BNL 50104 (T-490)
and
NSMC 517

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March 1968

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.
under contract with the
UNITED STATES ATOMIC ENERGY COMMISSION
and
U.S. NAVAL SUBMARINE MEDICAL CENTER
U.S. NAVY DEPARTMENT
BUREAU OF MEDICINE AND SURGERY

BNL 50104 (T-490)
(Biology and Medicine - TID-4500)

NSMC 517
MF022.03.03-9010.01
Approved 19 March 1968

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This investigation was conducted as a part of Bureau of Medicine and Surgery Work Unit MF022 03 03-9010 01 – Computer Programming for Solution of Decompression Equations This report was approved for publication on 19 March 1968 and has been designated as Submarine Medical Center, Submarine Medical Research Laboratory Report NSMC 517 The report is No 2 on the Work Unit shown above

Printed in the United States of America
Available from
Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U S Department of Commerce
Springfield, Virginia 22151
Price Printed Copy $3 00, Microfiche $0 65

May 1968 1225 copies

ABSTRACT

A digital computer program for calculating either continuous ascent or stop-type decompression schedules is described, and examples of applications are given The formulas used for continuous ascent were obtained analytically as solutions of differential equations relating the inert gas tension in the current critical tissue to the safe depth and with the actual depth kept equal to the safe depth at all times after an initial fast rise from the bottom to the safe depth Thus the rate of decompression of the critical tissue controls the rate of ascent Gas tensions in nine tissues having the same range of gas exchange half-times as have been used in EDU reports are calculated on a continuous basis, with the one having the deepest safe depth being the current critical tissue The stop-type ascent portion of the program may be used to generate a staged ascent using the same parameters for comparison with the continuous ascent schedule The starting conditions for ascent may either be computed by the program from the dive history or be communicated to it as a subroutine in connection with another program The program may be used either to prescribe ascent schedules or to analyze dives for which the history is known

CONTENTS

COMPUTATION OF CONTINUOUS DECOMPRESSION SCHEDULES FOR DEEP SEA DIVES

INTRODUCTION

Too rapid ascent from prolonged deep dives can result in decompression sickness or "the bends," an illness associated with inert gas bubble formation in the blood and tissues of the body This illness is preventable through the use of appropriate decompression schedules, which depend principally on the dive depth and its duration However, many other factors that may affect the diver's physiology, such as exercise, water temperature, and the effects of breathing different gas mixtures, must also be considered in constructing decompression schedules A panoramic view of recent work in diving physiology is presented in a book edited by Lambertsen [1]

Workman[2] has critically reviewed the development of the U S Navy's current decompression schedules [3] These are based on the principles of inert gas exchange as developed by Haldane and co-workers,[4] and on their determination of the amounts by which the inert gas tensions in the tissues may safely exceed the ambient pressure without producing the bends

The currently used decompression schedules involve a series of steps, or stages, at intervals of 10 ft of depth The diver waits at each stage until it is safe for him to be at the next stage, at which time he ascends to it, and so on, until the surface is reached These schedules have been constructed to minimize the decompression time, consistent with preventing the bends, and have been proved safe in thousands of real dives However, it is apparent that any staged decompression schedule is inherently less than optimal, because as soon as the diver has been at a given stage for even a short time, it would be safe for him to be at some shallower depth, which in turn would give an increase in the outgassing pressure gradient and a shortening of the time required for further decompression At the deeper stages, particularly in dives with short bottom times, some tissues may actually still be absorbing rather than releasing inert gases, thus obligating longer stops at subsequent stages The importance of this effect increases with the dive depth, but decreases with increasing bottom time

The potential advantages of continuous, rather than staged, ascent schedules have previously been recognized, for example, by Workman[2] and Bradner and Mackay [5] Shreiner and Kelly[6] have developed continuous decompression formulas assuming constant excess saturation pressure, both for constant partial pressures of oxygen and for constant percentage of oxygen in the breathing mixture

The purposes of this report are (1) to present the derivation of a set of formulas obtained as solutions of differential equations that include the assumption that the depth is continuously changing in such a way as to keep the diver exactly at his current safe depth, and (2) to describe a digital computer program, SIMDIVE, that has been developed to use the above method in the development of more nearly optimal decompression schedules

In this derivation, we do not consider the elaborate mechanisms involved in bubble formation, but work from the same assumptions used in developing the standard tables, to the effect that, for any particular inert gas partial pressure in a tissue, there is some corresponding minimal external pressure that is sufficient to prevent bubble formation [2] The depth associated with this minimal pressure is designated the safe depth

During the decompression process the gases are eliminated from the body and the required external pressure decreases The formulas developed for the SIMDIVE program combine the equations for the rates of uptake and release of inert gases with equations relating the internal partial pressures to the safe depth A schedule is produced such that, after an initial rapid ascent to the safe depth, the actual depth is kept equal to the instantaneous value of the safe depth

The formulas developed by the above methods are used in a computer subroutine called ASCENT ASCENT is designed to be called by SIMDIVE or another main program such as Moeller's STANDIVE[7] that supplies the parameters and constants needed to express the conditions of the dive and the diver's status with respect to his tissue inert gas partial pressures at the beginning of the ascent Another subroutine, DESCENT, provides an alternative method for generating the ascent starting conditions from the dive history

The SIMDIVE program and associated subroutines were originally written in FORTRAN II for compatibility among the Honeywell-800 at the SMC and the IBM-7094 and the CDC-6600 computers at BNL However, the version presented in this report includes some FORTRAN IV features adapted principally for use with the CDC-6600 computer

MATHEMATICAL BASIS

It is assumed that the driving force for gas exchange is the partial pressure gradient between the breathing gas mixture and the gas tension in the tissues For each tissue a rate-limiting gas exchange factor, λ, may be assigned This factor lumps the effects of several parameters It depends primarily upon the blood perfusion rate per gram of tissue and the solubility of the gas under consideration in the tissue relative to that in the blood, but also reflects variations in diffusion rates for the gases and the effects of temperature changes The λ's are related to tissue gas exchange half-times through the relationship $\lambda T = \log_e 2$ The various tissues are regarded as being in parallel for gas exchange considerations, and thus are treated independently For consistency with other work[2,7] nine tissues having a spectrum of λ's corresponding to gas exchange half-times ranging from 5 to 240 min are used These half-times were arbitrarily chosen to give the desired spread of values, and do not necessarily correspond to any particular anatomical tissues or organs The factors relating tissue gas tensions to the safe depth are also functions of the half-times Because of the different rates of uptake and release of the gases among the tissues, there will usually be one for which the safe depth at a given moment is greatest, and this will be called the critical tissue If two or more tissues tie for this distinction, the one with the longer half-time is taken

The plan for ascent is first to ascend as rapidly as is practical (60 ft/min) until the actual depth equals the safe depth for the critical tissue From this time on, the actual depth is kept equal to the safe depth for the current critical tissue Control passes from one tissue to the next when the curves representing their individual safe depths cross One of the programming problems, as discussed below, is to predict the time for changing the critical tissue For dives involving short bottom times, the rapidly exchanging tissues are the controlling ones at the beginning of ascent, and control passes to progressively slower tissues as the surface is approached For very prolonged dives, the slower tissues may be rate-controlling from the beginning of ascent

For comparison, a variation of the program produces a staged ascent In this variation the diver remains at a given stop until a time such that by ascending to the next even 10-ft level, at the maximum rate, he will arrive at the new depth at the instant this becomes his safe depth This is slightly different from the standard tables, in which the ascent time is not considered, but gives a fairer comparison with the continuous method

The notation to be used is given in Table 1

Insofar as possible, the derivations that follow are in terms of a single tissue, and, for simplicity of expression, subscripts are omitted when possible without ambiguity In the computer program the subscripts are needed to distinguish among the various tissues and gases

General

If $(P-Q)$ is the driving force and λ is the rate-limiting factor for inert gas exchange, then

$$\frac{dQ}{dt} = \lambda(P-Q)\,, \tag{1}$$

or, in standard linear equation form,

$$\frac{dQ}{dt} + \lambda Q = \lambda P\,, \tag{2}$$

also

$$AD = AD_0 - DD = AD_0 - \int_0^t R\,dt\,, \tag{3}$$

$$P = G(AD+33) = G\left(D - \int_0^t R\,dt\right) \tag{4}$$

Safe Depth

Workman[2] mentions several formulas that have been used to calculate safe inert gas partial pressures in tissues for given depths In the present no-

Table 1

Symbol	Explanation	Units
$Q(J,I)$	Ith gas tension in Jth tissue (range for I, 1-3, for J, 1-9)	ft of water
$Q(L,I)$	Ith gas tension in critical tissue, L ($I=1$ is used for total inert gas tension, $I=2$ for nitrogen, and $I=3$ for helium)	ft of water
$Q(J,I)_0$	$Q(J,I)$ at start of current step	ft of water
$Q(J,I)_s$	Safe value for $Q(J,I)$ at current depth	ft of water
$P(I)$	Partial pressure of Ith gas in breathing mixture	ft of water
$G(I)$	Fraction of Ith gas in breathing mixture	—
t	Time from start of current step	min
R	Rate of change of depth, taken as positive for ascent	ft/min
AD	Actual depth (gauge)	ft of water
$SD(J)$	Safe depth for Jth tissue (gauge)	ft of water
AD_0	Depth at start of current step (gauge)	ft of water
DD	$AD_0-AD=\int_0^t Rdt$, change of depth for step	ft of water
D	AD_0+33, total external pressure	ft of water
$\lambda(J)$	Turnover rate constant for Jth tissue, $\lambda=(\log_e 2)$/half-time	$\min^{-1}$
$AK(J)$	$Q(J,I)_s$ at surface	ft of water
$AC(J)$	$\Delta AK(J)$/ft of depth	—

NOTE All depths and pressures are measured in feet of sea water, absolute, unless gauge depth is specified (For fresh water dives $D=AD_0+34$, and the AK's and AC's are multiplied by 1 025, the density of sea water)

tation, the following formula is equivalent to the one used for constructing the tables of recommended M values in ref (2)

$$Q_s=AK+AC\cdot AD \tag{5}$$

By rearrangement of Eq (5), the safe depth for a given value of Q is

$$SD=(Q-AK)/AC \tag{6}$$

Thus, if Q changes, the SD changes proportionally

$$SD_0-SD=\frac{(Q_0-AK)}{AC}-\frac{(Q-AK)}{AC}$$

$$=\frac{(Q_0-Q)}{AC}, \tag{7}$$

or,

$$SD=SD_0-\frac{(Q_0-Q)}{AC} \tag{8}$$

Ascent Formulas

As mentioned above, the ascent schedule has two phases, first a rapid ascent to the minimum safe depth, then a slower ascent maintaining the current safe depth The former involves a constant rate of change of depth, whereas the latter involves a continuously changing rate The formulas for constant rate are simpler and are derived first These formulas are also used for descent and for computing staged ascent schedules

Constant Rate

With R constant,

$$\int_0^t Rdt=Rt\ , \tag{9}$$

Therefore, substitution of Rt into Eq (4) gives

$$P=G(D-Rt)\ , \tag{10}$$

and Eq (2) becomes

$$\frac{dQ}{dt}+\lambda Q=\lambda G(D-Rt)\ , \tag{11}$$

for which the solution is*

$$Q=\exp(-\lambda t)\left[\int_0^t \lambda G(D-Rt)\exp(\lambda t)\,dt+C\right] \tag{12}$$

Integration and simplification, with $C=Q_0$, yield

$$Q=GD[1-\exp(-\lambda t)]-\frac{GR[\lambda t-1+\exp(-\lambda t)]}{\lambda}+Q_0\exp(-\lambda t) \tag{13}$$

In this form it is seen that the third term on the right represents the function Q for $G=0$, i e , if the diver breathes pure oxygen Similarly, the first term represents the build-up in tissue inert gas partial pressure that would occur if $R=0$ and $Q_0=0$ The middle term corrects for the effect of

*The symbolism exp (X) is used here to represent e^X, where e is the base of the natural logarithms, 2 718 the rate of ascent For computing purposes, a rearrangement of Eq (13), with the exponential terms collected, is used

$$Q = GD - \frac{GR(\lambda t - 1)}{\lambda} + \left(Q_0 - GD - \frac{GR}{\lambda}\right)\exp(-\lambda t) \tag{14}$$

For constant depth, with $R=0$, Eq (14) becomes

$$Q = GD + (Q_0 - GD)\exp(-\lambda t) \tag{15}$$

The time required for Q to reach some other value, Q_t, at constant depth may be calculated by solving Eq (15) for t

$$t = \frac{\log_e[(Q_0 - GD)/(Q_t - GD)]}{\lambda} \tag{16}$$

provided that $GD \leqslant Q_t \leqslant Q_0$ or $Q_0 \leqslant Q_t \leqslant GD$

Intersection of Fast Ascent and Safe Depth Curves

To find the time of intersection of the fast ascent and safe depth curves, we set

$$AD = SD \tag{17}$$

and substitute Eq (3) and Eq (8)

$$AD_o - Rt = SD_o - \frac{(Q_0 - Q)}{AC} \tag{18}$$

But, from Eq (13),

$$(Q_0 - Q) = (Q_0 - GD)[1 - \exp(-\lambda t)] + \frac{GR[\lambda t - 1 + \exp(-\lambda t)]}{\lambda} \tag{19}$$

Substitution of the right-hand member of Eq (19) into Eq (18) eliminates Q and gives an expression involving only t and variables whose values are known at the start of a given step Although this expression cannot be solved analytically for t, a value of t may be obtained to any desired accuracy through successive iterations of Newton's aproximation formula [8]

If it is desired to solve $F(t)=0$ for t,

$$t \approx t_0 - \frac{F(t)}{F'(t)}, \tag{20}$$

where t_0 is an initial guess for t, and $F'(t) = dF(t)/dt$ The approximation obtained by the first solution of Eq (20) for t is used as the t_0 for the next iteration, etc , until the answer converges within the desired limits Thus t is obtained from successive iterations of

$$t = t_0 - \frac{AD_0 - SD_0 - Rt + \{(Q_0 - GD)[1 - \exp(-\lambda t)] + GR[\lambda t - 1 + \exp(-\lambda t)]/\lambda\}/AC}{-R + \{\lambda(Q_0 - GD)\exp(-\lambda t) + GR[1 - \exp(-\lambda t)]\}/AC} \tag{21}$$

The first t_0 is obtained by substituting the approximation

$$\exp(-\lambda t) \approx 1 + \lambda t - \tfrac{1}{2}(\lambda t)^2 \tag{22}$$

into Eq (19), and the result into Eq (18), and solving the resulting quadratic expression for t In subroutine ASCENT, the critical tissue at the time of intersection is determined by selecting the tissue for which the substitution involving Eq (22) gives the least value for t, then the exact value of t is calculated for the critical tissue only, by using Eq (21) When the diver's actual depth equals his safe depth, another set of equations involving the use of a variable ascent rate is needed The derivations for these equations follow

Variable Ascent Rate

To maintain $AD = SD(L)$,

$$R = \frac{dSD(L)}{dt} = -\frac{dQ(L,1)}{dt} \Big/ AC(L), \tag{23}$$

and

$$DD = \int_0^t R\,dt = \frac{[Q(L,1)_0 - Q(L,1)]}{AC(L)} \tag{24}$$

Substitution of Eq (24) into Eq (4) gives

$$P = G\left[D - \frac{[Q(L,1)_0 - Q(L,1)]}{AC(L)}\right], \tag{25}$$

and Eq (2) becomes

$$\frac{dQ(J,I)}{dt} + \lambda_J Q(J,I) = \lambda_J G_I\left[D - \frac{[Q(L,1)_0 - Q(L,1)]}{AC(L)}\right] \tag{26}$$

In order to obtain an integrable form of Eq (26), it is necessary first to solve for $Q(L,1)$ With the understanding that only the total inert gas tension in the critical tissue, $Q(L,1)$, is under consideration, the notation may be simplified

$$\frac{dQ}{dt} + \lambda Q = \lambda G\left(D - \frac{Q_0}{AC}\right) + \frac{\lambda G Q}{AC}, \tag{27}$$

or, in standard form

$$\frac{dQ}{dt} + \left(1 - \frac{G}{AC}\right)\lambda Q = \lambda G\left(D - \frac{Q_0}{AC}\right) \tag{28}$$

In Eq (28), let

$$K_1=\left(1-\frac{G}{AC}\right)=\frac{AC-G}{AC},$$

$$K_2=G\left(D-\frac{Q_0}{AC}\right),$$

$$K_3=\frac{K_2}{K_1}=\frac{G(D\cdot AC-Q_0)}{AC-G}$$

Then

$$\frac{dQ}{dt}+\lambda K_1 Q=\lambda K_2 \tag{29}$$

Solving Eq (29) gives

$$Q=\exp(-\lambda K_1 t)\left[\int_0^t \lambda K_2 \exp(\lambda K_1 t)\,dt+C\right] \tag{30}$$

Integrating between limits gives

$$Q=\exp(-\lambda K_1 t)\left\{\frac{\lambda K_2}{\lambda K_1}[\exp(\lambda K_1 t)-1]+C\right\} \tag{31}$$

For $t=0$, $C=Q_0$,

$$Q=K_3[1-\exp(-\lambda K_1 t)]+Q_0\exp(-\lambda K_1 t) \tag{32}$$

$$=K_3+(Q_0-K_3)\exp(-\lambda K_1 t) \tag{33}$$

for $Q(L,1)$, i e , the total inert gas tension in the critical tissue [Eq (33) is not directly applicable for other tissues or for individual inert gases]

From Eqs (3), (24), and (33), we obtain

$$DD=(Q_0-K_3)[1-\exp(-\lambda K_1 t)]/AC \tag{34}$$

To solve Eq (34) for t, let

$$K_4=(Q_0-K_3)/AC,$$

then

$$t=-\log_e(1-DD/K_4)/\lambda K_1 \tag{35}$$

Thus at this point, for the critical tissue, L, we have analytical solutions for Q, R, and DD as functions of time, and for time as a function of the change in depth, DD, all with $AD=SD$ Whether Eq (34) or Eq (35) is to be used depends on whether t or DD is known, respectively We proceed to solve Eq (26) for the other tissues and for the component inert gases

From Eq (33),

$$Q(L,1)_0-Q(L,1)$$
$$=[Q(L,1)_0-K_3][1-\exp(-\lambda_L K_1 t)] \tag{36}$$

Substitution of the right-hand member of Eq (36) into Eq (26) gives

$$\frac{dQ(J,I)}{dt}+\lambda_J Q(J,I)$$
$$=\lambda_J G_I\left\{D-\frac{[Q(L,1)_0-K_3][1-\exp(-\lambda_L K_1 t)]}{AC(L)}\right\} \tag{37}$$

From the definition of K_3 it is readily shown that

$$\frac{Q_0-K_3}{AC}\equiv\frac{G_1 D-K_3}{G_1} \tag{38}$$

With this substitution, Eq (37) reduces to

$$\frac{dQ(J,I)}{dt}+\lambda_J Q(J,I)$$
$$=\lambda_J G_1\left[\frac{K_3}{G_1}+\left(D-\frac{K_3}{G_1}\right)\exp(-\lambda_L K_1 t)\right] \tag{39}$$

with the solution

$$Q(J,I)=\exp(-\lambda_J t)\left\{\int_0^t \lambda_J G_I\left[\frac{K_3}{G_1}+\right.\right.$$
$$\left.\left.\frac{G_1 D-K_3}{G_1}\exp(-\lambda_L K_1)\right]\exp(\lambda_J t)dt+C\right\} \tag{40}$$

Integration of Eq (40) gives

$$Q(J,I)=\exp(-\lambda_J t)\left\{\frac{\lambda_J G_I}{G_1}\left(\frac{K_3}{\lambda_J}[\exp(\lambda_J t)-1]+\right.\right.$$
$$\left.\left.\frac{G_1 D-K_3}{\lambda_J-\lambda_L K_1}\{\exp[(\lambda_J-\lambda_L K_1)t]-1\}\right)+C\right\}, \tag{41}$$

$$Q(J,I)=\frac{G_I}{G_1}\left\{K_3[1-\exp(-\lambda_J t)]+\right.$$
$$\left.\frac{\lambda_J(G_1 D-K_3)}{\lambda_J-\lambda_L K_1}[\exp(-\lambda_L K_1 t)-\exp(-\lambda_J t)]\right\}+$$
$$C\exp(-\lambda_J t) \tag{42}$$

for $t=0$, $C=Q(J,I)_0$

Finally

$$Q(J,I)=\frac{G_I}{G_1}\left[K_3+\frac{\lambda_J(G_1 D-K_3)}{\lambda_J-\lambda_L K_1}\exp(-\lambda_L K_1 t)\right]+$$
$$\left[Q(J,I)_0-\frac{G_I}{G_1}\left(K_3+\frac{\lambda_J(G_1 D-K_3)}{\lambda_J-\lambda_L K_1}\right)\right]\exp(-\lambda_J t) \tag{43}$$

An indeterminancy arises in Eq (42) if $\lambda_J=\lambda_L K_1$, with

$$\frac{\exp(-\lambda_L K_1 t)-\exp(-\lambda_J t)}{\lambda_J-\lambda_L K_1}=\frac{0}{0} \tag{44}$$

This indeterminancy may be removed through an application of L'Hopital's rule

$$\lim_{\lambda_J \to \lambda_L K_1} \left[\frac{\exp(-\lambda_L K_1 t) - \exp(-\lambda_J t)}{\lambda_J - \lambda_L K_1} \right] = t \exp(-\lambda_L K_1 t) \quad (45)$$

In ASCENT, a modification of Eq (43) involving substitution of Eq (45) is used if

$$|\lambda_J - \lambda_L K_1| < 10^{-6}$$

Otherwise an expression equivalent to Eq (43) is used

Change of Critical Tissue

Except in saturation dives, when the critical tissue is the one with the longest half-time, the critical tissue changes whenever the safe depth curve of one of the slower tissues crosses that of the current critical tissue It is useful to be able to predict when this will occur, and this may be done through the use of the formulas derived below

The critical tissue changes when, for $J > L$ (assuming that the tissues are ordered by increasing half-times),

$$SD(J) = SD(L) \quad (46)$$

From Eq (8),

$$SD(J)_0 - \frac{[Q(J)_0 - Q(J)]}{AC(J)} = SD(L)_0 - \frac{[Q(L)_0 - Q(L)]}{AC(L)}, \quad (47)$$

$$SD(L)_0 - SD(J)_0 + \frac{[Q(J)_0 - Q(J)]}{AC(J)} - \frac{[Q(L)_0 - Q(L)]}{AC(L)} = 0 \quad (48)$$

Substitution from Eq (36) and Eq (43) with $G_I = G_1$ gives

$$SD(L)_0 - SD(J)_0 + \frac{[Q(J)_0 - K_3][1 - \exp(-\lambda_J t)] + \frac{\lambda_J (GD - K_3)}{\lambda_J - \lambda_L K_1}[\exp(-\lambda_L K_1 t) - \exp(-\lambda_J t)]}{AC(J)} - \frac{[Q(L)_0 - K_3][1 - \exp(-\lambda_L K_1 t)]}{AC(L)} = 0$$

Again, Eq (49) cannot be solved explicitly for t, but a numerical solution is obtainable by the same method as used above for the fast intersection If $F(t)$ is the left member of Eq (49),

$$F'(t) = \frac{[Q(J)_0 - K_3]\lambda_J \exp(-\lambda_J t) + \frac{\lambda_J (GD - K_3)}{\lambda_J - \lambda_L K_1}[\lambda_J \exp(-\lambda_J t) - \lambda_L K_1 \exp(-\lambda_L K_1 t)]}{AC(J)} - \frac{[Q(L)_0 - K_3]\lambda_L K_1 [\exp(-\lambda_L K_1 t)]}{AC(L)}$$

and

$$t \simeq t_0 - \frac{F(t)}{F'(t)} \quad (51)$$

In this case a satisfactory first estimate for t_0 is obtained by substituting the approximation

$$\exp(X) \simeq 1 + X \quad (52)$$

into Eq (49) and solving for t

$$t_0 = \frac{[SD(L)_0 - SD(J)_0]}{\left[\frac{Q(L)_0 - G_1 D}{AC(L)} \lambda_L - \frac{Q(J)_0 - G_1 D}{AC(J)} \lambda_J \right]} \quad (53)$$

The same expression for t_0 is obtained if the time of intersection of the tangents at $t=0$ for the two curves, $SD(J)$ and $SD(L)$ as defined by Eq 8, is taken

PROGRAM DESCRIPTION

Listings and logic diagrams for program SIMDIVE and its subroutines are given in Appendix B

As the "main" program, SIMDIVE reads in the initializing data and calls the appropriate subroutines The first two columns of the first card of a data deck determine whether the run will begin with DESCENT or will go directly to ASCENT, and whether new half-time, AK, AC, and gas mixture parameters or those for the preceding deck are to be used The balance of this card through column 72 may be used to give any alphanumeric information desired to identify the dive (For consistency with other reports, the half-times for nine tissues usually used are 5, 10, 20, 40, 80, 120, 160, 200, and 240 min) If DESCENT is used, and the diver is not at the surface when the END card is reached, the program automatically proceeds with ASCENT without first returning to SIMDIVE When the surface has been attained in ASCENT, there is a return to SIMDIVE, which proceeds to call TABLE and PLOT, then starts over or stops, depending on whether another dive follows

Subroutine DESCENT is used primarily to compute the inert gas partial pressures in the tissues at the beginning of ASCENT For each step it reads in the time and depth for the end of the step and the index for the gas mixture used during the step (In an alternative version, the actual gas mixture fractions are read in here) The starting time and depth for a given step are assumed to be those for the end of the immediately prior step Subroutine TENSION is called for computing the inert gas partial pressures in the tissues at the end of each step DESCENT may also be used to compute the safe depths, partial pressures, and safe partial pressures for the decompression steps in any dive in which the rates of change of depth are all constants Finally, DESCENT may be used to study the continuation of the decompression process after the diver has surfaced, for example, to obtain the starting partial pressures in the tissues for repetitive dives

ASCENT may be used as an independent subroutine, or may be joined with DESCENT, as is done in the listing given in Appendix B ASCENT inserts a dummy first step of zero duration to print out the starting conditions for ascent It automatically determines the gas mixture to use, based on the starting depth for each step The safe depths for all nine tissues are computed, and the tissue having the greatest safe depth is selected as the critical tissue If the distance from the actual depth to the safe depth for the critical tissue is >0 01 ft, the program calls subroutine FASTRIZ, which takes the diver to the current safe depth Otherwise the slow ascent method is used, in which the actual depth and safe depth are kept equal Normally a step is an interval of 10 ft, but if a change of critical tissues or a gas mixture boundary is encountered first, the information as of the intervening depth is printed out If the rate of ascent is >10 ft/min, ascent proceeds for 1 min rather than 10 ft for that step In the printout the critical tissue for the step is marked with an asterisk If the "stop" is due to a change in critical tissue, the next critical tissue is also marked

Subroutine FASTRIZ finds the time of intersection of the actual depth curve with the safe depth curve, assuming ascent at the maximum rate, which is taken as 60 ft/min unless another value is read in by SIMDIVE

Subroutine PLOT produces a graph of the DESCENT-ASCENT depth-time curve The ordinate scale is based on MAXDEEP A caption and ordinate labels for 0, ¼, ½, ¾, and 1 times MAXDEEP are printed out The time scale is adjusted to keep the plot on two pages, through factors entered as DATA statements Once the scales have been determined, PLOT proceeds by treating each line of printout as a time interval, and examining the end times for the dive steps in sequence If a step end time falls within the current time interval, the corresponding POINT is labeled with an asterisk When a step is encountered that is later than the current time interval, this interval is printed out, the labels for the steps that fell within the interval are "erased" (i e , labeled blank), and the program proceeds to the next time interval For intervals containing points printed out, the time of the last point in the interval is printed After the last step of the dive, the ordinate scales and captions are printed out again

Subroutine TABLE lists the starting and ending time and depth and the gas mixture for each step The times are converted from minutes to hours and minutes for use in TABLE

Subroutine TENSION uses the constant rate formula, Eq (14), for computing the inert gas partial pressures in the tissues

INPUT-OUTPUT

Input

The input data deck is described in Table 2

Output

SIMDIVE assigns consecutive serial numbers to the dives in a given run This dive number, the identification field of card 1, and the date of the run are printed at the beginning of the ouput, before TABLE and before PLOT If they are new parameters, H, AK, and AC are printed For DESCENT, the dive number, step number, prior depth, end-of-step depth, oxygen, nitrogen, and helium percentages, safe tissue pressures and Q values (total inert, nitrogen, and helium) for each of nine tissues, the step time interval, the cumulative dive time, the rate of ascent, and the safe depth for the critical tissue are printed out for each step The critical tissue is marked with an asterisk For ASCENT, the first five gas mixtures (oxygen, total inert, nitrogen, and helium) and the depths for which each is to be used, and the maximum rate of ascent are printed out The dive number, etc , as listed for DESCENT are printed except that the Q values are followed by the step time interval, the cumulative ascent time, the cumulative dive time, and the average ascent rate for each step, instead of the items listed for DESCENT Since the actual

Table 2

Input data deck		Entry	Meaning
Card 1	Col 1	Blank or 0	Use preceding parameters
		1	Read new parameters (Cards 2-14)
	Col 2	Blank, 0, or 1	Continuous ASCENT only
		2	DESCENT, then continuous ASCENT
		3	DESCENT, then staged ASCENT
	Col 3-72	Alphanumeric	Dive identification
If col 1, card 1 blank or zero, skip to card 15			
Card 2	8x 9F8 0	Real type numbers	$H(J), J=1,9$
Card 3	8x 9F8 0	" " "	$AC(J), J=1,9$
Card 4	8x 9F8 0	" " "	$AK(J), J=1,9$
Cards 5-14	Col 9-16	" " "	Nitrogen, GMIX(3,J)
	Col 17-24	" " "	Helium, GMIX(4,J), $J=1,10$
Card 15	Col 17-24	" " "	Initial time, T(1)
	Col 25-32	" " "	Initial depth, DEPTH(1)
	Col 33-37	Integer	MAXOEEP (for scaling ordinate)
	Col 38-45	Real type number	RATE (maximum ascent rate)
Cards 16-18	8x 9F8 4	" " "	Initial tissue pressures, $Q(I,J), I=1,9, J=1,3$
If col 2, card 1 blank, 0, or 1, skip to card $N+2$			
Cards 19-N*	Col 1-3	Blank	
	Col 4-8	Real type number	End of step hour
	Col 9-13	" " "	End of step minute
	Col 14-20	" " "	End of step depth
	Col 46-50	Integer 1-10	Index for step GMIX
Card $N+1$	Col 1-3	END	Indicates end of DESCENT deck
Card $N+2$	Card 1 of next data deck or end of file card		

*N may be any number 19-217, with one card per step in DESCENT

depth and the safe depth are kept equal after the initial fast ascent, the safe depth is not printed separately

After the diver has surfaced, or the 198th step, a tabulation of the step numbers, step times, beginning and end-of-step depths, beginning and end-of-step times, and the gas mixture for each step are printed by subroutine TABLE

Subroutine PLOT prints a graph of depth vs time for the dive

Execution time of the program on the CDC-6600 averages about 2 sec per dive for the 600-ft dives

APPLICATIONS

Figure 1 compares two ascent schedules, one for staged ascent and the other for continuous ascent, both as calculated with the SIMDIVE program following descent to 450 ft for 1 hr In both dives it is assumed that the breathing gas mixture is air during descent to 75 ft, then 96% helium, 4% oxygen for the rest of descent, while at 450 ft, and during ascent to 200 ft, after which air is again used Although there is very little difference between the two schedules for the early stages, the difference gradually accumulates, and the diver surfaces 2 hr sooner by the continuous method

In Figure 2 the standard table schedule for a dive to 190 ft for 1 hr on air is compared with ascent schedules calculated by the SIMDIVE staged and continuous methods Although the SIMDIVE staged schedule moves through the deeper stages a few minutes slower than does the standard table, it suggests that less time is needed at the 10-ft stage and that the diver could surface about 20 min sooner Use of the continuous schedule would save another 20 min in this dive

In Figure 3 a schedule for ascent as computed by the SIMDIVE method is compared with the schedule given in the diving manual table for ex-

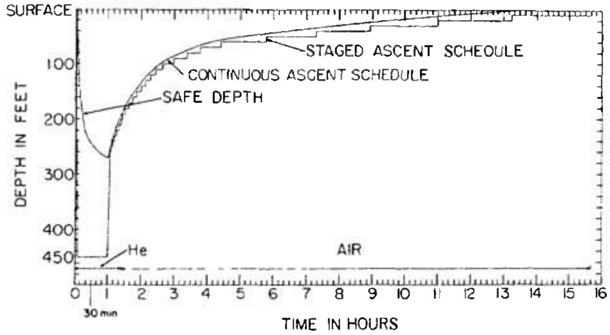

Figure 1 Comparison of staged and continuous ascent schedules, both as calculated by SIMDIVE for a helium dive to 450 ft for 60 min

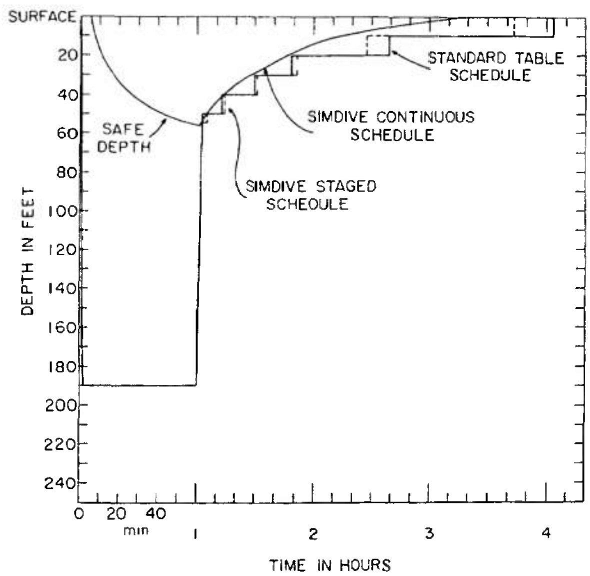

Figure 2 Comparison of staged and continuous schedules calculated by SIMDIVE with the staged schedule from the standard tables for a dive to 190 ft for 60 min on air

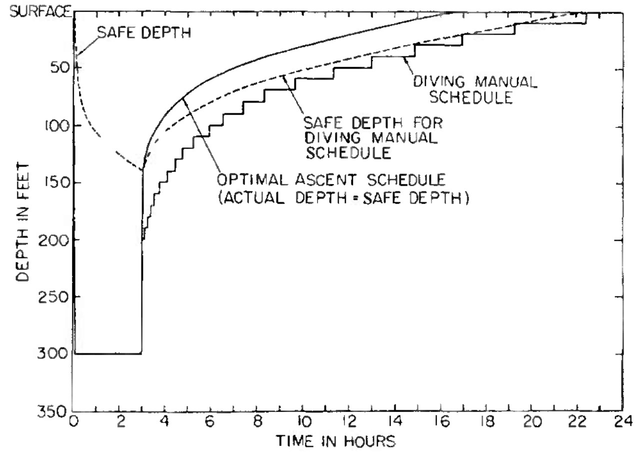

Figure 3 Comparison of continuous ascent schedule calculated by SIMDIVE with the corresponding schedule from the diving manual for a dive to 300 ft for 180 min on air

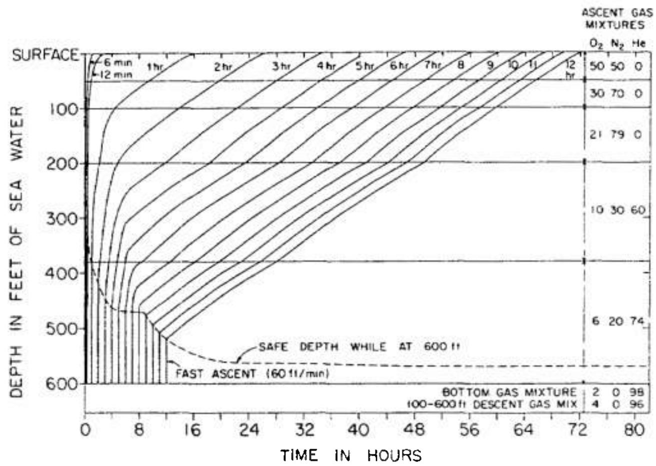

Figure 4 Continuous ascent schedules for mixed gas dives to 600 ft

treme exposures[3, p 103] for decompression following an air dive to 300 ft for 3 hr Here it is seen that for the shallow stages the safe depth as calculated by the present method, and assuming that the diving manual schedule is being followed, is in close agreement with the depths prescribed in the standard tables However, there is a large difference at the deep stages Thus the difference between the two schedules is due more to the different relationship assumed between tissue tension and the safe depth for the deep stages than to the difference between staged and continuous ascent schedules

Figure 4 shows a family of continuous ascent schedule curves for dives to 600 ft for various bottom times ranging from 6 min to 12 hr The gas mixtures used are tabulated at the right-hand side of the graph Changes in the gas mixtures account for some of the sharp changes in slope, while change of critical tissue accounts for others As the 240-min half-time tissue becomes more nearly saturated, it becomes the critical tissue earlier in ascent After about 20 hr bottom time, further increases in bottom time do not increase the ascent times

DISCUSSION

The above derivations provide the formulas needed for producing any desired decompression schedule, either with staged ascent or with a continuous ascent in which the actual depth is kept equal to the minimum safe depth at all times after an initial fast ascent to the safe depth, with the assumption that the safe total inert gas partial pressure in the critical tissue is linearly related to the depth according to Eq (5) If some other relationship is required, the formulas will have to be modified accordingly Other possible improvements include increasing the number of tissues considered, or even using a continuous spectrum of gas exchange half-times Either of these changes would produce a somewhat smoother schedule than does the present method, in which the rate changes abruptly when the critical tissue changes

The schedules produced by the present method are optimal in the sense that they lead to the shortest possible decompression schedules consistent with the assumptions made concerning the relationship between tissue tension and safe depth However, until any differences in schedules suggested by this method have been carefully tested with real ascents, they canot be recommended for use in practice

The practical difficulties involved in executing a complicated schedule approximating the optimal one is recognized Analogue computer methods[9,10] are being developed that may eventually automate the controls and make any desired schedule feasible

The principal value of the continuous ascent schedules at present is to indicate the areas in which improvements over the present schedules may or may not be expected to be possible The program can also be used to analyze given dive schedules and may be of use in pinpointing the reason if bends result during an actual dive

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APPENDIX A

Principal Variables Used in SIMDIVE and Subroutines, in Order of First Use

Variable	Input format	Explanation
		Program SIMDIVE
LDIVE		Serial number of dive in this run
K	I2	Determines type of run ($K=12$, descent with new parameters, $K=10$, 11, ascent with new parameters, $K=2$, descent with former parameters, $K=0$, 1, ascent with former parameters)
HEAD(7)	7A10	Dive identification
H(9)	9F8 0	Half-times in minutes for nine tissues
AC(9)	9F8 0	Slope of curve relating safe tension to depth
AK(9)	9F8 0	Safe total inert gas partial pressures in tissues, in feet of sea water
DKCON(9)		$\lambda(J)=\log_e 2/H(J)$
GMIX(4, 10)	2F8 2	Fractional partial pressures of nitrogen and helium for 10 mixtures (total inert $=N_2+He$, $O_2=1-$ total inert)
FGMIX(3, 10)		Ratio of individual inert gas to total inert gas
T(200)	F8 2	T(1) = starting time, in minutes
DEPTH(200)	F8 2	DEPTH(1) = starting gauge depth in feet of sea water
MAXDEEP	I5	Maximum depth to be shown on graph
RATE	F8 0	Maximum rate of ascent
Q(9, 3)	9F8 4	Total inert, nitrogen, and helium partial pressures (absolute) in nine tissues, in feet of sea water

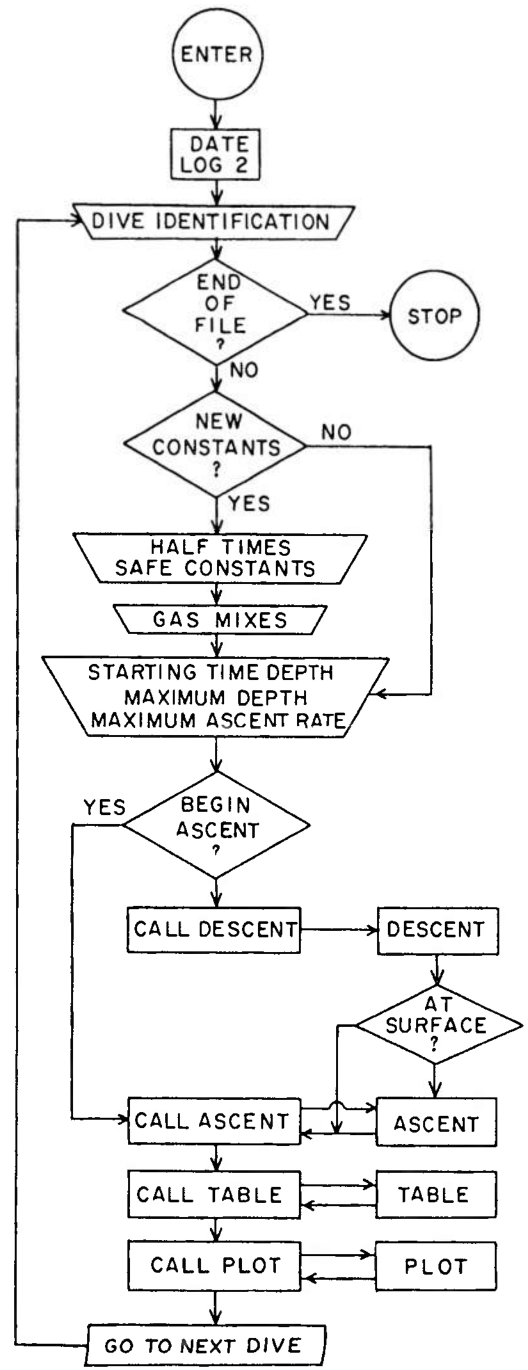
Variable	Input format	Explanation
		Subroutine DESCENT
NEND	A3	Signal for end of descent data
THOUR	F5 0	Hours component of step time
TMIN	F4 2	Minutes component of step time
DEPTH(200)	F8 0	Gauge depth for step, in feet of sea water
KG(200)	I5	Index number identifying gas mix for step
DTIME(200)		Time interval for step, in minutes
SAFEQ(9)		Safe total inert gas tension, in feet of sea water
DD		Change in depth during step, in feet of sea water
RATE2		Average rate of change of depth for step, in ft/min
SAFED(9)		Safe depth (gauge) for total inert gas tension in tissues
		Subroutine ASCENT
STIME		Starting time of ascent, in minutes
CUTIME		Accumulated ascent time
BLIM		Next depth boundary for change of gas mixture
DOD		Absolute external pressure (gauge depth + 33), in feet of sea water
DB		Distance from start of step to next BLIM
DEVEN		Distance from start of step to next even 10-ft level
PTI(9)		Provisional time of intersection of *J*th tissue with critical tissue safe depths
		Subroutine FASTRIZ
All variables defined above or by program statements		
		Subroutine PLOT
INDEX		Determines ordinate scale
JY(5)		Ordinate labels
ATIME		Time in minutes from T(1) to end of last step
TSCALE		Scaling factor for abscissa
POINT(101)		Ordinate location to be plotted
IPOINT(50)		POINT's actually used
KLS		Time in minutes for abscissal location *K*
		Subroutine TABLE
NTIME(4)		NTIME(1), (2), beginning step time in HR MIN NTIME(3), (4), end step time in HR MIN
		Subroutine TENSION
PPRES		Inert gas partial pressure in breathing gas mixture, in feet of sea water, absolute
PRDL		Correction for effect of ascent rate on dQ/dt

APPENDIX B

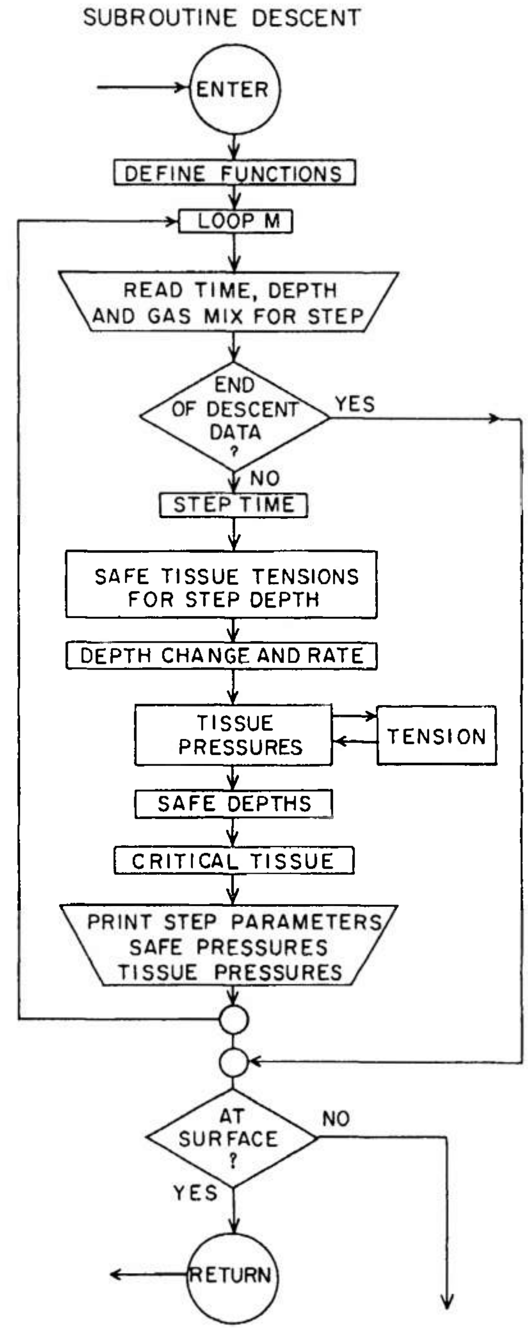
1 Listings and Logic Diagrams for Program SIMDIVE, Subroutine DESCENT, Subroutine ASCENT, Subroutine FASTRIZ, Subroutine PLOT, Subroutine TABLE, and Subroutine TENSION

```
      PROGRAM SIMDIVE(INPUT,OUTPUT,TAPE5=INPUT)
C     * * * * *                 6 OCTOBER 1967                * * * * *
      COMMON AC(9), AK(9), DEPTH(200), DKCON(9), DTIME(200),FGMIX(3,10),
     1  GMIX(4,10), H(9), HEAD(7), IPOINT(50), JY(5), KG(200),M,MAXDEEP,
     2  PTI(9), Q(9,3), RATE, RATE2, SAFED(9), SAFEQ(9), T(200)
      COMMON /START/ DLIM(5), LDIVE, K
      DATA DLIM/0.0, 50.0, 100.0, 200.0, 380.0 /
      DATA LDIVE/0/
   90 FORMAT(I2, 7A10)
   95 FORMAT(1H1   2X 11HDIVE NUMBER I4, 10X 7A10,  18X A9)
  100 FORMAT(16X, 2F8.2, I5, F8.0)
  101 FORMAT (8X 9F8.0)
  102 FORMAT(8X, 2F8.2)
  104 FORMAT (8X 9F8.4)
  115 FORMAT(4(/) 46X *HALF TIMES IN MINUTES FOR NINE TISSUES*/2X *H* 9X
     1  9F12.0//53X *TURNOVER RATE CONSTANTS*/2X *LAMBDA* 4X 9F12.6 //)
  116 FORMAT(25X,71HCONSTANTS RELATING SAFE DEPTH TO INERT GAS PARTIAL P
     1RESSURES IN TISSUES /3H AK,9X,9F12.4/3H AC,9X,9F12.4//)
C
      CALL DATE(DAY)
      ECON = ALOG(2.0)
    1 LDIVE = LDIVE + 1
      READ 90, K, HEAD
      IF(EOF,5)30, ,
    5 PRINT 95, LDIVE, HEAD, DAY
      IF(K .LT. 10)GO TO 4
      READ 101, H, AC, AK
      DO 6 J = 1,9
    6 DKCON(J) = ECON/H(J)
      PRINT 115, H, DKCON
      PRINT 116, AK, AC
      DO 3 J = 1, 10
      READ 102, (GMIX(I,J), I=3, 4)
      GMIX(2,J) = GMIX(3,J)+GMIX(4,J)
      GMIX(1,J) = 1.0-GMIX(2,J)
      IF(GMIX(2,J) .GT. 1.E-5) GO TO 35
      DO 34 I = 2,3
   34 FGMIX(I,J) = 0.0
   35 DO 3 I = 2, 3
    3 FGMIX(I,J) = GMIX(I+1,J)/GMIX(2,J)
    4 READ 100, T(1), DEPTH(1), MAXDEEP, RATE
      IF(MAXDEEP .EQ. 0) MAXDEEP = DEPTH(1)
      IF(RATE .EQ. 0.0) RATE = 60.
      READ 104, Q
      M = 1
      IF(MOD(K, 10) .LT. 2)GO TO 7
      CALL DESCENT
      GO TO 8
    7 CALL ASCENT
    8 PRINT 95, LDIVE, HEAD, DAY
      CALL TABLE
      PRINT 95, LDIVE, HEAD, DAY
      CALL PLOT
      GO TO 1
   30 STOP
      END
```

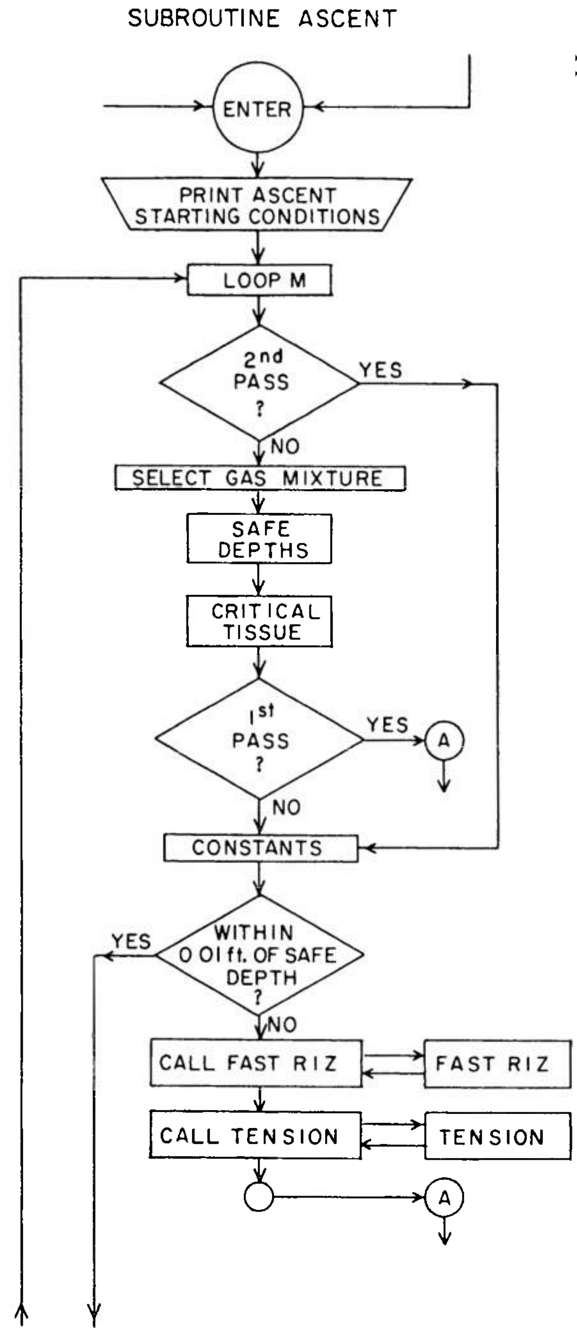
PROGRAM SIMDIVE



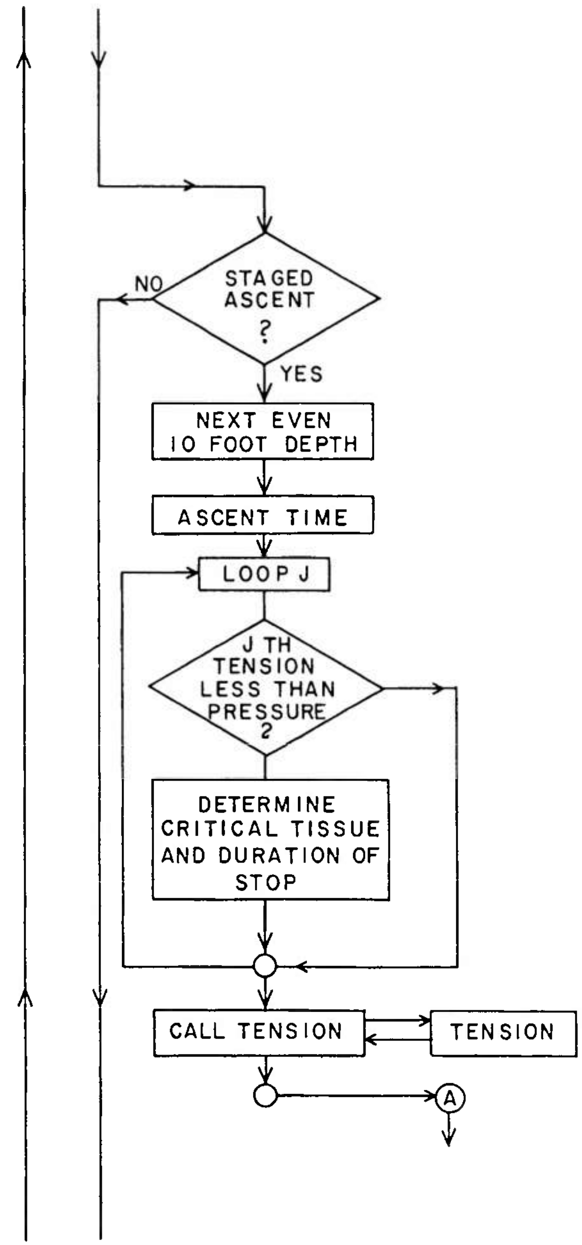
```
      SUBROUTINE DESCENT
C     * * * * *               6 OCTOBER 1967                    * * * * *
      COMMON AC(9), AK(9), DEPTH(200), DKCON(9), DTIME(200),FGMIX(3,10),
     1  GMIX(4,10), H(9), HEAD(7), IPOINT(50), JY(5), KG(200),M,MAXDEEP,
     2  PTI(9), Q(9,3), RATE, RATE2, SAFED(9), SAFEQ(9), T(200)
      COMMON /START/ DLIM(5), LDIVE, K
      COMMON/FAST/ DB, DD, G, GD, L, MM
      DIMENSION IHDG(9), MARK(9), ISK(2)
      DATA IEND/3HEND/
      DATA IHDG/1,2,3,4,5,6,7,8,9/
      DATA MARK/9*1H  /, ISK/6H*** **, 1H /
  101 FORMAT(A3, F5.0, F4.2, F8.0, 25X, I5)
  104 FORMAT(54X,12HGAS MIXTURES //28X,6HOXYGEN, 6X,11HTOTAL INERT, 5X,8
     1HNITROGEN, 8X, 6HHELIUM, 6X, 6HNUMBER //
     2  4(19X 4F15.6, I8, F8.0, * TO* F4.0, * FEET*/),
     3     19X 4F15.6, 7X *5* 4X *DEEPER THAN* F4.0, * FEET*//
     4  39X, 24HMAXIMUM RATE OF ASCENT = , F6.2, 12H FEET/MINUTE ////)
  106 FORMAT(/ 107X * OXYGEN NITROGEN HELIUM*/1H  104X 3(5X *PCT*))
  107 FORMAT(1H+, 5X,4HDIVE,I4,3X,4HSTEP,I4,69X,11HGAS MIXTURE,2P3F8.1)
  108 FORMAT (35X,13HPRIOR DEPTH =,F8.2,4X,12HTHIS DEPTH =, F8.2//52X
     1*TISSUE PRESSURES*/1H+18X9A10/13X9I10/11X*SAFE* 9F10.2/4X 11HTOTAL
     2 INERT  9F10.2/7X 8HNITROGEN  9F10.2/9X  6HHELIUM   9F10.2/)
  114 FORMAT(1H1)
  115 FORMAT(///45X *STARTING CONDITIONS FOR ASCENT*///)
  118 FORMAT(* STEP TIME =* F7.3, * MIN* 5X *ASCENT TIME =* F8.2, * MIN*
     1 5X *TOTAL DIVE TIME =* F5.0, * MIN* 5X *ASCENT RATE =* F7.3, * FT
     2/MIN*/)
 2118 FORMAT(10X *STEP TIME =*F7.1,* MIN* 6X    *DIVE TIME =*F4.0,* HR *
     1 F4.1, * MIN* 10X *RATE =* F8.3, * FT/MIN     SAFE DEPTH = * F8.2,
     2  * FEET*)
  120 FORMAT(13(4H ***) 12H END OF DIVE 13(4H ***))
      DDSLOW(A,B,DT) = A*(1.0-EXP(-B*DT))
      DTSLOW(DD,A,B) = ALOG(1.0-DD/A)/(-B)
C     ***DESCENT ASSUMES CONSTANT OR ZERO RATE FOR EACH STAGE ***
C     ***DESCENT MAY BE USED FOR ASCENT WITH KNOWN PARAMETERS ***
      DO 600 M = 2, 200
      MM = M - 1
      M2 = M - 2
      READ 101, NEND, THOUR, TMIN, DEPTH(M), KG(M)
      IF(NEND .EQ. IEND)GO TO 610
      KK = KG(M)
      T(M) = THOUR*60. + TMIN
      DTIME(M) = T(M) - T(MM)
      DO 521 J = 1,9
  521 SAFEQ(J) = AK(J) + AC(J)*DEPTH(M)
      IF(DTIME(M) .EQ.  0.0)510, 520
  510 DD = 0.
      RATE2 = 0.
      GO TO 523
  520 DD = DEPTH(MM) - DEPTH(M)
      RATE2 = DD/DTIME(M)
      CALL TENSION
  523 L = 1
      DO 525 J = 1,9
      SAFED(J) = (Q(J,1) - AK(J))/ AC(J)
      IF(SAFED(J) .GE. SAFED(L) - 0.01) L = J
  525 CONTINUE
      IF(MOD(M2,4) .EQ. 3) PRINT 114
      PRINT 106
      PRINT 107, LDIVE, M2, GMIX(1, KK), (GMIX(J,KK), J = 3,4)
      MARK(L) = ISK(1)
```



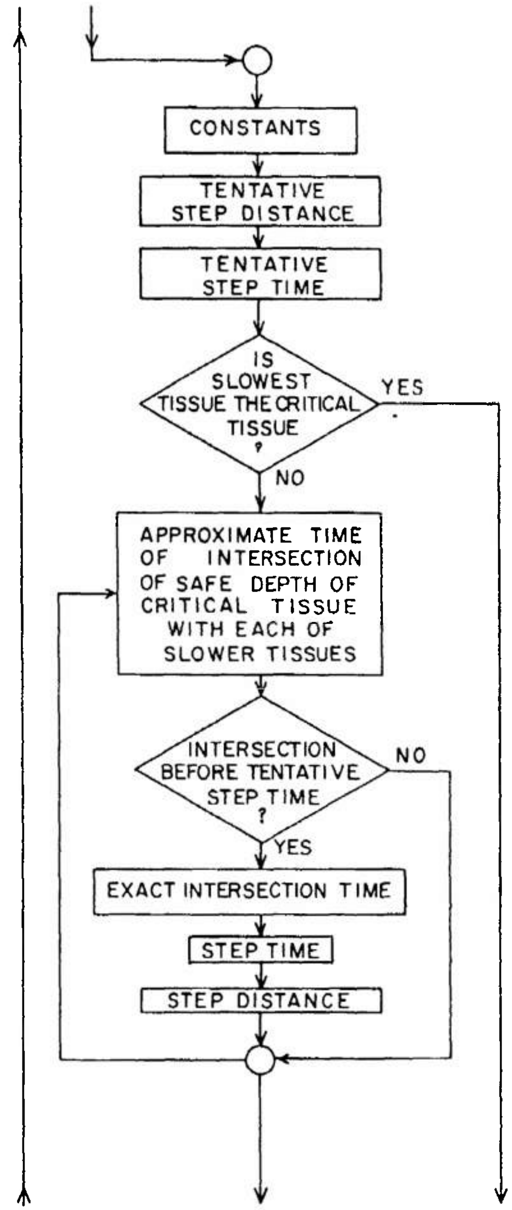
```
      PRINT 108, OEPTH(MM), OEPTH(M), MARK, IHDG, SAFEO, Q              OCENT 62
      MARK(L) = ISK(2)                                                  DCENT 63
      PRINT 2118, DTIME(M), THOUR, TMIN, RATE2, SAFEO(L)                DCENT 64
  600 CONTINUE                                                          DCENT 65
  610 M = MM                                                            OCENT 66
      IF(OEPTH(M) .LE. 0.0) 20,630                                      OCENT 67
  630 PRINT 114                                                         OCENT 68
C     * * * * *                END DESCENT                  * * * * *DCENT 69
C     * * * * *                BEGIN ASCENT                 * * * * *ACENT001
C     * *   ASCENT COMPUTES CONTINUOUS RATES OF ASCENT, MAINTAINING  * *ACENT002
C     * *   MINIMUM SAFE OEPTH.   IT ASSUMES EITHER A MAIN PROGRAM   * *ACENT003
C     * * GIVING TISSUE PRESSURES AT BOTTOM OEPTH OR PRIOR EXECUTION * *ACENT004
C     * * OF SUBROUTINE DESCENT.                                     * *ACENT005
      ENTRY ASCENT                                                      ACENT006
      STIME = T(M)                                                      ACENT007
      CUTIME = 0.                                                       ACENT008
      RATE2 = 0.                                                        ACENT009
      PRINT 115                                                         ACENT010
      PRINT 104,((GMIX(I,J),I=1,4), J, DLIM(J+1), OLIM(J), J=1,4),      ACENT011
     1  (GMIX(I,5),I = 1,4), DLIM(5), RATE                              ACENT012
      L = 1                                                             ACENT013
      NNN = M + 1                                                       ACENT014
      OTIME(NNN) = 0.0                                                  ACENT015
      OD = 0.                                                           ACENT016
C                              BEGIN MAIN LOOP                          ACENT017
      DO 190 M=NNN,200                                                  ACENT018
      MM = M - 1                                                        ACENT019
      M2 = M - 2                                                        ACENT020
      IF(M .EQ. NNN+1) 2,3                                              ACENT021
    2 KG(M) = KG(MM)                                                    ACENT022
      GO TO 8                                                           ACENT023
C                             SELECT GAS MIXTURE                        ACENT024
    3 DO 4 KK = 1,4                                                     ACENT025
      IF(OEPTH(MM) .GT. OLIM(KK+1)) 4,5                                 ACENT026
    4 CONTINUE                                                          ACENT027
      KK = 5                                                            ACENT028
    5 BLIM = DLIM(KK)                                                   ACENT029
      KG(M) = KK                                                        ACENT030
C                  OETERMINE SAFE DEPTH FOR EACH TISSUE                 ACENT031
C                        DETERMINE CRITICAL TISSUE                      ACENT032
      SAFEO(L) = (O(L,1)-AK(L))/AC(L)                                   ACENT033
      OO 7  J = 1,9                                                     ACENT034
      SAFEO(J) = (O(J,1)-AK(J))/AC(J)                                   ACENT035
      IF(SAFED(J) .GE. SAFEO(L) - .01) L = J                            ACENT036
    7 CONTINUE                                                          ACENT037
      LL = L                                                            ACENT038
      IF(M .EQ. NNN)GO TO 180                                           ACENT039
    8 DOO = OEPTH(M,I) + 33.                                            ACENT040
      G = GMIX(2,KK)                                                    ACENT041
      GD = G * DOD                                                      ACENT042
      DB = DEPTH(MM) - BLIM                                             ACENT043
      DEVEN = AMOD(DEPTH(MM), 10.)                                      ACENT044
      IF(OEVEN .LT. 0.01)DEVEN = OEVEN + 10.                            ACENT045
      DD = DEPTH(MM) - SAFEO(L)                                         ACENT046
      IF(OO .LT. 0.01) GO TO 292                                        ACENT047
C                               FAST ASCENT                             ACENT048
      CALL FASTRIZ                                                      ACENT049
      CALL TENSION                                                      ACENT050
      GO TO 180                                                         ACENT051
  292 IF(MOO(K,10) .LT. 3) GO TO 295                                    ACENT052
```



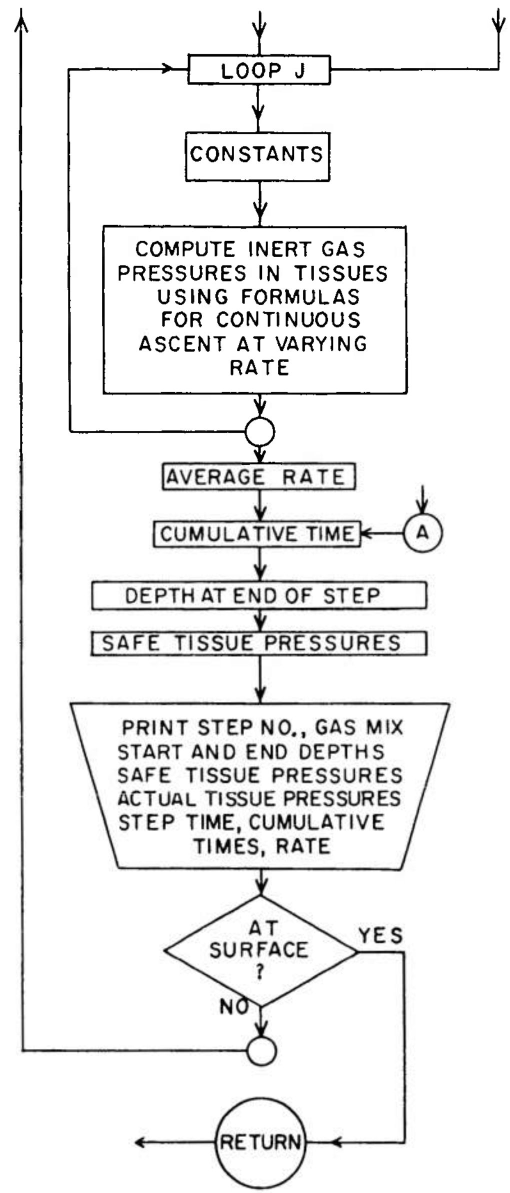
```
C      * * * * *             OPTION FOR STAGED ASCENT              * * * * *ACENT053
  293 DD = 0.                                                           ACENT054
      RATE2 = 0.                                                        ACENT055
      DNEXT = DEPTH(MM) - DEVEN                                         ACENT056
      DFT = DEVEN/RATE                                                  ACENT057
      DTIME(M) = 1.0                                                    ACENT058
      DO 294 J = L, 9                                                   ACENT059
      IF(Q(J,1) .LE. GD) GO TO 294                                      ACENT060
      QNEXT = AK(J) + DNEXT * AC(J)                                     ACENT061
      GRD = G * RATE/DKCON(J)                                           ACENT062
      DKT = DKCON(J) * DFT                                              ACENT063
      QSL = GRD + (QNEXT -  GD + GRD*(DKT-1.))*EXP(DKT)                 ACENT064
      TNEXT = ALOG((Q(J,1) - GD)/QSL)/DKCON(J)                          ACENT065
      IF(TNEXT .LT. DTIME(M)) GO TO 294                                 ACENT066
      DTIME(M) = TNEXT                                                  ACENT067
      LL = J                                                            ACENT068
  294 CONTINUE                                                          ACENT069
      IF(DTIME(M) .GT. 300.) DTIME(M) = 300.                            ACENT070
      CALL TENSION                                                      ACENT071
      GO TO 180                                                         ACENT072
```



```
C                                BEGIN SLOW ASCENT
  295 CONONE = 1./(AC(L) - G)
      DKL = DKCON(L)/AC(L)
      CONL1 = DKL * (AC(L) - G)
      QGL = Q(L,1) - GD
      CON4 = QGL * CONONE
      CON2 = CON4 * G
      CON3 = GD - CON2
      DD = AMIN1(DB, AMAX1(DDSLOW(CON4, CONL1, 1.), DEVEN))
      DTIME = DTSLOW(DD, CON4, CONL1)
C                TEST FOR CROSSOVER TO NEW CRITICAL TISSUE
      IF(L .EQ. 9)GO TO 315
      RATE4 = QGL*DKL
      LJ = L + 1
      DO 313 J = LJ, 9
      DKJ = DKCON( J)/AC( J)
      Z1 = DEPTH(MM) - SAFED( J)
      PTI = Z1 / (RATE4 - (Q(J,1) - GD) * DKJ)
      IF(PTI .GE. DTIME) GO TO 313
      LL = J
      Z1 = Z1 * AC( J)
      Z3 = Q( J,1) - CON3
      Z4 = CON2 * DKCON(J)
      Z5 = CON4*AC( J)
      TEST = DKCON( J)- CONL1
      IF(ABS(TEST) .GT. 1.E-6) GO TO 309
      DO 308 KM = 1,5
      EXP2 = EXP(-DKCON( J)*PTI)
  308 PTI = PTI-((Z5-Z3)-((Z5-Z3)-Z4*PTI)*EXP2-Z1)/((CONL1*(Z5-Z3) +
     1    Z4*(1.-CONL1*PTI)) * EXP2)
      GO TO 311
  309 Z4 = Z4/TEST
      DO 310 KM = 1,5
      EXP1 = EXP(-CONL1*PTI)
      EXP2 = EXP(-DKCON( J)*PTI)
  310 PTI = PTI+(Z5-Z3+(Z4-Z5)*EXP1+(Z3-Z4)*EXP2-Z1)/(CONL1*(Z4-Z5)*EXP1
     1  + DKCON( J) *(Z3-Z4)*EXP2)
  311 DTIME = AMIN1(DTIME, PTI)
      DD = DDSLOW(CON4, CONL1, DTIME)
  313 CONTINUE
C                     COMPUTE INERT GAS PRESSURES IN TISSUES
  315 DO 98 J = 1, 9
      EXPO = DKCON(J)*DTIME
      EXP2 = EXP(-EXPO)
      TEST = DKCON(J) - CONL1
      IF(ABS(TEST) .GT. 1.0E-6) GO TO 319
      CON8 = EXPO * CON2
      Q(J,1) = CON3 + (Q(J,1) - CON3 + CON8) * EXP2
      DO 318 I = 2,3
      CON9 = FGMIX(I,KK) * CON3
  318 Q(J,I) = CON9 + (Q(J,I)-CON9+FGMIX(I,KK)*CON8)*EXP2
      GO TO 98
  319 CON5 = DKCON(J) * CON2 / TEST
      CON6 = CON3 + CON5*EXP(-CONL1*DTIME)
      CON7 = CON3 + CON5
      Q(J,1) = CON6 + (Q(J,1) -CON7)*EXP2
      DO 98 I = 2,3
      Q(J,I) = FGMIX(I,KK)*CON6 + (Q(J,I)-FGMIX(I,KK)*CON7)*EXP2
   98 CONTINUE
      RATE2 = DD/DTIME
      DTIME(M) = DTIME
```

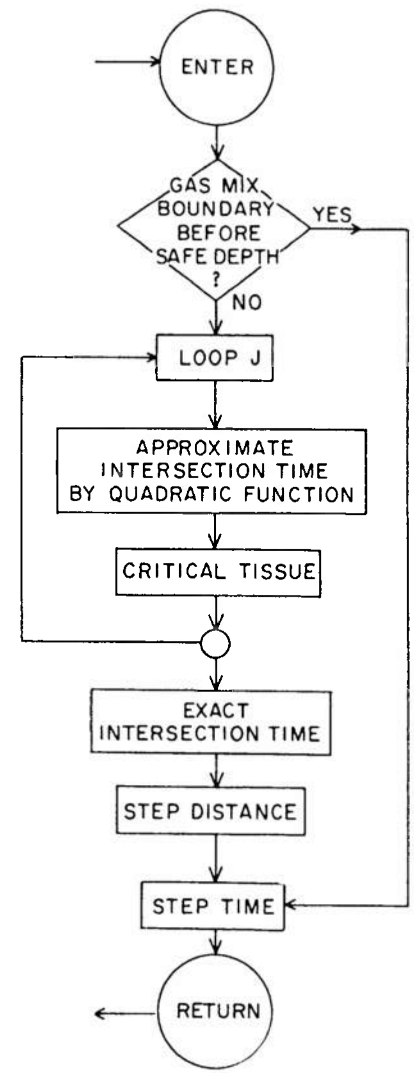


```
180 CUTIME = CUTIME + DTIME(M)                                  ACENT134
    T(M) = CUTIME + STIME                                       ACENT135
    DEPTH(M) = DEPTH(MM) - DD                                   ACENT136
    DO80 J=1,9                                                  ACENT137
 80 SAFEQ(J) = AK(J)+AC(J)*DEPTH(M)                             ACENT138
    IF(MOD(M-NNN, 4) .EQ. 1) PRINT 114                          ACENT139
    PRINT 106                                                   ACENT140
    PRINT 107, LDIVE, M2, GMIX(1, KK), (GMIX(J,KK), J = 3,4)    ACENT141
    MARK(LL) = ISK(1)                                           ACENT142
    MARK(L) = ISK(1)                                            ACENT143
    PRINT 108, DEPTH(MM), DEPTH(M), MARK, IHDG, SAFEQ, Q        ACENT144
    MARK(LL) = ISK(2)                                           ACENT145
    MARK(L) = ISK(2)                                            ACENT146
    PRINT 118, DTIME(M), CUTIME, T(M), RATE2                    ACENT147
    IF(DEPTH(M) .LT. 0.005) GO TO 20                            ACENT148
190 CONTINUE                                                    ACENT149
    M=MM+1                                                      ACENT150
 20 PRINT  120                                                  ACENT151
    RETURN                                                      ACENT152
    END                                                         ACENT153
```

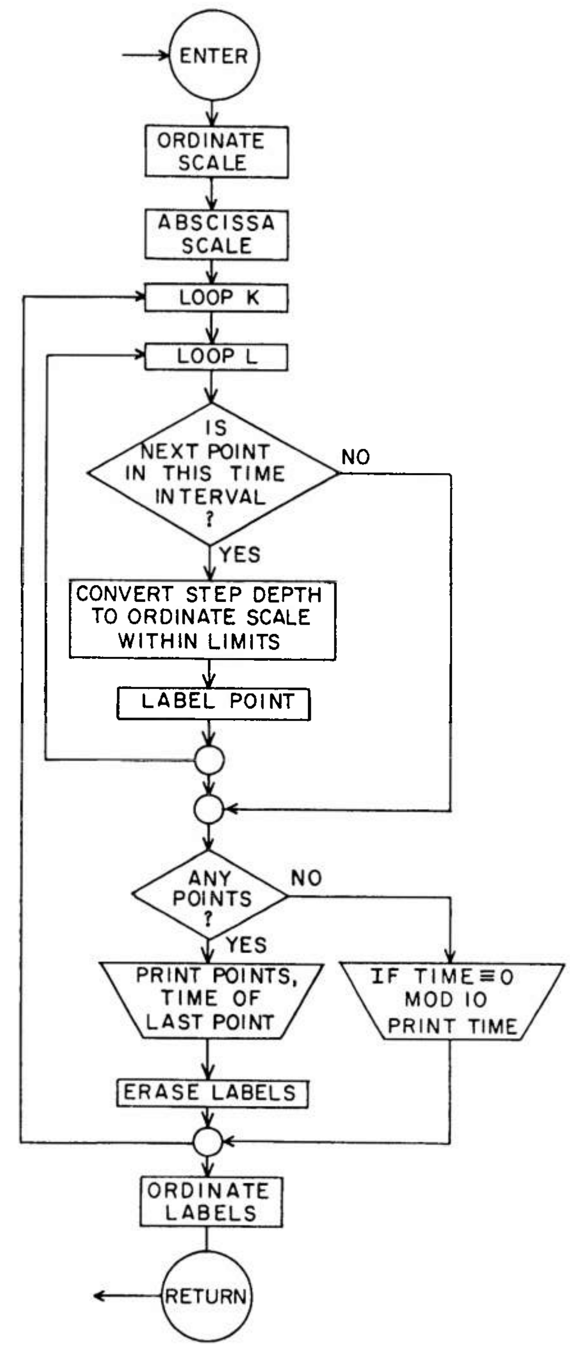


```
      SUBROUTINE FASTRIZ                                                FAST  D1
C     * * * * *                 5 SEPTEMBER 1967               * * * * *FAST  02
      COMMON AC(9), AK(9), DEPTH(2DD), DKCON(9), DTIME(20D),FGMIX(3,10),FAST  D3
     1  GMIX(4,10), H(9), HEAD(7), IPOINT(5D), JY(5), KG(2DD),M,MAXDEEP,FAST  04
     2  PTI(9), O(9,3), RATE, RATE2, SAFED(9), SAFEO(9), T(200)         FAST  D5
      COMMON/FAST/ DB, DD, G, GD, L, MM                                 FAST  D6
      ROOT1(AX2, B, C) = (2.*C)/(-B-SQRT(B*B - AX2*(2.*C)))             FAST  07
      RATE2 = RATE                                                      FAST  D8
      IF(DD .LT. DB) GO TO 9                                            FAST  D9
      DD = DB                                                           FAST  10
      GO TO 92                                                          FAST  11
    9 DO 91 J = L, 9                                                    FAST  12
      QGD = (Q(J,1)-GD)*DKCON(J)                                        FAST  13
      AX2 = (OGD - G*RATE)*DKCDN(J)                                     FAST  14
      B = RATE*AC(J) - QGD                                              FAST  15
      PTI(J) = ROOT1(AX2, B, (SAFED(J)-DEPTH(MM))*AC(J))                FAST  16
      IF(PTI(J) .LE. PTI(L))L=J                                         FAST  17
   91 CONTINUE                                                          FAST  18
      DDA = (DEPTH( )M)-SAFED(L))*AC(L)                                 FAST  19
      R1 = RATE*(G-AC(L))                                               FAST  20
      R2 = Q(L,1) - GD - G*RATE/DKCON(L)                                FAST  21
      DO 911 KR = 1,5                                                   FAST  22
      R3 = R2*EXP(-DKCON(L)*PTI(L))                                     FAST  23
  911 PTI(L) = PTI(L)-(DDA+R1*PTI(L)+R2-R3)/(R1+R3*DKCON(L))            FAST  24
      DD = AMIN1(PTI(L)*RATE, DB)                                       FAST  25
   92 DTIME(M) = DD / RATE                                              FAST  26
      RETURN                                                            FAST  27
      END                                                               FAST  28
```

SUBROUTINE FASTRIZ

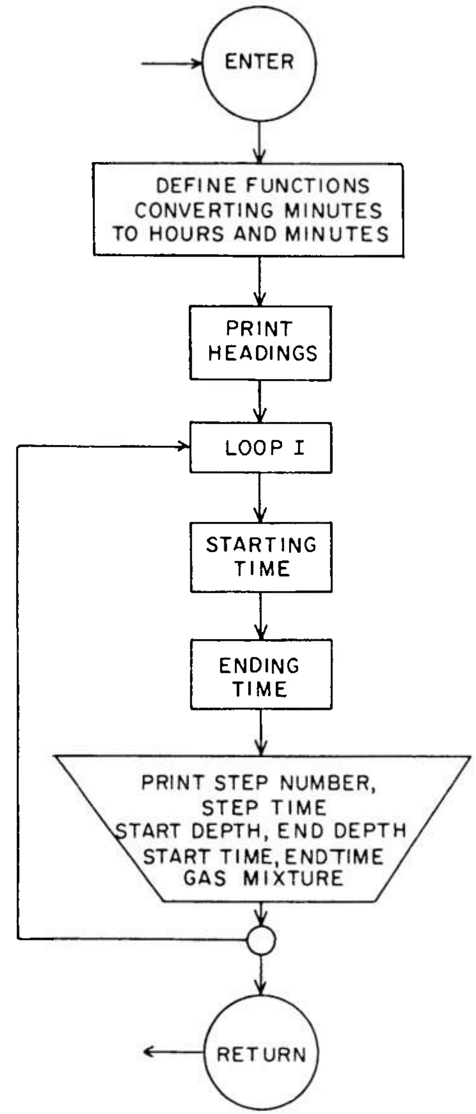


SUBROUTINE PLOT




```
      SUBROUTINE PLOT
C     * * * * *                15 AUGUST 1967                * * * * *
      COMMON AC(9), AK(9), DEPTH(200), DKCON(9), DTIME(200),FGMIX(3,10),
     1  GMIX(4,10), H(9), HEAD(7), IPOINT(50), JY(5), KG(200),M,MAXDEEP,
     2  PTI(9), Q(9,3), RATE, RATE2, SAFED(9), SAFEQ(9), T(200)
      COMMON /KPLOT/ POINT(101), SCALE(5), SLIM(4), TAB(2)
      DATA POINT/101(1H )/
      DATA SCALE/1.0,2.0,5.0,10.0,20.0/, SLIM/120., 240., 600., 1200./
      DATA TAB/1H*,1H /
 1003 FORMAT(1H+, 13X, 103(1H-)/15X,1HI,4(24X,1HI))
 1005 FORMAT(5X,F8.2,2H I,101A1,1HI)
 1007 FORMAT(6X, I4, 4X 1HI, 101X, 1HI)
 1008 FORMAT(13X,2H I,101X,1HI)
 1023 FORMAT(/8H    TIME, 50X, 13HDEPTH IN FEET / 11H IN MINUTES )
 1024 FORMAT(14X,I3,3(22X,I3),23X11)
 1100 FORMAT(/58X, 13HDEPTH IN FEET )
      IF(DEPTH(M) .LT. 0.0) DEPTH(M)=0.0
      INDEX = (MAXDEEP + 99)/100
      DO 2 I = 1,5
    2 JY(I) = INDEX*25*(5-I)
      PRINT 1023
      PRINT 1024,JY
      PRINT 1003
      ATIME = T(M) - T(1)
      DO 3 IS = 1,4
      IF(ATIME .LE. SLIM(IS))4, 3
    3 CONTINUE
      IS = 5
    4 TSCALE = 1.0/SCALE(IS)
      KMAX = INT(ATIME*TSCALE+1.5)
      ISCALE = INT(SCALE(IS))
      N=1
      DO 9  K = 1, KMAX
      KL = K-1
      KF = 1
      KP = 0
      DO 37 L=N,M
      IF(INT((T(L) - T(1))*TSCALE+0.5) .GT. KL ) GO TO 38
      KP = KP+1
      N=L
      I = MAX0(1, MIN0(101-INT(DEPTH(L)+0.5)/INDEX, 101))
      POINT(I) = TAB(1)
      IPOINT(KP) = I
      KF = 2
   37 CONTINUE
   38 GO TO (6,5),KF
    5 PRINT 1005,T(N),POINT
      DO 51 L = 1, KP
      I=IPOINT(L)
   51 POINT(I) = TAB(2)
      N = N + 1
      GO TO 9
    6 KLS = KL*ISCALE + INT(T(1) + .5)
      IF(MOD(KLS, 10) .NE. 0) GO TO 8
      PRINT 1007,KLS
      GO TO 9
    8 PRINT 1008
    9 CONTINUE
      PRINT 1003
      PRINT 1024, JY
      PRINT 1100
      RETURN
      END
```

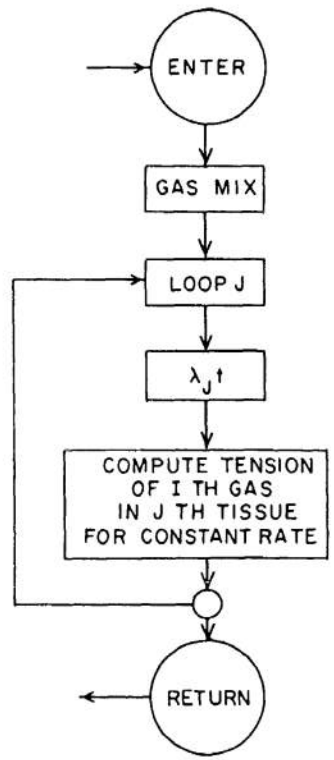
SUBROUTINE TABLE




```
      SUBROUTINE TABLE                                                  TABLE 01
C     * * * * *               15 AUGUST 1967                 * * * * *TABLE 02
      COMMON AC(9), AK(9), DEPTH(200), OKCON(9), DTIME(200),FGMIX(3,10),TABLE 03
     1  GMIX(4,10), H(9), HEAO(7), IPOINT(50), JY(5), KG(200),M,MAXOEEP,TABLE 04
     2  PTI(9), Q(9,3), RATE, RATE2, SAFED(9), SAFEQ(9), T(200)         TABLE 05
      DIMENSION NTI 1E(4)                                               TABLE 06
 1002 FORMAT(////3X *STEP* 3X *STEP TIME* 6X*DEPTH* 10X *CUMULATIVE TIMETABLE 07
     1* 10X *OXYGEN NITROGEN HELIUM*/13X *MIN* 10X *FEET* 11X *H  M* 5X TABLE 08
     2 *H  M* 8X 3(5X *PCT*)/)                                          TABLE 09
 1003 FORMAT(1H I5,2F10.0,* -* F4.0,I10,*9*I2,* -* I4,*9*I2, 8X2P 3F8.1)TABLE 10
      NHR(IMIN) = IMIN/60                                               TABLE 11
      NMN(IMIN) = MOO(IMIN,60)                                          TABLE 12
      NTIME(3)=NHR(INT(T(1)))                                           TABLE 13
      NTIME(4)=NMN(INT(T(1)))                                           TABLE 14
      PRINT 1002                                                        TABLE 15
      OO 100 I=2,M                                                      TABLE 16
      II=I-1                                                            TABLE 17
      M2 = I - 2                                                        TABLE 18
      KK = KG(I)                                                        TABLE 19
      NTIME(1)=NTIME(3)                                                 TABLE 20
      NTIME(2)=NTIME(4)                                                 TABLE 21
      INTT=INT(T(I))                                                    TABLE 22
      NTIME(3)=NHR(INTT)                                                TABLE 23
      NTIME(4)=NMN(INTT)                                                TABLE 24
      PRINT 1003, m2, OTImE(I), OEPTH(II), DEPTH(I), NTIME, GMIX(1,KK), TABLE 25
     1  (GMIX(J,KK), J=3,4)                                             TABLE 26
  100 CONTINUE                                                          TABLE 27
      RETURN                                                            TABLE 28
      END                                                               TABLE 29
```

```
      SUBROUTINE TENSION                                                TENSN 01
C     * * * * *             15 AUGUST 1967                   * * * * *TENSN 02
      COMMON AC(9), AK(9), DEPTH(200), DKCON(9), DTIME(200),FGMIX(3,10),TENSN 03
     1  GMIX(4,10), H(9), HEAD(7), IPOINT(50), JY(5), KG(200),M,MAXDEEP,TENSN 04
     2  PTI(9), Q(9,3), RATE, RATE2, SAFED(9), SAFEQ(9), T(200)         TENSN 05
      QPRES(A,B,C,D) = A-B*(C-1.) + (D-A-B)*EXP(-C)                     TENSN 06
      KK = KG(M)                                                        TENSN 07
      DO 19 J=1,9                                                       TENSN 08
      EFACT = DKCON(J)*DTIME(M)                                         TENSN 09
      RDK = RATE2/DKCON(J)                                              TENSN 10
      DO 18 I=3,4                                                       TENSN 11
      PPRES = GMIX(I,KK)*(DEPTH(M-1) + 33.0)                            TENSN 12
      PRDL = GMIX(I,KK) * RDK                                           TENSN 13
   18 Q(J,I-1) = QPRES(PPRES, PRDL, EFACT, Q(J,I-1))                    TENSN 14
   19 Q(J,1) = Q(J,2) + Q(J,3)                                          TENSN 15
      RETURN                                                            TENSN 16
      END                                                               TENSN 17
```

SUBROUTINE TENSION



2. Data Deck for the 450-Foot, 60-Minute Dive Presented in Appendix C

```
                  S A M P L E     D A T A     D E C K

                                                                                                      Where     Format
                                                                                                      Read    Identifier        Remarks
12  * * * * DIVE TO 450 FEET FOR 60 MINUTES. CONTINUOUS ASCENT * * * * *                             SIMDIVE     90     K=12, Alphanumeric Identification
 H TIME        5       10       20       40       80      120      160      200      240             SIMDIVE    101     Half-times in minutes
 HE AC       1.5      1.4      1.3      1.2      1.2      1.2      1.1      1.0      1.0             SIMDIVE    101     Slope constants for Helium
 HE AK        86       74       66       60       56       54       54       53       53             SIMDIVE    101     Safe Surface tensions for Helium
          .79018  .0
          .79018  .0                                                                                                         Gas mixtures
          .79018  .0                                                                                                       Nitrogen Helium
          .0      .96                                                                                SIMDIVE    102     First five used in ASCENT
          .0      .96                                                                                                   according to DLIM boundaries
          .79018  .0                                                                                                    All 10 may be used in DESCENT
          .0      .96
          .0      .0
          .0      .0
          .0      .0
                  0.00     0.00    450                                                               SIMDIVE    100     Start time, depth, MAXDEEP
TOTAL     260759  260759  260759  260759  260759  260759  260759  260759  260759                     SIMDIVE    104     Partial pressures in tissues at
NITROGEN  260759  260759  260759  260759  260759  260759  260759  260759  260759                                        start of dive (Air)
HELIUM       0       0       0       0       0       0       0       0       0
      0                   7902                       6                       1
      0001        75      7902                       6                       2
      0002        150              92                7                       3                       DESCENT    101     TIME, DEPTH and Gas mixture
      0003        250              92                7                       4                                          number for each step
      0004        350              92                7                       5
      0005        450              92                7                       6
      0100        450              92                7                       7                       DESCENT    101     Signals end of DESCENT
END
```

APPENDIX C

Computer Output for 450-Foot, 60-Minute Dive, With Ascent by the Continuous Method

The first 6 steps are produced by the DESCENT subroutine The 7th step indicates the diver's tissue inert gas partial pressure status at the beginning of ascent During the fast rise there is a "stop" at 380 ft because this is entered as a gas mixture boundary (Actually in this dive the gas mixture does not change, and the stop is unnecessary) From the 10th step to the time of surfacing on the 42nd step ASCENT uses the continuous ascent method, with the ascent rate governed by the rate of change of the safe depth The rate printed out for each step is the mean ascent rate for that step

DIVE NUMBER 1 * * * * DIVE TO 450 FEET FOR 60 MINUTES, CONTINUOUS ASCENT * * * * * 03/01/68

HALF TIMES IN MINUTES FOR NINE TISSUES

H	5	10	20	40	80	120	160	200	240

TURNOVER RATE CONSTANTS

LAMBDA	,138629	,069315	,034657	,017329	,008664	,005776	,004332	,003466	,002888

CONSTANTS RELATING SAFE DEPTH TO INERT GAS PARTIAL PRESSURES IN TISSUES

AK	86,0000	74,0000	66,0000	60,0000	56,0000	54,0000	54,0000	53,0000	53,0000
AC	1,5000	1,4000	1,3000	1,2000	1,2000	1,2000	1,1000	1,0000	1,0000

DIVE 1 STEP 0 PRIOR DEPTH = 0,00 THIS DEPTH = 0,00 GAS MIXTURE: OXYGEN PCT 21,0 NITROGEN PCT 79,0 HELIUM PCT 0,0

TISSUE PRESSURES

	1	2	3	4	5	***6**	7	8	9
SAFE	86,00	74,00	66,00	60,00	56,00	54,00	54,00	53,00	53,00
TOTAL INERT	26,08	26,08	26,08	26,08	26,08	26,08	26,08	26,08	26,08
NITROGEN	26,08	26,08	26,08	26,08	26,08	26,08	26,08	26,08	26,08
HELIUM	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

STEP TIME = 0,0 MIN DIVE TIME = 0 HR 0,0 MIN RATE = 0,000 FT/MIN SAFE DEPTH = -23,27 FEET

DIVE 1 STEP 1 PRIOR DEPTH = 0,00 THIS DEPTH = 75,00 GAS MIXTURE: OXYGEN PCT 21,0 NITROGEN PCT 79,0 HELIUM PCT 0,0

TISSUE PRESSURES

	1	2	3	4	5	***6**	7	8	9
SAFE	198,50	179,00	163,50	150,00	146,00	144,00	136,50	128,00	128,00
TOTAL INERT	30,00	28,08	27,09	26,59	26,33	26,25	26,20	26,18	26,16
NITROGEN	30,00	28,08	27,09	26,59	26,33	26,25	26,20	26,18	26,16
HELIUM	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

STEP TIME = 1,0 MIN DIVE TIME = 0 HR 1,0 MIN RATE = -75,000 FT/MIN SAFE DEPTH = -23,13 FEET

DIVE 1 STEP 2 PRIOR DEPTH = 75,00 THIS DEPTH = 150,00 GAS MIXTURE: OXYGEN PCT 4,0 NITROGEN PCT 0,0 HELIUM PCT 96,0

TISSUE PRESSURES

	1	2	3	4	5	***6**	7	8	9
SAFE	311,00	284,00	261,00	240,00	236,00	234,00	219,00	203,00	203,00
TOTAL INERT	44,31	35,58	30,93	28,53	27,31	26,90	26,69	26,57	26,49
NITROGEN	26,12	26,20	26,17	26,13	26,10	26,10	26,09	26,09	26,09
HELIUM	18,19	9,38	4,77	2,40	1,21	,80	,60	,48	,40

STEP TIME = 1,0 MIN DIVE TIME = 0 HR 2,0 MIN RATE = -75,000 FT/MIN SAFE DEPTH = -22,58 FEET

DIVE 1 STEP 3 PRIOR DEPTH = 150,00 THIS DEPTH = 250.00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
4,0	0,0	96,0

TISSUE PRESSURES

	***1**	2	3	4	5	6	7	8	9
SAFE	461,00	424,00	391,00	360,00	356,00	354,00	329,00	303,00	303,00
TOTAL INERT	67,67	48,22	37,51	31,89	29,00	28,03	27,55	27,25	27,06
NITROGEN	22,74	24,45	25,28	25,68	25,88	25,95	25,98	26,00	26,01
HELIUM	44,93	23,77	12,23	6,21	3,13	2,09	1,57	1,26	1,05

STEP TIME = 1,0 MIN DIVE TIME = 0 HR 3,0 MIN RATE =-100,000 FT/MIN SAFE DEPTH = -12,22 FEET

DIVE 1 STEP 4 PRIOR DEPTH = 250,00 THIS DEPTH = 350,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
4,0	0,0	96,0

TISSUE PRESSURES

	***1**	2	3	4	5	6	7	8	9
SAFE	611,00	564,00	521,00	480,00	476,00	474,00	439,00	403,00	403,00
TOTAL INERT	100,44	66,43	47,13	36,83	31,51	29,71	28,81	28,27	27,90
NITROGEN	19,79	22,81	24,42	25,24	25,66	25,80	25,87	25,91	25,94
HELIUM	80,64	43,62	22,71	11,59	5,86	3,92	2,94	2,36	1,97

STEP TIME = 1,0 MIN DIVE TIME = 0 HR 4,0 MIN RATE =-100,000 FT/MIN SAFE DEPTH = 9,62 FEET

DIVE 1 STEP 5 PRIOR DEPTH = 350,00 THIS DEPTH = 450,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
4,0	0,0	96,0

TISSUE PRESSURES

	***1**	2	3	4	5	6	7	8	9
SAFE	761,00	704,00	651,00	600,00	596,00	594,00	549,00	503,00	503,00
TOTAL INERT	141,39	89,86	59,69	43,34	34,83	31,94	30,48	29,61	29,02
NITROGEN	17,23	21,28	23,58	24,81	25,43	25,65	25,75	25,82	25,86
HELIUM	124,16	68,58	36,11	18,54	9,39	6,29	4,73	3,79	3,16

STEP TIME = 1,0 MIN DIVE TIME = 0 HR 5,0 MIN RATE =-100,000 FT/MIN SAFE DEPTH = 36,92 FEET

DIVE 1 STEP 6 PRIOR DEPTH = 450,00 THIS DEPTH = 450,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
4,0	0,0	96,0

TISSUE PRESSURES

	1	***2**	3	4	5	6	7	8	9
SAFE	761,00	704,00	651,00	600,00	596,00	594,00	549,00	503,00	503,00
TOTAL INERT	463,52	455,42	403,63	301,62	197,39	149,45	122,32	104,94	92,86
NITROGEN	,01	,47	3,51	9,56	15,79	18,67	20,29	21,34	22,06
HELIUM	463 51	454,95	400,12	292,05	181,60	130,78	102,03	83,60	70,80

STEP TIME = 55,0 MIN DIVE TIME = 1 HR 0,0 MIN RATE = 0,000 FT/MIN SAFE DEPTH = 272,44 FEET

STARTING CONDITIONS FOR ASCENT

GAS MIXTURES

OXYGEN	TOTAL INERT	NITROGEN	HELIUM	NUMBER	
.209820	.790180	.790180	0.000000	1	50 TO 0 FEET
.209820	.790180	.790180	0.000000	2	100 TO 50 FEET
.209820	.790180	.790180	0.000000	3	200 TO 100 FEET
.040000	.960000	0.000000	.960000	4	380 TO 200 FEET
.040000	.960000	0.000000	.960000	5	DEEPER THAN 380 FEET

MAXIMUM RATE OF ASCENT = 60.00 FEET/MINUTE

DIVE 1 STEP 7 PRIOR DEPTH = 450.00 THIS DEPTH = 450 00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
4.0	0.0	96.0

TISSUE PRESSURES

	1	***2**	3	4	5	6	7	8	9
SAFE	761.00	704.00	651.00	600.00	596.00	594.00	549.00	503.00	503.00
TOTAL INERT	463.52	455.42	403.63	301.62	197.39	149.45	122.32	104.94	92.86
NITROGEN	.01	.47	3.51	9.56	15.79	18.67	20.29	21.34	22.06
HELIUM	463.51	454.95	400.12	292.05	181.60	130.78	102.03	83.60	70.80

STEP TIME = 0.000 MIN ASCENT TIME = 0.00 MIN TOTAL DIVE TIME = 60 MIN ASCENT RATE = 0.000 FT/MIN

DIVE 1 STEP 8 PRIOR DEPTH = 450,00 THIS DEPTH = 380,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
4,0	0,0	96,0

TISSUE PRESSURES

	1	***2**	3	4	5	6	7	8	9
SAFE	656,00	606,00	560,00	516,00	512,00	510,00	472,00	433,00	433,00
TOTAL INERT	458,39	453,42	404,67	304,19	199,73	151,33	123,88	106,25	93,99
NITROGEN	,01	,43	3,37	9,37	15,63	18,54	20,19	21,25	21,99
HELIUM	458,39	452,98	401,30	294,81	184,10	132,79	103,68	85,00	72,01

STEP TIME = 1,167 MIN ASCENT TIME = 1,17 MIN TOTAL DIVE TIME = 61 MIN ASCENT RATE = 60,000 FT/MIN

DIVE 1 STEP 9 PRIOR DEPTH = 380,00 THIS DEPTH = 260,34 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
4,0	0,0	96,0

TISSUE PRESSURES

	1	***2**	3	4	5	6	7	8	9
SAFE	476,51	438,48	404,45	372,41	368,41	366,41	340,38	313,34	313,34
TOTAL INERT	428,93	438,48	400,24	305,36	202,12	153,48	125,73	107,85	95,40
NITROGEN	,01	,38	3,14	9,05	15,37	18,33	20,02	21,10	21,86
HELIUM	428,92	438,10	397,10	296,31	186,75	135,15	105,71	86,75	73,54

STEP TIME = 1,994 MIN ASCENT TIME = 3,16 MIN TOTAL DIVE TIME = 63 MIN ASCENT RATE = 60,000 FT/MIN

DIVE 1 STEP 10 PRIOR DEPTH = 260,34 THIS DEPTH = 254,82 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
4,0	0,0	96,0

TISSUE PRESSURES

	1	***2**	***3**	4	5	6	7	8	9
SAFE	468,23	430,74	397,26	365,78	361,78	359,78	334,30	307,82	307,82
TOTAL INERT	414,73	430,74	397,26	305,03	202,59	154,00	126,20	108,28	95,78
NITROGEN	,00	,36	3,06	8,94	15,27	18,25	19,96	21,05	21,82
HELIUM	414,73	430,39	394,20	296,09	187,32	135,74	106,25	87,23	73,96

STEP TIME = ,717 MIN ASCENT TIME = 3,88 MIN TOTAL DIVE TIME = 64 MIN ASCENT RATE = 7,706 FT/MIN

DIVE 1 STEP 11 PRIOR DEPTH = 254,82 THIS DEPTH = 250,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
4,0	0,0	96,0

TISSUE PRESSURES

	1	2	***3**	4	5	6	7	8	9
SAFE	461,00	424,00	391,00	360,00	356,00	354,00	329,00	303,00	303,00
TOTAL INERT	388,23	415,22	391,00	304,23	203,52	155,04	127,16	109,14	96,55
NITROGEN	,00	,32	2,91	8,71	15,07	18,10	19,83	20,94	21,72
HELIUM	388,22	414,90	388,09	295,52	188,44	136,94	107,33	88,20	74,83

STEP TIME = 1,504 MIN ASCENT TIME = 5,38 MIN TOTAL DIVE TIME = 65 MIN ASCENT RATE = 3,203 FT/MIN

DIVE 1 STEP 12 PRIOR DEPTH = 250,00 THIS DEPTH = 240,00 GAS MIXTURE

	OXYGEN	NITROGEN	HELIUM
	PCT	PCT	PCT
GAS MIXTURE	4,0	0,0	96,0

TISSUE PRESSURES

	1	2	***3**	4	5	6	7	8	9
SAFE	446,00	410,00	378,00	348,00	344,00	342,00	318,00	293,00	293,00
TOTAL INERT	344.73	385,76	378,00	302,22	205,24	157,08	129,08	110,87	98,11
NITROGEN	,00	,26	2,60	8,24	14,66	17,77	19,55	20,71	21,52
HELIUM	344,73	385,50	375,40	293,98	190,58	139,31	109,52	90,16	76,59

STEP TIME = 3,189 MIN ASCENT TIME = 8,57 MIN TOTAL DIVE TIME = 69 MIN ASCENT RATE = 3.135 FT/MIN

DIVE 1 STEP 13 PRIOR DEPTH = 240,00 THIS DEPTH = 230,00 GAS MIXTURE

	OXYGEN	NITROGEN	HELIUM
	PCT	PCT	PCT
GAS MIXTURE	4,0	0,0	96,0

TISSUE PRESSURES

	1	2	***3**	4	5	6	7	8	9
SAFE	431,00	396,00	365,00	336,00	332,00	330,00	307,00	283,00	283,00
TOTAL INERT	312.61	359,56	365,00	299,73	206,70	158,96	130,89	112,53	99,42
NITROGEN	,00	,21	2,32	7,79	14,25	17,43	19,28	20,48	21,32
HELIUM	312,60	359,35	362,68	291,94	192,45	141,53	111.61	92,05	78,30

STEP TIME = 3,284 MIN ASCENT TIME = 11,86 MIN TOTAL DIVE TIME = 72 MIN ASCENT RATE = 3,045 FT/MIN

DIVE 1 STEP 14 PRIOR DEPTH = 230,00 THIS DEPTH = 220,00 GAS MIXTURE

	OXYGEN	NITROGEN	HELIUM
	PCT	PCT	PCT
GAS MIXTURE	4,0	0,0	96,0

TISSUE PRESSURES

	1	2	***3**	4	5	6	7	8	9
SAFE	416,00	382,00	352,00	324,00	320,00	318,00	296,00	273,00	273,00
TOTAL INERT	288,14	336,12	352,00	296,76	207,88	160,68	132,59	114,11	101,06
NITROGEN	,00	,16	2,07	7,34	13,84	17,09	19,00	20,24	21,11
HELIUM	288,14	335,95	349,93	289,42	194,04	143,58	113,59	93,87	79,94

STEP TIME = 3,385 MIN ASCENT TIME = 15,24 MIN TOTAL DIVE TIME = 75 MIN ASCENT RATE = 2,954 FT/MIN

DIVE 1 STEP 15 PRIOR DEPTH = 220,00 THIS DEPTH = 210,00 GAS MIXTURE

	OXYGEN	NITROGEN	HELIUM
	PCT	PCT	PCT
GAS MIXTURE	4,0	0,0	96,0

TISSUE PRESSURES

	1	2	***3**	4	5	6	7	8	9
SAFE	401.00	368,00	339,00	312,00	308,00	306,00	285,00	263,00	263,00
TOTAL INERT	268,77	314,99	339,00	293,31	208,78	162,22	134,17	115,60	102,43
NITROGEN	,00	,13	1,83	6,91	13,43	16,75	18,71	20,00	20,90
HELIUM	268,77	314,86	337,17	286,40	195,36	145,47	115,46	95,60	81,53

STEP TIME = 3,492 MIN ASCENT TIME = 18,73 MIN TOTAL DIVE TIME = 79 MIN ASCENT RATE = 2,864 FT/MIN

DIVE 1 STEP 16 PRIOR DEPTH = 210,00 THIS DEPTH = 200,00

GAS MIXTURE	OXYGEN PCT	NITROGEN PCT	HELIUM PCT
	4.0	0.0	96,0

TISSUE PRESSURES

	1	2	***3**	4	5	6	7	8	9
SAFE	386,00	354,00	326,00	300,00	296,00	294,00	274,00	253,00	253,00
TOTAL INERT	252,75	295,81	326,00	289,38	209,39	163,59	135,63	117,00	103,74
NITROGEN	,00	,10	1,62	6,49	13,01	16,41	18,42	19,75	20,68
HELIUM	252,75	295,71	324,38	282,89	196,37	147,18	117,21	97,25	83,05

STEP TIME = 3.606 MIN ASCENT TIME = 22,34 MIN TOTAL DIVE TIME = 82 MIN ASCENT RATE = 2,773 FT/MIN

DIVE 1 STEP 17 PRIOR DEPTH - 200,00 THIS DEPTH = 190.00

GAS MIXTURE	OXYGEN PCT	NITROGEN PCT	HELIUM PCT
	21,0	79,0	0,0

TISSUE PRESSURES

	1	2	***3**	4	5	6	7	8	9
SAFE	371,00	340,00	313,00	288,00	284,00	282,00	263,00	243,00	243,00
TOTAL INERT	230,06	276,10	313,00	284,40	208,71	163,84	136,15	117,59	104,33
NITROGEN	56,04	30,73	17,51	14,41	16,87	18,93	20,30	21,24	21,92
HELIUM	174,02	245,37	295,49	269,99	191,85	144,91	115,85	96,35	82,41

STEP TIME = 2.692 MIN ASCENT TIME = 25,03 MIN TOTAL DIVE TIME = 85 MIN ASCENT RATE = 3.714 FT/MIN

DIVE 1 STEP 18 PRIOR DEPTH = 190,00 THIS DEPTH = 184,68

GAS MIXTURE	OXYGEN PCT	NITROGEN PCT	HELIUM PCT
	21,0	79,0	0,0

TISSUE PRESSURES

	1	2	***3**	***4**	5	6	7	8	9
SAFE	363,03	332,56	306,09	281,62	277,62	275,62	257,15	237,68	237,68
TOTAL INERT	219,71	266,20	306,09	281,62	208,27	163,93	136,39	117,87	104,63
NITROGEN	77,82	44,64	25,30	18,43	18,86	20,25	21,28	22,02	22,56
HELIUM	141,89	221,56	280,78	263,19	189,41	143,68	115,11	95,86	82,06

STEP TIME = 1,473 MIN ASCENT TIME = 26,50 MIN TOTAL DIVE TIME = 87 MIN ASCENT RATE = 3.611 FT/MIN

DIVE 1 STEP 19 PRIOR DEPTH = 184,68 THIS DEPTH = 180.00

GAS MIXTURE	OXYGEN PCT	NITROGEN PCT	HELIUM PCT
	21.0	79.0	0.0

TISSUE PRESSURES

	1	2	3	***4**	5	6	7	8	9
SAFE	356,00	326,00	300,00	276,00	272,00	270,00	252,00	233,00	233,00
TOTAL INERT	202,87	248,23	292,73	276,00	207,30	164,03	136,82	118,41	105,19
NITROGEN	109,07	68,08	39,54	26,08	22,72	22.81	23,19	23.54	23,83
HELIUM	93.80	180.15	253,19	249,92	184,58	141.22	113,64	94.87	81,36

STEP TIME = 2.985 MIN ASCENT TIME = 29.49 MIN TOTAL DIVE TIME = 89 MIN ASCENT RATE = 1.569 FT/MIN

DIVE 1 STEP 20 PRIOR DEPTH = 180,00 THIS DEPTH = 170,00 GAS MIXTURE OXYGEN PCT 21,0 NITROGEN PCT 79,0 HELIUM PCT 0.0

TISSUF PRESSURES

	1	2	3	***4**	5	6	7	8	9
SAFE	341,00	312,00	287,00	264,00	260,00	258,00	241,00	223,00	223,00
TOTAL INERT	179,51	217,48	266,60	264,00	204,93	164,04	137,59	119,44	106,30
NITROGEN	141,71	103,12	64,87	40,92	30,54	28,07	27,14	26,70	26,47
HELIUM	37,80	114,36	201,73	223,08	174,38	135,98	110,45	92,74	79,83

STEP TIME = 6,556 MIN ASCENT TIME = 36,05 MIN TOTAL DIVE TIME = 96 MIN ASCENT RATE = 1,525 FT/MIN

DIVE 1 STEP 21 PRIOR DEPTH = 170,00 THIS DEPTH = 160,00 GAS MIXTURE OXYGEN PCT 21,0 NITROGEN PCT 79,0 HELIUM PCT 0.0

TISSUE PRESSURES

	1	2	3	***4**	5	6	7	8	9
SAFE	326,00	298,00	274,00	252,00	248,00	246,00	230,00	213,00	213,00
TOTAL INERT	165,02	194,37	243,37	252,00	202,14	163,75	138,14	120,31	107,27
NITROGEN	150,34	123,09	84,11	53,79	37,76	33,03	30,90	29,73	29,00
HELIUM	14,69	71,28	159,26	198,21	164,38	130,72	107,24	90,57	78,27

STEP TIME = 6,821 MIN ASCENT TIME = 42,87 MIN TOTAL DIVE TIME = 103 MIN ASCENT RATE = 1,466 FT/MIN

DIVE 1 STEP 22 PRIOR DEPTH = 160,00 THIS DEPTH = 150,00 GAS MIXTURE OXYGEN PCT 21,0 NITROGEN PCT 79,0 HELIUM PCT 0.0

TISSUE PRESSURES

	1	2	3	***4**	5	6	7	8	9
SAFE	311,00	284,00	261,00	240,00	236,00	234,00	219,00	203,00	203,00
TOTAL INERT	154,28	176,41	222,63	240,00	198,94	163,14	138,46	120,99	108,11
NITROGEN	148,80	132,86	98,14	64,75	44,37	37,67	34,47	32,62	31,43
HELIUM	5,48	43,55	124,49	175,25	154,56	125,47	103,99	88,37	76,68

STEP TIME = 7,107 MIN ASCENT TIME = 49,97 MIN TOTAL DIVE TIME = 110 MIN ASCENT RATE = 1,407 FT/MIN

DIVE 1 STEP 23 PRIOR DEPTH = 150,00 THIS DEPTH = 140,00 GAS MIXTURE OXYGEN PCT 21,0 NITROGEN PCT 79,0 HELIUM PCT 0.0

TISSUE PRESSURES

	1	2	3	***4**	5	6	7	8	9
SAFE	296,00	270,00	248,00	228,00	224,00	222,00	208,00	193,00	193,00
TOTAL INERT	145,08	161,89	204,00	228,00	195,30	162,19	138,52	121,49	108,80
NITROGEN	143,12	135,84	107,74	73,90	50,37	41,99	37,83	35,36	33,74
HELIUM	1,96	26,04	96,26	154,10	144,94	120,20	100,70	86,13	75,06

STEP TIME = 7,420 MIN ASCENT TIME = 57,39 MIN TOTAL DIVE TIME = 117 MIN ASCENT RATE = 1,348 FT/MIN

DIVE 1 STEP 24 PRIOR DEPTH = 140.00 THIS DEPTH = 130.00 GAS MIXTURE OXYGEN PCT 21.0 NITROGEN PCT 79.0 HELIUM PCT 0.0

TISSUE PRESSURES

	1	2	3	***4**	5	6	7	8	9
SAFE	281.00	256.00	235.00	216.00	212.00	210.00	197.00	183.00	183.00
TOTAL INERT	136.48	149.60	187.15	216.00	191.23	160.90	138.33	121.79	109.33
NITROGEN	135.81	134.40	113.59	81.29	55.72	45.96	40.96	37.95	35.94
HELIUM	.67	15.21	73.56	134.71	135.51	114.93	97.37	83.84	73.39

STEP TIME = 7.760 MIN ASCENT TIME = 65.15 MIN TOTAL DIVE TIME = 125 MIN ASCENT RATE = 1.289 FT/MIN

DIVE 1 STEP 25 PRIOR DEPTH = 130.00 THIS DEPTH = 120.00 GAS MIXTURE OXYGEN PCT 21.0 NITROGEN PCT 79.0 HELIUM PCT 0.0

TISSUE PRESSURES

	1	2	3	***4**	5	6	7	8	9
SAFE	266.00	242.00	222.00	204.00	200.00	198.00	186.00	173.00	173.00
TOTAL INERT	128.10	138.76	171.79	204.00	186.71	159.24	137.86	121.87	109.69
NITROGEN	127.88	130.11	116.30	87.00	60.42	49.58	43.87	40.36	38.00
HELIUM	.22	8.65	55.49	117.00	126.29	109.66	94.00	81.51	71.69

STEP TIME = 8.134 MIN ASCENT TIME = 73.29 MIN TOTAL DIVE TIME = 133 MIN ASCENT RATE = 1.229 FT/MIN

DIVE 1 STEP 26 PRIOR DEPTH = 120.00 THIS DEPTH = 110.00 GAS MIXTURE OXYGEN PCT 21.0 NITROGEN PCT 79.0 HELIUM PCT 0.0

TISSUE PRESSURES

	1	2	3	***4**	5	6	7	8	9
SAFE	251.00	228.00	209.00	192.00	188.00	186.00	175.00	163.00	163.00
TOTAL INERT	119.81	128.82	157.67	192.00	181.72	157.20	137.10	121.73	109.87
NITROGEN	119.74	124.04	116.41	91.10	64.45	52.82	46.52	42.59	39.92
HELIUM	.07	4.79	41.27	100.90	117.28	104.38	90.58	79.13	69.94

STEP TIME = 8.545 MIN ASCENT TIME = 81.83 MIN TOTAL DIVE TIME = 142 MIN ASCENT RATE = 1.170 FT/MIN

DIVE 1 STEP 27 PRIOR DEPTH = 110.00 THIS DEPTH = 100.42 GAS MIXTURE OXYGEN PCT 21.0 NITROGEN PCT 79.0 HELIUM PCT 0.0

TISSUE PRESSURES

	1	2	3	***4**	***5**	6	7	8	9
SAFE	236.63	214.59	196.54	180.50	176.50	174.50	164.46	153.42	153.42
TOTAL INERT	111.89	119.82	145.11	180.50	176.50	154.87	136.08	121.36	109.85
NITROGEN	111.86	117.19	114.49	93.60	67.66	55.56	48.81	44.55	41.63
HELIUM	.02	2.63	30.61	86.91	108.84	99.31	87.26	76.80	68.22

STEP TIME = 8.615 MIN ASCENT TIME = 90.45 MIN TOTAL DIVE TIME = 150 MIN ASCENT RATE = 1.112 FT/MIN

DIVE 1 STEP 28 PRIOR DEPTH = 100,42 THIS DEPTH = 100,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	***5**	6	7	8	9
SAFE	236,00	214,00	196,00	180,00	176,00	174,00	164,00	153,00	153,00
TOTAL INERT	111,18	119,02	144,00	179,45	176,00	154,63	135,97	121,31	109,84
NITROGEN	111,16	116,53	114,23	93,76	67,92	55,79	49,01	44,72	41,78
HELIUM	,02	2,49	29,76	85,69	108,08	98,84	86,95	76,59	68,06

STEP TIME = ,816 MIN ASCENT TIME = 91,26 MIN TOTAL DIVE TIME = 151 MIN ASCENT RATE = ,513 FT/MIN

DIVE 1 STEP 29 PRIOR DEPTH = 100,00 THIS DEPTH = 90,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	***5**	6	7	8	9
SAFE	221,00	200,00	183,00	168,00	164,00	162,00	153,00	143,00	143,00
TOTAL INERT	100,19	104,88	122,23	156,32	164,00	148,75	133,05	119,95	109,34
NITROGEN	100,19	104,26	107,41	95,85	73,21	60,75	53,36	48,52	45,12
HELIUM	,00	,62	14,82	60,46	90,79	88,00	79,70	71,43	64,22

STEP TIME = 20,120 MIN ASCENT TIME = 111,38 MIN TOTAL DIVE TIME = 171 MIN ASCENT RATE = ,497 FT/MIN

DIVE 1 STEP 30 PRIOR DEPTH = 90,00 THIS DEPTH = 80,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	***5**	6	7	8	9
SAFE	206,00	186,00	170,00	156,00	152,00	150,00	142,00	133,00	133,00
TOTAL INERT	91,94	95,12	106,78	136,69	152,00	142,29	129,52	118,03	108,37
NITROGEN	91,94	94,98	99,72	94,96	76,57	64,52	56,88	51,71	48,00
HELIUM	,00	,14	7,06	41,73	75,43	77,77	72,64	66,32	60,37

STEP TIME = 21,394 MIN ASCENT TIME = 132,78 MIN TOTAL DIVE TIME = 193 MIN ASCENT RATE = ,467 FT/MIN

DIVE 1 STEP 31 PRIOR DEPTH = 80,00 THIS DEPTH = 70,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	***5**	6	7	8	9
SAFE	191,00	172,00	157,00	144,00	140,00	138,00	131,00	123,00	123,00
TOTAL INERT	83,85	86,52	94,75	119,81	140,00	135,23	125,35	115,54	106,90
NITROGEN	83,85	86,49	91,55	91,71	78,12	67,07	59,55	54,26	50,38
HELIUM	,00	,03	3,20	28,09	61,88	68,16	65,80	61,28	56,52

STEP TIME = 22,840 MIN ASCENT TIME = 155,62 MIN TOTAL DIVE TIME = 216 MIN ASCENT RATE = ,438 FT/MIN

DIVE 1 STEP 32 PRIOR DEPTH = 70,00 THIS DEPTH = 63,80 GAS MIXTURE

OXYGEN	NITROGEN	HELIUM
PCT	PCT	PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	***5**	***6**	7	8	9
SAFE	181,70	163,32	148,94	136,56	132,56	130,56	124,18	116,80	116,80
TOTAL INERT	78,85	81.34	88,26	110,44	132,56	130,56	122,43	113,68	105,71
NITROGEN	78,85	81,33	86,35	88,77	78,21	68,05	60,76	55,51	51,59
HELIUM	,00	,01	1,90	21,67	54.35	62,51	61,67	58,18	54,13

STEP TIME = 14,974 MIN ASCENT TIME = 170,59 MIN TOTAL DIVE TIME = 231 MIN ASCENT RATE = ,414 FT/MIN

DIVE 1 STEP 33 PRIOR DEPTH = 63,80 THIS DEPTH = 60.00 GAS MIXTURE

OXYGEN	NITROGEN	HELIUM
PCT	PCT	PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	5	***6**	7	8	9
SAFE	176,00	158,00	144,00	132,00	128,00	126,00	120,00	113,00	113,00
TOTAL INERT	75,06	77,10	82,87	102,39	125,62	126,00	119,48	111,75	104,42
NITROGEN	75,06	77,09	81,73	85,63	77,82	68,62	61,65	56,48	52,57
HELIUM	,00	,00	1,14	16,76	47,80	57,38	57,83	55,26	51,86

STEP TIME = 14,820 MIN ASCENT TIME = 185,41 MIN TOTAL DIVE TIME = 245 MIN ASCENT RATE = ,257 FT/MIN

DIVE 1 STEP 34 PRIOR DEPTH = 60,00 THIS DEPTH = 58,30 GAS MIXTURE

OXYGEN	NITROGEN	HELIUM
PCT	PCT	PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	5	***6**	***7**	8	9
SAFE	173,44	155,61	141,78	129,95	125,95	123,95	118,13	111.30	111,30
TOTAL INERT	73,62	75,47	80,76	99,11	122,60	123,95	118,13	110,84	103,81
NITROGEN	73,62	75,47	79,86	84,21	77,53	68,78	61,97	56,86	52,96
HELIUM	,00	,00	,90	14,90	45.07	55,17	56,15	53,98	50,85

STEP TIME = 6,788 MIN ASCENT TIME = 192,20 MIN TOTAL DIVE TIME = 252 MIN ASCENT RATE = ,251 FT/MIN

DIVE 1 STEP 35 PRIOR DEPTH = 58,30 THIS DEPTH = 56.50 GAS MIXTURE

OXYGEN	NITROGEN	HELIUM
PCT	PCT	PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	5	6	***7**	***8**	9
SAFE	170,75	153,10	139,45	127,80	123,80	121,80	116.15	109,50	109,50
TOTAL INERT	71,86	73,41	78,02	94,72	118,37	121,02	116,15	109,50	102.89
NITROGEN	71,86	73,41	77,39	82,18	77,82	68,93	62,37	57,35	53,48
HELIUM	,00	,00	,64	12,54	41,35	52,09	53.78	52,15	49,41

STEP TIME = 9,960 MIN ASCENT TIME = 202,16 MIN TOTAL DIVE TIME = 262 MIN ASCENT RATE = ,180 FT/MIN

DIVE 1 STEP 36 PRIOR DEPTH = 56,50 THIS DEPTH = 50,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	5	6	7	***8**	9
SAFE	161,00	144,00	131,00	120,00	116,00	114,00	109,00	103,00	103,00
TOTAL INERT	66,33	67,12	69,36	79,25	100,86	107,89	106,91	103,00	98,28
NITROGEN	66,33	67,12	69,25	73,91	73,87	68,70	63,46	59,04	55,42
HELIUM	,00	,00	,12	5,34	26,98	39,19	43,45	43,96	42,86

STEP TIME = 49,254 MIN ASCENT TIME = 251,41 MIN TOTAL DIVE TIME = 311 MIN ASCENT RATE = ,132 FT/MIN

DIVE 1 STEP 37 PRIOR DEPTH = 50,00 THIS DEPTH = 40,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	5	6	7	***8**	9
SAFE	146,00	130,00	118,00	108,00	104,00	102,00	98,00	93,00	93,00
TOTAL INERT	58,38	59,09	60,58	65,40	81,11	90,76	93,66	93,00	90,73
NITROGEN	58,38	59,09	60,57	64,05	67,55	65,98	62,85	59,61	56,65
HELIUM	,00	,00	,01	1,35	13,57	24,78	30,81	33,39	34,08

STEP TIME = 79,365 MIN ASCENT TIME = 330,78 MIN TOTAL DIVE TIME = 391 MIN ASCENT RATE = ,126 FT/MIN

DIVE 1 STEP 38 PRIOR DEPTH = 40,00 THIS DEPTH = 30,00 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	5	6	7	***8**	***9**
SAFE	131,00	116,00	105,00	96,00	92,00	90,00	87,00	83,00	83,00
TOTAL INERT	50,44	51,11	52,47	55,70	66,66	76,36	81,37	83,00	82,70
NITROGEN	50,44	51,11	52,46	55,39	60,12	61,12	59,98	58,06	55,98
HELIUM	,00	,00	,00	,31	6,54	15,23	21,39	24,94	26,72

STEP TIME = 84,228 MIN ASCENT TIME = 415,01 MIN TOTAL DIVE TIME = 475 MIN ASCENT RATE = ,119 FT/MIN

DIVE 1 STEP 39 PRIOR DEPTH = 30,00 THIS DEPTH = 28,23 GAS MIXTURE

OXYGEN PCT	NITROGEN PCT	HELIUM PCT
21,0	79,0	0,0

TISSUE PRESSURES

	1	2	3	4	5	6	7	***8**	***9**
SAFE	128,35	113,53	102,70	93,88	89,88	87,88	85,06	81,23	81,23
TOTAL INERT	49,04	49,70	51,04	54,14	64,46	74,03	79,28	81,23	81,23
NITROGEN	49,04	49,70	51,04	53,90	58,74	60,09	59,27	57,59	55,68
HELIUM	,00	,00	,00	,24	5,72	13,93	20.00	23,64	25,55

STEP TIME = 15,441 MIN ASCENT TIME = 430,45 MIN TOTAL DIVE TIME = 490 MIN ASCENT RATE = ,114 FT/MIN

DIVE 1	STEP 40		PRIOR DEPTH =	28,23	THIS DEPTH =	20.00		GAS MIXTURE	OXYGEN PCT 21,0	NITROGEN PCT 79,0	HELIUM PCT 0.0

TISSUE PRESSURES

	1	2	3	4	5	6	7	8	***9**
SAFE	116.00	102,00	92,00	84.00	80.00	78,00	76.00	73,00	73.00
TOTAL INERT	42.39	42,91	43,99	46,40	53,82	62.28	68,26	71,59	73.00
NITROGEN	42.39	42,91	43,99	46,35	51,18	53,95	54,67	54,23	53.25
HELIUM	,00	,00	,00	,05	2,64	8,33	13,60	17,36	19,75

STEP TIME = 89,141 MIN ASCENT TIME = 519,59 MIN TOTAL DIVE TIME = 580 MIN ASCENT RATE = ,092 FT/MIN

DIVE 1	STEP 41		PRIOR DEPTH =	20,00	THIS DEPTH =	10.00		GAS MIXTURE	OXYGEN PCT 21.0	NITROGEN PCT 79,0	HELIUM PCT 0.0

TISSUE PRESSURES

	1	2	3	4	5	6	7	8	***9**
SAFE	101,00	88,00	79,00	72,00	68,00	66.00	65,00	63,00	63,00
TOTAL INERT	34,46	34,94	35,92	37,98	43,35	50,21	56,20	60,41	63,00
NITROGEN	34,46	34,34	35,92	37,97	42,38	45,93	47,94	48,76	48,84
HELIUM	,00	,00	,00	,01	,97	4,28	8,25	11,64	14,16

STEP TIME =115,188 MIN ASCENT TIME = 634,78 MIN TOTAL DIVE TIME = 695 MIN ASCENT RATE = ,087 FT/MIN

DIVE 1	STEP 42		PRIOR DEPTH =	10,00	THIS DEPTH =	0.00		GAS MIXTURE	OXYGEN PCT 21,0	NITROGEN PCT 79,0	HELIUM PCT 0.0

TISSUE PRESSURES

	1	2	3	4	5	6	7	8	***9**
SAFE	86,00	74,00	66,00	60,00	56,00	54,00	54,00	53,00	53,00
TOTAL INERT	26,52	26,97	27,88	29,75	34,10	39,63	45,17	49,69	53,00
NITROGEN	26,52	26,97	27,88	29,75	33,76	37,54	40,34	42,11	43,10
HELIUM	,00	,00	,00	,00	,33	2,09	4,83	7,58	9,90

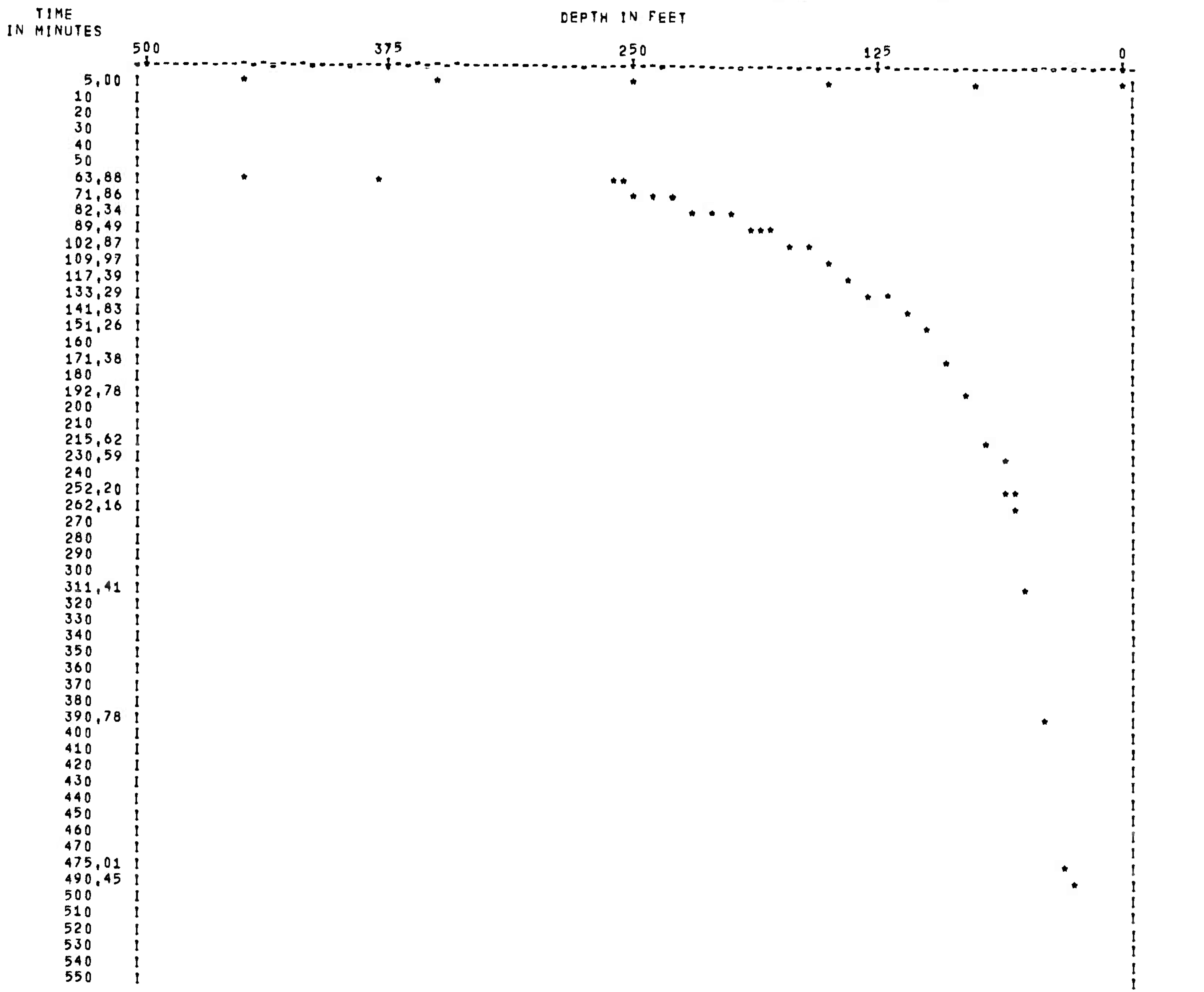
STEP TIME =123,836 MIN ASCENT TIME = 758,61 MIN TOTAL DIVE TIME = 819 MIN ASCENT RATE = ,081 FT/MIN

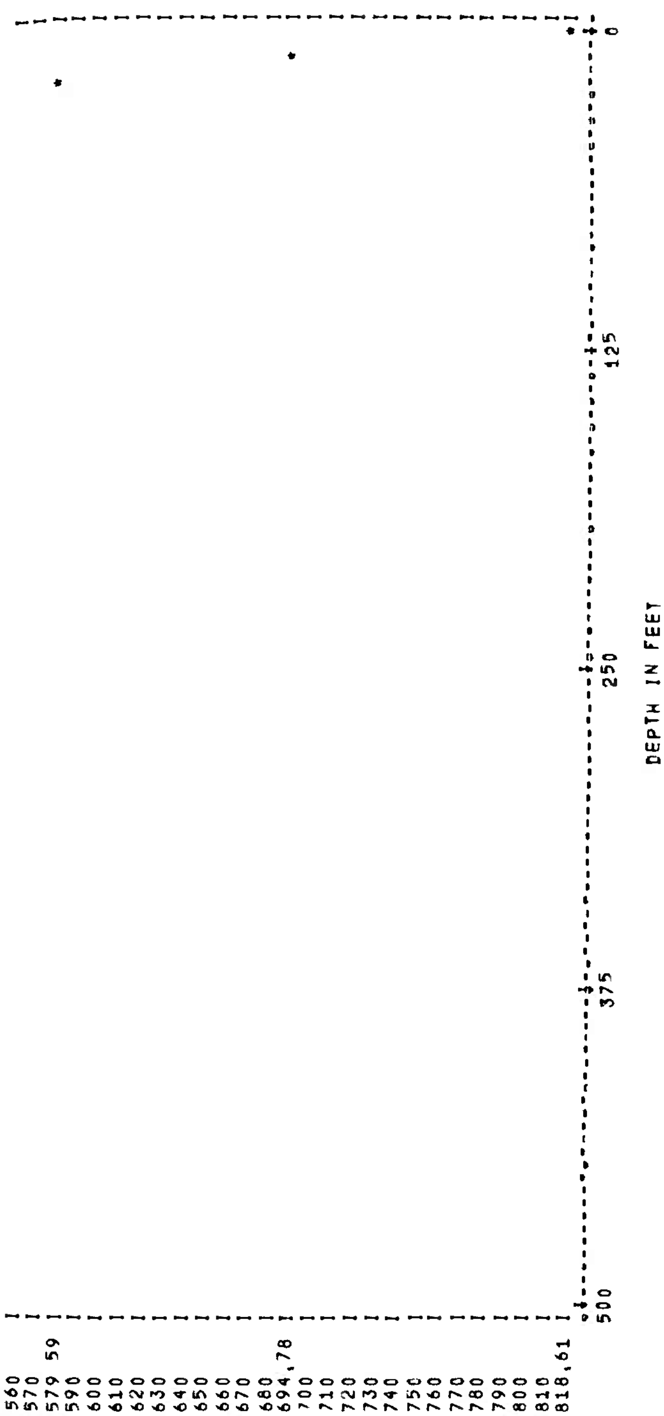
*** *** *** *** *** *** *** *** *** *** *** *** *** END OF DIVE *** *** *** *** *** *** *** *** *** *** *** *** ***

DIVE NUMBER 1 * * * * DIVE TO 450 FEET FOR 60 MINUTES, CONTINUOUS ASCENT * * * * * 03/01/68

STEP	STEP TIME MIN	DEPTH FEET	CUMULATIVE TIME H M - H M	OXYGEN PCT	NITROGEN PCT	HELIUM PCT
0	0	0 - 0	0:0 - 0:0	21.0	79.0	0.0
1	1	0 - 75	0:0 - 0:1	21.0	79.0	0.0
2	1	75 - 150	0:1 - 0:2	4.0	0.0	96.0
3	1	150 - 250	0:2 - 0:3	4.0	0.0	96.0
4	1	250 - 350	0:3 - 0:4	4.0	0.0	96.0
5	1	350 - 450	0:4 - 0:5	4.0	0.0	96.0
6	55	450 - 450	0:5 - 1:0	4.0	0.0	96.0
7	0	450 - 450	1:0 - 1:0	4.0	0.0	96.0
8	1	450 - 380	1:0 - 1:1	4.0	0.0	96.0
9	2	380 - 260	1:1 - 1:3	4.0	0.0	96.0
10	1	260 - 255	1:3 - 1:3	4.0	0.0	96.0
11	2	255 - 250	1:3 - 1:5	4.0	0.0	96.0
12	3	250 - 240	1:5 - 1:8	4.0	0.0	96.0
13	3	240 - 230	1:8 - 1:11	4.0	0.0	96.0
14	3	230 - 220	1:11 - 1:15	4.0	0.0	96.0
15	3	220 - 210	1:15 - 1:18	4.0	0.0	96.0
16	4	210 - 200	1:18 - 1:22	4.0	0.0	96.0
17	3	200 - 190	1:22 - 1:25	21.0	79.0	0.0
18	1	190 - 185	1:25 - 1:26	21.0	79.0	0.0
19	3	185 - 180	1:26 - 1:29	21.0	79.0	0.0
20	7	180 - 170	1:29 - 1:36	21.0	79.0	0.0
21	7	170 - 160	1:36 - 1:42	21.0	79.0	0.0
22	7	160 - 150	1:42 - 1:49	21.0	79.0	0.0
23	7	150 - 140	1:49 - 1:57	21.0	79.0	0.0
24	8	140 - 130	1:57 - 2:5	21.0	79.0	0.0
25	8	130 - 120	2:5 - 2:13	21.0	79.0	0.0
26	9	120 - 110	2:13 - 2:21	21.0	79.0	0.0
27	9	110 - 100	2:21 - 2:30	21.0	79.0	0.0
28	1	100 - 100	2:30 - 2:31	21.0	79.0	0.0
29	20	100 - 90	2:31 - 2:51	21.0	79.0	0.0
30	21	90 - 80	2:51 - 3:12	21.0	79.0	0.0
31	23	80 - 70	3:12 - 3:35	21.0	79.0	0.0
32	15	70 - 64	3:35 - 3:50	21.0	79.0	0.0
33	15	64 - 60	3:50 - 4:5	21.0	79.0	0.0
34	7	60 - 58	4:5 - 4:12	21.0	79.0	0.0
35	10	58 - 57	4:12 - 4:22	21.0	79.0	0.0
36	49	57 - 50	4:22 - 5:11	21.0	79.0	0.0
37	79	50 - 40	5:11 - 6:30	21.0	79.0	0.0
38	84	40 - 30	6:30 - 7:55	21.0	79.0	0.0
39	15	30 - 28	7:55 - 8:10	21.0	79.0	0.0
40	89	28 - 20	8:10 - 9:39	21.0	79.0	0.0
41	115	20 - 10	9:39 - 11:34	21.0	79.0	0.0
42	124	10 - 0	11:34 - 13:38	21.0	79.0	0.0

DIVE NUMBER 1 * * * * DIVE TO 450 FEET FOR 60 MINUTES. CONTINUOUS ASCENT * * * * * 03/01/68

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DEPTH IN FEET

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) U.S. Naval Submarine Medical Center, Submarine Medical Research Laboratory and Brookhaven National Laboratory	2a REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b GROUP

3 REPORT TITLE

COMPUTATION OF CONTINUOUS DECOMPRESSION SCHEDULES FOR DEEP SEA DIVES

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

Interim

5 AUTHOR(S) (First name, middle initial, last name)

James S. Robertson
George Moeller

6 REPORT DATE 19 March 1968	7a TOTAL NO OF PAGES	7b NO OF REFS 10

8a CONTRACT OR GRANT NO b PROJECT NO MF022.03.03-9010.01 c d	9a ORIGINATOR'S REPORT NUMBER(S) NSMC 517 and BNL 50104 (T-490) 9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10 DISTRIBUTION STATEMENT

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11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY U.S. Naval Submarine Medical Center Box 600, Naval Submarine Base Groton, Connecticut 06340

13 ABSTRACT

A digital computer program for calculating either continuous ascent or stop type decompression schedules is described, and examples of applications are given. The formulas used for continuous ascent were obtained analytically as solutions of differential equations relating the inert gas tension in the current critical tissue to the safe depth and with the actual depth kept equal to the safe depth at all times after an initial fast rise from the bottom to the safe depth. Thus the rate of decompression of the critical tissue controls the rate of ascent. Gas tensions in nine tissues having the same range of gas exchange half-times as have been used in EDU reports are calculated on a continuous basis, with the one having the deepest safe depth being the current critical tissue. The stop type ascent portion of the program may be used to generate a staged ascent using the same parameters for comparison with the continuous ascent schedule. The starting conditions for ascent may either be computed by the program from the dive history or be communicated to it as a subroutine in connection with another program. The program may be used either to prescribe ascent schedules or to analyze dives for which the history is known.

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6801

UNCLASSIFIED

Security Classification

3ND PPSO 13152

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Decompression schedules						
Continuous ascent						
Computer, digital						
Inert gas exchange						