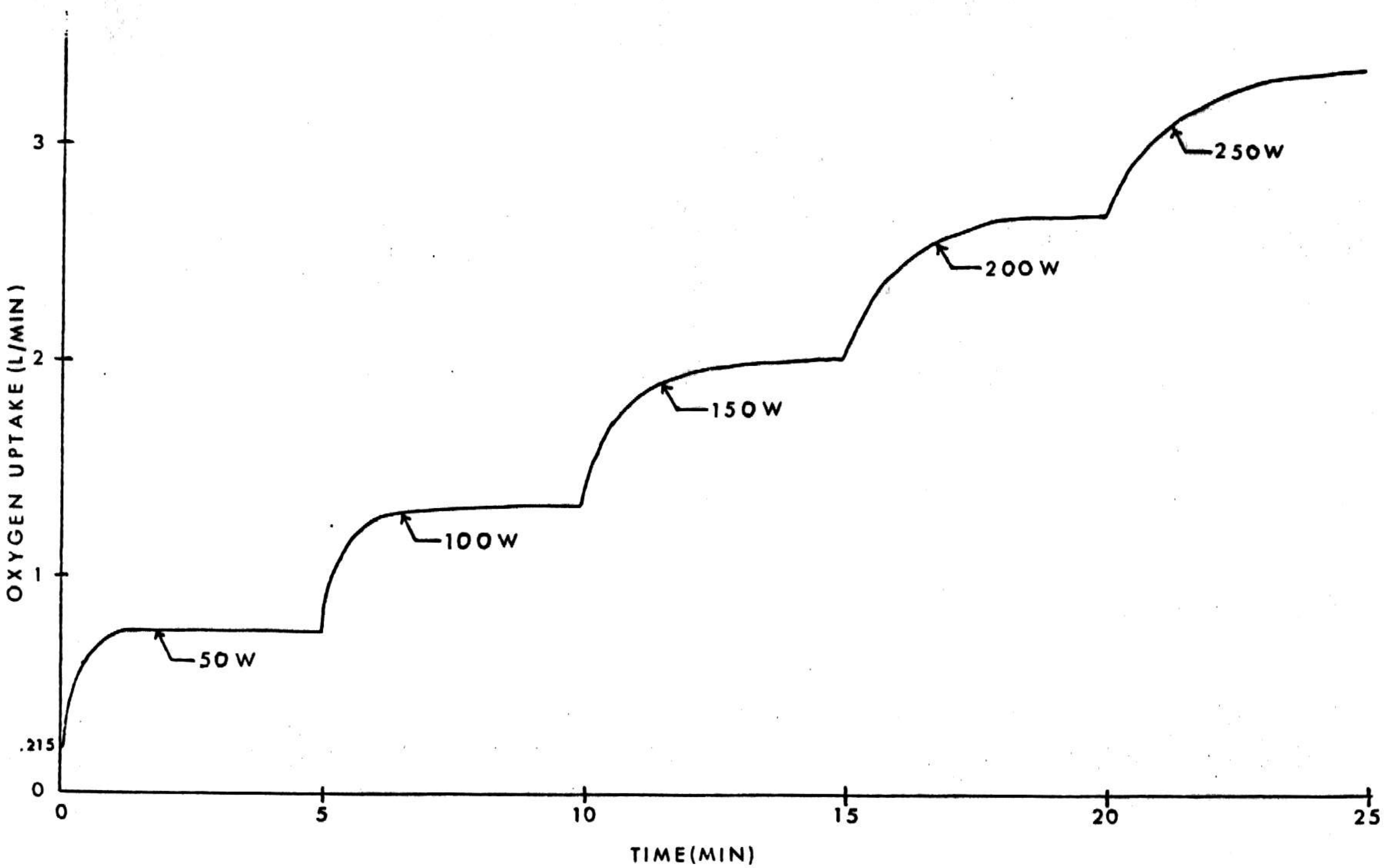


FIGURE 9. Uptake of oxygen for successive work loads

the previous work load. This is physiologically justified because the swiftness by which the body returns to the resting state is dependent upon how hard it was working. The harder it worked during the previous interval the longer it takes to replace the oxygen and high energy stores of the body.

Figure 10 is a plot of RMT(2) from a working level to rest, for five different work loads.

For both increasing and decreasing work loads the metabolic production of carbon dioxide, RMT(1), is calculated by the same equations:

$$RMT(1) = (TVNT + 40.77)*RMT(2)/88.5 \quad (6)$$

for TVNT less than or equal to 37.

For TVNT greater than 37

$$RMT(1) = 0.88RMT(2) \quad (7)$$

where TVNT is the minute volume.

C. System Controller Equation

Up to this point, only the alteration of the system equations during exercise has been discussed. It is still necessary to determine how the controller equation subroutine, RC17, is modified to take exercise into account.

As before, a flow chart can be obtained for RC17 as shown in Figure 11. From the flow chart it is still difficult to determine the interaction of the steps and how the various individual elements of the routine interact. To get a better feel for this, a print routine is added to this subroutine which prints out the important variables. When the program is run at different work loads, knowledge of the subroutine functioning is obtained by utilizing the printouts as shown in Figure 12.

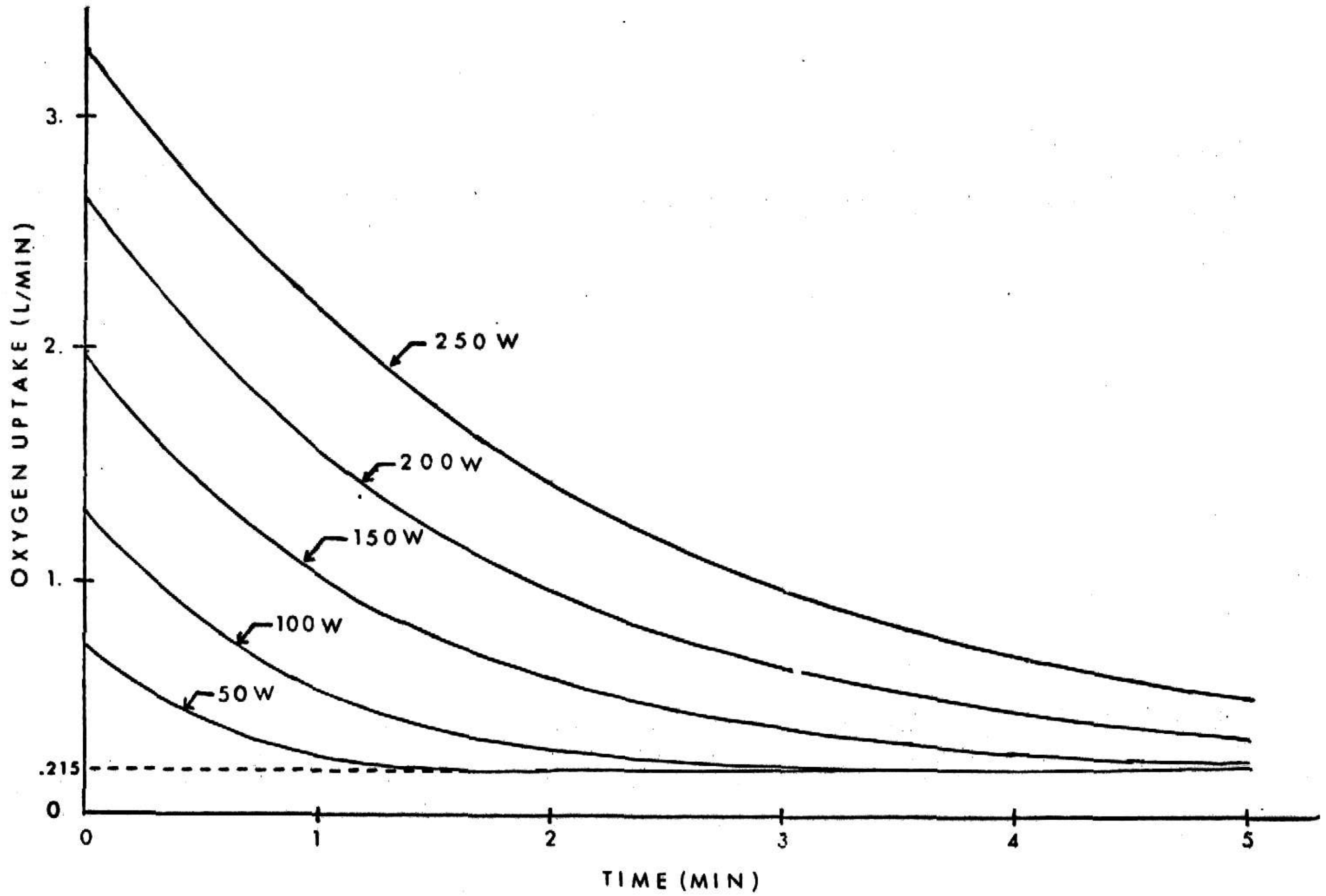
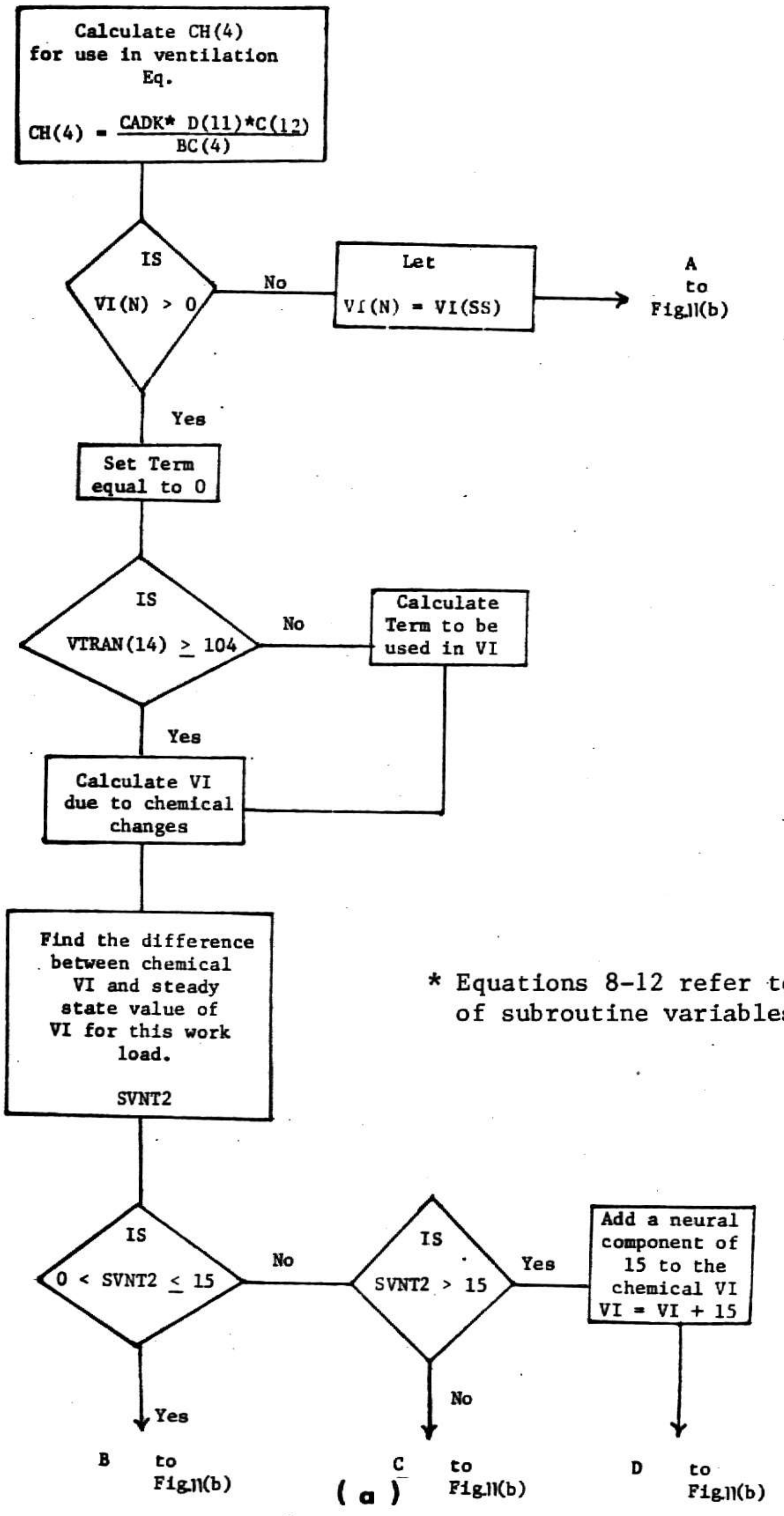


FIGURE 10. Oxygen uptake for decreasing work loads

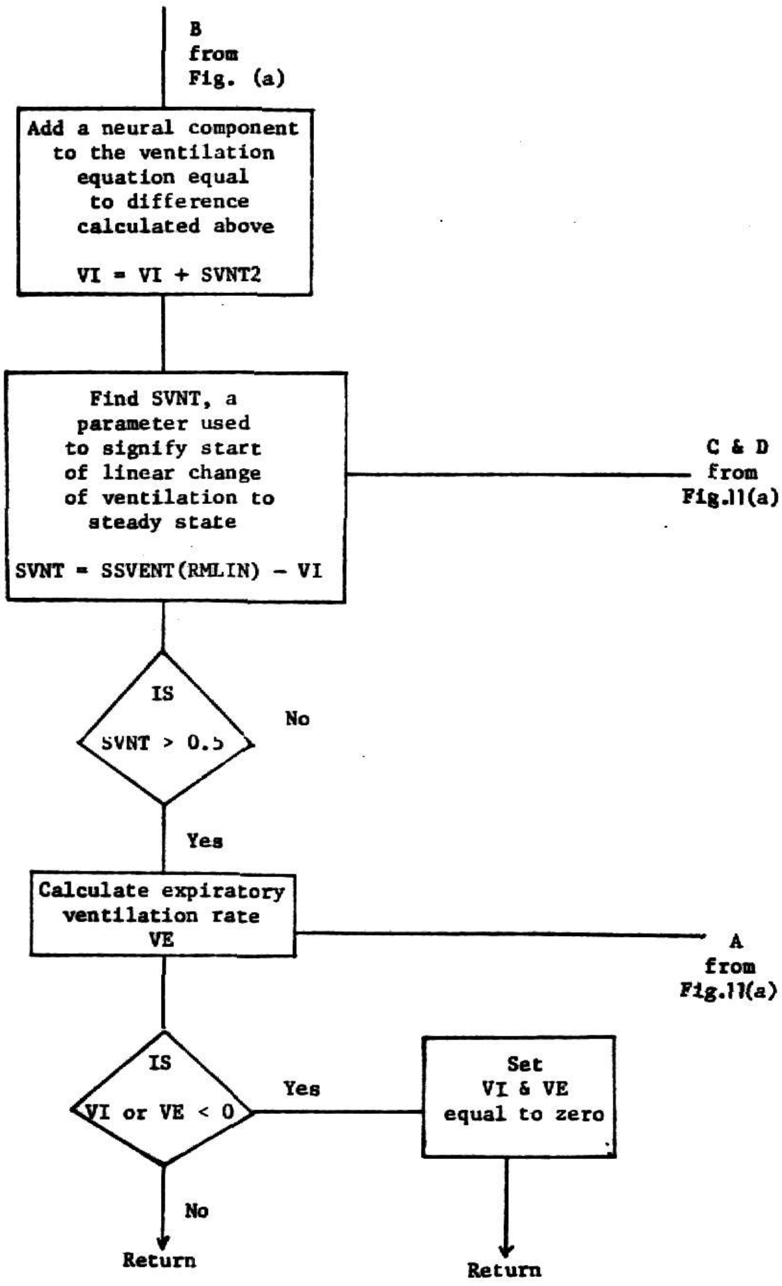
(8)*



* Equations 8-12 refer to calculations of subroutine variables.

(9)

FIGURE 11. Flow chart for controller subroutine



(10)

(11)

(12)

FIGURE 11 (b)

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THIS IS THE BEST COPY AVAILABLE

```
      0.0000     6.0500     0.0000    23.6917   18.5201   3.0554   1.7813   0.0000   3.2857   0.5608   0.7408
      0.0000     6.0500     0.0000    23.6917   18.5201   3.0555   1.7813   0.0000   3.2857   0.5608   0.7408
      0.0000     6.0500     0.0000    23.6917   18.5201   3.0555   1.7813   0.0000   3.2857   0.5608   0.7408
      0.0000     6.0500     0.0000    23.6917   18.5201   3.0555   1.7813   0.0000   3.2857   0.5608   0.7408
L=   3   I=  15   C(I)=   30.0001   SC(I,1)=   0.0159
      0.0000     6.0500     0.0000    23.6917   18.5529   3.0555   1.7813   0.0000   3.2857   0.5636   0.7421
      0.0000     6.0500     0.0000    23.6917   18.5529   3.0557   1.7891   0.0000   3.2857   0.5636   0.7421
      0.0000     6.0500     0.0000    23.6917   18.5529   3.0558   1.7891   0.0000   3.2857   0.5636   0.7421
      0.0000     6.0500     0.0000    23.6917   18.5529   3.0558   1.7891   0.0000   3.2857   0.5636   0.7421
      0.0000     6.0500     0.0000    23.6917   18.5529   3.0558   1.7891   0.0000   3.2857   0.5636   0.7421
L=   3   I=  15   C(I)=   30.0001   SC(I,1)=   0.0158
      0.0000     6.0500     0.0000    23.6917   18.5858   3.0558   1.7891   0.0000   3.2857   0.5664   0.7434
      0.0000     6.0500     0.0000    23.6917   18.5858   3.0560   1.7969   0.0000   3.2857   0.5664   0.7434
      0.0000     6.0500     0.0000    23.6917   18.5858   3.0561   1.7969   0.0000   3.2857   0.5664   0.7434
      0.0000     6.0500     0.0000    23.6917   18.5858   3.0560   1.7969   0.0000   3.2857   0.5664   0.7434
      0.0000     6.0500     0.0000    23.6917   18.5858   3.0561   1.7969   0.0000   3.2857   0.5664   0.7434
L=   3   I=  15   C(I)=   30.0001   SC(I,1)=   0.0158
      0.0000     6.0500     0.0000    23.6917   18.6187   3.0561   1.7969   0.0000   3.2857   0.5692   0.7447
      0.0000     6.0500     0.0000    23.6917   18.6187   3.0563   1.8047   0.0000   3.2857   0.5692   0.7447
      0.0000     6.0500     0.0000    23.6917   18.6187   3.0564   1.8047   0.0000   3.2857   0.5692   0.7447
      0.0000     6.0500     0.0000    23.6917   18.6187   3.0563   1.8047   0.0000   3.2857   0.5692   0.7447
      0.0000     6.0500     0.0000    23.6917   18.6187   3.0563   1.8047   0.0000   3.2857   0.5692   0.7447
L=   3   I=  15   C(I)=   30.0001   SC(I,1)=   0.0158

CHANGE IN METABOLIC RATES     MRCO2=    0.8318     MRO2=    0.9452

       TIME     1.8047                                                                          ALV FG    0.1749   FC DIFF   0.7173
                CO2        C2        N2         D E R I V A T I V E S          PCO2      PO2      PN2      (H+)      PH        HCO2
   ALVEOLAR     0.2275   0.2951    0.4773    0.0158   -0.0889    0.0732    48.4653  62.8619  101.6708
   ARTERIAL     0.6220   0.1802    0.0017                                  48.4653  62.8619  101.5708  44.0135   7.3564   0.1782
      BRAIN     0.6597   0.0013    0.0014    0.0138   -0.0001    0.0004    52.3714  40.5011   81.9797  44.6666   7.3474
     TISSUE     0.6372   0.0006    0.0012    0.0158   -0.0001    0.0001    47.2967  20.1476   72.6894  41.6153   7.3787
        CSF                                  0.5072    0.5437    1.9647    48.2066  36.5516   66.6219  44.1024   7.3555
    V BRAIN     0.6485   0.1427    0.0014                                  52.3714  40.5011   81.9797  45.7647   7.3407   0.1414
   V TISSUE     0.6434   0.0754    0.0012                                  47.2967  20.1476   72.6694  41.3895   7.3331   0.0747
    TRANSPORT TIMES --    AB        VB        VT        AT        AC  **    VI       VE        Q        FB     DERIVATIVES
                         0.1190    0.0670    0.3570    0.1919    0.1134    6.0500   3.0563    9.9359   1.2627   0.1103   0.3125
  RESP FREQ    15.8772    MINUTE VOLUME      6.5507    DEAD SPACE VENT     1.9975            HEART RAT.  98.0961
      0.0000     6.0500     0.0000    23.6917   18.6515   3.0563   1.8047   0.0000   3.2857   0.5720   0.7461
      0.0000     6.0500     0.0000    23.6917   18.6515   3.0566   1.8125   0.0000   3.2857   0.5720   0.7461
      0.0000     6.0500     0.0000    23.6917   18.6515   3.0567   1.8125   0.0000   3.2857   0.5720   0.7461
      0.0000     6.0500     0.0000    23.6917   18.6515   3.0566   1.8125   0.0000   3.2857   0.5720   0.7461
      0.0000     6.0500     0.0000    23.6917   18.6515   3.0566   1.8125   0.0000   3.2857   0.5720   0.7461
L=   3   I=  15   C(I)=   30.0001   SC(I,1)=   0.0158
      0.0000     6.0500     0.0000    23.6917   18.6844   3.0566   1.8125   0.0000   3.2857   0.5748   0.7474
      0.0000     6.0500     0.0000    23.6917   18.6844   3.0569   1.8203   0.0000   3.2857   0.5748   0.7474
      0.0000     6.0500     0.0000    23.6917   18.6844   3.0569   1.8203   0.0000   3.2857   0.5748   0.7474
      0.0000     6.0500     0.0000    23.6917   18.6844   3.0569   1.8203   0.0000   3.2857   0.5748   0.7474
      0.0000     6.0500     0.0000    23.6917   18.6844   3.0569   1.8203   0.0000   3.2857   0.5748   0.7474
L=   3   I=  15   C(I)=   30.0001   SC(I,1)=   0.0158
      0.0000     6.0500     0.0000    23.6917   18.7172   3.0569   1.8203   0.0000   3.2857   0.5776   0.7487
      0.0000     6.0500     0.0000    23.6917   18.7172   3.0572   1.8281   0.0000   3.2857   0.5776   0.7487
      0.0000     6.0500     0.0000    23.6917   18.7172   3.0572   1.8281   0.0000   3.2857   0.5776   0.7487
      0.0000     6.0500     0.0000    23.6917   18.7172   3.0572   1.8281   0.0000   3.2857   0.5776   0.7487
      0.0000     6.0500     0.0000    23.6917   18.7172   3.0572   1.8281   0.0000   3.2857   0.5776   0.7487
L=   3   I=  15   C(I)=   30.0001   SC(I,1)=   0.0157
      0.0000     6.0500     0.0000    23.6917   18.7501   3.0572   1.8281   0.0000   3.2857   0.5804   0.7500
```

FIGURE 12. Sample printout from RC17

Verification that the modification of the controller equation is based on the neurohumoral theory as discussed in Section IIC is possible. That is, it consists of a fast neural component and a slower humoral component. Referring to Figure 13, which is the subroutine listing, the first calculation made is that of the ventilation as given by Grodins' controller equation, (VI). This value is then subtracted from the steady state ventilation for the work load of interest, (SSVENT(SS02W(WORK))). This steady state ventilation is calculated using the relationship given by the plot in Figure 14. This plot effectively illustrates that steady state ventilation is linearly related to steady state oxygen consumption. However, oxygen consumption is dependent upon the work load as previously discussed. The difference between this steady state value and the value obtained by Grodins' controller equation is the neural component if the difference is less than or equal to 15 liters per minute. If the difference is greater than 15 liters per minute, the neural component is set equal to 15. The difference is given the variable name SVNT2. This neural component is added to the value of ventilation that is calculated by Grodins' controller equation and a new value for VI is obtained. This description of VI is given by Equations 13 and 14

$$VI = VI + SVNT2 \quad \text{for } 0 \leq SVNT2 \leq 15 \tag{13}$$

or

$$VI = VI + 15 \quad \text{for } SVNT2 > 15 \tag{14}$$

At this point, another variable is calculated, SVNT. SVNT is the difference between another steady state value for ventilation defined by the term SSVENT(RMLIN) and the value of ventilation which is calculated in Equation 13 or 14.

$$SVNT = SSVENT(RMLIN) - VI \tag{15}$$

```
                    RESP CASE NO. 1                                    DATE  220672  PAGE    40
@ FOR,* RC17,RC17                                                      22 JUN 72                 15: 2:32
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:32

   SUBROUTINE RC17      ENTRY POINT 000171

   STORAGE USED: CODE(1) 000173; DATA(0) 000157; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z      002376
    0004   R      000014

   EXTERNAL REFERENCES (BLOCK, NAME)

    0005   SSVENT
    0006   SS02W
    0007   NEXP6$
    0010   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000015 1708L     0001   000033 1720L     0001   000127 1730L     0001   000160 1740L     0000   000136 6969F
    0003   002232 A         0000   000027 BAD       0003 R 002317 BC        0003 R 000000 C         0003 R 002363 CADK
    0003   002336 CC        0003 R 002344 CH        0003   002341 CHB       0003   002361 CPB       0003   002350 CPH
    0003   002362 CPT       0004   000002 CXT       0003 R 002240 D         0003   002214 DC        0003   002353 DQ
    0003   002365 DT        0004   000004 DUM1      0004   000005 DUM2      0004   000006 DUM3      0003 R 002257 F
    0003   002372 I         0003   002371 INDEX     0000   000151 INJP$     0003   002366 IRK       0003   002370 ITERX
    0003   002373 J         0003   002367 LOC       0003   002374 M         0003   002375 N         0003 R 002323 QF
    0003   002016 RK        0004 R 000013 RMLIN     0003   002315 RMT       0004   000010 RMTB      0004   000011 RMTB2
    0003   002106 SC        0006 R 000000 SS02W     0005 R 000000 SSVENT    0003   000170 SV        0000 R 000002 SVNT
    0000 R 000001 SVNT2     0003   002331 TAU       0000 R 000000 TERM      0004   000012 TIMEOF    0003 R 002357 VE
    0003 R 002360 VI        0003   002303 VOL       0003 R 001774 VTRAN     0004 R 000003 WORK      0004   000007 WORK2
    0003   002364 X         0004   000000 XDS       0004   000001 XMH       0003   000050 XN


                 SUBROUTINE RC17
                 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/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
                 NAMELIST/BAD/CH(4),CADK,D(11),C(12),BC(4),C(37),C(38),VTRAN(14),
                1TERM,VI,C(20),C(16),VTRAN(15),C(21),VTRAN(13),C(37),D(9),C(11),
                2VTRAN(16),QF(1),VTRAN(17),C(10),F(11),
          6969            FORMAT(1H 8HSUB RC17)
          C      CALCULATES VENTILATION
                 CH(4)  = CADK*D(11)*C(12)/BC(4)
```

(a)

FIGURE 13. Subroutine RC17 program listing

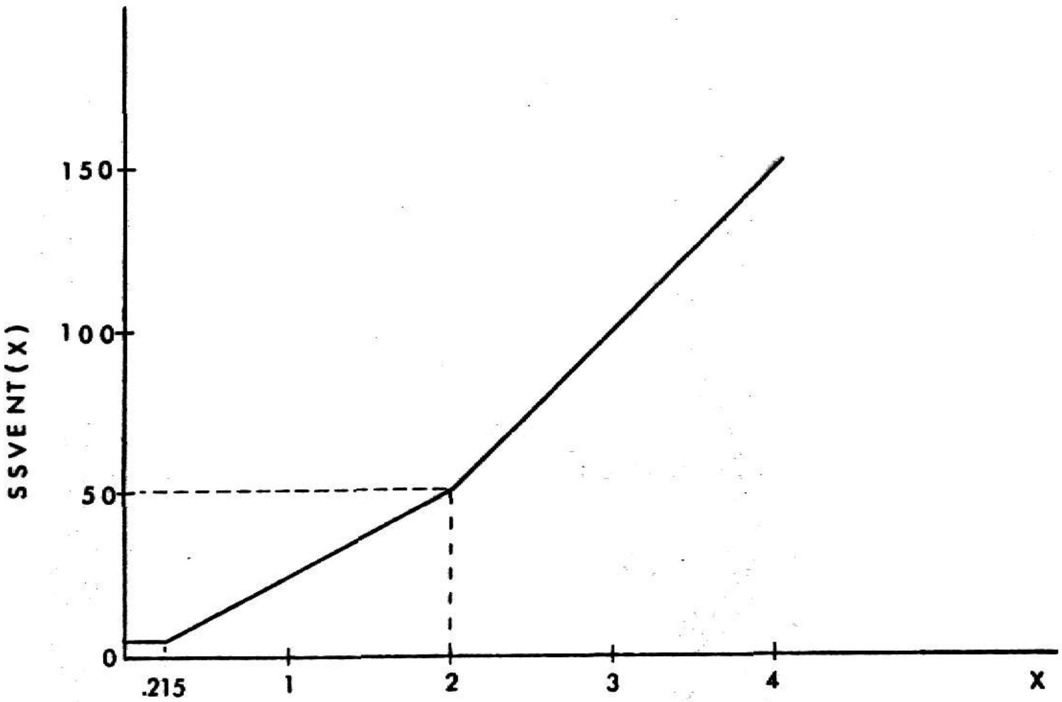
```
                 RESP CASE NO. 1                                      DATE  220672  PAGE   91
00111                IF (C(37) .GT. 1.0E-5)        GO TO 1700
00113          1704 VI = C(38)
00114                GO TO 1730
00115          1700 TERM = 0.0
00116                IF (VTRAN(19) - 104.0)        1710, 1720, 1720
00121          1710 TERM = (23.6E-9)*((104.0 - VTRAN(19))**4.9)
00122          1720 VI = C(20)*(C(16)*VTRAN(15) + (1.0 - C(16))*CH(4))
00122               1      + C(21)*VTRAN(13) + TERM - C(37)
00123                SVNT2=SSVENT(SSO2W(WORK))  -VI
00124                IF((SVNT2.GT.0.).AND.(SVNT2.LE.15.))    VI=VI+SVNT2
00126                IF(SVNT2.GT.15.)  VI=VI+15.
00130                SVNT =SSVENT(RMLIN ) -VI
00131                IF(SVNT.GT.0.5)   VI=VI+0.75*SVNT
00133          1730 VE = VI + D(9)*(C(11)*VTRAN(16) + QF(1)*VTRAN(17) - C(10)*F(11))
00134                IF (VI .LT. 0.0 .OR. VE .LT. 0.0)     GO TO 1740
00136                RETURN
00137          1740 VI = 0.0
00140                VE = 0.0
00141                RETURN
00142                END

    END OF COMPILATION:          NO  DIAGNOSTICS.
 RC17              SYMBOLIC                               29 JAN 72  16:17:26   0  01475462   19    36  (DELETED)
 RC17     CODE     RELOCATABLE                            29 JAN 72  16:17:26   1  01476452   36     1  (DELETED)
                                                                                0  01476516   19    20
```

```
VO=VI
SW=SSVENT(SSO2W(WORK))
SR=SSVENT(RMLIN)
1735 WRITE(6,1737)VO,VI,SVNT2,SW,SR,VE,C(35),SVNT,TCT,
    1 VTIME,RMLIN
1737 FORMAT(11F12.4)
```

3

FIGURE 13(b)



When X=SSO2W(WORK) this plot illustrates a linear relationship between steady state ventilation and steady state oxygen uptake

FIGURE 14. Steady state ventilation

The argument used to determine the steady state ventilation term is calculated in RC12. RMLIN is a slowed down, linearlized version of RMT(2). It is given by

$$RMLIN = SSO2W(WORK) - (SSO2W(WORK) - RMTB2)(1.-VTIME) \quad (16)$$

where SSO2W(WORK) and RMTB2 are as discussed before. VTIME is the function that slows down RMLIN in relationship to RMT(2). It is given by

$$VTIME = TCT(CXT - TIMEON)/9.2 \quad \text{for } VTIME < 1 \quad (17)$$

The value 9.2 makes RMLIN approach its steady state value at a rate four times slower than RMT(2) when the work load is 100 watts. For work loads less than 100 watts, the response of RMT(2) is less than four times as fast. For work loads greater than 100 watts, the response of RMT(2) is greater than four times as fast. Figures 15 and 16 show the relationship between RMLIN and RMT(2) for two different work loads (25 watts and 75 watts).

When VTIME reaches the value of 1, RMLIN has reached steady state and is given by:

$$RMLIN = SSO2W(WORK) \ . \quad (18)$$

Going back to the discussion of the controller equation, if SVNT is greater than 0.5, ventilation will start to linearly approach its steady state value. This is done by adding 75% of SVNT to the value of VI calculated above. The relation used is:

$$VI = VI + 0.75SVNT \quad (19)$$

After inspiratory ventilation has been calculated, expiratory ventilation is calculated, again using a relationship given by Grodins (2).

Figures 17 and 18 are plots of the different variables discussed above for work loads of 25 and 75 watts. In both figures, it is seen that the sum of VO and SVNT2 equals SSVENT(SSO2W(WORK)) for SSVENT(RMLIN) < 0.5

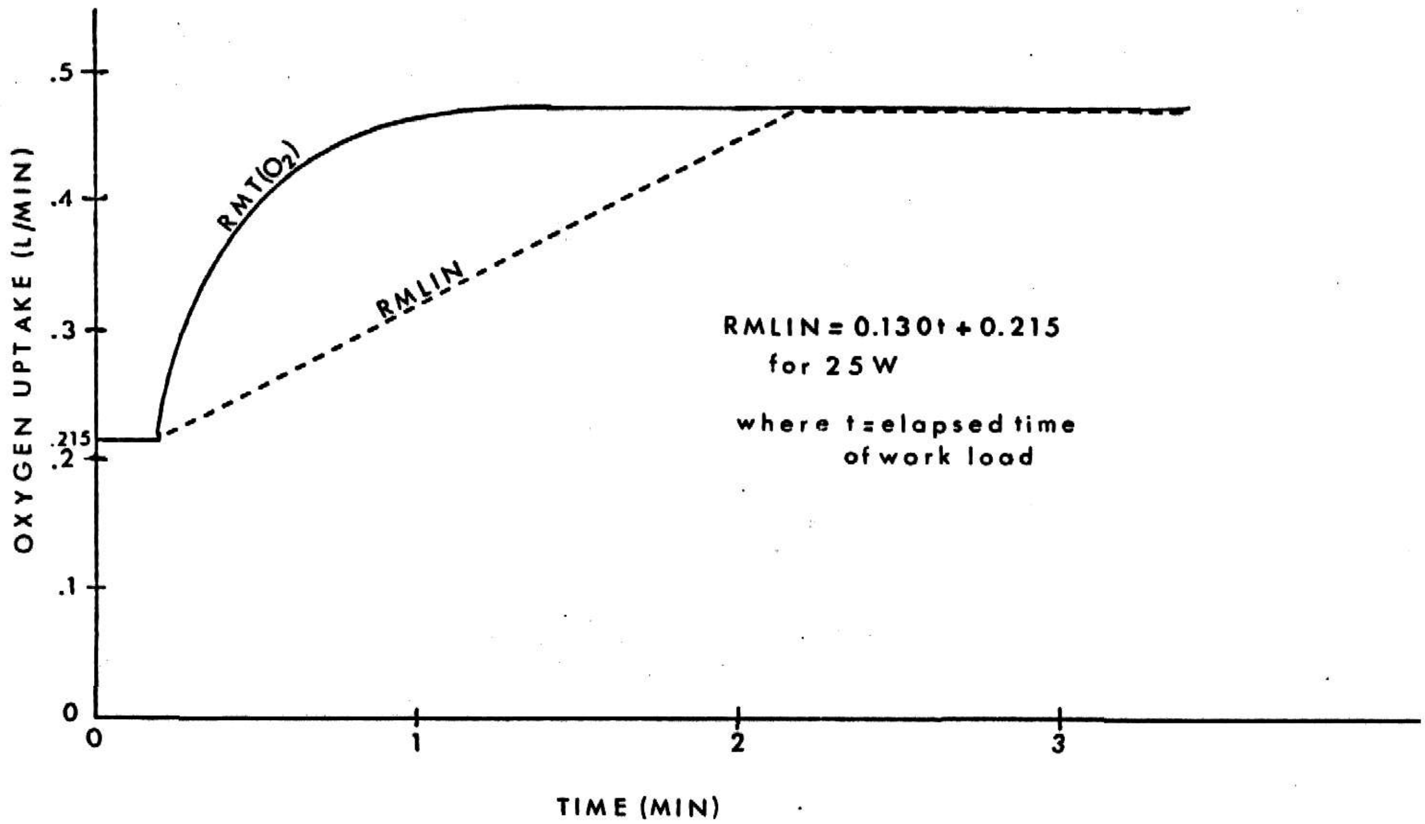


FIGURE 15. The relationship between oxygen uptake and RMLIN

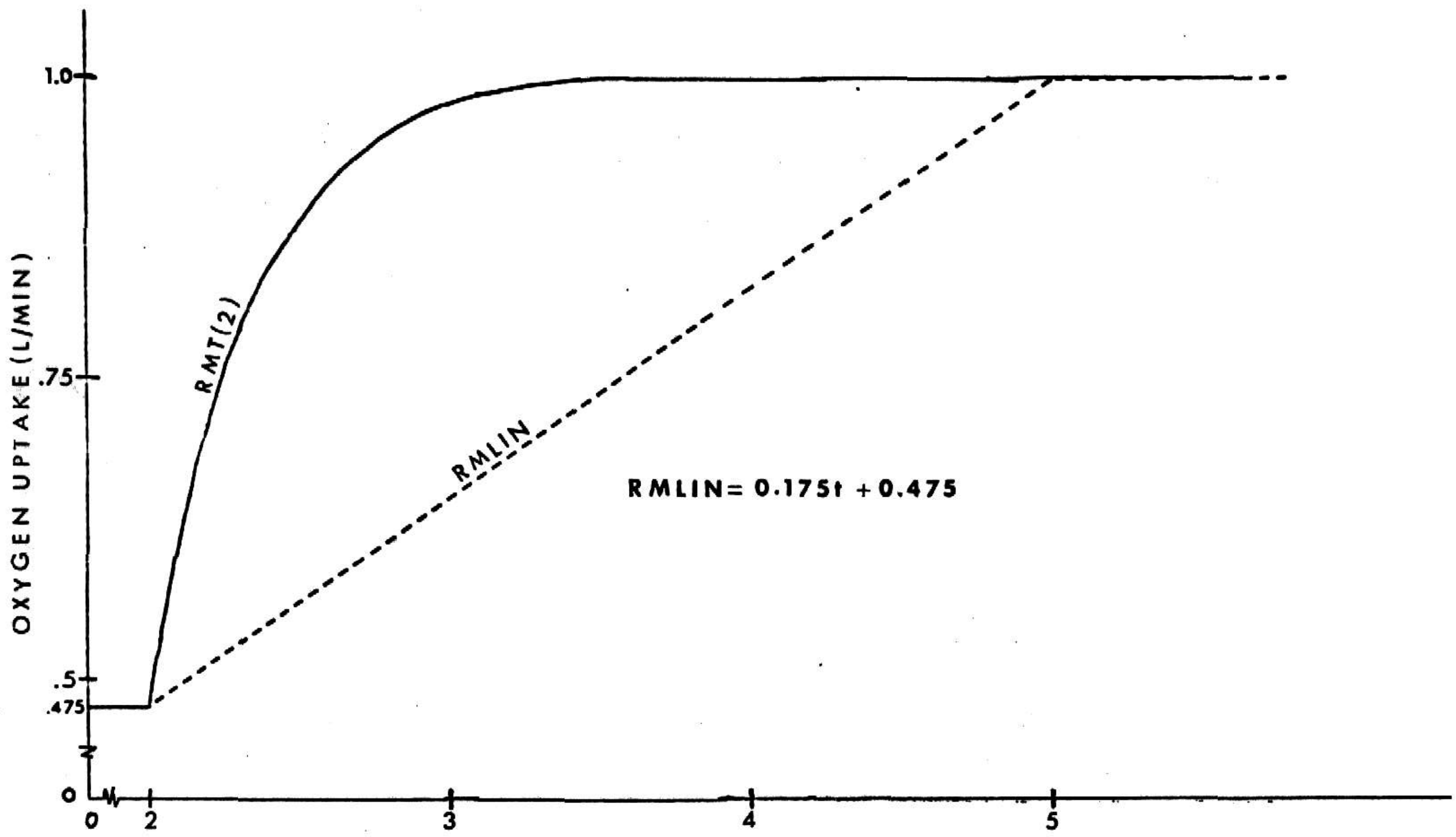


FIGURE 16. The relationship between oxygen uptake and RMLIN for 75 watts from 25 watts

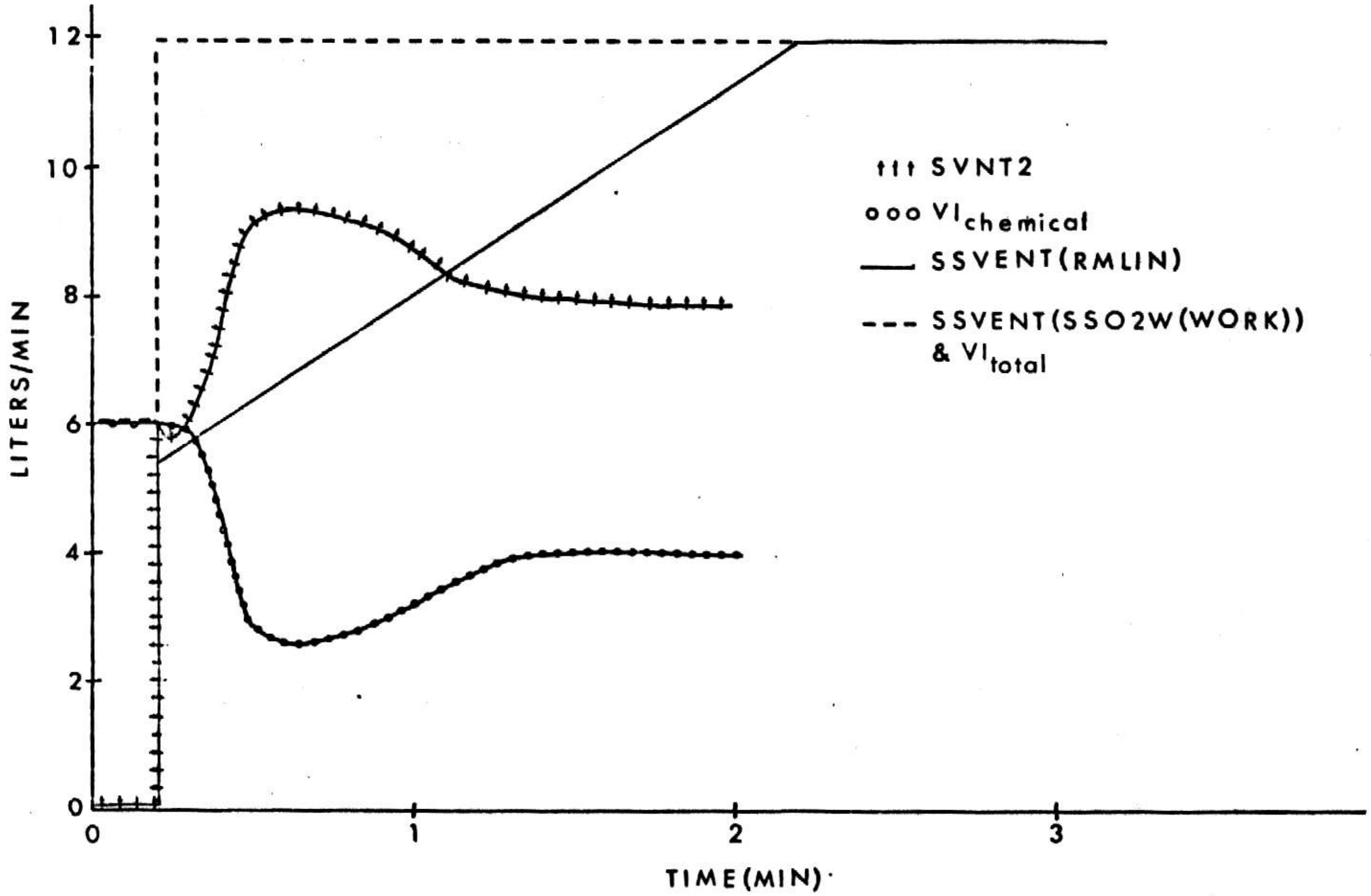


FIGURE 17. Relationship between important variables used in controller equation at 25 watts

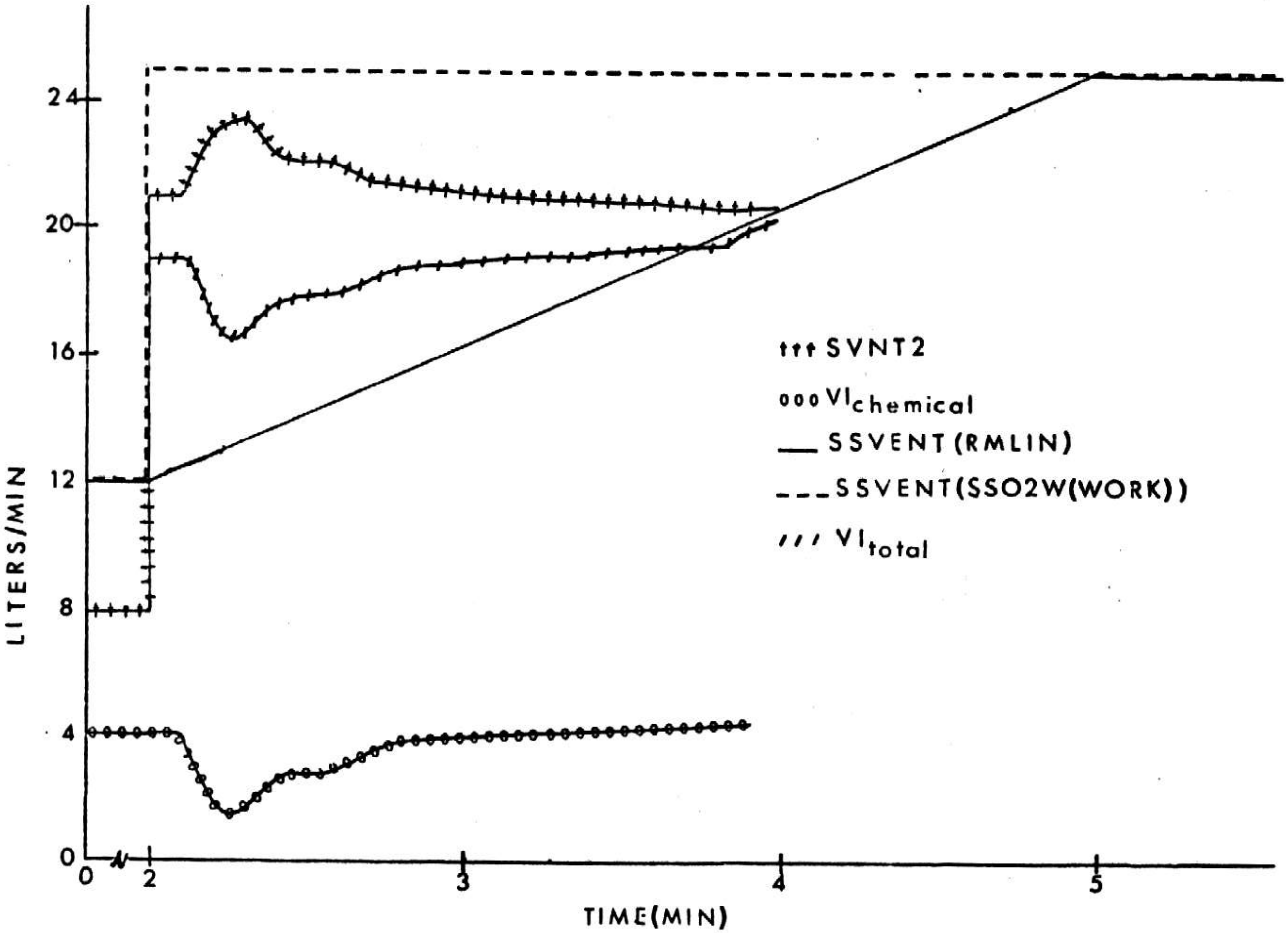


FIGURE 18. Relationship between important variables used in controller equation at 75 watts

+ VI. VI is equal to VO plus the neural component. As soon as SSVENT(RMLIN) becomes large enough (SSVENT(RMLIN) > 0.5 + VI) VI starts a linear increase to the steady state value using Equation 19.

The above controller modification does not have any physiological significance. It is only a routine that permits a reasonable reproduction of a limited set of experimental data (18). It can be said that the fast increase is the neural component. However, the device used to simulate this response is not part of a set of system equations that actually describe the system. Currently such a set of system equations is unknown.

IV. DISCUSSION

Five different simulation runs were made with varying exercise conditions and transitions in order to determine how the exercise portion of this respiratory control model operated. Using the program which appears in Appendix B the runs proved to be very expensive and time consuming when run on the IBM 360/50. This means that for all runs, it was financially prohibitive to let the work loads run until steady state was reached. Sometimes transition from one work load to the next occurred during the transient portion of the response for a given work load. Whether the responses obtained this way are valid or not is a question that cannot be answered at this time. This is due to the fact that nowhere in the literature is there any experimental data which can be quantitatively compared to these responses. Table 1 lists the values of the input data cards used in each simulation run made for this study.

Table 1. Input data card and work load values for each simulation run

Input Data Cards	Run #1	Run #2	Run #3	Run #4	Run #5
C(1)	0.1783		0.1674	0.1746	
C(2)	0.5336		0.5419	0.5231	
C(3)	0.2881		0.2907	0.3123	
C(4)	0.6413		0.6345	0.6359	
C(5)	0.0012		0.0011	0.0011	
C(6)	0.0011		0.0011	0.0011	
C(7)	0.6153	Same	0.6164	0.6390	Same
C(8)	0.0015	as	0.0011	0.0007	as
C(9)	0.0012	Run #1	0.0012	0.0011	Run #1
C(10)	0.0000		7.380	11.5717	
C(11)	0.7496		0.6839	0.7260	
C(12)	48.1202		47.9542	47.3567	
C(13)	36.6316		36.0486	35.3290	
C(14)	70.6804		68.5268	66.2437	
RMT(1)	0.1820		0.1820	1.1699	
RMT(2)	0.2150		0.2150	1.3294	
WORK2	0.0/0.2	0.0/0.2	25/0.2	100/2.5	0.0/0.2
WORK2	50/1.8	25/1.8	70/2.0	0.0/30	50/2.5
WORK2	100/2.0	75/2.0	100/2.0	----	0.0/2.0

Watts/Min

Another point made by these runs is that the neural component is sensitive to the increments taken in the work load. In simulation runs made by Gallagher (19) at work loads of 50 watts, 100 watts and 150 watts, it was seen that there was no neural component at the 100 watts and the 150 watts work loads when the transition was made during steady state. In simulation runs made during this study, the transition from 50 watts to 100 watts gave the same results, that is the absence of a fast change. The change in work load was made during the transient response for 50 watts. Figure 19 is a plot of VI for this run.

When a simulation run was made at work loads of 25 watts and 75 watts, two fast components were observed. One component occurred when the work load shifted from zero watts to 25 watts and one occurred when it shifted from 25 watts to 75 watts. Figure 20 is a plot of VI for this run. Also, from this response it is observed that at 25 watts the neural component accounts for the total ventilatory change allowing this system to reach steady state immediately. This is in agreement with experiments performed by D'Angelo et al. (20), where it was shown that the neural component accounts for approximately 100% of the total ventilatory change for low work loads.

Another run made with an initial work level of 25 watts and then increasing to 70 and 100 watts showed fast changes at both 70 and 100 watts as illustrated in Figure 21. It seems apparent that the increments in work load are critical to the response. Again there is no published data available to which these responses can be compared.

The next run, Run #4, was made to see what the response would be if 100 watts went to steady state and then a change was made to zero work load. The initial condition was taken as the condition existing at the

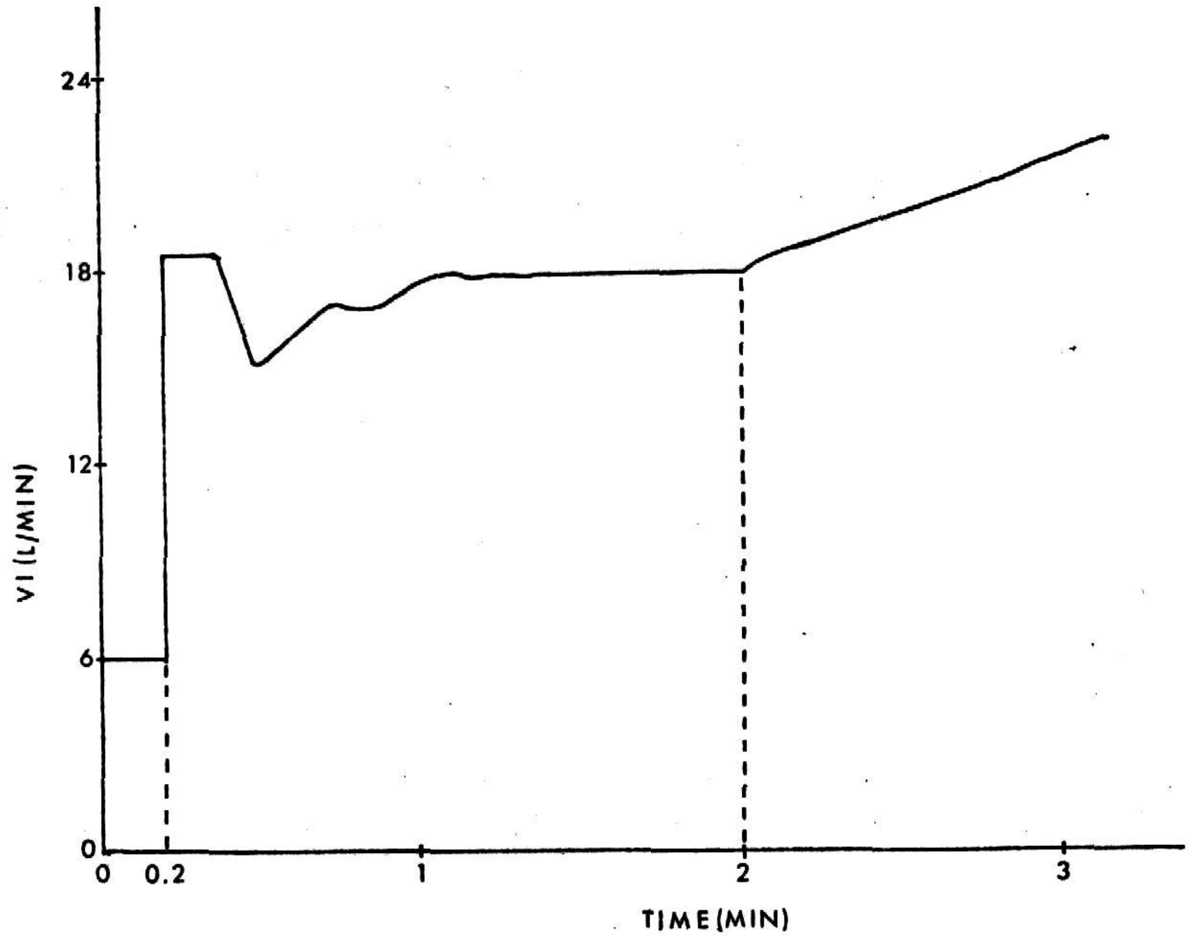


FIGURE 19. Simulation run number one for 0–50–100 watts

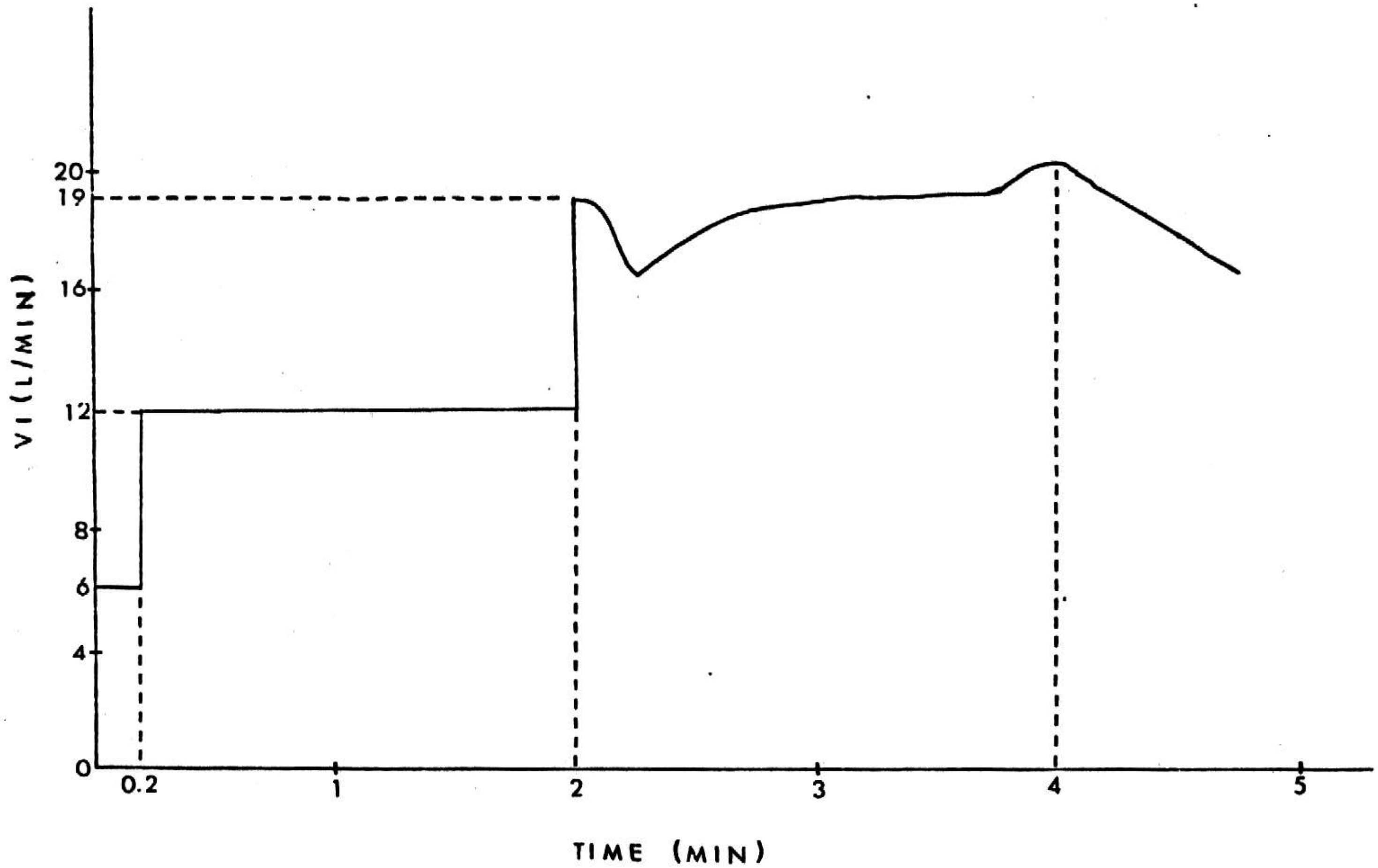


FIGURE 20. Simulation run for 0–25–75–0 watts

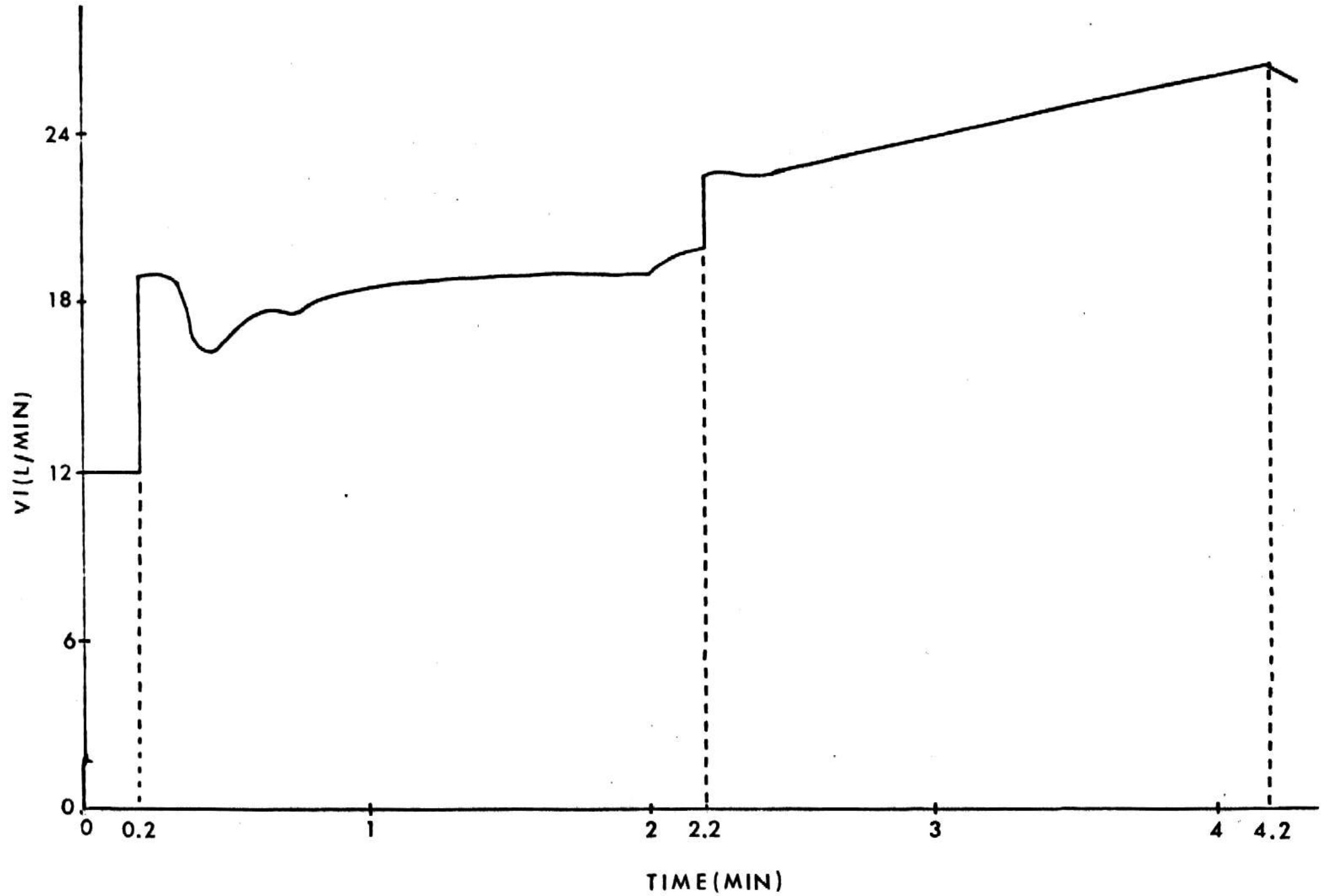


FIGURE 21. Simulation run number three for 25-70-100-0 watts

last printout of Run #3 for 100 watts. It was assumed that a continuation would be possible from this point. However, it was observed that there was an immediate unjustifiable increment in the VI response for the 100 watts exercise level. The response then proceeded to approach steady state. Careful investigation of the complete program showed that at the start of the first calculation of the controller equation, which occurs before RC12 is performed, the work level is considered to be at zero watts rather than at 100 watts. This, of course, makes the transient component of the responses invalid and questions the exactness of the steady state values. However, in order to analyze the simulation of the off-transient exercise responses, these steady state values were assumed adequate.

V. CONCLUSIONS AND RECOMMENDATIONS

This investigation has revealed the essence of Weissman's modification of Grodins' respiratory control model and the interrelationships of the parameters that comprise this modification. It was observed that the metabolic rate of oxygen consumption is the basis for this modification. From this parameter, the system equations are directly modified. The system controller equation is based on the neurohumoral theory which simulates a fast neural component and a slow linear component. The slow component is also related to oxygen consumption by making use of a slowed down linear version of RMT(2), RMLIN.

It is apparent from this study that certain changes must be made within the program. First, the expression for VTIME should be modified from:

$$VTIME = TCT(CXT - TIMEON)/9.2 \quad (20)$$

to

$$VTIME = TCT(CXT - TIMEON)/4.6 \quad (21)$$

so that the responses to exercise will be faster; therefore, representing experimental data more faithfully.

Second, the punched card output should be changed to include work load, time, metabolic rate of oxygen, RMT(2), and metabolic rate of carbon dioxide, RMT(1). Along with this change, the initialization of time and work load should be removed. This change would permit the responses corresponding to one work load to be used as the initial condition for a succeeding work load. This removal will require a renaming of some variables in the controller equation since WORK is used even when the simulation is for resting conditions.

Third a more extensive analysis of the off-transient portion of this program is needed. Figures 22 and 23 are plots of two runs made to analyze

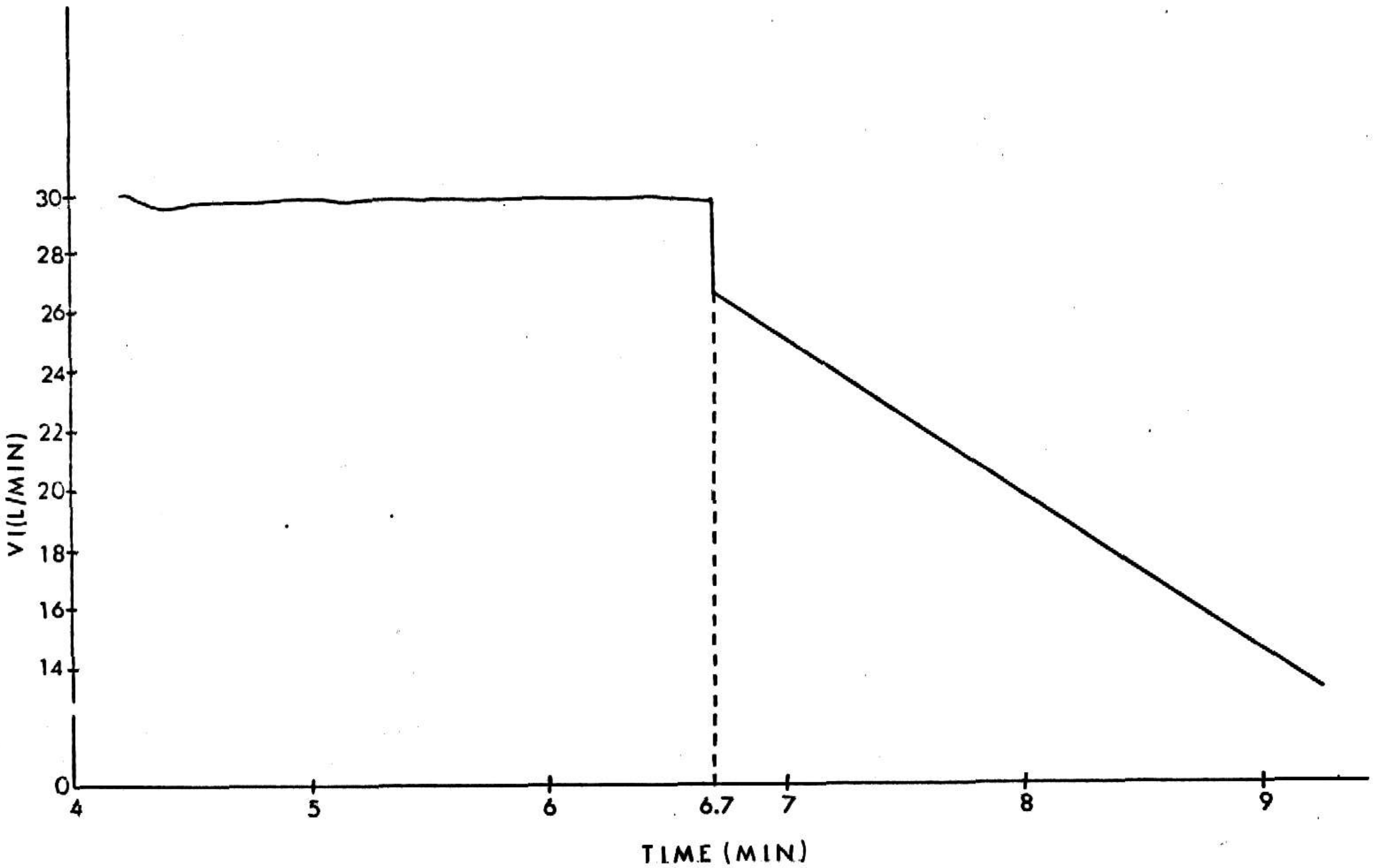


FIGURE 22. Simulation of off-transient from steady state at 100 watts

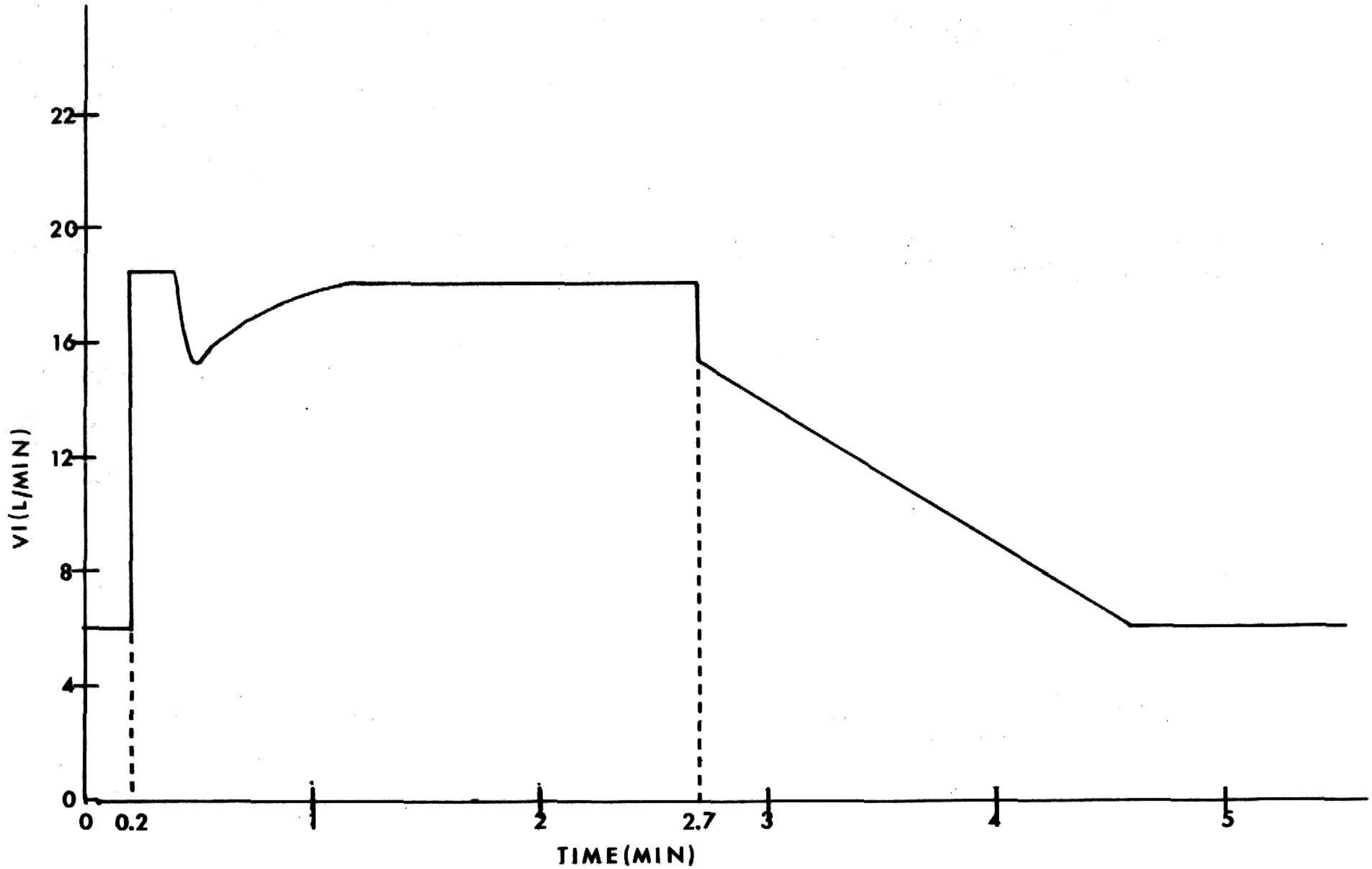


FIGURE 23. Simulation run number five for 0–50–0 watts

the off-transient in this study. Run #4 used the last output of Run #3 at 100 watts as the initial condition. After 2.5 minutes, it was assumed that steady state was reached for 100 watts and the work load shifted to zero watts. An instantaneous decrease in VI is seen and then a linear decrease to resting level. The instantaneous decrease is considerably less than the corresponding initial response seen at the start of exercise. This implies that there is still a neural component functioning after exercise has ceased. Whether this is physiologically the case is not certain.

Run #5 was made with 50 watts. After steady state was reached, the work load was again shifted to zero watts. Again an initial decrease, slightly smaller than in the previous case for 100 watts, is present followed by a linear decrease to steady state.

In runs made with steady state not being reached and an off-transient initiated, there was no initial decrease and, in some cases, there was an increase. This is a fallacy in the program caused by the fact that Grodins' controller equation had not reached a steady state value, and the routine for the off-transient is dependent upon the inspired ventilation reaching steady state. Therefore, there must be a program change that will eliminate the fallacy and give a better representation of the system at all instances of time.

Finally, the heart rate (HRATE) and respiration frequency (FREQ) expressions employed in the exercise subroutine need to be modified. As currently programmed, HRATE and FREQ follow the metabolic rate of oxygen consumption (RMT2); that is, RMT(2) is the forcing function. The expressions are given by:

$$HRATE = 43.8 * (RMT(2) + MRB(O_2)) + 54.5 \qquad (22)$$

and

$$FREQ = 8.1 + 7.815 * (RMT(2) + MRB(O_2)) \qquad (23)$$

where $MRB(O_2)$ is the metabolic uptake of oxygen by the brain, which remains relatively constant during exercise.

It has been shown that at the start of exercise, the heart rate increases instantaneously. This factor is not observed with the expression given above. Since RMT(2) does not change instantaneously, neither will HRATE. The immediate increase in heart rate is of a neurological origin. Another fact that the present expression does not illustrate is that the initial increase in heart rate usually overshoots the steady state value and then decreases to steady state (17).

There is a definite relationship between steady state heart rate and work load. This fact coupled with a neural component can be employed in a relationship that will better represent the actual time course of heart rate during exercise. Figure 24 was plotted from data obtained on a bicycle ergometer (21). It illustrates how steady state HRATE changes with work load. If another increase in work load were made, it would show a leveling off of heart rate at about 200 beats per minute which is the maximum for a normal individual. Data similar to this, in addition to some that can be related to the neural component, which would also be a function of work, would make the basis for a reasonable expression for HRATE.

The same argument would hold for respiration frequency, except that there is generally no overshoot of the steady state value by the immediate increase in ventilation.

Both expressions will have the form:

$$x(t) = f(y,z,t) \tag{24}$$

where

$x(t)$ = heart rate or respiratory frequency

y = steady state value due to exercise

z = neural component due to exercise

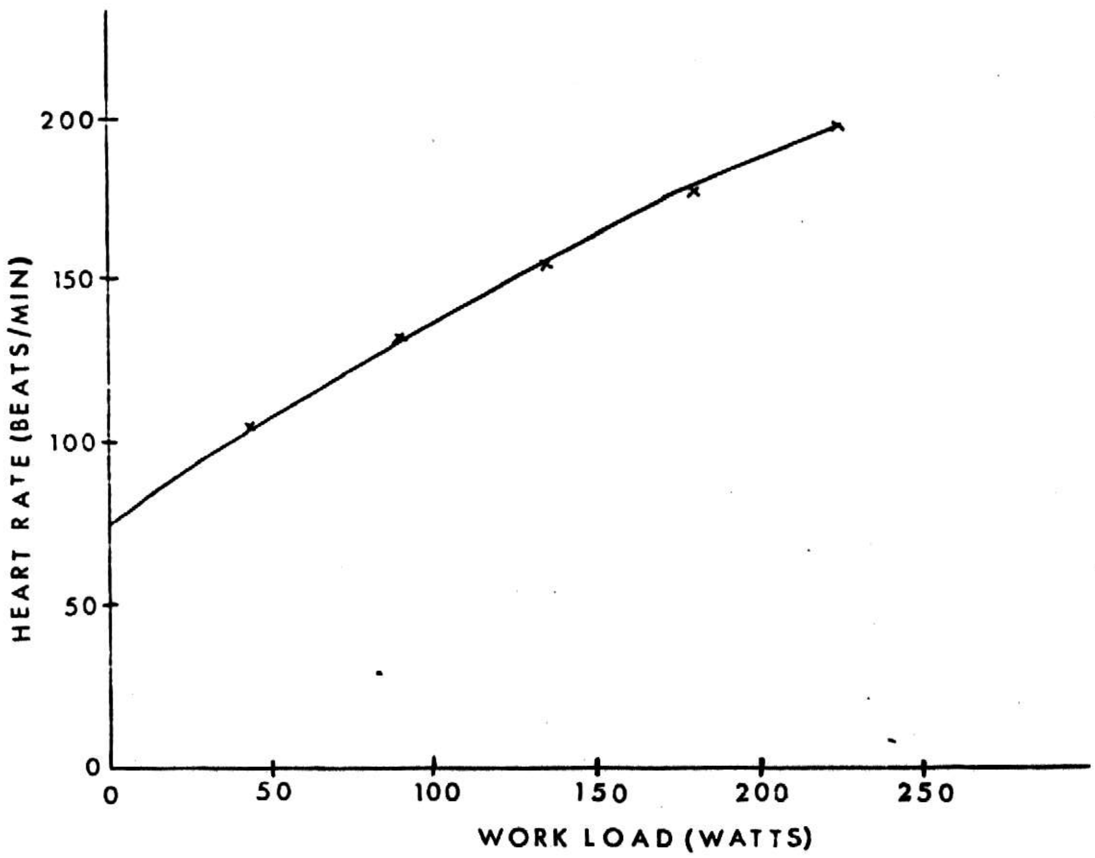


FIGURE 24. The relationship between heart rate and work load

It is felt that once these changes have been made, the respiratory control system will be better represented by this model. This will permit this model to be used with much more confidence.

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I would finally like to thank my wife Gail for her understanding and encouragement throughout my course of studies.

VIII. APPENDICES

A. NOVA 1200 Minicomputer Runs

This appendix contains the program listings for the programs run on the NOVA 1200 minicomputer along with the printouts for each run.

ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

Calculates oxygen uptake for increasing work loads for 5 minute durations starting from rest

```
10  LET W=50
20  LET T0= 0
21  LET T2=5
25  LET T= 0
27  LET R0=.215
30  IF W>=50 GOTO  60
40  LET T1=4.6
50  GOTO  70
60  LET T1=2.3/(2*W/200)
70  IF W>250 GOTO  130
80  IF W<75 GOTO  110
90  LET S2=W/75
100  GOTO  133
110  LET S2=W/75+.215*(75-W)/75
120  GOTO  133
130  LET S2=3.5
131  PRINT
132  PRINT
133  PRINT "TIME CONSTANT= ",T1,"WORK LOAD= ",W,"WATTS"
134  PRINT
135  PRINT
136  PRINT "TIME(MIN)                RMT(O2)"
140  LET R2=S2-(S2-R0)* EXP (-T1*(T-T0))
170  PRINT  TAB (5),T, TAB (10),R2
180  LET T=T+.5
190  IF T>T2 GOTO  210
200  GOTO  140
210  LET W=W+50
215  PRINT
216  PRINT
220  IF W<=250 GOTO  20
230  END
```

TIME CONSTANT= 4.6 WORK LOAD= 50 WATTS

TIME(MIN)	HMT(O2)
0	.215
.3	.685864
1	.733073
1.5	.737806
2	.73[illegible]28
2.5	.738328
3	.738333
3.5	.738333
4	.738333
4.5	.738333
5	.738333

TIME CONSTANT= 2.3 WORK LOAD= 100 WATTS

TIME(MIN)	RMT(O2)
0	.215
.5	.979228
1	1.22121
1.5	1.29783
2	1.32209
2.5	1.32977
3	1.33221
3.5	1.33298
4	1.33322
4.5	1.3333
5	1.33332

TIME CONSTANT= 1.53333 WORK LOAD= 150 WATTS

TIME(MIN)	RMT(O2)
0	.215
.5	1.17076
1	1.61477
1.5	1.82104
2	1.91686
2.5	1.96138
3	1.98206
3.5	1.99166
4	1.99613
4.5	1.9982
5	1.99916

TIME CONSTANT= 1.15 WORK LOAD= 200 WATTS

TIME(MIN)	RMT(O2)
0	.215001
.5	1.2871
1	1.89038
1.5	2.22985
2	2.42087
2.5	2.52835
3	2.58884
3.5	2.62287
4	2.64202
4.5	2.6528
5	2.65886

TIME CONSTANT= .92 WORK LOAD= 250 WATTS

TIME(MIN)	RMT(O2)
0	.215001
.5	1.[illegible]6478
1	2.00062
1.5	2.[illegible]
2	2.83[illegible]
2.5	3.0[illegible]
3	3.13[illegible]
3.5	3.[illegible]
4	3.[illegible]5468
4.5	3.[illegible]6368
5	3.30199

Calculates oxygen uptake for increasing work without returning to rest

```
10   LET W=50
20   LET TO= 0
21   LET T2=T+5
25   LET T= 0
27   LET RO=.215
30   IF W>=50 GOTO  60
40   LET T1=4.6
50   GOTO  70
60   LET T1=2.3/(2*W/200)
70   IF W>250 GOTO  130
80   IF W<75 GOTO  110
90   LET S2=W/75
100   GOTO  133
110   LET S2=W/75+.215*(75-W)/75
120   GOTO  133
130   LET S2=3.5
133   PRINT "TIME CONSTANT= ",T1,"WORK LOAD= ",W,"WATTS"
134   PRINT
135   PRINT
136   PRINT "TIME(MIN)              RMT(02)"
140   LET R2=S2-(S2-R0)* EXP (-T1*(T-TO))
170   PRINT  TAB (5),T, TAB (10),R2
180   LET T=T+.5
190   IF T>T2 GOTO  210
200   GOTO  140
210   LET W=W+50
212   LET T=T-.5
213   LET RO=R2
214   LET T2=T+5
215   LET TO=T
216   PRINT
217   PRINT
220   IF W<=250 GOTO  30
230   END
```

RUN

TIME CONSTANT= 4.6 WORK LOAD= 50 WATTS

TIME(MIN)	RMT(O2)
0	.215
.5	.685864
1	.733073
1.5	.737806
2	.73828
2.5	.738328
3	.738333
3.5	.738333
4	.738333
4.5	.738333
5	.738333

TIME CONSTANT= 2.3 WORK LOAD= 100 WATTS

TIME(MIN)	RMT(O2)
5	.738333
5.5	1.14493
6	1.27368
6.5	1.31444
7	1.32735
7.5	1.33144
8	1.33273
8.5	1.33314
9	1.33327
9.5	1.33331
10	1.33333

TIME CONSTANT= 1.53333 WORK LOAD= 150 WATTS

TIME(MIN)	RMT(O2)
10	1.33333
10.5	1.69029
11	1.85612
11.5	1.93316
12	1.96895
12.5	1.98557
13	1.9933
13.5	1.99689
14	1.99855
14.5	1.99933
15	1.99969

TIME CONSTANT= 1.15 WORK LOAD= 200 WATTS

TIME(MIN)	RMT(O2)
15	1.99969
15.5	2.29135
16	2.45548
16.5	2.54783
17	2.5998
17.5	2.62904
18	2.64549
18.5	2.65475
19	2.65996
19.5	2.66289
20	2.66454

TIME CONSTANT= .92 WORK LOAD= 250 WATTS

TIME(MIN)	RMT(O2)
20	2.66454
20.5	2.91114
21	3.06681
21.5	3.16508
22	3.22712
22.5	3.26628
23	3.291
23.5	3.30661
24	3.31646
24.5	3.32268
25	3.32661

Calculates oxygen uptake for decreasing work loads

```
10  LET W=250
20  LET T0= 0
21  LET T2=5
25  LET T= 0
30  IF W>=50 GOTO  60
40  LET T1=4.6
50  GOTO  70
60  LET T1=2.3/(2*W/200)
70  IF W>250 GOTO  130
80  IF W<75 GOTO  110
90  LET S2=W/75
100  GOTO  133
110  LET S2=W/75+.215*(75-W)/75
120  GOTO  133
130  LET S2=3.5
133  PRINT "TIME CONSTANT= ",T1,"WORK LOAD= ",W,"WATTS"
134  PRINT
135  PRINT
136  PRINT "TIME(MIN)              RMT(O2)"
137  LET R1=S2
140  LET R2=.215-(.215-R1)* EXP (-T1*(T-T0)/2)
170  PRINT  TAB (5),T, TAB (10),R2
180  LET T=T+.5
190  IF T>T2 GOTO  210
200  GOTO  140
210  LET W=W-50
211  PRINT
212  PRINT
220  IF W>=50 GOTO  20
230  END
```

TIME CONSTANT= .92 WORK LOAD= 250 WATTS

TIME(MIN)	RMT(O2)
0	3.33333
.5	2.69262
1	2.18355
1.5	1.77908
2	1.45772
2.5	1.20238
3	.999506
3.5	.838316
4	.710246
4.5	.60849
5	.527641

TIME CONSTANT= 1.15 WORK LOAD= 200 WATTS

TIME(MIN)	RMT(O2)
0	2.66667
.5	2.05408
1	1.59456
1.5	1.24986
2	.991288
2.5	.797322
3	.651821
3.5	.542675
4	.460801
4.5	.399385
5	.353314

TIME CONSTANT= 1.53333 WORK LOAD= 150 WATTS

TIME(MIN)	RMT(O2)
0	2
.5	1.43163
1	1.04424
1.5	.780197
2	.60023
2.5	.477567
3	.393962
3.5	.336978
4	.298138
4.5	.271666
5	.253623

TIME CONSTANT= 2.3 WORK LOAD= 100 WATTS

TIME(MIN)	RMT(O2)
0	1.33333
.5	.844291
1	.569105
1.5	.414257
2	.327123
2.5	.278092
3	.250502
3.5	.234977
4	.226241
4.5	.221326
5	.218559

TIME CONSTANT= 4.6 WORK LOAD= 50 WATTS

TIME(MIN)	RMT(O2)
0	.738333
.5	.380706
1	.267469
1.5	.231614
2	.22026
2.5	.216666
3	.215527
3.5	.215167
4	.215053
4.5	.215017
5	.215005

Calculates RMLIN for different work loads starting from rest

```
10  LET W=50
20  LET T0= 0
21  LET T2=5
25  LET T= 0
27  LET R0=.215
30  IF W>=50 GOTO  60
40  LET T1=4.6
50  GOTO  70
60  LET T1=2.3/(2*W/200)
70  IF W>250 GOTO  130
80  IF W<75 GOTO  110
90  LET S2=W/75
100  GOTO  133
110  LET S2=W/75+.215*(75-W)/75
120  GOTO  133
130  LET S2=3.5
133  PRINT "TIME CONSTANT= ",T1,"WORK LOAD= ",W,"WATTS"
134  PRINT
135  PRINT
136  PRINT "TIME(MIN)                    RMLIN              VTIME"
140  LET V4=T1*(T-T0)/9.2
145  IF V4>=1 GOTO  160
150  LET R6=S2-(S2-R0)*(1-V4)
155  GOTO  170
160  LET R6=S2
170  PRINT  TAB (5),T, TAB (13),R6, TAB (13),V4
180  LET T=T+.5
190  IF T>T2 GOTO  210
200  GOTO  140
210  LET W=W+50
211  PRINT
212  PRINT
220  IF W<=250 GOTO  20
230  END
```

TIME CONSTANT= 4.6 WORK LOAD= 50 WATTS

TIME(MIN)	RMLIN	VTIME
0	.215	0
.5	.345833	.25
1	.476667	.5
1.5	.6075	.75
2	.738333	1
2.5	.738333	1.25
3	.738333	1.5
3.5	.738333	1.75
4	.738333	2
4.5	.738333	2.25
5	.738333	2.5

TIME CONSTANT= 2.3 WORK LOAD= 100 WATTS

TIME(MIN)	RMLIN	VTIME
0	.215	0
.5	.354792	.125
1	.494583	.25
1.5	.634375	.375
2	.774167	.5
2.5	.913958	.625
3	1.05375	.75
3.5	1.19354	.875
4	1.33333	1
4.5	1.33333	1.125
5	1.33333	1.25

TIME CONSTANT= 1.53333 WORK LOAD= 150 WATTS

TIME(MIN)	RMLIN	VTIME
0	.215	0
.5	.36375	8.33333E-2
1	.5125	.166667
1.5	.66125	.25
2	.81	.333333
2.5	.95875	.416667
3	1.1075	.5
3.5	1.25625	.583333
4	1.405	.666667
4.5	1.55375	.75
5	1.7025	.833333

TIME CONSTANT= 1.15 WORK LOAD= 200 WATTS

TIME(MIN)	RMLIN	VTIME
0	.215	0
.5	.368229	.0625
1	.521459	.125
1.5	.674688	.1875
2	.827917	.25
2.5	.981146	.3125
3	1.13438	.375
3.5	1.2876	.4375
4	1.44083	.5
4.5	1.59406	.5625
5	1.74729	.625

TIME CONSTANT= .92 WORK LOAD= 250 WATTS

TIME(MIN)	RMLIN	VTIME
0	.215	0
.5	.370917	.05
1	.526834	.1
1.5	.68275	.15
2	.838667	.2
2.5	.994584	.25
3	1.1505	.3
3.5	1.30642	.35
4	1.46233	.4
4.5	1.61825	.45
5	1.77417	.5

Calculates RMLIN for different work loads without returning to rest

```
10  LET W=50
20  LET T0= 0
21  LET T2=T+5
25  LET T= 0
27  LET R0=.215
30  IF W>=50 GOTO  60
40  LET T1=4.6
50  GOTO  70
60  LET T1=2.3/(2*W/200)
70  IF W>250 GOTO  130
80  IF W<75 GOTO  110
90  LET S2=W/75
100  GOTO  133
110  LET S2=W/75+.215*(75-W)/75
120  GOTO  133
130  LET S2=3.5
133  PRINT "TIME CONSTANT= ",T1,"WORK LOAD= ",W,"WATTS"
134  PRINT
135  PRINT
136  PRINT "TIME(MIN)         RMLIN            VTIME                SSO2(WORK)"
140  LET R2=S2-(S2-R0)* EXP (-T1*(T-T0))
145  LET V4=T1*(T-T0)/9.2
146  IF V4>=1 GOTO  160
150  LET R6=S2-(S2-R0)*(1-V4)
155  GOTO  170
160  LET R6=S2
170  PRINT  TAB (5),T, TAB (13),R6, TAB (12),V4, TAB (12),S2
180  LET T=T+.5
190  IF T>T2 GOTO  210
200  GOTO  140
210  LET W=W+50
212  LET T=T-.5
213  LET R0=R2
214  LET T2=T+5
215  LET T0=T
216  PRINT
217  PRINT
220  IF W<=250 GOTO  30
230  END
```

TIME CONSTANT= 4.6 WORK LOAD= 50 WATTS

TIME(MIN)	RMLIN	VTIME	SSO2(WORK)
0	.215	0	.738333
.5	.345833	.25	.738333
1	.476667	.5	.738333
1.5	.6075	.75	.738333
2	.738333	1	.738333
2.5	.738333	1.25	.738333
3	.738333	1.5	.738333
3.5	.738333	1.75	.738333
4	.738333	2	.738333
4.5	.738333	2.25	.738333
5	.738333	2.5	.738333

TIME CONSTANT= 2.3 WORK LOAD= 100 WATTS

TIME(MIN)	RMLIN	VTIME	SSO2(WORK)
5	.738333	0	1.33333
5.5	.812708	.125	1.33333
6	.887083	.25	1.33333
6.5	.961458	.375	1.33333
7	1.03583	.5	1.33333
7.5	1.11021	.625	1.33333
8	1.18458	.75	1.33333
8.5	1.25896	.875	1.33333
9	1.33333	1	1.33333
9.5	1.33333	1.125	1.33333
10	1.33333	1.25	1.33333

TIME CONSTANT= 1.53333 WORK LOAD= 150 WATTS

TIME(MIN)	RMLIN	VTIME	SSO2(WORK)
10	1.33333	0	2
10.5	1.38888	8.33333E-2	2
11	1.44444	.166667	2
11.5	1.5	.25	2
12	1.55555	.333333	2
12.5	1.61111	.416667	2
13	1.66666	.5	2
13.5	1.72222	.583333	2
14	1.77778	.666667	2
14.5	1.83333	.75	2
15	1.88889	.833333	2

TIME CONSTANT= 1.15 WORK LOAD= 200 WATTS

TIME(MIN)	RMLIN	VTIME	SSO2(WORK)
15	1.99969	0	2.66667
15.5	2.04137	.0625	2.66667
16	2.08306	.125	2.66667
16.5	2.12475	.1875	2.66667
17	2.16643	.25	2.66667
17.5	2.20812	.3125	2.66667
18	2.2498	.375	2.66667
18.5	2.29149	.4375	2.66667
19	2.33318	.5	2.66667
19.5	2.37486	.5625	2.66667
20	2.41655	.625	2.66667

TIME CONSTANT= .92 WORK LOAD= 250 WATTS

TIME(MIN)	RMLIN	VTIME	SSO2(WORK)
20	2.66454	0	3.33333
20.5	2.69798	.05	3.33333
21	2.73142	.1	3.33333
21.5	2.76486	.15	3.33333
22	2.7983	.2	3.33333
22.5	2.83174	.25	3.33333
23	2.86518	.3	3.33333
23.5	2.89862	.35	3.33333
24	2.93206	.4	3.33333
24.5	2.9655	.45	3.33333
25	2.99894	.5	3.33333

B. Program Listing for Complete Respiratory Control Model

This appendix contains the program listing of the complete Respiratory Control Model. RC12 is the exercise subroutine, with RC11, RC13, RC17 and the other subroutines in the exercise loop. RC13 and RC17 have been modified for this study. The modifications made are indicated in the right margins of these two subroutines. The addition to RC13 is to prevent the program from getting into a loop that was found to occur with certain conditions present. The addition to RC17 is an additional print routine mentioned in the text.

PROGRAM DESCRIPTION

A. IDENTIFICATION

Program Name - RCHEM (Respiratory Control System)

Programmer's Name - V. J. Marks, GE-AGS, Houston

Date of Issue - 9/22/72

B. GENERAL DESCRIPTION

The purpose of this model is to illustrate the transient and steady-state responses of the respiratory control system, for variations in volumetric fractions of inspired gases and special system parameters. Although the program contains a change-in-work load version, the immediate emphasis is on the resting subject.

The program is based on Grodin's respiratory control model and can be envisioned as a feedback control system comprised of a "plant" (the controlled system) and the regulating component (controlling system). The controlled system is partitioned into 3 compartments corresponding to lungs, brain, and tissue with a fluid interconnecting path representing the blood.

C. USAGE AND RESTRICTIONS

Machine and compiler required - UNIVAC 1108, FORTRAN V
Also available on Sigma 3
See TIR 741-MED-3009

Peripheral equipment required - Card Reader, Card Punch, Printer, One Tape Drive.

Approximate amount of memory required - 8,500

D. PARTICULAR DESCRIPTION

See TIR (TBD)

E. DESCRIPTION OF INPUT

1. Machine Control and Program Cards -(Beginning in Column 1)

```
@N MSG              File REQ    Tape 1    FH132   0   FSTRN 0
@ PLT
@L FPR
@ ASG A A07172      Program Tape
@ TCP
@ XQT CUR           Puts program in computer
```

```
  IN A
  REL A
  TØC                      Table of Contents (lists Subroutines)
@E HDG
  (Source deck - See Appendix A for listing and example)

@N XQT RCHEM
  (Data Cards)
@ EØF
```

2. Data Cards (column number, format symbol)

first 48 data cards:

1-5			Blank
6-20	F15.0	INPUT VALUE	(see list below for initial values)
21-25			Blank
26-37	2A6	SYMBOL NAME	(listed below)

Card No.	Symbol Col. 26-37)	Normal Initial Value (Col. 6-20)	Description
1 2 3	FA(CO2) FA(O2) FA(N2)	.0527 .1514 .7959	Alveolar gas fractions (dry), volumetric fraction of gas, dimensionless
4 5 6	CB(CO2) CB(O2) CB(N2)	.6397 .0011 .0097	Concentration of gas in brain, liters (STPD)/liter brain.
7 8 9	CT(CO2) CT(O2) CT(N2)	.6132 .0014 .0097	Concentration of gas in tissue compartment. Liters (STPD)/liter tissue
10 11	Q QB	6.0000 .7370	Cardiac output blood flow, liters/min Cerebral blood flow, liters/min.
12 13 14	PCSF(CO2) PCSF(O2) PCSF(N2)	47.8[illegible] 36.0047 567.4731	Partial pressure of gas in cerebrospinal fluid compartment, mmHg.
15	TMAX	30.0000	Length of computer run, min.
16	CENT SENS PT	0.0000	Central Sensitivity Partition. Weighting of the H+ concentration in CSF with that of venous blood in the brain. With C(16)=0, zero weight is given to venous blood at level of the brain and a weight of one is given to H^+ conc. in CSF.

Card No.	Symbol	Normal Initial Value	Description
17	HB	.2000	Blood oxygen capacity, liters (STPD)/liter blood
18	R1	.1000	Time constants for cardiac output response (R1) and cerebral blood
19	R2	.1000	flow response (R2) for changes in blood chemical composition.
20	CNT SENS COF	1.1380	Controller sensitivity weightlings,
21	CRTD BDY SCF		i.e.,

$$V_I = (\text{Cent. Sens. Coef.})*(\text{Cent. Sens. Part.} * C_A(H^+)(t-\tau_{aB}))$$

$$+ (1.0 - \text{Cent. Sens. Part.}) * CH(4)$$

$$+ C_A(H^+)(t-\tau_{ao}) + TERM - C(37)$$

where

τ_{ao} = Blood transport delay from lung to carotid body,

τ_{aB} = Blood transport delay from lung to brain

V_I defined in C(37), and

TERM = function of $F_{A(02)}$.

Card No.	Symbol	Normal Initial Value	Description
22	KL	3.0000	Volumes of lung (alveoli), brain, and
23	KB	1.0000	tissue compartments, liters.
24	KT	39.0000	
25	MRB (C02)	.0500	Metabolic rates by brain, liters
26	MRB (02)	.0500	(STPD)/min.
27	D (C02)	81.9900	Diffusion coefficient for gas across
28	D (02)	4.3610	"blood-brain", liters $(10)^{-7}$ (STPD)/
29	D (N2)	2.5240	min per mmHg.
30	B	760.0000	Barometric pressure, mmHg.
31	FI (C02)	.1000	Volumetric fraction of gas (dry inspired),
32	FI (02)	.1100	dimensionless
33	FI (N2)	.7900	
34	KCSF	.1000	Volume of cerebrospinal fluid, liters
35	T	.0000	Initial time.
36	H	.0078125	Size of computer time step, min.

Card No.	Symbol	Normal Initial Value	Description
37	VI(N)	87.5500	Constant that is involved in the controller equation (See C(21)). Determines the normal level of Alveolar ventilation so that $P_{A(CO2)} \approx 40.0$ at rest, breathing air at sea level. When the controller sensitivity weightings are changed VI(N) should be altered accordingly.
38	VI (SS)	5.3900	Value used for normal resting alveolar ventilation. This is not used in the program if VI (N) is known.
39	PRINT AL TIM	0.50000	Output printed in these time increments. However, there is an over-riding statement that permits no increments greater than 0.5 min.
40	UNKNOWN	0.0000	Importance related to C (39), but doesn't seem to be of any real significance.
41	BHCO3 Blood	.5470	Standard bicarbonate content, liters CO_2 (STPD)/liter X, 37°C where
42	BHCO3 Brain	.5850	
43	BHCO3 Tissue	.5850	
44	BHCO3 CSF	.5850	
			X = Blood, brain, tissue, CSF.
45	RMT(CO2)	.1820	Metabolic rates by tissue, liters (STPD)/min.
46	RMT(O2)	.2150	
47	DJ1	.0000	Used in performing Dejours experiment (Not utilized in present runs). Brief description of Dejours work relating O_2 and CO_2 threshold effects is given in Grodins' paper.
48	DJ2	.0000	

49th Card:

1-6	F6.2	WORK2	(work load)
7-9			Blank
10-15	F6.2	DURAT*	(run time for work load)

*if DURAT is less than TMAX (card 15) another work load card is read when print time exceeds DURAT.

3. TAPES AND FORMATS - Standard 1108 program PCF tape

F. DESCRIPTION OF OUTPUT

1. PRINTER OUTPUT - (See Appendix A for Sample)

TIME (minutes)

ALVEOLAR, ARTERIAL, BRAIN, TISSUE, V BRAIN, and V TISSUE volumetric fractions of CO_2, O_2, and N_2.

ALVEOLAR, ARTERIAL, BRAIN, TISSUE, CSF, V BRAIN, and V TISSUE partial pressures of CO_2, O_2, and N_2. (mm Hg)

ALVEOLAR, BRAIN, TISSUE, and CSF derivatives of the partial pressures of CO_2, O_2, and N_2. (mm Hg)

ARTERIAL, BRAIN, TISSUE, CSF, V BRAIN, and V TISSUE hydrogen ion(H^+) concentrations (nanomoles) and pH.

ARTERIAL, V BRAIN, AND V TISSUE concentration of HbO_2 (oxyhemoglobin), (liters O_2-STPD)

ALVEOLAR RQ

RQ DIFF

TRANSPORT TIMES: (Minutes)

AB = Lung to brain

VB = Brain to lung

VT = Tissue to lung

AT = Lung to tissue

AC = Lung to carotid body

VI = Inspired ventilation (liters/min)

VE = Expired ventilation (liters/min)

Q = Cardiac output (liters/min)

FB = Brain blood flow (liters/min)

DERIVATIVES of Q and FB

RESP FREQ (breaths/min)

MINUTE VOLUME (liters/min)

DEAD SPACE VENTILATION (liters/min)

HEART RATE (beats/min)

2. PUNCHED CARDS - 15 cards used to restart a new case, punched upon normal termination of run.

G. INTERNAL CHECKS AND EXITS

Check DURAT against TMAX to determine if more data cards are read.

When DURAT exceeds TMAX normal termination occurs.

H. INDEPENDENT SUBROUTINES

See Appendix A for listing of all subroutines required.

I. SYSTEM SUBROUTINES

No special system subroutines required.

J. COMPLETION OR FINAL CHECKOUT DATE

11/10/72

SOURCE DECK LISTING

AND

SAMPLE CASE

```
@ XQT CUR                                                       22 JUN 72        15: 2: 2
   1.  IN A                                                                      15: 2: 3

    END OF FILE -- UNIT A
   2.  REL A                                                                     15: 2: 6
   3.  TOC                                                                       15: 2: 6
```

ELEMENT TABLE

RCHEM		SYMBOLIC	24 JAN 72	16:17:05	0	01436670	14	263
RCHEM	CODE	RELOCATABLE	24 JAN 72	16:17:05	1	01446032	40	1
					0	01446112	14	56
RC3		SYMBOLIC	24 JAN 72	16:17:06	0	01447532	14	21
RC3	CODE	RELOCATABLE	24 JAN 72	16:17:06	1	01450200	24	1
					0	01450230	14	5
RC4		SYMBOLIC	24 JAN 72	16:17:07	0	01450336	14	20
RC4	CODE	RELOCATABLE	24 JAN 72	16:17:07	1	01450766	24	1
					0	01451016	14	8
RC5		SYMBOLIC	24 JAN 72	16:17:08	0	01451176	14	20
RC5	CODE	RELOCATABLE	24 JAN 72	16:17:08	1	01451626	24	1
					0	01451656	14	8
RC6		SYMBOLIC	24 JAN 72	16:17:09	0	01452036	14	16
RC6	CODE	RELOCATABLE	24 JAN 72	16:17:09	1	01452376	24	1
					0	01452426	14	3
RC7		SYMBOLIC	24 JAN 72	16:17:11	0	01452500	14	26
RC7	CODE	RELOCATABLE	24 JAN 72	16:17:11	1	01453254	24	1
					0	01453304	14	7
RC8		SYMBOLIC	24 JAN 72	16:17:12	0	01453446	14	65
RC8	CODE	RELOCATABLE	24 JAN 72	16:17:12	1	01455264	24	1
					0	01455314	14	25
RC9		SYMBOLIC	24 JAN 72	16:17:14	0	01456052	14	46
RC9	CODE	RELOCATABLE	24 JAN 72	16:17:14	1	01457256	24	1
					0	01457306	14	16
RC10		SYMBOLIC	24 JAN 72	16:17:15	0	01457646	14	42
RC10	CODE	RELOCATABLE	24 JAN 72	16:17:15	1	01460762	24	1
					0	01461012	14	14
RC11		SYMBOLIC	24 JAN 72	16:17:17	0	01461316	14	37
RC11	CODE	RELOCATABLE	24 JAN 72	16:17:17	1	01462324	24	1
					0	01462354	14	18
RC12		SYMBOLIC	24 JAN 72	16:17:19	0	01462750	14	120
RC12	CODE	RELOCATABLE	24 JAN 72	16:17:19	1	01464170	36	1
					0	01466234	14	71
RC13		SYMBOLIC	24 JAN 72	16:17:21	0	01470176	14	63
RC13	CODE	RELOCATABLE	24 JAN 72	16:17:21	1	01471760	24	1
					0	01472010	14	27
RC14		SYMBOLIC	24 JAN 72	16:17:22	0	01472602	14	25
RC14	CODE	RELOCATABLE	24 JAN 72	16:17:22	1	01473340	36	1
					0	01473404	14	9
RC15		SYMBOLIC	24 JAN 72	16:17:24	0	01473602	14	19
RC15	CODE	RELOCATABLE	24 JAN 72	16:17:24	1	01474214	24	1
					0	01474244	14	6
RC16		SYMBOLIC	24 JAN 72	16:17:25	0	01474370	14	32
RC16	CODE	RELOCATABLE	24 JAN 72	16:17:25	1	01475270	24	1
					0	01475320	14	7
RC17		SYMBOLIC	24 JAN 72	16:17:26	0	01475462	14	36
RC17	CODE	RELOCATABLE	24 JAN 72	16:17:26	1	01476452	36	1
					0	01476516	14	28
RC19		SYMBOLIC	24 JAN 72	16:17:27	0	01477326	14	20
RC19	CODE	RELOCATABLE	24 JAN 72	16:17:27	1	01477756	24	1
					0	01500006	14	10
RC20		SYMBOLIC	24 JAN 72	16:17:29	0	01500222	14	23
RC20	CODE	RELOCATABLE	24 JAN 72	16:17:29	1	01500724	24	1

					0	01500754	14	7
RC21		SYMBOLIC	24 JAN 72	16:17:30	0	01501116	14	19
RC21	CODE	RELOCATABLE	24 JAN 72	16:17:30	1	01501530	24	1
					0	01501560	14	9
RC22		SYMBOLIC	24 JAN 72	16:17:31	0	01501756	14	20
RC22	CODE	RELOCATABLE	24 JAN 72	16:17:31	1	01502406	24	1
					0	01502436	14	5
RC23		SYMBOLIC	24 JAN 72	16:17:32	0	01502544	14	27
RC23	CODE	RELOCATABLE	24 JAN 72	16:17:32	1	01503336	24	1
					0	01503366	14	7
RCF1		SYMBOLIC	24 JAN 72	16:17:33	0	01503530	14	12
RCF1	CODE	RELOCATABLE	24 JAN 72	16:17:33	1	01504000	24	1
					0	01504030	14	3
RCF2		SYMBOLIC	24 JAN 72	16:17:34	0	01504102	14	12
RCF2	CODE	RELOCATABLE	24 JAN 72	16:17:34	1	01504352	24	1
					0	01504402	14	3
RCF3		SYMBOLIC	24 JAN 72	16:17:35	0	01504454	14	12
RCF3	CODE	RELOCATABLE	24 JAN 72	16:17:35	1	01504724	24	1
					0	01504754	14	3
SS02W		SYMBOLIC	24 JAN 72	16:17:36	0	01505026	14	10
SS02W	CODE	RELOCATABLE	24 JAN 72	16:17:36	1	01505242	24	1
					0	01505272	14	6
SSVENT		SYMBOLIC	24 JAN 72	16:17:38	0	01505416	14	6
SSVENT	CODE	RELOCATABLE	24 JAN 72	16:17:38	1	01505542	24	1
					0	01505572	14	6

ENTRY POINT TABLE

RCF1	(RCF1/CODE)	1	000015	RCF2	(RCF2/CODE)	1	000017	RCF3	(RCF3/CODE)	1	000022
RC10	(RC10/CODE)	1	000127	RC11	(RC11/CODE)	1	000225	RC12	(RC12/CODE)	1	001011
RC13	(RC13/CODE)	1	000322	RC14	(RC14/CODE)	1	000077	RC15	(RC15/CODE)	1	000042
RC16	(RC16/CODE)	1	000062	RC17	(RC17/CODE)	1	000171	RC14	(RC14/CODE)	1	000045
RC20	(RC20/CODE)	1	000051	RC21	(RC21/CODE)	1	000040	RC22	(RC22/CODE)	1	000031
RC23	(RC23/CODE)	1	000062	RC3	(RC3/CODE)	1	000040	RC4	(RC4/CODE)	1	000055
RC5	(RC5/CODE)	1	000044	RC6	(RC6/CODE)	1	000022	RC7	(RC7/CODE)	1	000044
RC8	(RC8/CODE)	1	000325	RC9	(RC9/CODE)	1	000166	SS02W	(SS02W/CODE)	1	000045
SSVENT	(SSVENT/CODE)	1	000053								

BLOCK TABLE EMPTY

COBOL LIBRARY TABLE EMPTY

PROCEDURE NAME TABLE EMPTY

END CUR LCC 1102-0034 L4

4E HDG RESP CASE NO. 1

```
                         RESP CASE NO. 1                                        DATE  220672  PAGE     9
@ FOR,* RCHEM,RCHEM                                                                    22 JUN 72                15: 2: 6
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:07

  MAIN PROGRAM

  STORAGE USED: CODE(1) 000736; DATA(0) 000126; BLANK COMMON(2) 000000

   COMMON BLOCKS:

   0003   Z       002376
   0004   R       000014

  EXTERNAL REFERENCES (BLOCK, NAME)

   0005   RC22
   0006   RC3
   0007   RC4
   0010   RC5
   0011   RC21
   0012   RC19
   0013   RC20
   0014   RC7
   0015   RC8
   0016   RC9
   0017   RC10
   0020   RC11
   0021   RC12
   0022   RC15
   0023   RC16
   0024   RC13
   0025   RC23
   0026   RC14
   0027   NPRT$
   0030   NIO2$
   0031   NRDU$
   0032   NIO1$
   0033   NRDC$
   0034   NEXP6$
   0035   NWDC$
   0036   NWDU$
   0037   NSTOP$

  STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

   0001     000010 112G      0001     000020 117G      0001     000032 127G      0001     000052 136G      0001     000063 144G
   0001     000075 154G      0001     000115 163G      0001     000173 170G      0000     000046 190F      0000     000051 192F
   0000     000054 194F      0001     000140 201G      0001     000241 201L      0001     000311 207L      0001     000160 210G
   0001     000166 215G      0001     000203 226G      0001     000442 240L      0001     000701 250L      0001     000305 270G
   0001     000090 309L      0001     000712 301L      0001     000407 331G      0001     000675 423G      0001     000704 430G
   0001     000713 416G      0001     000531 5GL       0001     000535 6GL       0001     000417 80L       0000     000031 90F
   0000     000047 97F       0003 R 002272 A         0003 R 002317 BC        0003 R 000000 C         0003 R 002363 CADR
   0003 R 002336 CC        0000 R 000014 CDJ       0003 R 002344 CM        0003 R 002341 CMB       0003 R 002361 CPB
   0003 R 002350 CPM       0003 R 002362 CPT       0000 R 000030 CTERM     0004 R 000002 CXT       0003 R 002240 D
   0003     002214 DC        0000 R 000010 DJ        0003     002353 DD        0003     002365 DT        0004 R 000004 DUM1
   0004 R 000005 DUM2      0004 R 000006 DUM3      0003 R 002257 F         0003 I 002372 I         0000 I 000072 IDJ
```

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                        RESP CASE NO. 1                                      DATE  220672  PAGE     6
  0003   002371 INDEX   0000 I 000024 IP40   0003 I 002366 IRK    0003   002370 ITERX   0003 I 002373 J
  0003   002367 LOC     0003 I 002374 M      0000 I 005025 MMM    0003 I 002375 N       0003 R 002323 OF
  0003   002016 RK      0004   000013 RMLIN  0003 R 002315 RMT    0004 R 000010 RMTB    0004 R 000011 RMTB2
  0003   002106 SC      0000 R 000026 SK     0003   000170 SV     0003   002331 TAU     0004 R 000012 TIMECF
  0000 R 000027 UU      0003   002357 VE     0003 R 002360 VI     0003 R 002303 VOL     0003 R 001774 VTRAN
  0004 R 000003 WORK    0004 R 000007 WORK2  0003   002364 X      0004 R 000030 XOS     0004 R 000001 XMN
  0003 R 000050 IN      0000 R 000000 INS

00101            DIMENSION C(40), IN(40,2), SV(18,50), VTRAN(10), RK(14,4),
00101           1          SC(14,5), GC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00101           2          BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00101           3          DD(4)
00101       C    C(40)
00101       C     1   FA(CO2)
00101       C     2   FA( O2)
00101       C     3   FA(N2)
00101       C     4   CB(CO2)
00101       C     5   CB(O2)
00101       C     6   CB(N2)
00101       C     7   CT(CO2)
00101       C     8   CT(O2)
00101       C     9   CT(N2)
00101       C    10   Q
00101       C    11   QB
00101       C    12   PCSF(CO2)
00101       C    13   PCSF(O2)
00101       C    14   PCSF(N2)
00101       C    15   TMAX
00101       C    16   CENTRAL SENSITIVITY PARTITION
00101       C    17   (HB)
00101       C    18   R1
00101       C    19   R2
00101       C    20   CENTRAL SENSITIVITY COEFFICIENT
00101       C    21   CAROTID BODY SENSITIVITY COEFFICIENT
00101       C    22   KL
00101       C    23   KB
00101       C    24   KT
00101       C    25   MRB(CO2)
00101       C    26   MRB(O2)
00101       C    27   DCO2
00101       C    28   DO2
00101       C    29   DN2
00101       C    30   B
00101       C    31   FI(CO2)
00101       C    32   FI(O2)
00101       C    33   FI(N2)
00101       C    34   KCSF
00101       C    35   T
00101       C    36   H
00101       C    37   VI(H)
00101       C    38   VI(SS)
00101       C    39   PRINT-ALL TIME
00101       C    SV(18,50)
00101       C     1   CA(CO2)
00101       C     2   CA(O2)
```

```
                  RESP CASE NO. 1                                   DATE  220672  PAGE    7
00101    C     3   CA(N2)
00101    C     4   CVB(CO2)
00101    C     5   CVB(O2)
00101    C     6   CVB(N2)
00101    C     7   CVT(CO2)
00101    C     8   CVT(O2)
00101    C     9   CVT(N2)
00101    C    10   Q
00101    C    11   QB
00101    C    12   QT
00101    C    13   CA(H+)
00101    C    14   PA(O2)
00101    C    15   --
00101    C    16   CVB(CO2) + CVB(O2) + CVB(N2)
00101    C    17   CVT(CO2) + CVT(O2) + CVT(N2)
00101    C    18   T
00101    C   VTRAN(18)
00101    C     1   CAB(CO2) = CA(CO2)(T - TAB)
00101    C     2   CAB(O2) = CA(O2)(T - TAB)
00101    C     3   CAB(N2) = CA(N2)(T - TAB)
00101    C     4   CVB(CO2)(T - TVB)
00101    C     5   CVB(O2)(T - TVB)
00101    C     6   CVB(N2)(T - TVB)
00101    C     7   CVT(CO2)(T - TVT)
00101    C     8   CVT(O2)(T - TVT)
00101    C     9   CVT(N2)(T - TVT)
00101    C    10   CAT(CO2) = CA(CO2)(T - TAT)
00101    C    11   CAT(O2) = CA(O2)(T - TAT)
00101    C    12   CAT(N2) = CA(N2)(T - TAT)
00101    C    13   CAD(H+) = CA(H+)(T - TAD)
00101    C    14   PAD(O2) = PA(O2)(T - TAD)
00101    C    15   CAB(H+) = CA(H+)(T - TAB)
00101    C    16   (CVB(CO2) + CVB(O2) + CVB(N2))(T - TVB)
00101    C    17   (CVT(CO2) + CVT(O2) + CVT(N2))(T - TVT)
00101    C   D(15)
00101    C     1   B - 47
00101    C     2   K ACO2
00101    C     3   K AO2
00101    C     4   K AN2
00101    C     5   K AN2 (B - 47)
00101    C     6   K AO2 (B - 47)
00101    C     7   K AN2 (B - 47)
00101    C     8   0.16 + 2.3(HB)
00101    C     9   863/(B - 47)
00101    C    10   0.62
00101    C    11   K ACSF(CO2)
00101    C    12   K ACSF(O2)
00101    C    13   K ACSF(N2)
00101    C    14   2*H
00101    C    15   1.44*H
00101    C   F(20)
00101    C     1   PA(O2)
00101    C     2   K ACO2 PA(CO2)
00101    C     3   PB(O2)
00101    C     4   K ACO2 PB(CO2)
00101    C     5   PT(O2)
00101    C     6   K ACO2 PT(CO2)
00101    C     7   PA(CO2)
```

```
00101   C        8   PA(O2)
00101   C        4   CA(O2)
00101   C       10   CA(N2)
00101   C       11   CA(CO2) + CA(O2) + CA(N2)
00101   C       12   CVB(O2)
00101   C       13   CVT(O2)
00101   C       14   DCO2 (PB(CO2) - PCSF(CO2))
00101   C       15   DO2 (PB(O2) - PCSF(O2))
00101   C       16   DN2 (PB(N2) - PCSF(N2))
00101   C       17   PB(O2)
00101   C       18   PB(N2)
00103           DIMENSION XNB(4,2), DJ(4), CDJ(6), IDJ(2)
00104           COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, OF,
00104          1       TAU, CC, CMB, CM, CPM, DD, VE, VI, CPB, CPT, CADK, X, DT,
00104          2       IRK, LCC, ITERX, INDEX, I, J, M, N
00105           COMMON/R/ XDS,XMM,CXT,WORK,DUM1,DUM2,DUM3,WORK2,RMTB,RMTB2,TIMEOF
00105          1  ,RMLIN
00105   C       DATA FOR INITIAL CONDITIONS
00106   300     CONTINUE
00107           PRINT 40
00111           DO 10 I = 1,40
00114           READ(5,140,END=301) C(I),(XN(I,J),J=1,2)
00123           PRINT      42, I, C(I), (XN(I,J), J = 1,2)
00133        10 CONTINUE
00135           DO 20 I = 1,4
00140           IP40 = I + 40
00141           READ      140, BC(I), (XNB(I,J), J = 1,2)
00150           PRINT      42, IP40,BC(I),(XNB(I,J),J=1,2)
00160        20 CONTINUE
00162           DO 30 I = 1,2
00165           READ      140, RMT(I), (XNB(I,J), J = 1,2)
00174           IP40 = I + 44
00175           PRINT      42, IP40, RMT(I), (XNB(I,J), J = 1,2)
00204        30 CONTINUE
00207           DO 40 I = 1,2
00212           READ      140, DJ(I), (XNB(I,J), J = 1,2)
00221           IP40 = I + 46
00222           PRINT      42, IP40, DJ(I), (XNB(I,J), J = 1,2)
00232        40 CONTINUE
00232   C
00234           DUM1=C(31)
00235           DUM2=C(32)
00236           DUM3-C(33)
00237           WORK=0.
00240           WORK2=0.
00241           RMTB-RMT(2)
00242           RMTB2 RMT(2)
00243           TIMEOF=0.
00244           XDS=0.
00245           XMM=10.*C(36)/0.0078125
00246           MMM=0
00247   201     CONTINUE
00250           XDS=XDS+XMM
00251           IF(MMM.EQ.1)XDS=XDS+C(36)
00253           MMM=1
00254           C(35)=0.
00255           C(40)=0.
00255   C
```

```
00255    C     INITIAL GUESSES FOR ITERATIVE LOOPS
00256          CC(1) = 0.6
00257          CC(2) = C(4)
00260          CC(3) = C(7)
00261          CPB = 50.0
00262          CPT = 50.0
00263          IF(IDS.GT.IMM) GOTO202
00263    C     SETS VARIOUS CONSTANTS AND AGGREGATES OF CONSTANTS
00265          C(15) = C(15) + .0001
00266          C(39) = C(39) + .0001
00267          DO 200 I = 27,29
00272          C(I) = .0000001 * C(I)
00273      200 CONTINUE
00275     202  CONTINUE
00276          IRK = 1
00277          M = 14
00300          N = 5
00301          IDJ(1) = 0
00302          IF (DJ(1) .GT. 0.0)   CALL RC22 (CDJ, DJ, IDJ)
00304          A(1) = 0.51
00305          A(2) = 0.029
00306          A(3) = 0.013
00307          A(4) = 0.51
00310          A(5) = 0.029
00311          A(6) = 0.013
00312          SK = 0.00132
00313          CADK = 795.0
00314          VOL(1) = 0.015
00315          VOL(2) = 1.062
00316          VOL(3) = 0.188
00317          VOL(4) = 0.06
00320          VOL(5) = 0.188
00321          VOL(6) = 2.99
00322          VOL(7) = 0.735
00323          VOL(8) = 1.062
00324          VOL(9) = 0.008
00325          VOL(10)= 1.062
00326          DF(6) = (C(25) + RMT(1))/(C(26) + RMT(2))
00327          D(1)=C(30)-47.
00330          DO 210 I = 2,4
00333          D(I) = SK*A(I-1)
00334          D(I+4) = SK*A(I+2)
00335          D(I+3) = D(1)*D(I)
00336      210 CONTINUE
00340          D(8) = 0.16 + 2.3*C(17)
00341          D(9) = 863.0/D(1)
00342          D(10) = 0.62
00343          D(14) = C(36)*2.0
00344          D(15) = D(14) - .01*C(36)
00345          CALL RC3
00346          CALL RC4
00347          CALL RC5 (CPB, F(4), C(4), BC(2))
00350          CALL RC21 (CHB(2), F(3), F(4), C(4), CH(2), CPH(2))
00351          CALL RC19 (CPB, CHB(2), CC(2), BC(1), F(4))
00352          CALL RC5 (CPT, F(6), C(7), BC(3))
00353          CALL RC21 (CHB(3), F(5), F(6), C(7), CH(3), CPH(3))
00354          CALL RC19 (CPT, CHB(3), CC(3), BC(1), F(6))
00355          CALL RC20
```

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                  RESP CASE NO. 1                          DATE  220672  PAGE    10
00356              CALL RC7
00357              CALL RC8
00360              CALL RC9
00361              CALL RC10
00362              CALL RC11
00363              CALL RC12
00364              GO TO 60
00365           50 CALL RC15
00366              CALL RC16
00367           60 CALL RC13
00370              CALL RC12
00370        C
00371              IF(C(34).GE.XMN) GO TO 201
00371        C
00373              IF (IOJ(1) .EQ. 1)      CALL RC23 (COJ, DJ, IOJ)
00375              IF (C(35) .GT. C(15)) GOTO80
00377              IF(CXT.GT.C(15)) GOTO 80
00401           70 CALL RC14
00402              UU = AMOD(C(35), D(14))
00403              IF (UU .LT. .000) .OR. UU .GT. D(15))   GOTO50
00405              GOTO 60
00406           80 IF (C(37) .GT. 1.0E-5)     GO TO 250
00410          220 CTERM = 0.0
00411              IF (VTRAN(14) - 104.0)       230, 240, 240
00414          230 CTERM = (23.6E-4)*((104.0 - VTRAN(14))**4.4)
00415          240 C(37) = C(20)*(C(16)*VTRAN(15) + (1.0 - C(16))*CN(4))
00415            1       + C(21)*VTRAN(13) + CTERM - VI
00416              I = 37
00417              PUNCH 192, I, C(I), (XN(I,J), J = 1,2)
00427          250 DO 260 I = 1,14
00432              PUNCH 192, I, C(I), (XN(I,J), J = 1,2)
00442          260 CONTINUE
00444              WRITE (61, 194)
00446              GOTO300
00447        301   CONTINUE
00450              STOP
00451           90 FORMAT (1H148X37H*RESPIRATORY CHEMOSTAT -- INPUT DATA*///)
00452           92 FORMAT (42XI3,14XF10.4,10X2A6)
00453          190 FORMAT (5XF15.0,5X2A6)
00454          192 FORMAT (I3,2XF15.5,5X2A8)
00455          194 FORMAT (1H1)
00456              END

    END OF COMPILATION:        NO  DIAGNOSTICS.
 RCHEM          SYMBOLIC                          24 JAN 72  16:17:05   0  01436670    14   263  (DELETED)
 RCHEM   CODE   RELOCATABLE                       24 JAN 72  16:17:05   1  01446032    40     1  (DELETED)
                                                                        0  01446112    14    56
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                          RESP CASE NO. 1                                                DATE  220672  PAGE    12
@ FORC@ RC3,RC3      SYMBOLIC                                  24 JAN 72  16:17:06   0  01447932 JUN102    21  (DELETED)2:10
UNIVAC1110B FORTRAN V EXEC8 LEVEL 25A  -(EXEC8 LEVEL E1201001OA)  24 JAN 72  16:17:06   1  01450200    24     1  (DELETED)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:10                                    0  01450230    14     5

   SUBROUTINE RC3        ENTRY POINT 000040

   STORAGE USED: CODE(1) 000043; DATA(0) 000012; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003  Z      002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000    000000 6969F       0003    002232 A          0003    002317 BC         0003 R 000000 C          0003    002363 CADX
    0003    002336 CC          0003    002344 CH         0003    002341 CHB        0003 R 002361 CPB        0003    002350 CPM
    0003 R 002362 CPT          0003 R 002240 D           0003    002214 DC         0003    002353 DO        0003    002365 DT
    0003 R 002257 F            0003    002372 I          0003    002371 INDEX      0000    000003 INJP$     0003    002366 IRK
    0003    002370 ITERX       0003    002373 J          0003    002367 LOC        0003    002374 M         0003    002375 N
    0003 R 002323 OF           0003    002016 RK         0003    002315 RMT        0003    002106 SC        0003    000170 SV
    0003    002331 TAU         0003    002357 VE         0003    002360 VI         0003    002303 VOL       0003    001774 VTRAN
    0003    002364 X           0003    000050 XN


00101               SUBROUTINE RC3
00103               DIMENSION C(40), XN(40,2), SV(10,50), VTRAN(10), RK(14,4),
00103              1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103              2          BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPM(3),
00103              3          DO(4)
00104               COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, OF,
00104              1      TAU, CC, CHB, CH, CPM, DO, VE, VI, CPB, CPT, CADX, X, DT,
00104              2      IRK, LOC, ITERX, INDEX, I, J, M, N
00105          6969          FORMAT(1H 7HSUB RC3)
00105        C      SETS TIME-DEPENDENT EXPRESSIONS
00106               OF(1) = C(10) - C(11)
00107               F(1) = D(1)*C(2)
00110               F(2) = D(5)*C(1)
00111               F(3) = C(5)/D(3)
00112               F(4) = D(2)*CPB
00113               F(5) = C(8)/D(3)
00114               F(6) = D(2)*CPT
00115               F(7) = D(1)*C(1)
00116               F(8) = D(1)*C(2)
00117               RETURN
00120               END

      END OF COMPILATION:        NO  DIAGNOSTICS.
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                           RESP CASE NO. 1                                          DATE  220672  PAGE    13
* FOR,* RC9,RC9                                                                                   22 JUN 72                 19: 2:11
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E1201001OA)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:11

   SUBROUTINE RC9        ENTRY POINT 000055

   STORAGE USED: CODE(1) 000057; DATA(0) 000021; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z       002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   RC21
    0005   RCF1
    0006   RC6
    0007   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000    000003 3000F      0001    000000 910L       0000    000000 6969F      0003    002232 A          0003 R 002317 BC
    0003 R 000000 C          0003    002363 CADX       0003 R 002336 CC         0003 R 002344 CH         0003 R 002341 CHB
    0003    002361 CPB        0003 R 002350 CPH        0003    002362 CPT        0003 R 002240 D          0003    002214 DC
    0003    002353 DO         0003    002365 DT         0003 R 002257 F          0003    002372 I          0003    002371 INDEX
    0000    000014 INJP$      0003    002366 IRK        0003 I 002370 ITERX      0003    002373 J          0003    002367 LDC
    0003    002374 M          0003    002375 N          0003    002323 QF         0005 R 000000 RCF1       0003    002016 RK
    0003    002315 RMT        0003    002106 SC         0003    000170 SV         0003    002331 TAU        0003    002357 VE
    0003    002360 VI         0003    002303 VOL        0003    001774 VTRAN      0003 R 002364 X          0003    000050 XN


00101              SUBROUTINE RC9
00103              DIMENSION C(90), XN(90,2), SV(18,50), VTRAN(18), RK(19,9),
00103             1          SC(19,5), DC(19), A(6), D(15), F(20), VOL(10), RMT(2),
00103             2          BC(9), QF(6), TAU(5), CC(3), CHB(3), CH(9), CPH(3),
00103             3          DO(9)
00104              COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104             1       TAU, CC, CHB, CH, CPH, DO, VE, VI, CPB, CPT, CADX, X, DT,
00104             2       IRK, LDC, ITERX, INDEX, I, J, M, N
00104        C     ITERATES FOR CC(1), ARTERIAL CO2 CONCENTRATION
00105         6969              FORMAT(1H THSUB RC9)
00106          910 CALL RC21 (CHB(1), F(1), F(2), CC(1), CH(1), CPH(1))
00107              X = (CC(1) - F(2))/(0.01*F(7))
00110              X = RCF1(X)
00111              X = BC(1) + 0.375*(C(17) - CHB(1)) + F(2) - D(8)*(X - 0.14)
00112              CALL RC6 (CC(1))
00113              CC(1) = CC(1) + 2.0*(X - CC(1))/3.0
00114         3000 FORMAT(1H ,5HCC(1),5X,E16.6)
00115              IF (ITERX)   920, 910, 920
00120          920 RETURN
00121              END
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              RESP CASE NO. 1                                      DATE  220672  PAGE   19

    END OF COMPILATION:        NO  DIAGNOSTICS.
   RC9             SYMBOLIC                               29 JAN 72  16:17:07   0  01950336    19    20 (DELETED)
   RC9     CODE    RELOCATABLE                            29 JAN 72  16:17:07   1  01950766    29     1 (DELETED)
                                                                                0  01951016    19     0
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                    RESP CASE NO. 1                                   DATE  220672  PAGE    19
@ FOR,* RCS,RCS                                                                22 JUN 72              15: 2:12
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:12

   SUBROUTINE RC5       ENTRY POINT 000044

   STORAGE USED- CODE(1) 000063; DATA(0) 000027; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z       002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   RCF1
    0005   RC6
    0006   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   000003 3000F      0001   000000 510L      0000   000000 6969F     0003   002232 A        0003   002317 BC
    0003   000000 C          0003   002363 CADK      0003   002336 CC        0003   002344 CH       0003   002341 CHB
    0003   002361 CPB        0003   002350 CPH       0003   002362 CPT       0003 R 002240 D        0003   002214 DC
    0003   002353 DO         0003   002365 DT        0003   002257 F         0003   002372 I        0003   002371 INDEX
    0000   000020 INJP$      0003   002366 IRK       0003 I 002370 ITERX     0003   002373 J        0003   002367 LOC
    0003   002374 M          0003   002375 N         0003   002323 QF        0004 R 000000 RCF1     0003   002016 RK
    0003   002315 RMT        0003   002156 SC        0003   000170 SV        0003   002331 TAU      0003   002357 VE
    0003   002360 VI         0003   002303 VOL       0003   001774 VTRAN     0003 R 002364 X        0003   000050 XN


00101            SUBROUTINE RC5 (CP, FB, CCB, BHC)
00103            DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(19), RK(19,4),
00103          1           SC(19,5), DC(14), A(6), D(15), F(25), VOL(10), RMT(2),
00103          2           BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103          3           DO(4)
00104            COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104          1        TAU, CC, CHB, CH, CPH, DO, VE, VI, CPB, CPT, CADK, X, DT,
00104          2        IRK, LOC, ITERX, INDEX, I, J, M, N
00104      C     ITERATES FOR BRAIN AND TISSUE PCO2
00105       6969              FORMAT(1H 7HSUB RC5)
00106        510 X = (CCB - FB)/(0 01*CP)
00107            X = RCF1(X)
00110            X = (-BHC + CCB + D(10)*(X - 0.14))/D(2)
00111            CALL RC6 (CP)
00112            CP = CP + (X - CP)/10.0
00113            FB = D(2)*CP
00114       3000 FORMAT(1H ,4HCP= ,E16 6,4HFB= E16.6,5HCCB= E16.6,5HBHC= E16.6)
00115            IF (ITERX)   520, 510, 520
00120        520 RETURN
00121            END
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                RESP CASE NO. 1                              DATE 220672 PAGE    16

  END OF COMPILATION:        NO DIAGNOSTICS.
RCS                SYMBOLIC                      29 JAN 72 16:17:00  0 01951176   19   20 (DELETED)
RCS       CODE     RELOCATABLE                   29 JAN 72 16:17:00  1 01951626   29    1 (DELETED)
                                                                     0 01951656   19    8
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                         RESP CASE NO. 1                                  DATE  220672  PAGE    17
* FOR,* RC6,RC6                                                                  22 JUN 72               15: 2:13
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E1201001OA)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:13
```

SUBROUTINE RC6   ENTRY POINT 000022

STORAGE USED· CODE(1) 000024; DATA(0) 000012; BLANK COMMON(2) 000000

COMMON BLOCKS:

0003   Z   002376

EXTERNAL REFERENCES (BLOCK, NAME)

0004   NERR3$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000013 630L	0000	000001 6969F	0003	002232 A	0003	002317 BC	0003	000000 C
0003	002363 CADR	0003	002336 CC	0003	002344 CH	0003	002341 CHB	0003	002361 CPB
0003	002350 CPM	0003	002362 CPT	0003	002240 D	0003	002214 DC	0000 R	000000 DIFF
0003	002353 DO	0003	002365 DT	0003	002257 F	0003	002372 I	0003	002371 INDEX
0000	000005 INJP$	0003	002366 IRK	0003 I	002370 ITERX	0003	002373 J	0003	002367 LOC
0003	002374 M	0003	002375 N	0003	002323 OF	0003	002016 RK	0003	002315 RMT
0003	002104 SC	0003	000170 SV	0003	002331 TAU	0003	002357 VE	0003	002360 VI
0003	002303 VOL	0003	001774 VTRAN	0003 R	002364 X	0003	000050 XN		

```
00101       1*           SUBROUTINE RC6 (Y)
00103       2*           DIMENSION C(40), XN(40,2), SV(10,50), VTRAN(10), RK(14,4),
00103       3*          1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103       4*          2          BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPM(3),
00103       5*          3          DO(4)
00104       6*           COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, OF,
00104       7*          1        TAU, CC, CHB, CH, CPM, DO, VE, VI, CPB, CPT, CADR, X, DT,
00104       8*          2        IRK, LOC, ITERX, INDEX, I, J, M, N
00104       9*       C    CHECKS CONVERGENCE OF ITERATIVE PROCEDURES
00105      10*        6969              FORMAT(1H 7HSUB RC6)
00106      11*           ITERX = 0
00107      12*           DIFF = ABS ((X - Y)/Y)
00110      13*           IF (DIFF - 1.0E-5)    620, 620, 630
00113      14*       620 ITERX = 1
00114      15*       630 RETURN
00115      16*           END
```

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     END OF COMPILATION·         NO  DIAGNOSTICS.
   RC6               SYMBOLIC                               24 JAN 72  16:17:04   0  01442036     14     16  (DELETED)
   RC6      CODE     RELOCATABLE                            24 JAN 72  16:17:04   1  01452376     24      1  (DELETED)
                                                                                  0  01452426     14      3
```

RESP CASE NO. 1 DATE 220672 PAGE 10

@ FOR,@ RC7,RC7 22 JUN 72 15: 2:14

UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A -(EXEC8 LEVEL E1201001OA)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:15

SUBROUTINE RC7 ENTRY POINT 000044

STORAGE USED: CODE(1) 000052, DATA(0) 000031, BLANK COMMON(2) 000000

COMMON BLOCKS:

0003 Z 002376
0004 R 000014

EXTERNAL REFERENCES (BLOCK, NAME)

0005 RC16
0006 NERR3$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000012 113G	0001 000013 116G	0001 000025 126G	0001 000023 2L	0000 000003 3000F
0000 000000 6969F	0003 002232 A	0003 002317 BC	0003 000000 C	0003 002363 CADK
0003 002336 CC	0003 002344 CH	0003 002341 CHB	0003 002361 CPB	0003 002350 CPN
0003 002362 CPT	0004 000002 CXT	0003 R 002240 D	0003 002214 DC	0003 002353 DO
0003 002365 DT	0004 000004 DUM1	0004 000005 DUM2	0004 000006 DUM3	0003 002257 F
0003 I 002372 I	0003 002371 INDEX	0000 000020 INJP$	0003 002366 IAK	0003 002370 ITERX
0003 I 002373 J	0003 002367 LOC	0003 002374 M	0003 002375 N	0003 002323 OF
0003 002016 RK	0004 000013 RMLIN	0003 002315 RMT	0004 000010 RMTB	0004 000011 RMTB2
0003 002106 SC	0003 R 000170 SV	0003 002331 TAU	0004 000012 TIMEOF	0003 002357 VE
0003 002360 VI	0003 002303 VOL	0003 001774 VTRAN	0004 000003 WORK	0004 000007 WORK2
0003 002364 X	0004 R 000000 XDS	0004 R 000001 XMN	0003 000050 XN	

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00101            SUBROUTINE RC7
00103            DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103           1        SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103           2        BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPN(3),
00103           3        DO(4)
00104            COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, OF,
00104           1        TAU, CC, CHB, CH, CPN, DO, VE, VI, CPB, CPT, CADK, X, DT,
00104           2        IAK, LOC, ITERX, INDEX, I, J, M, N
00105            COMMON/R/ XDS,XMN,CXT,WORK,DUM1,DUM2,DUM3,WORK2,RMTB,RMTB2,TIMEOF
00105           1  ,RMLIN
00106      6969            FORMAT(1H 7HSUB RC7)
00106      C     FILLS SV ARRAY WITH INITIAL CONDITIONS
00107            CALL RC16
00110            IF(XDS.GT.XMN) GOTO2
00112            DO 720 I = 1,17
00115            DO 720 J = 2,50
00120            SV(I,J) = SV(I,1)
00121        720 CONTINUE
00124      2     CONTINUE
```

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                        RESP CASE NO. 1                                      DATE  220672  PAGE    14
00125     20*           DO 730 J = 2,50
00130     21*           SV(18,J) = SV(18,J - 1) - D(14)
00131     22*       730 CONTINUE
00133     23*      3000 FORMAT(1H ,12H18SV S D(14),6(3X,E16.6)/1H ,6(3X,E16.6)/1H ,7(3X,E1
00133     24*          C6.6))
00134     25*           RETURN
00135     26*           END

    END OF COMPILATION:         NO  DIAGNOSTICS.
   RCT           SYMBOLIC                                        24 JAN 72  16:17:11  0  01452500    14    26  (DELETED)
   RC7     CODE  RELOCATABLE                                     24 JAN 72  16:17:11  1  01453254    24     1  (DELETED)
                                                                                      0  01453304    14     7
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                    RESP CASE NO. 1                                    DATE  220672  PAGE    20
@ FOR,* RC8,RC8                                                                       22 JUN 72                 15: 2:16
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:16

   SUBROUTINE RC8        ENTRY POINT 000325

   STORAGE USED- CODE(1) 000390; DATA(0) 000053; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z       002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   NERR2$
    0005   NPRT$
    0006   NIO2$
    0007   SORT
    0010   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001    000005 107G      0001    000063 133G      0001    000173 157G      0000    000012 6969F     0001    000025 810L
    0001    000032 812L      0001    000037 814L      0001    000044 816L      0001    000053 820L      0001    000056 822L
    0001    000074 824L      0001    000116 830L      0001    000126 832L      0001    000142 834L      0001    000214 840L
    0001    000234 846L      0001    000247 850L      0001    000273 860L      0000    000015 890F      0003    002232 A
    0000 R  000007 AA        0000 R  000006 AB        0003    002317 BC        0003 R  000000 C         0003    002343 CADX
    0003    002336 CC        0003    002344 CH        0003    002341 CHB       0003    002361 CPB       0003    002350 CPH
    0003    002362 CPT       0003 R  002240 D         0000 R  000010 DA        0003    002214 DC        0003    002353 DQ
    0003 R  002365 DT        0000 R  000011 DV        0003    002257 F         0003 I  002372 I         0000 I  000005 IJ
    0003    002371 INDEX     0000    000025 INJP$     0003    002366 IRK       0003    002370 ITERX     0003 I  002373 J
    0000 I  000004 K         0003    002367 LOC       0003    002374 M         0003    002375 N         0000 I  000002 NB
    0000 I  000001 NC        0000 I  000000 ND        0000 R  000003 QA        0003 R  002323 OF        0003    002016 RX
    0003    002315 RMT       0003    002104 SC        0003 R  000170 SV        0003 R  002311 TAU       0003    002357 VE
    0003    002360 VI        0003 R  002303 VOL       0003    001774 VTRAN     0003    002364 X         0003    000050 XN


00101       1*           SUBROUTINE RC8
00103       2*           DIMENSION C(40), XN(40,2), SV(10,50), VTRAN(10), RX(14,4),
00103       3*          1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103       4*          2          BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103       5*          *          DQ(4)
00104       6*           COMMON/Z/ C, XN, SV, VTRAN, RX, SC, DC, A, D, F, VOL, RMT, BC, OF,
00104       7*          1       TAU, CC, CHB, CH, CPH, DQ, VE, VI, CPB, CPT, CADX, X, DT,
00104       8*          2       IRK, LOC, ITERX, INDEX, I, J, M, N
00104       9*        C      CALCULATES TRANSPORT TIMES
00105      10*         6969             FORMAT(1H THSUB RC8)
00106      11*           DO 870 I = 1,5
00111      12*           DT = C(35) - SV(10,1)
00112      13*           ND = 1
00113      14*           GO TO (810,812,814,816,810), I
00114      15*       810 NC = 11
```

RESP CASE NO. 1 DATE 220672 PAGE 21

```
00115          NB = 10
00116          GO TO 820
00117      812 NC = 10
00120          NB = 11
00121          GO TO 820
00122      814 NC = 10
00123          NB = 12
00124          GO TO 820
00125      816 NC = 12
00126          NB = 10
00127          QA = QF(1)
00130          GO TO 822
00131      820 QA = C(NC)
00132      822 DO 860 J = 1,2
00134          GO TO (834,824), J
00136      824 NC = NB
00137          ND = K + 1
00140          IF (K)              826, 826, 832
00143      826 IF (NC - 12)        830, 828, 830
00144      828 QA = SV(NC,1) - (SV(NC,1) - QF(1))*DT/(C(35) - SV(18,1))
00147          GO TO 834
00150      830 QA = SV(NC,1) - (SV(NC,1) - C(NC))*DT/(C(35) - SV(18,1))
00151          GO TO 834
00152      832 QA = SV(NC,ND) - (SV(NC,K) - SV(NC,ND))*DT/D(14)
00153      834 IJ = 2*I + J - 2
00154          AB = VCL(IJ)
00155          AA = DT*(QA + SV(NC,ND))/2.0
00156          DO 838 K = ND,49
00161          IF (AA - AB)        836, 836, 840
00164      836 AA = AA + C(36)*(SV(NC,K) + SV(NC,K+1))
00165      838 CONTINUE
00167          PRINT 890, I
00172      840 DA = AA- AB
00173          K = K -1
00174          IF (K)              842, 842, 846
00177      842 DV = SV(NC,1) - QA
00200          IF (DV)             850, 844, 850
00203      844 DT = DA/QA
00204          GO TO 860
00205      846 DV = SV(NC,K+1) - SV(NC,K)
00206          IF (DV)             850, 848, 850
00211      848 DT = DA/SV(NC,K)
00212          GO TO 860
00213      850 DT = (SV(NC,K+1) - SQRT (SV(NC,K+1)**2 - DV*DA/C(36)))/(DV/D(14))
00214      860 CONTINUE
00216          TAU(I) = C(35) - SV(18,K + 1) - DT
00217      870 CONTINUE
00221          RETURN
00222      890 FORMAT (5X27HSV ARRAY EXCEEDED ON CYCLE I2)
00223          END

   END OF COMPILATION:        NO  DIAGNOSTICS.
RCP             SYMBOLIC          24 JAN 72  16:17:12   0  01453446   14    65  (DELETED)
RCB     CODE    RELOCATABLE       24 JAN 72  16:17:12   1  01455264   24     1  (DELETED)
                                                        0  01455314   14    25
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                    RESP CASE NO. 1                                  DATE  220672  PAGE    22
@ FOR,* RC9,RC9                                                                            22 JUN 72                15: 2:18
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E1201001OA)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:18

   SUBROUTINE RC9        ENTRY POINT 000166

   STORAGE USED· CODE(1) 000174; DATA(0) 000042; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z       002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   RCF3
    0005   NPRT$
    0006   NI02$
    0007   NERR2$
    0010   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001     000002 107G      0001     000057 130G      0001     000075 140G      0001     000113 150G      0001     000131 160G
    0000     000003 6969F     0001     000032 904L      0001     000055 910L      0001     000073 920L      0001     000111 930L
    0001     000127 940L      0001     000141 950L      0001     000151 960L      0000     000013 990F      0003     002232 A
    0003     002317 BC        0003 R 000000 C          0003     002363 CADX      0003     002336 CC        0003     002344 CH
    0003     002341 CHB       0003     002361 CPB       0003     002350 CPH       0003     002362 CPT       0003 R 002240 D
    0003     002214 DC        0000     000006 DCNM      0003     002353 DQ        0003 R 002365 DT         0003     002257 F
    0003 I 002372 I           0003     002371 INDEX     0000     000031 INJP$     0003     002366 IRK       0003     002370 ITERX
    0003 I 002373 J           0003 I 002367 LOC        0003     002374 M         0003     002375 N         0003     002323 OF
    0004 R 000000 RCF3        0003     002016 RK        0003     002315 RMT       0003     002106 SC        0003 R 000170 SV
    0000 R 000000 TA          0003 R 002331 TAU        0000 R 000002 TB         0003     002357 VE        0003     002360 VI
    0003     002303 VOL       0003 R 001774 VTRAN      0003     002364 X         0000 R 000001 XLOC       0003     000050 XN


00101              SUBROUTINE RC9
00103              DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103             1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103             2          BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103             3          DQ(4)
00104              COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, OF,
00104             1       TAU, CC, CHB, CH, CPH, DQ, VE, VI, CPB, CPT, CADX, X, DT,
00104             2       IRK, LOC, ITERX, INDEX, I, J, M, N
00104        C     SETS VALUES IN VTRAN ARRAY
00105         6969             FORMAT(1H 7HSUB RC9)
00106              DO 960 I = 1,5
00111              TA = TAU(I) - (C(35) - SV(18,1))
00112              LOC = TA/D(14)
00113              IF (LOC - 49)      904, 904, 902
00116          902 PRINT 990, I, LOC
00122              LOC = 49
00123          904 XLOC = LOC
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                         RESP CASE NO. 1                                       DATE  220672  PAGE    23
00124                       TB = XLOC+DX(14)
00125                       DT = TA - TB
00126                       GO TO (910,920,930,940,950), I
00127                   910 DO 914 J = 1,3
00132                       VTRAN(J) = RCF3(J)
00133                   914 CONTINUE
00135                       VTRAN(15) = RCF3(13)
00136                       GO TO 960
00137                   920 DO 924 J = 4,6
00142                       VTRAN(J) = RCF3(J)
00143                   924 CONTINUE
00145                       VTRAN(16) = RCF3(16)
00146                       GO TO 960
00147                   930 DO 934 J = 7,9
00152                       VTRAN(J) = RCF3(J)
00153                   934 CONTINUE
00155                       VTRAN(17) = RCF3(17)
00156                       GO TO 960
00157                   940 DO 944 J = 1,3
00162                       VTRAN(J+9) = RCF3(J)
00163                   944 CONTINUE
00165                       GO TO 960
00166                   950 VTRAN(13) = RCF3(13)
00167                       VTRAN(14) = RCF3(14)
00170                   960 CONTINUE
00172                       NAMELIST/DCNM/VTRAN
00173                       RETURN
00174                   990 FORMAT (5X27H5V ARRAY EXCEEDED ON CYCLE I2,12H WITH LOC = I4)
00175                       END

   END OF COMPILATION:          NO  DIAGNOSTICS.
 RC9             SYMBOLIC                                 24 JAN 72  16:17:14   0  01456052   14    46  (DELETED)
 RC9     CODE    RELOCATABLE                              24 JAN 72  16:17:14   1  01457256   24     1  (DELETED)
                                                                                0  01457306   14    16
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RESP CASE NO. 1                                         DATE  220672  PAGE    24
@ FOR,* RC10,RC10                                                             22 JUN 72              15: 2:19
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E1201001OA)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:19

   SUBROUTINE RC10       ENTRY POINT 000127

   STORAGE USED- CODE(1) 000131; DATA(0) 000050; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z       002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000012 1016L    0001   000036 1020L    0001   000037 1024L    0001   000040 1028L    0001   000052 1036L
    0001   000055 1040L    0001   000061 1044L    0001   000076 1052L    0001   000106 1060L    0000   000000 6969F
    0003   002232 A        0003   002317 BC       0003   000050 C        0003   002363 CADX     0003   002336 CC
    0003   002344 CH       0003   002341 CHB      0003   002361 CPB      0003   002350 CPM      0003   002362 CPT
    0003   002240 D        0003   002214 DC       0000   000003 DG       0003 R 002351 DO       0003   002365 DT
    0003 R 002257 F        0003   002372 I        0003   002371 INDEX    0000   000043 INJP$    0003   002366 IRK
    0003   002370 ITERX    0003   002373 J        0003   002367 LCC      0003   002374 M        0003   002375 N
    0003   002323 QF       0003   002016 RK       0003   002315 RMT      0003   002106 SC       0003   000170 SV
    0003   002331 TAU      0003   002357 VE       0003   002360 VI       0003   002303 VOL      0003   001774 VTRAN
    0003   002364 X        0003   000050 XN


00101               SUBROUTINE RC10
00103               DIMENSION C(40), XN(40,2), SV(10,50), VTRAN(18), RK(14,4),
00103              1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103              2          BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPM(3),
00103              3          DO(4)
00104               COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104              1       TAU, CC, CHB, CH, CPM, DO, VE, VI, CPB, CPT, CADX, X, DT,
00104              2       IRK, LCC, ITERX, INDEX, I, J, M, N
00105          6969              FORMAT(IN RHSUB RC10)
00105         C     COMPUTES EMPIRICAL FUNCTIONS FOR ACRDIAC OUTPUT AND BRAIN BLOOD
00105         C     FLOW DIFFERENTIAL EQUATIONS
00106               IF (F(8) - 104 0)                1008, 1020, 1020
00111          1008 DO(1) = ((-1 0033E-5*F(8) + 2.9241E-3)*F(8) - 0.2885)*F(8) +9.6651
00112               DO(2) = (((7.6559E-8*F(8) - 2.324E-5)*F(8) + 2.6032E-3)*F(8)
00112              1       - 0.1327)*F(8) + 2.785
00113               IF (DO(1))                       1012, 1016, 1016
00116          1012 DO(1) = 0.0
00117          1016 IF (DO(2))                       1024, 1028, 1028
00122          1020 DO(1) = 0.0
00123          1024 DO(2) = 0.0
00124          1028 IF (F(7) - 60 0)                 1032, 1032, 1036
00124         C
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                        RESP CASE NO. 1                                   DATE  220672  PAGE    25
00124      C      IF PCO2 GT 60 DO(3) STAYS AT ITS VALUE AT 60 - - OLD ROUTINE SETS
00124      C      THE VALUE OF DO(3) EQUAL TO 0
00127       1032 IF (F(7) - 40.0)               2036, 1040, 1040
00132       2036 DO(3)=0.
00133             GOTO1044
00134      1036  DO(3)=6.0
00134      C
00135             GO TO 1044
00136       1040 DO(3) = 0.3*(F(7) - 40.0)
00137       1044 IF (F(7) - 38.0)               1048, 1052, 1052
00142       1048 DO(4) = (8.0163E-4*F(7) - 3.1073E-2)*F(7) + 2.3232E-2
00143             RETURN
00144       1052 IF (F(7) - 44.0)               1056, 1056, 1060
00147       1056 DO(4) = 0.0
00150             RETURN
00151       1060 DO(4) = (((-2.1748E-7*F(7) + 9.3918E-5)*F(7) - 1.2997E-2)*F(7)
00151          1         + 0.7607)*F(7) - 15.58
00152             NAMELIST/DG/DO,F
00153             RETURN
00154             END

    END OF COMPILATION:        NO  DIAGNOSTICS.
RC10              SYMBOLIC                           29 JAN 72  16:17:15  0  01457646   14    42 (DELETED)
RC10      CODE    RELOCATABLE                        29 JAN 72  16:17:15  1  01460762   24     1 (DELETED)
                                                                          0  01461012   14    14
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                          RESP CASE NO. 1                                             DATE  220672  PAGE    26
* FOR,* RC11,RC11                                                                                22 JUN 72                 15: 2:21
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:21

   SUBROUTINE RC11       ENTRY POINT 000225

   STORAGE USED: CODE(1) 000230; DATA(0) 000026; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z        002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   RC17
    0005   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000     000001 6969F      0003     002232 A         0000     000004 AB        0003     002317 BC        0003 R 000000 C
    0003     002353 CADR       0003 R 002336 CC          0003     002344 CH        0003     002341 CHB       0003     002361 CPB
    0003     002350 CPH        0003     002362 CPT       0003 R 002240 D           0003 R 002214 DC          0003 R 002353 DB
    0003     002365 DT         0003 R 002257 F           0003     002372 I         0003     002371 INDEX     0000     000016 INJP$
    0003     002366 IRK        0003     002370 ITERX     0003     002373 J         0003     002367 LOC       0003     002374 M
    0003     002375 N          0003 R 002323 QF          0003     002016 RK        0003 R 002315 RMT         0003     002106 SC
    0003     000170 SV         0003     002331 TAU       0003 R 002357 VE          0003 R 002360 VI          0003     002303 VOL
    0003 R 001774 VTRAN        0003     002364 X         0000 R 000000 XAB         0003     000050 XN


00101      1*          SUBROUTINE RC11
00103      2*          DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103      3*         1        SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103      4*         2         BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103      5*         3         DB(4)
00104      6*          COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104      7*         1       TAU, CC, CHB, CH, CPH, DB, VE, VI, CPB, CPT, CADR, X, DT,
00104      8*         2       IRK, LOC, ITERX, INDEX, I, J, M, N
00104      9*     C    CALCULATES DIFFERENTIAL EQUATIONS
00105     10*      6969              FORMAT(1H @HSUB RC11)
00106     11*          CALL RC17
00107     12*          DC(1) = (VI*C(31) - VE*C(1) + D(4)*(C(11)*VTRAN(4) + QF(1)
00107     13*         1         *VTRAN(7) - C(10)*CC(1)))/C(22)
00110     14*          DC(2) = (VI*C(32) - VE*C(2) + D(4)*(C(11)*VTRAN(5) + QF(1)
00110     15*         1         *VTRAN(8) - C(10)*F(9)))/C(22)
00111     16*          DC(3) = (VI*C(33) - VE*C(3) + D(4)*(C(11)*VTRAN(6) + QF(1)
00111     17*         1         *VTRAN(9) - C(10)*F(10)))/C(22)
00112     18*          DC(4) = (C(25) + C(11)*(VTRAN(1) - CC(2)) - F(14))/C(23)
00113     19*          DC(5) = (-C(26) + C(11)*(VTRAN(2) - F(12)) - F(15))/C(23)
00114     20*          DC(6) = (C(11)*(VTRAN(3) - C(6)) - F(16))/C(23)
00115     21*          DC(7) = (RMT(1) + QF(1)*(VTRAN(10) - CC(3)))/C(24)
00116     22*          DC(8) = (-RMT(2) + QF(1)*(VTRAN(11) - F(13)))/C(24)
00117     23*          DC(9) = QF(1)*(VTRAN(12) - C(9))/C(24)
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                           RESP CASE NO. 1                                      DATE  220672  PAGE    27
00120                DC(10) = (-C(10) + 6.0 * DD(1) + DD(3))/C(18)
00120        C
00120        C
00121                XAB=5.5 *(AMT(2)-.215)*6.-C(10)
00122                IF((AMT(2).GT..215).AND.(XAB.GT.0.))DC(10)=DC(10)+XAB/.010
00122        C
00122        C
00124                DC(11) = (-C(11) + 0.75 * DD(2) + DD(4))/C(19)
00125                DC(12) = F(14)/(C(34)*D(11))
00126                DC(13) = F(15)/(C(34)*D(12))
00127                DC(14) = F(16)/(C(34)*D(13))
00130                NAMELIST/AB/DC
00131                RETURN
00132                END

    END OF COMPILATION:         NO  DIAGNOSTICS.
  AC11           SYMBOLIC                                    24 JAN 72  16:17:17   0  01461316    14    37 (DELETED)
  AC11    CODE   RELOCATABLE                                 24 JAN 72  16:17:17   1  01462324    24     1 (DELETED)
                                                                                   0  01462354    14    10
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                     RESP CASE NO. 1                                        DATE  220672  PAGE    20
@ FOR,* RC12,RC12                                                                                22 JUN 72           15: 2:23
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E1201001OA)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:23

   SUBROUTINE RC12       ENTRY POINT 001011

   STORAGE USED- CODE(1) 001016; DATA(0) 000270; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z        002376
    0004   R        000014

   EXTERNAL REFERENCES (BLOCK, NAME)

    0005   SS02W
    0006   RCF1
    0007   EXP
    0010   NPRT$
    0011   NIO2$
    0012   NIO1$
    0013   NRDU$
    0014   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001     000044 1L        0001     000706 101L      0001     000236 1214L     0001     000335 1220L     0001     000561 1230L
    0000     000044 1290F     0000     000047 1292F     0000     000051 1805F     0000     000052 1810F     0000     000102 1815F
    0000     000106 1820F     0000     000113 1825F     0000     000116 1830F     0000     000122 1835F     0000     000125 1840F
    0000     000132 1845F     0000     000137 1850F     0000     000162 1855F     0001     000201 2L        0001     000354 207G
    0001     000361 213G      0001     000413 237G      0001     000420 243G      0001     000437 256G      0001     000444 262G
    0001     000463 275G      0000     000293 300F      0001     000470 301G      0000     000206 305F      0000     000027 333F
    0001     000536 337G      0001     000564 500L      0000     000024 6969F     0003     002232 A         0003     002317 BC
    0003 R   000000 C         0003 R   002363 CADK      0003 R   002334 CC        0003 R   002344 CH        0003 R   002341 CHB
    0003 R   002361 CPB       0003 R   002350 CPH       0003 R   002362 CPT       0004 R   000002 CXT       0003 R   002240 D
    0003 R   002214 DC        0000 R   000001 DEADVT    0003     002353 DD        0003     002365 DT        0004     000004 DUM1
    0004     000005 DUM2      0004     000006 DUM3      0000 R   000022 DURAT     0003 R   002257 F         0000 R   000000 FREQ
    0000 R   000003 HHATE     0000 R   000015 HVB       0000 R   000017 HVT       0003 I   002372 I         0003     002371 INDEX
    0000     000254 INJP$     0003     002366 IRK       0003     002370 ITERX     0003     002373 J         0003     002367 LOC
    0003     002374 M         0000 I   000004 MARKER    0003 I   002375 N         0000 R   000011 PAN2      0000 R   000014 PHCSF
    0000 R   000016 PHVB      0000 R   000020 PHVT      0000 R   000013 PTN2      0000 R   000012 PTD2      0003 R   002323 OF
    0006 R   000000 RCF1      0003     002016 RK        0004 R   000013 RMLIN     0003 R   002315 RMT       0004 R   000010 RMTB
    0004 R   000011 RMTB2     0000 R   000021 RMTM      0000 R   000021 RO        0003     002106 SC        0005 R   000000 SS02W
    0003     000174 SV        0003 R   002331 TAU       0000 R   000005 TCT       0004 R   000012 TIMECF    0000 R   000006 TIMECN
    0000 R   000002 TVNT      0000 R   000010 U         0003 R   002257 VE        0003 R   002360 VI        0001     002303 VOL
    0000 R   000007 VTIME     0003 R   001774 VTRAN     0004 R   000003 WORK      0004 R   000007 WORK2     0003     002364 X
    0004 R   000000 XDS       0004     000001 XMN       0003     000050 XN


00101        1*          SUBROUTINE RC12
00103        2*          DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103        3*         1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(15), RMT(2),
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                     RESP CASE NO. 1                                         DATE  220672  PAGE    29
00103            2         BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103            3         OO(4)
00104            COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, AMT, BC, OF,
00104            1         TAU, CC, CHB, CH, CPH, OO, VE, VI, CPB, CPT, CADK, X, DT,
00104            2         IRK, LOC, ITERX, INDEX, I, J, M, N
00105            COMMON/R/ XDS,XMN,CXT,WORK,DUM1,DUM2,DUM3,WORK2,AMTB,AMTB2,TIMEOF
00105            1   ,AMLIN
00106       6969                  FORMAT(1H 8HSUB RC12)
00106      C     OUTPUT -- PUNCHED CARDS AND PRINTED
00107            CXT=C(35)*XDS-10.
00110            IF(CXT.LE.0.)CXT=+0.
00112            FREQ=8.1+7.815*(AMT(2)*C(26))
00113            DEADVT=.1107*FREQ+.0785*VE
00113      C     C(31)=(DEADVT*C(1)+VE*DUM1)/(DEADVT+VE)
00113      C     C(32)=(DEADVT*C(2)+VE*DUM2)/(DEADVT+VE)
00113      C     C(33)=(DEADVT*C(3)+VE*DUM3)/(DEADVT+VE)
00114            TVNT=DEADVT*(VE+VI)/2.
00115            HRATE=43.8*(AMT(2)*C(26))+54.5
00116            IF(CXT.GE.TIMEOF)  GOTO500
00120            IF(MARKER.EQ.0) GOTO101
00122       1    WORK=WORK2
00123            MARKER=1
00124            IF(WORK.LE.0.)GOTO2
00126            IF(WORK.GE.50.) TCT=2.3/(2.+WORK/200.)
00130            IF(WORK.LT.50)TCT=4.6
00132            AMT(2)=SSO2W(WORK)-(SSO2W(WORK)-AMTB2)*EXP(-TCT*(CXT  -TIMEON))
00133            VTIME=TCT*(CXT-TIMEON)/4.2
00134            AMLIN =SSO2W(WORK)-(SSO2W(WORK)-AMTB2)*(1.-VTIME)
00135            IF(VTIME.GE.1.) AMLIN=SSO2W(WORK)
00137            AMT(1)=.88*AMT(2)
00140            IF(TVNT.GT.37.) AMT(1)=(TVNT+40.77)*AMT(2)/80.5
00142            IF(C(35).LT.C(40)) GOTO2
00144            PRINT 333,AMT(1),AMT(2)
00150     333    FORMAT(  ///,1X,25HCHANGE IN METABOLIC RATES,5X,7HMRCO2= ,F10.4,
00150           1  5X,6HMRO2= ,F10.4,/)
00151       2    CONTINUE
00152            U = AMOD(C(35), 0.5)
00153            IF (U .LT. 1.0E-5 .OR. U .GT. .4999)        GO TO 1210
00155            IF(C(35).LT.C(40))GOTO1230
00157            C(40)=C(40)+C(39)
00160     1210   PAN2 = D(1)*C(3)
00161            PTO2 = C(8)/D(3)
00162            PTN2 = C(9)/D(4)
00163            PHCSF = 9. - RCF1(CH(4))
00164            HVB   = CADK*F(4)/(CC(2) - F(4))
00165            PHVB  = 9. - RCF1(HVB)
00166            HVT   = CADK*F(6)/(CC(3) - F(6))
00167            PHVT  = 9. - RCF1(HVT)
00170            RQ = ((C(11)*VTRAN(4) + OF(1)*VTRAN(7))/C(10) - CC(1))/
00170           1      (F(4) - (C(11)*VTRAN(5) + OF(1)*VTRAN(8))/C(10))
00171            OF(5) = OF(6) - RQ
00172            IF (N .NE. 4)      GO TO 1220
00174            N = 0
00175            PRINT 1805
00177     1220   N = N + 1
00177      C
00200            PRINT  1810,                               CXT,RQ,OF(5)
00200      C
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                         RESP CASE NO. 1                                        DATE  220672  PAGE    30
00205                  PRINT       1815, (C(I), I = 1,3), (DC(I), I = 1,3), F(7), F(1),
00205                 1      PAN2
00222                  PRINT       1820, CC(1), F(9), F(10), F(7), F(1), PAN2, CM(1),
00222                 1      CPM(1), CMB(1)
00235                  PRINT       1825, (C(I), I = 4,6), (DC(I), I = 4,6), CPB, F(17),
00235                 1      F(18), CM(2), CPM(2)
00254                  PRINT       1830, (C(I), I = 7,9), (DC(I), I = 7,9), CPT, PTO2,
00254                 1      PTN2, CM(3), CPM(3)
00273                  PRINT       1835, (DC(I), I = 12,14), (C(I), I = 12,14), CM(4),
00273                 1      PMCSF
00307                  PRINT       1840, CC(2), F(12), C(6), CPB, F(17), F(18), HVB,
00307                 1      PHVB, CMB(2)
00322                  PRINT       1845, CC(3), F(13), C(9), CPT, PTO2, PTN2, HVT,
00327                 1      PHVT, CMB(3)
00335                  PRINT       1850, (TAU(I), I = 1,5), VI, VE, C(10), C(11), DC(10),
00335                 1      DC(11)
00351                  PRINT 1855, FREQ,TVNT,DEADVT,HRATE
00357             1230 RETURN
00360             1290 FORMAT (5H XXXX5X7F10.4)
00361             1292 FORMAT (8F10.4)
00362             1805 FORMAT (1H1)
00363             1810 FORMAT (1H0X14HTIMEF10.4,7X16HALV ROF10.4,3X7HRQ DIFFF10.4/
00363                 1      16X3HCO2PX2HO2PX2HN27X21HD E R I V A T I V E S9X4HPCO26X
00363                 2      3HPO27X3HPN27X4HCH+17X2HPH7X4HHBO2)
00364             1815 FORMAT (3XPHALVEOLAR9F10.4)
00365             1820 FORMAT (3XPHARTERIAL3F10.4,30X6F10.4)
00366             1825 FORMAT (6X5HBRAIN11F10.4)
00367             1830 FORMAT (5X6HTISSUE11F10.4)
00370             1835 FORMAT (8X3HCSF30XPF10.4)
00371             1840 FORMAT (4X7HV BRAIN3F10.4,30X6F10.4)
00372             1845 FORMAT (3XPHV TISSUE3F10.4,30X6F10.4)
00373             1850 FORMAT (5X12HTRANSPORT TIMES --4X2HABRX2HVBRX2HVTRX2HATRX2HAC2X
00373                 1  2H**4X2HVI8X2HVERX1HO9X2HFB7X11HDERIVATIVES/21X11F10.4)
00374             1855 FORMAT( 3X,9HRESP FREQ,F10 4,5X,13HMINUTE VOLUME,F10.4,5X,
00374                 1   15HDEAD SPACE VENT,F10 4,10X,10HHEART RATE,F10.4)
00375             500  READ(5,300,END=2) WORK2,DURAT
00401             300  FORMAT(F6.2,3X,F6.2)
00402                  PRINT 305, WORK2
00405             305  FORMAT(//1X,29HCHANGE IN WORK LOAD,  WORK = , F6.2,1X,5HWATTS)
00406                  TIMEOF=DURAT+CXT
00407                  TIMEON=CXT
00410                  IF(WORK2.GE.WORK)RMTB2=RMT(2)
00412                  IF(WORK2.LT.WORK) RMTM=RMT(2)
00414                  IF(WORK2.LT.WORK)RMTB=SSO2W(WORK2)
00416                  IF((WORK2.LT.WORK).AND.(WORK.GE.50.))   TCT=2.3/(2.+WORK/200.)
00420                  IF((WORK2.LT.WORK).AND.(WORK.LT.50.))TCT=4.6
00422                  IF(WORK2.GE.WORK) GOTO1
00424              101 WORK=WORK2
00425                  MARKER=0
00426                  RMT(2)=RMTB-(RMTB-RMTM)*EXP(-TCT*(CXT-TIMEON)*.50)
00427                  VTIME=TCT*(CXT-TIMEON)/4.2
00430                  RMLIN =RMTB-(RMTB-RMTM)*(1.-VTIME)
00431                  IF(VTIME.GE.1.) RMLIN=RMTB
00433                  RMT(1)=.88*RMT(2)
00434                  IF(TVNT.GT 37.) RMT(1)=(TVNT+40.77)*RMT(2)/88.5
00436                  IF(C(35).LT.C(40)) GOTO2
00440                  PRINT 333,RMT(1),RMT(2)
00444                  GOTO2
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                    RESP CASE NO. 1                                DATE 220672 PAGE   31
00945    120*       END

     END OF COMPILATION:       NO DIAGNOSTICS.
   RC12              SYMBOLIC                      29 JAN 72  16:17:19   0  01962750   19   120 (DELETED)
   RC12     CODE     RELOCATABLE                   29 JAN 72  16:17:19   1  01966170   36     1 (DELETED)
                                                                         0  01966239   19    71
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                    RESP CASE NO. 1                              DATE  220672  PAGE    32
@ FOR,* RC13,RC13                                                              22 JUN 72          15: 2:26
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E1201001OA)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:26

  SUBROUTINE RC13      ENTRY POINT 000322

  STORAGE USED· CODE(1) 000333; DATA(0) 000057; BLANK COMMON(2) 000000

   COMMON BLOCKS:

   0003   Z       002376

  EXTERNAL REFERENCES (BLOCK, NAME)

   0004   RC14
   0005   NERR2$
   0006   NERR3$

  STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

   0001     000006 113G       0001     000022 116G       0001     000050 125G       0001     000037 1312L      0001     000057 1320L
   0001     000110 1328L      0001     000136 1336L      0001     000141 1340L      0001     000171 1352L      0001     000176 1356L
   0001     000101 136G       0001     000230 1364L      0001     000131 146G       0001     000152 156G       0001     000202 170G
   0001     000237 202G       0001     000261 211G       0001     000274 221G       0001     000275 224G       0000     000001 6969F
   0003     002232 A          0003     002317 BC         0003 R 000000 C           0003     002363 CADX       0003     002336 CC
   0003     002344 CH         0003     002341 CHB        0003     002361 CPB        0003     002350 CPH        0003     002362 CPT
   0003     002240 D          0000     000006 DBG        0003 R 002214 DC          0003     002353 DD         0003     002365 DT
   0003     002257 F          0003 I 002372 I            0003 I 002371 INDEX       0000     000037 INJP$      0003 I 002366 IRK
   0003     002370 ITERX      0003 I 002373 J            0003     002367 LOC        0003 I 002374 M           0003     002375 N
   0003     002323 OF         0003 R 002016 RK           0003     002315 RMT        0003 R 002106 SC          0003     000170 SV
   0003     002331 TAU        0000 R 000000 TI           0003     002357 VE         0003     002360 VI         0003     002303 VOL
   0003     001774 VTRAN      0003     002364 X          0003     000050 XN
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00101            SUBROUTINE RC13
00103            DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103           1         SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103           2        BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103           3         DD(4)
00104            COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, OF,
00104           1       TAU, CC, CHB, CH, CPH, DD, VE, VI, CPB, CPT, CADX, X, DT,
00104           2       IRK, LOC, ITERX, INDEX, I, J, M, N
00105       6969             FORMAT(1H PNSUB RC13)
00105      C     SOLVES M DIFFERENTIAL EQUATIONS BY FOURTH-ORDER RUNGE-KUTTA AND
00105      C     ADAMS-MOULTON PREDICTOR-CORRECTOR METHODS
00106            NAMELIST/DBG/C,DC,SC                  <--------------------------- L≈0
00107            IF (IRK - 4)        1304, 1356, 1356
00112       1304 DO 1352 INDEX = 1,4
00115            DO 1308 I = 1,M
00120            RK(I,INDEX) = DC(I)
00121       1308 CONTINUE
00123            GO TO (1312, 1320, 1328, 1340), INDEX
```

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                     RESP CASE NO. 1                              DATE  220672  PAGE   33
00124      1312 DO 1316 I = 1,M
00127           SC(I,IRK+1) = C(I)
00130           SC(I,IRK) = DC(I)
00131      1316 CONTINUE
00133           TI = C(35)
00134      1320 C(35) = TI + C(36)/2.0
00135           DO 1324 I = 1,M
00140           C(I) = SC(I,IRK+1) + C(36)*RK(I,INDEX)/2.0
00141      1324 CONTINUE
00143           GO TO 1336
00144      1328 C(35) = TI + C(36)
00145           DO 1332 I = 1,M
00150           C(I) = SC(I,IRK+1) + C(36)*RK(I,INDEX)
00151      1332 CONTINUE
00153      1336 CALL RC14
00154           GO TO 1352
00155      1340 DO 1344 I = 1,M
00160           C(I) = SC(I,IRK+1) + C(36)*(RK(I,1) + 2.0*RK(I,2) + 2.0*RK(I,3)
00160          1        + RK(I,4))/6.0
00161      1344 CONTINUE
00163           IRK = IRK + 1
00164      1352 CONTINUE
00166           RETURN
00167      1356 DO 1360 I = 1,M
00172           SC(I,5) = C(I)
00173           SC(I,4) = DC(I)
00174           C(I) = SC(I,5) + C(36)*(55.0*SC(I,4) - 59.0*SC(I,3) + 37.0*SC(I,2)
00174          1        - 9.0*SC(I,1))/24.0
00175      1360 CONTINUE
00177           C(35) = C(35) + C(36)
00200      1364 CALL RC14
00201           DO 1368 I = 1,M
00204           SC(I,1) = C(I)
00205           C(I) = SC(I,5) + C(36)*(9.0*DC(I) + 19.0*SC(I,4) - 5.0*SC(I,3)
00205          1        + SC(I,2))/24.0
00206      1368 CONTINUE
00210           DO 1372 I = 1,M
00213           IF  (ABS  (C(I) - SC(I,1)) - 1.0E-5)  1372, 1372, 1364
00216      1372 CONTINUE
00220           DO 1376 I = 1,M
00223           DO 1376 J = 1,3
00226           SC(I,J) = SC(I,J+1)
00227      1376 CONTINUE
00232           RETURN
00233           END
```

Handwritten corrections (with arrows to the listing):

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                                        1372,1372,1370
1370  L=L+1
      IF(L-15)1364,1364,1377
1377  WRITE(6,1378) L, I, C(I), SC(I,1)
1378  FORMAT(2X,2HL=,I4,3X,2HI=,I4,3X,5HC(I)=,
     1 F10.4,3X,8HSC(I,1)=, F10.4)
```

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   END OF COMPILATION:        NO  DIAGNOSTICS.
RC13            SYMBOLIC                     24 JAN 72  16:17:21   0  01470176   14    63 (DELETED)
RC13     CODE   RELOCATABLE                  24 JAN 72  16:17:21   1  01471760   24     1 (DELETED)
                                                                   0  01472010   14    27
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                    RESP CASE NO. 1                                    DATE  220672  PAGE    34
* FOR,* RC14,RC14                                                                            22 JUN 72          15: 2:28
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E1201001OA)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:28

   SUBROUTINE RC14      ENTRY POINT 000077

   STORAGE USED- CODE(1) 000101; DATA(0) 000010; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z       002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   RC3
    0005   RC8
    0006   RC9
    0007   RC4
    0010   RC5
    0011   RC21
    0012   RC19
    0013   RC10
    0014   RC20
    0015   RC11
    0016   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000     000000 6969F      0003     002232 A        0003 R 002317 BC       0003 R 000000 C        0003     002363 CADX
    0003 R 002336 CC         0003 R 002344 CN         0003 R 002341 CNB      0003 R 002361 CPB      0003 R 002350 CPN
    0003 R 002362 CPT        0003     002240 D        0003     002214 DC     0003     002353 DQ      0003     002365 DT
    0003 R 002257 F          0003     002372 I        0003     002371 INDEX   0000     000003 INJP$   0003     002366 IRK
    0003     002370 ITERX    0003     002373 J        0003     002367 LOC     0003     002374 M       0003     002375 N
    0003     002323 QF       0003     002016 RK       0003     002315 RMT     0003     002106 SC      0003     000170 SV
    0003     002331 TAU      0003     002357 VE       0003     002360 VI      0003     002303 VOL     0003     001774 VTRAN
    0003     002364 X        0003     000050 XN


00101        1*           SUBROUTINE RC14
00103        2*           DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103        3*          1         SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103        4*          2         BC(4), QF(6), TAU(5), CC(3), CNB(3), CN(4), CPN(3),
00103        5*          3         DQ(4)
00104        6*           COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104        7*          1      TAU, CC, CNB, CN, CPN, DQ, VE, VI, CPB, CPT, CADX, X, DT,
00104        8*          2      IRK, LOC, ITERX, INDEX, I, J, M, N
00104        9*       C   CALLS OTHER SUBROUTINES IN A BLOCK
00105       10*      6969            FORMAT(1H 8HSUB RC14)
00106       11*           CALL RC3
00107       12*           CALL RC8
00110       13*           CALL RC9
00111       14*           CALL RC4
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                         RESP CASE NO. 1                                      DATE  220672  PAGE    35
00112            CALL RC5 (CPB, F(4), C(4), BC(2))
00113            CALL RC21 (CMB(2), F(3), F(4), C(4), CM(2), CPM(2))
00114            CALL RC14 (CPB, CMB(2), CC(2), BC(1), F(4))
00115            CALL RC5 (CPT, F(6), C(7), BC(3))
00116            CALL RC21 (CMB(3), F(5), F(6), C(7), CM(3), CPM(3))
00117            CALL RC14 (CPT, CMB(3), CC(3), BC(1), F(6))
00120            CALL RC10
00121            CALL RC20
00122            CALL RC11
00123            RETURN
00124            END

     END OF COMPILATION:        NO  DIAGNOSTICS.
   RC14           SYMBOLIC                                24 JAN 72  16:17:22   0  01472602   14    25  (DELETED)
   RC14    CODE   RELOCATABLE                             24 JAN 72  16:17:22   1  01473340   36     1  (DELETED)
                                                                                0  01473404   14     9
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                         RESP CASE NO. 1                                    DATE  220672  PAGE    38
@ FOR,IS RC15,RC15    RELOCATABLE                                29 JAN 72  16:17:24   1  01474228 JUN292     1  (DELETED)2:29
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E1201001OA)                     0  01474244    14      6
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:29

   SUBROUTINE RC15       ENTRY POINT 000042

   STORAGE USED: CODE(1) 000050, DATA(0) 000026, BLANK COMMON(2) 000000

   COMMON BLOCKS:

    0003   Z        002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001    000002 11GG       0001   000005 113G       0000   000042 6969F      0003   002232 A          0003   002317 BC
    0003    000000 C          0003   002363 CADR       0003   002334 CC         0003   002344 CH         0003   002341 CHB
    0003    002361 CPB        0003   002350 CPH        0003   002342 CPT        0003   002240 D          0003   002214 DC
    0003    002353 DO         0003   002365 DT         0003   002257 F          0003 I 002372 I          0003   002371 INDEX
    0000    000014 INJP$      0003   002366 IRK        0003   002370 ITERX      0003 I 002373 J          0000 I 000000 JM
    0000 I  000001 JMM        0003   002367 LOC        0003   002374 M          0003   002375 N          0003   002323 QF
    0003    002016 RK         0003   002315 RMT        0003   002106 SC         0000   000007 SCH        0003 R 000170 SV
    0003    002331 TAU        0003   002357 VE         0003   002360 VI         0003   002303 VOL        0003   001774 VTRAN
    0003    002364 X          0003   000050 XN


00101       1*          SUBROUTINE RC15
00103       2*          DIMENSION C(40), XN(40,2), SV(10,50), VTRAN(10), RK(14,4),
00103       3*         1           SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103       4*         2           BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103       5*         3           DO(4)
00104       6*          COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104       7*         1       TAU, CC, CHB, CH, CPH, DO, VE, VI, CPB, CPT, CADR, X, DT,
00104       8*         2       IRK, LOC, ITERX, INDEX, I, J, M, N
00105       9*      6969             FORMAT(1H @HSUB RC15)
00106      10*          NAMELIST/SCH/SV
00106      11*     C    SHIFTS VALUES IN SV ARRAY
00107      12*          DO 1520 I = 1,10
00112      13*          DO 1520 J = 1,49
00115      14*          JM = 51 - J
00116      15*          JMM = JM - 1
00117      16*          SV(I,JM) = SV(I,JMM)
00120      17*     1520 CONTINUE
00123      18*          RETURN
00124      19*          END

      END OF COMPILATION:        NO  DIAGNOSTICS.
   RC15              SYMBOLIC                                        29 JAN 72  16:17:24   0  01473602    14     19  (DELETED)
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                          RESP CASE NO. 1                                  DATE  220672  PAGE    30
@ FOR,* RC16,RC16                                                                 22 JUN 72               15: 2:30
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E1201001OA)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:31

   SUBROUTINE RC16      ENTRY POINT 000062

   STORAGE USED: CODE(1) 000071; DATA(0) 000022; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z       002376
    0004   R       000014

   EXTERNAL REFERENCES (BLOCK, NAME)

    0005   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000     000000 6969F      0003    002232 A         0003    002317 BC        0003 R 000000 C          0003    002363 CADK
    0003 R 002336 CC           0003 R 002344 CH         0003    002341 CHB       0003    002361 CPB       0003    002350 CPN
    0003    002362 CPT         0004    000002 CXT       0003    002240 D         0003    002214 DC        0003    002353 DQ
    0003    002365 DT          0004    000004 DUM1      0004    000005 DUM2      0004    000006 DUM3      0003 R 002297 F
    0003    002372 I           0003    002371 INDEX     0000    000003 INJP$     0003    002366 IRK       0003    002370 ITERX
    0003    002373 J           0003    002367 LOC       0003    002374 M         0003    002375 N         0003 R 002323 QF
    0003    002016 RK          0004    000013 RMLIN     0003    002315 RMT       0004    000010 RMTB      0004    000011 RMTB2
    0003    002106 SC          0003 R 000170 SV         0003    002331 TAU       0004    000012 TIMEOF    0003    002357 VE
    0003    002360 VI          0003    002303 VOL       0003    001774 VTRAN     0004    000003 WORK      0004    000007 WORK2
    0003    002364 X           0004    000000 XDS       0004    000001 XMN       0003    000050 XN


00101       1*            SUBROUTINE RC16
00103       2*            DIMENSION C(40), XN(40,2), SV(10,50), VTRAN(10), RK(14,4),
00103       3*           1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103       4*           2          BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPN(3),
00103       5*           3          DQ(4)
00104       6*            COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104       7*           1       TAU, CC, CHB, CH, CPN, DQ, VE, VI, CPB, CPT, CADK, X, DT,
00104       8*           2       IRK, LOC, ITERX, INDEX, I, J, M, N
00105       9*            COMMON/R/ XDS,XMN,CXT,WORK,DUM1,DUM2,DUM3,WORK2,RMTB,RMTB2,TIMEOF
00105      10*           1  ,RMLIN
00106      11*        6969           FORMAT(1H RHSUB RC16)
00106      12*      C     SETS VALUES FOR SV ARRAY
00107      13*            SV(1,1) = CC(1)
00110      14*            SV(2,1) = F(9)
00111      15*            SV(4,1) = CC(2)
00112      16*            SV(3,1) = F(10)
00113      17*            SV(5,1) = F(12)
00114      18*            SV(6,1) = C(6)
00115      19*            SV(7,1) = CC(3)
00116      20*            SV(8,1) = F(13)
00117      21*            SV(9,1) = C(9)
```

```
                 RESP CASE NO. 1                                DATE  220672  PAGE    39
                 SV(10,1) = C(10)
                 SV(11,1) = C(11)
                 SV(12,1) = OF(1)
                 SV(13,1) = CH(1)
                 SV(14,1) = F(1)
                 SV(15,1) = 0.0
                 SV(16,1) = SV(4,1) + SV(5,1) + SV(6,1)
                 SV(17,1) = SV(7,1) + SV(8,1) + SV(9,1)
                 SV(18,1) = C(35)
                 RETURN
                 END

   END OF COMPILATION:        NO  DIAGNOSTICS.
 RC16            SYMBOLIC                              24 JAN 72  16:17:25  0  01474370   14    32 (DELETED)
 RC16    CODE    RELOCATABLE                           24 JAN 72  16:17:25  1  01475270   24     1 (DELETED)
                                                                            0  01475320   14     7
```

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                         RESP CASE NO. 1                               DATE  220672  PAGE     40
* FOR,* RC17,RC17                                                                   22 JUN 72              15: 2:32
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:32

   SUBROUTINE RC17       ENTRY POINT 000171

   STORAGE USED- CODE(1) 000173; DATA(0) 000157; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003  Z      002376
    0004  R      000014

   EXTERNAL REFERENCES (BLOCK, NAME)

    0005   SSVENT
    0006   SS02W
    0007   NEXP6$
    0010   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001     000015 1700L      0001     000033 1720L      0001     000127 1730L      0001     000160 1740L      0000     000136 6969F
    0003     002232 A          0000     000027 BAD        0003 R 002317 BC          0003 R 000000 C           0003 R 002363 CADX
    0003     002336 CC         0003 R 002344 CH          0003     002341 CHB        0003     002361 CPB        0003     002350 CPH
    0003     002362 CPT        0004     000002 CXT        0003 R 002240 D           0003     002214 DC         0003     002353 DQ
    0003     002365 DT         0004     000004 DUM1       0004     000005 DUM2       0004     000006 DUM3       0003 R 002257 F
    0003     002372 I          0003     002371 INDEX      0000     000151 INJP$      0003     002366 IRK        0003     002370 ITERX
    0003     002373 J          0003     002367 LOC        0003     002374 M          0003     002375 N          0003 R 002323 QF
    0003     002016 RK         0004 R 000013 RMLIN       0003     002315 RMT        0004     000010 RMTB       0004     000011 RMTB2
    0003     002106 SC         0006 R 000000 SS02W       0005 R 000000 SSVENT      0003     000170 SV         0000 R 000002 SVNT
    0000 R 000001 SVNT2       0003     002331 TAU        0000 R 000000 TERM        0004     000012 TIMEOF     0003 R 002357 VE
    0003 R 002360 VI          0003     002303 VOL        0003 R 001774 VTRAN       0004 R 000003 WORK        0004     000007 WORK2
    0003     002364 X          0004     000000 XDS        0004     000001 XMH        0003     000050 XN


00101      1*           SUBROUTINE RC17
00103      2*           DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103      3*          1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103      4*          2          BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103      5*          3          DQ(4)
00104      6*           COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104      7*          1       TAU, CC, CHB, CH, CPH, DQ, VE, VI, CPB, CPT, CADX, X, DT,
00104      8*          2       IRK, LOC, ITERX, INDEX, I, J, M, N
00105      9*           COMMON/R/ XDS,XMH,CXT,WORK,DUM1,DUM2,DUM3,WORK2,RMTB,RMTB2,TIMEOF
00105     10*          1  ,RMLIN
00106     11*           NAMELIST/BAD/CH(4),CADX,D(11),C(12),BC(4),C(37),C(38),VTRAN(14),
00106     12*          1TERM,VI,C(20),C(16),VTRAN(15),C(21),VTRAN(13),C(37),D(9),C(11),
00106     13*          2VTRAN(16),QF(1),VTRAN(17),C(10),F(11),
00107     14*      6969             FORMAT(1H PHSUB RC17)
00107     15*     C     CALCULATES VENTILATION
00110     16*           CH(4)  = CADX*D(11)*C(12)/BC(4)
```

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                 RESP CASE NO. 1                                   DATE  220672  PAGE    91
      IF (C(37) .GT. 1.0E-5)       GO TO 1708
 1709 VI = C(38)
      GO TO 1730
 1708 TERM = 0.0
      IF (VTRAN(19) - 109.0)       1710, 1720, 1720
 1710 TERM = (23.6E-9)*((109.0 - VTRAN(19))**4.9)
 1720 VI = C(20)*(C(16)*VTRAN(15) + (1.0 - C(16))*CM(9))
     1       + C(21)*VTRAN(13) + TERM - C(37)
      SVNT2=SSVENT(SSO2W(WORK))  -VI
      IF((SVNT2.GT.0.) AND.(SVNT2.LE.15.))   VI=VI+SVNT2
      IF(SVNT2.GT.15.)  VI=VI+15.
      SVNT =SSVENT(RMLIN ) -VI
      IF(SVNT.GT.0.5)   VI=VI+0.75*SVNT
 1730 VE = VI + D(9)*(C(11)*VTRAN(16) + DF(1)*VTRAN(17) - C(10)*F(15))
      IF (VI .LT. 0.0 .OR. VE .LT. 0.0)     GO TO 1740
      RETURN
 1740 VI = 0.0
      VE = 0.0
      RETURN
      END

    END OF COMPILATION          NO  DIAGNOSTICS.
  RC17              SYMBOLIC                          29 JAN 72  16:17:26  0  01975962   19    36 (DELETED)
  RC17      CODE    RELOCATABLE                       29 JAN 72  16:17:26  1  01974952   36     1 (DELETED)
                                                                           0  01976516   19    28
```

VO=VI

SW=SSVENT(SSO2W(WORK))
SR=SSVENT(RMLIN)
1735 WRITE(6,1737)VO,VI,SVNT2,SW,SR,VE,C(35),SVNT,TCT,
1 VTIME,RMLIN
1737 FORMAT(11F12.4)

RESP CASE NO. 1 DATE 220672 PAGE 92

@ FOR,* RC19,RC19 22 JUN 72 15: 2:33

UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A -(EXEC8 LEVEL E1201001OA)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:33

SUBROUTINE RC19 ENTRY POINT 000095

STORAGE USED: CODE(1) 000076; DATA(0) 000092; BLANK COMMON(2) 000000

COMMON BLOCKS:

0003 Z 002376

EXTERNAL REFERENCES (BLOCK, NAME)

0004 RCF1
0005 RC6
0006 NERR3$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000000 1910L	0000	000021 6969F	0003	002232 A	0003	002317 BC	0003 R	000060 C
0003	002363 CADR	0003	002336 CC	0003	002344 CH	0003	002341 CHB	0003	002361 CPB
0003	002350 CPH	0003	002362 CPT	0003 R	002240 D	0003	002214 DC	0000	000000 DM2
0003	002353 DO	0003	002365 DT	0003	002257 F	0003	002372 I	0003	002371 INDEX
0000	000031 INJP$	0003	002366 IRK	0003 I	002370 ITERX	0003	002373 J	0003	002367 LOC
0003	002374 M	0003	002375 N	0003	002323 OF	0004 R	000000 RCF1	0003	002016 RK
0003	002315 RMT	0003	002106 SC	0003	000170 SV	0003	002331 TAU	0003	002357 VE
0003	002360 VI	0003	002303 VOL	0003	001774 VTRAN	0003 R	002364 X	0003	000050 XN

```
00101             SUBROUTINE RC19 (CPA, CVHBA, CVC, BHCA, FC)
00103             DIMENSION C(90), XN(40,2), SV(18,50), VTRAN(18), RK(19,9),
00103            1          SC(19,9), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103            2          BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103            3          DO(4)
00104             COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, OF,
00104            1        TAU, CC, CHB, CH, CPH, DO, VE, VI, CPB, CPT, CADR, X, DT,
00104            2        IRK, LOC, ITERX, INDEX, I, J, M, N
00105             NAMELIST/DM2/CPA,CVHBA,CVC,BHCA,FC
00106        6969             FORMAT(1H BHSUB RC19)
00106      C      ITERATES FOR VENOUS BRAIN AND VENOUS TISSUE CO2 CONCENTRATION
00107        1910 X = (CVC - FC)/(0.01*CPA)
00110             X = RCF1(X)
00111             X = BHCA + 0.375*(C(17) - CVHBA) - D(8)*(X - 0.14) + FC
00112             CALL RC6 (CVC)
00113             CVC = CVC + 2.0*(X - CVC)/3.0
00114             IF (ITERX)         1920, 1910, 1920
00117        1920 CONTINUE
00120             RETURN
00121             END
```

RESP CASE NO. 1 DATE 220672 PAGE 93

```
   END OF COMPILATION:        NO  DIAGNOSTICS.
RC19          SYMBOLIC                          29 JAN 72  16:17:27  0  01977326   19   20 (DELETED)
RC19    CODE  RELOCATABLE                       29 JAN 72  16:17:27  1  01977756   29    1 (DELETED)
                                                                     0  01500006   19   10
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                    RESP CASE NO. 5                                  DATE  220672  PAGE    44
@ FOR,* RC20,RC20                                                                  22 JUN 72          15: 2:34
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E1201001OA)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:34

   SUBROUTINE RC20       ENTRY POINT 000051

   STORAGE USED- CODE(1) 000053; DATA(0) 000015; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z        002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004    NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   000005 4969F      0003   002212 A        0003   002317 BC       0003 R 000000 C       0003   002363 CADR
    0003 R 002334 CC         0003   002344 CH       0003 R 002341 CHB      0003 R 002361 CPB     0003   002350 CPH
    0003   002362 CPT        0003 R 002240 D        0003   002214 DC       0003   002353 DD     0003   002365 DT
    0003 R 002257 F          0003   002372 I        0003   002371 INDEX    0000   000010 INJP$  0003   002366 IRR
    0003   002370 ITERX      0003   002373 J        0003   002367 LOC      0003   002374 M      0003   002375 N
    0000   000000 NMF        0003   002323 OF       0003   002016 RK       0003   002315 RMT    0003   002106 SC
    0003   000170 SV         0003   002331 TAU      0003   002357 VE       0003   002360 VI     0003   002303 VOL
    0003   001774 VTRAN      0003   002364 X        0003   000050 XN


00101       1*          SUBROUTINE RC20
00103       2*          DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103       3*         1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103       4*         2          BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103       5*         3          DD(4)
00104       6*          COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, OF,
00104       7*         1      TAU, CC, CHB, CH, CPH, DD, VE, VI, CPB, CPT, CADR, X, DT,
00104       8*         2      IRR, LOC, ITERX, INDEX, I, J, M, N
00105       9*          NAMELIST/NMF/F
00106      10*     4969            FORMAT(1H PHSUB RC20)
00106      11*    C     SETS TIME DEPENDENT EXPRESSIONS
00107      12*          F(9) = D(6)*C(2) + CHB(1)
00110      13*          F(10) = D(7)*C(3)
00111      14*          F(11) = CC(1) + F(9) + F(10)
00112      15*          F(12) = C(5) + CHB(2)
00113      16*          F(13) = C(8) + CHB(3)
00114      17*          F(17) = C(5)/D(3)
00115      18*          F(18) = C(6)/D(4)
00116      19*          F(14) = C(27)*(CPB - C(12))
00117      20*          F(15) = C(28)*(F(17) - C(13))
00120      21*          F(16) = C(24)*(F(18) - C(14))
00121      22*          RETURN
00122      23*          END
```

END OF COMPILATION: NO DIAGNOSTICS.

RC20		SYMBOLIC	29 JAN 72	16:17:29	0	01500222	19	23	(DELETED)
RC20	CODE	RELOCATABLE	29 JAN 72	16:17:29	1	01500729	29	1	(DELETED)
					0	01500759	19	7	

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                    RESP CASE NO. 1                                        DATE  220672  PAGE    96
@ FOR,* RC21,RC21                                                                   22 JUN 72              15: 2:36
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:36

   SUBROUTINE RC21       ENTRY POINT 000040

   STORAGE USED- CODE(1) 000065; DATA(0) 000037; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z       002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   RCF1
    0005   RCF2
    0006   EXP
    0007   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   000000 6969F     0003   002232 A       0003   002317 BC       0003 R 000000 C       0003 R 002363 CADK
    0003   002336 CC        0003   002344 CH      0003   002341 CHB      0003   002361 CPB     0003   002350 CPH
    0003   002362 CPT       0003   002240 D       0003   002214 DC       0003   002353 DQ      0003   002365 DT
    0003   002257 F         0003   002372 I       0003   002371 INDEX    0000   000031 INJP$   0003   002366 IRK
    0003   002370 ITERX     0003   002373 J       0003   002367 LOC      0003   002374 M       0003   002375 N
    0000   000003 PB        0003   002323 QF      0004 R 000000 RCF1     0005 R 000000 RCF2    0003   002016 RK
    0003   002315 RMT       0003   002106 SC      0003   000170 SV       0003   002331 TAU     0003   002357 VE
    0003   002360 VI        0003   002303 VOL     0003   001774 VTRAN    0003 R 002364 X       0003   000050 XN


00101                SUBROUTINE RC21 (CHBA, FA, FD, CCA, CHA, CPHA)
00103                DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103              1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103              2          BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103              3          DQ(4)
00104                COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104              1        TAU, CC, CHB, CH, CPH, DQ, VE, VI, CPB, CPT, CADK, X, DT,
00104              2        IRK, LOC, ITERX, INDEX, I, J, M, N
00105         6969              FORMAT(1H RHSUB RC21)
00106                NAMELIST/PB/CHBA,FA,FD,CCA,CHA,CPHA
00106         C      COMPUTES H+ ION, PH, AND OXYHEMOGLOBIN
00107                CHA = CADK*FD/(CCA - FD)
00110                CPHA = 9.0 - RCF1(CHA)
00111                X = RCF2(CPHA)
00112                X = -X + FA
00113                X = (1.0 - EXP (X))**2
00114                CHBA = X*C(17)
00115                RETURN
00116                END
```

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                     RESP CASE NO. 1                                        DATE  220672  PAGE    97

   END OF COMPILATION:        NO  DIAGNOSTICS.
 RC21           SYMBOLIC                                  29 JAN 72  16:17:30   0  01501116    19    19 (DELETED)
 RC21    CODE   RELOCATABLE                               29 JAN 72  16:17:30   1  01501530    29     1 (DELETED)
                                                                                0  01501560    19     9
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                          RESP CASE NO. 1                                            DATE  220672  PAGE    40
* FORC*2RC22C*OE2   RELOCATABLE                                  24 JAN 72  16:17:31   1  01502408 JUN272    1 (DELETED)2:37
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E1201001OA)                     0  01502436    14     9
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:37

   SUBROUTINE RC22       ENTRY POINT 000031

   STORAGE USED: CODE(1) 000036; DATA(0) 000014; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z       002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   RERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   000000 6969F      0003   002232 A        0003   002317 BC       0003 R 000000 C        0003   002363 CADK
    0003   002336 CC         0003   002344 CH       0003   002341 CHB      0003   002361 CPB      0003   002350 CPH
    0003   002362 CPT        0003   002240 D        0003   002214 DC       0003   002353 DD       0003   002365 DT
    0003   002257 F          0003   002372 I        0003   002371 INDEX    0000   000004 INJP$    0003   002366 IRK
    0003   002370 ITERX      0003   002373 J        0003   002367 LOC      0003   002374 M        0003   002375 N
    0003   002323 QF         0003   002016 RK       0003   002315 RMT      0003   002106 SC       0003   000170 SV
    0003   002331 TAU        0003   002357 VE       0003   002360 VI       0003   002303 VOL      0003   001774 VTRAN
    0003   002364 X          0003   000050 XN


00101            SUBROUTINE RC22 (COJA, DJA, IDJA)
00103            DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103           1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103           2          BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103           3          DD(4)
00104            COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104           1       TAU, CC, CHB, CH, CPH, DD, VE, VI, CPB, CPT, CADK, X, DT,
00104           2       IRK, LOC, ITERX, INDEX, I, J, M, N
00105            DIMENSION CDJA(6), DJA(4), IDJA(2)
00106       6969          FORMAT(1H ,8HSUB RC22)
00106      C     SETS UP CONDITIONS FOR DEJOURS EXPERIMENT
00107            COJA(1) = C(31)
00110            COJA(2) = C(33)
00111            COJA(3) = 0.0
00112            COJA(4) = C(31) + C(33)
00113            IDJA(1) = 1
00114            IDJA(2) = 1
00115            DJA(3) = DJA(1) - .0001
00116            RETURN
00117            END

      END OF COMPILATION:        NO  DIAGNOSTICS.
    RC22             SYMBOLIC                                     24 JAN 72  16:17:31   0  01501756    14    70 (DELETED)
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                    RESP CASE NO. 1                              DATE  220672  PAGE    50
* FOR,* RC23,RC23                                                      22 JUN 72             15: 2:30
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXFCB LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:30

  SUBROUTINE RC23       ENTRY POINT 000062

  STORAGE USED- CODE(1) 000070; DATA(0) 000016; BLANK COMMON(2) 000000

   COMMON BLOCKS:

   0003   Z        002376

  EXTERNAL REFERENCES (BLOCK, NAME)

   0004   NERR3$

  STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

   0001    000035 2320L     0000   000000 6969F     0003   002232 A        0003   002317 BC       0003 R 000000 C
   0003    002363 CADX      0003   002336 CC        0003   002344 CH       0003   002341 CHB      0003   002361 CPB
   0003    002350 CPH       0003   002362 CPT       0003   002240 D        0003   002214 DC       0003   002353 OO
   0003    002365 DT        0003   002257 F         0003   002372 I        0003   002371 INDEX    0000   000004 INJP$
   0003 I  002366 IRK       0003   002370 ITERX     0003   002373 J        0003   002367 LCC      0003   002374 M
   0003    002375 N         0003   002323 OF        0003   002016 RK       0003   002315 RMT      0003   002106 SC
   0003    000170 SV        0003   002331 TAU       0003   002357 VE       0003   002360 VI       0003   002303 VOL
   0003    001774 VTRAN     0003   002364 X         0003   000050 XN


00101            SUBROUTINE RC23 (COJB, DJB, IOJB)
00103            DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103           1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103           2          BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103           3          OO(4)
00104            DIMENSION COJB(6), DJB(4), IOJB(2)
00105            COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, OF,
00105           1       TAU, CC, CHB, CH, CPH, OO, VE, VI, CPB, CPT, CADX, X, DT,
00105           2       IRK, LCC, ITERX, INDEX, I, J, M, N
00105      C     CHANGES CONDITIONS DURING DE JOURS EXPERIMENT
00106       6969               FORMAT(1H PHSUB RC23)
00107            DJB(3) = DJB(3) - C(36)
00110            IF (DJB(3) .GT. 0.0)  RETURN
00112            IF (IOJB(2))       2320, 2310
00115       2310 DJB(3) = DJB(1) - .0001
00116            C(31) = COJB(1)
00117            C(33) = COJB(2)
00120            IOJB(2) = 1
00121            IRK = 1
00122            RETURN
00123       2320 DJB(3) = DJB(2) - .0001
00124            C(31) = COJB(3)
00125            C(33) = COJB(4)
00126            IOJB(2) = 0
```

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                        RESP CASE NO. 1                                      DATE  220672  PAGE     51
00127      25*          IRK = 1
00130      26*          RETURN
00131      27*          END

     END OF COMPILATION:          NO  DIAGNOSTICS.
   RC23              SYMBOLIC                          29 JAN 72  16:17:32   0  01502599    19    27 (DELETED)
   RC23     CODE     RELOCATABLE                       29 JAN 72  16:17:32   1  01503336    29     1 (DELETED)
                                                                             0  01503366    19     7
```

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                    RESP CASE NO. 1                              DATE  220672  PAGE    92
@ FOR,* RCF1,RCF1                                                                      22 JUN 72          19: 2:39
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:39

 FUNCTION RCF1          ENTRY POINT 000015

 STORAGE USED: CODE(1) 000021; DATA(0) 000010; BLANK COMMON(2) 000000

  COMMON BLOCKS:

  0003   Z       002376

 EXTERNAL REFERENCES (BLOCK, NAME)

  0004   ALOG
  0005   NERR3$

 STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

  0003   002232 A        0003   002317 BC       0003   000000 C        0003   002363 CADX     0003   002336 CC
  0003   002344 CH       0003   002341 CHB      0003   002361 CPB      0003   002350 CPH      0003   002362 CPT
  0003   002240 D        0003   002214 DC       0003   002353 DQ       0003   002365 DT       0003   002257 F
  0003   002372 I        0003   002371 INDEX    0000   000002 INJP$    0003   002366 IRK      0003   002370 ITERX
  0003   002373 J        0003   002367 LOC      0003   002374 M        0003   002375 N        0003   002323 QF
  0000 R 000000 RCF1     0003   002016 RK       0003   002315 RMT      0003   002106 SC       0003   000170 SV
  0003   002331 TAU      0003   002357 VE       0003   002360 VI       0003   002303 VOL      0003   001774 VTRAN
  0003   002364 X        0003   000050 XN


00101      1*          FUNCTION RCF1(W)
00103      2*          DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103      3*         1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103      4*         2          BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103      5*         3          DQ(4)
00104      6*          COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104      7*         1      TAU, CC, CHB, CH, CPH, DQ, VE, VI, CPB, CPT, CADX, X, DT,
00104      8*         2      IRK, LOC, ITERX, INDEX, I, J, M, N
00104      9*     C    LOGARITHM TO BASE 10
00105     10*          RCF1    = 0.43429448 * ALOG(W)
00106     11*          RETURN
00107     12*          END

    END OF COMPILATION:        NO  DIAGNOSTICS.
 RCF1           SYMBOLIC                          24 JAN 72  16:17:33   0  01403430    14     12  (DELETED)
 RCF1    CODE   RELOCATABLE                       24 JAN 72  16:17:33   1  01404000    24      1  (DELETED)
                                                                        0  01404030    14      3
```

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                         RESP CASE NO. 1                                    DATE  220672  PAGE    43
@ FOR,* RCF2,RCF2                                                                          22 JUN 72              15: 2:40
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:40

  FUNCTION RCF2        ENTRY POINT 000017

  STORAGE USED: CODE(1) 000021; DATA(0) 000012; BLANK COMMON(2) 000000

   COMMON BLOCKS:

   0003   Z       002376

  EXTERNAL REFERENCES (BLOCK, NAME)

   0004    NERR3$

  STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

   0003    002232 A        0003    002317 BC       0003    000000 C        0003    002363 CADX     0003    002336 CC
   0003    002344 CH       0003    002341 CHB      0003    002361 CPB      0003    002350 CPH      0003    002362 CPT
   0003    002240 D        0003    002214 DC       0003    002353 DD       0003    002365 DT       0003    002257 F
   0003    002372 I        0003    002371 INDEX    0004    000005 INJP$    0003    002366 IRK      0003    002370 ITERX
   0003    002373 J        0003    002367 LOC      0003    002374 M        0003    002375 N        0003    002323 OF
   0000 R  000000 RCF2     0003    002016 RK       0003    002315 RMT      0003    002104 SC       0003    000170 SV
   0003    002331 TAU      0003    002357 VE       0003    002360 VI       0003    002303 VOL      0003    001774 VTRAN
   0003    002364 X        0003    000050 XN


00101        1*          FUNCTION RCF2(Z)
00103        2*          DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103        3*         1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103        4*         2          BC(4), OF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103        5*         3          DD(4)
00104        6*          COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, OF,
00104        7*         1       TAU, CC, CHB, CH, CPH, DD, VE, VI, CPB, CPT, CADX, X, DT,
00104        8*         2       IRK, LOC, ITERX, INDEX, I, J, M, N
00104        9*      C   OXYHEMOGLOBIN - PH EMPIRICAL FUNCTION
00105       10*          RCF2    = (((0.0066815*Z) - 0.10098)*Z + 0.44921)*Z - 0.454
00106       11*          RETURN
00107       12*          END

     END OF COMPILATION:         NO  DIAGNOSTICS.
   RCF2            SYMBOLIC                                                 24 JAN 72  16:17:34   0  01504102    14     12  (DELETED)
   RCF2     CODE   RELOCATABLE                                              24 JAN 72  16:17:34   1  01504352    24      1  (DELETED)
                                                                                                  0  01504402    14      3
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                    RESP CASE NO. 1                                      DATE  220672  PAGE    54
@ FOR,* RCF3,RCF3                                                                  22 JUN 72          15: 2:41
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:41

   FUNCTION RCF3        ENTRY POINT 000022

   STORAGE USED: CODE(1) 000025; DATA(0) 000007; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   Z       002376

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0003    002232 A        0003    002317 BC       0003    000000 C        0003    002363 CADK     0003    002336 CC
    0003    002344 CH       0003    002341 CHB      0003    002361 CPB      0003    002350 CPH      0003    002362 CPT
    0003 R  002240 D        0003    002214 DC       0003    002353 DQ       0003 R  002365 DT       0003    002257 F
    0003    002372 I        0003    002371 INDEX    0050    000051 INJP$    0003    002366 IRK      0003    002370 ITERX
    0003    002373 J        0003 I  002367 LOC      0003    002374 M        0003    002375 N        0003    002323 QF
    0000 R  000000 RCF3     0003    002016 RK       0003    002315 RMT      0003    002106 SC       0003 R  000170 SV
    0003    002331 TAU      0003    002357 VE       0003    002360 VI       0003    002303 VOL      0003    001774 VTRAN
    0003    002364 X        0003    000050 XN


00101       1*          FUNCTION RCF3(KK)
00103       2*          DIMENSION C(40), XN(40,2), SV(18,50), VTRAN(18), RK(14,4),
00103       3*         1          SC(14,5), DC(14), A(6), D(15), F(20), VOL(10), RMT(2),
00103       4*         2          BC(4), QF(6), TAU(5), CC(3), CHB(3), CH(4), CPH(3),
00103       5*         3          DQ(4)
00104       6*          COMMON/Z/ C, XN, SV, VTRAN, RK, SC, DC, A, D, F, VOL, RMT, BC, QF,
00104       7*         1       TAU, CC, CHB, CH, CPH, DQ, VE, VI, CPB, CPT, CADK, X, DT,
00104       8*         2       IRK, LOC, ITERX, INDEX, I, J, M, N
00104       9*     C    VTRAN FUNCTION
00105      10*          RCF3 = SV(KK,LOC) + (SV(KK,LOC + 1) - SV(KK,LOC))*DT/D(14)
00106      11*          RETURN
00107      12*          END

     END OF COMPILATION:        NO  DIAGNOSTICS.
   RCF3            SYMBOLIC                                        24 JAN 72  16:17:35   0  01504454     14     12  (DELETED)
   RCF3    CODE    RELOCATABLE                                     24 JAN 72  16:17:35   1  01504724     24      1  (DELETED)
                                                                                         0  01504754     14      3
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                        RESP CASE NO. 1                                    DATE  220672  PAGE    55
@ FOR,* SS02W,SS02W                                                                      22 JUN 72            15: 2:42
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:43

   FUNCTION SS02W        ENTRY POINT 000045

   STORAGE USED: CODE(1) 000055; DATA(0) 000013; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000020 1L        0001   000025 2L        0000   000006 INJP$     0000 R 000000 SS02W


00101       1*          FUNCTION SS02W(X)
00103       2*          IF(X.GT.250.)GOTO1
00105       3*          IF( X.LT.75.)GOTO2
00107       4*          SS02W=X/75.
00110       5*          RETURN
00111       6*    1     SS02W=3.5
00112       7*          RETURN
00113       8*    2     SS02W=(X/75.)*.215+(75.-X)/75.
00114       9*          RETURN
00115      10*          END

     END OF COMPILATION:         NO  DIAGNOSTICS.
   SS02W          SYMBOLIC                                   24 JAN 72  16:17:36   0  01505026    14    10  (DELETED)
   SS02W   CODE   RELOCATABLE                                24 JAN 72  16:17:36   1  01505242    24     1  (DELETED)
                                                                                   0  01505272    14     6
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                    RESP CASE NO. 1                              DATE 220672  PAGE    56
@ FOR,* SSVENT,SSVENT                                                         22 JUN 72              15: 2:49
UNIVAC 1108 FORTRAN V EXEC II LEVEL 25A  -(EXEC8 LEVEL E12010010A)
THIS COMPILATION WAS DONE ON 22 JUN 72 AT 15:02:49

  FUNCTION SSVENT       ENTRY POINT 000052

  STORAGE USED- CODE(1) 000059; DATA(0) 000019; BLANK COMMON(2) 000000

  EXTERNAL REFERENCES (BLOCK, NAME)

   0003   NERR3$

  STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

   0000   000006 INJP$      0000 R 000000 SSVENT


00101      1*           FUNCTION  SSVENT(X)
00103      2*           IF(X.LE..215) SSVENT=5.398
00105      3*           IF((X.GT..215).AND.(X.LT.2.))SSVENT=25.*X
00107      4*           IF(X.GE.2.)SSVENT=50.+50.*(X-2.)
00111      5*           RETURN
00112      6*           END

     END OF COMPILATION:         NO  DIAGNOSTICS.
   SSVENT           SYMBOLIC                       29 JAN 72  16:17:38   0  01505416    19     6  (DELETED)
   SSVENT  CODE     RELOCATABLE-                   29 JAN 72  16:17:38   1  01505542    29     1  (DELETED)
                                                                         0  01505572    19     6

@N XQT RCHEM                                                                  22 JUN 72              15: 2:45
```

RESP CASE NO. 1 DATE 220672 PAGE 97

RESPIRATORY CHEMOSTAT -- INPUT DATA

1	.0527	FA(CO2)
2	.1514	FA(O2)
3	.7959	FA(N2)
4	.6397	CB(CO2)
5	.0011	CB(O2)
6	.0047	CB(N2)
7	.6132	CT(CO2)
8	.0014	CT(O2)
9	.0097	CT(N2)
10	6.0000	Q
11	.7370	QB
12	47.8529	PCSF(CO2)
13	36.0047	PCSF(O2)
14	567.4731	PCSF(N2)
15	30.0000	TMAX
16	.0000	CENT SENS PT
17	.2000	HB
18	.1000	R1
19	.1000	R2
20	1.1380	CNT SENS COF
21	1.1540	CRTD BDY SCF
22	3.0000	KL
23	1.0000	KB
24	39.0000	KT
25	.0500	MPB(CO2)
26	.0500	MPB(O2)
27	81.9900	D(CO2)
28	4.3610	D(O2)
29	2.5240	D(N2)
30	760.0000	B
31	.0004	FI(CO2)
32	.2096	FI(O2)
33	.7900	FI(N2)
34	.1000	KCSF
35	.0000	T
36	.0078	H
37	87.5500	VI(N)
38	5.3900	VI(SS)
39	2.0000	PRINT ALL TI
40	.0000	UNKNOWN
41	.5470	BHCO3 BLOOD
42	.5850	BHCO3 BRAIN
43	.5850	BHCO3TISSUE
44	.5850	BHCO3 CSF
45	.1820	AMT(CO2)
46	.2150	AMT(O2)
47	.0000	DJ1
48	.0000	DJ2

CHANGE IN WORK LOAD, WORK = .00 WATTS

TIME	.0000						ALV RQ	.8744	RQ DIFF	.0
	CO2	O2	N2	D E R I V A T I V E S	PCO2	PO2	PN2	(H+)	PH	HB

		RESP CASE NO. 1					DATE	220672	PAGE 58			
ALVEOLAR	.0527	.1514	.7959	.0002	-.0003	.0001	37.5608	107.9767	567.4629			
ARTERIAL	.5631	.2015	.0097				37.5608	107.9767	567.4629	37.3757	7.4279	.1
BRAIN	.6397	.0011	.0097	-.0000	.0000	-.0000	47.8539	35.9848	567.5991	42.1558	7.3751	
TISSUE	.6132	.0014	.0097	-.0000	.0000	-.0000	42.3119	45.7702	567.5991	38.7290	7.4120	
CSF				.0001	-.0027	.0185	47.8529	36.0047	567.4731	43.7780	7.3587	
V BRAIN	.6310	.1336	.0097				47.8539	35.9848	567.5991	42.7729	7.3680	.1
V TISSUE	.5977	.1606	.0097				42.3119	45.7702	567.5991	39.7808	7.4003	.1
TRANSPORT TIMES --		AB	VB	VT	AT	AC **	VI	VE	Q	FB	DERIVATIVES	
		.1974	.1127	.5900	.3167	.1879	5.4019	5.3616	6.0000	.7370	.0000	.0
RESP FREQ	10.1710	MINUTE VOLUME		6.9285	DEAD SPACE VENT		1.5468		HEART RATE	66.1070		
TIME	.0078								ALV RQ	.8743	RQ DIFF	.0
	CO2	O2	N2	D E R I V A T I V E S			PCO2	PO2	PN2	(H+)	PH	HB
ALVEOLAR	.0527	.1514	.7959	.0002	-.0003	.0001	37.5620	107.9749	567.4631			
ARTERIAL	.5631	.2015	.0097				37.5620	107.9749	567.4631	37.3767	7.4279	.1
BRAIN	.6397	.0011	.0097	-.0000	.0000	-.0000	47.8539	35.9931	567.5983	42.1558	7.3751	
TISSUE	.6132	.0015	.0097	-.0000	.0000	-.0000	42.3119	45.7726	567.5989	38.7290	7.4120	
CSF				.0001	-.0016	.0184	47.8529	36.0047	567.4732	43.7780	7.3587	
V BRAIN	.6310	.1336	.0097				47.8539	35.9931	567.5983	42.7733	7.3680	.1
V TISSUE	.5977	.1606	.0097				42.3119	45.7726	567.5989	39.7809	7.4003	.1
TRANSPORT TIMES --		AB	VB	VT	AT	AC **	VI	VE	Q	FB	DERIVATIVES	
		.1974	.1127	.5900	.3167	.1879	5.4019	5.3615	6.0000	.7370	.0000	.0
RESP FREQ	10.1710	MINUTE VOLUME		6.9285	DEAD SPACE VENT		1.5468		HEART RATE	66.1070		
TIME	.5000								ALV RQ	.8740	RQ DIFF	.0
	CO2	O2	N2	D E R I V A T I V E S			PCO2	PO2	PN2	(H+)	PH	HB
ALVEOLAR	.0527	.1514	.7959	.0000	-.0001	.0000	37.5666	107.9322	567.5011			
ARTERIAL	.5632	.2015	.0097				37.5666	107.9322	567.5011	37.3795	7.4279	.1
BRAIN	.6398	.0011	.0097	.0000	-.0000	-.0000	47.8551	36.0090	567.5604	42.1566	7.3751	
TISSUE	.6132	.0015	.0097	.0000	-.0000	-.0000	42.3121	45.8058	567.5907	38.7291	7.4120	
CSF				.0003	.0005	.0118	47.8530	36.0050	567.4802	43.7784	7.3587	
V BRAIN	.6310	.1337	.0097				47.8551	36.0090	567.5604	42.7744	7.3680	.1
V TISSUE	.5977	.1607	.0097				42.3121	45.8058	567.5907	39.7821	7.4003	.1
TRANSPORT TIMES --		AB	VB	VT	AT	AC **	VI	VE	Q	FB	DERIVATIVES	
		.1974	.1127	.5900	.3167	.1879	5.4074	5.3670	6.0000	.7372	.0000	-.0
RESP FREQ	10.1710	MINUTE VOLUME		6.9344	DEAD SPACE VENT		1.5472		HEART RATE	66.1070		
TIME	1.0000								ALV RQ	.8748	RQ DIFF	.0
	CO2	O2	N2	D E R I V A T I V E S			PCO2	PO2	PN2	(H+)	PH	HB
ALVEOLAR	.0527	.1514	.7959	.0000	.0000	-.0000	37.5663	107.9360	567.4977			
ARTERIAL	.5632	.2015	.0097				37.5663	107.9360	567.4977	37.3793	7.4279	.1
BRAIN	.6398	.0011	.0097	.0000	.0000	-.0000	47.8561	36.0083	567.5423	42.1572	7.3751	
TISSUE	.6132	.0015	.0097	.0000	-.0000	-.0000	42.3126	45.8049	567.5849	38.7294	7.4120	
CSF				.0004	.0004	.0084	47.8531	36.0052	567.4850	43.7790	7.3587	
V BRAIN	.6310	.1337	.0097				47.8561	36.0083	567.5423	42.7755	7.3680	..1
V TISSUE	.5977	.1606	.0097				42.3126	45.8049	567.5849	39.7824	7.4003	.1
TRANSPORT TIMES --		AB	VB	VT	AT	AC **	VI	VE	Q	FB	DERIVATIVES	
		.1974	.1127	.5901	.3167	.1876	5.4062	5.3661	6.0000	.7372	.0000	.0
RESP FREQ	10.1710	MINUTE VOLUME		6.9333	DEAD SPACE VENT		1.5472		HEART RATE	66.1070		
TIME	1.5000								ALV RQ	.8748	RQ DIFF	.0
	CO2	O2	N2	D E R I V A T I V E S			PCO2	PO2	PN2	(H+)	PH	HB
ALVEOLAR	.0527	.1514	.7959	.0000	.0000	-.0000	37.5668	107.9426	567.4907			
ARTERIAL	.5632	.2015	.0097				37.5668	107.9426	567.4907	37.3796	7.4279	.1
BRAIN	.6398	.0011	.0097	.0000	.0000	-.0000	47.8566	36.0094	567.5281	42.1575	7.3751	
TISSUE	.6132	.0015	.0097	.0000	.0000	-.0000	42.3129	45.8056	567.5795	38.7297	7.4120	
CSF				.0004	.0005	.0059	47.8533	36.0055	567.4883	43.7792	7.3587	
V BRAIN	.6310	.1337	.0097				47.8566	36.0094	567.5281	42.7758	7.3680	.1

AN ANALYSIS OF A RESPIRATORY CONTROL

MODEL UNDER EXERCISE CONDITIONS

by

CARLO STRIPPOLI

B.S., Western New England College, 1969

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Electrical Engineering

Kansas State University
Manhattan, Kansas

1973

AN ANALYSIS OF A RESPIRATORY CONTROL MODEL
UNDER EXERCISE CONDITIONS

ABSTRACT

Several respiratory control system models have been developed, each corresponding to specific environmental or physiological constraints. One such model was developed by Grodins which simulated the control of the respiratory system at rest under different inspired gaseous concentrations. A previous modification to this model has been developed to include the physiological effects of exercise at sea level conditions. This report includes an analysis of this modification and an evaluation of its extension to an altered environment of approximately one-third atmosphere with 70% O_2, 28.08% N_2, and 1.92% CO_2 gaseous concentrations.

Detailed flow charts are made for the exercise subroutines and the controller equation. Important expressions within the modifications are investigated utilizing the NOVA 1200 Minicomputer. Plots from these illustrate relationships between system variables. Five simulation runs were made on the IBM 360/50 digital computer. These runs simulate various exercise conditions illustrating the corresponding transient responses for the exercise transitions.

It is determined that the response of the model to different exercise levels depends upon the magnitude of the increments taken between exercise levels and whether the steady state response had been achieved at the previous level. Without further modification of the program, the system variables at one exercise level cannot be used as the initial conditions for another level. The model must always initiate from the resting state

if the transient response is to be valid. To allow for simulations of exercise increments that do not start from the resting state, the punch routine and the initialization routines should be changed so that one exercise response may be used as the initial condition for the succeeding exercise level; therefore, maintaining the fidelity of the transient response.

Suggestions are also made for changes in the heart rate and respiration frequency formulations so that they will include a neural component.