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Summary Report
On a Basic Model of Circulatory, Fluid, and Electrolyte Regulation in the Human System Based Upon the Model of Guyton

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This Study Report provides a detailed description of Guytons' model and modifications developed by Dr. Ronald White. Also included in the study report are descriptions of several typical experiments which the model can simulate to illustrate the model's general utility. Chapter IV of the study report includes a discussion of the problems associated with the interfacing of the model to other models such as respiratory and thermal regulation models which is of prime importance since these stimuli are not present in the current model.

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SUMMARY REPORT

ON

A BASIC MODEL OF CIRCULATORY, FLUID, AND ELECTROLYTE REGULATION IN THE HUMAN SYSTEM BASED UPON THE MODEL OF GUYTON

DEVELOPED BY

RONALD J. WHITE, Ph. D.

INTRODUCTION

The basic model of Guyton and co-workers is a model of circulatory, fluid, and electrolyte regulation. The model is functional in nature and is based almost entirely on experimental data and cumulative present knowledge of the many facets of the circulatory, fluid, and electrolyte regulatory systems of the human body.

The attached Study Report (attachment 1) provides a detailed description of Guytons' model and modifications developed by Dr. Ronald White. Also included in the study report are descriptions of several typical experiments which the model can simulate to illustrate the model's general utility. Chapter IV of the study report includes a discussion of the problems associated with the interfacing of the model to other models such as respiratory and thermal regulation models which is of prime importance since these stimuli are not present in the current model.

Attachment 2 (TIR 741-MED-3017) provides a user's guide for the operation of the model on the Xerox Sigma 3 computer. Two programs are described in the user's guide. Model A is the basic Guyton model and Model B is Dr. Ronald White's version of the Guyton model.

Attachment 3 (TIR 741-MED-3026) presents a verification plan and procedure for performing experiments with the model.

MODEL DESCRIPTION

The model consists of 16 distinct subroutines concerned with physiological function, and contains almost 100 independent parameters as well as more than 350 mathematical relations. (see figure 1). Each function has only been modeled in a crude way with little attention being given to fine details. The systems analysis thus developed is successful in predicting the outcome of many varied stress experiments. This is only possible because of the extreme stability and built-in compensations of the body's actual circulatory system.

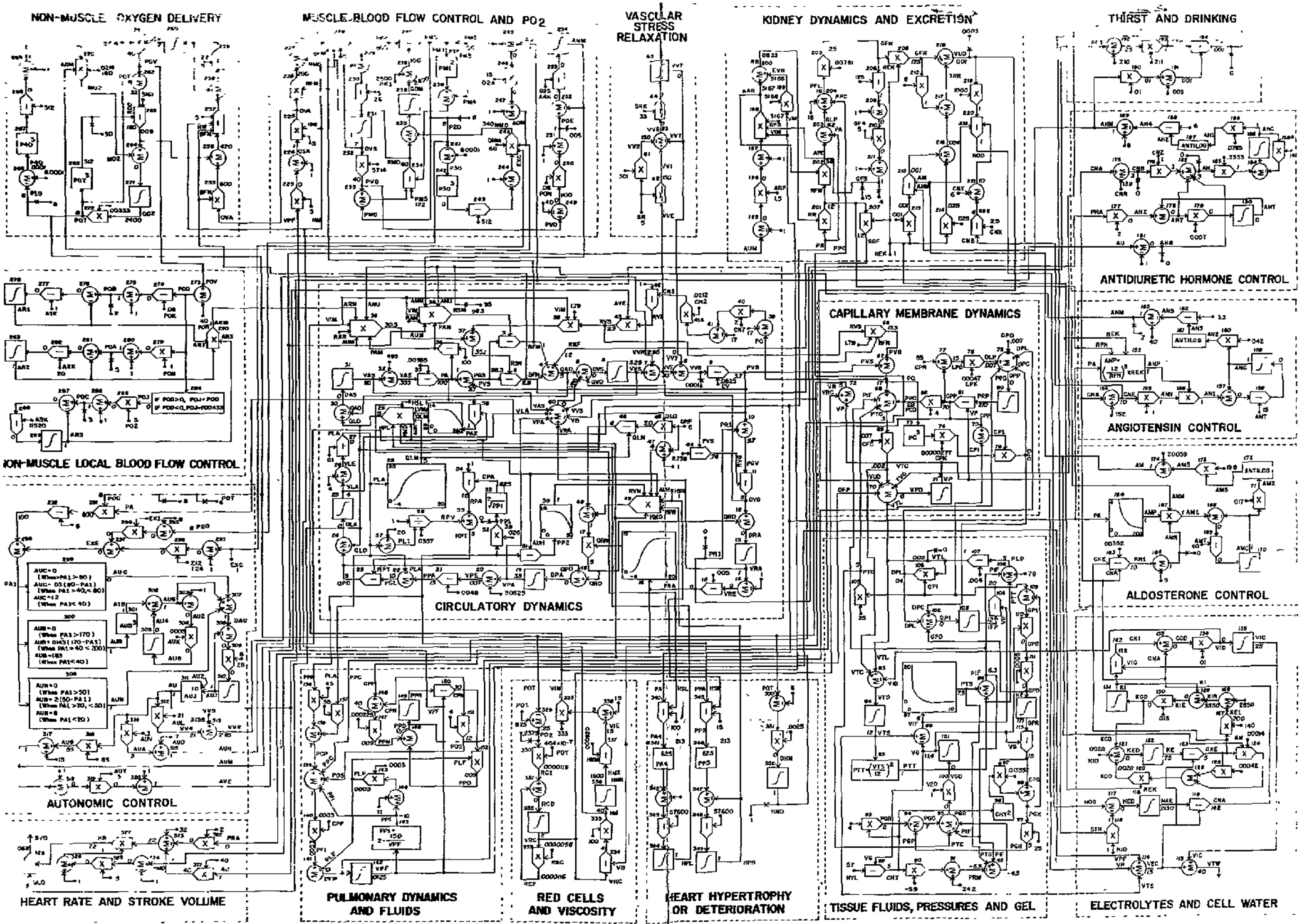

FIGURE 1

1 FOLDOUT FRAME

2 FOLDOUT FRAME

The model may be viewed as a controlled system plus controlling system with the controlling system having three major components: local control, hormonal control, and autonomic control. These controls act to drive the controlled system to the appropriate level in response to stress. There are no thermal regulatory components present in either the controlled or controlling system. Respiratory elements remain to be added with the exception of the effect of pulmonary interstitial fluid on aortic oxygen saturation. Future plans include the addition of hydrogen ion considerations. Only the major cations, Na^+ and K^+, are treated presently. The model may be classified as an intermediate to long-term model with simulations of the order of days or weeks being the primary concern, although short-term simulations, as in the exercise experiment, may be conducted.

A BASIC MODEL OF CIRCULATORY, FLUID, AND ELECTROLYTE REGULATION IN THE HUMAN SYSTEM

-Study Report-

by

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I. Introduction

In recent years, it has become increasingly evident that systems analysis and control theory offer a convenient path to the goal of understanding the functioning and interrelation between various parts of complex physiological systems. For a system as large and complex as the human body, the systems analysis may be broken down into several large interacting subsystems and each subsystem may be treated somewhat independently of the others. These large subsystems, each with many subsystems of its own, may then be combined to produce a model of the overall functioning of the human body.

This study report considers only a model of circulatory, fluid, and electrolyte regulation developed recently by Guyton, Coleman, and Granger (1). Other models of fluid and electrolyte regulation are briefly summarized elsewhere (2). The model of Guyton and co-workers is functional in nature and is based almost entirely on experimental data and cumulative present knowledge of the many facets of the circulatory, fluid, and electrolyte regulatory systems.

The model itself consists of 16 distinct subroutines concerned with physiological function, and contains almost 100 independent parameters as well as more than 350 mathematical relations. Each function has only been modelled in a crude way with little attention being given to fine details. The systems analysis thus developed is successful in predicting the outcome of many varied stress experiments. Apparently, this is only possible because of the extreme stability and many built-in compensations of the actual circulatory system.

A flowchart showing the interconnection of the basic subroutines is given in Figure 1. The subroutines PUTIN and PUTOUT are input-output routines and are not discussed here. (The use of this model is discussed elsewhere (3), (4).) The following chapter considers each of the physiological routines in detail, while Chapter III presents results obtained from typical experiments. Chapter IV contains a brief summary of the model characteristics as a whole and discusses the problem of interfacing the Guyton model with appropriate respiratory and thermal models.

II. The Model

The model of Guyton and co-workers will be examined subroutine by subroutine. For each subroutine, a color-coded flow chart is given and a line-by-line description is presented.* Red indicates a variable input from another subroutine, blue indicates a variable output to another subroutine, green indicates a variable never calculated (independent), and black indicates a variable used only in the subroutine being considered. A complete glossary of terms is presented in Appendix A. Units used are: volume in liters, mass in grams, time in minutes, chemical units in milliequivalents, pressure in millimeters of mercury, and control factors as ratio to normal.

*This description was provided by Dr. A. C. Guyton.

SUBROUTINE HEMO

Program Listing: See Program 1.

Flowchart: See Figure 2.

Line 15. Addition of blood volume (VP+VRC) and subtraction of volumes of blood in all portions of the systemic circulation (VVS, VAS, VLA, VPA, VRA) to yield the net difference between blood volume and volume calculated in all the capacitative reservoirs of the systemic circulation; output of this line represents the correlation factor (VBD) that is added to the flow of the systemic circulation into the small veins, thus bringing the volume of blood in the circulation up to the appropriate level. This allows updating of blood volume when volumes pass through the capillary walls, when volume is gained by the process of drinking, or lost through the kidneys, and so forth.

Line 16. Integration of rate of blood flow into the veins (DVS) plus correction factor (VBD) gives volume of blood in the veins of the systemic circulation (VVS).

Line 17. Integration of rate of change of volume in the pulmonary arteries (DPA) plus correction factory (VBD) gives the instantaneous volume in the pulmonary arteries (VPA).

Line 18. Integration of rate of change of volume in systemic arteries (DAS) plus correction factor (VBD) gives actual volume in systemic arteries (VAS).

Line 19. Integration of rate of change of volume in left atrium and pulmonary veins (DLA) plus correction factor (VBD) gives instantaneous volume in left atrium and pulmonary veins (VLA).

Line 20. Integration of rate of change of volume in right atrium (DRA) plus correction factor (VBD) gives volume of blood in right atrium (VRA).

Line 21. Volume in systemic arteries (VAS) minus constant gives excess volume in systemic arteries (VAE) that causes stretch of the arterial walls.

Line 22. Excess volume in systemic arteries (VAE) divided by compliance of the systemic arteries gives arterial pressure (PA).

Line 23. Factor of 100 divided by arterial pressure (PA) gives arterial pressure multiplier factor for alteration of peripheral resistance caused by stretching of arteries resulting from arterial pressure (PAM).

Line 24. Effect of autonomic stimulation (AUH) on loading effect of systemic arterial pressure (PA) to give effective arterial pressure on left ventricle (PA2).

Line 25. Function curve (See Figure 3.) showing effect of systemic arterial pressure (PA2) in loading left ventricle and determining its pumping effectiveness (LVM).

Line 26. Volume of blood in right atrium (VRA) minus constant gives excess volume of blood in right atrium (VRE) that causes stretching of right atrium.

Line 27. Excess volume of blood in right atrium (VRE) divided by compliance of right atrium gives right atrial pressure (PRA).

Line 28. Curve (See Figure 4.) relating right atrial pressure (PRA) to output of right atrium under normal operating conditions of right atrium (QRN).

Line 29. Volume in the pulmonary arteries (VPA) minus a constant factor gives the excess volume in the pulmonary arteries that causes stretch of the arteries (VPE).

Line 30. Excess volume in the pulmonary arteries (VPE) divided by the capacitance of the pulmonary arteries gives the pulmonary arterial pressure (PPA).

Line 31-33. Curve fitting process to empirically calculate resistance in pulmonary arteries to the midpoint of the pulmonary capillaries (RPA) from the pulmonary arterial pressure (PPA).

Line 34. Calculation of the effect of autonomic stimulation (AUH) on the degree of loading of the right ventricle (PP2) caused by pulmonary arterial pressure (PPA).

Line 35. Curve (See Figure 15.) relating effective pulmonary arterial pressure (PP2), and pumping effectiveness of the right ventricle (RVM).

Line 36. Volume of blood in pulmonary veins and left atrium (VLA) minus constant factor gives excess volume (VLE) causing stretch of left atrium and pulmonary veins.

Line 37. Excess volume in left atrium and pulmonary veins (VLE) divided by capacitance of left atrium and pulmonary veins gives pressure in the left atrium (PLA).

Line 38. Curve (See Figure 6.) giving normal output of left ventricle (QLN) for each given value of pulmonary left atrial pressure (PLA).

Line 39. Curve fitting process based primarily on waterfall effect to calculate resistance of pulmonary veins (RPV) whose change depends primarily on level of left atrial pressure (PLA).

Line 40. Calculation of total pulmonary resistance (RPT) by adding pulmonary arterial resistance to midpoint of capillaries (RPA) and pulmonary venous resistance from midpoint of capillaries to left atrium (RPV).

Line 41. Pulmonary arterial pressure (PPA) minus left atrial pressure (PLA) gives the pressure gradient through the lungs (PGL).

Line 42. Pressure gradient through the lungs (PGL) divided by resistance of the pulmonary circuit (RPT) gives rate of blood flow into the pulmonary veins and left atrium (QPO).

Lines 43-44. Calculation of vasoconstrictor factor caused by angiotensin (ANU) (but does not fall below 0.8.).

Line 45. Volume of blood in the veins (VVS) minus volume of blood at zero venous pressure (VVR) minus vasoconstrictor effect of angiotensin (ANU) gives excess venous volume before correction factor for stress relaxation (VVE).

Lines 46-47. Excess volume of blood in the circulation (VVE) minus stress relaxation factor (VV7) gives excess volume of blood in the systemic veins after stress relaxation factor correction (VV8)(not allowed to fall below 0.0001).

Line 48. Excess systemic venous volume (VV8) divided by capacitance the veins (CV) gives pressure in the veins (PVS).

Lines 49-50. Right atrial pressure (PRA) but never negative (PR1).

Line 51. Calculation of resistance between veins and right atrium (RVG) as determined by the level of small vein venous pressure (PVS).

Line 52. Pressure gradient from the veins to the right atrium (PVS-PR1) divided by the large vein resistance (RVG) gives rate of blood flow into the right atrium (QVO).

Lines 53-55. Curve fitting process to give effect of changing capillary pressure (PC) and autonomic stimulation (AVE) on venous resistance (RVS), showing principally a partial waterfall effect, the constancy of the pressure of which is determined by the constant CN7.

Line 56. Arterial pressure (PA) minus pressure in the small veins (PVS) gives pressure gradient of the systemic circulation (PGS).

Line 57. Addition of the resistance from the aorta to the midpoint of the capillaries to the resistance from the midpoint of the capillaries to veins to give the total resistance of the non-muscle, non-renal portion of the systemic circulation (RSN).

Line 58. Pressure gradient in the systemic circulation (PGS) divided by the resistance in the non-muscle, non-renal circulation (RSN) gives blood flow in the non-muscle, non-renal circulation (BFN).

Line 59. Calculations of the resistance through the muscle circulation of the body (RSM).

Line 60. Pressure gradient in the systemic circulation (PGS) divided by resistance in the muscle circulation (RSM) gives blood flow in the muscle circulation (BFM).

Line 61. Addition of blood flow in the non-muscle, non-renal circulation (BFN) plus muscle blood flow (BFM) plus renal blood flow (RBF) plus A-V fistula flow (FIS) gives blood flow from aorta through the systemic circulation (QAO).

Line 62. Calculation of actual output of left ventricle (QLO) based on the following factors: Output of left ventricle under normal conditions (QLN), effect of arterial pressure loading factor on left ventricle (LVN), basic strength of left ventricle (HSL), degree of autonomic stimulation of left ventricle (AUH), degree of deterioration of left ventricle caused by low coronary blood flow (HMD), and degree of hypertrophy of the left ventricle (HPL).

Line 63. Calculation of actual output of right ventricle (QRO) similar to line 62, except that left ventricular pumping (QLO) plays a part.

Line 64. Stability check on calculation of rate of blood flow into the pulmonary veins and left atrium (QPO).

Line 65. Stability check on calculation of rate of blood flow into right atrium (QVO).

Line 66. Blood flow through the systemic circulation (QAO) minus blood flow out of the small veins into the atria (QVO) gives rate of change of volume in the systemic veins (DVS).

Line 67. Output of right ventricle into pulmonary arteries (QRO) minus rate of blood flow from the pulmonary arteries into the pulmonary veins and left atrium (QPO) gives rate of change of volume in the pulmonary arteries (DPS).

Line 68. Actual rate of output of left ventricle (QLO) minus rate of blood flow from systemic arteries through systemic circulation (QAO) gives rate of change of blood volume in systemic arteries (DAS).

Line 69. Rate of blood flow into the pulmonary veins and left atrium (QPO) minus rate of blood flow out of the pulmonary veins and left atrium (QLO) gives the rate of change of volume in the left atrium and pulmonary veins (DLA).

Line 70. Rate of blood flow into the right atrium (QVO) minus rate of blood flow out of right atrium (QRO) gives rate of change of blood volume in right atrium (DRA).

SUBROUTINE AUTO

Program Listing: See Program 2.

Flowchart: See Figure 7.

Line 9. Calculation of the bias on the setting of the autonomic drives in the central nervous system (EXE) due to the degree of exercise (EXC) and muscle P_{O_2} (P2O). The factor EXE is normally zero, but increases with degree of exercise or decrease in muscle P2O. The effect of muscle P2O is presumably mediated through such factors as release of lactic acid and pH, CO_2, and P2O changes in blood carried from muscles to chemoreceptive areas.

Lines 10-12. Calculation of the effect of tissue P_{O_2} (POQ), limited between values of 4 and 8, for determining the factor that drives autonomic responses, assuming that the tissue P_{O_2} biases the setting of the effect of pressure on the central nervous system autonomic feedbacks. The P_{O_2} effect acts through direct effect of P_{O_2} on the vasomotor center, through associated effects of CO_2 that go along with P_{O_2} changes, through possible cardiac receptors and other peripheral receptors that may be related to tissue blood flow and tissue P_{O_2}.

Line 13. Calculation of (PA1) both the effect of exercise and arterial pressure (PA) and tissue P_{O_2} (POQ) that cause biasing of the factor for control of autonomic outputs.

Lines 14-16. Effect of drive factor on the vasomotor center (PA1) of the autonomic system caused by pressure effects operating indirectly through the chemoreceptors (AUC). The function is expressed algebraically with two break points in the curve, at 80 and at 40. The autonomic output is expressed in terms of positive sympathetic drive and negative parasympathetic drive.

Lines 17-19. Similar function as in line 14-16, but this time resprsenting pressure effect operating through baroreceptors to stimulate the autonomic system. Output (AUB) represents positive sympathetic drive and negative parasympathetic drive.

Line 20. Adjustment of sensitivity of baroreceptor drive with output A1B.

Lines 21-23. Similar function as in line 14-16 or line 17-19, but this time for central nervous ischemic response, with output AUN.

Lines 24-25. These lines plus line 27 of SUBROUTINE MISC1 allow for adaptation of the baroreceptor system. The time constant for adaptation is determined by AUK. AU6 always reapproaches the value 1 with time because of adaptation.

Line 26. Summation of autonomic stimulation from chemoreceptors (AUC), baroreceptors (AU6), and CNS ischemic response (AUN) to give the final equilibrium summated effect that will be approached (DAU).

Lines 27-29. Time delay circuit for full realization of autonomic drive. The output AUJ approaches the final equilibrium (DAU) with time constant determined by Z8.

Lines 30-32. Calculation of the overall activity of autonomic system (AU) which represents the tendency to increase overall functional activity of the heart and to increase vascular constriction throughout the body.

Line 33. Allows pre-set value (STA) to be substituted for AU.

Line 34 Calculates departure of overall activity (AU) from normal (AUO).

Line 35. Calculation of autonomic drive for peripheral circulation (AUP) from sensitivity control (AUQ) and autonomic level (AUO).

Line 36. Same as line 35, except for heart (AUH).

Line 37. Same as line 35, except for heart rate (AUR).

Line 38. Sets sensitivity for control of systemic venous vascular volume (VVR).

Line 39. Determines sensitivity of autonomic drive to control arteriolar resistance in the muscle and non-muscle portions of the circulation, and also to control the degree of stimulation of the afferent arterioles of the kidneys (AUM).

SUBROUTINE HORMON

Program Listing: See Program 3.

Flowchart: See Figure 8.

Lines 12-13. Determination of effect of the ratio of extracellular fluid potassium (CKE) to sodium concentration (CNA) by means of curve fitting on control of aldosterone secretion (AMR).

Line 14. Function curve (See Figure 9.) to determine the effect of arterial pressure (PA) on aldosterone secretion (AMP).

Line 15. Calculation of total control effect on aldosterone secretion (AM1) by multiplying effect of potassium of sodium ratio (AMR), pressure (AMP), and stimulatory effect of angiotensin (ANM).

Line 16. Decay effect which specifies rate of buildup of aldosterone in the interstitial fluids. This level approaches the level set by the aldosterone control (AM1) with time constant AMT. The output is AMC, the concentration of aldosterone expressed as the ratio of the concentration to the normal value.

Line 17. Calculation of the degree of effect of aldosterone (AM) from the aldosterone concentration by empirical means.

Lines 23-24. Subtraction of concentration of sodium in extracellular fluids (CNA) from a constant to give sodium concentration factor for control of angiotension secretion (CNE), a factor never less than 1.

Line 25. Determination of effect of glomerular filtration rate (GFN), extracellular sodium concentration (CNA), and degree of normality of kidneys (REK) on renin output and subsequent formation of angiotensin (ANR).

Lines 26-30. Curve fitting technique which allows for effect of renal blood flow and sodium level on angiotensin formation (ANP).

Line 31. Mathematical technique to allow for stability control of total factor for angiotensin control (AN1).

Line 32. Decay effect which allows for a buildup of angiotensin in the circulation. The time constant for the delay is ANT and the concentration of angiotensin is ANC.

Lines 33-34. Calculation of the degree of effect of angiotensin (ANM) from angiotensin concentration (ANC). ANM has a lower limit of 0.7.

SUBROUTINE BLOOD

Program Listing: See Program 4.

Flowchart: See Figure 10.

Line 9. Calculation of blood volume (VB) by adding plasma volume (VP) and red cell volume (VRC).

Line 10. Calculation of hematocrit (HM) by dividing red cell volume (VRC) by blood volume (VB) and multiplying by 100.

Line 11. Calculation of the actual viscosity of blood caused by hematocrit (VIE). HMK and HKM are constants.

Line 12. Calculation of total relative viscosity of blood (VIB), assuming viscosity of water to equal one, by adding viscosity caused by red cells (VIE) to a constant factor representing viscosity of plasma.

Line 13. Calculation of viscosity multiplier (VIM) by multiplying relative viscosity times a constant. This factor is the viscosity multiplier factor that determines relative changes in vascular resistance with changes in viscosity from normal.

Line 17. Calculates rate of red cell destruction (RC2) by multiplying volume of red cells in circulation (VRC) times a constant (RKC).

Lines 18-20. Calculation of the effect of non-muscle tissue PO_2 (POT) as a drive in causing formation of red blood cells. The drive is considered to be zero when POT equals the constant factor PO1 and to increase as the tissue P_{O_2} falls below this value. The drive factor (PO2) has a minimum value. POY determines the sensitivity of the circuit and RC1 is the rate of red cell production.

Line 21. Calculation of net rate of change of red cell volume (RCD) from red cell production rate (RC1) and red cell destruction rate (RC2).

Line 22. Calculation of volume of red cells in circulation (VRC) by integration.

SUBROUTINE MUSCLE

Program Listing: See Program 5.

Flowchart: See Figure 11.

Line 8. Calculation of aortic arterial oxygen saturation (OSA) by subtracting the fraction of desaturation of arterial blood (calculated by multiplying quantity of free fluid in lungs (VPF) times a constant) from maximum saturation (ALO) of one.

Line 9. Calculation of volume of oxygen per liter of aortic arterial blood (OVA) by multiplying arterial oxygen saturation (OSA) times hematocrit (HM) times a constant.

Line 10. Calculation of actual venous oxygen saturation (OVS) by means of a delay mechanism which allows the venous saturation to rise to its equilibrium value. The product of muscle blood flow (BFM) and volume of oxygen per liter (OVA) is the rate of delivery of oxygen to the muscle cells. Subtracting the rate of oxygen utilization by the tissues (RMO) gives the rate of oxygen delivery to the veins. Dividing this by the muscle blood flow (BFM), hematocrit (HM), and a constant yields the venous oxygen saturation after equilibrium has been established. The rest is the delay mechanism with the constant Z6 controlling the time constant.

Line 11. Calculation of venous oxygen pressure (PVO) by multiplying venous oxygen saturation (OVS) times a constant.

Line 12. Calculation of rate of oxygen delivery to muscle cells from capillaries (RMO). The assumption is made that oxygen in the muscle capillaries is equal to oxygen in the venous blood (PVO). The pressure difference between oxygen in the muscle capillaries (PVO) and oxygen in the muscle cells (PMO) is multiplied by a constant (PM5) and divided by a resistance factor determined by the number of capillaries that are open at any given time.

Line 13. Calculation of total quantity of oxygen stored in cells (QOM) by integration of rate of change of oxygen in muscle cells (RMO-MMO). The exponential factor represents a damped integration. Note that QOM represents oxygen stored in all of its energy forms, including dissolved oxygen, oxygen bound with myoglobin, and oxygen equivalents of energy compounds such as ATP and creatine phosphate.

Lines 14-16. Calculation of pressure of oxygen in muscle cells (PMO or PM1) by a curve fitting process from the quantity of oxygen in the cells (QOM). Note that PM1 cannot fall below 0.001 mm Hg.

Lines 17-18. Calculation of muscle cell oxygen pressure effective in depressing rate of metabolism in cell (P2O).

Line 19. Calculation of the effect of the degree of autonomic stimulation (AUP) on the rate of metabolism expressed as an autonomic multiplier effect on metabolism (AOM). This value is normally unity. The sensitivity of the effect of autonomic stimulation on metabolism is determined by the constant O2A.

Line 20. Calculation of rate of utilization of oxygen by the cells (MMO) by multiplying autonomic effect (AOM), exercise effect (EXC), basal level of oxygen utilization (OMM), and the effect of decrease in muscle cell P_{O_2}. This last effect is a curve fitting process involving P2O that assumes that the oxygen level must fall nearly to zero before very significant decrease in the rate of metabolism occurs.

Line 21. Calculation of difference between capillary P_{O_2}, assuming this equals venous PO_2 (PVO), and normal capillary P_{O_2} of 40.

Lines 22-23. Calculation of sensitivity control for oxygen feedback loop (POE). The constant POM determines the degree of sensitivity.

Line 24. Calculation of the autoregulation multiplier for the muscle vascular circuit (AMM) by a time delay mechanism. The constant A4K is the time constant for this delay.

SUBROUTINE AUTORG

Program Listing: See Program 6.

Flowchart: See Figure 12.

Line 11. Calculation of the actual venous oxygen saturation (OSV) based on a delayed approach to its equilibrium value. The product of the volume of oxygen in each liter of arterial blood (OVA) and blood flow to the non-muscle tissues (BFN) gives the rate of transport of oxygen by arteries to the non-muscle tissues. By subtracting the rate of oxygen utilization of the tissues (DOB), the rate of oxygen delivery to the veins of the non-muscle tissue is obtained. This difference divided by the blood flow to the tissues (BFN), hematocrit, and a constant yields the equilibrium venous oxygen saturation. The time constant is Z7.

Line 12. Calculation of venous oxygen P_{O_2} (POV) from venous oxygen saturation (OSV).

Lines 13-14. Calculation of resistance of diffusions of oxygen from capillaries to cells (RDO) assuming that far greater numbers of capillaries open up and the resistance decreases as the tissue P_{O_2} (POT) falls below normal.

Line 15. Calculation of rate of delivery of oxygen from capillaries to tissue cells (DOB) by multiplying pressure difference between pressure of oxygen in tissue capillaries (assumed equal to POV) and pressure of oxygen in the tissue cells (POT) times a constant and dividing by the resistance for diffusion of oxygen (RDO).

Line 16. Calculation of the rate of oxygen utilization by cells (MO2) by multiplying basal level of oxygen utilization (O2M) by the autonomic stimulatory effect (AOM) and the tissue P_{O_2} effect on oxygen utilization.

Line 17. Calculation of actual total quantity of oxygen accumulated in the cells (QO2) by integration of the rate of accumulation of oxygen in the tissue cells. This rate is determined by subtracting the rate of utilization of oxygen in the cells (MO2) from rate of delivery of oxygen to cells (DOB).

Line 18. Calculation of tissue cell P_{O_2} (POT) from quantity of oxygen accumulated in the cells (QO2).

Lines 19-20. Calculation of effective tissue P_{O_2} for oxygen utilization (PIO).

Line 21. Calculation of pressure difference that acts as control factor for autoregulation of non-muscle blood flow (POD) by subtracting reference value (POR) from capillary P_{O_2} in non-muscle tissues (assumed to equal POV).

Lines 22-23. Calculation of rate of change of rapid autoregulation vasoconstrictor effect (POB) from pressure difference POD. The sensitivity is set by POK.

Line 24. Calculation of rapid autoregulation multiplier factor (AR1) by time delay mechanism with time constant A1K.

Line 25. Multiplication of the three autoregulation factors, short-time (AR1), intermediate-time (AR2), and long-time (AR3), to give the total autoregulation factor (ARM) which multiplies the basic resistance for blood flow through the non-renal sector of the circulation.

Lines 29-30. Calculation of rate of change of intermediate autoregulation vasoconstrictor effect (POA) from pressure difference POD. The sensitivity is set by PON.

Line 31. Calculation of intermediate autoregulation multiplier factor (AR2) by time delay mechanism with time constant A2K.

Line 35. Branching step depending on whether POD is positive or negative.

Lines 36-37. Calculation of rate of change of long-time autoregulation vasoconstrictor effect (POC) if POD is positive. The sensitivity is set by POZ.

Line 38. Calculation of rate of change of long-time autoregulation vasoconstrictor effect (POC) if POD is negative. The sensitivity is set by POZ.

Line 39. Minimum value set for POC.

Line 40. Calculation of long-time autoregulation multiplier factor (AR3) by time delay mechanism with time constant A3K.

SUBROUTINE ADH

Program Listing: See Program 7.

Flowchart: See Figure 13.

Line 7. Calculation of the effect of extracellular fluid osmolarity on antidiuretic hormone secretion (CNB) by subtracting a reference value (CNR) from the concentration of sodium in the extracellular fluids (CNA) (taken to be a measure of the osmolarity of extracellular fluids).

Line 8. Calculation of the partial effect of right atrial pressure (PRA) in controlling antidiuretic hormone secretion (AHZ).

Line 9. Calculation of the degree of adaptation of the right atrial pressure mechanism for affecting antidiuretic hormone secretion (AHY) by time delay mechanism.

Lines 10-11. Calculation of the effect of autonomic stimulation on the rate of antidiuretic hormone secretion (AH8) from the autonomic multiplier AUP.

Line 12. Prevents sodium factor CNB (line 7) from being negative.

Lines 13-14. Calculation of the equilibrium control value of antidiuretic hormone secretion (AH) by summation of the factors that cause antidiuretic hormone secretion. These factors are the sodium factor (CNB), the right atrial pressure factor (AHZ and AHY), and the autonomic factor (AH8).

Line 15. Calculation of rate of buildup of antidiuretic hormone concentration (AHC) in the body fluids by time delay mechanism with time constant AHK. Normally AHC = 1.

Lines 16-17. Calculation of antidiuretic hormone multiplier (AHM) by a curve fitting process from the antidiuretic hormone concentration (AHC).

SUBROUTINE MISC1

Program Listing: See Program 8.

Flowchart: See Figure 14.

Line 10. Calculation of the rate of progression of stress relaxation (VV6) by subtracting from excess systemic venous volume (SR*VVE) the reference volume (.301*SR) and the actual degree of stress relaxation (VV7). The factor SR is the adjustable intensity of stress relaxation.

Line 11. Calculates the actual stress relaxation volume (VV7) by integration with time constant SRK. The amount of stress relaxation in the systemic veins is set to be somewhat higher than the normal stress relaxation of the venous system to make up for the fact that similar stress relaxation factors are not calculated for other parts of the circulation.

Lines 17-19. Calculation of rate of water intake (TVD) by multiplying the tissue perfusion factor for thirst stimulation (STH) by the thirst center drive. The thirst center drive is calculated from the antidiuretic hormone multiplier (AHM) by curve fitting under the assumption that the same factors that drive antidiuretic hormone secretion play a similar role in causing thirst.

Line 20. Calculation of total body water (VTW) by adding extracellular fluid volume (VEC) to intracellular fluid volume (VIC).

Line 27. Calculation of effective adaptation of baroreceptor system (AU4) when coupled to lines 24-25 of SUBROUTINE AUTO.

SUBROUTINE HEART

Program Listing: See Program 9.

Flowchart: See Figure 15.

Line 10. Calculation of rate of deterioration of the heart (DHM) by a curve fitting process that assumes the deterioration increases progressively as tissue P_{O_2} (POT) falls below 6 mm Hg.

Lines 11-12. Calculation of deterioration multiplier factor (HMD) which multiplies the strength of the two ventricles by integrating the rate DHM.

Line 16. Calculation of mean circulatory pressure (PMC) by adding excess blood volume in systemic arteries (VAE), excess venous vascular volume (VVE), excess volume in right atrium (VRE), excess volume in pulmonary arteries (VPE), and excess volume in left atrium (VLE), and dividing by a constant.

Line 17. Calculation of the mean systemic pressure (PMS) by adding excess blood volume in systemic arteries (VAE), excess volume in venous system (VVE), and excess volume in right atrium (VRE), and dividing by a constant.

Line 18. Calculation of the mean pulmonary pressure (PMP) by adding excess volume in pulmonary arteries (VPE), and excess volume in left atrium (VLE), and dividing by a constant.

Line 24. Calculation of heart rate (HR) by multiplying the summation of a basic heart rate factor (a constant), the reflex effect due to right atrial pressure (PRA), and the autonomic drive effect (AUR) by the effect of cardiac deterioration expressed in terms of the degree of normality of the heart (HMD).

Line 25. Calcualtion of total peripheral resistance (RTP) by dividing the difference between aortic pressure (PA) and right atrial pressure (PRA) by the blood flow in the systemic arterial system (QAO).

Line 26. Calculation of the stroke volume (SVO) by dividing the cardiac output (QLO) by the heart rate (HR).

SUBROUTINE CAPMBD

Program Listing: See Program 10.

Flowchart: See Figure 16.

Line 9. Calculation of total tissue pressure (PTT) from total volume of fluid in the interstitial compartment (VTS).

Line 10. Calculation of free fluid in the interstitial spaces (VIF) by subtracting volume of gel fluid (VG) from total interstitial fluid volume (VTS).

Line 11. Calculation of solid tissue pressure (PTS) from volume of free interstitial fluid (VIF) by graphical interpolation (See Figure 17.).

Line 12. Calculation of pressure of free interstitial fluid (PIF) by subtracting solid tissue pressure (PTS) from total tissue pressure (PTT).

Line 13. Calculation of concentration of protein in free interstitial fluid (CPI) by dividing quantity of protein (IFP) by volume of free fluid (VIF).

Line 14. Calculation of colloid osmotic pressure of free interstitial fluid (PTC) by multiplying concentration of protein in free fluid (CPI) by a constant factor.

Line 15. Calculation of concentration of proteins in plasma (CPP) by dividing quantity of protein in the plasma (PRP) by the plasma volume (VP).

Line 16. Calculation of colloid osmotic pressure of plasma (PPC) by multiplying the concentration of plasma protein (CPP) by a constant.

Line 17. Calculation of pressure gradient from midpoint of the capillaries to the veins (PVG) by multiplying resistance of the veins (RVS) times the blood flow through the non-renal, non-muscular portions of the circulation (BFN) and times a constant to account for blood flow through the other portions of the circulation.

Line 18. Calculation of capillary pressure (PC) by adding the pressure gradient from the capillaries to the veins (PVG) to the pressure that is in the veins (PVS).

Line 19. Calculation of the net pressure difference across the capillary membrane to cause movement of fluid molecules through the capillary pores (PCD) by adding capillary pressure (PC) and tissue colloid osmotic pressure (PTC) and subtracting plasma colloid osmotic pressure (PPC) and interstitial fluid pressure (PIF).

Line 20. Calculation of rate of fluid movement through the capillary membrane (VTC) by multiplying pressure gradient across the capillary membrane (PCD) by the capillary filtration coefficient (CFC).

Line 21. Calculation of the driving pressure for moving fluid into the lymphatics (PLD) by adding free interstitial fluid pressure (PIF), subtracting total tissue pressure (PTT), and adding a constant factor to account for lymphatic pumping. The total tissue pressure is considered to oppose lymph flow because of compression of the lymphatics while the interstitial fluid pressure is considered to promote lymph flow.

Lines 22-23. Calculation of rate of lymph flow (VTL) from driving pressure for lymphatic flow (PLD).

Line 24. Calculation of rate of change of fluid in interstitial fluid compartment (VTD) by adding rate of movement of fluid into interstitial spaces from capillaries (VTC), subtracting rate of loss of fluid from the interstitial fluid compartment by way of lymph flow (VTL), and subtracting rate of movement of fluid from interstitial fluid compartment into cells (VID).

Line 25. Calculation of total fluid in interstitial compartment (VTS) by integration of rate of change of fluid in interstitial compartment (VTD).

Line 26. Calculation of rate of change of plasma volume (VPD) by adding fluid intake by drinking (TVD) and fluid return to circulation by way of lymphatics (VTL), and subtracting rate of movement of fluid through the capillaries (VTC), urinary output (VUD), and rate of fluid loss from the plasma through the pulmonary capillary membranes into the pulmonary spaces (DFP).

SUBROUTINE PULMON

Program Listing: See Program 11.

Flowchart: See Figure 18.

Line 7. Calculation of plasma volume (VP) by integration of rate of change of plasma volume (VPD) (calculated on line 26 of SUBROUTINE CAMBD).

Line 9. Calculation of pulmonary capillary pressure (PCP) from effects of pulmonary arterial pressure (PPA) and left atrial pressure (PLA).

Line 10. Calculation of pressure of the free fluid in the pulmonary interstitial fluid spaces (PPI) from volume of free fluid in interstitial spaces of lungs (VPF).

Line 11. Calculation of protein in free fluid of lungs (CPN) by division of quantity of protein in pulmonary interstitial spaces (PPR) by volume of free fluid in lungs (VPF).

Line 12. Calculation of colloid osmotic pressure of protein in free fluids of the lungs (POS) from the concentration of protein in free fluid of lungs (CPN).

Line 13. Calculation of pulmonary lymph flow (PLF) from driving pressure for pulmonary lymph flow. This driving pressure is determined gy adding pulmonary free interstitial fluid pressure (PPI) to a constant.

Line 14. Calculation of rate of removal of protein from interstitial spaces of lungs by way of lymph (PPO) from pulmonary lymph flow (PLF) times concentration of protein in free fluid of lungs (CPN).

Line 15. Calculation of rate of movement of protein through pulmonary capillary membranes into interstitial spaces (PPN) from the protein difference across the pulmonary capillary membrane. This latter quantity is determined by subtracting the pulmonary interstitial fluid concentration of protein (CPN) from the plasma concentration of protein (CPP).

Line 16. Calculation of net rate of change of protein quantity in pulmonary interstitial fluids (PPD) by subtracting protein removal from interstitial spaces by lymph flow (PPO) from protein movement into interstitial spaces through capillary membranes (PPN).

Line 17. This line tests to see if the total protein in the pulmonary fluids (PPR) as determined by integration of PPD calculated by line 16 is less than 0.025. If so, PPD is calculated directly from PPR.

Line 18. Calculation of rate of fluid movement through pulmonary capillary membrane (PFI) by multiplication of pulmonary capillary filtration coefficient (CPF) times net pressure difference acorss pulmonary capillary membrances. The net pressure difference is obtained by adding pulmonary capillary pressure (PCP), and pulmonary interstitial fluid colloid osmotic pressure (POS), and subtracting pulmonary interstitial fluid pressure (PPI) and plasma colloid osmotic pressure (PPC).

Line 19. Calculation of net rate of change of fluid in pulmonary interstitial spaces (DFP) by subtracting rate of fluid movement from pulmonary interstitial spaces into pulmonary lymph and thence into the plasma (PLF) from fluid movement from pulmonary capillaries into interstitial spaces (PFI).

Line 20. This line tests to see if the volume of free fluid in the interstitial spaces of lungs (VPF) is less than 0.001. If so, DFP is calculated directly from VPF.

Line 21. Calculation of actual volume of free fluid in interstitial spaces of lungs (VPF) by integration of DFP. (Note that there is no calculation in the pulmonary fluid system for interstitial gel.)

Line 22. Calculation of total protein in the pulmonary fluids (PPR) by integration of PPD.

SUBROUTINE MISC2

Program Listing: See Program 12.

Flowchart: See Figure 19.

Line 9. Calculation of hypertrophy of the left ventricle (HPL) by means of a time delay mechanism from the drive factor based on the arterial pressure (PA) and the strength of the left ventricle (HSL).

Line 10. Calculation of hypertrophy of the right ventricle (HPR) by means of a time delay mechanism from the drive factor based on the pulmonary arterial pressure (PPA) and the right heart strength (HSR).

Lines 16-18. Calculation of the effect of tissue perfusion (expressed in terms of tissue oxygenation (POT)) on the mechanism for salt and water intake (STH).

SUBROUTINE PROTEN

Program Listing: See Program 13.

Flowchart: See Figure 20.

Line 11. Calculation of rate of return of protein from interstitial spaces to the plasma (DPL) by multiplying rate of lymph flow (VTL) times concentration of protein in free interstitial fluid (CPI).

Line 12. This line tests to see if the capillary pressure (PC) is negative. If it is, PC is set to zero.

Line 13. Calculation of the rate of protein movement through the capillary membrane (DPC) by multiplying the permeability of the capillaries to protein (considering that this permeability increases with the cube of capillary pressure (PC) and that its degree is set by a constant (CPD)) times the concentration difference between protein in plasma (CPP) and protein in the interstitial fluid (CPI).

Line 14. Calculation of part of the rate of change of protein in the free fluid of the interstitial spaces (DPI) by subtracting the rate of return of protein to the plasma by way of the lymph (DPL) from the rate of movement of protein into interstitial spaces through the capillary membrane (DPC). (Note that the rate of movement of protein into the interstitial gel is not subtracted until line 25.)

Lines 15-16. Calculation of undamped rate at which the liver produces plasma proteins (DLZ) from the difference between a reference factor (CPR) and the concentration of plasma proteins (CPP).

Line 17. Calculation of rate at which the liver produces plasma protein (DLP) by damping DLZ.

Line 18. Calculation of the quantity of plasma protein (PRP) by integration of the rate of change of plasma protein as determined by adding the rate of formation of plasma protein by the liver (DLP) and the rate of return of proteins to the plasma by the lymphatics (DPL) and subtracting the rate of destruction or loss of plasma proteins by the body (DPO), the rate of loss of proteins through the capillary membrane (DPC), and the rate of loss of plasma protein through the pulmonary capillaries (PPD).

Line 22. Calculation of the activity factor for protein in the interstitial fluid (PGX) by summing the effect of concentration of the protein in the gel (CPG) and the effect of concentration of hyaluronic acid in gel (CHY) to exacerbate the colloid osmotic pressure effect of protein in the gel.

Line 23. Calculation of the rate of protein movement into gel (GPD) by multiplying the activity difference between the free fluid and gel times a constant. This activity difference is itself calculated by multiplying the gel volume (VG) times the protein difference between interstitial fluid (CPI) and gel protein activity (PGX).

Line 24. Calculation of the quantity of protein in the gel (GPR) by integration of the rate of movement of protein into gel (GPD).

Line 25. Calculation of the quantity of protein in the free interstitial fluid (IFP) by integration of the rate of increase of protein in the gel. This latter quantity is obtained by subtracting the rate of movement of protein from free interstitial fluid into interstitial gel fluid (GPD) from DPI calculated on line 14.

SUBROUTINE KIDNEY

Program Listing: See Program 14.

Flowchart: See Figure 21.

Lines 8-10. Calculation of degree of autoregulatory feedback at macular densa (GF3) from glomerular filtration rate (GFN). This in turn, controls afferent arteriolar resistance. The factor GF4 controls the feedback gain of the autoregulatory loop.

Line 11. Calculation of the afferent arteriolar resistance to the midpoint of the glomeruli (AAR) by multiplying the autonomic effect by the viscosity of the blood (VIM) and by the degree of autoregulatory feedback at the macular densa (GF3). The autonomic effect is calculated from the autonomic multiplier (AUM) and the factor ARF which increases or decreases the effect of the autonomics on the kidneys. A value of ARF of zero will set the sensitivity to zero.

Line 12. Calculation of the renal resistance (RR) by addition of the afferent arteriolar resistance (AAR) and the efferent (postglomerular) resistance. The efferent resistance is calculated by multiplying a constant times the viscosity of the blood (VIM).

Line 13. Calculation of renal arterial pressure (PAR) by subtracting the Goldblatt parameter (GBL) from the arterial pressure (PA).

Line 14. Calculation of the blood flow through the kidneys (RFN)(assuming the kidneys are normal) by dividing the renal arterial pressure (PAR) by the renal resistance (RR).

Line 15. Calculation of renal blood flow (RBF) by multiplying the blood flow through the normal kidney (RFN) by the degree of normality of the kidneys (REK).

Line 16. Calculation of the pressure drop in the afferent arterioles (APD) by multiplying the normal renal blood flow (RFN) by the afferent arteriolar resistance (AAR).

Line 17. Calculation of glomerular pressure (GLP) by subtracting the pressure drop in the afferent arterioles (APD) from the renal arterial pressure (PAR).

Line 18. Calculation of glomerular filtration pressure (PFL) by subtracting plasma colloid osmotic pressure (PPC) and a constant value representing Bowman's capsule pressure from the glomerular pressure (GLP).

Line 19. This saves the value of GFN as GF1.

Line 20. Calculation of glomerular filtration (if the kidneys are normal) (GFN) by multiplying glomerular filtration pressure (PFL) times a constant representing the glomerular filtration coefficient. The factors GF2 and Z represent damping effects.

Line 21. This is a test to see if the normal glomerular filtration has changed by more than 0.002. If it has, the calculation goes back to line 8 until stabilization is obtained.

Line 22. Calculation of actual glomerular filtration rate (GFR) by multiplying normal filtration rate (GPN) by degree of normality of the kidneys (REK).

Line 23. Calculation of total tubular reabsorption (TRR) by adding the amount of glomerular filtrate that is reabsorbed irrespective of control by aldosterone and antidiuretic hormone (approximately 0.8 of GFR) and the maximum amount of fluid capable of being reabsorbed by the tubules each minute under the control of aldosterone and antidiuretic hormone, and by subtracting the amount of fluid not reabsorbed but could have been reabsorbed under the control of aldosterone and antidiuretic hormone.

Lines 24-25. Calculation of the rate of urinary output (VUD) by subtracting total tubular reabsorption (TRR) from glomerular filtration rate (GFR).

Line 30. Calculation of (undamped) rate of sodium loss in urine (NOZ) assuming a normal concentration of sodium in the urine of 100 meq/liter and assuming that there are three factors that affect this output; the volume of urine formed each minute (VUD), the aldosterone multiplier effect (AM), and the "third factor" effect related to the change in concentration of sodium in the extracellular fluid (CNE).

Line 31. Calculation of the rate of sodium loss in the urine (NOD) by damping NOZ.

Line 32. Calculation of the net rate of change of sodium in the extracellular fluid (NED) from intake of salt, expressed as basic intake of sodium (NID) times appetite factor (STH), and sodium loss (NOD).

Line 33. Calculation of quantity of sodium in extracellular fluid (NAE) by integration of net rate of change of sodium in extracellular fluids (NED).

SUBROUTINE IONS

Program Listing: See Program 15.

Flowchart: See Figure 22.

Line 7. Calculation of extracellular fluid volume (VEC) by addition of plasma volume (VP), volume of fluid in the interstitial spaces of the systemic circulatory bed (VTS), and volume of fluid in the interstitial spaces of the lungs (VPF).

Line 8. Calculation of concentration of potassium in extracellular fluid (CKE) by division of the quantity of potassium in the extracellular fluid (KE) by volume of extracellular fluid (VEC).

Line 9. Calculation of the rate of renal excretion of potassium (KOD) by multiplying the degree of normality of the kidneys (REK) by the sum of the non-aldosterone controlled portion of potassium excretion and the aldosterone (AM) controlled portion of potassium excretion.

Line 10. Calculation of total expected quantity of potassium in the intracellular fluid under equilibrium conditions (KIR) by addition of a constant value representing potassium in cells that is not dependent upon extracellular potassium concentration and the quantity of potassium inside the intracellular fluid that is dependent upon extracellular potassium concentration (CKE).

Line 11. Calculation of potassium gradient that causes potassium movement into the cells (KIE) by subtracting the actual level of potassium in the cells (KIR).

Line 12. Calculation of rate of movement of potassium through cell membranes (KCD) by multiplying difference between expected and actual potassium levels (KIE) times a constant for potassium diffusion.

Line 13. Calculation of quantity of potassium in the intracellular fluid (KI) by integration of the rate of movement of potassium into the intracellular fluid (KCD)

Line 14. Calculation of net rate of change of potassium in the interstitial fluid (KED) by subtracting the rate of loss of potassium in the urine (KOD) and rate of movement of potassium into the cells (KCD) from the rate of potassium intake (KID).

Line 15. Calculation of total quantity of potassium in extracellular fluid (KE) by integration of the net rate of change of potassium in extracellular fluid (KED).

Line 16. Calculation of concentrations of potassium in intracellular fluids (CKI) by division of quantity of potassium in intracellular fluids (KI) by volume of intracellular fluid (VIC).

Line 17. Calculation of concentration of sodium in extracellular fluid (CNA) by division of quantity of sodium in extracellular fluid (NAE) by volume of extracellular fluid (VEC).

Line 18. Calculation of concentration gradient between intracellular and extracellular fluids by subtracting the concentration of sodium in the extracellular fluids (CNA) as an indicator of the osmolarity of the extracellular fluid from the concentration of potassium in the intracellular fluids (CKI) as an indicator of the osmolarity inside the cells.

Line 19. Calculation of the rate of movement of water into cells from the extracellular fluid space (VID) from the osmolarity factor difference (CCD).

Line 20. Calculation of volume of water in cells (VIC) by integration of the rate of movement of water into the cells (VID).

SUBROUTINE GELFLD

Program Listing: See Program 16.

Flowchart: See Figure 23.

Line 7. Calculation of concentration of hyaluronic acid in gel of interstitial spaces (CHY) by dividing quantity of hyaluronic acid (HYL) by volume of gel (VG).

Line 8. Calculation of elastic suction of the hyaluronic acid in the tissues caused by elastic recoil of the gel (PRM) from the concentration of hyaluronic acid in gel (CHY).

Line 9. Calculation of colloid osmotic pressure of the gel reticulum caused by Donnen equilibrium (PGR) of hyaluronic acid (CHY).

Line 10. Calculation of the concentration of protein in gel (CPG) by division of quantity of protein in gel (GPR) by volume of gel (VG).

Line 11. Calculation of colloid osmotic pressure of the protein in the gel (PGP) by multiplying the activity of the protein in the gel (PGX) by a constant.

Line 12. Calculation of total colloid osmotic pressure of the fluid inside the gel (PGC) by adding that caused by the reticulum itself (PGR) to that caused by the protein in the gel (PGP).

Line 13. Calculation of the volume of free fluid in the interstitial spaces (VIF) by subtracting volume of gel fluid (VG) from total interstitial fluid volume (VTS).

Line 14. Calculation of solid tissue pressure (PTS) by graphical means (See Figure 17.) from volume of free interstitial fluid (VIF).

Line 15. Calculation of pressure of free interstitial fluid (PIF) by subtracting solid tissue pressure (PTS) from total tissue pressure (PTT).

Line 16. Calculation of concentration of protein in free interstitial fluid (CPI) by dividing quantity of protein (IFP) by volume of free fluid (VIF).

Line 17. Calculation of colloid osmotic pressure of free interstitial fluid (PTC) by multiplying concentration of protein in the interstitial fluid (CPI) times a constant.

Line 18. Calculation of net mechanical forces attempting to cause movement into or out of gel (PGH) by summing the elastic recoil suction of gel (PRM), solid tissue pressure (PTS), and interstitial fluid pressure (PIF).

Line 19. Calculation of the rate of movement of fluid between gel and free interstitial fluid (VGD) by multiplying the resistance factor (V2D) by net pressure difference at the gel surface. This net pressure difference is obtained by subtracting the colloid osmotic pressure of the free fluid of the interstitial spaces (PTC) and the mechanical suction of the gel (PGH) from the sum of the total colloid osmotic pressure of the gel fluid (PGC) and the pressure of the interstitial fluid (PIF).

Lines 20-21. Calculation of the gel volume (VG) by integration of the net movement of fluid through the gel surface (VGD).

Line 22. This is a test to see if the net movement of fluid through the gel surface (VGD) exceeds 0.012. If so the program returns to line 7 until VGD $<$ 0.012.

III. Typical Model Experiments

In this chapter, the model is used to simulate a few typical experimental situations in order to illustrate the models general utility.

Experiment 1: Hypertension in a salt loaded, renal deficient patient (Table 1).

Variables monitored- extracellular fluid volume (VEC), blood volume (VB), sympathetic stimulation (AU), cardiac output (QLO), total peripheral resistance (RTP), aortic pressure (PA), heart rate (HR), angiotensin concentration (normal=1)(ANC), urinary output (VUD).

Changes made-After 2 hours, the renal mass was reduced to 0.3 normal (REK=0.3). After 4 days, the salt intake was increased to five times normal (NID=0.5). Total experimental time was 8 days.

Observations-The initial decrease in renal mass had only a slight effect on variables monitored with the exception of a slight decrease in cardiac output and simultaneous increase in total peripheral resistance. The arterial pressure elevated a small amount. Increase of salt load caused more dramatic effects. The extracellular volume and blood volume rose, the cardiac output increased considerably and then stabilized, while the total peripheral resistance fell. The rise in cardiac output increased the arterial pressure. After 120 hours, the cardiac output stabilized, while the peripheral resistance rose. The arterial pressure continued to increase, which demonstrates that the increase in total peripheral resistance, not cardiac output, was responsible for the long-term hypertension. Note that urinary output increased during salt loading because of the effect of high salt intake on thirst.

Experiment 2: Nephrosis due to protein loss by plasma (Table 2).

Variables monitored-urinary output (VUD), interstitial fluid gel volume (VG), total interstitial fluid volume (VTS), plasma volume (VP), total plasma protein (PRP), interstitial fluid pressure (PIF), aortic pressure (PA), cardiac output (QLO).

Changes made-After 1 hour, the rate of loss of plasma protein was increased sevenfold (DPO=0.05). After 108 hours the rate of loss of plasma protein was put back at three times normal (DPO=0.021). Total experimental time was 5 1/2 days.

Observations–The initial decrease in plasma protein initiated slight decreases in both arterial pressure and cardiac output and marked decrease in in urinary output. The fluid thus retained caused swelling of the interstitial gel. The volume of free interstitial fluid (VTS-VG) remained relatively stable until the interstitial fluid pressure rose into the positive range. Then, marked edema occured with sharp drop of cardiac output. When the rate of renal loss of protein was increased to the point where the liver could increase the plasma protein level, the edema was relieved with high diuresis and increased cardiac output.

Experiment 3: Severe muscle exercise (Table 3).

Variables monitored–urinary output (VUD), muscle venous oxygen pressure (PVO), muscle cell oxygen pressure (PMO), aortic pressure (PA), sympathetic stimulation (AUP), cardiac output (QLO), muscle blood flow (BFM), rate of oxygen utilization by muscle cells (MMO).

Changes made–After 30 seconds, the exercise parameter was changed to 60 times its normal value (EXC=60), corresponding to a whole body metabolism increase of approximately 15 times. At the same time, the time constant for local vascular response to metabolic activity was reduced by 1/40 (A4K=0.025), the damping factor Z was increased 5 fold (Z=5.), and the factors Z5, Z6, and Z8 were modified (Z5=1., Z6=10., Z8=3.). The value of I3 was also set at zero to prevent long integration steps. After 2 minutes, the value of EXC was put back to normal (EXC=1). After 5 minutes I3 was set back to normal (I3=20).

Observations–At the onset of exercise, cardiac output and muscle blood flow increased considerably within seconds. Urinary output fell to obligatory level while arterial pressure rose moderately. Muscle cell and venous P_{O_2} fell rapidly. Muscle metabolic activity showed an instantaneous increase, but then decreased considerably because of the development of a metabolic deficit in the muscles. When exercise was stopped, muscle metabolic activity fell to below normal, but cardiac output, muscle blood flow, and arterial pressure remained elevated for a while as the person was repaying his oxygen debt.

Experiment 4: Atrioventricular fistula (Table 4)

Variables monitored–extracellular fluid volume (VEC), blood volume (VB), autonomic stimulation (AU), cardiac output (QLO), total peripheral resistance (RTP), aortic pressure (PA), heart rate (HR), angiotensin concentration (relative to 1 at normal)(ANC), urinary output (VUD).

Changes made-After 2 hours a fistula was created which would double cardiac output (FIS=0.05). After 4 days the fistula was closed (FIS=0.0). Total experimental time was 9 days.

Observations-Opening the fistual caused an immediate dramatic change in cardiac output, total peripheral resistance, and heart rate. Urinary output decreased to obligatory levels. As the body adapted, extracellular fluid volume and blood volume increased to compensate for the fistula with the result that after a few days arterial pressure, heart rate, and urinary output were near normal levels. Cardiac output doubled and peripheral resistance halved. When the fistula was closed, dramatic effects again occurred with rapid decrease in cardiac output, rapid increase in peripheral resistance, moderate increase in arterial pressure, and moderate decrease in heart rate. Marked diuresis reduced extracellular fluid volume and blood volume to normal or slightly below. After several days, the patient was nearly normal.

IV. Model Characteristics and Interfacing Problems

The experiments contained in Chapter III, and others not reported here, demonstrate that the model of Guyton is capable of responding in a correct overall fashion to a variety of stress conditions despite the fact that the model itself is based on the gross function of the many different parts of circulation. Most of the subsections of the model are, in fact, developed at a crude level with minute details completely absent. The overall correctness of the model predictions is a result of the facts that the interactions between the basic regulatory mechanisms of the body possesses an inherent stability and that this stability is more important than the details of any one mechanism.

The model presented and discussed here may be viewed as a controlled system plus controlling system with the controlling system having three major components: local control, hormonal control, and autonomic control. These controls act to drive the controlled system to the appropriate level in response to stress. There are no thermal regulatory components present in either the controlled or controlling system. Respiratory elements are absent as well with the exception of the effect of pulmonary interstitial fluid on aortic oxygen saturation. Hydrogen ion levels are not considered. Only the major cations, Na^+ and K^+, are treated. The model may be classified as an intermediate to long-term model with simulations of the order of days or weeks being the primary concern, although short-term simulations, as in the exercise experiment of Chapter III, are possible.

It should be possible to modify the present model to accomodate stimuli to which the model does not presently respond. Probably the most important of these stimuli are concerned with temperature regulation in the body and the regulation of respiration. Related to the latter is the problem of hydrogen ion regulation. Large mathematical models of the thermal regulatory (5) and respiratory regulatory systems (6) are presently available and have been subjected to considerable study. One basic question that immediately arises concerns the possibility of interfacing or combining these models with the circulatory model discussed here in order to include simulated responses by a patient to a wider variety of stimuli.

Usually, it is not possible to directly interface different models. This is so because different models generally utilize distinct approaches to the study of their respective systems with the different types of both controlled and controlling equations resulting in partial or complete incompatability of models. Some models are developed as short-term models only, and their use in conjunction with an intermediate or long-term model would make little sense. Often the major controlling feature of one model is completely absent from a model of a different system, in spite of the fact that the second system plays some role in the regulation of this component. At times, two different controlling systems drive the same component. Here, a decision as to the proper way of combining these driving forces must be made and this decision may be difficult to arrive at.

There are several distinct approaches which may be utilized to interface subsystem models and so form an overall composite model. To begin with, the individual models could simply be run simultaneously under a single monitor system with no thought of making the models interact. Thus, each model would react independently and output would be selected only from the model of interest at any particular time. This solution is not very satisfactory, both from the point of view of resource availability and the point of view of physiological realism. Such a system would not really represent an overall regulatory model and would answer few, if any, questions that the individual model systems alone could not answer. A second approach to forming a composite model would be to identify all elements in common from each of the controlling elements of the respective subsystem models and to implement a new overall controlling system which receives dynamic data from each subsystem and then regulates each controlled system according to overall current information. This approach is much more attractive than the first approach mentioned, but suffers at least one serious disadvantage, other than the basic one of how to write the controller equations. This disadvantage stems from the fact that the subsystem models themselves are designed to be realistic for different time periods. Thus, the respiratory model may be reliable for experiment times of 20-30 minutes while the circulatory model of Guyton may be used for experimental times of days or weeks. This limitation would make a composite model of this type almost prohibitively expensive to run for any reasonable length of time because of the simple fact that the time limiting step size must be controlled by the model with the shortest response.

A third path to the formation of a composite model appears to offer the most attractive alternative. This approach is similar, in some ways, to the second alternative mentioned above. Instead of implementing the detailed subsystem models, this third alternative would utilize the Guyton model discussed in this report as a basic master model with the other subsystem models included in their gross function only. This new master model would be carefully planned so as to be compatible with the detailed subsystem models. The detailed subsystem models would be utilized only in the event that detailed response of a particular subsystem is of interest. Otherwise, only crude responses of the gross system would be calculated. Thus, the overall model would be capable of producing long-term regulatory features while the detailed subsystem models would be capable of examining short-term transient effects. This alternative presents a considerable challenge to modellers in the form of compatibility requirements, but it must be remembered that the overall system being modelled is capable of functioning as one unit. It is suggested that this alternative be explored in depth in future researches.

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Table 1. Salt Loaded Renal Deficient Kidney

HOUR	VEC	VB	AU	QLO	RTP	PA	HR	ANC	VUD
0	15.0	5.00	0.989	5.12	19.4	99.7	71.7	0.996	1.03
2	15.0	5.00	0.991	5.11	19.4	99.4	71.8	1.002	0.98
	REK = 0.3								
3	15.0	5.03	0.938	4.87	21.9	103.6	69.4	0.286	0.55
6	15.0	5.06	0.815	4.76	21.9	105.1	64.7	0.209	1.02
12	15.0	5.06	0.840	4.74	22.0	104.0	65.6	0.224	0.92
18	15.0	5.04	0.871	4.69	22.2	104.0	66.8	0.238	0.83
24	15.0	5.04	0.891	4.67	22.3	104.1	67.5	0.244	0.78
30	15.0	5.04	0.899	4.67	22.4	104.5	67.8	0.245	0.77
36	15.0	5.04	0.901	4.68	22.4	104.9	67.9	0.244	0.78
42	15.0	5.04	0.902	4.69	22.5	105.3	68.0	0.241	0.79
48	15.0	5.04	0.904	4.71	22.5	105.6	68.0	0.240	0.80
54	15.0	5.04	0.905	4.72	22.5	106.1	68.1	0.239	0.81
60	15.0	5.04	0.908	4.71	22.6	106.3	68.2	0.238	0.82
72	15.0	5.05	0.914	4.71	22.7	106.9	68.5	0.237	0.82
96	15.0	5.05	0.926	4.72	22.8	107.9	68.9	0.236	0.82
	NID = 0.5								
97	15.1	5.07	0.910	4.96	22.7	110.5	68.5	0.221	0.90
102	15.6	5.23	0.646	5.44	21.2	117.0	58.8	0.012	2.38
108	15.7	5.31	0.579	5.73	20.6	119.3	56.7	0.010	3.08
114	15.7	5.34	0.571	5.84	20.6	121.1	56.5	0.010	3.25
120	15.6	5.35	0.580	5.88	20.8	122.5	56.9	0.010	3.23
126	15.5	5.35	0.595	5.87	21.0	123.8	57.5	0.010	3.16
138	15.5	5.35	0.627	5.86	21.4	126.3	58.7	0.010	3.01
150	15.4	5.35	0.656	5.87	21.8	128.6	59.8	0.010	2.93
162	15.4	5.35	0.682	5.87	22.2	130.8	60.8	0.010	2.86
174	15.5	5.35	0.706	5.87	22.5	132.7	61.7	0.010	2.81
192	15.5	5.35	0.739	5.87	22.9	135.4	63.0	0.010	2.73

Table 2. Nephrosis Due to Plasma Protein Loss

HOUR	VUD	VG	VTS	VP	PRP	PIF	PA	QLO
1	1.03	11.5	12.1	2.96	207.7	-5.98	99.7	5.09
	DPO = 0.05							
2	0.94	11.5	12.1	2.95	205.4	-5.93	98.8	5.04
4	0.36	11.6	12.2	2.92	200.8	-5.78	96.4	4.98
6	0.20	11.7	12.3	2.88	196.7	-5.60	94.8	4.87
9	0.20	11.9	12.5	2.83	191.2	-5.32	92.1	4.75
13	0.20	12.1	12.7	2.76	184.8	-4.89	89.0	4.66
17	0.20	12.3	12.9	2.73	179.4	-4.54	90.6	4.59
21	0.20	12.4	13.1	2.74	174.8	-4.24	90.6	4.56
25	0.20	12.6	13.2	2.74	170.9	-3.99	90.7	4.58
31	0.20	12.7	13.4	2.79	165.9	-3.74	94.0	4.63
37	0.98	12.7	13.4	2.84	161.6	-3.66	94.3	4.66
43	0.84	12.8	13.5	2.84	157.2	-3.43	93.2	4.66
49	0.75	12.9	13.6	2.83	152.7	-3.15	92.6	4.66
55	0.69	13.0	13.7	2.83	147.9	-2.83	91.8	4.63
61	0.69	13.1	13.9	2.82	142.9	-2.50	91.1	4.61
67	0.56	13.2	14.0	2.82	137.8	-2.14	90.0	4.58
73	0.41	13.4	14.2	2.80	132.3	-1.76	88.7	4.53
79	0.20	13.6	14.5	2.77	126.5	-1.28	86.2	4.45
85	0.20	13.8	14.8	2.73	120.4	-0.78	84.6	4.38
91	0.20	14.0	15.0	2.71	114.2	-0.31	84.2	4.29
94	0.20	14.0	15.2	2.71	111.2	-0.08	83.8	4.28
95	0.20	14.1	15.2	2.71	110.1	0.00	83.7	4.27
97	0.20	14.2	15.3	2.71	108.1	0.15	83.4	4.25
103	0.20	14.3	15.6	2.70	102.0	0.55	82.3	4.19
108	0.20	14.5	15.9	2.68	96.9	0.91	81.7	4.12
	DPO =0.021							
109	0.20	14.5	15.9	2.68	97.5	0.96	82.1	4.18
115	0.91	14.6	16.0	2.75	101.1	1.08	85.8	4.42
121	4.47	14.2	15.4	2.92	105.3	-0.01	89.9	4.70
127	2.29	13.9	14.9	2.90	108.6	-0.44	85.1	4.67
132	1.71	13.8	14.8	2.88	110.6	-0.51	85.4	4.66

Table 3. Simulation of Severe Muscle Exercise

SECS	VUD	PVO	PMO	PA	AUP	QLO	BFM	MMO
30	1.07	39.9	8.00	99.9	0.98	5.12	0.99	59.9
	EXC = 60.							
31	1.00	37.1	5.25	100.6	1.14	5.29	0.93	352.8
32	0.76	29.1	3.96	103.6	1.38	5.60	1.09	331.6
33	0.32	25.7	3.13	108.5	1.69	6.26	1.97	307.5
34	0.20	26.8	2.70	112.1	1.94	7.13	3.13	291.4
45	0.20	28.1	1.35	137.5	3.49	14.0	11.1	210.2
60	0.20	27.9	1.08	140.8	4.10	17.7	14.6	186.0
75	0.20	27.9	1.00	142.2	4.31	18.9	15.8	178.1
90	0.20	27.9	0.97	142.4	4.40	19.4	16.4	175.1
105	0.20	27.9	0.96	142.4	4.45	19.7	16.6	174.0
120	0.20	27.9	0.95	142.4	4.49	19.8	16.7	173.5
	EXC = 1.0							
121	0.20	27.9	0.98	142.1	4.41	19.7	16.4	29.5
130	0.20	28.0	1.32	125.6	3.37	14.7	11.8	34.0
140	0.20	28.4	1.78	118.8	2.67	11.3	7.89	39.7
150	0.20	29.1	2.29	115.6	2.19	9.06	5.39	45.0
165	0.20	30.3	3.08	111.1	1.76	7.31	3.40	51.3
180	0.20	31.6	3.85	108.0	1.52	6.45	2.42	55.6
195	0.20	33.0	4.54	106.0	1.38	5.99	1.90	58.3
210	0.20	34.2	5.16	104.6	1.29	5.71	1.60	59.8
225	0.20	35.2	5.68	103.5	1.23	5.52	1.41	60.6
240	0.24	36.0	6.12	102.6	1.18	5.40	1.29	60.9
255	0.32	36.7	6.48	101.9	1.15	5.31	1.20	60.9
270	0.38	37.3	6.78	101.2	1.13	5.25	1.14	60.9
285	0.42	37.7	7.01	100.8	1.11	5.20	1.10	60.8
300	0.46	38.0	7.20	100.4	1.09	5.17	1.06	60.8
360	0.47	38.4	7.58	100.4	1.09	5.17	1.04	60.8
420	0.49	38.6	7.72	100.6	1.09	5.18	1.02	60.8
480	0.50	38.8	7.79	100.7	1.09	5.18	1.01	60.8
540	0.52	38.9	7.82	100.8	1.08	5.18	1.00	60.8

Table 4. Simulation of Atrioventricular Fistula

HOUR	VEC	VB	AU	QLO	RTP	PA	HR	ANC	VUD
2	15.0	5.00	0.99	5.11	19.4	99.4	71.8	1.00	0.98
	FIS = 0.05								
3	15.1	5.00	1.67	8.22	9.83	81.9	100.4	1.69	0.20
6	15.5	4.94	1.97	8.74	10.2	88.4	112.2	3.12	0.20
12	16.2	5.14	1.51	9.16	9.82	92.0	95.0	2.72	0.20
18	16.6	5.28	1.22	9.48	9.53	92.7	84.0	2.74	0.20
24	16.7	5.44	1.01	9.72	9.45	95.0	77.2	2.55	0.26
30	16.9	5.55	0.96	9.87	9.33	95.8	76.6	2.35	0.71
36	16.9	5.64	0.93	9.99	9.23	96.4	76.5	2.14	1.01
42	17.0	5.70	0.92	10.10	9.15	96.8	76.6	1.94	1.17
48	16.9	5.75	0.91	10.18	9.09	97.0	76.9	1.77	1.24
54	16.9	5.78	0.92	10.25	9.04	97.2	77.3	1.62	1.25
60	16.9	5.80	0.92	10.31	9.00	97.3	77.7	1.50	1.24
66	16.8	5.82	0.93	10.35	8.97	97.4	78.0	1.39	1.22
72	16.8	5.82	0.93	10.39	8.95	97.6	78.3	1.31	1.19
78	16.8	5.83	0.94	10.42	8.94	97.6	78.6	1.25	1.16
84	16.7	5.83	0.94	10.44	8.93	97.7	78.8	1.19	1.13
90	16.7	5.83	0.95	10.46	8.92	97.8	79.0	1.15	1.10
96	16.7	5.83	0.96	10.47	8.92	97.8	79.1	1.12	1.08
	FIS = 0.0								
97	16.3	5.75	0.44	7.70	14.4	111.6	54.9	0.04	13.12
99	15.1	5.54	0.48	6.96	15.7	108.5	54.2	0.01	11.70
102	14.1	5.28	0.69	5.92	18.1	106.4	60.8	0.65	6.35
108	13.9	4.93	1.10	4.87	19.5	94.4	75.7	1.54	0.20
114	14.2	4.77	1.44	4.58	19.9	89.7	88.7	2.07	0.20
120	14.5	4.73	1.42	4.43	20.5	90.3	87.9	2.47	0.20
132	14.9	4.75	1.24	4.46	20.4	90.9	81.0	2.90	0.20
144	15.1	4.92	0.81	4.78	20.3	98.0	64.3	2.35	1.74
156	15.0	4.95	0.86	4.88	20.0	97.5	66.4	1.91	1.33
168	15.0	4.96	0.89	4.93	19.8	97.7	67.7	1.61	1.19
180	15.0	4.98	0.91	4.99	19.6	98.0	68.6	1.41	1.12
192	15.0	4.98	0.93	5.02	19.6	98.2	69.4	1.27	1.08
216	15.0	4.99	0.96	5.05	19.4	98.5	70.3	1.11	1.03

Figure 1. Flow Chart for Circulatory, Fluid, and Electrolyte Regulation Model.

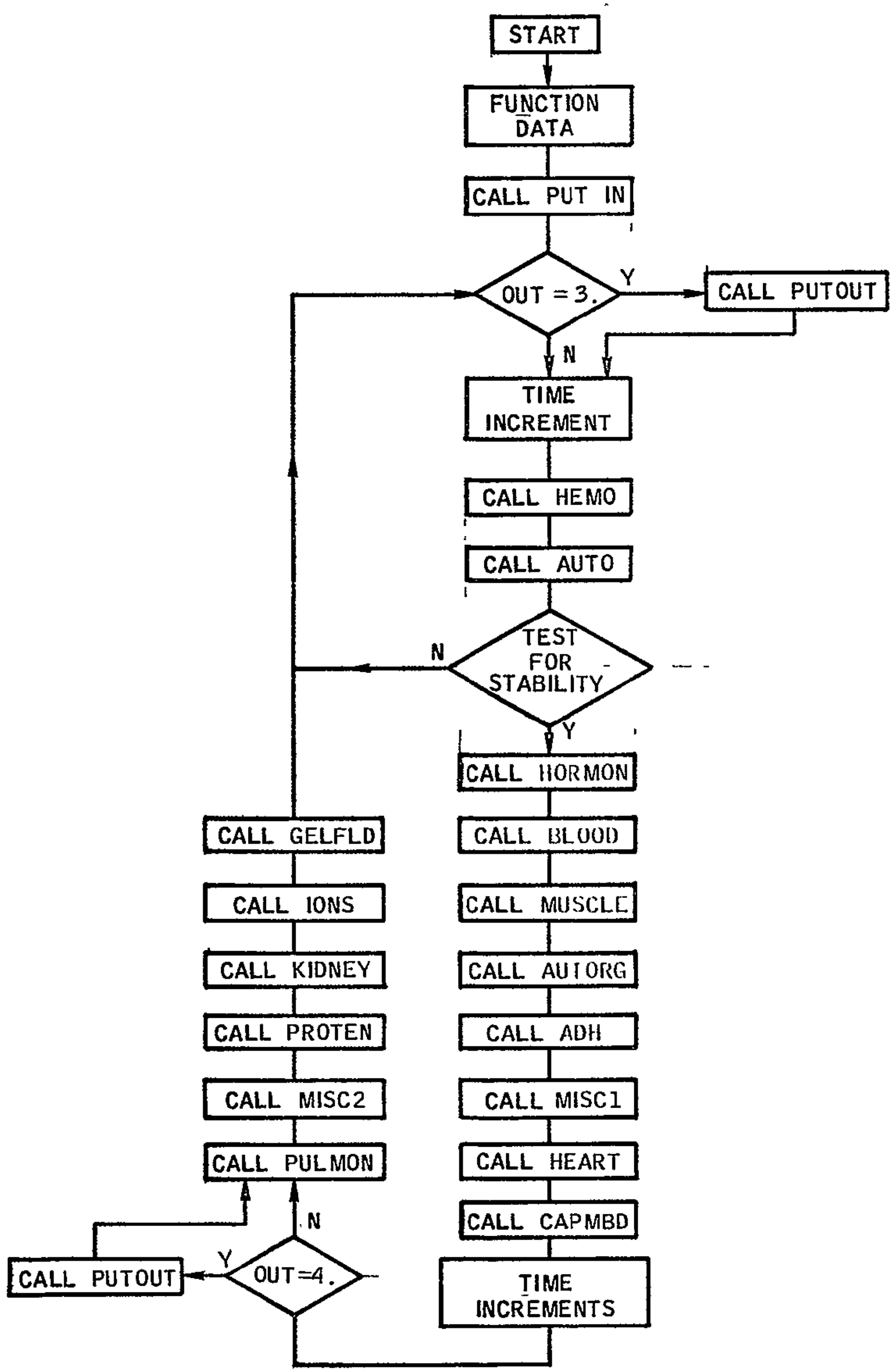
START
FUNCTION DATA
CALL PUT IN
OUT = 3.
Y
CALL PUTOUT
N
TIME INCREMENT
CALL HEMO
CALL AUTO
TEST FOR STABILITY
N
Y
CALL HORMON
CALL BLOOD
CALL MUSCLE
CALL AUTORG
CALL ADH
CALL MISC1
CALL HEART
CALL CAPMBD
TIME INCREMENTS
CALL GELFLD
CALL IONS
CALL KIDNEY
CALL PROTEN
CALL MISC2
CALL PULMON
N
OUT=4.
Y
CALL PUTOUT

Figure 2. Flow Chart for Subroutine HEMO.

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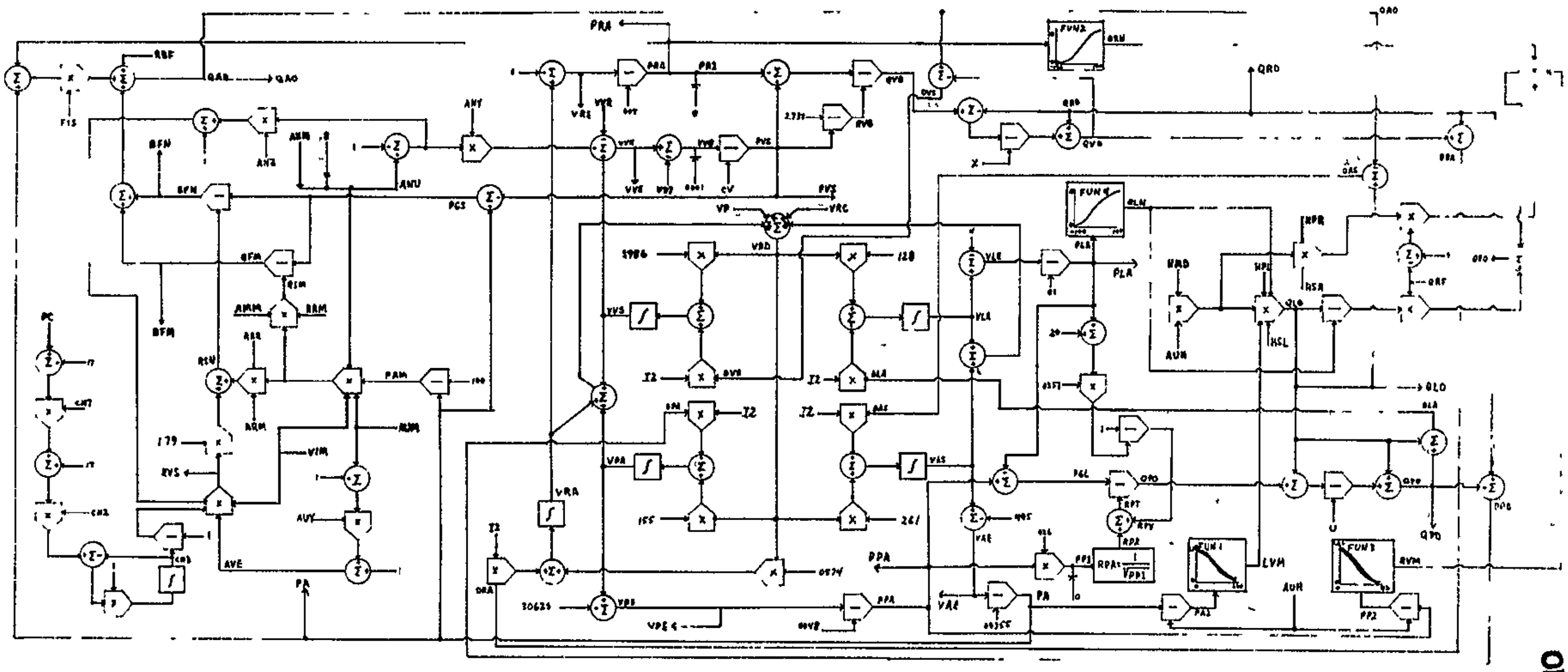

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Figure 3. Relationship Between Effective Arterial Pressure (PA2) and Left Ventricular Pumping Effectiveness (LVM), Function 1.

FUNCTION 1

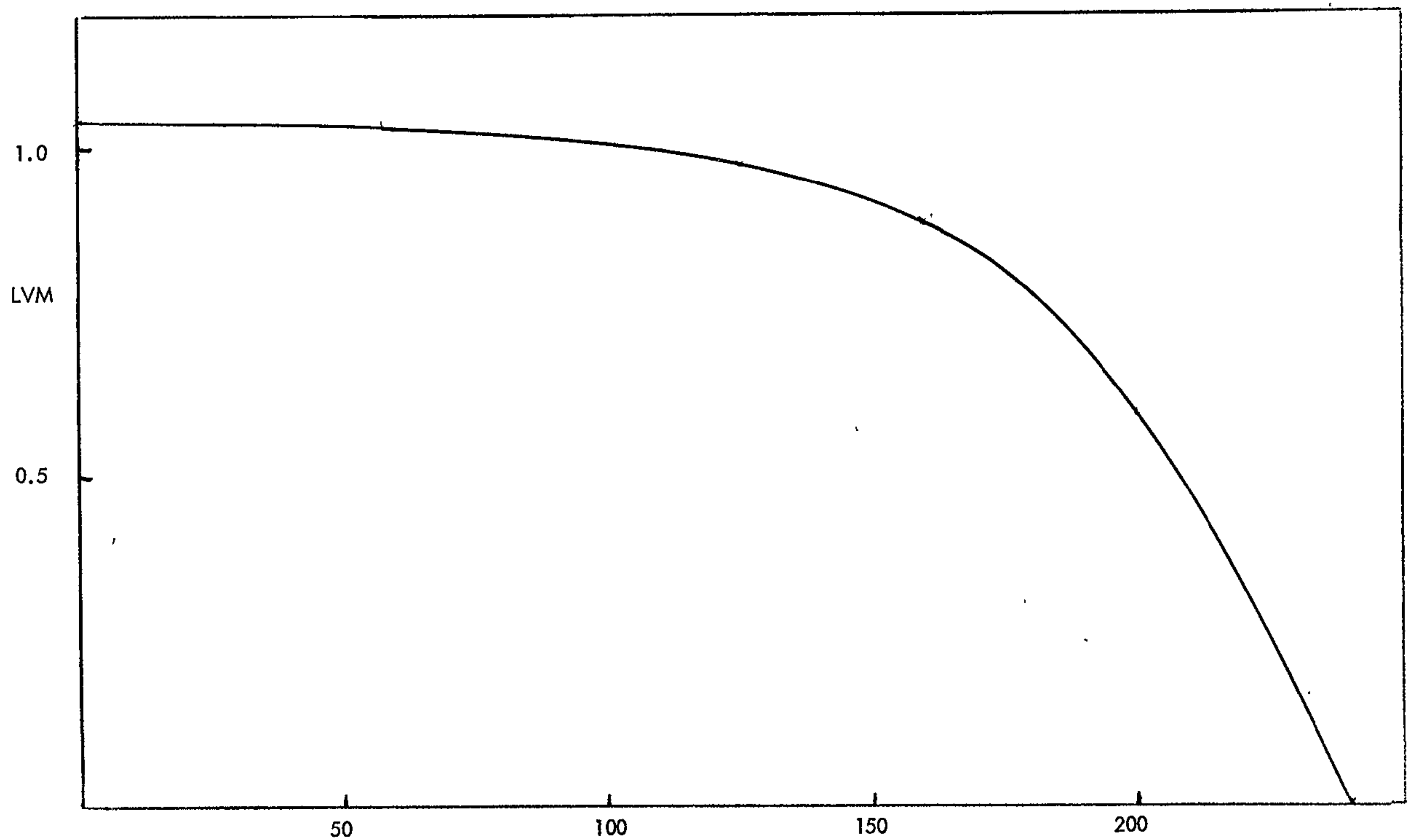

Figure 4. Relationship Between Right Atrial Pressure (PRA) and Normal Output of Right Atrium (QRN), Function 2.

FUNCTION 2

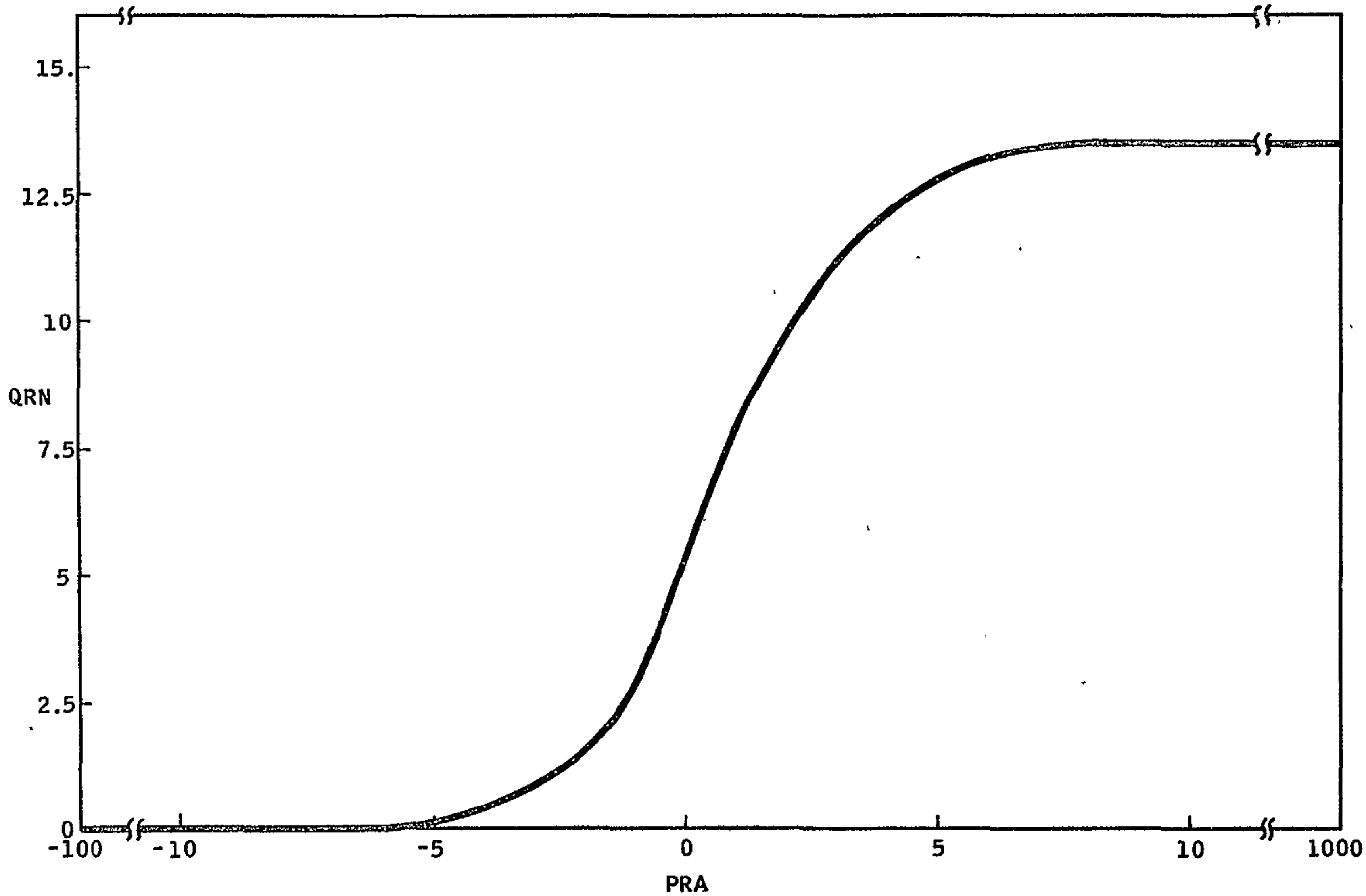

Figure 5. Relationship Between Effective Pulmonary Arterial Pressure (PP2) and Pumping Effectiveness of Right Ventricle (RVM), Function 3.

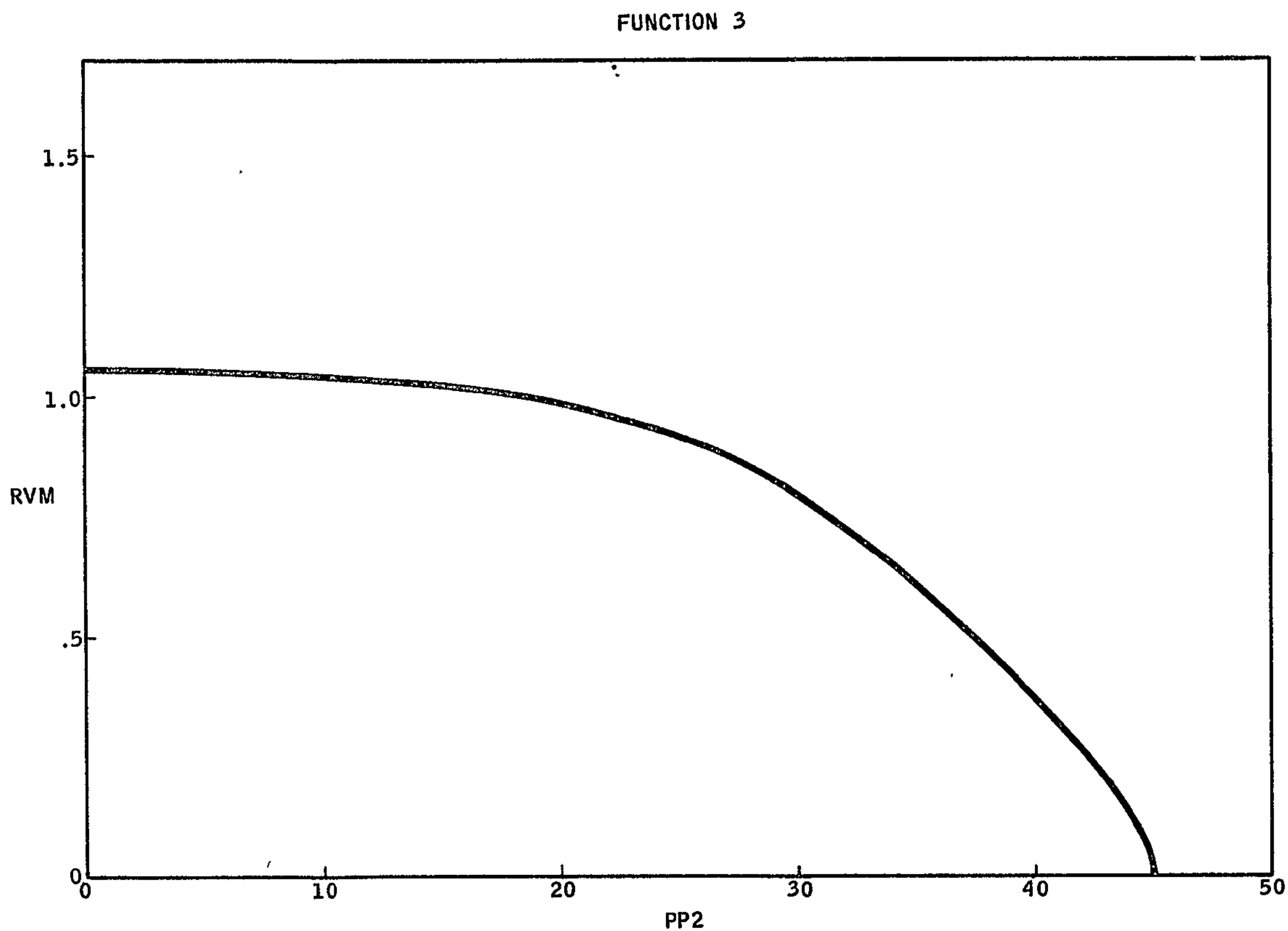
FUNCTION 3
RVM
1.5
1.0
.5
0
0
10
20
30
40
50
PP2

Figure 6. Relationship Between Left Atrial Pressure (PLA) and Normal Output of Left Ventricle (QLN), Function 4.

FUNCTION 4

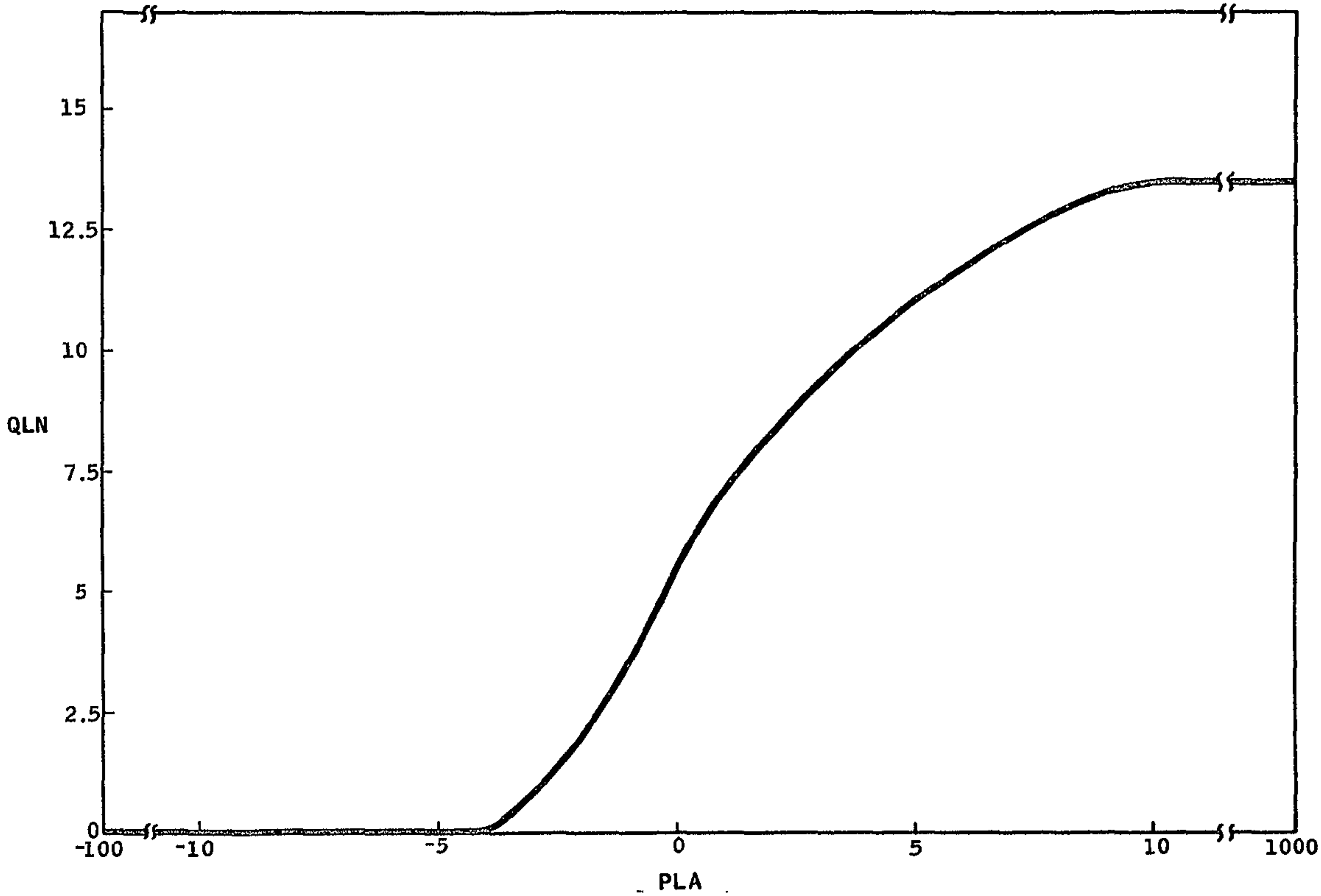

Figure 7. Flow Chart for Subroutine AUTO.

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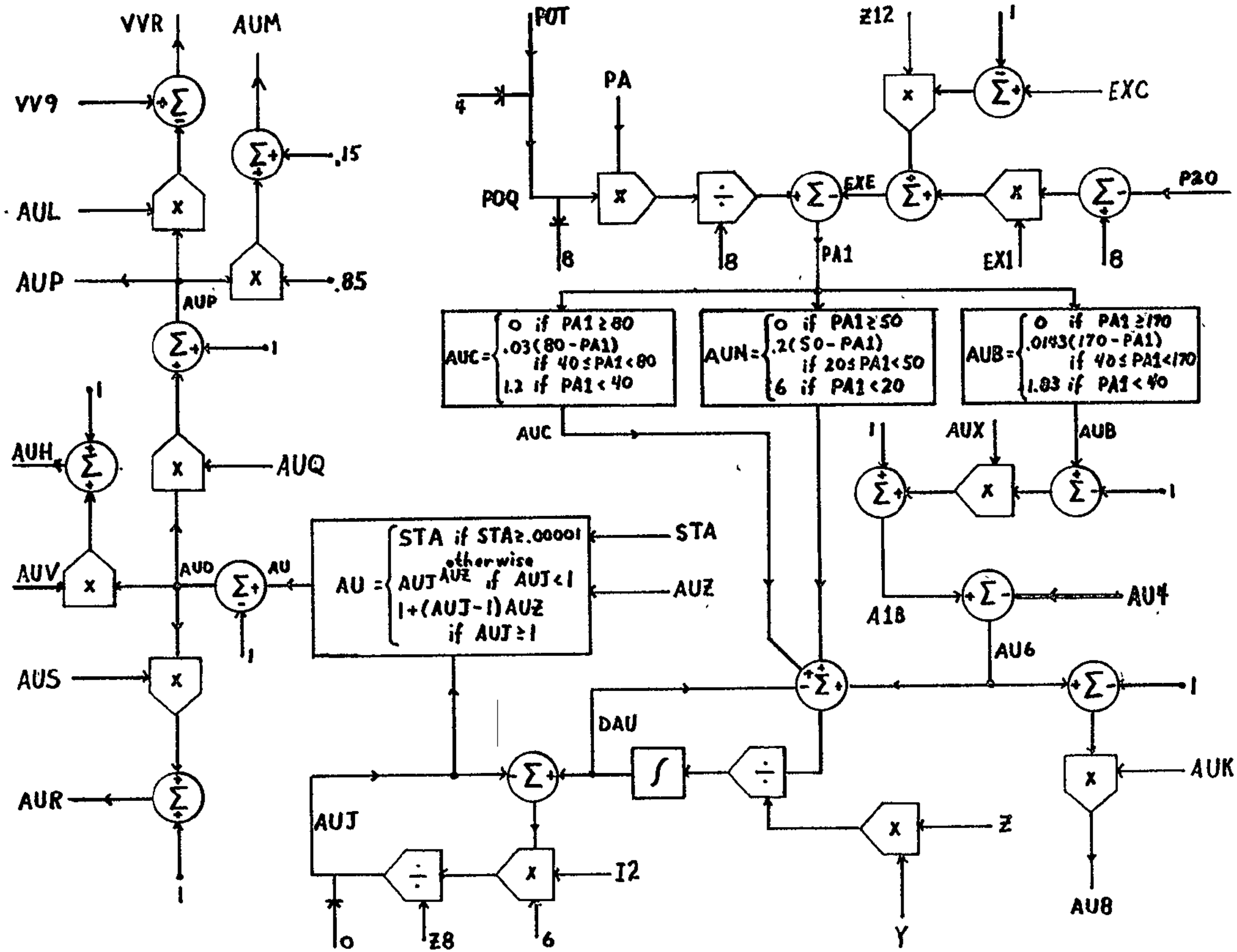

Figure 8. Flow Chart for Subroutine HORMON.

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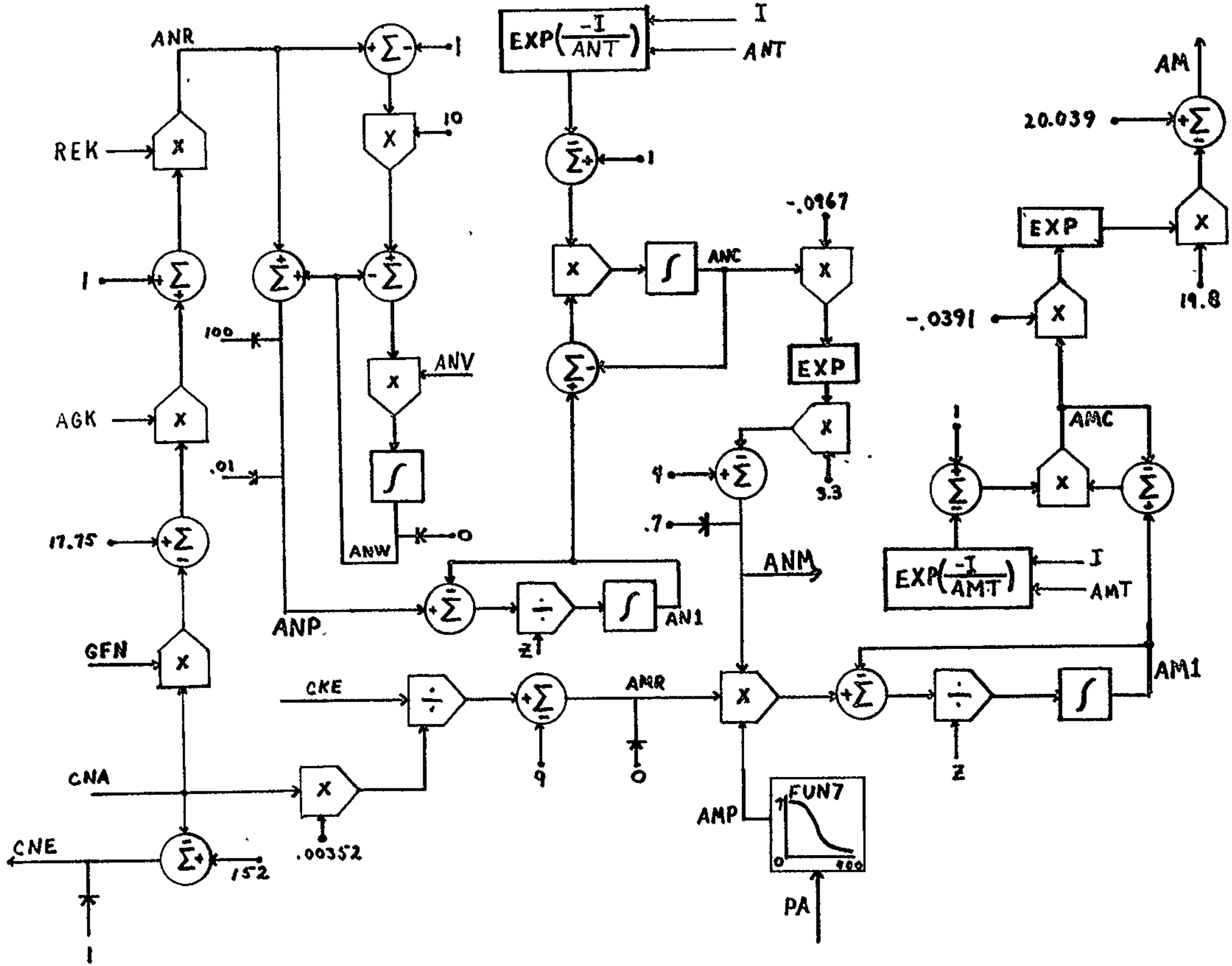


Figure 9. Relationship Between Arterial Pressure (PA) and Aldosterone Secretion (AMP), Function 7.

FUNCTION 7

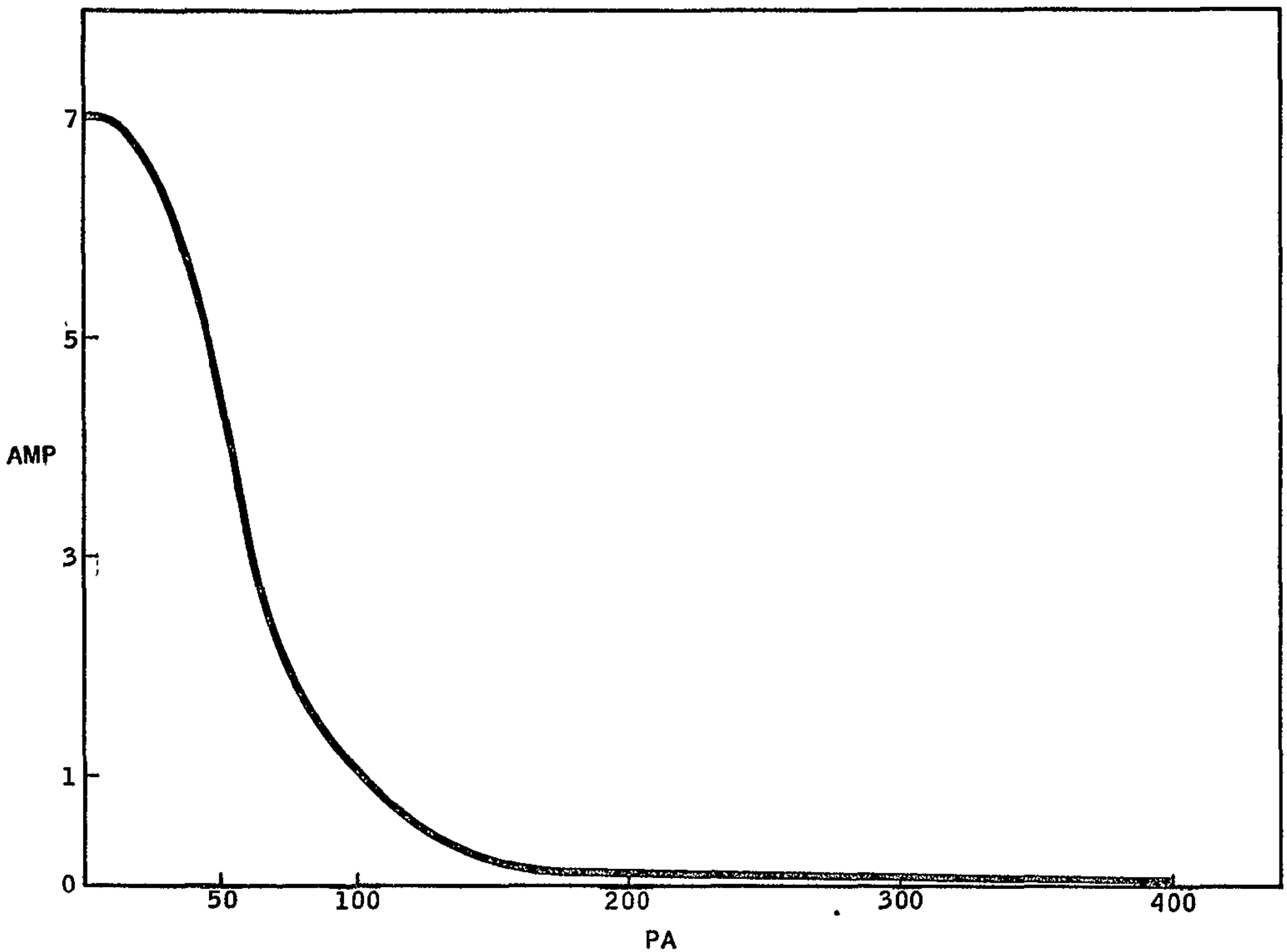
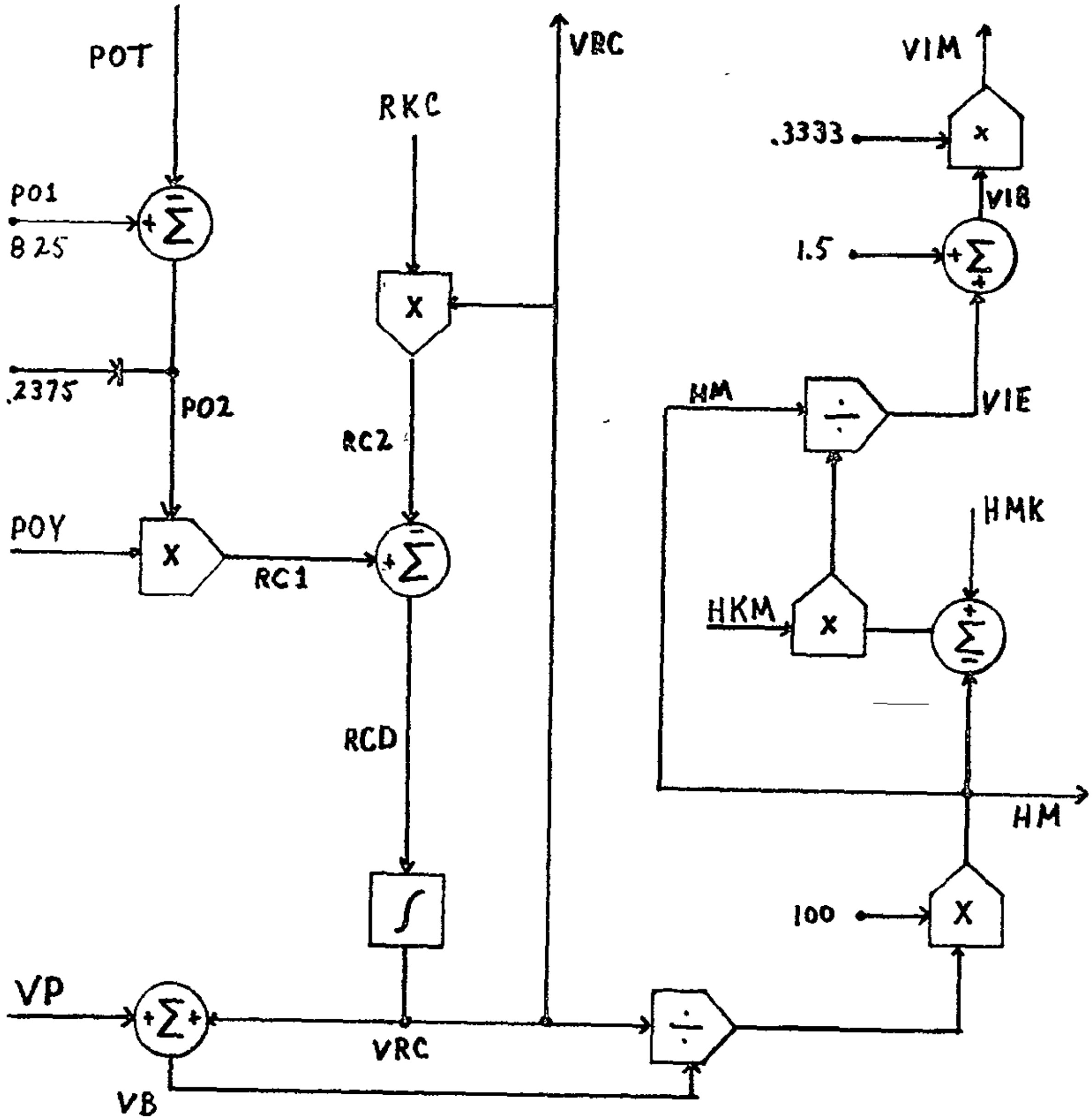


Figure 10. Flow Chart for Subroutine BLOOD.



POT
PO1
8.25
.2375
PO2
POY
X
RC1
RKC
X
RC2
RCD
VRC
VP
VB
VRC
VIM
.3333
x
VIB
1.5
HM
VIE
HMK
HKM
x
HM
100
X

Figure 11. Flow Chart for Subroutine MUSCLE.

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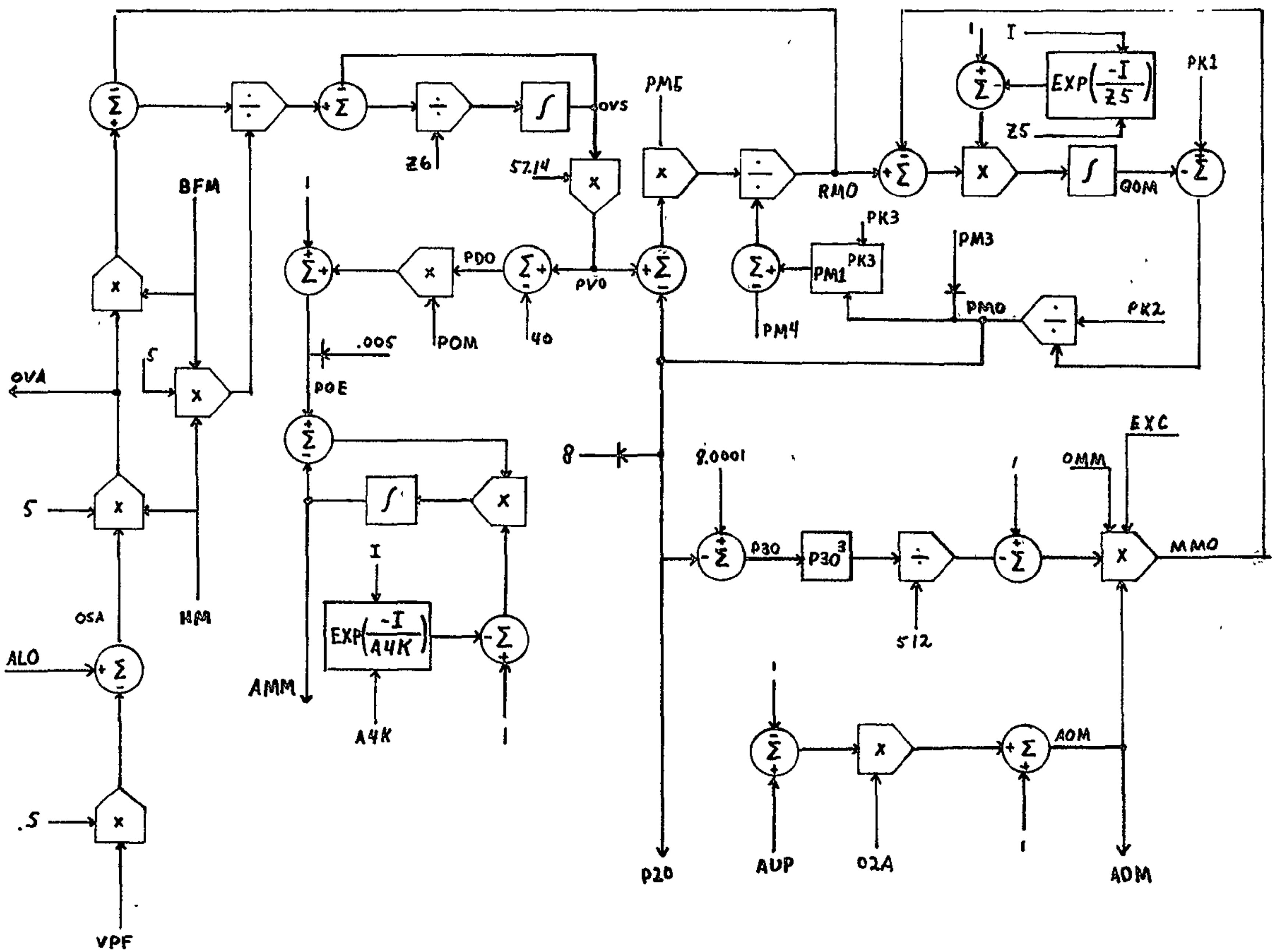

Figure 12. Flow Chart for Subroutine AUTORG.

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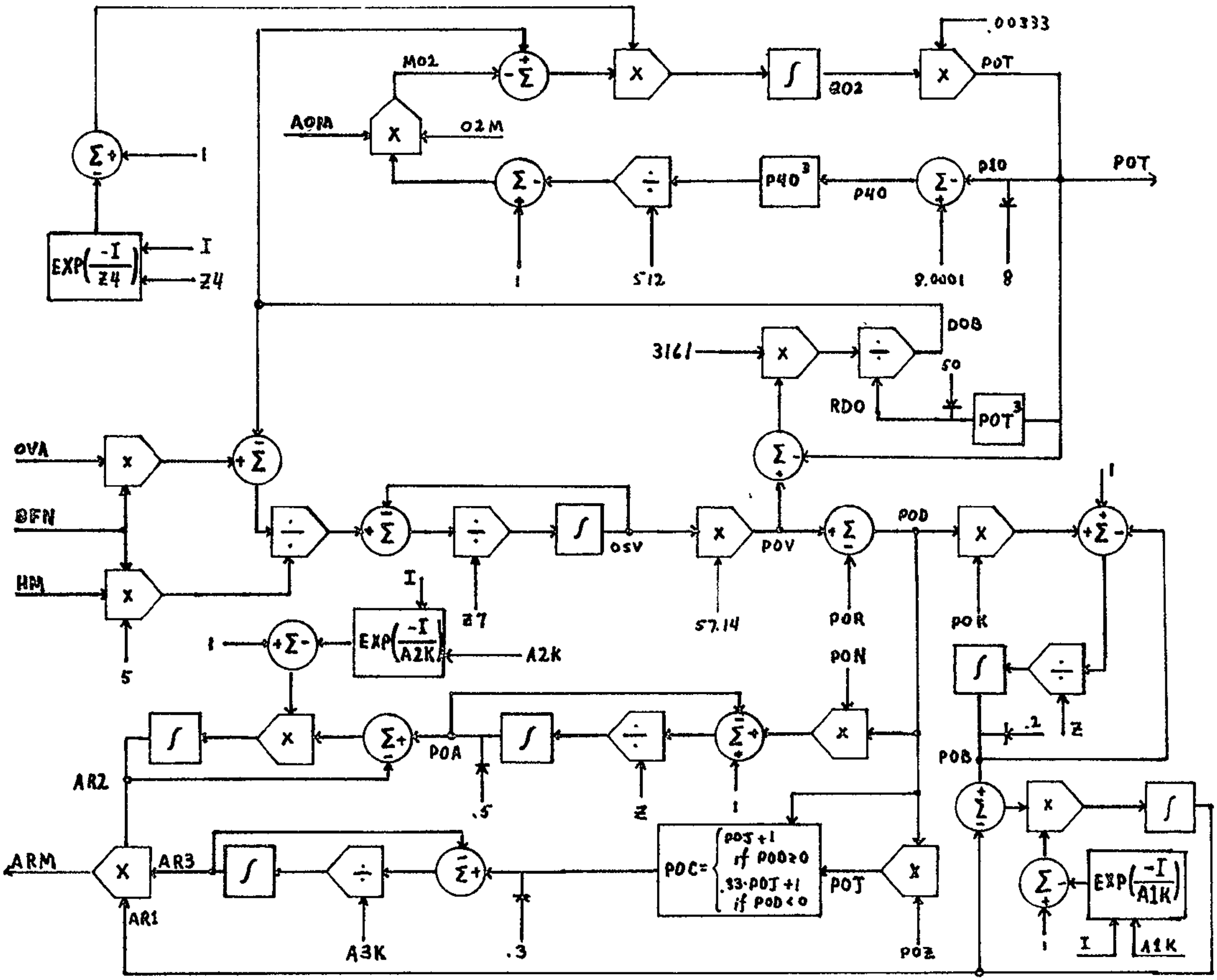

Figure 13. Flow Chart for Subroutine ADH.

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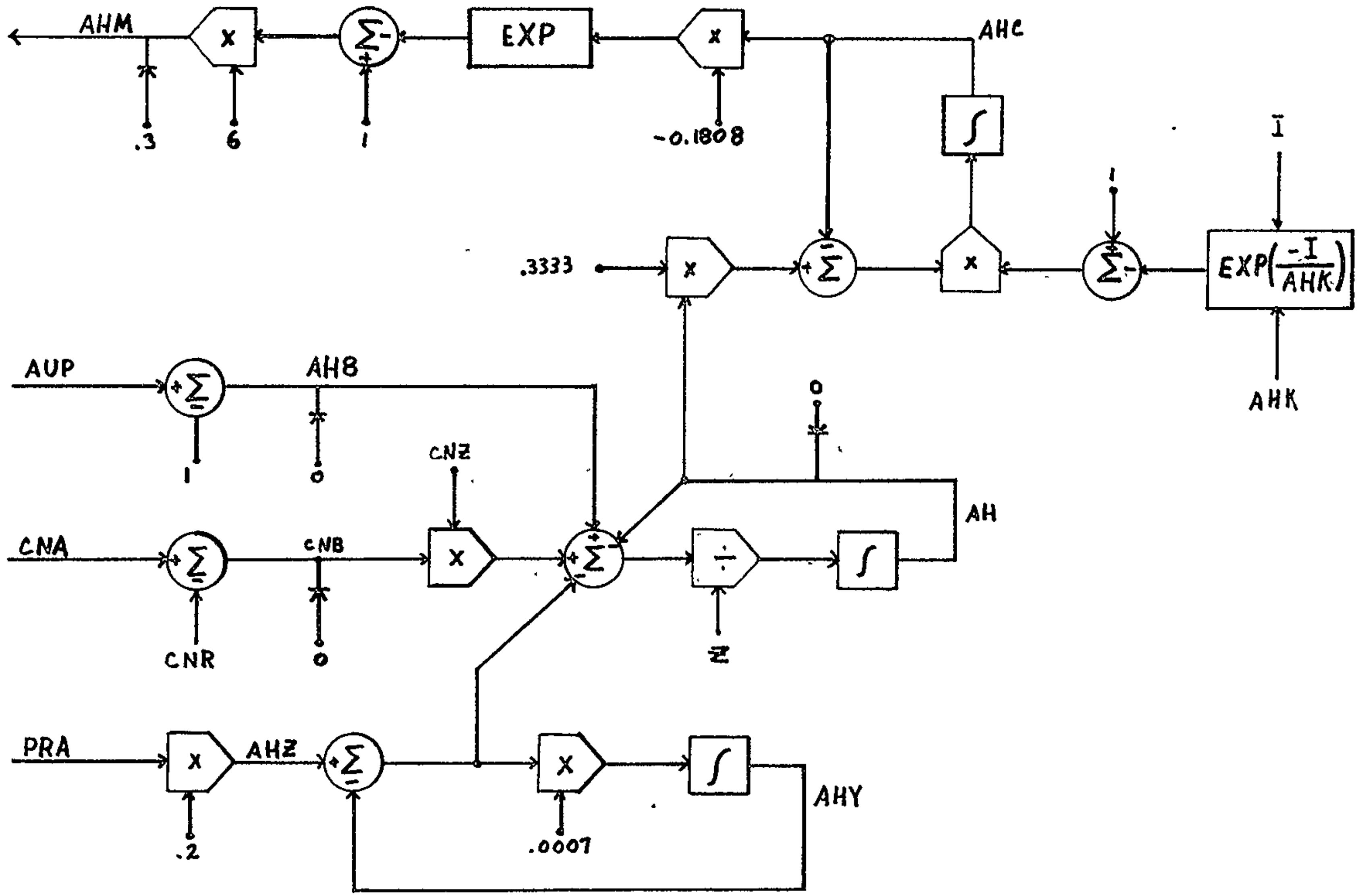

Figure 14. Flow Chart for Subroutine MISC1.

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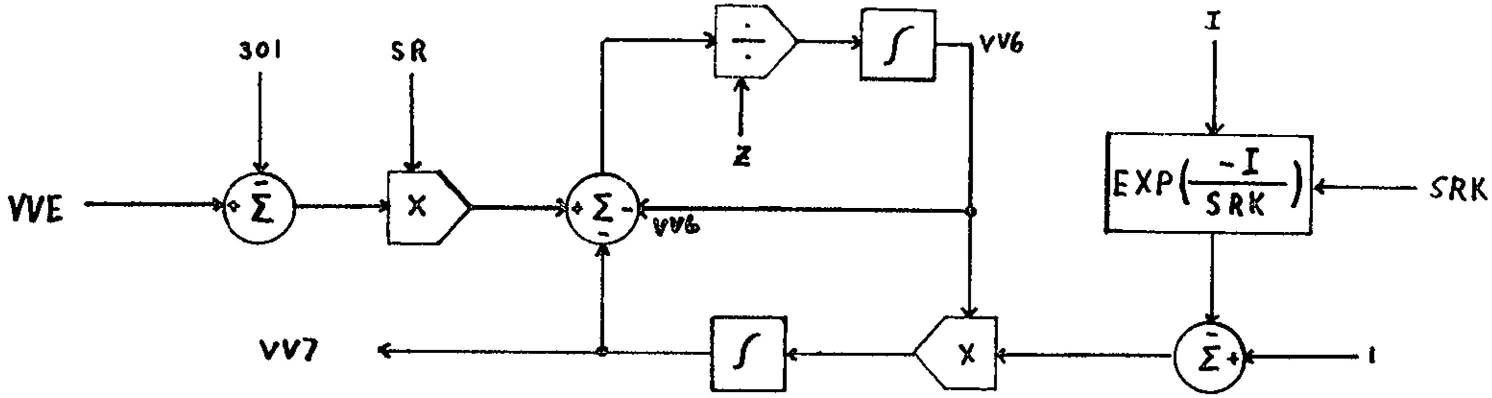

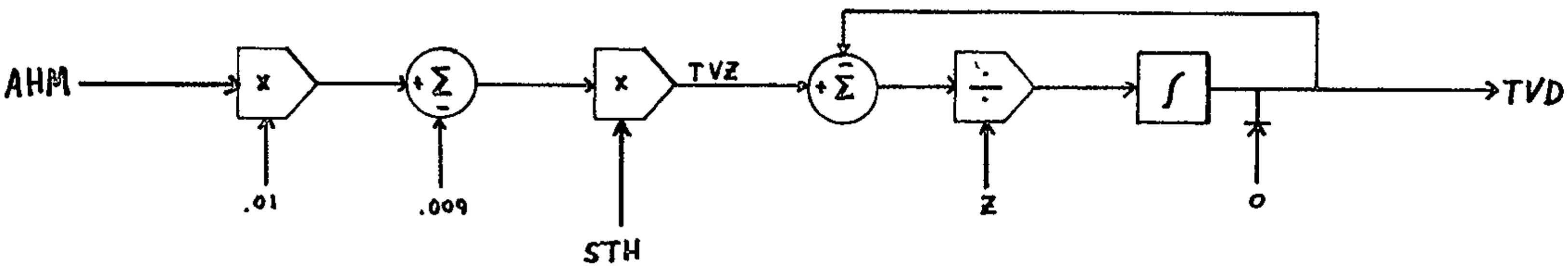

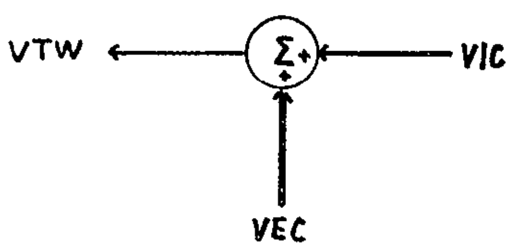

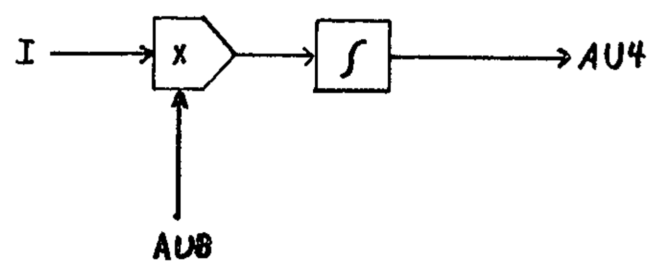

Figure 15. Flow Chart for Subroutine HEART.

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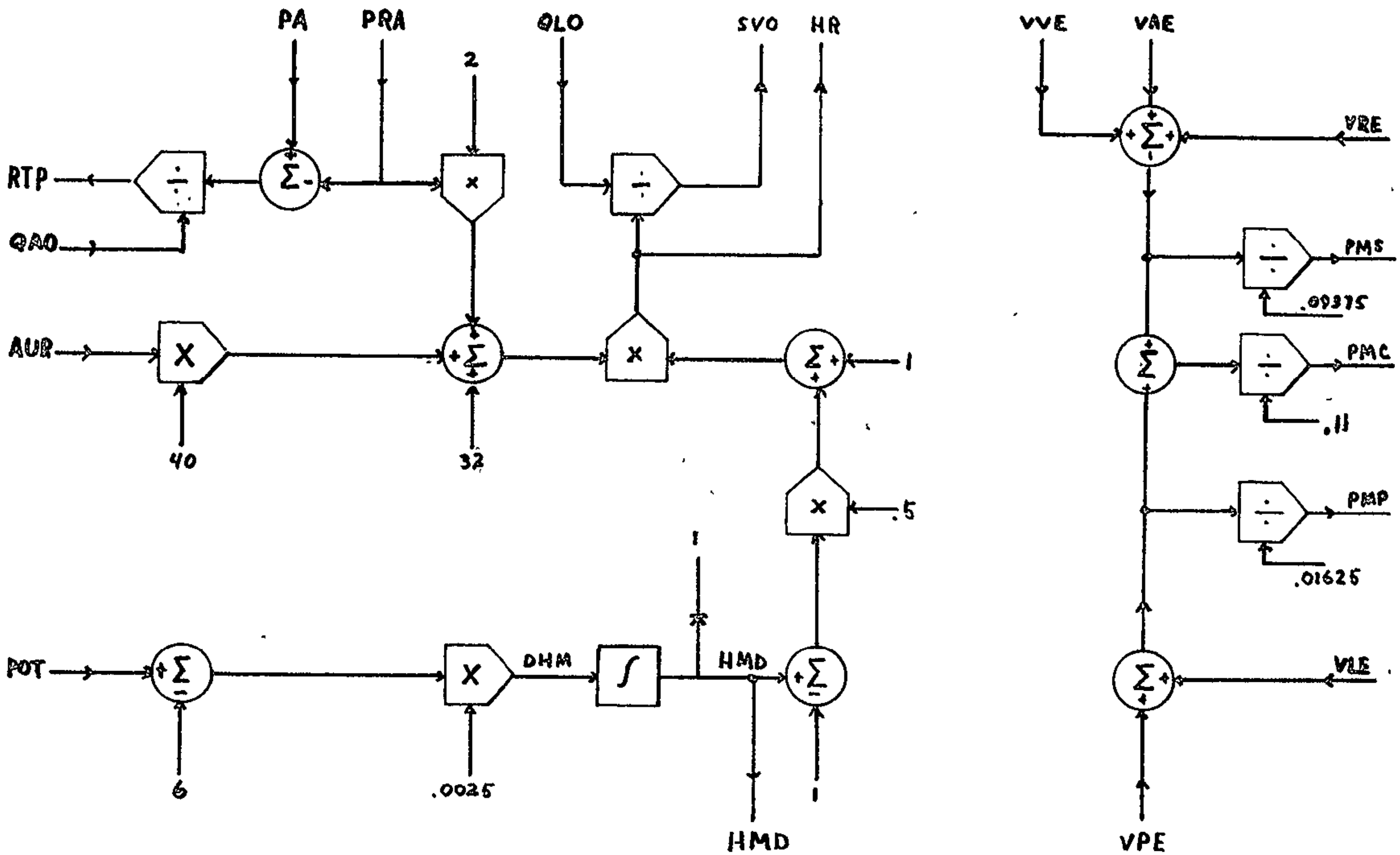

Figure 16. Flow Chart for Subroutine CAPMBD.

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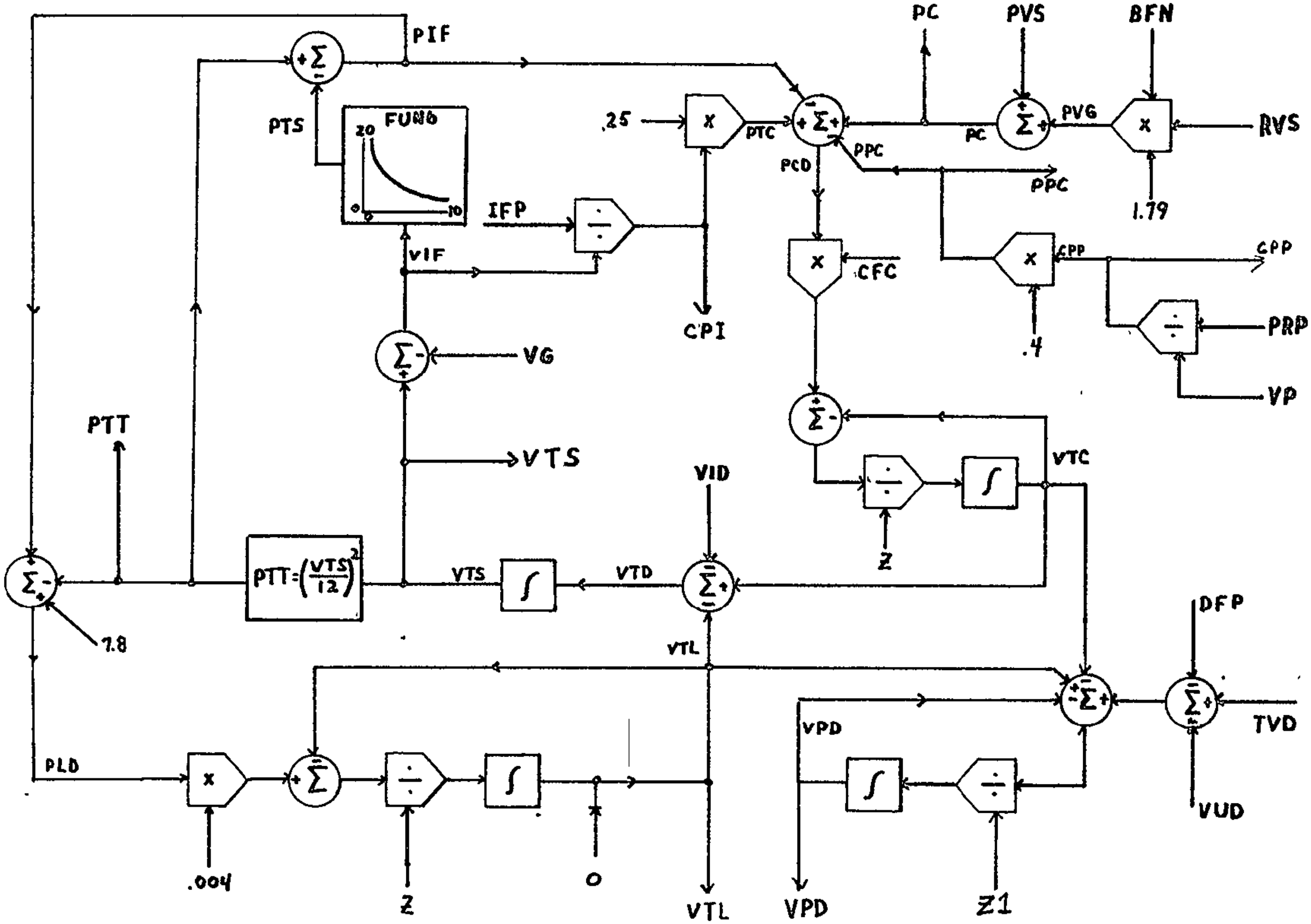

Figure 17. Relationship Between Volume of Free Interstitial Fluid (VIF) and Solid Tissue Pressure (PTS), Function 6.

FUNCTION 6

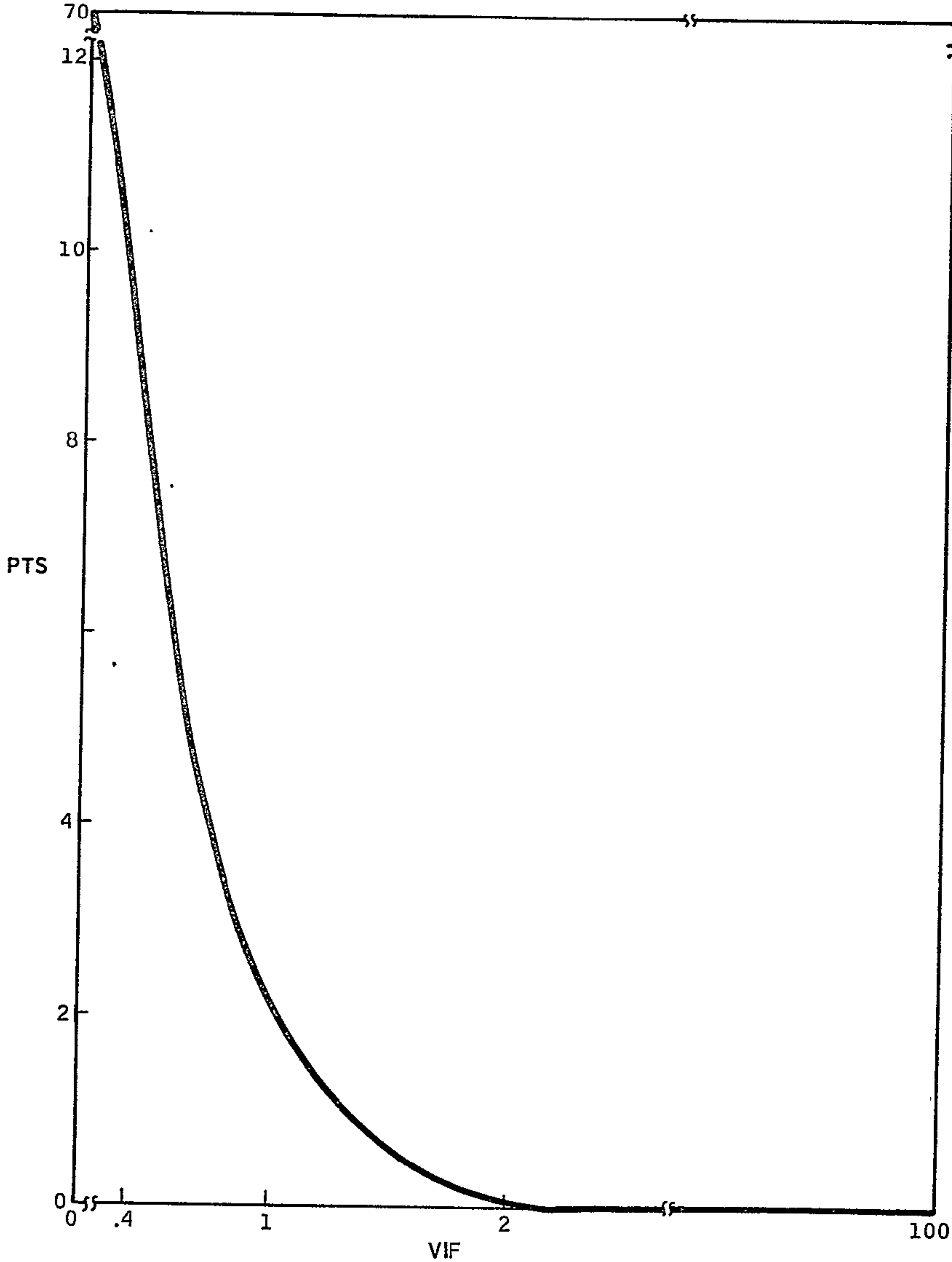

Figure 18. Flow Chart for Subroutine PULMON.

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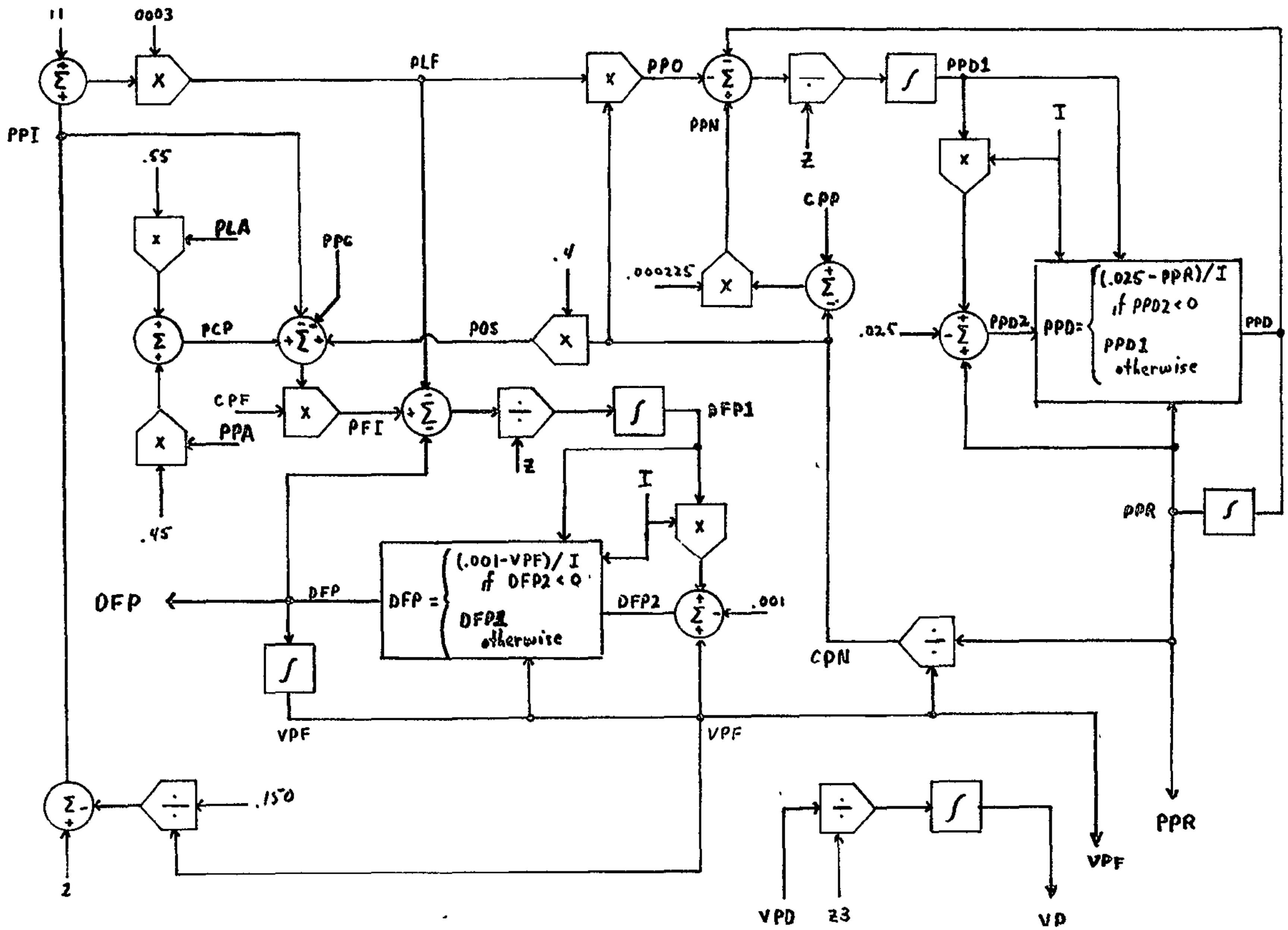

Figure 19. Flow Chart for Subroutine MISC2.

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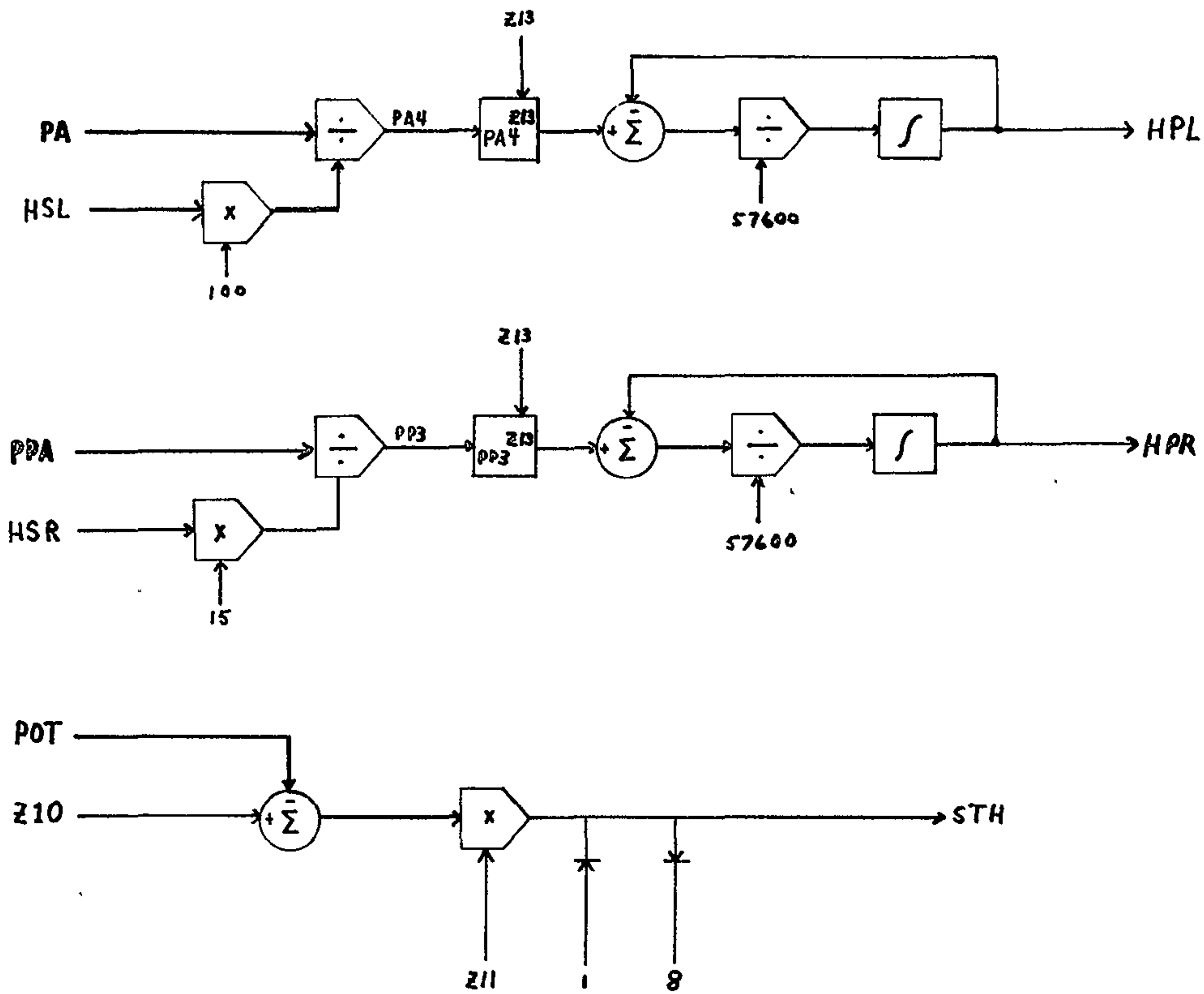

Figure 20. Flow Chart for Subroutine PROTEN.

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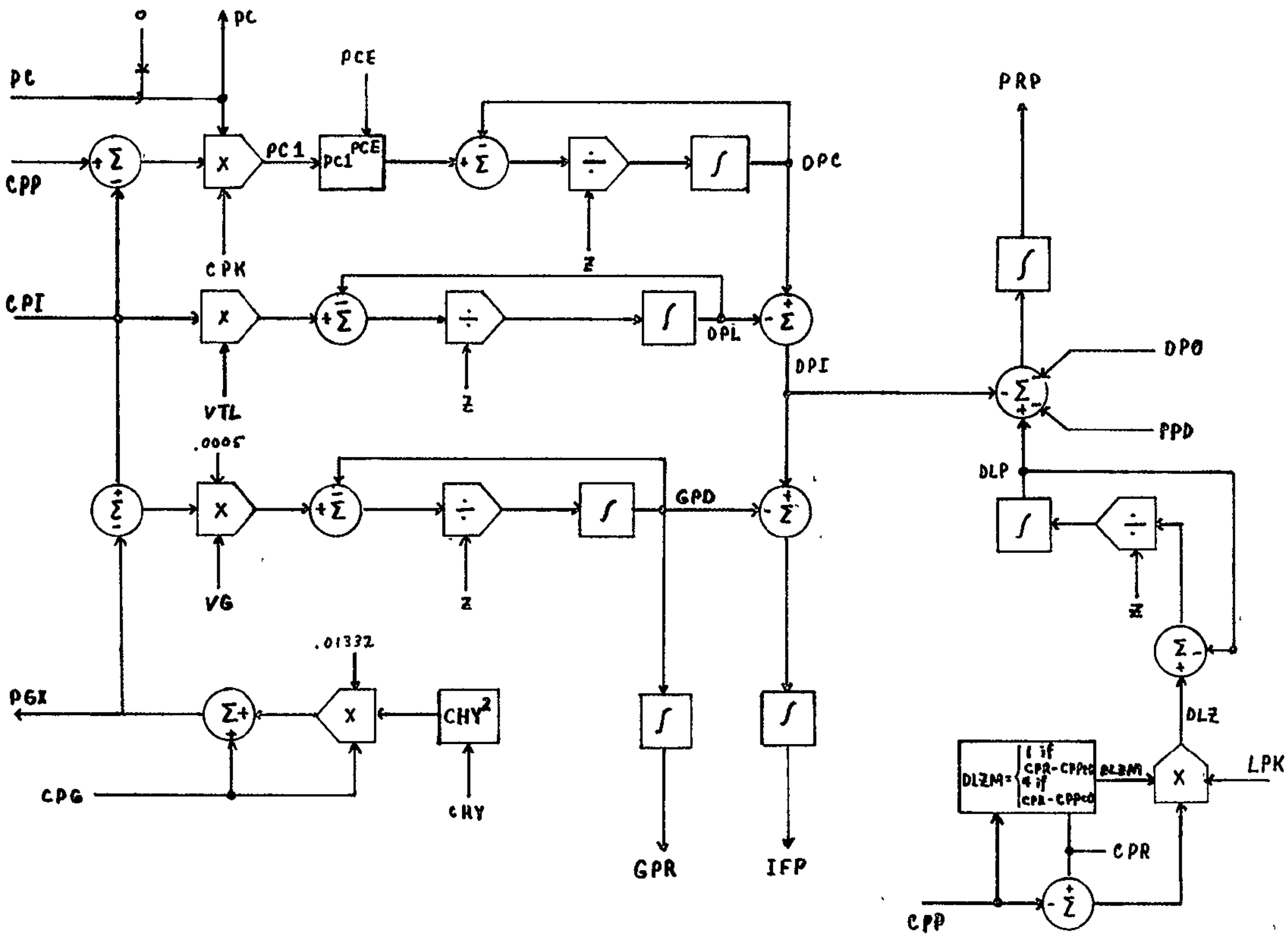

Figure 21. Flow Chart for Subroutine KIDNEY.

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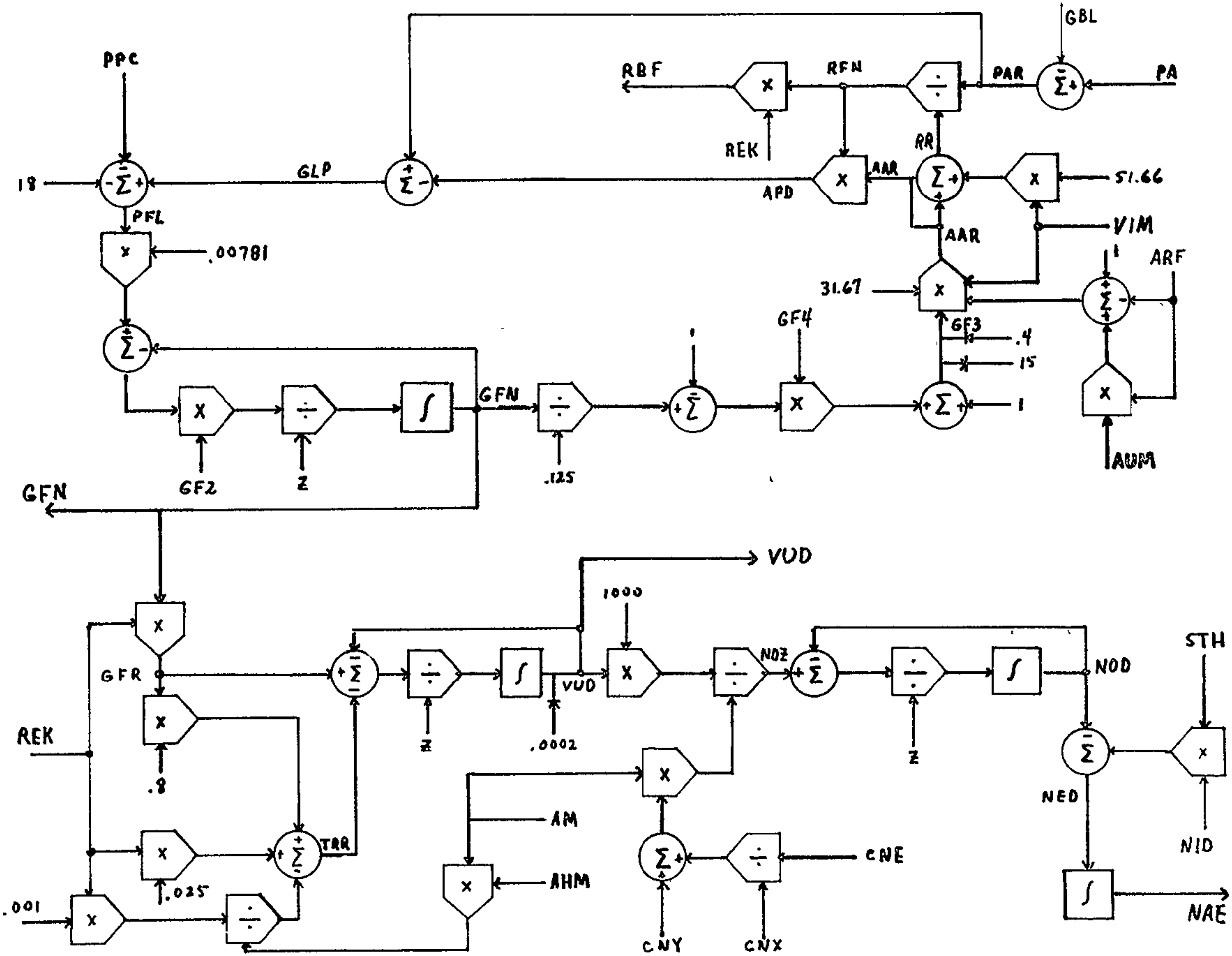

Figure 22. Flow Chart for Subroutine IONS.

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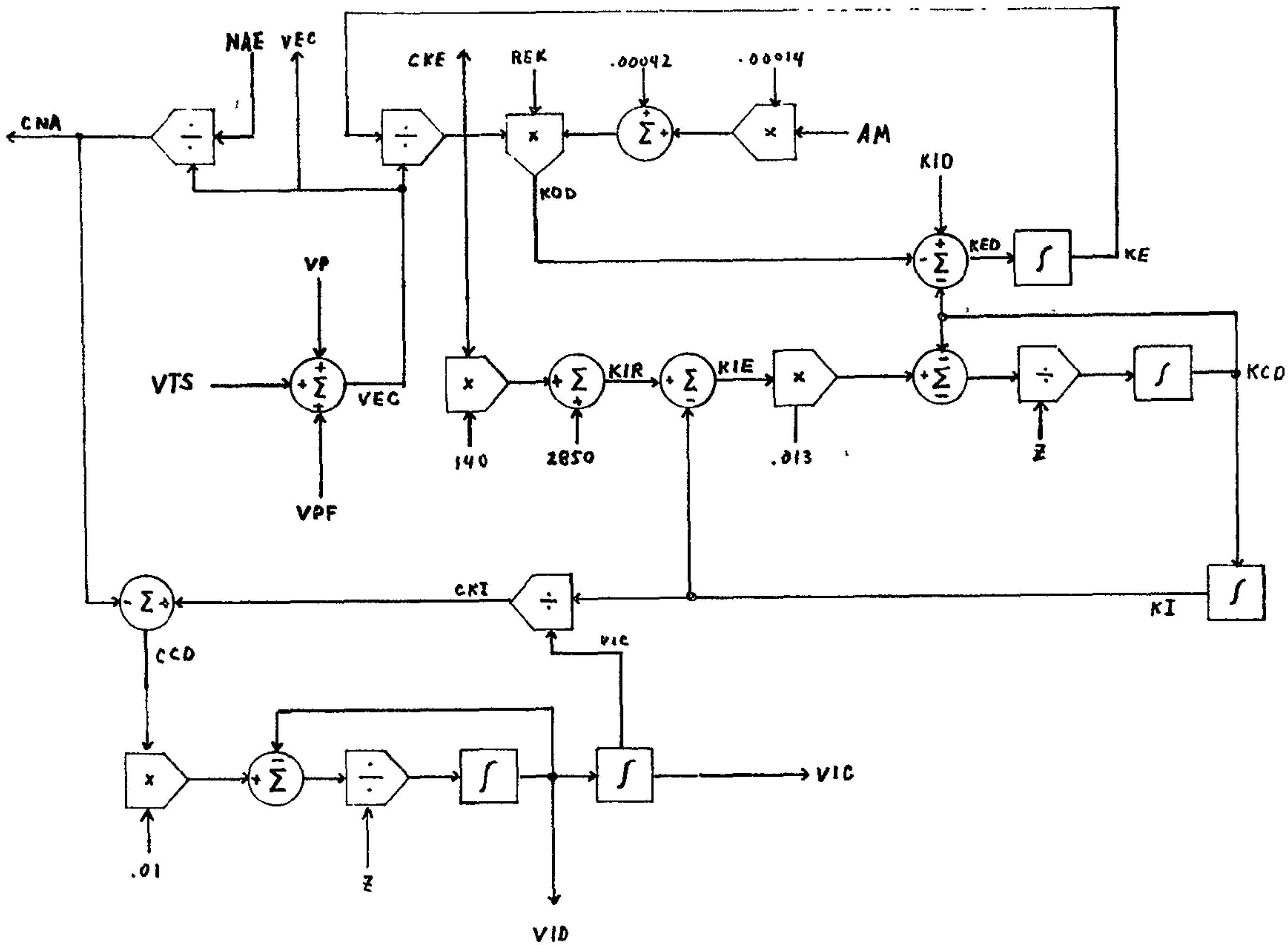
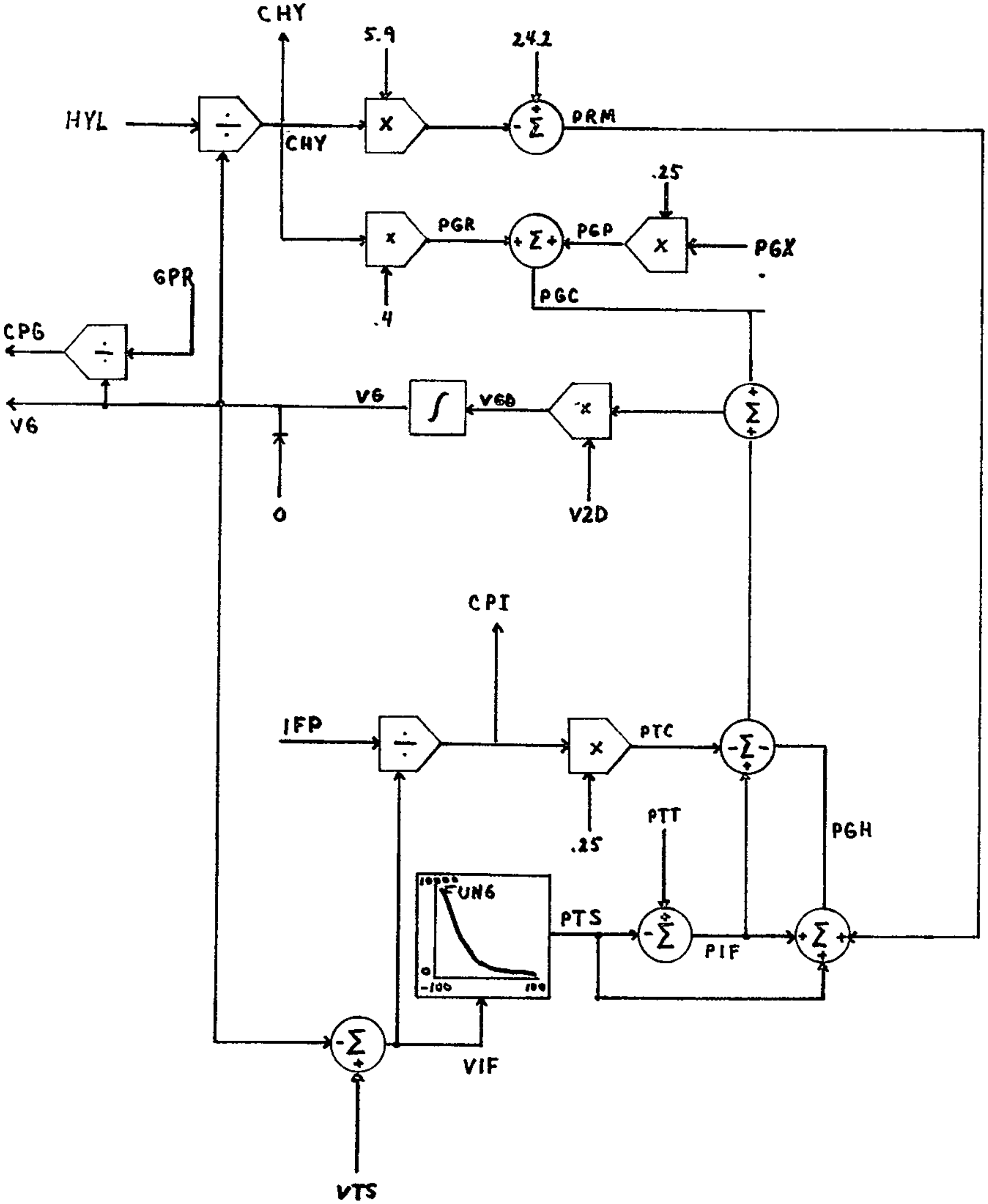


Figure 23. Flow Chart for Subroutine GELFLD.



NASA S-73-31078

Program 1. SUBROUTINE HEMO.

```
      SUBROUTINE HEMO (AMM,ANM,ANU,ANY,ANZ,ARM,AUH,AUM,AUY,AVE,BFM,BFN,
     *                 CN2,CN3,CN7,CV ,DAS,DLA,DPA,DRA,DVS,FIS,HMD,HPL,
     *                 HPR,HSL,HSR,I2 ,LVM,PA ,PAM,PA2,PC ,PGL,PGS,PLA,
     *                 PPA,PP1,PP2,PRA,PR1,PVS,QAO,QLN,QLO,QPO,QRF,QRN,
     *                 QRO,QVO,RAM,RAR,RBF,RPA,RPT,RPV,RSM,RSN,RVG,RVM,
     *                 RVS,U  ,VAE,VAS,VBD,VIM,VLA,VLE,VP ,VPA,VPE,VRA,
     *                 VRC,VRE,VVE,VVR,VVS,VV7,VV8,X  ,FUN1,FUN2,FUN3,
     *                 FUN4)
      DIMENSION FUN1(14),FUN2(14),FUN3(14),FUN4(14)
      REAL I2,LVM
C
C    CIRCULATORY DYNAMICS BLOCK
C   HEMODYNAMICS
C
      VBD=VP+VRC-VVS-VAS-VLA-VPA-VRA
      VVS=VVS+DVS*I2+VBD*.3986
      VPA=VPA+DPA*I2+VBD*.155
      VAS=VAS+DAS*I2+VBD*.261
      VLA=VLA+DLA*I2+VBD*.128
      VRA=VRA+DRA*I2+VBD*.0574
      VAE=VAS-.495
      PA=VAE/.00355
      PAM=100./PA
      PA2=PA/AUH
      CALL FUNCTN(PA2,LVM,FUN1)
      VRE=VRA-.1
      PRA=VRE/.005
      CALL FUNCTN(PRA,QRN,FUN2)
      VPE=VPA-.30625
      PPA=VPE/.0048
      PP1=.026*PPA
      IF (PP1.LT.0.)PP1=0.
      RPA=PP1**(-.5)
      PP2=PPA/AUH
      CALL FUNCTN(PP2,RVM,FUN3)
      VLE=VLA-.4
      PLA=VLE/.01
      CALL FUNCTN(PLA,QLN,FUN4)
      RPV=1./(PLA+20.)/.0357
      RPT=RPV+RPA
      PGL=PPA-PLA
      QPO=PGL/RPT
      ANU=ANM
      IF (ANU.LT..8)ANU=.8
      VVE=VVS-VVR-(ANU-1.)*ANY
      VV8=VVE-VV7
      IF(VV8.LT..0001)VV8=.0001
      PVS=VV8/CV
      PR1=PRA
      IF (PRA.LT.0.)PR1=0.
```

```
      RVG=2.738/PVS
      QVO=(PVS-PR1)/RVG
      CN3=CN3+(((PC-17.)*CN7+17.)*CN2-CN3)*.1
      AVE=(AUM-1.)*AUY+1.
      RVS=AVE*(1./CN3)*VIM*((ANU-1.)*ANZ+1.)
      PGS=PA-PVS
      RSN=RAR*ARM*ANU*AUM*PAM*VIM+RVS*1.79
      BFN=PGS/RSN
      RSM=ANU*VIM*PAM*AUM*AMM*RAM
      BFM=PGS/RSM
      QAO=BFN+BFM+RBF+(PA-PRA)*FIS
      QLO=LVM*QLN*AUH*HSL*HMD*HPL
      QRO=QRN*((1.-QRF)*AUH*RVM*HSR*HMD*HPR+QRF*QLO/QLN)
      QPO=QLO+(QPO-QLO)/U
      QVO=QRO+(QVO-QRO)/X
      DVS=QAO-QVO
      DPA=QRO-QPO
      DAS=QLO-QAO
      DLA=QPO-QLO
      DRA=QVO-QRO
      RETURN
      END
```

Program 2. SUBROUTINE AUTO.

C-2

```
      SUBROUTINE AUTO (AU ,AUB,AUC,AUH,AUJ,AUK,AJL,AUM,AUN,AUO,AUP,AUQ,
     *                 AUR,AUS,AUV,AUX,AUZ,AU4,AJ6,AU8,A1B,DAU,EXC,EXE,
     *                 EX1,I2 ,PA ,PA1,POQ,POT,P20,STA,VVR,VV9,Y  ,Z,
     *                 Z8 ,Z12)
      REAL I2
C
C     AUTONOMIC CONTROL BLOCK
C
  120 EXE=(8.-P20)*EX1+(EXC-1.)*Z12
      POQ=POT
      IF (POQ.GT.8.)POQ=8.
      IF (POQ.LT.4.)POQ=4.
      PA1=PA*POQ/8.-EXE
      AUC=0.
      IF(PA1.LT.80.)AUC=.03*(80.-PA1)
      IF(PA1.LT.40.)AUC=1.2
      AUB=0.
      IF(PA1.LT.170.)AUB=.014286*(170.-PA1)
      IF(PA1.LT.40.)AUB=1.83
  122 A1B=(AUB-1.)*AUX+1.
  124 AUN=0
      IF(PA1.LT.50.)AUN=.2*(50.-PA1)
      IF(PA1.LT.20.)AUN=6.0
      AU6=A1B-AU4
      AU8=AJK*(AU6-1.)
      DAU=DAU+(AUC+AU6+AUN-DAU)/Z/Y
      AUJ=AUJ+(DAU-AUJ)*I2*6./Z8
      IF(AUJ.LT.0.)AUJ=0.
      IF(AUJ-1.)126,127,127
  126 AU=AUJ**AUZ
      GO TO 128
  127 AU=(AUJ-1.)*AUZ+1.
  128 IF(STA.GT..00001)AU=STA
      AUO=AU-1.
      AUP=AUO*AUQ+1.
      AUH=AUO*AUV+1.
      AUR=AUO*AUS+1.
      VVR=VV9-AJL*AUP
      AUM=.15+.85*AUP
      RETURN
      END
```

Program 3. SUBROUTINE HORMON.

```
      SUBROUTINE HORMON(AM ,AMC,AMP,AMR,AMT,AM1,ANM,CKE,PA,Z,FUN7,
     *                  AGK,ANC,ANP,ANR,ANT,ANV,ANW,AN1,CNA,CNE,GFN,
     *                  I   ,REK)
      DIMENSION FUN7(14)
      REAL I
C
C****************************************************************
C
C     ALDOSTERONE CONTROL BLOCK
C
C****************************************************************
  168 AMR=CKE/CNA/.00352-9.
      IF(AMR.LT.0.)AMR=0.
      CALL FUNCTN (PA,AMP,FUN7)
      AM1=AM1+(ANM*AMP*AMR-AM1)/Z
      AMC=AMC+(AM1-AMC)*(1.-EXP(-I/AMT))
      AM=20.039-19.8*EXP(-.0391*AMC)
C****************************************************************
C
C     ANGIOTENSIN CONTROL BLOCK
C
C****************************************************************
      CNE=152.-CNA
      IF(CNE.LT.1.)CNE=1.
      ANR=((17.75-GFN*CNA)*AGK+1.)*REK
      ANW=ANW+((ANR-1.)*10.-ANW)*ANV*I
      IF(ANW.LT..0)ANW=0.
      ANP=ANR+ANW
      IF(ANP.GT.100.)ANP=100.
      IF(ANP.LT..01)ANP=.01
      AN1=AN1+(ANP-AN1)/Z
      ANC=ANC+(AN1-ANC)*(1.-EXP(-I/ANT))
      ANM=4.0-3.3*EXP(-.0967*ANC)
      IF(ANM.LT..7)ANM=.7
      RETURN
      END
```

Program 4. SUBROUTINE BLOOD.

```
      SUBROUTINE BLOOD (HKM,HM ,HMK,I  ,POT,POY,PO1,PO2,RC1,RC2,RCD,RKC,
     *                  VB ,VIB,VIE,VIM,VP ,VRC)
      REAL I
C
C     RED CELLS AND VISCOSITY BLOCK
C-----------------------------------------------------------------------
C     BLOOD VISCOSITY
C-----------------------------------------------------------------------
  170 VB=VP+VRC
      HM=100.*VRC/VB
      VIE=HM/(HMK-HM)/HKM
      VIB=VIE+1.5
      VIM=.3333*VIB
C-----------------------------------------------------------------------
C     RED BLOOD CELLS
C-----------------------------------------------------------------------
      RC2=RKC*VRC
      PO2=PO1-POT
      IF(PO2.LT..2375)PO2=.2375
      RC1=POY*PO2
      RCD=RC1-RC2
      VRC=VRC+RCD*I
      RETURN
      END
```

Program 5. SUBROUTINE MUSCLE

```
      SUBROUTINE MUSCLE(ALO,AMM,AOM,AUP,A4K,BFM,EXC,HM ,I  ,MMO,OMM,OSA,
     *                  OVA,OVS,O2A,PDO,PK1,PK2,PK3,PMO,PM1,PM3,PM4,PM5,
     *                  POE,POM,PVO,P2O,QOM,RMO,VPF,Z5 ,Z6)
      REAL I,MMO
C
C     MUSCLE BLOOD FLOW CONTROL AND PO2 BLOCK
C
 18C  OSA=ALO-VPF*.5
      OVA=OSA*HM*5.
      OVS=OVS+((BFM*OVA-RMO)/HM/5./BFM-OVS)/Z6
      PVO=57.14*OVS
      RMO=(PVO-PMO)*PM5/(PM1**PK3-PM4)
      QOM=QOM+(RMO-MMO)*(1.-EXP(-I/Z5))
      PMO=PK2/(PK1-QOM)
      PM1=PMO
      IF(PM1.LT.PM3)PM1=PM3
      P2O=PMO
      IF(P2O.GT.8.)P2O=8.
      AOM=(AUP-1.)*O2A+1.
      MMO=AOM*OMM*EXC*(1.-(8.0001-P2O)**3./512.)
      PDO=PVO-40.
      POE=POM*PDO+1.
      IF(POE.LT..005)POE=.005
      AMM=AMM+(POE-AMM)*(1.-EXP(-I/A4K))
      RETURN
      END
```

Program 6. SUBROUTINE AUTORG.

```
      SUBROUTINE AUTORG(AOM,ARM,AR1,AR2,AR3,A1K,A2K,A3K,BFN,DOB,HM ,I,
     *                  MO2,OSV,OVA,O2M,POA,POB,POC,POD,POK,PON,POR,POT,
     *                  POV,POZ,P10,QO2,RDO,Z   ,Z4 ,Z7)
      REAL I,MO2
C
C     NON-MUSCLE OXYGEN DELIVERY BLOCK
C     AND NON-MUSCLE LOCAL BLOOD FLOW CONTROL BLOCK
C-----------------------------------------------------------------------
C     AUTOREGULATION,RAPID
C-----------------------------------------------------------------------
      OSV=OSV+((BFN*OVA-DOB)/HM/5./BFN-OSV)/Z7
      POV=OSV*57.14
      RDO=POT**3.
      IF(RDO.LT.50.)RDO=50.
      DOB=(POV-POT)*3161./RDO
      MO2=AOM*O2M*(1.-(8.0001-P10)**3./512.)
      QO2=QO2+(DOB-MO2)*(1.-EXP(-I/Z4))
      POT=QO2*.00333
      P10=POT
      IF(POT.GT.8.)P10=8.
      POD=POV-POR
      POB=POB+(POK*POD+1.-POB)/Z
      IF(POB.LT..2)POB=.2
      AR1=AR1+(POB-AR1)*(1.-EXP(-I/A1K))
      ARM=AR1*AR2*AR3
C-----------------------------------------------------------------------
C     AUTOREGULATION,INTERMEDIATE
C-----------------------------------------------------------------------
      POA=POA+(PON*POD+1.-POA)/Z
      IF (POA.LT..5)POA=.5
      AR2=AR2+(POA-AR2)*(1.-EXP(-I/A2K))
C-----------------------------------------------------------------------
C     AUTOREGULATION,LONG-TERM
C-----------------------------------------------------------------------
      IF(POD)194,192,192
  192 POC=POZ*POD+1.
      GO TO 196
  194 POC=POZ*POD*.33+1.
  196 IF (POC.LT..3)POC=.3
      AR3=AR3+(POC-AR3)*I/A3K
      RETURN
      END
```

Program 7. SUBROUTINE ADH.

```
      SUBROUTINE ADH   (AH ,AHC,AHK,AHM,AHY,AHZ,AH7,AH8,AUP,CNA,CNB,CNR,
     *                  CNZ,I  ,PRA,Z)
      REAL I
C
C     ANTIDIURETIC HORMONE
C
      CNB=CNA-CNR
      AHZ=.2*PRA
      AHY=AHY+(AHZ-AHY)*.0007*I
      AH8=AUP-1.
      IF(AH8.LT.0.)AH8=0.
      IF(CNB.LT.0.)CNB=0.
      AH=AH+(CNZ*CNB+AH8-AHZ+AHY-AH)/Z
      IF(AH.LT.0.)AH=0.
      AHC=AHC+(.3333*AH-AHC)*(1.-EXP(-I/AHK))
      AHM=6.*(1.-EXP(-0.1808*AHC))
      IF(AHM.LT..3)AHM=.3
      RETURN
      END
```

Program 8. SUBROUTINE MISC1.

```
      SUBROUTINE MISC1 (AHM,AU4,AU8,I  ,SR ,SRK,STH,TVD,TVZ,VEC,VIC,VTW,
     *                  VVE,VV6,VV7,Z)
      REAL I
C
C***********************************************************************
C
C     VASCULAR STRESS RELAXATION BLOCK
C
C***********************************************************************
      VV6=VV6+(SR*(VVE-.301)-VV7-VV6)/Z
      VV7=VV7+VV6*(1.-EXP(-I/SRK))
C***********************************************************************
C
C     THIRST AND DRINKING BLOCK
C***********************************************************************
C
      TVZ=(.01*AHM-.009)*STH
      TVD=TVD+(TVZ-TVD)/Z
      IF(TVD.LT.0.)TVD=0.
      VTW=VIC+VEC
C***********************************************************************
C
C     AUTONOMIC CONTROL BLOCK
C     ADAPTATION OF BARORECEPTORS
C
C***********************************************************************
      AU4=AU4+AU8*I
      RETURN
      END
```

Program 9. SUBROUTINE HEART.

```
      SUBROUTINE HEART (AUR,DHM,HMD,HR ,I  ,PA ,PMC,PMP,PMS,POT,PRA,QAO,
     *                  QLO,RTP,SVO,VAE,VLE,VPE,VRE,VVE)
      REAL I
C
C     HEART HYPERTROPHY OR DETERIORATION BLOCK
C
C----------------------------------------------------------------------
C     HEART VICIOUS CYCLE
C----------------------------------------------------------------------
      DHM=(POT-6.)*.0025
      HMD=HMD+DHM*I
      IF (HMD.GT.1.)HMD=1.
C----------------------------------------------------------------------
C     MEAN CIRCULATORY PRESSURES
C----------------------------------------------------------------------
      PMC=(VAE+VVE+VRE+VPE+VLE)/.11
      PMS=(VAE+VVE+VRE)/.09375
      PMP=(VPE+VLE)/.01625
C*********************************************************************
C
C     HEART RATE AND STROKE VOLUME BLOCK AND TOTAL PERIPHERAL RESISTANCE
C
C*********************************************************************
      HR=(32.+40.*AUR+PRA*2.)*((HMD-1.)*.5+1.)
      RTP=(PA-PRA)/QAO
      SVO=QLO/HR
      RETURN
      END
```

Program 10. SUBROUTINE CAPMBD.

```
      SUBROUTINE CAPMBD(BFN,CFC,CPI,CPP,DFP,I  ,IFP,PC ,PCD,PIF,PLD,PPC,
     *                  PRP,PTC,PTS,PTT,PVG,PVS,RVS,TVD,VG ,VID,VIF,VP,
     *                  VPD,VTC,VTD,VTL,VTS,VUD,Z  ,Z1,FUN6)
      DIMENSION FUN6(14)
      REAL I,IFP
C
C     CAPILLARY MEMBRANE DYNAMICS BLOCK
C
  130 PTT=(VTS/12.)**2.
      VIF=VTS-VG
      CALL FUNCTN (VIF,PTS,FUN6)
      PIF=PTT-PTS
      CPI=IFP/VIF
      PTC=.25*CPI
      CPP=PRP/VP
      PPC=.4*CPP
      PVG=RVS*1.79*BFN
      PC=PVG+PVS
      PCD=PC+PTC-PPC-PIF
      VTC=VTC+(CFC*PCD-VTC)/Z
      PLD=7.8+PIF-PTT
      VTL=VTL+(.004*PLD-VTL)/Z
      IF(VTL.LT.0.)VTL=0.
      VTD=VTC-VTL-VID
      VTS=VTS+VTD*I
      VPD=VPD+(TVD-VTC+VTL-VUD-DFP-VPD)/Z1
      RETURN
      END
```

Program 11. SUBROUTINE PULMON.

```
      SUBROUTINE PULMON(CPF,CPP,CPN,DFP,I  ,PCP,PFI,PLA,PLF,POS,PPA,PPC,
     *                  PPD,PPI,PPN,PPO,PPR,VP ,VPO,VPF,Z  ,Z3)
      REAL I
C
C     PULMONARY DYNAMICS AND FLUIDS BLOCK
C
      VP=VP+(VPO*I)/Z3
C
  200 PCP=.45*PPA+.55*PLA
      PPI=2.-.150/VPF
      CPN=PPR/VPF
      POS=CPN*.4
      PLF=(PPI+11.)*.0003
      PPO=PLF*CPN
      PPN=(CPP-CPN)*.000225
      PPD=PPD+(PPN-PPO-PPD)/Z
      IF(PPR+PPD*I-.025.LT.0.)PPD=(.025-PPR)/I
      PFI=(PCP-PPI+POS-PPC)*CPF
      DFP=DFP+(PFI-PLF-DFP)/Z
      IF(VPF+DFP*I-.001.LT.0.)DFP=(.001-VPF)/I
      VPF=VPF+DFP*I
      PPR=PPR+PPD*I
      RETURN
      END
```

Program 12. SUBROUTINE MISC2.

```
      SUBROUTINE MISC2 (HPL,HPR,HSL,HSR,I,PA,PPA,POT,STH,Z10,Z11,Z13)
      REAL I
C
C*****************************************************************************
C
C     HEART HYPERTROPHY OR DETERIORATION BLOCK
C
C*****************************************************************************
      HPL=HPL+(((PA/100./HSL)**Z13)-HPL)*I/57600.
      HPR=HPR+(((PPA/15./HSR)**Z13)-HPR)*I/57600.
C*****************************************************************************
C
C     TISSUE EFFECT ON THIRST AND SALT INTAKE
C
C*****************************************************************************
      STH=(Z10-POT)*Z11
      IF(STH.LT.1.)STH=1.
      IF(STH.GT.8.)STH=8.
      RETURN
      END
```

Program 13. SUBROUTINE PROTEN.

```
      SUBROUTINE PROTEN(CHY,CPG,CPI,CPK,CPP,CPR,CPI,DLP,DLZ,DPC,DPI,DPL,
     *                  DPO,DPY,GPD,GPR,I  ,IFP,LPK,PC ,PCE,PGX,PRP,VG ,
     *                  VTL,Z  ,PPD)
      REAL I,IFP,LPK
C
C     TISSUE FLUIDS,PRESSURES AND GEL BLOCK
C
C-----------------------------------------------------------------------
C     PLASMA AND TISSUE FLUID PROTEIN
C-----------------------------------------------------------------------
  135 DPL=DPL+(VTL*CPI-DPL)/Z
      IF (PC.LT.0.)PC=0.
      DPC=DPC+(CPK*(CPP-CPI)*PC**PCE-DPC)/Z
      CPI=DPC-DPL
      DLZ=LPK*(CPR-CPP)
      IF(CPP.GT.CPR)DLZ=4.*DLZ
      DLP=DLP+(DLZ-DLP)/Z
      PRP=PRP+(DLP-DPO+DPL-DPC-PPD)*I
C-----------------------------------------------------------------------
C     GEL PROTEIN DYNAMICS
C-----------------------------------------------------------------------
  141 PGX=CHY**2*.01332*CPG+CPG
      GPD=GPD+(.0005*(CPI-PGX)*VG-GPD)/Z
      GPR=GPR+GPD*I
      IFP=IFP+(DPI-GPD)*I
      RETURN
      END
```

Program 14. SUBROUTINE KIDNEY.

```
      SUBROUTINE KIDNEY(AAR,AHM,AM ,APD,ARF,AUM,CNE,CNX,CNY,GBL,GFN,GFR,
     *                  GF2,GF3,GF4,GLP,I  ,NAE,NED,NID,NOD,NOZ,PA ,PAR,
     *                  PFL,PPC,RBF,REK,RFN,RR ,STH,TRR,VIM,VUD,Z)
      REAL I,NAE,NED,NID,NOD,NOZ
C
C     KIDNEY DYNAMICS AND EXCRETION BLOCK
C
  142 GF3=((GFN/.125-1.)*GF4)+1.
      IF(GF3.GT.15.)GF3=15.
      IF(GF3.LT..4)GF3=.4
      AAR=31.67*VIM*(AUM*ARF+1.-ARF)*GF3
      RR=AAR+51.66*VIM
      PAR=PA-GBL
      RFN=PAR/RR
      RBF=REK*RFN
  150 APD=AAR*RFN
      GLP=PAR-APD
      PFL=GLP-PPC-18.
      GF1=GFN
      GFN=GFN+(PFL*.00781-GFN)*GF2/Z
      IF (ABS(GFN-GF1).GT..002)GO TO 142
      GFR=GFN*REK
      TRR=.8*GFR+.025*REK-.001*REK/AM/AHM
      VUD=VUD+(GFR-TRR-VUD)/Z
      IF(VUD.LT..0002)VUD=.0002
C----------------------------------------------------------------------
C    KIDNEY SALT OUTPUT AND SALT INTAKE
C    (SEE ALSO ELECTROLYTES AND CELL WATER BLOCK)
C----------------------------------------------------------------------
      NOZ=1000.*VUD/AM/(CNE/CNX+CNY)
      NOD=NOD+(NOZ-NOD)/Z
      NED=NID*STH*NOD
      NAE=NAE+NED*I
      RETURN
      END
```

Program 15. SUBROUTINE IONS.

```
      SUBROUTINE IONS  (AM ,CCD,CKE,CKI,CNA,I  ,KCD,KE ,KED,KI ,KID,KIE,
     *                  KIR,KOD,NAE,REK,VEC,VIC,VID,VP ,VPF,VTS,Z)
      REAL I,KCD,KE,KED,KI,KID,KIE,KIR,KOD,NAE
C
C     ELECTROLYTES AND CELL WATER BLOCK
C
  160 VEC=VTS+VP+VPF
      CKE=KE/VEC
      KOD=(.00042*CKE+.00014*AM*CKE)*REK
      KIR=2850.+140.*CKE
      KIE=KIR-KI
      KCD=KCD+(KIE*.013-KCD)/Z
      KI=KI+KCD*I
      KED=KID-KCD-KOD
      KE=KE+KED*I
      CKI=KI/VIC
      CNA=NAE/VEC
      CCD=CKI-CNA
      VID=VID+(.01*CCD-VID)/Z
      VIC=VIC+VID*I
      RETURN
      END
```

Program 16. SUBROUTINE GELFLD.

```
      SUBROUTINE GELFLD(CHY,CPG,CPI,GPR,HYL,IFP,PGC,PGH,PGP,PGR,PGX,PIF,
     *                  PRM,PTC,PTS,PTT,VG ,VGD,VIF,VRS,VTS,V2D,FUN6)
      DIMENSION FUN6(14)
      REAL IFP
C
C     GEL FLUID DYNAMICS
  140 CHY=HYL/VG
      PRM=-5.9*CHY+24.2
      PGR=.4*CHY
      CPG=GPR/VG
      PGP=.25*PGX
      PGC=PGP*PGR
      VIF=VTS-VG
      CALL FUNCTN (VIF,PTS,FUN6)
      PIF=PTT-PTS
      CPI=IFP/VIF
      PTC=.25*CPI
      PGH=PIF+PTS+PRM
      VGD=V2D*(PIF+PGC-PTC-PGH)
      VG=VG+VGD
      IF(VG.LT.0.)VG=0.
      IF(.012.LT.ABS(VGD)) GO TO 140
      RETURN
      END
```

Appendix A – Glossary of Terms

The following list includes all variables used in the model together with the normal values of these variables. Independent variables (never calculated by the program) are indicated by *. Units used are: volume in liters, mass in grams, time in minutes, chemical units in milliequivalents, pressure in millimeters of mercury, and control factors as ratio to normal.

AAR- afferent arteriolar resistance (31.7)

AGK*- constant concerned with effect of renin on angiotensin formation (0.20)

AH- antidiuretic hormone secretion rate (3.0)

AHC- antidiuretic hormone concentration (1.0)

AHK*- constant used in calculating antidiuretic hormone concentration (7.0)

AHM- antidiuretic hormone multiplier (1.0)

AHY- adapted effect of right atrial pressure on antidiuretic hormone secretion rate (0.0)

AHZ- basic effect of right atrial pressure on antidiuretic hormone secretion rate (0.0)

AH8- effect of autonomic stimulation on antidiuretic hormone secretion rate (0.0)

ALO*- maximum aortic arterial oxygen saturation (1.0)

AM- aldosterone multiplier (1.0)

AMC- aldosterone concentration (1.0)

AMM- muscle vascular constriction caused by local tissue control, ratio to resting state (1.0)

AMP- effect of arterial pressure on rate of aldosterone secretion (1.0)

AMR- effect of sodium to potassium ratio on rate of aldosterone secretion (1.0)

AMT*- time constant of aldosterone accumulation and destruction (60)

AM1- rate of aldosterone secretion (1.0)

ANC- angiotensin concentration (1.0)

ANM- angiotensin multiplier effect on vascular resistance, ratio to normal (1.0)

ANP- effect of renal blood flow on angiotensin formation (1.0)

ANR- effect of glomerular filtration and sodium concentration on renin formation with consequent effect on angiotensin formation (1.0)

ANT*- time constant of angiotensin accumulation and destruction (15.0)

ANU- non-renal effect of angiotensin (1.0)

ANV*- constant used in calculating effect of renin formation on angiotensin formation (0.0003)

ANW- partial effect of renin on angiotensin formation (0.0)

ANY*- constant used to calculate angiotensin effect on venous volume (-0.2)

ANZ*- constant used to calculate angiotensin effect on venous resistance (0.4)

AN1 - rate of angiotensin formation (1.0)

AOM- autonomic effect on tissue oxygen utilization (1.0)

APD- afferent arteriolar pressure drop (38.0)

ARF*- intensity of sympathetic effects on renal function (1.5)

ARM- vasoconstrictor effect of all types of autoregulation (1.0)

AR1- vasoconstrictor effect of rapid autoregulation (1.0)

AR2- vasoconstrictor effect of intermediate autoregulation (1.0)

AR3- vasoconstrictor effect of long-term autoregulation (1.0)

AU- overall activity of autonomic system (1.0)

AUB- effect of baroreceptors on autoregulation (1.0)

AUC- effect of chemoreceptors on autonomic stimulation (0.0)

AUH- autonomic stimulation of heart (1.0)

AUJ- basic overall autonomic stimulation (1.0)

AUK*- time constant of baroreceptor adaptation (0.0005)

AUL*- sensitivity of sympathetic control of vascular capacitance (0.21)

AUM- sympathetic vasoconstrictor effect on arteries (1.0)

AUN- effect of CNS ischemic reflex on autoregulation (0.0)

AUO- fractional departure of overall activity of autonomic system from normal (0.0)

AUP- autonomic stimulation of peripheral circulatory sensitivity (1.0)

AUQ*- sensitivity of sympathetic control of peripheral circulation (1.0)

AUR- autonomic stimulation for heart rate (1.0)

AUS*- sensitivity of sympathetic control of heart rate (1.0)

AUV*- sensitivity of sympathetic control on heart function (0.3)

AUX*- sensitivity of baroreceptors (3.0)

AUY*- sensitivity of sympathetic control of veins (0.25)

AUZ*- overall sensitivity of autonomic control (1.0)

AU4- degree of adjustment of baroreceptor response (0.0)

AU6- adapted baroreceptor response (1.0)

AU8- rate of adaptation of baroreceptors (0.0)

AVE- effect of autonomic stimulation on venous resistance (1.0)

A1B- sensitivity parameter for baroreceptor drive (1.0)

A1K*- time constant of rapid autoregulation

A2K*- time constant of intermediate autoregulation (20.0)

A3K*- time constant of long-term autoregulation (11520.0)

A4K*- time constant for muscle local vascular response to metabolic activity (1.0)

BFM- muscle blood flow (1.0)

BFN- blood flow in non-muscle, non-renal tissues (3.0)

CCD- concentration gradient across cell membrane (0.0)

CFC*- capillary filtration coefficient (0.007)

CHY- concentration of hyaluronic acid in tissue fluids (5.0)

CKE- extracellular potassium concentration (5.0)

CKI- intracellular potassium concentration (142.0)

CNA- extracellular sodium concentration (142.0)

CNB- difference between extracellular sodium concentration and set point used to calculate antidiuretic hormone secretion rate (3.0).

CNR*- reference sodium concentration used in determining effect of sodium on antidiuretic hormone secretion rate (139.0).

CNE- sodium concentration abnormality causing third factor effect (10.0)

CNX* constant used in calculation of renal excretion rate of sodium (2.5)

CNY*- constant used in calculation of renal excretion rate of sodium (6.0)

CNZ*- sensitivity of antidiuretic hormone production rate to extracellular sodium concentration (1.0)

CN2* constant used in calculation of venous resistance (0.0212)

CN3- dummy variable used in calculation of the effect of capillary pressure on venous resistance (0.366)

CN7*- constant used in calculation of venous resistance (0.2).

CPF*- sensitivity of rate of transfer of fluid across pulmonary capillaries to pressure gradient (0.0003)

CPG- concentration of protein in tissue gel (12.5)

CPI- concentration of protein in free interstitial fluid (16.5)

CPK*- rate constant used in determining loss of plasma protein through systemic capillaries (1.6×10^{-7})

CPN- concentration of protein in pulmonary fluids (30.0)

CPP- plasma protein concentration (70.0)

CPR*- reference plasma protein concentration governing protein production by liver (85.0)

CV*- venous capacitance (0.0925)

DAS- rate of volume increase of systemic arteries (0.0)

DAU- autonomic stimulation drive (1.0)

DFP- rate of increase in pulmonary free fluid (0.0)

DHM- rate of cardiac deterioration caused by hypoxia (0.0)

DLA- rate of volume increase in pulmonary veins and left atrium (0.0)

DLP- rate of formation of plasma protein by liver (0.007)

DLZ- undamped plasma protein concentration differential causing protein production by liver (0.007)

DOB- rate of oxygen delivery to non-muscle cells (180.0)

DPA- rate of increase in pulmonary volume (0.0)

DPC- rate of loss of plasma proteins through systemic capillaries (0.05)

DPI- rate of change of protein in free interstitial fluid (0.0)

DPL- rate of systemic lymphatic return of protein (0.05)

DPO*- rate of loss of plasma protein (0.007)

DRA- rate of increase in right atrial volume (0.0)

DVS- rate of increase in venous vascular volume (0.0)

EXC* exercise activity, ratio to normal at rest (1.0)

EXE- exercise effect on autonomic stimulation (0.0)

EX1*- constant concerned with effect of muscle cell P_{O_2} on autonomic stimulation during exercise (3.0)

FIS*- fistula parameter (0.0)

GBL*- Goldblatt hypertension parameter (0.0)

GFN- glomerular filtration rate of undamaged kidney (0.125)

GFR- glomerular filtration rate (0.125)

GF1 - value of GFN on previous iteration (0.125)

GF2*- constant used in calculation of glomerular filtration rate (0.05)

GF3- degree of autoregulatory feedback at macular densa (1.0)

GF4*- constant controlling the feedback loop for GF3 (5.0)

GLP- glomerular pressure (62.0)

GPD- rate of increase of protein in gel (0.0)

GPR- total protein in gel (143.0)

HKM*- constant used in calculation of portion of blood viscosity caused by red blood cells (0.53)

HM- hematocrit (41.0)

HMD- cardiac depressant effect of hypoxia (1.0)

HMK*- constant used in calculation of portion of blood viscosity caused by red blood cells (90.0)

HPL- hypertrophy effect on left ventricle (1.0)

HPR- hypertrophy effect on right ventricle (1.0)

HR- heart rate (72.0)

HSL*- basic left ventricular strenght (1.0)

HSR*- basic right ventricular strength (1.0)

HYL*- quantity of hyaluronic acid in tissues (57.0)

I- integration step size (0.73)

IFP- interstitial fluid protein (9.1)

I1- variable integration step size utilized on stable asymptote

I2*-	normal increment on time (0.003)
I3*-	maximum time increment for stable asymptote (20.0)
KCD-	rate of change of intracellular potassium concentration (0.0)
KE-	total extracellular fluid potassium (75.0)
KED-	rate of change of extracellular potassium concentration (0.0)
KI-	total intracellular potassium concentration (3550.0)
KID*	rate of potassium intake (0.0028)
KIE-	excess potassium concentration causing change in intracellular potassium level (0.0)
KIR-	total expected level of potassium in the intracellular fluid under equilibrium conditions (3550.0)
KOD-	rate of renal loss of potassium (0.0028)
LPK* -	rate constant for plasma protein production by liver (0.00047)
LVM-	effect of aortic pressure on left ventricular output (1.0)
MMO-	rate of oxygen utilization by muscle cells (60.0)
MO2-	rate of oxygen utilization by non-muscle cells (180)
NAE-	total extracellular sodium (2136.0)
NED-	rate of change of sodium in extracellular fluids (0.0)
NID*-	rate of sodium intake (0.1)
NOD -	rate of renal excretion of sodium (0.1)
NOZ-	effect of urinary output, aldosterone, and sodium level on renal excretion rate for sodium (0.1)
OMM*-	muscle oxygen utilization at rest (60.0)
OSA-	aortic oxygen saturation (1.0)
OSV-	non-muscle venous oxygen saturation (0.7)

OVA- oxygen volume in aortic blood (203.0)

OVS- muscle venous oxygen saturation (0.7)

O2A*- sensitivity of the effect of autonomic stimulation on metabolism (1.5)

O2M*- basic oxygen utilization in non-muscle body tissues (180.0)

PA- aortic pressure (100.0)

PAM- effect of arterial pressure in distending arteries, ratio to normal (1.0)

PAR- renal arterial pressure (100.0)

PA1- effective pressure drive on autonomic system (100.0)

PA2- effective arterial pressure on left ventricle (100.0)

PC- capillary pressure (18.4)

PCD- net pressure gradient across capillary membrane (0.45)

PCE*- capillary pressure exponent (3.0)

PCP- pulmonary capillary pressure (7.0)

PDO- difference between muscle venous oxygen P_{O_2} and normal venous oxygen P_{O_2} (0.0)

PFI- rate of transfer of fluid across pulmonary capillaries (0.0)

PFL- renal filtration pressure (16.0)

PGC- colloid osmotic pressure of tissue gel (6.1)

PGH- absorbency effect of gel caused by recoil of gel reticulum (-4.0)

PGL- pressure gradient in lungs (15.2)

PGP- colloid osmotic pressure of tissue gel caused by entrapped protein (4.13)

PGR- colloid osmotic pressure of interstitial gel caused by Donnan equilibrium (2.0)

PGS- pressure difference between arteries and veins (96.0)

PGV- venous pressure gradient (3.7)

PGX- activity factor for protein in the interstitial fluid (16.5)

PIF- interstitial fluid pressure (-6.0)

PK1*- constant used in calculating muscle cell P_{O_2} from total volume of oxygen in muscle cells (2500.0)

PK2*- constant used in calculating muscle cell P_{O_2} from total volume of oxygen in muscle cells (800.0)

PK3*- constant used in calculating rate of oxygen transport to muscle cells (2.0)

PLA- left atrial pressure (0.0)

PLD- pressure gradient to cause lymphatic flow (0.8)

PLF- pulmonary lymphatic flow (0.0003)

PMC- mean circulatory pressure (6.9)

PMO- muscle cell P_{O_2} (8.0)

PMP- mean pulmonary pressure (4.6)

PMS- mean systemic pressure (7.25)

PM1- effective muscle cell P_{O_2} (8.0)

PM3*- minimum value allowed for PM1 (0.001)

PM4*- constant used in calculating rate of oxygen transport to muscle cells (-1.0)

PM5*- constant used in calculating rate of oxygen transport to muscle cells (122.0)

POA- rate of change of intermediate autoregulation vasoconstrictor effect (1.0)

POB- rate of change of rapid autoregulation vasoconstrictor effect (1.0)

POC- rate of change of long-term autoregulation vasoconstrictor effect (1.0)

POD- non-muscle venous P_{O_2} minus normal value (0.0)

POE- sensitivity control for oxygen feedback control loop (1.0)

POK*- sensitivity of rapid system of autoregulation (0.06)

POM*- sensitivity of oxygen feedback control loop (0.08)

PON*- sensitivity of intermediate autoregulation (0.3)

POQ- effective non-muscle cell P_{O_2} (8.0)

POR*- reference value of capillary P_{O_2} in non-muscle tissue (40.0)

POS- pulmonary interstitial fluid colloid osmotic pressure (12.0)

POT- non-muscle cell P_{O_2} (8.2)

POV- non-muscle venous P_{O_2} (40.0)

POY*- sensitivity of red cell production (0.0000464)

POZ*- sensitivity of long-term autoregulation (0.3)

PO1*- constant used in determining oxygen deficit factor causing red cell production (8.25)

PO2- oxygen deficit factor causing red cell production (0.25)

PPA- pulmonary arterial pressure (15.4)

PPC- plasma colloid osmotic pressure (28.0)

PPD- rate of change of protein in pulmonary fluids (0.0)

PPI- pulmonary interstitial fluid pressure (-10.0)

PPN- rate of pulmonary capillary protein loss (0.0)

PPO- pulmonary lymph protein flow (0.009)

PPR- total protein in pulmonary fluids (0.38)

PP1- variable used to empirically relate pulmonary arterial pressure and pulmonary arterial resistance (0.4)

PP2- effective pulmonary arterial pressure (15.5)

PRA- right atrial pressure (0.0)

PRM- pressure caused by compression of interstitial fluid gel reticulum (-5.0)

PRP- total plasma protein (208.0)

PR1- effective right atrial pressure (0.0)

PTC- interstitial fluid colloid osmotic pressure (4.1)

PTS- solid tissue pressure (7.0)

PTT- total tissue pressure (1.0)

PVG- venous pressure gradient (14.6)

PVO- muscle venous P_{O_2} (40.0)

PVS- average venous pressure (3.8)

P1O- tissue P_{O_2} effective in oxygen utilization (8.0)

P2O- muscle cell P_{O_2} effective in depressing rate of metabolism (8.0)

QAO- blood flow in the systemic arterial system (5.0)

QLN- basic left ventricular output (5.0)

QLO- output of left ventricle (cardiac output) (5.0)

QOM- total volume of oxygen in muscle cells (2400.0)

QO2- non-muscle total cellular oxygen (2400.0)

QPO- rate of blood flow into pulmonary veins and left atrium (5.0)

QRF*- feedback effect of left ventricular function on right ventricular function (0.6)

QRN- basic right ventricular output (5.0)

QRO- actual right ventricular output (5.0)

QVO - rate of blood flow from veins into right atrium (5.0)

RAM*- basic vascular resistance of muscles (96.3)

RAR*- basic resistance of non-muscular and non-renal arteries (30.52)

RBF- renal blood flow (1.2)

RCD- rate of change of red cell mass (0.0)

RC1- red cell production rate (0.000011)

RC2- red cell destruction rate (0.000011)

RDO- resistance of diffusion of oxygen from capillaries to cells (555.0)

REK*- fraction of normal renal function (1.0)

RFN- renal blood flow if kidney is not damaged (1.2)

RKC*- rate constant for red cell destruction (5.8×10^{-6})

RMO- rate of oxygen utilization by tissues (60.0)

RPA- pulmonary arterial resistance (1.6)

RPT- pulmonary vascular resistance (3.0)

RPV- pulmonary venous resistance (1.4)

RR- renal resistance (84.0)

RSM- vascular resistance in muscle (96.5)

RSN- vascular resistance in non-muscle, non-renal tissues (32.5)

RTP- total peripheral resistance (19.4)

RVG- resistance from veins to right atrium (0.72)

RVM- depressing effect of pulmonary arterial pressure on right ventricle (1.0)

RVS- venous resistance (2.8)

SR*- intensity factor for stress relaxation (0.5)

SRK*- time constant for stress relaxation (33.0)

STA*- overriding value of overall activity of autonomic system AU (0.0)

STH- effect of tissue hypoxia on salt and water intake (1.0)

SVO- stroke volume output (0.07)

T-	total time elapsed
TRR-	tubular reabsorption rate (0.124)
TVD-	rate of drinking (0.001)
TVZ-	combined effect of tissue ischemia and central nervous stimulation on thirst and drinking (0.001)
T1-	total time elapsed on previous step
U*-	damping factor for QPO (4.0)
VAE-	excess volume in systemic arteries that causes stretch of arterial walls (0.354)
VAS-	volume in systemic arteries (0.85)
VB-	blood volume (5.0)
VBD-	volume correction factor added to systemic circulation to allow for updating blood volume (0.0)
VEC-	extracellular fluid volume (15.0)
VG-	volume of interstitial fluid gel (11.5)
VGD-	rate of change of tissue gel volume (0.0)
VIB-	blood viscosity, ratio to that of water (3.0)
VIC-	cell volume (25.0)
VID-	rate of fluid transfer between interstitial fluid and cells (0.0)
VIE-	portion of blood viscosity caused by red blood cells (1.5)
VIF-	volume of free interstitial fluid (0.55)
VIM-	blood viscosity, ratio to normal (1.0)
VLA-	volume in left atrium (0.40)
VLE-	excess volume in left atrium causing stretch of left atrium and pulmonary veins (0.0)
VP-	plasma volume (3.0)

VPA- volume in pulmonary arteries (0.38)

VPD- rate of change of plasma volume (0.0)

VPE- excess volume in right atrium causing stretching of the right atrium (0.07)

VPF- pulmonary free fluid volume (0.012)

VRA right atrial volume (0.1)

VRC- volume of red blood cells (2.0)

VRE- excess volume in right atrium causing stretching of the right atrium (0.0)

VTC- rate of fluid transfer across systemic capillary membrances (0.0)

VTD- rate of volume change in total interstitial fluid (0.0)

VTL- rate of systemic lymph flow (0.003)

VTS- total interstitial fluid volume (12.0)

VTW- total body water (40.0)

VUD- rate of urinary output (0.001)

VVE- excess venous vascular volume before stress relaxation correction (0.33)

VVR- volume of blood in veins at zero venous pressure (2.95)

VVS- venous vascular volume (3.0)

VV6- rate of change of vascular stress relaxation effect (0.0)

VV7- increased vascular volume caused by stress relaxation (0.0)

VV8- excess volume of blood in the systemic veins after stress relaxation correction (0.31)

VV9*- reference venous vascular volume (3.159)

V2D*- resistance factor which converts pressure drop to rate of change of tissue gel volume (0.02)

X*- damping factor for QVO (10.0)

Y*- damping factor for DAU (1.0)

Z*- damping factor for AH, DAU, DFP, DLP, DPC, DPL, GFN, GPD, KCD, NOD, POA, POB, PPD, TVD, VID, VTC, VTL, VUD, VV6 (1.0)

Z1*- damping factor for VPD (1.0)

Z3*- damping factor for VP (4.0)

Z4*- time constant used to calculate non-muscle cell total cellular oxygen (10.0)

Z5*- time constant used to calculate volume of oxygen in muscle cells (10.0)

Z6*- damping factor for OVS (5.0)

Z7*- damping factor for OSV (5.0)

Z8*- time constant of autonomic response (1.0)

Z10*- constant used to calculate effect of tissue hypoxia on salt and water intake (8.25)

Z11*- constant used to calculate effect of tissue hypoxia on salt and water intake (4.0)

Z12*- constant that converts exercise activity to autonomic stimulation (1.24)

Z13*- constant used in calculating heart hypertrophy (0.625)

PROGRAM DESCRIPTION GUIDE

A. IDENTIFICATION

Program Name - Guyton

Programmer's Names - Guyton, White, and Marks

Programmer Contact - V. J. Marks, GE/AGS, Houston

Date of Issue - April 16, 1973

B. GENERAL DESCRIPTION

This model presents a systems analysis of human circulatory regulation based almost entirely on experimental data and cumulative present knowledge of the many facets of the circulatory system. The model itself consists of 18 different major systems that enter into circulatory control. These systems are grouped into 16 distinct sub-programs that are melded together to form the total model.

In spite of the fact that the total model contains almost 100 independent variables and over 350 mathematical relations of various types, each major system is modeled in a relatively crude way only, with emphasis placed on gross correctness, not fine details. It has been found that the systems analysis thus developed is successful in predicting the outcome of many varied stress experiments. This is only possible because of the extreme stability and many built-in compensations of the actual circulatory system. Without this inherent stability, each system would have to have been modeled in a much more detailed fashion to produce the requisite correlation with experiment.

The model develops circulatory regulation and fluid regulation in a simultaneous manner. Thus, the effects of hormonal and autonomic control, electrolyte regulation and excretory dynamics are all important and are all included in the model. The model does not treat respiration or thermal regulation.

C. USAGE AND RESTRICTIONS

Machine and Compiler Required - XEROX Sigma 3, ANSI Fortran

Peripheral Equipment Required - Card Reader, Printer, Teletype

Approximate Amount of Memory Required - Guyton (Model A) - +32AA
Guyton (Model B) - +393C

D. PARTICULAR DESCRIPTION

Equations used - See the following reference.

Guyton, A.C., Coleman, T.G., and Granger, H.I., "Circulation: Overall Regulation," Annual Review of Physiology, V. 34: 13-46, 1972.

Definitions of Terms - Appendix A

Values of Variables - Appendix B

E. DESCRIPTION OF INPUT

1. Machine Control Cards

```
!JØB
!FØRTRAN

          Source Cards (See Appendix C for listing of Guyton Model A)
                       (See Appendix D for listing of Guyton Model B)

!EØD
!ØLØAD
!$RØØT 512,,GØ
!$MP
!$END
!XEQ

          Data Cards   (See Appendix B for printout of input variables)

!EØD
```

2. Data Cards

The GUYTON MODEL A reads data variables as illustrated in Appendix B.

Column	Format	Description
1-13	E13.6	Variable Value
14-15	2X	Blank
16-20	I5	Array location (stop reading of input data if less than 1)
21-22	2X	Blank
23-26	A4	Variable Name

The GUYTON MODEL A utilizes the teletype to input initial data, modify specific data, and output requested data. See Subroutine INPUT in Appendix C for complete explanation.

The GUYTON MODEL B reads initial data using the same format as does the GUYTON MODEL A, but does not require as many input variables because of internal initialization of some variables. See Appendix E for those variables required. The GUYTON MODEL B does not interact with the teletype and thus requires additional data cards.

Column	Format	Description
Card A+1		
1-80	20A4	Variable names of required output variables. If columns 1-3 contain ALL, then all variables will be printed as shown in Appendix E.
Card A+2		
1-5	I5	Model time for next output printing, change of time units, or change of specified variables.
6	1X	Blank
7-10	A4	Model units of time (SECS, MIN, HOUR, or DAYS)
Card A+3 to A+N		
1-5	I5	Same as card A+2
6	1X	Blank
7-10	A4	Same as card A+2 if units of time require changing. Blank to change variables values. Same as last card to continue run.
11-14	A4	Variable name for which value requires changing.
15-27	E13.6	New value of variable

If columns 7-14 are blank the program will stop.

F. DESCRIPTION OF OUTPUT

See Appendix B for example of GUYTON MODEL A output. See Appendix E for example of GUYTON MODEL B output.

G. INTERNAL CHECKS AND EXITS

Curve limits are checked with a diagnostic message being printed if they are exceeded.
The GUYTON MODEL B checks input data for invalid requests and exits when it finds one.

H. INDEPENDENT SUBROUTINES

See Appendix C for listing of all subroutines required by the GUYTON MODEL A.

See Appendix D for listing of all subroutines required by the GUYTON MODEL B.

I. SYSTEM SUBROUTINES

No special system subroutines required.

J. COMPLETION OR FINAL CHECKOUT DATE

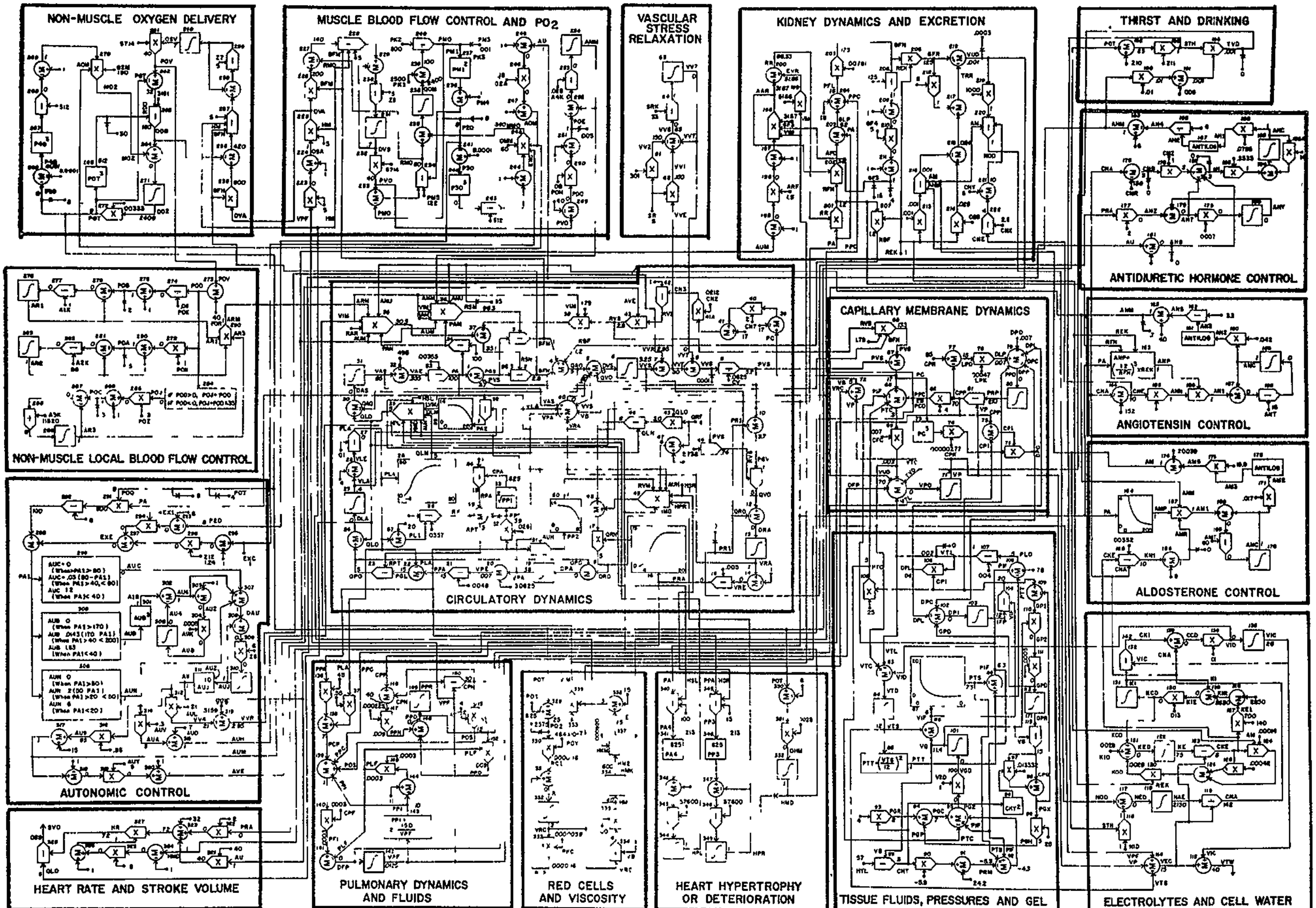
3/10/73

APPENDIX A

FIGURE 1. Systems analysis diagram for regulation of the circulation. Units are the following: volume in liters, mass in grams, time in minutes, chemical units in milliequivalents, pressure in millimeters of mercury, control factors in arbitrary units but in most instances expressed as the ratio to normal—for instance, a value of 1 represents normal. Normal values are given on the lines that represent the respective variables.

The following is a list of the important dependent and independent variables in the analysis (additional variables are present for purposes of calculation but generally have no physiological significance)

AAR—afferent arteriolar resistance
AHM—antidiuretic hormone multiplier, ratio of normal effect
AM—aldosterone multiplier, ratio of normal effect
AMC—aldosterone concentration
AMM—muscle vascular constriction caused by local tissue control, ratio to resting state
AMP—effect of arterial pressure on rate of aldosterone secretion
AMR—effect of sodium to potassium ratio on aldosterone secretion rate
AMT—time constant of aldosterone accumulation and destruction
ANC—angiotensin concentration
ANM—angiotensin multiplier effect on vascular resistance, ratio to normal
ANN—effect of sodium concentration on rate of angiotensin formation
ANP—effect of renal blood flow on angiotensin formation
ANT—time constant of angiotensin accumulation and destruction
ANU—nonrenal effect of angiotensin
AOM—autonomic effect on tissue oxygen utilization
APD—afferent arteriolar pressure drop
ARF—intensity of sympathetic effects on renal function
ARM—vasoconstrictor effect of all types of autoregulation
AR1—vasoconstrictor effect of rapid autoregulation
AR2—vasoconstrictor effects of intermediate autoregulation
AR3—vasoconstrictor effect of long term autoregulation
AU—overall activity of autonomic system, ratio to normal
AUB—effect of baroreceptors on autoregulation
AUC—effect of chemoreceptors on autonomic stimulation
AUH—autonomic stimulation of heart, ratio to normal
AUK—time constant of baroreceptor adaptation
AUL—sensitivity of sympathetic control of vascular capacitance
AUM—sympathetic vasoconstrictor effect on arteries
AUN—effect of CNS ischemic reflex on autoregulation
AUV—sensitivity control of autonomics on heart function
AUY—sensitivity of sympathetic control of veins
AUZ—overall sensitivity of autonomic control
AVE—sympathetic vasoconstrictor effect on veins
A1K—time constant of rapid autoregulation
A2K—time constant of intermediate autoregulation
A3K—time constant of long-term autoregulation
A4K—time constant for muscle local vascular response to metabolic activity
BFM—muscle blood flow
BFN—blood flow in non muscle non-renal tissues
CA—capacitance of systemic arteries
CCD—concentration gradient across cell membrane
CHY—concentration of hyaluronic acid in tissue fluids
CKE—extracellular potassium concentration
CKI—intracellular potassium concentration
CNA—extracellular sodium concentration
CNE—sodium concentration abnormality causing third factor effect
CPG—concentration of protein in tissue gel
CPI—concentration of protein in free interstitial fluid
CPN—concentration of protein in pulmonary fluids
CPP—plasma protein concentration
CV—venous capacitance
DAS—rate of volume increase of systemic arteries
DFP—rate of increase in pulmonary free fluid
DHM—rate of cardiac deterioration caused by hypoxia
DLA—rate of volume increase in pulmonary veins and left atrium
DLP—rate of formation of plasma protein by liver
DOB—rate of oxygen delivery to non muscle cells
DPA—rate of increase in pulmonary volume
DPC—rate of loss of plasma proteins through systemic capillaries
DPI—rate of change of protein in free interstitial fluid
DPL—rate of systemic lymphatic return of protein
DPO—rate of loss of plasma protein
DRA—rate of increase in right atrial volume
DVS—rate of increase in venous vascular volume
EVR—postglomerular resistance
EXC—exercise activity, ratio to activity at rest
EXE—exercise effect on autonomic stimulation
GFN—glomerular filtration rate of undamaged kidney
GFR—glomerular filtration rate
GLP—glomerular pressure
GPD—rate of increase of protein in gel
GPR—total protein in gel
HM—hematocrit
HMD—cardiac depressant effect of hypoxia
HPL—hypertrophy effect on left ventricle
HPR—hypertrophy effect on heart, ratio to normal
HR—heart rate
HSL—basic left ventricular strength
HSR—basic strength of right ventricle
HYL—quantity of hyaluronic acid in tissues
IFP—interstitial fluid protein
KCD—rate of change of potassium concentration
KE—total extracellular fluid potassium
KED—rate of change of extracellular fluid concentration
KI—total intracellular potassium concentration
KID—rate of potassium intake
KOD—rate of renal loss of potassium
LVM—effect of aortic pressure on left ventricular output
MMO—rate of oxygen utilization by muscle cells
MO2—rate of oxygen utilization by non muscle cells
NAE—total extracellular sodium
NED—rate of change of sodium in intracellular fluids
NID—rate of sodium intake
NOD—rate of renal excretion of sodium
OMM—muscle oxygen utilization at rest
OSA—aortic oxygen saturation
OSV—non muscle venous oxygen saturation
OVA—oxygen volume in aortic blood
OVS—muscle venous oxygen saturation
O2M—basic oxygen utilization in non muscle body tissues
PA—aortic pressure
PAM—effect of arterial pressure in distending arteries, ratio to normal
PC—capillary pressure
PCD—net pressure gradient across capillary membrane
PCP—pulmonary capillary pressure
PDO—difference between muscle venous oxygen PO_2 and normal venous oxygen PO_2
PFI—rate of transfer of fluid across pulmonary capillaries
PFL—renal filtration pressure
PGC—colloid osmotic pressure of tissue gel
PGH—absorbency effect of gel caused by recoil of gel reticulum
PGL—pressure gradient in lungs
PGP—colloid osmotic pressure of tissue gel caused by entrapped protein
PGR—colloid osmotic pressure of interstitial gel caused by Donnan equilibrium
PIF—interstitial fluid pressure
PLA—left atrial pressure
PLD—pressure gradient to cause lymphatic flow
PLF—pulmonary lymphatic flow
PMO—muscle cell PO_2
POD—non-muscle venous PO_2 minus normal value
POK—sensitivity of rapid system of autoregulation
PON—sensitivity of intermediate autoregulation
POS—pulmonary interstitial fluid colloid osmotic pressure
POT—non muscle cell PO_2
POV—non muscle venous PO_2
POY—sensitivity of red cell production
POZ—sensitivity of long term autoregulation
PO2—oxygen deficit factor causing red cell production
PPA—pulmonary arterial pressure
PPC—plasma colloid osmotic pressure
PPD—rate of change of protein in pulmonary fluids
PPI—pulmonary interstitial fluid pressure
PPN—rate of pulmonary capillary protein loss
PPO—pulmonary lymph protein flow
PPR—total protein in pulmonary fluids
PRA—right atrial pressure
PRM—pressure caused by compression of interstitial fluid gel reticulum
PRP—total plasma protein
PTC—interstitial fluid colloid osmotic pressure
PTS—solid tissue pressure
PTT—total tissue pressure
PGV—pressure from veins to right atrium
PVG—venous pressure gradient
PVO—muscle venous PO_2
PVS—average venous pressure
QAO—blood flow in the systemic arterial system
QLN—basic left ventricular output
QLO—output of left ventricle
QOM—total volume of oxygen in muscle cells
QO2—non muscle total cellular oxygen
QPO—rate of blood flow into pulmonary veins and left atrium
QRF—feedback effect of left ventricular function on right ventricular function
QRN—basic right ventricular output
QRO—actual right ventricular output
QVO—rate of blood flow from veins into right atrium
RAM—basic vascular resistance of muscles
RAR—basic resistance of non-muscular and non-renal arteries
RBF—renal blood flow
RC1—red cell production rate
RC2—red cell destruction rate
RCD—rate of change of red cell mass
REK—percent of normal renal function
RFN—renal blood flow if kidney is not damaged
RKC—rate factor for red cell destruction
RMO—rate of oxygen transport to muscle cells
RPA—pulmonary arterial resistance
RPT—pulmonary vascular resistance
RPV—pulmonary venous resistance
RR—renal resistance
RSM—vascular resistance in muscles
RSN—vascular resistance in non muscle non-renal tissues
RVG—resistance from veins to right atrium
RVM—depressing effect on right ventricle of pulmonary arterial pressure
RVS—venous resistance
SR—intensity factor for stress relaxation
SRK—time constant for stress relaxation
STH—effect of tissue hypoxia on salt and water intake
SVO—stroke volume output
TRR—tubular reabsorption rate
TVD—rate of drinking
VAS—volume in systemic arteries
VB—blood volume
VEC—extracellular fluid volume
VG—volume of interstitial fluid gel
VGD—rate of change of tissue gel volumes
VIB—blood viscosity, ratio to that of water
VIC—cell volume
VID—rate of fluid transfer between interstitial fluid and cells
VIE—portion of blood viscosity caused by red blood cells
VIF—volume of free interstitial fluid
VIM—blood viscosity (ratio to normal blood)
VLA—volume in left atrium
VP—plasma volume
VPA—volume in pulmonary arteries
VPD—rate of change of plasma volume
VPF—pulmonary free fluid volume
VRA—right atrial volume
VRC—volume of red blood cells
VTC—rate of fluid transfer across systemic capillary membranes
VTD—rate of volume change in total interstitial fluid
VTL—rate of systemic lymph flow
VTS—total interstitial fluid volume
VTW—total body water
VUD—rate of urinary output
VV7—increased vascular volume caused by stress relaxation
VVR—diminished vascular volume caused by sympathetic stimulation
VVS—venous vascular volume
Z8—time constant of autonomic response


NON-MUSCLE OXYGEN DELIVERY
MUSCLE BLOOD FLOW CONTROL AND PO2
VASCULAR STRESS RELAXATION
KIDNEY DYNAMICS AND EXCRETION
THIRST AND DRINKING
ANTIDIURETIC HORMONE CONTROL
NON-MUSCLE LOCAL BLOOD FLOW CONTROL
CAPILLARY MEMBRANE DYNAMICS
ANGIOTENSIN CONTROL
CIRCULATORY DYNAMICS
ALDOSTERONE CONTROL
AUTONOMIC CONTROL
HEART RATE AND STROKE VOLUME
PULMONARY DYNAMICS AND FLUIDS
RED CELLS AND VISCOSITY
HEART HYPERTROPHY OR DETERIORATION
TISSUE FLUIDS, PRESSURES AND GEL
ELECTROLYTES AND CELL WATER

APPENDIX B

```
***** I N P U T   P A R A M E T E R S ****

A(108) 0.317222E+02 = AAR
A(163) 0.200000E+00 = AGK
A(203) 0.302806E+01 = AH
A(204) 0.100911E+01 = AHC
A(247) 0.700000E+01 = AHK
A(208) 0.100039E+01 = AHM
A(288) 0.194279E-01 = AHY
A(287) 0.183110E-01 = AHZ
A(205) 0.792152E-01 = AH1
A(206) 0.120009E+01 = AH2
A(207) 0.499961E+01 = AH4
A(201) -.111689E-02 = AH7
A(202) 0.000000E+00 = AH8
A(318) 0.100000E+01 = ALØ
A(161) 0.993475E+00 = AM
A(157) 0.992485E+00 = AMC
A(343) 0.994666E+00 = AMM
A(155) 0.101307E+01 = AMP
A(154) 0.980250E+00 = AMR
A(238) 0.600000E+02 = AMT
A(156) 0.994222E+00 = AM1
A(158) 0.168723E-01 = AM2
A(159) 0.103961E+01 = AM3
A(160) 0.190455E+02 = AM5
A(166) 0.995995E+00 = ANC
A(170) 0.100303E+01 = ANM
A(164) 0.995531E+00 = ANP
A(374) 0.995531E+00 = ANR
A(239) 0.150000E+02 = ANT
A(269) 0.100303E+01 = ANU
A(372) 0.300000E-03 = ANV
A(373) 0.000000E+00 = ANW
A(371) -.446948E-01 = ANX
A(369) -.200000E+00 = ANY
A(370) 0.400000E+00 = ANZ
A(165) 0.995826E+00 = AN1
A(167) 0.418318E-01 = AN2
A(168) 0.110111E+01 = AN3
A(169) 0.299697E+01 = AN5
A(188) 0.998304E+00 = AØM
A(111) 0.376883E+02 = APD
A(329) 0.150000E+01 = ARF
A(198) 0.896017E+00 = ARM
A(194) 0.985931E+00 = AR1
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A(197) 0.977277E+00 = AR3
A( 61) 0.988693E+00 = AU
A( 54) 0.100375E+01 = AUB
A( 53) 0.000000E+00 = AUC
A( 63) 0.988693E+00 = AUH
A( 60) 0.988693E+00 = AUJ
A(227) 0.500000E-03 = AUK
A(324) 0.210000E+00 = AUL
A( 66) 0.990389E+00 = AUM
A( 55) 0.000000E+00 = AUN
A( 62) -.113072E-01 = AUØ
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A(281) 0.988693E+00 = AUP
A(375) 0.100000E+01 = AUQ
A(376) 0.988693E+00 = AUR
A(377) 0.100000E+01 = AUS
A(282) 0.300000E+00 = AUV
A(226) 0.300000E+01 = AUX
A(284) 0.250000E+00 = AUY
A(228) 0.100000E+01 = AUZ
A( 57) -.969967E-02 = AU2
A( 67) 0.209558E-01 = AU4
A( 56) 0.990300E+00 = AU6
A( 58) -.484984E-05 = AU8
A( 65) 0.840389E+00 = AU9
A( 38) 0.997600E+00 = AVE
A( 26) 0.101126E+01 = A1B
A(242) 0.100000E+01 = A1K
A(243) 0.200000E+02 = A2K
A(244) 0.115200E+05 = A3K
A(344) 0.100000E+01 = A4K
A(332) 0.994639E+00 = BFM
A(186) 0.295463E+01 = BFN
A(174) 0.166661E+04 = B1
A(131) -.400162E-02 = CCD
A(230) 0.700000E-02 = CFC
A( 92) 0.495104E+01 = CHY
A(122) 0.498957E+01 = CKE
A(129) 0.142025E+03 = CKI
A(130) 0.142029E+03 = CNA
A(199) 0.302961E+01 = CNB
A(162) 0.997039E+01 = CNE
A(245) 0.139000E+03 = CNR
A(210) 0.250000E+01 = CNX
A(209) 0.600000E+01 = CNY
A(246) 0.100000E+01 = CNZ
A( 39) 0.212000E-01 = CN2
A( 40) 0.366284E+00 = CN3
A(225) 0.200000E+00 = CN7
A( 19) 0.632025E+00 = CPA
A(305) 0.300000E-03 = CPF
A( 95) 0.124609E+02 = CPG
A( 73) 0.165321E+02 = CPI
A(231) 0.160000E-06 = CPK
A(291) 0.301352E+02 = CPN
A( 75) 0.701082E+02 = CPP
A(233) 0.850000E+02 = CPR
A( 86) 0.535762E+02 = CP1
A(224) 0.825000E-01 = CV
A( 49) -.125924E-01 = DAS
A( 59) 0.988056E+00 = DAU
A(307) 0.100000E+01 = DA1
A(298) -.888210E-08 = DFP
A(143) 0.363798E-09 = DFZ
A(273) 0.554421E-02 = DHM
A( 50) 0.128508E-03 = DLA
A( 90) 0.700026E-02 = DLP
A(308) 0.699915E-02 = DLZ
A( 48) 0.146389E-02 = DPA
A( 87) 0.532462E-01 = DPC
A( 88) 0.661090E-04 = DPI
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A( 85) 0.531801E-01 = DPL
A(235) 0.700000E-02 = DP0
A( 91) -.674377E-04 = DPP
A(309) 0.531878E-01 = DPY
A(310) 0.529841E-01 = DPZ
A(187) 0.179681E+03 = D0B
A( 51) 0.716209E-03 = DRA
A(286) 0.300000E+01 = DSP
A( 47) 0.102838E-01 = DVS
A(104) 0.326489E+00 = EPH
A(319) 0.100000E+01 = EXC
A(328) 0.000000E+00 = EXE
A(350) 0.300000E+01 = EX1
A(365) 0.000000E+00 = FIS
A(368) 0.000000E+00 = GBL
A(200) 0.125130E+00 = GFN
A(114) 0.125130E+00 = GFR
A( 97) 0.125131E+00 = GF1
A(271) 0.500000E-01 = GE2
A(279) 0.100525E+01 = GF3
A(280) 0.500000E+01 = GF4
A(112) 0.620504E+02 = GLP
A(107) -.154896E-04 = GPD
A(151) 0.143459E+03 = GPR
A(311) 0.187144E-04 = GPZ
A(105) 0.325108E-02 = GP1
A(106) 0.374288E-01 = GP2
A(260) 0.533330E+00 = HKM
A(173) 0.408241E+02 = HM
A(272) 0.100000E+01 = HMD
A(259) 0.900000E+02 = HMK
A(172) 0.408241E+00 = HM1
A(316) 0.100243E+01 = HPL
A(315) 0.100509E+01 = HPR
A(304) 0.717308E+02 = HR
A(219) 0.100000E+01 = HSL
A(218) 0.100000E+01 = HSR
A(236) 0.570000E+02 = HYL
A(  2) 0.726600E+00 = I
A(136) 0.670675E+03 = I1
A(145) 0.300000E-02 = I2
A(275) 0.200000E+02 = I3
A(150) 0.914784E+01 = IFP
A(127) 0.115573E-03 = KCD
A(313) 0.119019E-03 = KCZ
A(133) 0.750493E+02 = KE
A(128) -.105172E-03 = KED
A(124) 0.698539E+03 = KE1
A(134) 0.354853E+04 = KI
A(237) 0.280000E-02 = KID
A(126) 0.915527E-02 = KIE
A(125) 0.354854E+04 = KIR
A(153) 0.998025E+01 = KN1
A(152) 0.351305E-01 = KN3
A(123) 0.278960E-02 = K0D
A( 89) 0.148918E+02 = LPD
A(234) 0.470000E-03 = LPK
A( 12) 0.990411E+00 = LVM
A(340) 0.598982E+02 = MM0
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A(266) 0.179695E+03 = MØ2
A(120) 0.213630E+04 = NAE
A(119) -.362377E-02 = NED
A(220) 0.100000E+00 = NID
A(118) 0.103624E+00 = NØD
A(312) 0.103915E+00 = NØZ
A(346) 0.600000E+02 = ØMM
A(289) 0.993753E+00 = ØSA
A(190) 0.695877E+00 = ØSV
A(285) 0.300000E+01 = ØUT
A(185) 0.202845E+03 = ØVA
A(334) 0.698845E+00 = ØVS
A(326) 0.150000E+00 = Ø2A
A(320) 0.180000E+03 = Ø2M
A( 10) 0.997387E+02 = PA
A( 11) 0.100262E+01 = PAM
A(367) 0.997387E+02 = PAR
A( 52) 0.997387E+02 = PA1
A(321) 0.100878E+03 = PA2
A( 78) 0.183755E+02 = PC
A( 79) 0.454161E+00 = PCD
A(232) 0.300000E+01 = PCE
A(306) 0.697848E+01 = PCP
A(341) -.679865E-01 = PDØ
A(297) 0.298392E-03 = PFI
A(113) 0.160071E+02 = PFL
A( 99) 0.611260E+01 = PGC
A(100) -.400010E+01 = PGH
A( 29) 0.152458E+02 = PGL
A( 96) 0.413219E+01 = PGP
A( 94) 0.198042E+01 = PGR
A( 42) 0.959435E+02 = PGS
A( 35) 0.370362E+01 = PGV
A( 98) 0.165288E+02 = PGX
A(101) -.922036E-02 = PG2
A( 72) -.598890E+01 = PIF
A(354) 0.250000E+04 = PK1
A(363) 0.800000E+03 = PK2
A(364) 0.200000E+01 = PK3
A( 23) 0.117865E+00 = PLA
A(293) 0.298391E-03 = PLF
A( 81) 0.800060E+00 = PLØ
A( 25) 0.201179E+02 = PL1
A(301) 0.686006E+01 = PMC
A(338) 0.800240E+01 = PMØ
A(303) 0.461073E+01 = PMP
A(302) 0.724995E+01 = PMS
A(347) 0.800240E+01 = PM1
A(348) 0.100000E-02 = PM3
A(349) -.100000E+01 = PM4
A(353) 0.122000E+03 = PM5
A(267) 0.929492E+00 = PØA
A(193) 0.985898E+00 = PØB
A(196) 0.976478E+00 = PØC
A(192) -.237595E+00 = PØD
A(342) 0.994561E+00 = PØE
A(240) 0.600000E-01 = PØK
A(345) 0.800000E-01 = PØM
A(241) 0.300000E+00 = PØN
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A(274) 0.800000E+01 = PØQ
A(270) 0.400000E+02 = PØR
A(292) 0.120541E+02 = PØS
A(191) 0.821768E+01 = PØT
A(261) 0.397624E+02 = PØV
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A(262) 0.300000E+00 = PØZ
A( 69) 0.825000E+01 = PØ1
A(179) 0.237500E+00 = PØ2
A( 17) 0.153637E+02 = PPA
A( 76) 0.280433E+02 = PPC
A(296) 0.159315E-05 = PPD
A(290) -.100054E+02 = PPI
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A(294) 0.899208E-02 = PPØ
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A(142) 0.185170E-05 = PPZ
A( 18) 0.399456E+00 = PP1
A(322) 0.155392E+02 = PP2
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A( 93) -.501114E+01 = PRM
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A(146) 0.915550E-01 = PR1
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A( 70) 0.101104E+01 = PTT
A( 77) 0.145804E+02 = PVG
A(335) 0.399320E+02 = PVØ
A( 34) 0.379517E+01 = PVS
A(189) 0.800000E+01 = P1Ø
A(339) 0.800000E+01 = P2Ø
A( 44) 0.513746E+01 = QAØ
A( 24) 0.522090E+01 = QLN
A( 46) 0.512487E+01 = QLØ
A(337) 0.240003E+04 = QØM
A(264) 0.246777E+04 = QØ2
A( 30) 0.512500E+01 = QPØ
A(330) 0.600000E+00 = QRF
A( 15) 0.521973E+01 = QRN
A( 45) 0.512646E+01 = QRØ
A( 37) 0.512718E+01 = QVØ
A(327) 0.394053E+01 = Q1
A(351) 0.180000E+02 = Q2
A(352) 0.119632E+04 = Q3
A( 31) 0.292328E+02 = Q5
A(333) 0.963000E+02 = RAM
A(223) 0.305200E+02 = RAR
A(265) 0.118807E+01 = RBF
A(182) -.834661E-06 = RCD
A(181) 0.110200E-04 = RC1
A(178) 0.118547E-04 = RC2
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A(117) 0.100000E+01 = REK
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A(336) 0.598937E+02 = RMØ
A( 20) 0.158222E+01 = RPA
A( 28) 0.297457E+01 = RPT
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A( 27) 0.139235E+01 = RPV
A(109) 0.839500E+02 = RR
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A( 43) 0.193962E+02 = RTP
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A( 21) 0.989118E+00 = RVM
A( 41) 0.275684E+01 = RVS
A(283) 0.273012E+01 = RV1
A(221) 0.500000E+00 = SR
A(248) 0.330000E+02 = SRK
A(366) 0.000000E+00 = STA
A(317) 0.100000E+01 = STH
A(323) 0.714458E-01 = SV0
A(  1) 0.000000E+00 = T
A(249) 0.191600E+05 = TM
A(115) 0.124098E+00 = TRR
A(216) 0.100536E-02 = TVD
A(141) 0.100391E-02 = TVZ
A(278) 0.000000E+00 = T1
A(276) 0.400000E+01 = U
A(  9) 0.354072E+00 = VAE
A(  6) 0.849072E+00 = VAS
A(171) 0.500662E+01 = VB
A(  3) -.392832E-05 = VBD
A(121) 0.150413E+02 = VEC
A(103) 0.115125E+02 = VG
A(176) 0.303328E+01 = VIB
A(135) 0.249852E+02 = VIC
A(132) -.120985E-04 = VID
A(175) 0.153328E+01 = VIE
A( 68) 0.553337E+00 = VIF
A(177) 0.101099E+01 = VIM
A(314) -.400162E-04 = VIZ
A(102) -.184407E-03 = VG0
A(  7) 0.401179E+00 = VLA
A( 22) 0.117865E-02 = VLE
A(148) 0.296271E+01 = VP
A(277) 0.100000E-01 = VP1
A(  5) 0.379996E+00 = VPA
A( 84) -.205207E-04 = VPD
A( 16) 0.737455E-01 = VPE
A(299) 0.124944E-01 = VPF
A(  8) 0.100458E+00 = VRA
A(183) 0.204391E+01 = VRC
A( 13) 0.457775E-03 = VRE
A( 80) 0.319994E-02 = VTC
A( 83) 0.124043E-06 = VTD
A( 82) 0.320494E-02 = VTL
A(147) 0.120661E+02 = VTS
A(217) 0.400264E+02 = VTW
A(137) 0.317912E-02 = VTY
A(139) 0.320024E-02 = VTZ
A(116) 0.103115E-02 = VUD
A(140) 0.103220E-02 = VUZ
A( 32) 0.325152E+00 = VVE
A(  4) 0.327592E+01 = VVS
A(222) 0.295137E+01 = VVR
A(211) 0.162576E+00 = VV1
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A(212) 0.150500E+00 = VV2
A( 64) 0.207625E+00 = VV4
A(213) 0.253618E-04 = VV5
A(214) 0.827931E-05 = VV6
A(215) 0.120510E-01 = VV7
A( 33) 0.313102E+00 = VV8
A(325) 0.315900E+01 = VV9
A(250) 0.200000E-01 = V2D
A(144) 0.100000E+02 = X
A(229) 0.100000E+01 = Y
A(138) 0.100000E+01 = Z
A(251) 0.100000E+01 = Z1
A(252) 0.100000E+01 = Z2
A(253) 0.400000E+01 = Z3
A(254) 0.100000E+02 = Z4
A(255) 0.100000E+02 = Z5
A(256) 0.500000E+01 = Z6
A(257) 0.500000E+01 = Z7
A(258) 0.100000E+01 = Z8
A(355) 0.120000E+00 = Z9
A(356) 0.825000E+01 = Z10
A(357) 0.400000E+01 = Z11
A(358) 0.124000E+01 = Z12
A(359) 0.625000E+00 = Z13
A(360) 0.000000E+00 = Z14
A(361) 0.000000E+00 = Z15
A(362) 0.000000E+00 = Z16
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A(396) 0.000000E+00 =
A(397) 0.000000E+00 =
A(398) 0.000000E+00 =
A(399) 0.000000E+00 =
A(400) 0.000000E+00 =
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APPENDIX C

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C      R67093,8 LARRY NEAL--MATH; NASA FILE
C
C      PROGRAM GUYTON
C      CIRCULATORY DYNAMICS - CIRCE
C           CIRCE1
       REAL LVM,I,IFP,LPD,KE,KE1,KOD,KIR,KIE,KI,KCD,KED,KN1,KN3
       REAL NAE,NED,NID,NOD,I1,LPK,KID,MO2,NOZ,KCZ,HPL,HPR,I2,I3,MMO
       DIMENSION FUN1(14),FUN2(14),FUN3(14),FUN4(14),FUN6(14),FUN7(14)
       COMMON/ARRAY/T,I,VBD,VVS,VPA,VAS,VLA,VRA,VAE,PA,PAM,LVM,
     *              VRE,PRA,QRN,VPE,PPA,PP1,CPA,RPA,RVM,VLE,PLA,QLN,PL1,
     *              A1B,RPV,RPT,PGL,QPO,Q5 ,VVE,VV8,PVS,PGV,RVG,QVO,AVE
       COMMON/ARRAY/CN2,CN3,RVS,PGS,RTP,QAO,QRO,QLO,DVS,DPA,DAS,DLA,DRA,
     *              PA1,AUC,AUB,AUN,AU6,AU2,AU8,DAU,AUJ,AU ,AUO,AUH,VV4,
     *              AU9,AUM,AU4,VIF,PO1,PTT,PTS,PIF,CPI,PTC,CPP,PPC,PVG
       COMMON/ARRAY/PC ,PCD,VTC,PLD,VTL,VTD,VPD,DPL,CP1,DPC,DPI,LPD,DLP,
     *              DPP,CHY,PRM,PGR,CPG,PGP,GF1,PGX,PGC,PGH,PG2,VGD,VG ,
     *              EPH,GP1,GP2,GPD,AAR,RR ,RFN,APD,GLP,PFL,GFR,TRR,VUD
       COMMON/ARRAY/REK,NOD,NED,NAE,VEC,CKE,KOD,KE1,KIR,KIE,KCD,KED,CKI,
     *              CNA,CCD,VID,KE ,KI ,VIC,I1 ,VTY,Z  ,VTZ,VUZ,TVZ,PPZ,
     *              DFZ,X  ,I2 ,PR1,VTS,VP ,PRP,IFP,GPR,KN3,KN1,AMR,AMP
       COMMON/ARRAY/AM1,AMC,AM2,AM3,AM5,AM ,CNE,AGK,ANP,AN1,ANC,AN2,AN3,
     *              AN5,ANM,VB ,HM1,HM ,B1 ,VIE,VIB,VIM,RC2,PO2,RKC,RC1,
     *              RCD,VRC,RSN,OVA,BFN,DOB,AOM,P1O,OSV,POT,POD,POB,AR1
       COMMON/ARRAY/AR2,POC,AR3,ARM,CNB,GFN,AH7,AH8,AH ,AHC,AH1,AH2,AH4,
     *              AHM,CNY,CNX,VV1,VV2,VV5,VV6,VV7,TVD,VTW,HSR,HSL,NID,
     *              SR ,VVR,RAR,CV ,CN7,AUX,AUK,AUZ,Y  ,CFC,CPK,PCE,CPR
       COMMON/ARRAY/LPK,DPO,HYL,KID,AMT,ANT,POK,PON,A1K,A2K,A3K,CNR,CNZ,
     *              AHK,SRK,TM ,V2D,Z1 ,Z2 ,Z3 ,Z4 ,Z5 ,Z6 ,Z7 ,Z8 ,HMK,
     *              HKM,POV,POZ,RDO,QO2,RBF,MO2,POA,POY,ANU,POR,GF2,HMD
       COMMON/ARRAY/DHM,POQ,I3 ,U  ,VP1,T1 ,GF3,GF4,AUP,AUV,RV1,AUY,OUT,
     *              DSP,AHZ,AHY,OSA,PPI,CPN,POS,PLF,PPO,PPN,PPD,PFI,DFP,
     *              VPF,PPR,PMC,PMS,PMP,HR ,CPF,PCP,DA1,DLZ,DPY,DPZ,GPZ
       COMMON/ARRAY/NOZ,KCZ,VIZ,HPR,HPL,STH,ALO,EXC,O2M,PA2,PP2,SVO,AUL,
     *              VV9,O2A,Q1 ,EXE,ARF,QRF,RSM,BFM,RAM,OVS,PVO,RMO,QOM,
     *              PMO,P2O,MMO,PDO,POE,AMM,A4K,POM,OMM,PM1,PM3,PM4,EX1
       COMMON/ARRAY/Q2 ,Q3 ,PM5,PK1,Z9 ,Z10,Z11,Z12,Z13,Z14,Z15,Z16,PK2,
     *              PK3,FIS,STA,PAR,GBL,ANY,ANZ,ANX,ANV,ANW,ANR,AUQ,AUR,
     *              AUS,PTM ,DUMMY(22),TITLE(400)
       DATA FUN1(1),FUN1(2),FUN1(3),FUN1(4),FUN1(5),FUN1(6),FUN1(7),
     *FUN1(8),FUN1(9),FUN1(10),FUN1(11),FUN1(12),FUN1(13),FUN1(14)/
     *0.,1.04,60.,1.025,125.,.97,160.,.88,200.,.59,240.,0.,240.,0./
       DATA FUN2(1),FUN2(2),FUN?(3),FUN2(4),FUN2(5),FUN2(6),FUN2(7),
     *FUN2(8),FUN2(9),FUN2(10),FUN2(11),FUN2(12),FUN2(13),FUN2(14)/
     *-100.,0.0,-6.,0.0,-3.,.75,-1.,2.6,2.,9.8,8.,13.5,1000.,13.5/
       DATA FUN3(1),FUN3(2),FUN3(3),FUN3(4),FUN3(5),FUN3(6),FUN3(7),
     *FUN3(8),FUN3(9),FUN3(10),FUN3(11),FUN9(12),FUN3(13),FUN3(14)/
     *0.0,1.06,20.,.97,24.,.93,30.,.8,38.,.46,45.,0.,45.,0./
       DATA FUN4(1),FUN4(2),FUN4(3),FUN4(4),FUN4(5),FUN4(6),FUN4(7),
     *FUN4(8),FUN4(9),FUN4(10),FUN4(11),FUN4(12),FUN4(13),FUN4(14)/
     *-100.,0.,-4.,0.,-1.,3.6,3.,9.4,6.,11.6,10.,13.5,1000.,13.5/
       DATA FUN6(1),FUN6(2),FUN6(3),FUN6(4),FUN6(5),FUN6(6),FUN6(7),
     *FUN6(8),FUN6(9),FUN6(10),FUN6(11),FUN6(12),FUN6(13),FUN6(14)/
     *-100.,10000.,0.,70.,.4,9.3,.8,3.3,1.2,1.3,1.6,.43,100.,0./
       DATA FUN7(1),FUN7(2),FUN7(3),FUN7(4),FUN7(5),FUN7(6),FUN7(7),
     *FUN7(8),FUN7(9),FUN7(10),FUN7(11),FUN7(12),FUN7(13),FUN7(14)/
     *0.,7.,30.,6.25,60.,3.,100.,1.,160.,.15,400.,.05,400.,.05/
C
       WRITE (102,5)
```

```
      WRITE (6,5)
    5 FORMAT (/'   GUYTON MODEL FROM WHITE'/
     * '    REFER TO GE-AGS USER GUIDE TIR 741-MED-3017'//)
      WRITE(102,60)
   60 FORMAT(10X,'KEY-IN CODES'/10X,'------------'//
     *5X,'001 = INITIALIZE FROM CARDS'/
     *5X,'002 = CHANGE VARIABLES'/
     *5X,'003 = PRINT OUT VARIABLES'/
     *5X,'004 = PRINT OUT COMPLETE ARRAY'//)
C
   90 CALL INPUT
C.
      PRTIME=PTM
      IF(I .GT. 0.5) I=0.5
      IOUT=OUT
  100 IF(T .LT. PRTIME) GO TO 300
      CALL INPUT
      PRTIME=PRTIME+PTM
C
C100  IF(OUT .EQ. 3.) CALL OUTPUT
C     IF(DSP .EQ. 3.) CALL DSPLAY
C
  300 T=T+I2
C
      CALL HEMO       (AMM,ANM,ANU,ANY,ANZ,ARM,AUH,AUM,AUY,AVE,BFM,BFN,
     *                 CN2,CN3,CN7,CV ,DAS,DLA,DPA,DRA,DVS,FIS,HMD,HPL,
     *                 HPR,HSL,HSR,I2 ,LVM,PA ,PAM,PA2,PC ,PGL,PGS,PLA,
     *                 PPA,PP1,PP2,PRA,PR1,PVS,QAO,QLN,QLO,QPO,QRF,QRN,
     *                 QRO,QVO,RAM,RAR,RBF,RPA,RPT,RPV,RSM,RSN,RVG,RVM,
     *                 RVS,U  ,VAE,VAS,VBD,VIM,VLA,VLE,VP ,VPA,VPE,VRA,
     *                 VRC,VRE,VVE,VVR,VVS,VV7,VV8,X  ,FUN1,FUN2,FUN3,
     *                 FUN4)
C
  120 CALL AUTO       (AU ,AUB,AUC,AUH,AUJ,AUK,AUL,AUM,AUN,AUO,AUP,AUQ,
     *                 AUR,AUS,AUV,AUX,AUZ,AU4,AU6,AU8,A1B,DAU,EXC,EXE,
     *                 EX1,I2 ,PA ,PA1,POQ,POT,P2O,STA,VVR,VV9,Y  ,Z,
     *                 Z8 ,Z12)
C
      IF(I3.LE.I2)GO TO 168
      IF(ABS(DAU-AUJ).GT.DA1)GO TO 100
  110 IF (ABS(QAO-QLO).GT..2)GO TO 100
      IF (ABS(QAO-QPO).GT..2)GO TO 100
      IF (ABS(QAO-QRO).GT..4)GO TO 100
C
  168 CALL HORMON     (AM ,AMC,AMP,AMR,AMT,AM1,ANM,CKE,PA,Z,FUN7,
     *                 AGK,ANC,ANP,ANR,ANT,ANV,ANW,AN1,CNA,CNE,GFN,
     *                 I  ,REK)
C
  170 CALL BLOOD      (HKM,HM ,HMK,I  ,POT,POY,PO1,PO2,RC1,RC2,RCD,RKC,
     *                 VB ,VIB,VIE,VIM,VP ,VRC)
C
  180 CALL MUSCLE     (ALO,AMM,AOM,AUP,A4K,BFM,EXC,HM ,I  ,MMO,OMM,OSA,
     *                 OVA,OVS,O2A,PDO,PK1,PK2,PK3,PMO,PM1,PM3,PM4,PM5,
     *                 POE,POM,PVO,P2O,QOM,RMO,VPF,Z5 ,Z6)
C
      CALL AUTORG     (AOM,ARM,AR1,AR2,AR3,A1K,A2K,A3K,BFN,DOB,HM ,I,
     *                 MO2,OSV,OVA,O2M,POA,POB,POC,POD,POK,PON,POR,POT,
     *                 POV,POZ,P1O,QO2,RDO,Z  ,Z4 ,Z7)
C
```

```
      CALL ADH        (AH ,AHC,AHK,AHM,AHY,AHZ,AH7,AH8,AUP,CNA,CNB,CNR,
     *                 CNZ,I  ,PRA,Z)
C
      CALL MISC1      (AHM,AU4,AU8,I  ,SR ,SRK,STH,TVD,TVZ,VEC,VIC,VTW,
     *                 VVE,VV6,VV7,Z)
C
      CALL HEART      (AUR,DHM,HMD,HR ,I  ,PA ,PMC,PMP,PMS,POT,PRA,QAO,
     *                 QLO,RTP,SVO,VAE,VLE,VPE,VRE,VVE)
C
  130 CALL CAPMBD     (BFN,CFC,CPI,CPP,DFP,I  ,IFP,PC ,PCD,PIF,PLD,PPC,
     *                 PRP,PTC,PTS,PTT,PVG,PVS,RVS,TVD,VG ,VID,VIF,VP,
     *                 VPD,VTC,VTD,VTL,VTS,VUD,Z  ,Z1 ,FUN6)
C
      I=I*1.2+T-T1
      I1=ABS(VP1/VPD/I)
      IF(I1.LT.I) I=I1
      IF(I3+T-T1.LT.I) I=I3+T-T1
      T=I+T1
      T1=T
      IF (T.LT.PRTIME) GO TO 200
      CALL INPUT
      PRTIME=PRTIME+PTM
C
C     IF(OUT.EQ.4.) CALL PUTOUT
C
C     IF(OUT.EQ.4.) CALL OUTPUT
C     IF(DSP.EQ.4.) CALL DSPLAY
C
  200 CALL PULMON     (CPF,CPP,CPN,DFP,I  ,PCP,PFI,PLA,PLF,POS,PPA,PPC,
     *                 PPD,PPI,PPN,PPO,PPR,VP ,VPD,VPF,Z  ,Z3)
C
      CALL MISC 2     (HPL,HPR,HSL,HSR,I,PA,PPA,POT,STH,Z10,Z11,Z13)
C
  135 CALL PROTEN     (CHY,CPG,CPI,CPK,CPP,CPR,CP1,DLP,DLZ,DPC,DPI,DPL,
     *                 DPP,DPY,GPD,GPR,I  ,IFP,LPK,PC ,PCE,PGX,PRP,VG ,
     *                 VTL,Z  ,DPO,PPD)
C
  142 CALL KIDNEY     (AAR,AHM,AM ,APD,ARF,AUM,CNE,CNX,CNY,GBL,GFN,GFR,
     *                 GF2,GF3,GF4,GLP,I  ,NAE,NED,NID,NOD,NOZ,PA ,PAR,
     *                 PFL,PPC,RBF,REK,RFN,RR ,STH,TRR,VIM,VUD,Z)
C
  160 CALL IONS       (AM ,CCD,CKE,CKI,CNA,I  ,KCD,KE ,KED,KI ,KID,KIE,
     *                 KIR,KOD,NAE,REK,VEC,VIC,VID,VP ,VPF,VTS,Z)
C
  140 CALL GELFLD     (CHY,CPG,CPI,GPR,HYL,IFP,PGC,PGH,PGP,PGR,PGX,PIF,
     *            VTS,PRM,PTC,PTS,PTT,VG ,VGD,VIF,VRS,V2D,FUN6)
C
      GO TO 100
      END
      SUBROUTINE HEMO (AMM,ANM,ANU,ANY,ANZ,ARM,AUH,AUM,AUY,AVE,BFM,BFN,
     *                 CN2,CN3,CN7,CV ,DAS,DLA,DPA,DRA,DVS,FIS,HMD,HPL,
     *                 HPR,HSL,HSR,I2 ,LVM,PA ,PAM,PA2,PC ,PGL,PGS,PLA,
     *                 PPA,PP1,PP2,PRA,PR1,PVS,QAO,QLN,QLO,QPO,QRF,QRN,
     *                 QRO,QVO,RAM,RAR,RBF,RPA,RPT,RPV,RSM,RSN,RVG,RVM,
     *                 RVS,U  ,VAE,VAS,VBD,VIM,VLA,VLE,VP ,VPA,VPE,VRA,
     *                 VRC,VRE,VVE,VVR,VVS,VV7,VV8,X  ,FUN1,FUN2,FUN3,
     *                 FUN4)
      REAL  I2,LVM
C
```

```
C      CIRCULATORY DYNAMICS BLOCK
C     HEMODYNAMICS
C
        VBD=VP+VRC-VVS-VAS-VLA-VPA-VRA
        VVS=VVS+DVS*I2+VBD*.3986
        VPA=VPA+DPA*I2+VBD*.155
        VAS=VAS+DAS*I2+VBD*.261
        VLA=VLA+DLA*I2+VBD*.128
        VRA=VRA+DRA*I2+VBD*.0574
        VAE=VAS-.495
        PA=VAE/.00355
        PAM=100./PA
        PA2=PA/AUH
        CALL FUNCTN(PA2,LVM,FUN1)
        VRE=VRA-.1
        PRA=VRE/.005
        CALL FUNCTN(PRA,QRN,FUN2)
        VPE=VPA-.30625
        PPA=VPE/.0048
        PP1=.026*PPA
        IF (PP1.LT.0.)PP1=0.
        RPA=PP1**(-.5)
        PP2=PPA/AUH
        CALL FUNCTN(PP2,RVM,FUN3)
        VLE=VLA-.4
        PLA=VLE/.01
        CALL FUNCTN(PLA,QLN,FUN4)
        RPV=1./(PLA+20.)/.0357
        RPT=RPV+RPA
        PGL=PPA-PLA
        QPO=PGL/RPT
        ANU=ANM
        IF (ANU.LT..8)ANU=.8
        VVE=VVS-VVR-(ANU-1.)*ANY
        VV8=VVE-VV7
        IF(VV8.LT..0001)VV8=.0001
        PVS=VV8/CV
        PR1=PRA
        IF (PRA.LT.0.)PR1=0.
        RVG=2.738/PVS
        QVO=(PVS-PR1)/RVG
        CN3=CN3+(((PC-17.)*CN7+17.)*CN2-CN3)*.1
        AVE=(AUM-1.)*AUY+1.
        RVS=AVE*(1./CN3)*VIM*((ANU-1.)*ANZ+1.)
        PGS=PA-PVS
        RSN=RAR*ARM*ANU*AUM*PAM*VIM+RVS*1.79
        BFN=PGS/RSN
        RSM=ANU*VIM*PAM*AUM*AMM*RAM
        BFM=PGS/RSM
        QAO=BFN+BFM+RBF+(PA-PRA)*FIS
        QLO=LVM*QLN*AUH*HSL*HMD*HPL
        QRO=QRN*((1.-QRF)*AUH*RVM*HSR*HMD*HPR+QRF*QLO/QLN)
        QPO=QLO+(QPO-QLO)/U
        QVO=QRO+(QVO-QRO)/X
        DVS=QAO-QVO
        DPA=QRO-QPO
        DAS=QLO-QAO
        DLA=QPO-QLO
        DRA=QVO-QRO
```

```
      RETURN
      END
      SUBROUTINE AUTO (AU ,AUB,AUC,AUH,AUJ,AUK,AUL,AUM,AUN,AUO,AUP,AUQ,
     *                 AUR,AUS,AUV,AUX,AUZ,AU4,AU6,AU8,A1B,DAU,EXC,EXE,
     *                 EX1,I2 ,PA ,PA1,POQ,POT,P2O,STA,VVR,VV9,Y  ,Z,
     *                 Z8 ,Z12)
      REAL  I2
C
C     AUTONOMIC CONTROL BLOCK
C
  120 EXE=(8.-P2O)*EX1+(EXC-1.)*Z12
      POQ=POT
      IF (POQ.GT.8.)POQ=8.
      IF (POQ.LT.4.)POQ=4.
      PA1=PA*POQ/8.-EXE
      AUC=0.
      IF(PA1.LT.80.)AUC=.03*(80.-PA1)
      IF(PA1.LT.40.)AUC=1.2
      AUB=0.
      IF(PA1.LT.170.)AUB=.014286*(170.-PA1)
      IF(PA1.LT.40.)AUB=1.83
  123 A1B=(AUB-1.)*AUX+1.
  124 AUN=0
      IF(PA1.LT.50.)AUN=.2*(50.-PA1)
      IF(PA1.LT.20.)AUN=6.0
      AU6=A1B-AU4
      AU8=AUK*(AU6-1.)
      DAU=DAU+(AUC+AU6+AUN-DAU)/Z/Y
      AUJ=AUJ+(DAU-AUJ)*I2*6./Z8
      IF(AUJ.LT.0.)AUJ=0.
      IF(AUJ-1.)126,127,127
  126 AU=AUJ**AUZ
      GO TO 128
  127 AU=(AUJ-1.)*AUZ+1.
  128 IF(STA.GT..00001)AU=STA
      AUO=AU-1.
      AUP=AUO*AUQ+1.
      AUH=AUO*AUV+1.
      AUR=AUO*AUS+1.
      VVR=VV9-AUL*AUP
      AUM=.15+.85*AUP
      RETURN
      END
      SUBROUTINE HORMON(AM ,AMC,AMP,AMR,AMT,AM1,ANM,CKE,PA,Z,FUN7,
     *                 AGK,ANC,ANP,ANR,ANT,ANV,ANW,AN1,CNA,CNE,GFN,
     *                I  ,REK)
      REAL  I
C
C*********************************************************************
C
C     ALDOSTERONE CONTROL BLOCK
C
C*********************************************************************
  168 AMR=CKE/CNA/.00352-9.
      IF(AMR.LT.0.)AMR=0.
      CALL FUNCTN (PA,AMP,FUN7)
      AM1=AM1+(ANM*AMP*AMR-AM1)/Z
      AMC=AMC+(AM1-AMC)*(1.-EXP(-I/AMT))
      AM=20.039-19.8*EXP(-.0391*AMC)
```

```
C***********************************************************************
C
C     ANGIOTENSIN CONTROL BLOCK
C
C***********************************************************************
      CNE=152.-CNA
      IF(CNE.LT.1.)CNE=1.
      ANR=((17.75-GFN*CNA)*AGK+1.)*REK
      ANW=ANW+((ANR-1.)*10.-ANW)*ANV*I
      IF(ANW.LT..0)ANW=0.
      ANP=ANR+ANW
      IF(ANP.GT.100.)ANP=100.
      IF(ANP.LT..01)ANP=.01
      AN1=AN1+(ANP-AN1)/Z
      ANC=ANC+(AN1-ANC)*(1.-EXP(-I/ANT))
      ANM=4.0-3.3*EXP(-.0967*ANC)
      IF(ANM.LT..7)ANM=.7
      RETURN
      END
      SUBROUTINE BLOOD (HKM,HM ,HMK,I   ,POT,POY,PO1,PO2,RC1,RC2,RCD,RKC,
     *                  VB ,VIB,VIE,VIM,VP ,VRC)
      REAL  I
C
C     RED CELLS AND VISCOSITY BLOCK
C-----------------------------------------------------------------------
C     BLOOD VISCOSITY
C-----------------------------------------------------------------------
 170  VB=VP+VRC
      HM=100.*VRC/VB
      VIE=HM/(HMK-HM)/HKM
      VIB=VIE+1.5
      VIM=.3333*VIB
C-----------------------------------------------------------------------
C     RED BLOOD CELLS
C-----------------------------------------------------------------------
      RC2=RKC*VRC
      PO2=PO1-POT
      IF(PO2.LT..2375)PO2=.2375
      RC1=POY*PO2
      RCD=RC1-RC2
      VRC=VRC+RCD*I
      RETURN
      END
      SUBROUTINE MUSCLE(ALO,AMM,AOM,AUP,A4K,BFM,EXC,HM ,I   ,MMO,OMM,OSA,
     *                  OVA,OVS,O2A,PDO,PK1,PK2,PK3,PMO,PM1,PM3,PM4,PM5,
     *                  POE,POM,PVO,P2O,QOM,RMO,VPF,Z5 ,Z6)
      REAL  I,MMO
C
C     MUSCLE BLOOD FLOW CONTROL AND PO2 BLOCK
C
 180  OSA=ALO-VPF*.5
      OVA=OSA*HM*5.
      OVS=OVS+((BFM*OVA-RMO)/HM/5./BFM-OVS)/Z6
      PVO=57.14*OVS
      RMO=(PVO-PMO)*PM5/(PM1**PK3-PM4)
      QOM=QOM+(RMO-MMO)*(1.-EXP(-I/Z5))
      PMO=PK2/(PK1-QOM)
      PM1=PMO
      IF(PM1.LT.PM3)PM1=PM3
```

```
           P2O=PMO
           IF(P2O.GT.8.)P2O=8.
           AOM=(AUP-1.)*O2A+1.
           MMO=AOM*OMM*EXC*(1.-(8.0001-P2O)**3./512.)
           PDO=PVO-40.
           POE=POM*PDO+1.
           IF(POE.LT..005)POE=.005
           AMM=AMM+(POE-AMM)*(1.-EXP(-I/A4K))
           RETURN
           END
           SUBROUTINE AUTORG(AOM,ARM,AR1,AR2,AR3,A1K,A2K,A3K,BFN,DOB,HM ,I,
     *                     MO2,OSV,OVA,O2M,POA,POB,POC,POD,POK,PON,POR,POT,
     *                     POV,POZ,P1O,QO2,RDO,Z  ,Z4 ,Z7)
           REAL  I,MO2
C
C     NON-MUSCLE OXYGEN DELIVERY BLOCK
C     AND NON-MUSCLE LOCAL BLOOD FLOW CONTROL BLOCK
C-----------------------------------------------------------------------
C     AUTOREGULATION,RAPID
C-----------------------------------------------------------------------
           OSV=OSV+((BFN*OVA-DOB)/HM/5./BFN-OSV)/Z7
           POV=OSV*57.14
           RDO=POT**3.
           IF(RDO.LT.50.)RDO=50.
           DOB=(POV-POT)*3161./RDO
           MO2=AOM*O2M*(1.-(8.0001-P1O)**3./512.)
           QO2=QO2+(DOB-MO2)*(1.-EXP(-I/Z4))
           POT=QO2*.00333
           P1O=POT
           IF(POT.GT.8.)P1O=8.
           POD=POV-POR
           POB=POB+(POK*POD+1.-POB)/Z
           IF(POB.LT..2)POB=.2
           AR1=AR1+(POB-AR1)*(1.-EXP(-I/A1K))
           ARM=AR1*AR2*AR3
C-----------------------------------------------------------------------
C     AUTOREGULATION,INTERMEDIATE
C-----------------------------------------------------------------------
           POA=POA+(PON*POD+1.-POA)/Z
           IF (POA.LT..5)POA=.5
           AR2=AR2+(POA-AR2)*(1.-EXP(-I/A2K))
C-----------------------------------------------------------------------
C     AUTOREGULATION,LONG-TERM
C-----------------------------------------------------------------------
           IF(POD)194,192,192
  192      POC=POZ*POD+1.
           GO TO 196
  194      POC=POZ*POD*.33+1.
  196      IF (POC.LT..3)POC=.3
           AR3=AR3+(POC-AR3)*I/A3K
           RETURN
           END
           SUBROUTINE ADH   (AH ,AHC,AHK,AHM,AHY,AHZ,AH7,AH8,AUP,CNA,CNB,CNR,
     *                     CNZ,I   ,PRA,Z)
           REAL  I
C
C     ANTIDIURETIC HORMONE
C
           CNB=CNA-CNR
```

```
      AHZ=.2*PRA
      AHY=AHY+(AHZ-AHY)*.0007*I
      AH8=AUP-1.
      IF(AH8.LT.0.)AH8=0.
      IF(CNB.LT.0.)CNB=0.
      AH=AH+(CNZ*CNB+AH8-AHZ+AHY-AH)/Z
      IF(AH.LT.0.)AH=0.
      AHC=AHC+(.3333*AH-AHC)*(1.-EXP(-I/AHK))
      AHM=6.*(1.-EXP(-0.1808*AHC))
      IF(AHM.LT..3)AHM=.3
      RETURN
      END
      SUBRØUTINE MISC1 (AHM,AU4,AU8,I   ,SR ,SRK,STH,TVD,TVZ,VEC,VIC,VTW,
     *                 VVE,VV6,VV7,Z)
      REAL  I
C
C**********************************************************************
C
C     VASCULAR STRESS RELAXATIØN BLØCK
C
C**********************************************************************
      VV6=VV6+(SR*(VVE-.301)-VV7-VV6)/Z
      VV7=VV7+VV6*(1.-EXP(-I/SRK))
C**********************************************************************
C
C     THIRST AND DRINKING BLØCK
C**********************************************************************
C
      TVZ=(.01*AHM-.009)*STH
      TVD=TVD+(TVZ-TVD)/Z
      IF(TVD.LT.0.)TVD=0.
      VTW=VIC+VEC
C**********************************************************************
C
C     AUTØNØMIC CØNTRØL BLØCK
C     ADAPTATIØN ØF BARØRECEPTØRS
C
C**********************************************************************
      AU4=AU4+AU8*I
      RETURN
      END
      SUBRØUTINE HEART (AUR,DHM,HMD,HR ,I   ,PA ,PMC,PMP,PMS,PØT,PRA,QAØ,
     *                 QLØ,RTP,SVØ,VAE,VLE,VPE,VRE,VVE)
      REAL  I
C
C     HEART HYPERTRØPHY ØR DETERIØRATIØN BLØCK
C
C----------------------------------------------------------------------
C     HEART VICIØUS CYCLE
C----------------------------------------------------------------------
      DHM=(PØT-6.)*.0025
      HMD=HMD+DHM*I
      IF (HMD.GT.1.)HMD=1.
C----------------------------------------------------------------------
C     MEAN CIRCULATØRY PRESSURES
C----------------------------------------------------------------------
      PMC=(VAE+VVE+VRE+VPE+VLE)/.11
      PMS=(VAE+VVE+VRE)/.09375
      PMP=(VPE+VLE)/.01625
```

```
C*********************************************************************
C
C     HEART RATE AND STRØKE VØLUME BLØCK AND TØTAL PERIPHERAL RESISTANCE
C
C*********************************************************************
      HR=(32.+40.*AUR+PRA*2.)*((HMD-1.)*.5+1.)
      RTP=(PA-PRA)/QAØ
      SVØ=QLØ/HR
      RETURN
      END
      SUBRØUTINE CAPMBD(BFN,CFC,CPI,CPP,DFP,I   ,IFP,PC ,PCD,PIF,PLD,PPC,
     *                  PRP,PTC,PTS,PTT,PVG,PVS,RVS,TVD,VG ,VID,VIF,VP,
     *                  VPD,VTC,VTD,VTL,VTS,VUD,Z   ,Z1 ,FUN6)
      REAL  I,IFP
C
C     CAPILLARY MEMBRANE DYNAMICS BLØCK
C
  130 PTT=(VTS/12.)**2.
      VIF=VTS-VG
      CALL FUNCTN (VIF,PTS,FUN6)
      PIF=PTT-PTS
      CPI=IFP/VIF
      PTC=.25*CPI
      CPP=PRP/VP
      PPC=.4*CPP
      PVG=RVS*1.79*BFN
      PC=PVG+PVS
      PCD=PC+PTC-PPC-PIF
      VTC=VTC+(CFC*PCD-VTC)/Z
      PLD=7.8+PIF-PTT
      VTL=VTL+(.004*PLD-VTL)/Z
      IF(VTL.LT.0.)VTL=0.
      VTD=VTC-VTL-VID
      VTS=VTS+VTD*I
      VPD=VPD+(TVD-VTC+VTL-VUD-DFP-VPD)/Z1
      RETURN
      END
      SUBRØUTINE PULMØN(CPF,CPP,CPN,DFP,I   ,PCP,PFI,PLA,PLF,PØS,PPA,PPC,
     *                  PPD,PPI,PPN,PPØ,PPR,VP ,VPD,VPF,Z   ,Z3)
      REAL  I
C
C     PULMØNARY DYNAMICS AND FLUIDS BLØCK
C
      VP=VP+(VPD*I)/Z3
C
  200 PCP=.45*PPA+.55*PLA
      PPI=2.-.150/VPF
      CPN=PPR/VPF
      PØS=CPN*.4
      PLF=(PPI+11.)*.0003
      PPØ=PLF*CPN  .
      PPN=(CPP-CPN)*.000225
      PPD=PPD+(PPN-PPØ-PPD)/Z
      IF(PPR+PPD*I-.025.LT.0.)PPD=(.025-PPR)/I
      PFI=(PCP-PPI+PØS-PPC)*CPF
      DFP=DFP+(PFI-PLF-DFP)/Z
      IF(VPF+DFP*I-.001.LT.0.)DFP=(.001-VPF)/I
      VPF=VPF+DFP*I
      PPR=PPR+PPD*I
```

```
      RETURN
      END
      SUBRØUTINE MISC2 (HPL,HPR,HSL,HSR,I,PA,PPA,PØT,STH,Z10,Z11,Z13)
      REAL  I
C
C***********************************************************************
C
C     HEART HYPERTRØPHY ØR DETERIØRATIØN BLØCK
C
C***********************************************************************
      HPL=HPL+(((PA/100./HSL)**Z13)-HPL)*I/57600.
      HPR=HPR+(((PPA/15./HSR)**Z13)-HPR)*I/57600.
C***********************************************************************
C
C     TISSUE EFFECT ØN THIRST AND SALT INTAKE
C
C***********************************************************************
      STH=(Z10-PØT)*Z11
      IF(STH.LT.1.)STH=1.
      IF(STH.GT.8.)STH=8.
      RETURN
      END
      SUBRØUTINE PRØTEN(CHY,CPG,CPI,CPK,CPP,CPR,CP1,DLP,DLZ,DPC,DPI,DPL,
     *                  DPP,DPY,GPD,GPR,I   ,IFP,LPK,PC  ,PCE,PGX,PRP,VG ,
     *                  VTL,Z   ,DPØ,PPD)
      REAL  I,IFP,LPK
C
C     TISSUE FLUIDS,PRESSURES AND GEL BLØCK
C
C-----------------------------------------------------------------------
C     PLASMA AND TISSUE FLUID PRØTEIN
C-----------------------------------------------------------------------
  135 DPL=DPL+(VTL*CPI-DPL)/Z
      IF  (PC.LT.0.)PC=0.
      DPC=DPC+(CPK*(CPP-CPI)*PC**PCE-DPC)/Z
      DPI=DPC-DPL
      DLZ=LPK*(CPR-CPP)
      IF(CPP.GT.CPR)DLZ=4.*DLZ
      DLP=DLP+(DLZ-DLP)/Z
      PRP=PRP+(DLP-DPØ+DPL-DPC-PPD)*I
C-----------------------------------------------------------------------
C     GEL PRØTEIN DYNAMICS
C-----------------------------------------------------------------------
  141 PGX=CHY**2*.01332*CPG+CPG
      GPD=GPD+(.0005*(CPI-PGX)*VG-GPD)/Z
      GPR=GPR+GPD*I
      IFP=IFP+(DPI-GPD)*I
      RETURN
      END
      SUBRØUTINE KIDNEY(AAR,AHM,AM ,APD,ARF,AUM,CNE,CNX,CNY,GBL,GFN,GFR,
     *                  GF2,GF3,GF4,GLP,I   ,NAE,NED,NID,NØD,NØZ,PA ,PAR,
     *                  PFL,PPC,RBF,REK,RFN,RR ,STH,TRR,VIM,VUD,Z)
      REAL  I,NAE,NED,NID,NØD,NØZ
C
C     KIDNEY DYNAMICS AND EXCRETIØN BLØCK
C
  142 GF3=((GFN/.125-1.)*GF4)+1.
      IF(GF3.GT.15.)GF3=15.
      IF(GF3.LT..4)GF3=.4
```

```
      AAR=31.67*VIM*(AUM*ARF+1.-ARF)*GF3
      RR=AAR+51.66*VIM
      PAR=PA-GBL
      RFN=PAR/RR
      RBF=REK*RFN
  150 APD=AAR*RFN
      GLP=PAR-APD
      PFL=GLP-PPC-18.
      GF1=GFN
      GFN=GFN+(PFL*.00781-GFN)*GF2/Z
      IF (ABS(GFN-GF1).GT..002)GO TO 142
      GFR=GFN*REK
      TRR=.8*GFR+.025*REK-.001*REK/AM/AHM
      VUD=VUD+(GFR-TRR-VUD)/Z
      IF(VUD.LT..0002)VUD=.0002
C-----------------------------------------------------------------------
C     KIDNEY SALT OUTPUT AND SALT INTAKE
C     (SEE ALSO ELECTROLYTES AND CELL WATER BLOCK)
C-----------------------------------------------------------------------
      NOZ=1000.*VUD/AM/(CNE/CNX+CNY)
      NOD=NOD+(NOZ-NOD)/Z
      NED=NID*STH-NOD
      NAE=NAE+NED*I
      RETURN
      END
      SUBROUTINE IONS  (AM ,CCD,CKE,CKI,CNA,I  ,KCD,KE ,KED,KI ,KID,KIE,
     *                   KIR,KOD,NAE,REK,VEC,VIC,VID,VP ,VPF,VTS,Z)
      REAL  I,KCD,KE,KED,KI,KID,KIE,KIR,KOD,NAE
C
C     ELECTROLYTES AND CELL WATER BLOCK
C
  160 VEC=VTS+VP+VPF
      CKE=KE/VEC
      KOD=(.00042*CKE+.00014*AM*CKE)*REK
      KIR=2850.+140.*CKE
      KIE=KIR-KI
      KCD=KCD+(KIE*.013-KCD)/Z
      KI=KI+KCD*I
      KED=KID-KCD-KOD
      KE=KE+KED*I
      CKI=KI/VIC
      CNA=NAE/VEC
      CCD=CKI-CNA
      VID=VID+(.01*CCD-VID)/Z
      VIC=VIC+VID*I
      RETURN
      END
      SUBROUTINE GELFLD(CHY,CPG,CPI,GPR,HYL,IFP,PGC,PGH,PGP,PGR,PGX,PIF,
     *                 VTS,PRM,PTC,PTS,PTT,VG ,VGD,VIF,VRS,V2D,FUN6)
      REAL  IFP
C
C     GEL FLUID DYNAMICS
  140 CHY=HYL/VG
      PRM=-5.9*CHY+24.2
      PGR=.4*CHY
      CPG=GPR/VG
      PGP=.25*PGX
      PGC=PGP+PGR
      VIF=VTS-VG
```

```
      CALL FUNCTN (VIF,PTS,FUN6)
      PIF=PTT-PTS
      CPI=IFP/VIF
      PTC=.25*CPI
      PGH=PIF+PTS+PRM
      VGD=V2D*(PIF+PGC-PTC-PGH)
      VG=VG+VGD
      IF(VG.LT.0.)VG=0.
      IF(.012.LT.ABS(VGD)) GO TO 140
      RETURN
      END
      SUBROUTINE FUNCTN(TH,POL,TAB)
      DIMENSION TAB(14)
      N=14
      DO 110 I=1,N,2
      IF(TAB(I)-TH) 110,120,110
  110 CONTINUE
      GO TO 140
  120 POL=TAB(I+1)
  130 RETURN
  140 NN=N-2
      DO 150 I=1,NN,2
  150 IF(TAB(I) .LT. TH .AND. TAB(I+2) .GT. TH) GO TO 160
      WRITE(6,100) TH
  100 FORMAT(5X,' ***** CURVE LIMITS EXCEEDED ***** ',G12.6//)
      IF(TH .LT. TAB(1)) POL=TAB(2)
      IF(TH .GT. TAB(N-1)) POL=TAB(N)
      GO TO 130
  160 POL=TAB(I+1)+(TAB(I+3)-TAB(I+1))*((TH-TAB(I))/(TAB(I+2)-TAB(I)))
      GO TO 130
      END
      SUBROUTINE INPUT
      COMMON/ARRAY/ A(400)
      DIMENSION NV(50)
      DATA NYES/'YE'/
    1 WRITE(102,100)
  100 FORMAT(//2X,'*** INITIALIZE, CHANGE, OR OUTPUT DATA (YES OR NO)'/)
      READ(101,200) NOP
  200 FORMAT(A2)
      IF(NOP .NE. NYES) GO TO 999
      WRITE(102,250)
  250 FORMAT(2X,'*** INPUT CODE')
      READ(101,300) KEY
  300 FORMAT(I3)
      GO TO (10,20,30,40),KEY
   10 WRITE(102,400)
  400 FORMAT(//2X,'*** INPUT INITIAL DATA ***'//)
      CALL PUTIN
      WRITE(102,450)
  450 FORMAT(2X,'*** YOU MAY CHANGE INITIALIZED DATA IF DESIRED')
      GO TO 1
   20 WRITE(102,500)
  500 FORMAT(2X,'*** NUMBER OF VARIABLES TO BE INPUT(I3)'//)
      READ(101,300) NVAR
      WRITE(6,600)
  600 FORMAT(//2X,'VARIABLES TO BE CHANGED')
      WRITE(102,650)
  650 FORMAT(6X,'*** ARRAY NUMBER,VALUE(I3,E13.6)')
      DO 25 I=1,NVAR
```

```
      READ(101,700) N,V
  700 FØRMAT(I3,E13.6)
      WRITE(6,800) N,V
      WRITE(102,800) N,V
  800 FØRMAT(5X,'*** A(',I3,')=',E13.6)
   25 A(N)=V
      GØ TØ 1
   30 WRITE(102,900)
  900 FØRMAT(2X,'*** VARIABLE TØ BE PRINTED ØUT(I3) - IF LESS THAN 1,RET
     *URN'//)
   35 READ(101,300) NVAR
      IF(NVAR .LT. 1) GØ TØ 1
      WRITE(6,902)
  902 FØRMAT(//2X,'VARIABLES TØ BE PRINTED ØUT')
      WRITE(102,800) NVAR,A(NVAR)
      WRITE(6,800) NVAR,A(NVAR)
      GØ TØ 35
   40 WRITE(102,903)
  903 FØRMAT(//2X,'*** CØMPLETE ARRAY IS ØUTPUT ØN LINE PRINTER'//)
      CALL PUTØUT
      GØ TØ 1
  999 RETURN
      END
      SUBRØUTINE PUTIN
      CØMMØN/ARRAY/A(400),TITLE(400)
      WRITE(6,300)
  300 FØRMAT(1H1,39X,' ***** I N P U T   P A R A M E T E R S *****'//)
    1 READ(5,100) X,N,T
  100 FØRMAT(E13.6,2X,I5,2X,A4)
      IF(N .LT. 1) RETURN
      A(N)=X
      TITLE(N)=T
      WRITE (6,400) N,A(N),TITLE(N)
  400 FØRMAT (50X,'A(',I3,') ',E12.6,' = ',A4)
      GØ TØ 1
      END
      SUBRØUTINE PUTØUT
      CØMMØN/ARRAY/A(400),TITLE(400)
      WRITE(6,100) A(1)
  100 FØRMAT(//2X,'***** ØUTPUT AT ',F10.4,'  MINUTES *****'//)
      WRITE(6,200) (I,A(I),TITLE(I),I=1,378)
  200 FØRMAT(3(15X,'A(',I3,') ',E12.6,' = ',A4))
      RETURN
      END
!EØD
```

APPENDIX D

```
C      R67093,8 LARRY NEAL--MATH; NASA FILE
C
C      PROGRAM GUYTON
C      CIRCULATORY DYNAMICS - CIRCE
C               CIRCE1
       REAL LVM,I,IFP,LPD,KE,KE1,KOD,KIR,KIE,KI,KCD,KED,KN1,KN3
       REAL NAE,NED,NID,NOD,I1,LPK,KID,MO2,NOZ,KCZ,HPL,HPR,I2,I3,MMO
       DIMENSION FUN1(14),FUN2(14),FUN3(14),FUN4(14),FUN6(14),FUN7(14)
       COMMON/ARRAY/T,I,VBD,VVS,VPA,VAS,VLA,VRA,VAE,PA,PAM,LVM,
      *              VRE,PRA,QRN,VPE,PPA,PP1,CPA,RPA,RVM,VLE,PLA,QLN,PL1,
      *              A1B,RPV,RPT,PGL,QPO,Q5 ,VVE,VV8,PVS,PGV,RVG,QVO,AVE
       COMMON/ARRAY/CN2,CN3,RVS,PGS,RTP,QAO,QRO,QLO,DVS,DPA,DAS,DLA,DRA,
      *              PA1,AUC,AUB,AUN,AU6,AU2,AU8,DAU,AUJ,AU ,AUO,AUH,VV4,
      *              AU9,AUM,AU4,VIF,PO1,PTT,PTS,PIF,CPI,PTC,CPP,PPC,PVG
       COMMON/ARRAY/PC ,PCD,VTC,PLD,VTL,VTD,VPD,DPL,CP1,DPC,DPI,LPD,DLP,
      *              DPP,CHY,PRM,PGR,CPG,PGP,GF1,PGX,PGC,PGH,PG2,VGD,VG ,
      *              EPH,GP1,GP2,GPD,AAR,RR ,RFN,APD,GLP,PFL,GFR,TRR,VUD
       COMMON/ARRAY/REK,NOD,NED,NAE,VEC,CKE,KOD,KE1,KIR,KIE,KCD,KED,CKI,
      *              CNA,CCD,VID,KE ,KI ,VIC,I1 ,VTY,Z  ,VTZ,VUZ,TVZ,PPZ,
      *              DFZ,X  ,I2 ,PR1,VTS,VP ,PRP,IFP,GPR,KN3,KN1,AMR,AMP
       COMMON/ARRAY/AM1,AMC,AM2,AM3,AM5,AM ,CNE,AGK,ANP,AN1,ANC,AN2,AN3,
      *              AN5,ANM,VB ,HM1,HM ,B1 ,VIE,VIB,VIM,RC2,PO2,RKC,RC1,
      *              RCD,VRC,RSN,OVA,BFN,DOB,AOM,P1O,OSV,POT,POD,POB,AR1
       COMMON/ARRAY/AR2,POC,AR3,ARM,CNB,GFN,AH7,AH8,AH ,AHC,AH1,AH2,AH4,
      *              AHM,CNY,CNX,VV1,VV2,VV5,VV6,VV7,TVD,VTW,HSR,HSL,NID,
      *              SR ,VVR,RAR,CV ,CN7,AUX,AUK,AUZ,Y  ,CFC,CPK,PCE,CPR
       COMMON/ARRAY/LPK,DPO,HYL,KID,AMT,ANT,POK,PON,A1K,A2K,A3K,CNR,CNZ,
      *              AHK,SRK,TM ,V2D,Z1 ,Z2 ,Z3 ,Z4 ,Z5 ,Z6 ,Z7 ,Z8 ,HMK,
      *              HKM,POV,POZ,RDO,QO2,RBF,MO2,POA,POY,ANU,POR,GF2,HMD
       COMMON/ARRAY/DHM,POQ,I3 ,U  ,VP1,T1 ,GF3,GF4,AUP,AUV,RV1,AUY,OUT,
      *              DSP,AHZ,AHY,OSA,PPI,CPN,POS,PLF,PPO,PPN,PPD,PFI,DFP,
      *              VPF,PPR,PMC,PMS,PMP,HR ,CPF,PCP,DA1,DLZ,DPY,DPZ,GPZ
       COMMON/ARRAY/NOZ,KCZ,VIZ,HPR,HPL,STH,ALO,EXC,O2M,PA2,PP2,SVO,AUL,
      *              VV9,O2A,Q1 ,EXE,ARF,QRF,RSM,BFM,RAM,OVS,PVO,RMO,QOM,
      *              PMO,P2O,MMO,PDO,POE,AMM,A4K,POM,OMM,PM1,PM3,PM4,EX1
       COMMON/ARRAY/Q2 ,Q3 ,PM5,PK1,Z9 ,Z10,Z11,Z12,Z13,Z14,Z15,Z16,PK2,
      *              PK3,FIS,STA,PAR,GBL,ANY,ANZ,ANX,ANV,ANW,ANR,AUQ,AUR,
      *              AUS,A378,DUMMY(22),TITLE(400),DUMNY(40)
       COMMON/NUMBER/NOUMY(22),DMMY
       DATA FUN1(1),FUN1(2),FUN1(3),FUN1(4),FUN1(5),FUN1(6),FUN1(7),
      *FUN1(8),FUN1(9),FUN1(10),FUN1(11),FUN1(12),FUN1(13),FUN1(14)/
      *0.,1.04,60.,1.025,125.,.97,160.,.88,200.,.59,240.,0.,240.,0./
       DATA FUN2(1),FUN2(2),FUN2(3),FUN2(4),FUN2(5),FUN2(6),FUN2(7),
      *FUN2(8),FUN2(9),FUN2(10),FUN2(11),FUN2(12),FUN2(13),FUN2(14)/
      *-100.,0.0,-6.,0.0,-3.,.75,-1.,2.6,2.,9.8,8.,13.5,1000.,13.5/
       DATA FUN3(1),FUN3(2),FUN3(3),FUN3(4),FUN3(5),FUN3(6),FUN3(7),
      *FUN3(8),FUN3(9),FUN3(10),FUN3(11),FUN3(12),FUN3(13),FUN3(14)/
      *0.0,1.06,20.,.97,24.,.93,30.,.8,38.,.46,45.,0.,45.,0./
       DATA FUN4(1),FUN4(2),FUN4(3),FUN4(4),FUN4(5),FUN4(6),FUN4(7),
      *FUN4(8),FUN4(9),FUN4(10),FUN4(11),FUN4(12),FUN4(13),FUN4(14)/
      *-100.,0.,-4.,0.,-1.,3.6,3.,9.4,6.,11.6,10.,13.5,1000.,13.5/
       DATA FUN6(1),FUN6(2),FUN6(3),FUN6(4),FUN6(5),FUN6(6),FUN6(7),
      *FUN6(8),FUN6(9),FUN6(10),FUN6(11),FUN6(12),FUN6(13),FUN6(14)/
      *-100.,10000.,0.,70.,.4,9.3,.8,3.3,1.2,1.3,1.6,.43,100.,0./
       DATA FUN7(1),FUN7(2),FUN7(3),FUN7(4),FUN7(5),FUN7(6),FUN7(7),
      *FUN7(8),FUN7(9),FUN7(10),FUN7(11),FUN7(12),FUN7(13),FUN7(14)/
      *0.,7.,30.,6.25,60.,3.,100.,1.,160.,.15,400.,.05,400.,.05/
C
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```
          WRITE (102,5)
          WRITE (6,5)
        5 FORMAT (/'   GUYTON MODEL FROM WHITE'/
         * '    REFER TO GE-AGS USER GUIDE TIR 741-MED-3017'//)
       90 CALL PUTIN
C
C90       CALL INPUT
C
          IF(I .GT. 0.5) I=0.5
      100 IF(OUT .EQ. 3.) CALL PUTOUT
C
C100      IF(OUT .EQ. 3.) CALL OUTPUT
C         IF(DSP .EQ. 3.) CALL DSPLAY
C
          T=T+I2
C
          CALL HEMO           (AMM,ANM,ANU,ANY,ANZ,ARM,AUH,AUM,AUY,AVE,BFM,BFN,
         *                     CN2,CN3,CN7,CV ,DAS,DLA,DPA,DRA,DVS,FIS,HMD,HPL,
         *                     HPR,HSL,HSR,I2 ,LVM,PA ,PAM,PA2,PC ,PGL,PGS,PLA,
         *                     PPA,PP1,PP2,PRA,PR1,PVS,QAO,QLN,QLO,QPO,QRF,QRN,
         *                     QRO,QVO,RAM,RAR,RBF,RPA,RPT,RPV,RSM,RSN,RVG,RVM,
         *                     RVS,U  ,VAE,VAS,VBD,VIM,VLA,VLE,VP ,VPA,VPE,VRA,
         *                     VRC,VRE,VVE,VVR,VVS,VV7,VV8,X  ,FUN1,FUN2,FUN3,
         *                     FUN4)
C
      120 CALL AUTO           (AU ,AUB,AUC,AUH,AUJ,AUK,AUL,AUM,AUN,AUO,AUP,AUQ,
         *                     AUR,AUS,AUV,AUX,AUZ,AU4,AU6,AU8,A1B,DAU,EXC,EXE,
         *                     EX1,I2 ,PA ,PA1,POQ,POT,P2O,STA,VVR,VV9,Y  ,Z,
         *                     Z8 ,Z12)
C
          IF(I3.LE.I2)GO TO 168
          IF(ABS(DAU-AUJ).GT.DA1)GO TO 100
      110 IF (ABS(QAO-QLO).GT..2)GO TO 100
          IF (ABS(QAO-QPO).GT..2)GO TO 100
          IF (ABS(QAO-QRO).GT..4)GO TO 100
C
      168 CALL HORMON         (AM ,AMC,AMP,AMR,AMT,AM1,ANM,CKE,PA,Z,FUN7,
         *                     AGK,ANC,ANP,ANR,ANT,ANV,ANW,AN1,CNA,CNE,GFN,
         *                     I  ,REK)
C
      170 CALL BLOOD          (HKM,HM ,HMK,I  ,POT,POY,PO1,PO2,RC1,RC2,RCD,RKC,
         *                     VB ,VIB,VIE,VIM,VP ,VRC)
C
      180 CALL MUSCLE         (ALO,AMM,AOM,AUP,A4K,BFM,EXC,HM ,I  ,MMO,OMM,OSA,
         *                     OVA,OVS,O2A,PDO,PK1,PK2,PK3,PMO,PM1,PM3,PM4,PM5,
         *                     POE,POM,PVO,P2O,QOM,RMO,VPF,Z5 ,Z6)
C
          CALL AUTORG         (AOM,ARM,AR1,AR2,AR3,A1K,A2K,A3K,BFN,DOB,HM ,I,
         *                     MO2,OSV,OVA,O2M,POA,POB,POC,POD,POK,PON,POR,POT,
         *                     POV,POZ,P1O,QO2,RDO,Z  ,Z4 ,Z7)
C
          CALL ADH            (AH ,AHC,AHK,AHM,AHY,AHZ,AH7,AH8,AUP,CNA,CNB,CNR,
         *                     CNZ,I  ,PRA,Z)
C
          CALL MISC1          (AHM,AU4,AU8,I  ,SR ,SRK,STH,TVD,TVZ,VEC,VIC,VTW,
         *                     VVE,VV6,VV7,Z)
C
          CALL HEART          (AUR,DHM,HMD,HR ,I  ,PA ,PMC,PMP,PMS,POT,PRA,QAO,
         *                     QLO,RTP,SVO,VAE,VLE,VPE,VRE,VVE)
```

```
C
  130 CALL CAPMBD      (BFN,CFC,CPI,CPP,DFP,I   ,IFP,PC ,PCD,PIF,PLD,PPC,
     *                  PRP,PTC,PTS,PTT,PVG,PVS,RVS,TVD,VG ,VID,VIF,VP,
     *                  VPD,VTC,VTD,VTL,VTS,VUD,Z   ,Z1 ,FUN6)
C
      I=I*1.2+T-T1
      I1=ABS(VP1/VPD/I)
      IF(I1.LT.I) I=I1
      IF(I3+T-T1.LT.I) I=I3+T-T1
      T=I+T1
      T1=T
C
      IF(OUT.EQ.4.) CALL PUTOUT
C
C     IF(OUT.EQ.4.) CALL OUTPUT
C     IF(DSP.EQ.4.) CALL DSPLAY
C
  200 CALL PULMON      (CPF,CPP,CPN,DFP,I   ,PCP,PFI,PLA,PLF,POS,PPA,PPC,
     *                  PPD,PPI,PPN,PPO,PPR,VP ,VPD,VPF,Z   ,Z3)
C
      CALL MISC2       (HPL,HPR,HSL,HSR,I,PA,PPA,POT,STH,Z10,Z11,Z13)
C
  135 CALL PROTEN      (CHY,CPG,CPI,CPK,CPP,CPR,CP1,DLP,DLZ,DPC,DPI,DPL,
     *                  DPO,DPY,GPD,GPR,I   ,IFP,LPK,PC ,PCE,PGX,PRP,VG ,
     *                  VTL,Z   ,PPD)
C
  142 CALL KIDNEY      (AAR,AHM,AM ,APD,ARF,AUM,CNE,CNX,CNY,GBL,GFN,GFR,
     *                  GF2,GF3,GF4,GLP,I   ,NAE,NED,NID,NOD,NOZ,PA ,PAR,
     *                  PFL,PPC,RBF,REK,RFN,RR ,STH,TRR,VIM,VUD,Z)
C
  160 CALL IONS        (AM ,CCD,CKE,CKI,CNA,I   ,KCD,KE ,KED,KI ,KID,KIE,
     *                  KIR,KOD,NAE,REK,VEC,VIC,VID,VP ,VPF,VTS,Z)
C
  140 CALL GELFLD      (CHY,CPG,CPI,GPR,HYL,IFP,PGC,PGH,PGP,PGR,PGX,PIF,
     *                  PRM,PTC,PTS,PTT,VG ,VGD,VIF,VRS,VTS,V2D,FUN6)
C
      GO TO 100
      END
      SUBROUTINE HEMO (AMM,ANM,ANU,ANY,ANZ,ARM,AUH,AUM,AUY,AVE,BFM,BFN,
     *                 CN2,CN3,CN7,CV ,DAS,DLA,DPA,DRA,DVS,FIS,HMD,HPL,
     *                 HPR,HSL,HSR,I2 ,LVM,PA ,PAM,PA2,PC ,PGL,PGS,PLA,
     *                 PPA,PP1,PP2,PRA,PR1,PVS,QAO,QLN,QLO,QPO,QRF,QRN,
     *                 QRO,QVO,RAM,RAR,RBF,RPA,RPT,RPV,RSM,RSN,RVG,RVM,
     *                 RVS,U   ,VAE,VAS,VBD,VIM,VLA,VLE,VP ,VPA,VPE,VRA,
     *                 VRC,VRE,VVE,VVR,VVS,VV7,VV8,X   ,FUN1,FUN2,FUN3,
     *                 FUN4)
      DIMENSION FUN1(14),FUN2(14),FUN3(14),FUN4(14)
      REAL I2,LVM
C
C    CIRCULATORY DYNAMICS BLOCK
C   HEMODYNAMICS
C
      VBD=VP+VRC-VVS-VAS-VLA-VPA-VRA
      VVS=VVS+DVS*I2+VBD*.3986
      VPA=VPA+DPA*I2+VBD*.155
      VAS=VAS+DAS*I2+VBD*.261
      VLA=VLA+DLA*I2+VBD*.128
      VRA=VRA+DRA*I2+VBD*.0574
      VAE=VAS-.495
```

```
      PA=VAE/.00355
      PAM=100./PA
      PA2=PA/AUH
      CALL FUNCTN(PA2,LVM,FUN1)
      VRE=VRA-.1
      PRA=VRE/.005
      CALL FUNCTN(PRA,QRN,FUN2)
      VPE=VPA-.30625
      PPA=VPE/.0048
      PP1=.026*PPA
      IF (PP1.LT.0.)PP1=0.
      RPA=PP1**(-.5)
      PP2=PPA/AUH
      CALL FUNCTN(PP2,RVM,FUN3)
      VLE=VLA-.4
      PLA=VLE/.01
      CALL FUNCTN(PLA,QLN,FUN4)
      RPV=1./(PLA+20.)/.0357
      RPT=RPV+RPA
      PGL=PPA-PLA
      QPO=PGL/RPT
      ANU=ANM
      IF (ANU.LT..8)ANU=.8
      VVE=VVS-VVR-(ANU-1.)*ANY
      VV8=VVE-VV7
      IF(VV8.LT..0001)VV8=.0001
      PVS=VV8/CV
      PR1=PRA
      IF (PRA.LT.0.)PR1=0.
      RVG=2.738/PVS
      QVO=(PVS-PR1)/RVG
      CN3=CN3+(((PC-17.)*CN7+17.)*CN2-CN3)*.1
      AVE=(AUM-1.)*AUY+1.
      RVS=AVE*(1./CN3)*VIM*((ANU-1.)*ANZ+1.)
      PGS=PA-PVS
      RSN=RAR*ARM*ANU*AUM*PAM*VIM+RVS*1.79
      BFN=PGS/RSN
      RSM=ANU*VIM*PAM*AUM*AMM*RAM
      BFM=PGS/RSM
      QAO=BFN+BFM+RBF+(PA-PRA)*FIS
      QLO=LVM*QLN*AUH*HSL*HMD*HPL
      QRO=QRN*((1.-QRF)*AUH*RVM*HSR*HMD*HPR+QRF*QLO/QLN)
      QPO=QLO+(QPO-QLO)/U
      QVO=QRO+(QVO-QRO)/X
      DVS=QAO-QVO
      DPA=QRO-QPO
      DAS=QLO-QAO
      DLA=QPO-QLO
      DRA=QVO-QRO
      RETURN
      END
      SUBROUTINE AUTO (AU ,AUB,AUC,AUH,AUJ,AUK,AUL,AUM,AUN,AUO,AUP,AUQ,
     *                 AUR,AUS,AUV,AUX,AUZ,AU4,AU6,AU8,A1B,DAU,EXC,EXE,
     *                 EX1,I2 ,PA ,PA1,POQ,POT,P2O,STA,VVR,VV9,Y  ,Z,
     *                 Z8 ,Z12)
      REAL I2
C
C     AUTONOMIC CONTROL BLOCK
C
```

```
  120 EXE=(8.-P2Ø)*EX1+(EXC-1.)*Z12
      PØQ=PØT
      IF (PØQ.GT.8.)PØQ=8.
      IF (PØQ.LT.4.)PØQ=4.
      PA1=PA*PØQ/8.-EXE
      AUC=0.
      IF(PA1.LT.80.)AUC=.03*(80.-PA1)
      IF(PA1.LT.40.)AUC=1.2
      AUB=0.
      IF(PA1.LT.170.)AUB=.014286*(170.-PA1)
      IF(PA1.LT.40.)AUB=1.83
  123 A1B=(AUB-1.)*AUX+1.
  124 AUN=0
      IF(PA1.LT.50.)AUN=.2*(50.-PA1)
      IF(PA1.LT.20.)AUN=6.0
      AU6=A1B-AU4
      AU8=AUK*(AU6-1.)
      DAU=DAU+(AUC+AU6+AUN-DAU)/Z/Y
      AUJ=AUJ+(DAU-AUJ)*I2*6./Z8
      IF(AUJ.LT.0.)AUJ=0.
      IF(AUJ-1.)126,127,127
  126 AU=AUJ**AUZ
      GØ TØ 128
  127 AU=(AUJ-1.)*AUZ+1.
  128 IF(STA.GT..00001)AU=STA
      AUØ=AU-1.
      AUP=AUØ*AUQ+1.
      AUH=AUØ*AUV+1.
      AUR=AUØ*AUS+1.
      VVR=VV9-AUL*AUP
      AUM=.15+.85*AUP
      RETURN
      END
      SUBRØUTINE HØRMØN(AM ,AMC,AMP,AMR,AMT,AM1,ANM,CKE,PA,Z,FUN7,
     *                  AGK,ANC,ANP,ANR,ANT,ANV,ANW,AN1,CNA,CNE,GFN,
     *                  I   ,REK)
      DIMENSIØN FUN7(14)
      REAL I
C
C*********************************************************************
C
C     ALDØSTERØNE CØNTRØL BLØCK
C
C*********************************************************************
  168 AMR=CKE/CNA/.00352-9.
      IF(AMR.LT.0.)AMR=0.
      CALL FUNCTN (PA,AMP,FUN7)
      AM1=AM1+(ANM*AMP*AMR-AM1)/Z
      AMC=AMC+(AM1-AMC)*(1.-EXP(-I/AMT))
      AM=20.039-19.8*EXP(-.0391*AMC)
C*********************************************************************
C
C     ANGIØTENSIN CØNTRØL BLØCK
C
C*********************************************************************
      CNE=152.-CNA
      IF(CNE.LT.1.)CNE=1.
      ANR=((17.75-GFN*CNA)*AGK+1.)*REK
      ANW=ANW+((ANR-1.)*10.-ANW)*ANV*I
```

```
      IF(ANW.LT..0)ANW=0.
      ANP=ANR+ANW
      IF(ANP.GT.100.)ANP=100.
      IF(ANP.LT..01)ANP=.01
      AN1=AN1+(ANP-AN1)/Z
      ANC=ANC+(AN1-ANC)*(1.-EXP(-I/ANT))
      ANM=4.0-3.3*EXP(-.0967*ANC)
      IF(ANM.LT..7)ANM=.7
      RETURN
      END
      SUBRØUTINE BLØØD (HKM,HM ,HMK,I  ,PØT,PØY,PØ1,PØ2,RC1,RC2,RCD,RKC,
     *                  VB ,VIB,VIE,VIM,VP ,VRC)
      REAL I
C
C     RED CELLS AND VISCØSITY BLØCK
C-----------------------------------------------------------------------
C     BLØØD VISCØSITY
C-----------------------------------------------------------------------
  170 VB=VP+VRC
      HM=100.*VRC/VB
      VIE=HM/(HMK-HM)/HKM
      VIB=VIE+1.5
      VIM=.3333*VIB
C-----------------------------------------------------------------------
C     RED BLØØD CELLS
C-----------------------------------------------------------------------
      RC2=RKC*VRC
      PØ2=PØ1-PØT
      IF(PØ2.LT..2375)PØ2=.2375
      RC1=PØY*PØ2
      RCD=RC1-RC2
      VRC=VRC+RCD*I
      RETURN
      END
      SUBRØUTINE MUSCLE(ALØ,AMM,AØM,AUP,A4K,BFM,EXC,HM ,I  ,MMØ,ØMM,ØSA,
     *                  ØVA,ØVS,Ø2A,PDØ,PK1,PK2,PK3,PMØ,PM1,PM3,PM4,PM5,
     *                  PØE,PØM,PVØ,P2Ø,QØM,RMØ,VPF,Z5 ,Z6)
      REAL I,MMØ
C
C     MUSCLE BLØØD FLØW CØNTRØL AND PØ2 BLØCK
C
  180 ØSA=ALØ-VPF*.5
      ØVA=ØSA*HM*5.
      ØVS=ØVS+((BFM*ØVA-RMØ)/HM/5./BFM-ØVS)/Z6
      PVØ=57.14*ØVS
      RMØ=(PVØ-PMØ)*PM5/(PM1**PK3-PM4)
      QØM=QØM+(RMØ-MMØ)*(1.-EXP(-I/Z5))
      PMØ=PK2/(PK1-QØM)
      PM1=PMØ
      IF(PM1.LT.PM3)PM1=PM3
      P2Ø=PMØ
      IF(P2Ø.GT.8.)P2Ø=8.
      AØM=(AUP-1.)*Ø2A+1.
      MMØ=AØM*ØMM*EXC*(1.-(8.0001-P2Ø)**3./512.)
      PDØ=PVØ-40.
      PØE=PØM*PDØ+1.
      IF(PØE.LT..005)PØE=.005
      AMM=AMM+(PØE-AMM)*(1.-EXP(-I/A4K))
      RETURN
```

```
      END
      SUBRØUTINE AUTØRG(AØM,ARM,AR1,AR2,AR3,A1K,A2K,A3K,BFN,DØB,HM ,I,
     *                  MØ2,ØSV,ØVA,Ø2M,PØA,PØB,PØC,PØD,PØK,PØN,PØR,PØT,
     *                  PØV,PØZ,P1Ø,QØ2,RDØ,Z  ,Z4 ,Z7)
      REAL I,MØ2
C
C     NØN-MUSCLE ØXYGEN DELIVERY BLØCK
C     AND NØN-MUSCLE LØCAL BLØØD FLØW CØNTRØL BLØCK
C-----------------------------------------------------------------------
C     AUTØREGULATIØN,RAPID
C-----------------------------------------------------------------------
      ØSV=ØSV+((BFN*ØVA-DØB)/HM/5./BFN-ØSV)/Z7
      PØV=ØSV*57.14
      RDØ=PØT**3.
      IF(RDØ.LT.50.)RDØ=50.
      DØB=(PØV-PØT)*3161./RDØ
      MØ2=AØM*Ø2M*(1.-(8.0001-P1Ø)**3./512.)
      QØ2=QØ2+(DØB-MØ2)*(1.-EXP(-I/Z4))
      PØT=QØ2*.00333
      P1Ø=PØT
      IF(PØT.GT.8.)P1Ø=8.
      PØD=PØV-PØR
      PØB=PØB+(PØK*PØD+1.-PØB)/Z
      IF(PØB.LT..2)PØB=.2
      AR1=AR1+(PØB-AR1)*(1.-EXP(-I/A1K))
      ARM=AR1*AR2*AR3
C-----------------------------------------------------------------------
C     AUTØREGULATIØN,INTERMEDIATE
C-----------------------------------------------------------------------
      PØA=PØA+(PØN*PØD+1.-PØA)/Z
      IF (PØA.LT..5)PØA=.5
      AR2=AR2+(PØA-AR2)*(1.-EXP(-I/A2K))
C-----------------------------------------------------------------------
C     AUTØREGULATIØN,LØNG-TERM
C-----------------------------------------------------------------------
      IF(PØD)194,192,192
  192 PØC=PØZ*PØD+1.
      GØ TØ 196
  194 PØC=PØZ*PØD*.33+1.
  196 IF (PØC.LT..3)PØC=.3
      AR3=AR3+(PØC-AR3)*I/A3K
      RETURN
      END
      SUBRØUTINE ADH   (AH ,AHC,AHK,AHM,AHY,AHZ,AH7,AH8,AUP,CNA,CNB,CNR,
     *                  CNZ,I  ,PRA,Z)
      REAL I
C
C     ANTIDIURETIC HØRMØNE
C
      CNB=CNA-CNR
      AHZ=.2*PRA
      AHY=AHY+(AHZ-AHY)*.0007*I
      AH8=AUP-1.
      IF(AH8.LT.0.)AH8=0.
      IF(CNB.LT.0.)CNB=0.
      AH=AH+(CNZ*CNB+AH8-AHZ+AHY-AH)/Z
      IF(AH.LT.0.)AH=0.
      AHC=AHC+(.3333*AH-AHC)*(1.-EXP(-I/AHK))
      AHM=6.*(1.-EXP(-0.1808*AHC))
```

```
      IF(AHM.LT..3)AHM=.3
      RETURN
      END
      SUBRØUTINE MISC1 (AHM,AU4,AU8,I   ,SR ,SRK,STH,TVD,TVZ,VEC,VIC,VTW,
     *                 VVE,VV6,VV7,Z)
      REAL I
C
C*********************************************************************
C
C     VASCULAR STRESS RELAXATIØN BLØCK
C
C*********************************************************************
      VV6=VV6+(SR*(VVE-.301)-VV7-VV6)/Z
      VV7=VV7+VV6*(1.-EXP(-I/SRK))
C*********************************************************************
C
C     THIRST AND DRINKING BLØCK
C*********************************************************************
C
      TVZ=(.01*AHM-.009)*STH
      TVD=TVD+(TVZ-TVD)/Z
      IF(TVD.LT.0.)TVD=0.
      VTW=VIC+VEC
C*********************************************************************
C
C     AUTØNØMIC CØNTRØL BLØCK
C     ADAPTATIØN ØF BARØRECEPTØRS
C
C*********************************************************************
      AU4=AU4+AU8*I
      RETURN
      END
      SUBRØUTINE HEART (AUR,DHM,HMD,HR ,I   ,PA ,PMC,PMP,PMS,PØT,PRA,QAØ,
     *                 QLØ,RTP,SVØ,VAE,VLE,VPE,VRE,VVE)
      REAL I
C
C     HEART HYPERTRØPHY ØR DETERIØRATIØN BLØCK
C
C---------------------------------------------------------------------
C     HEART VICIØUS CYCLE
C---------------------------------------------------------------------
      DHM=(PØT-6.)*.0025
      HMD=HMD+DHM*I
      IF (HMD.GT.1.)HMD=1.
C---------------------------------------------------------------------
C     MEAN CIRCULATØRY PRESSURES
C---------------------------------------------------------------------
      PMC=(VAE+VVE+VRE+VPE+VLE)/.11
      PMS=(VAE+VVE+VRE)/.09375
      PMP=(VPE+VLE)/.01625
C*********************************************************************
C
C     HEART RATE AND STRØKE VØLUME BLØCK AND TØTAL PERIPHERAL RESISTANCE
C
C*********************************************************************
      HR=(32.+40.*AUR+PRA*2.)*((HMD-1.)*.5+1.)
      RTP=(PA-PRA)/QAØ
      SVØ=QLØ/HR
      RETURN
```

```
      END
      SUBROUTINE CAPMBD(BFN,CFC,CPI,CPP,DFP,I   ,IFP,PC ,PCD,PIF,PLD,PPC,
     *                  PRP,PTC,PTS,PTT,PVG,PVS,RVS,TVD,VG ,VID,VIF,VP,
     *                  VPD,VTC,VTD,VTL,VTS,VUD,Z   ,Z1,FUN6)
      DIMENSION FUN6(14)
      REAL I,IFP
C
C     CAPILLARY MEMBRANE DYNAMICS BLOCK
C
 130  PTT=(VTS/12.)**2.
      VIF=VTS-VG
      CALL FUNCTN (VIF,PTS,FUN6)
      PIF=PTT-PTS
      CPI=IFP/VIF
      PTC=.25*CPI
      CPP=PRP/VP
      PPC=.4*CPP
      PVG=RVS*1./9*BFN
      PC=PVG+PVS
      PCD=PC+PTC-PPC-PIF
      VTC=VTC+(CFC*PCD-VTC)/Z
      PLD=7.8+PIF-PTT
      VTL=VTL+(.004*PLD-VTL)/Z
      IF(VTL.LT.0.)VTL=0.
      VTD=VTC-VTL-VID
      VTS=VTS+VTD*I
      VPD=VPD+(TVD-VTC+VTL-VUD-DFP-VPD)/Z1
      RETURN
      END
      SUBROUTINE PULMON(CPF,CPP,CPN,DFP,I   ,PCP,PFI,PLA,PLF,POS,PPA,PPC,
     *                  PPD,PPI,PPN,PPO,PPR,VP ,VPD,VPF,Z   ,Z3)
      REAL I
C
C     PULMONARY DYNAMICS AND FLUIDS BLOCK
C
      VP=VP+(VPD*I)/Z3
C
 200  PCP=.45*PPA+.55*PLA
      PPI=2.-.150/VPF
      CPN=PPR/VPF
      POS=CPN*.4
      PLF=(PPI+11.)*.0003
      PPO=PLF*CPN
      PPN=(CPP-CPN)*.000225
      PPD=PPD+(PPN-PPO-PPD)/Z
      IF(PPR+PPD*I-.025.LT.0.)PPD=(.025-PPR)/I
      PFI=(PCP-PPI+POS-PPC)*CPF
      DFP=DFP+(PFI-PLF-DFP)/Z
      IF(VPF+DFP*I-.001.LT.0.)DFP=(.001-VPF)/I
      VPF=VPF+DFP*I
      PPR=PPR+PPD*I
      RETURN
      END
      SUBROUTINE MISC2 (HPL,HPR,HSL,HSR,I,PA,PPA,POT,STH,Z10,Z11,Z13)
      REAL I
C
C**********************************************************************
C
C     HEART HYPERTROPHY OR DETERIORATION BLOCK
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```
C
C*********************************************************************
      HPL=HPL+(((PA/100./HSL)**Z13)-HPL)*I/57600.
      HPR=HPR+(((PPA/15./HSR)**Z13)-HPR)*I/57600.
C*********************************************************************
C
C     TISSUE EFFECT ON THIRST AND SALT INTAKE
C
C*********************************************************************
      STH=(Z10-POT)*Z11
      IF(STH.LT.1.)STH=1.
      IF(STH.GT.8.)STH=8.
      RETURN
      END
      SUBROUTINE PROTEN(CHY,CPG,CPI,CPK,CPP,CPR,CP1,DLP,DLZ,DPC,DPI,DPL,
     *                  DPO,DPY,GPD,GPR,I   ,IFP,LPK,PC  ,PCE,PGX,PRP,VG  ,
     *                  VTL,Z   ,PPD)
      REAL I,IFP,LPK
C
C     TISSUE FLUIDS,PRESSURES AND GEL BLOCK
C
C---------------------------------------------------------------------
C     PLASMA AND TISSUE FLUID PROTEIN
C---------------------------------------------------------------------
  135 DPL=DPL+(VTL*CPI-DPL)/Z
      IF (PC.LT.0.)PC=0.
      DPC=DPC+(LPK*(CPP-CPI)*PC**PCE-DPC)/Z
      DPI=DPC-DPL
      DLZ=LPK*(CPR-CPP)
      IF(CPP.GT.CPR)DLZ=4.*DLZ
      DLP=DLP+(DLZ-DLP)/Z
      PRP=PRP+(DLP-DPO+DPL-DPC-PPD)*I
C---------------------------------------------------------------------
C     GEL PROTEIN DYNAMICS
C---------------------------------------------------------------------
  141 PGX=CHY**2*.01332*CPG+CPG
      GPD=GPD+(.0005*(CPI-PGX)*VG-GPD)/Z
      GPR=GPR+GPD*I
      IFP=IFP+(DPI-GPD)*I
      RETURN
      END
      SUBROUTINE KIDNEY(AAR,AHM,AM  ,APD,ARF,AUM,CNE,CNX,CNY,GBL,GFN,GFR,
     *                  GF2,GF3,GF4,GLP,I   ,NAE,NED,NID,NOD,NOZ,PA  ,PAR,
     *                  PFL,PPC,RBF,REK,RFN,RR  ,STH,TRR,VIM,VUD,Z)
      REAL I,NAE,NED,NID,NOD,NOZ
C
C     KIDNEY DYNAMICS AND EXCRETION BLOCK
C
  142 GF3=((GFN/.125-1.)*GF4)+1.
      IF(GF3.GT.15.)GF3=15.
      IF(GF3.LT..4)GF3=.4
      AAR=31.67*VIM*(AUM*ARF+1.-ARF)*GF3
      RR=AAR+51.66*VIM
      PAR=PA-GBL
      RFN=PAR/RR
      RBF=REK*RFN
  150 APD=AAR*RFN
      GLP=PAR-APD
      PFL=GLP-PPC-18.
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```
      GF1=GFN
      GFN=GFN+(PFL*.00781-GFN)*GF2/Z
      IF (ABS(GFN-GF1).GT..002)GØ TØ 142
      GFR=GFN*REK
      TRR=.8*GFR+.025*REK-.001*REK/AM/AHM
      VUD=VUD+(GFR-TRR-VUD)/Z
      IF(VUD.LT..0002)VUD=.0002
C-------------------------------------------------------------------
C     KIDNEY SALT ØUTPUT AND SALT INTAKE
C     (SEE ALSØ ELECTRØLYTES AND CELL WATER BLØCK)
C-------------------------------------------------------------------
      NØZ=1000.*VUD/AM/(CNE/CNX+CNY)
      NØD=NØD+(NØZ-NØD)/Z
      NED=NID*STH-NØD
      NAE=NAE+NED*I
      RETURN
      END
      SUBRØUTINE IØNS  (AM ,CCD,CKE,CKI,CNA,I  ,KCD,KE ,KED,KI ,KID,KIE,
     *                  KIR,KØD,NAE,REK,VEC,VIC,VID,VP ,VPF,VTS,Z)
      REAL I,KCD,KE,KED,KI,KID,KIE,KIR,KØD,NAE
C
C     ELECTRØLYTES AND CELL WATER BLØCK
C
 160  VEC=VTS+VP+VPF
      CKE=KE/VEC
      KØD=(.00042*CKE+.00014*AM*CKE)*REK
      KIR=2850.+140.*CKE
      KIE=KIR-KI
      KCD=KCD+(KIE*.013-KCD)/Z
      KI=KI+KCD*I
      KED=KID-KCD-KØD
      KE=KE+KED*I
      CKI=KI/VIC
      CNA=NAE/VEC
      CCD=CKI-CNA
      VID=VID+(.01*CCD-VID)/Z
      VIC=VIC+VID*I
      RETURN
      END
      SUBRØUTINE GELFLD(CHY,CPG,CPI,GPR,HYL,IFP,PGC,PGH,PGP,PGR,PGX,PIF,
     *                  PRM,PTC,PTS,PTT,VG ,VGD,VIF,VRS,VTS,V2D,FUN6)
      DIMENSIØN FUN6(14)
      REAL IFP
C
C     GEL FLUID DYNAMICS
 140  CHY=HYL/VG
      PRM=-5.9*CHY+24.2
      PGR=.4*CHY
      CPG=GPR/VG
      PGP=.25*PGX
      PGC=PGP+PGR
      VIF=VTS-VG
      CALL FUNCTN (VIF,PTS,FUN6)
      PIF=PTT-PTS
      CPI=IFP/VIF
      PTC=.25*CPI
      PGH=PIF+PTS+PRM
      VGD=V2D*(PIF+PGC-PTC-PGH)
      VG=VG+VGD
```

```
      IF(VG.LT.0.)VG=0.
      IF(.012.LT.ABS(VGD)) GO TO 140
      RETURN
      END
      SUBROUTINE FUNCTN(TH,POL,TAB)
      DIMENSION TAB(14)
      N=14
      DO 110 I=1,N,2
      IF(TAB(I)-TH) 110,120,110
  110 CONTINUE
      GO TO 140
  120 POL=TAB(I+1)
  130 RETURN
  140 NN=N-2
      DO 150 I=1,NN,2
  150 IF(TAB(I) .LT. TH .AND. TAB(I+2) .GT. TH) GO TO 160
      WRITE(6,100) TH
  100 FORMAT(5X,' ***** CURVE LIMITS EXCEEDED ***** ',G12.6//)
      IF(TH .LT. TAB(1)) POL=TAB(2)
      IF(TH .GT. TAB(N-1)) POL=TAB(N)
      GO TO 130
  160 POL=TAB(I+1)+(TAB(I+3)-TAB(I+1))*((TH-TAB(I))/(TAB(I+2)-TAB(I)))
      GO TO 130
      END
      SUBROUTINE PUTIN
C
      COMMON/ARRAY/A(400),TITLE(400),COL(20),ALPHA(20)
      COMMON/NUMBER/K,NO(20),NTIMEC,UNITS
      DATA ALL/'ALL '/,BLANK/'    '/
      DO 1 J=1,400
      A(J)=0.
    1 TITLE(J)=BLANK
    2 READ(5,100) VALUE,NUMBER,SYMBOL
  100 FORMAT      (E13.6,2X,I5,2X,A4)
      IF(NUMBER.EQ.0) GO TO 3
      A(NUMBER)=VALUE
      TITLE(NUMBER)=SYMBOL
      GO TO 2
    3 READ(5,200) (ALPHA(J),J=1,20)
  200 FORMAT      (20A4)
      IF(ALPHA(1).NE.ALL) GO TO 4
      READ(5,300) NTIMEC,UNITS
      WRITE(6,30) UNITS,(TITLE(J),A(J),J=1,377)
      GO TO 31
    4 DO 5 K=1,20
      IF(ALPHA(K).EQ.BLANK) GO TO 6
    5 CONTINUE
    6 IF(K.LT.20) K=K-1
      DO 10 J=1,K
      L=1
    7 IF(ALPHA(J).EQ.TITLE(L)) GO TO 9
      L=L+1
      IF(L.LT.401) GO TO 7
      WRITE(6,8) ALPHA(J)
    8 FORMAT(1H1////44X,'THE VARIABLE 'A4,'WAS ILLEGALLY CALLED FOR.')
      COL(J)=0.
      NO(J)=1
      ALPHA(J)=TITLE(1)
      GO TO 10
```

```
    9 COL(J)=A(L)
      NO(J)=L
   10 CONTINUE
      READ(5,300) NTIMEC,UNITS
  300 FORMAT      (I5,1X,A4)
      IF(K.GT.9) GO TO 20
      GO TO(11,12,13,14,15,16,17,18,19),K
   11 WRITE(6,21) UNITS,ALPHA(1),COL(1)
      GO TO 31
   12 WRITE(6,22) UNITS,(ALPHA(J),J=1,2),(COL(L),L=1,2)
      GO TO 31
   13 WRITE(6,23) UNITS,(ALPHA(J),J=1,3),(COL(L),L=1,3)
      GO TO 31
   14 WRITE(6,24) UNITS,(ALPHA(J),J=1,4),(COL(L),L=1,4)
      GO TO 31
   15 WRITE(6,25) UNITS,(ALPHA(J),J=1,5),(COL(L),L=1,5)
      GO TO 31
   16 WRITE(6,26) UNITS,(ALPHA(J),J=1,6),(COL(L),L=1,6)
      GO TO 31
   17 WRITE(6,27) UNITS,(ALPHA(J),J=1,7),(COL(L),L=1,7)
      GO TO 31
   18 WRITE(6,28) UNITS,(ALPHA(J),J=1,8),(COL(L),L=1,8)
      GO TO 31
   19 WRITE(6,29) UNITS,(ALPHA(J),J=1,9),(COL(L),L=1,9)
      GO TO 31
   20 WRITE(6,30) UNITS,(ALPHA(J),COL(J),J=1,K)
   21 FORMAT(1H1,56X,A4,7X,A4//59X,1H0,2X,E13.6)
   22 FORMAT(1H1,49X,A4,3X,2(4X,A4,6X)//52X,2H0 ,2(1X,E13.6))
   23 FORMAT(1H1,42X,A4,3X,3(4X,A4,6X)//45X,2H0 ,3(1X,E13.6))
   24 FORMAT(1H1,35X,A4,3X,4(4X,A4,6X)//38X,2H0 ,4(1X,E13.6))
   25 FORMAT(1H1,28X,A4,3X,5(4X,A4,6X)//31X,2H0 ,5(1X,E13.6))
   26 FORMAT(1H1,21X,A4,3X,6(4X,A4,6X)//24X,2H0 ,6(1X,E13.6))
   27 FORMAT(1H1,14X,A4,3X,7(4X,A4,6X)//17X,2H0 ,7(1X,E13.6))
   28 FORMAT(1H1, 7X,A4,3X,8(4X,A4,6X)//10X,2H0 ,8(1X,E13.6))
   29 FORMAT(1H1,1X,A4,3X,8(4X,A4,6X),4X,A4//4X,2H0 ,9(1X,E13.6))
   30 FORMAT(1H1,63X,2H0 ,A4//5(4X,A4,2H= ,E13.6,3X))
   31 RETURN
      END
      SUBROUTINE PUTOUT
C
      COMMON/ARRAY/A(400),TITLE(400),COL(20), ALPHA(20)
      COMMON/NUMBER/K,N1,N2,N3,N4,N5,N6,N7,N8,N9,N10,
     *               N11,N12,N13,N14,N15,N16,N17,N18,N19,N20,
     *               NTIMEC,UNITS
      DATA SECS/'SECS'/,TMIN/'MINS'/,HOUR/'HOUR'/,DAYS/'DAYS'/
      DATA NTIMEP/1/,N/0/,NN/1/,ALL/'ALL '/,BLANK/'    '/
C     EQUIVALENCE(A(1),T)
      T=A(1)
      IF(UNITS.EQ.SECS) GO TO 2
      IF(UNITS.EQ.TMIN) GO TO 3
      IF(UNITS.EQ.HOUR) GO TO 4
      IF(UNITS.EQ.DAYS) GO TO 5
      WRITE(6,1) UNITS
    1 FORMAT(1H1,47X,'YOU CANNOT ASKED FOR TIME UNITS OF 'A4,'.'/
     *        45X,43HUSE EITHER "SECS","MINS","HOUR", OR "DAYS".)
      GO TO 66
    2 NTIME=T*60.
      IF(NTIME.LT.NTIMEP) GO TO 65
      IF(NTIME.LT.(N+1)*60) GO TO 6
```

```
      N=N+1
      GRØSSU=TMIN
      GØ TØ 6
    3 NTIME=T
      IF(NTIME.LT.NTIMEP) GØ TØ 65
      IF(NTIME.LT.(N+1)*60) GØ TØ 6
      N=N+1
      GRØSSU=HØUR
      GØ TØ 6
    4 NTIME=T/60.
      IF(NTIME.LT.NTIMEP) GØ TØ 65
      IF(NTIME.LT.(N+1)*24) GØ TØ 6
      N=N+1
      GRØSSU=DAYS
      GØ TØ 6
    5 NTIME=T/1440.
      IF(NTIME.LT.NTIMEP) GØ TØ 65
    6 IF(ALPHA(1).NE.ALL) GØ TØ 7
      WRITE(6,50) NTIME,UNITS,(TITLE(J),A(J),J=1,377)
      GØ TØ 51
    7 GØ TØ(30,29,28,27,26,25,24,23,22,21,
     *       20,19,18,17,16,15,14,13,12,11),K
   11 CØL(20)=A(N20)
   12 CØL(19)=A(N19)
   13 CØL(18)=A(N18)
   14 CØL(17)=A(N17)
   15 CØL(16)=A(N16)
   16 CØL(15)=A(N15)
   17 CØL(14)=A(N14)
   18 CØL(13)=A(N13)
   19 CØL(12)=A(N12)
   20 CØL(11)=A(N11)
   21 CØL(10)=A(N10)
   22 CØL(9)=A(N9)
   23 CØL(8)=A(N8)
   24 CØL(7)=A(N7)
   25 CØL(6)=A(N6)
   26 CØL(5)=A(N5)
   27 CØL(4)=A(N4)
   28 CØL(3)=A(N3)
   29 CØL(2)=A(N2)
   30 CØL(1)=A(N1)
      IF(K.GT.9) GØ TØ 40
      GØ TØ (31,32,33,34,35,36,37,38,39),K
   31 WRITE(6,41) NTIME,CØL(1)
      GØ TØ 51
   32 WRITE(6,42) NTIME,(CØL(J),J=1,2)
      GØ TØ 51
   33 WRITE(6,43) NTIME,(CØL(J),J=1,3)
      GØ TØ 51
   34 WRITE(6,44) NTIME,(CØL(J),J=1,4)
      GØ TØ 51
   35 WRITE(6,45) NTIME,(CØL(J),J=1,5)
      GØ TØ 51
   36 WRITE(6,46) NTIME,(CØL(J),J=1,6)
      GØ TØ 51
   37 WRITE(6,47) NTIME,(CØL(J),J=1,7)
      GØ TØ 51
   38 WRITE(6,48) NTIME,(CØL(J),J=1,8)
```

```
      GO TO 51
   39 WRITE(6,49) NTIME,(COL(J),J=1,9)
      GO TO 51
   40 WRITE(6,50) NTIME,UNITS,(ALPHA(J),COL(J),J=1,K)
   41 FORMAT(55X,I5,2X,E13.6)
   42 FORMAT(48X,I5,1X,2(1X,E13.6))
   43 FORMAT(41X,I5,1X,3(1X,E13.6))
   44 FORMAT(34X,I5,1X,4(1X,E13.6))
   45 FORMAT(27X,I5,1X,5(1X,E13.6))
   46 FORMAT(20X,I5,1X,6(1X,E13.6))
   47 FORMAT(13X,I5,1X,7(1X,E13.6))
   48 FORMAT(6X ,I5,1X,8(1X,E13.6))
   49 FORMAT(I5,1X,9(1X,E13.6))
   50 FORMAT(///60X,I5,1X,A4//5(4X,A4,2H= ,E13.6,3X))
   51 NTIMEP=NTIME+1
      IF(N.LT.NN) GO TO 53
      WRITE(6,52) N,GROSSU
   52 FORMAT(I4,1X,A4)
      NN=N+1
   53 IF(NTIME.LT.NTIMEC) GO TO 65
   54 READ(5,400) NTIMEC,CUNITS,SYMBOL,CVALUE
  400 FORMAT      ( I5,1X, A4   ,   A4   ,E13.6)
      IF(SYMBOL.EQ.CUNITS) GO TO 66
      IF(CUNITS.NE.BLANK) GO TO 59
      DO 55 MN=1,400
      IF(SYMBOL.EQ.TITLE(MN)) GO TO 57
   55 CONTINUE
      WRITE(6,56) SYMBOL
   56 FORMAT(/26X,'THE VARIABLE 'A4,'WHICH YOU WANT TO CHANGE '
     *                 'DOES NOT MATCH ANY EXISTING VARIABLE.')
      GO TO 66
   57 WRITE(6,58) NTIME,UNITS,SYMBOL,A(MN),CVALUE
   58 FORMAT(/16X,'AT'I5,1X,A4,' INTO THE SIMULATION, THE VALUE OF '
     *                 A4,'WAS CHANGED FROM 'E13.6,'  TO 'E13.6,'.'/)
      A(MN)=CVALUE
      GO TO 54
   59 IF(UNITS.EQ.CUNITS) GO TO 65
      WRITE(6,60) UNITS,CUNITS
   60 FORMAT(//34X,'THE TIME INCREMENT FOR OUTPUT HAS BEEN '
     *                'CHANGED FROM 'A4,' TO 'A4,'.'//)
      UNITS=CUNITS
      IF(UNITS.EQ.SECS) GO TO 61
      IF(UNITS.EQ.TMIN) GO TO 62
      IF(UNITS.EQ.HOUR) GO TO 63
      NTIMEP=T/1440.+1.
      GO TO 65
   61 NTIMEP=T*60.+1.
      N=T
      GO TO 64
   62 NTIMEP=T+1.
      N=T/60.
      GO TO 64
   63 NTIMEP=T/60.+1.
      N=T/1440.
   64 NN=N+1
   65 RETURN
   66 STOP
      END
```

APPENDIX E

0 SECS

T	= 0.000000E+00	I	= 0.726600E+00	VBD	= -0.392832E-05	VVS	= 0.327592E+01	VPA	= 0.379996E+00
VAS	= 0.849072E+00	VLA	= 0.401179E+00	VRA	= 0.100458E+00	VAE	= 0.354072E+00	PA	= 0.997387E+02
PAM	= 0.100262E+01	LVM	= 0.990411E+00	VRE	= 0.457775E-03	PRA	= 0.915550E-01	QRN	= 0.521973E+01
VPE	= 0.737455E-01	PPA	= 0.153637E+02		= 0.000000E+00		= 0.000000E+00	RPA	= 0.158222E+01
RVM	= 0.989118E+00	VLE	= 0.117865E-02	PLA	= 0.117865E+00	QLN	= 0.522090E+01		= 0.000000E+00
A1B	= 0.101126E+01	RPV	= 0.139235E+01	RPT	= 0.297457E+01	PGL	= 0.152458E+02	QPØ	= 0.512500E+01
	= 0.000000E+00	VVE	= 0.325152E+00		= 0.000000E+00	PVS	= 0.379517E+01		= 0.000000E+00
RVG	= 0.721443E+00	QVØ	= 0.512718E+01	AVE	= 0.997600E+00	CN2	= 0.212000E-01	CN3	= 0.366284E+00
RVS	= 0.275684E+01		= 0.000000E+00	RTP	= 0.193962E+02	QAØ	= 0.513746E+01	QRØ	= 0.512646E+01
QLØ	= 0.512487E+01	DVS	= 0.102838E-01	DPA	= 0.146389E-02	DAS	= -0.125924E-01	DLA	= 0.128508E-03
DRA	= 0.716209E-03		= 0.000000E+00	AUC	= 0.000000E+00	AUB	= 0.100375E+01	AUN	= 0.000000E+00
	= 0.000000E+00		= 0.000000E+00	AU8	= -0.484984E-05	DAU	= 0.988056E+00	AUJ	= 0.988693E+00
AU	= 0.988693E+00	AUØ	= -0.113072E-01	AUH	= 0.988693E+00		= 0.000000E+00		= 0.000000E+00
AUM	= 0.990389E+00	AU4	= 0.209558E-01	VIF	= 0.553337E+00	PØ1	= 0.825000E+01	PTT	= 0.101104E+01
PTS	= 0.699994E+01	PIF	= -0.598890E+01	CPI	= 0.165321E+02		= 0.000000E+00	CPP	= 0.701082E+02
PPC	= 0.280433E+02	PVG	= 0.145804E+02	PC	= 0.183755E+02	PCD	= 0.454161E+00	VTC	= 0.319994E-02
PLØ	= 0.800060E+00	VTL	= 0.320494E-02	VTD	= 0.124043E-06	VPD	= -0.205207E-04	DPL	= 0.531801E-01
	= 0.000000E+00	DPC	= 0.532462E-01	DPI	= 0.661090E-04		= 0.000000E+00	DLP	= 0.700026E-02
	= 0.000000E+00	CHY	= 0.495104E+01	PRM	= -0.501114E+01	PGR	= 0.198042E+01	CPG	= 0.124609E+02
PGP	= 0.413219E+01		= 0.000000E+00	PGX	= 0.165288E+02	PGC	= 0.611260E+01	PGH	= -0.400010E+01
	= 0.000000E+00	VGØ	= -0.184407E-03	VG	= 0.115125E+02		= 0.000000E+00		= 0.000000E+00
	= 0.000000E+00	GPD	= -0.154896E-04		= 0.000000E+00	RR	= 0.839500E+02		= 0.000000E+00
APD	= 0.376883E+02	GLP	= 0.620504E+02	PFL	= 0.160071E+02	GFR	= 0.125130E+00	TRR	= 0.124098E+00
VUD	= 0.103115E-02	REK	= 0.100000E+01	NØD	= 0.103624E+00	NED	= -0.362377E-02	NAE	= 0.213630E+04
VEC	= 0.150413E+02	CKE	= 0.498957E+01	KØD	= 0.278960E-02		= 0.000000E+00	KIR	= 0.354854E+04
KIE	= 0.915527E-02	KCD	= 0.115573E-03	KED	= -0.105172E-03	CKI	= 0.142025E+03	CNA	= 0.142029E+03
CCD	= -0.400162E-02	VID	= -0.120985E-04	KE	= 0.750493E+02	KI	= 0.354853E+04	VIC	= 0.249852E+02
	= 0.000000E+00		= 0.000000E+00	Z	= 0.100000E+01		= 0.000000E+00		= 0.000000E+00
TVZ	= 0.100391E-02		= 0.000000E+00		= 0.000000E+00	X	= 0.100000E+02	I2	= 0.300000E-02
	= 0.000000E+00	VTS	= 0.120661E+02	VP	= 0.296271E+01	PRP	= 0.207711E+03	IFP	= 0.914784E+01
GPR	= 0.143459E+03		= 0.000000E+00		= 0.000000E+00	AMR	= 0.980250E+00	AMP	= 0.101307E+01
AM1	= 0.994222E+00	AMC	= 0.992485E+00		= 0.000000E+00		= 0.000000E+00		= 0.000000E+00
AM	= 0.993475E+00	CNE	= 0.997039E+01	AGK	= 0.200000E+00	ANP	= 0.995531E+00	AN1	= 0.995826E+00
ANC	= 0.995995E+00		= 0.000000E+00		= 0.000000E+00		= 0.000000E+00	ANM	= 0.100303E+01
VB	= 0.500662E+01		= 0.000000E+00	HM	= 0.408241E+02		= 0.000000E+00	VIE	= 0.153328E+01
VIB	= 0.303328E+01	VIM	= 0.101099E+01	RC2	= 0.118547E-04	PØ2	= 0.237500E+00	RKC	= 0.580000E-05
RC1	= 0.110200E-04	RCD	= -0.834661E-06	VRC	= 0.204391E+01	RSN	= 0.324723E+02	ØVA	= 0.202845E+03
BFN	= 0.295463E+01	DØB	= 0.179681E+03	AØM	= 0.998304E+00	P16	= 0.800000E+01	ØSV	= 0.695877E+00
PØT	= 0.821768E+01		= 0.000000E+00	PØB	= 0.985898E+00	AR1	= 0.985931E+00	AR2	= 0.929921E+00
	= 0.000000E+00	AR3	= 0.977277E+00	ARM	= 0.896017E+00		= 0.000000E+00	GFN	= 0.125130E+00
	= 0.000000E+00		= 0.000000E+00	AH	= 0.302806E+01	AHC	= 0.100911E+01		= 0.000000E+00
	= 0.000000E+00		= 0.000000E+00	AHM	= 0.100039E+01	CNY	= 0.600000E+01	CNX	= 0.250000E+01
	= 0.000000E+00		= 0.000000E+00		= 0.000000E+00	VV6	= 0.827931E-05	VV7	= 0.120510E-01
TVD	= 0.100536E-02	VTW	= 0.400264E+02	HSR	= 0.100000E+01	HSL	= 0.100000E+01	NID	= 0.100000E+00
SR	= 0.500000E+00	VVR	= 0.295137E+01	RAR	= 0.305200E+02	CV	= 0.825000E-01	CN7	= 0.200000E+00
AUX	= 0.300000E+01	AUK	= 0.500000E-03	AUZ	= 0.100000E+01	Y	= 0.100000E+01	CFC	= 0.700000E-02
CPK	= 0.160000E-06	PCE	= 0.300000E+01	CPR	= 0.850000E+02	LPK	= 0.470000E-03	DPØ	= 0.700000E-02
HYL	= 0.570000E+02	KID	= 0.280000E-02	AMT	= 0.600000E+02	ANT	= 0.150000E+02	PØK	= 0.600000E-01
PØN	= 0.300000E+00	A1K	= 0.100000E+01	A2K	= 0.200000E+02	A3K	= 0.115200E+05	CNR	= 0.139000E+03
CNZ	= 0.100000E+01	AHK	= 0.700000E+01	SRK	= 0.330000E+02		= 0.000000E+00	V2D	= 0.200000E-01
Z1	= 0.100000E+01		= 0.000000E+00	Z3	= 0.400000E+01	Z4	= 0.100000E+02	Z5	= 0.100000E+02
Z6	= 0.500000E+01	Z7	= 0.500000E+01	Z8	= 0.100000E+01	HMK	= 0.900000E+02	HKM	= 0.533330E+00
	= 0.000000E+00	PØZ	= 0.300000E+00		= 0.000000E+00	QØ2	= 0.246777E+04	RBF	= 0.118807E+01
MØ2	= 0.179695E+03	PØA	= 0.929492E+00	FØY	= 0.464000E-04	ANU	= 0.100303E+01	PØR	= 0.400000E+02
GE2	= 0.500000E-01	HMD	= 0.100000E+01	DHM	= 0.554421E-02		= 0.000000E+00	I3	= 0.200000E+02
U	= 0.400000E+01	VP1	= 0.100000E-01	T1	= 0.000000E+00		= 0.000000E+00	GF4	= 0.500000E+01
AUP	= 0.988693E+00	AUV	= 0.300000E+00		= 0.000000E+00	AUY	= 0.250000E+00	ØUT	= 0.300000E+01

DSP	0.300000E+01	AHZ	0.183110E-01	AHY	0.194279E-01	ØSA	0.993753E+00		0.000000E+00
CPN	0.301352E+02	PØS	0.120541E+02	PLF	0.298391E-03	PPØ	0.899208E-02	PPN	0.899393E-02
PPD	0.159315E-05	PFI	0.298392E-03	DFP	-0.888210E-08	VPF	0.124944E-01	PPR	0.376523E+00
PMC	0.686006E+01	PMS	0.724995E+01	PMP	0.461073E+01	HR	0.717308E+02	CPF	0.300000E-03
RCP	0.697848E+01	DA1	0.100000E+01	DLZ	0.699915E-02		0.000000E+00		0.000000E+00
	0.000000E+00	NØZ	0.103915E+00		0.000000E+00		0.000000E+00	HPR	0.100509E+01
HPL	0.100243E+01	STH	0.100000E+01	ALØ	0.100000E+01	EXC	0.100000E+01	Ø2M	0.180000E+03
	0.000000E+00		0.000000E+00	SVØ	0.714458E-01	AUL	0.210000E+00	VV9	0.315900E+01
Ø2A	0.150000E+00		0.000000E+00	EXE	0.000000E+00	ARF	0.150000E+01	QRF	0.600000E+00
RSM	0.964606E+02	BFM	0.994639E+00	RAM	0.963000E+02	ØVS	0.698845E+00		0.000000E+00
RMØ	0.598937E+02	QØM	0.240003E+04	PMØ	0.800240E+01	P2Ø	0.800000E+01	MMØ	0.598982E+02
RDØ	-0.679865E-01		0.000000E+00	AMM	0.994666E+00	A4K	0.100000E+01	PØM	0.800000E-01
ØMM	0.600000E+02	PM1	0.800240E+01	PM3	0.100000E-02	PM4	-0.100000E+01	EX1	0.300000E+01
	0.000000E+00		0.000000E+00	PM5	0.122000E+03	PK1	0.250000E+04		0.000000E+00
Z10	0.825000E+01	Z11	0.400000E+01	Z12	0.124000E+01	Z13	0.625000E+00		0.000000E+00
	0.000000E+00		0.000000E+00	PK2	0.800000E+03	PK3	0.200000E+01	FIS	0.000000E+00
STA	0.000000E+00	PAR	0.997387E+02	GBL	0.000000E+00	ANY	-0.200000E+00	ANZ	0.400000E+00
	0.000000E+00	ANV	0.300000E-03	ANW	0.000000E+00		0.000000E+00	AUQ	0.100000E+01
AUR	0.988693E+00	AUS	0.100000E+01						

36 SECS

T	0.603000E+00	I	0.603000E+00	VBD	-0.625849E-05	VVS	0.327595E+01	VPA	0.379999E+00
VAS	0.849033E+00	VLA	0.401178E+00	VRA	0.100460E+00	VAE	0.354033E+00	PA	0.997275E+02
PAM	0.100273E+01	LVM	0.990419E+00	VRE	0.459731E-03	PRA	0.919462E-01	QRN	0.522067E+01
VPE	0.737493E-01	PPA	0.153644E+02		0.399475E+00		0.000000E+00	RPA	0.158218E+01
RVM	0.990069E+00	VLE	0.117850E-02	PLA	0.117850E+00	QLN	0.522088E+01		0.000000E+00
A1B	0.101174E+01	RPV	0.139236E+01	RPT	0.297453E+01	PGL	0.152466E+02	QPØ	0.512504E+01
	0.000000E+00	VVE	0.325184E+00		0.313133E+00	PVS	0.379556E+01		0.000000E+00
RVG	0.721370E+00	QVØ	0.512980E+01	AVE	0.997597E+00	CN2	0.212000E-01	CN3	0.366279E+00
RVS	0.275687E+01		0.959319E+02	RTP	0.193968E+02	QAØ	0.513669E+01	QRØ	0.512932E+01
QLØ	0.512482E+01	DVS	0.689316E-02	DPA	0.428009E-02	DAS	-0.118761E-01	DLA	0.222206E-03
DRA	0.480652E-03		0.997275E+02	AUC	0.000000E+00	AUB	0.100391E+01	AUN	0.000000E+00
	0.990783E+00		0.000000E+00	AU8	-0.460851E-05	DAU	0.990783E+00	AUJ	0.988731E+00
AU	0.988731E+00	AUØ	-0.112694E-01	AUH	0.996619E+00		0.000000E+00		0.000000E+00
AUM	0.990421E+00	AU4	0.209535E-01	VIF	0.553558E+00	PØ1	0.825000E+01	PTT	0.101105E+01
PTS	0.699662E+01	PIF	-0.598558E+01	CPI	0.165256E+02		0.413140E+01	CPP	0.701085E+02
PPC	0.280434E+02	PVG	0.145779E+02	PC	0.183735E+02	PCD	0.446128E+00	VTC	0.312290E-02
PLØ	0.803991E+00	VTL	0.321596E-02	VTD	-0.809693E-04	VPD	0.686865E-04	DPL	0.531415E-01
	0.000000E+00	DPC	0.531779E-01	DPI	0.363886E-04		0.000000E+00	DLP	0.699902E-02
	0.000000E+00	CHY	0.495114E+01	PRM	-0.501173E+01	PGR	0.198046E+01	CPG	0.124611E+02
PGP	0.413238E+01		0.000000E+00	PGX	0.165295E+02	PGC	0.611283E+01	PGH	-0.400069E+01
	0.000000E+00	VGØ	-0.690460E-04	VG	0.115124E+02		0.000000E+00		0.000000E+00
	0.000000E+00	GPD	-0.300390E-04		0.319658E+02	RR	0.845947E+02		0.117889E+01
APD	0.376840E+02	GLP	0.620435E+02	PFL	0.160001E+02	GFR	0.125121E+00	TRR	0.124090E+00
VUD	0.103104E-02	REK	0.100000E+01	NØD	0.103985E+00	NED	-0.398546E-02	NAE	0.213630E+04
VEC	0.150413E+02	CKE	0.498956E+01	KØD	0.278904E-02		0.000000E+00	KIR	0.354854E+04
KIL	0.830078E-02	KCD	0.107910E-03	KED	-0.969458E-04	CKI	0.142025E+03	CNA	0.142029E+03
CCD	-0.376892E-02	VID	-0.376892E-04	KE	0.750492E+02	KI	0.354853E+04	VIC	0.249852E+02
	0.241441E+03		0.000000E+00	Z	0.100000E+01		0.000000E+00		0.000000E+00
TVZ	0.100676E-02		0.000000E+00		0.000000E+00	X	0.100000E+02	I2	0.300000E-02
	0.919462E-01	VTS	0.120661E+02	VP	0.296272E+01	PRP	0.207711E+03	IFP	0.914788E+01
GPR	0.143459E+03		0.000000E+00		0.000000E+00	AMR	0.980297E+00	AMP	0.101363E+01
AM1	0.996664E+00	AMC	0.992520E+00		0.000000E+00		0.000000E+00		0.000000E+00
AM	0.992676E+00	CNE	0.997101E+01	AGK	0.200000E+00	ANP	0.995578E+00	AN1	0.995578E+00
ANC	0.995981E+00		0.000000E+00		0.000000E+00		0.000000E+00	ANM	0.100300E+01
VB	0.500662E+01		0.000000E+00	PM	0.408241E+02		0.000000E+00	VIE	0.155657E+01

```
VIB =  0.305657E+01
RC1 =  0.110200E-04
BFN =  0.295412E+01
POT =  0.821767E+01
    =  0.976360E+00
    =  0.000000E+00
    =  0.000000E+00
    =  0.000000E+00
TVD =  0.100676E-02
SR  =  0.500000E+00
AUX =  0.300000E+01
CPK =  0.160000E-06
HYL =  0.570000E+02
RON =  0.300000E+00
CNZ =  0.100000E+01
Z1  =  0.100000E+01
Z6  =  0.500000E+01
    =  0.397612E+02
MO2 =  0.179696E+03
GE2 =  0.500000E-01
U   =  0.400000E+01
AUP =  0.988731E+00
DSP =  0.300000E+01
CPN =  0.301353E+02
PPD =  0.199676E-05
PMC =  0.686004E+01
RCP =  0.697882E+01
    =  0.000000E+00
HPL =  0.100243E+01
    =  0.100868E+03
O2A =  0.150000E+00
RSM =  0.964616E+02
RMO =  0.598912E+02
PBO = -0.695496E-01
OMM =  0.600000E+02
    =  0.000000E+00
Z10 =  0.825000E+01
    =  0.000000E+00
STA =  0.000000E+00
    =  0.000000E+00
AUR =  0.988731E+00
```

```
VIM =  0.101875E+01
RCD = -0.834676E-06
DOB =  0.179675E+03
    = -0.238785E+00
AR3 =  0.977277E+00
    =  0.000000E+00
    =  0.000000E+00
    =  0.000000E+00
VTW =  0.400265E+02
VVR =  0.295137E+01
AUK =  0.500000E-03
PCE =  0.300000E+01
KID =  0.280000E-02
A1K =  0.100000E+01
AHK =  0.700000E+01
    =  0.000000E+00
Z7  =  0.500000E+01
POZ =  0.300000E+00
POA =  0.928365E+00
HMD =  0.100000E+01
VP1 =  0.100000E-01
AUV =  0.300000E+00
AHZ =  0.183892E-01
POS =  0.120541E+02
PFI =  0.298480E-03
PMS =  0.724988E+01
DA1 =  0.100000E+01
NOZ =  0.103985E+00
STH =  0.100000E+01
    =  0.155402E+02
    =  0.000000E+00
BFM =  0.994509E+00
QOM =  0.240003E+04
    =  0.994436E+00
PM1 =  0.800234E+01
    =  0.000000E+00
Z11 =  0.400000E+01
    =  0.000000E+00
PAR =  0.997275E+02
ANV =  0.300000E-03
AUS =  0.100000E+01
```

```
RC2 =  0.118547E-04
VRC =  0.204391E+01
AOM =  0.998310E+00
POB =  0.985673E+00
ARM =  0.895912E+00
AH  =  0.303003E+01
AHM =  0.100068E+01
    =  0.000000E+00
HSR =  0.100000E+01
RAR =  0.305200E+02
AUZ =  0.100000E+01
CPR =  0.850000E+02
AMT =  0.600000E+02
A2K =  0.200000E+02
SRK =  0.330000E+02
Z3  =  0.400000E+01
Z8  =  0.100000E+01
    =  0.554941E+03
POY =  0.464000E-04
DHM =  0.554417E-02
T1  =  0.603000E+00
    =  0.000000E+00
AHY =  0.194275E-01
PLF =  0.298386E-03
DFP =  0.945292E-07
PMP =  0.461094E+01
DLZ =  0.699902E-02
    =  0.000000E+00
ALO =  0.100000E+01
SVO =  0.714428E-01
EXE =  0.000000E+00
RAM =  0.963000E+02
PMO =  0.800234E+01
AMM =  0.994575E+00
PM3 =  0.100000E-02
PM5 =  0.122000E+03
Z12 =  0.124000E+01
PK2 =  0.800000E+03
GBL =  0.000000E+00
ANW =  0.000000E+00
```

```
PO2 =  0.237500E+00
RSN =  0.324740E+02
P1O =  0.800000E+01
AR1 =  0.985829E+00
    =  0.302899E+01
AHC =  0.100916E+01
CNY =  0.600000E+01
VV6 =  0.411160E-04
HSL =  0.100000E+01
CV  =  0.825000E-01
Y   =  0.100000E+01
LPK =  0.470000E-03
ANT =  0.150000E+02
A3K =  0.115200E+05
    =  0.000000E+00
Z4  =  0.100000E+02
HMK =  0.900000E+02
QO2 =  0.246777E+04
ANU =  0.100303E+01
    =  0.800000E+01
    =  0.100520E+01
AUY =  0.250000E+00
OSA =  0.993753E+00
PPO =  0.899196E-02
VPF =  0.124945E-01
HR  =  0.717331E+02
    =  0.000000E+00
    =  0.000000E+00
EXC =  0.100000E+01
AUL =  0.210000E+00
ARF =  0.150000E+01
OVS =  0.698818E+00
P2O =  0.800000E+01
A4K =  0.100000E+01
PM4 = -0.100000E+01
PK1 =  0.250000E+04
Z13 =  0.625000E+00
PK3 =  0.200000E+01
ANY = -0.200000E+00
    =  0.995578E+00
```

```
RKC =  0.580000E-05
OVA =  0.202846E+03
OBV =  0.695856E+00
AR2 =  0.929883E+00
GFN =  0.125121E+00
    =  0.000000E+00
CNX =  0.250000E+01
VV7 =  0.120516E-01
NID =  0.100000E+00
CN7 =  0.200000E+00
CFC =  0.700000E-02
DPO =  0.700000E-02
POK =  0.600000E-01
CNR =  0.139000E+03
V2D =  0.200000E-01
Z5  =  0.100000E+02
HKM =  0.533330E+00
RBF =  0.117889E+01
POR =  0.400000E+02
I3  =  0.200000E+02
GF4 =  0.500000E+01
OUT =  0.300000E+01
    = -0.100054E+02
PPN =  0.899395E-02
PPR =  0.376524E+00
CPF =  0.300000E-03
    =  0.000000E+00
HPR =  0.100509E+01
O2M =  0.180000E+03
VV9 =  0.315900E+01
QRF =  0.600000E+00
    =  0.399305E+02
MMO =  0.598986E+02
POM =  0.800000E-01
EX1 =  0.300000E+01
    =  0.000000E+00
    =  0.000000E+00
FIS =  0.000000E+00
ANZ =  0.400000E+00
AUQ =  0.100000E+01
```

THE TIME INCREMENT FOR OUTPUT HAS BEEN 'CHANGED FROM SECS TO HOUR.

1 HOUR

```
T   =  0.652088E+02
VAS =  0.848902E+00
PAM =  0.100310E+01
VPE =  0.731975E-01
RVM =  0.991133E+00
A1B =  0.101361E+01
    =  0.000000E+00
RVG =  0.724181E+00
```

```
I   =  0.114105E+02
VLA =  0.400638E+00
LVM =  0.991116E+00
PPA =  0.152495E+02
VLE =  0.[illegible]8068E-03
RPV =  0.139611E+01
VVE =  0.323430E+00
QVO =  0.509913E+01
```

```
VBD = -0.232339E-03
VRA =  0.100293E+00
VRE =  0.292838E-03
    =  0.396487E+00
PLA =  0.638068E-01
RPT =  0.298424E+01
    =  0.311918E+00
AVE =  0.997494E+00
```

```
VVS =  0.327435E+01
VAE =  0.353902E+00
PRA =  0.585675E-01
    =  0.000000E+00
QLN =  0.514252E+01
PGL =  0.151857E+02
PVS =  0.378082E+01
CN2 =  0.212000E-01
```

```
VPA =  0.379448E+00
PA  =  0.996907E+02
QRN =  0.514056E+01
RPA =  0.158813E+01
    =  0.000000E+00
QPO =  0.509045E+01
    =  0.000000E+00
CN3 =  0.366472E+00
```

RVS	0.277737E+01
QLØ	0.509106E+01
DRA	0.453568E-02
	0.992931E+00
AU	0.988291E+00
AUM	0.990047E+00
PTS	0.698778E+01
RPC	0.280705E+02
PLØ	0.812717E+00
	0.000000E+00
	0.000000E+00
RØP	0.413084E+01
	0.000000E+00
	0.000000E+00
APD	0.376552E+02
VUD	0.103092E-02
VEC	0.150419E+02
KIE	-0.134277E-01
CCD	0.508118E-02
	0.126200E+02
TVZ	0.964638E-03
	0.585675E-01
GPR	0.143454E+03
AM1	0.999865E+00
AØ	0.993988E+00
ANC	0.995638E+00
VB	0.500364E+01
VIB	0.305821E+01
RC1	0.110200E-04
BFN	0.294666E+01
PØT	0.821676E+01
	0.974345E+00
	0.000000E+00
	0.000000E+00
	0.000000E+00
TVD	0.964638E-03
SR	0.500000E+00
AUX	0.300000E+01
CPK	0.160000E-06
HYL	0.570000E+02
PØN	0.300000E+00
CNZ	0.100000E+01
Z1	0.100000E+01
Z6	0.500000E+01
	0.397409E+02
MØ2	0.179684E+03
GE2	0.500000E-01
U	0.400000E+01
AUP	0.988291E+00
DSP	0.300000E+01
CPN	0.304262E+02
PPD	0.411402E-03
PMC	0.683146E+01
PCP	0.689736E+01
	0.000000E+00
HPL	0.100241E+01
	0.100045E+03
Ø2A	0.150000E+00
RSM	0.968703E+02

	0.959099E+02
DVS	0.158691E-01
	0.996839E+02
	0.000000E+00
AUØ	-0.117092E-01
AU4	0.206422E-01
PIF	-0.597617E+01
PVG	0.146493E+02
VTL	0.325087E-02
DPC	0.537444E-01
CHY	0.494994E+01
	0.000000E+00
VGØ	-0.530434E-04
GPD	-0.262686E-04
GLP	0.620355E+02
REK	0.100000E+01
CKE	0.498939E+01
KCD	-0.174560E-03
VID	0.508118E-04
	0.000000E+00
	0.000000E+00
VTS	0.120694E+02
	0.000000E+00
AMC	0.994282E+00
CNE	0.999338E+01
	0.000000E+00
	0.000000E+00
VIM	0.101930E+01
RCD	-0.834421E-06
DØB	0.179615E+03
	-0.259140E+00
AR3	0.977264E+00
	0.000000E+00
	0.000000E+00
	0.000000E+00
VTW	0.400301E+02
VVR	0.295146E+01
AUK	0.500000E-03
PCE	0.300000E+01
KID	0.280000E-02
A1K	0.100000E+01
AHK	0.700000E+01
	0.000000E+00
Z7	0.500000E+01
PØZ	0.300000E+00
PØA	0.922258E+00
HMD	0.100000E+01
VP1	0.100000E-01
AUV	0.300000E+00
AHZ	0.117135E-01
PØS	0.121705E+02
PFI	0.318773E-03
PMS	0.722800E+01
DA1	0.100000E+01
NØZ	0.103743E+00
STH	0.1[illegible]000E+01
	0.153036E+02
	0.000000E+00
BFM	0.990085E+00

RTP	0.194784E+02
DPA	0.413704E-02
AUC	0.000000E+00
AU8	-0.353444E-05
AUH	0.996487E+00
VIF	0.554148E+00
CPI	0.165212E+02
PC	0.184301E+02
VTD	-0.349137E-05
DPI	0.438876E-04
PRM	-0.500462E+01
PGX	0.165234E+02
VG	0.115152E+02
	0.319625E+02
PFL	0.159650E+02
NØD	0.103743E+00
KØD	0.278986E-02
KED	0.184702E-03
KE	0.750520E+02
Z	0.100000E+01
	0.000000E+00
VP	0.295957E+01
	0.000000E+00
	0.000000E+00
AGK	0.200000E+00
	0.000000E+00
HM	0.408476E+02
RC2	0.118544E-04
VRC	0.204386E+01
AØM	0.998244E+00
PØB	0.984452E+00
ARM	0.889430E+00
AH	0.301409E+01
AHM	0.996464E+00
	0.000000E+00
HSR	0.100000E+01
RAR	0.305200E+02
AUZ	0.100000E+01
CPR	0.850000E+02
AMT	0.600000E+02
A2K	0.200000E+02
SRK	0.330000E+02
Z3	0.400000E+01
Z8	0.100000E+01
	0.554783E+03
PØY	0.464000E-04
DHM	0.554189E-02
T1	0.652088E+02
	0.000000E+00
AHY	0.191842E-01
PLF	0.280428E-03
DFP	0.383449E-04
PMP	0.454373E+01
DLZ	0.696714E-02
	0.000000E+00
ALØ	0.100000E+01
SVØ	0.710558E-01
EXE	0.679493E-02
RAM	0.963000E+02

QAØ	0.511500E+01
DAS	-0.239344E-01
AUB	0.100454E+01
DAU	0.992931E+00
	0.000000E+00
PØ1	0.825000E+01
	0.413031E+01
PCD	0.464957E+00
VPD	-0.694443E-04
	0.000000E+00
PGR	0.197997E+01
PGC	0.611082E+01
	0.000000E+00
RR	0.846196E+02
GFR	0.125106E+00
NED	-0.374323E-02
	0.000000E+00
CKI	0.142007E+03
KI	0.354853E+04
	0.000000E+00
X	0.100000E+02
PRP	0.207700E+03
AMR	0.981927E+00
	0.000000E+00
ANP	0.996191E+00
	0.000000E+00
	0.000000E+00
PØ2	0.237500E+00
RSN	0.325487E+02
P1Ø	0.800000E+01
AR1	0.984452E+00
	0.300662E+01
AHC	0.100451E+01
CNY	0.600000E+01
VV6	-0.297081E-03
HSL	0.100000E+01
CV	0.825000E-01
Y	0.100000E+01
LPK	0.470000E-03
ANT	0.150000E+02
A3K	0.115200E+05
	0.000000E+00
Z4	0.100000E+02
HMK	0.900000E+02
QØ2	0.246749E+04
ANU	0.100276E+01
	0.800000E+01
	0.100513E+01
AUY	0.250000E+00
ØSA	0.993784E+00
PPØ	0.853236E-02
VPF	0.128699E-01
HR	0.716488E+02
	0.000000E+00
	0.000000E+00
EXC	0.100000E+01
AUL	0.210000E+00
ARF	0.150000E+01
ØVS	0.698000E+00

GRØ	0.509459E+01
DLA	-0.607491E-03
AUN	0.000000E+00
AUJ	0.988291E+00
	0.000000E+00
PTT	0.101161E+01
CPP	0.701763E+02
VTC	0.325470E-02
DPL	0.537005E-01
DLP	0.696714E-02
CPG	0.124577E+02
PGH	-0.399301E+01
	0.000000E+00
	0.117810E+01
TRR	0.124075E+00
NAE	0.213598E+04
KIR	0.354851E+04
CNA	0.142002E+03
VIC	0.249890E+02
	0.000000E+00
I2	0.300000E-02
IFP	0.915521E+01
AMP	0.101547E+01
	0.000000E+00
AN1	0.996191E+00
ANM	0.100290E+01
VIE	0.155821E+01
RKC	0.580000E-05
ØVA	0.202968E+03
ØSV	0.695500E+00
AR2	0.923648E+00
GFN	0.125106E+00
	0.000000E+00
CNX	0.250000E+01
VV7	0.114378E-01
NID	0.100000E+00
CN7	0.200000E+00
CFC	0.700000E-02
DPØ	0.700000E-02
PØK	0.600000E-01
CNR	0.139000E+03
V2D	0.200000E-01
Z5	0.100000E+02
HKM	0.533330E+00
RBF	0.117810E+01
PØR	0.400000E+02
I3	0.200000E+02
GF4	0.500000E+01
ØUT	0.300000E+01
	-0.100652E+02
PPN	0.894377E-02
PPR	0.382965E+00
CPF	0.300000E-03
	0.000000E+00
HPR	0.100509E+01
Ø2M	0.180000E+03
VV9	0.315900E+01
QRF	0.600000E+00
	0.398837E+02

RMØ =	0.598809E+02	QØM =	0.239996E+04	PMØ =	0.799709E+01	P2Ø =	0.799709E+01	MMØ =	0.598946E+02
PDØ =	-0.116302E+00	=	0.990696E+00	AMM =	0.990696E+00	A4K =	0.100000E+01	PØM =	0.800000E-01
ØMM =	0.600000E+02	PM1 =	0.799709E+01	PM3 =	0.100000E-02	PM4 =	-0.100000E+01	EX1 =	0.300000E+01
=	0.000000E+00	=	0.000000E+00	PM5 =	0.122000E+03	PK1 =	0.250000E+04	=	0.000000E+00
Z10 =	0.825000E+01	Z11 =	0.400000E+01	Z12 =	0.124000E+01	Z13 =	0.625000E+00	=	0.000000E+00
=	0.000000E+00	=	0.000000E+00	PK2 =	0.800000E+03	PK3 =	0.200000E+01	FIS =	0.000000E+00
STA =	0.000000E+00	PAR =	0.996907E+02	GBL =	0.000000E+00	ANY =	-0.200000E+00	ANZ =	0.400000E+00
=	0.000000E+00	ANV =	0.300000E-03	ANW =	0.000000E+00	=	0.996191E+00	AUQ =	0.100000E+01
AUR =	0.988291E+00	AUS =	0.100000E+01						

VERIFICATION PLAN AND PROCEDURE FOR

WHITE'S VERSION OF GUYTON'S MODEL

The input-output subroutines are designed to accept data from punched cards and display desired output on 132-column listing paper.

The user should first determine exactly what experiment he wishes to do. Thus he must decide what parameters he wishes to monitor (as many as twenty) and how often the values of these (dependent) variables are needed in the output (e.g. each simulated second, minute, hour, or day.) The program is flexible enough to allow the user to change the frequency of output at any predetermined time or times. Then the user must decide what independent variables are to be changed, at what time or times these changes are to take place in the simulatio and what the new values of these variables should be. There is no limit to the number of variables which may be changed at any given time, nor is there a limit to the number of times changes may occur. Finally, he must decide at what time the experiment is to be terminated.

The input cards should be arranged as follows:

STEP 1.

For each of the nearly 400 variables, a card should be read giving the initial value, array number, and symbol of that particular variable. The initial value should appear in the first 13 columns in E13.6 notation. Thus the decimal point should be in column 3 followed by six digits, the letter "E" in column 10, and the exponent right-justified to column 13. The array number of the variable being initialized should appear as an integer right-justified in columns 18-20, and the symbol for that variable should appear left-justified in columns 23-26. These cards should be read in one after another, one variable per card. A blank card should follow the last variable initialized.

STEP 2.

Following this blank card, one card should be read containing the symbol(s) for the variable(s) to be monitored. The order in which the values of these variable(s) appear as output will be the same as the order in which the sumbol(s) for these variables are read in at this step. The symbol for the first variable desired in output should appear left-justified in columns 1-4, the symbol for the second variable left-justified in columns 5-8, the symbol for the third variable left-justified in columns 9-12, and so on, each symbol left-justified in a field of four columns, with a maximum of 80/4=20 symbols. For best results, it is suggested that no more than nine variables be monitored at a time so that the output appears in nice column form. If the values of all variables are desired, simply punch "ALL" in columns 1-3 of this card.

STEP 3.

The next card read should contain the time at which the first (or next) change of independent variable is to be made, in the units of time that the user desires the output to appear until that change is made. For example, "8 HOUR" would cause the output to appear each hour up thru 8 hours, then a change of variable(s) (or a change in time units for output) would be expected. The time should appear as an integer right-justified in columns 1-5 and the units in either "SECS", "MINS", "HOUR", or "DAYS" in columns 7-10.

STEP 4.

Following the time card there should be the card or cards which change the values of the desired independent variable(s). For each variable to be changed, one card should be read with the symbol of that variable left-justified in columns 11-14 and the new value of that variable in E13.6 format in columns 15-27, with the decimal in column 17 followed by six digits and an "E" in column 24 with the exponent right-justified in column 27. The user may change the values of as many independent variables at this time as he wishes, one change of variable per card, according to the instructions above, one card after another.

Steps 3 and 4 may now be repeated as often as desired; step 3 to give the time at which the next change is to occur and the units of time for output until that change occurs, and step 4 to make the desired changes.

To terminate the experiment at a predetermined time, read this time in according to the format given in step 3 and follow this "termination time" card with a blank.

EXERCISE STRESS EXPERIMENT

CARDS 1-377: (Variable initializing cards)

standard deck in your possession

CARD 1:

0.000000E 00 1 T

.
.
.
.

CARD 377:

0.100000E 01 377 AUS

CARD 378:

-- (BLANK) --

CARD 379:

VUD PVO PMO PA AUP QLP BFM MM0

CARD 380:

30 SECS

CARDS 381-386:

EXC	6.000000E 01
A4K	0.025000E 00
Z	5.000000E 00
Z8	3.000000E 00
Z5	1.000000E 00
Z6	1.000000E 01

CARD 387:

120 SECS

CARD 388:

EXC 1.0000000E 00

CARD 389:

300 SECS

CARD 390:

I3 2.000000E 01

CARD 391:

10 MINS.

CARD 392:

-- (BLANK) --

Note: For this experiment, the initial value of I3 is 0.

NEPHROSIS EXPERIMENT

CARDS 1-377(Initializing cards)

standard deck in your possession

CARD 1:

```
 0.000000E 00      1  T
    .
    .
    .
```

CARD 377:

```
 0.100000E 01    377  AUS
```

CARD 378:

-- (BLANK) --

CARD 379:

```
VUD VG  VTS VP  PRP PIF PA  QLO
```

CARD 380:

```
   24 HOUR
```

CARD 381:

```
          DPO   .050000E 00
```

CARD 382:

```
  128  HOUR
```

CARD 383:

```
          DPO   .021000E 00
```

CARD 384:

312 HOUR

CARD 385:

-- (BLANK) --