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Single-tissue modeling of decompression schedules

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Baz, A., and A. Seireg. 1979. Single-tissue modeling of decompression schedules. Undersea Biomed. Res. 6(3):217–229.—This paper deals with the development of a single-tissue model that simulates the uptake and elimination of inert gases by the body of a diver. The model utilizes an effective single tissue with different uptake and elimination time constants to account for the asymmetrical behavior of multiple-tissue human body models. The parameters of this effective tissue are selected according to an optimal strategy that minimizes safe deviation from the decompression requirements recommended by safe practice. The developed strategy is general in nature and can be readily applied to select the optimal parameters for a single-tissue model suitable for any dive regimen on air or mixed gas. As an illustration, the procedure is used to select the optimal tissue that best fits the Standard Air Decompression Tables recommended by the U.S. Navy. The results obtained are in close and safe agreement with the requirements of the U.S. Navy, and consistently fall in the range between the U.S. Navy and the Royal Navy tables.

single tissue
decompression schedules
optimal tissue parameters
standard air tables

The increasing need to be able to conduct deep and long-duration dives for work and recreation has created serious physiological problems for divers. Important among these problems is decompression sickness, i.e., the bends. This sickness occurs during fast ascents when the diver's body cannot release, through normal lung ventilation, the excess inert gas absorbed throughout the dive. Bubbles of gas that develop in the diver's bloodstream and tissues can cause serious sickness. The mathematical basis for analysis of this physiological problem was developed by Haldane (Boycott, Damant, and Haldane 1908). Haldanian theory introduced the vitally important concept that the tissues can withstand an internal overpressure (what Haldane termed "super-saturation") during decompression without producing clinical bends. However, this theory was based on the assumption of symmetrical rates of uptake and elimination of inert gas, which was proven to be incorrect by physiological evidence produced by Hempleman (1965) and Berghage, Dyson, and McCracken (1978).

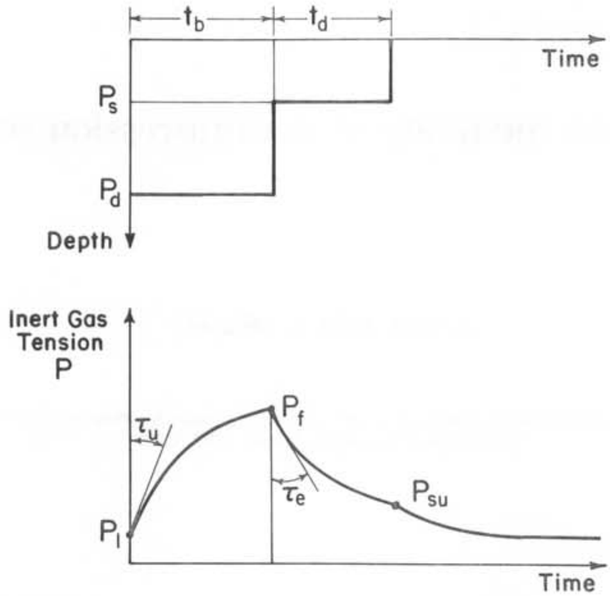


Fig. 1. Tissue and dive parameters.

Although Haldanian theory has been the basis for the standard U.S. Navy tables for many years, other models have been thought to simulate the decompression mechanism closely, particularly for long and deep dives. Some of these models are more elegant and perhaps more descriptive of the physiological processes involved in decompression (Hempleman 1969; Hills 1969; Albano and Columba 1971), and others are more complex and speculative (Dieter 1967; Schreiner and Kelley 1971; Workman 1971; Kidd and Stubbs 1971). Although these models predict safe decompression for various dive conditions, the concepts and assumptions utilized in each are quite different. For example, the models discussed in Hills (1969), Albano and Columba (1971), and Dieter (1967) are based on the assumption that there are inert gas bubbles during asymptomatic decompression, while the models of Hempleman (1969), and Schreiner and Kelley (1971) do not consider gas phase separation. Also, the models of Hempleman (1965), Albano and Columba (1971), Schreiner and Kelley (1971), Workman (1971), and Kidd and Stubbs (1971) assume that inert gas transport is a perfusion-limited process, whereas the model of Hills (1969) considers it to be diffusion limited. The number and arrangement of the tissue compartments used in the different models vary also, from 9 parallel tissues in Workman's modification of the Haldanian model (Workman 1971) to 4 in-series tissues in the Canadian model (Kidd and Stubbs 1971). These complex arrangements were necessary to account for the asymmetric behavior of human tissues.

Despite all these differences, these models represent the considerable effort that has been expended to quantify the mechanism of decompression sickness. However, until the true mechanism of decompression is fully understood, other approaches are needed to develop safe decompression schedules consistent with established practices but still simple in concept.

The present study describes the development of a single-tissue model (Seireg and Baz 1977a; Seireg and Baz 1977b) that simulates the asymmetrical nature of the uptake and release of inert gas by a diver's body. The model considerably simplifies the calculations associated with multi-tissue models, thereby providing a simple means for predicting safe decompression schedules.

A procedure is given for selecting the parameters of an effective single tissue that is suitable for computing decompression profiles corresponding to any dive regimen or breathing mixture.

It should be noted that despite the fact that the proposed model is based on a single-tissue simulation, it does not have the limitations of other single-tissue models, which are unsafe for no-decompression dives below 80 ft, bounce dives, and repetitive dives (Howard, Brander, and Schmitt 1976).

Asymmetrical single-tissue decompression model

Since this model is based on a single-tissue simulation, it requires only three parameters to compute the decompression requirements for any diving situation. These parameters are: the uptake time constant, the elimination time constant, and the allowable supersaturation ratio. With so few parameters, the model can be efficiently used for computing decompression schedules. It can also be conveniently utilized to adapt the diving plan to different individuals, work loads, and environmental temperatures.

Figure 1 shows the variation of the inert gas tension with dive depth and duration for a dive with a single decompression stop. This is considered to illustrate how the three parameters (uptake time constant, elimination time constant, and supersaturation ratio) can be used to compute a decompression schedule.

The build-up of inert gas tension can be described by the following equation

$$P_f = x_i P_d - (x_i P_d - P_1) e^{-t_b/\tau_u} \quad (1)$$

where P_f = inert gas tension in tissue; x_i = fraction of inert gas in breathing mixture; P_d = pressure at dive depth; P_1 = initial inert gas tension in tissue; t_b = bottom time; and τ_u = uptake time constant. If the diver is to surface, he can safely ascend to a depth P_s according to the allowable supersaturation ratio S_R. The stop depth P_s can be determined from

$$P_s = P_f / S_R \quad (2)$$

Once the diver reaches this depth, he starts eliminating the inert gas absorbed during his dive according to the following relation

$$P_{su} = x_i P_s - (x_i P_s - P_f) e^{-t_d/\tau_e} \quad (3)$$

where P_{su} = inert gas pressure in tissue after remaining at stop depth P_s at time t_d; P_s = stop depth; t_d = decompression time at stop; and τ_e = elimination time constant.

Whenever P_{su} reaches a value such that

$$P_{su} / P_{\text{atm}} \leq S_R \quad (4)$$

where P_{atm} is ambient atmospheric pressure, the diver can return to the surface safely.

Therefore, the three parameters τ_u, τ_e, and S_R can be used, as indicated in the simple one-stop dive, to determine the first safe decompression stop P_s and decompression time t_d at this stop by using Eqs. *1, 2,* and *3* as follows

$$P_s = [x_i P_d - (x_i P_d - P_1) e^{-t_b/\tau_u}] / S_R \quad (5)$$

and

$$t_d = \tau_e ln[(P_f - x_i P_s)/(S_R P_{sn} - x_i P_s)] \quad (6)$$

where P_{sn} = the depth at the next decompression stop.

For deep and long-duration dives that require more than one decompression stop, Eqs. *5* and *6* can be applied repeatedly, as often as needed, to determine the depths of the different decompression stops as well as the time spent at each stop. Accordingly, the three-parameter asymmetrical single-tissue model can be used to simulate complex decompression profiles accurately and safely and in a relatively simple way.

Optimal selection of effective tissue parameters

For the single-tissue model, if the dive depth P_d and the bottom time t_b are known, it would be possible to find the optimum values for the uptake time constant τ_u, elimination time constant τ_e, and supersaturation ratio S_R that minimize the safe deviation between the decompression time predicted by the single-tissue model and that recommended by any naval practice.

In a more general way, knowing the dive depth and time ranges, the optimal parameters of the effective single tissue can be determined using a specially developed optimization procedure. The procedure aims at finding the values of the three parameters (τ_u, τ_e, and S_R) that minimize the total safe deviation between the model and naval recommendations over the considered depth and time ranges. In addition, the procedure limits the search for optimal parameters to parameter values that ensure that the predicted decompression stops and times are deeper and longer than the required practices. The search is also confined to values for the elimination time constants that are larger than the uptake time constants, to conform with the physiological evidence of Hempleman (1965) and Berghage et al. (1978).

ABBREVIATIONS

- D — dive depth, ft
- P_{atm} — atmospheric pressure, psia
- P_d — pressure at dive depth, psia
- $P_{f,I}$ — final and initial inert gas tension in tissue, psia
- P_s — pressure at decompression stop, psia
- $\overline{P}_s$ — pressure at decompression stop recommended by Navy, psia
- P_{sn} — pressure at next decompression stop, psia
- P_{su} — inert gas pressure in tissue after stopping at stop P_s at time t_d, psia
- S_R — supersaturation ratio
- t — time, min
- t_b — bottom time, min
- t_d — decompression time at stop, min
- $\overline{t}_d$ — decompression time at stop recommended by Navy, min
- x_i — fraction of inert gas in breathing mixture
- $\tau_{e,u}$ — elimination and uptake time constants, min

The developed optimization procedure is general in nature and can be readily applied to select the optimal tissue parameters suitable to any dive regimen or breathing mixture.

Optimal single-tissue simulation of the U.S. Navy Standard Air Schedules

If the single-tissue model is used to simulate closely the U.S. Navy Standard Air Diving Schedules (1970), the developed optimization procedure shows that a tissue with τ_u = 22 min and τ_e = 40 min or a tissue with τ_u = 30 min and τ_e = 40 min would yield the same minimum total deviation of 10% from the decompression time recommended by the U.S. Navy. In Fig. 2, the contours representing a given deviation percentage are indicated as a function of the uptake and elimination time constants, to illustrate the two local minima.

The tissue with τ_u = 22 min and τ_e = 40 min is favored over that with τ_u = 30 min and τ_e = 40 min because the former predicts greater safety in the untested no-decompression dives between 70–110 ft than the latter does, as shown in Fig. 3. Such additional safety is considered an important feature, and one which makes this selection more appealing, particularly for sports diving.

The tissue with τ_u = 22 min and τ_e = 40 min has optimum values of supersaturation ratios expressed as a function of dive depth and time as follows:

$$\begin{aligned} S_R = {} & 5.8114 + (3.1089E-3)D - (6.2995E-4)Dt_b \\ & - 1.3978/t_b + (2.457E\text{-}8)D^2t_b^2 + (1.5764E\text{-}6)/D^2t_b^2 \\ & - 4630.3008/Dt_b - (1.3833E\text{-}5)D^2 + (1.482E\text{-}4)D^2/t_b^2 \end{aligned} \tag{7}$$

where D is the dive depth, ft; and t_b is the dive time, min.

Equation 7 is obtained by applying linear regression techniques to develop an expression for the optimum values of the supersaturation ratios that minimize the safe deviation between the model and naval practices at each dive depth and time. The obtained expression is found to curve-fit closely the complex variation pattern of the supersaturation ratio with a standard error of estimate of 0.089. This error represents 6.59% of the minimum value of the supersaturation ratio allowed throughout the dive regimen. Despite its seemingly complex form, the supersaturation ratio expression can be manipulated easily by any programmable microprocessor.

It should be noted that Eq. 7 represents the best fit for the supersaturation ratio with the optimally selected fixed-time constants. Other simpler forms of this function may exist if more deviation from the Navy tables is allowed or if other variation patterns are selected for the time constants.

The optimized single-tissue parameters τ_u, τ_e, and S_R are then used to generate the decompression schedules for single air dives. The obtained **untested** schedules are listed in Table 1.

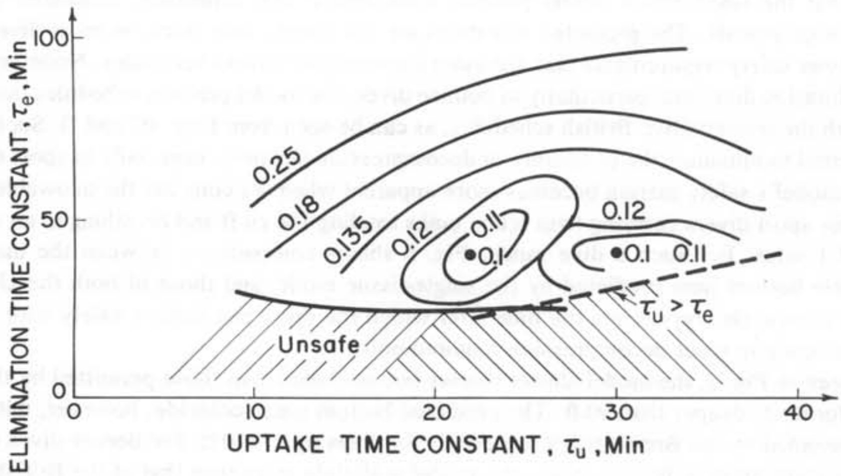


Fig. 2. Iso-deviation contours as a function of uptake and elimination time constants.

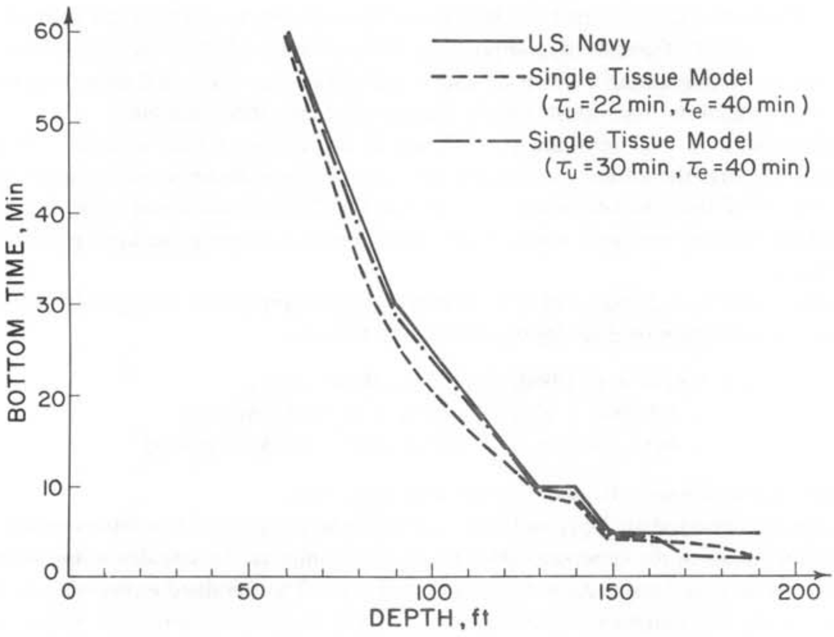


Fig. 3. No-decompression limits for optimal tissues compared to U.S. Navy limits.

Total time in the table includes ascent period, in minutes, calculated from (depth [ft]/60 + 1) and eliminating any fraction of a minute.

A sample of typical comparisons between the schedules predicted by the single-tissue model and those recommended by the U.S. Navy and by the British Navy (Hempleman 1969) is given in Figs. 4A, B, C, and D for diving depths of 60, 100, 150, and 190, respectively. The figures show that the single-tissue model predicts consistently safe schedules, compared to U.S. Navy requirements. The predicted schedules are not overly safe since, in most dives, they have fewer safety requirements than the more conservative British schedules. Nonetheless, in short-duration dives and particularly in bounce dives, the model predicts schedules that are in line with the conservative British schedules, as can be seen from Figs. 4C and D. Such safety is essential to minimize the possibility of decompression sickness, especially in sport diving.

The model's safety margin becomes more apparent when we consider the allowable diving range for sport divers carrying twin scuba tanks totaling 144 cu ft and breathing at an average rate of 1 scfm. For such a dive range, Fig. 5 shows comparisons between the maximum allowable bottom time predicted by the single-tissue model and those of both the U.S. and British navies; this represents the time after which the biver can surface safely with enough gas remaining to meet decompression requirements.

As seen in Fig. 5, the model allows shorter bottom times than those permitted by the U.S. Navy for dives deeper than 90 ft. The predicted bottom times coincide, however, with those recommended by the British Navy, especially for dives up to 110 ft. For deeper dives that are also short-duration or bounce dives, the model is slightly safer than that of the British Navy, and accordingly it is suitable for sport diving conditions.

TABLE 1
Decompression Schedules for Standard Air Dives

Depth, ft	Bottom Time, min	Decompression Stop, ft: 80	70	60	50	40	30	20	10	Total Ascent Time, min	U.S. Navy Total Ascent Time, min
60	60	0	0	0	0	0	0	0	0	2	1.00
60	70	0	0	0	0	0	0	0	2	4	3.00
60	80	0	0	0	0	0	0	0	6	8	8.00
60	100	0	0	0	0	0	0	0	16	18	15.00
60	120	0	0	0	0	0	0	5	25	32	27.00
60	140	0	0	0	0	0	0	17	29	48	40.00
60	160	0	0	0	0	0	5	25	34	66	49.00
60	180	0	0	0	0	0	14	29	40	85	57.00
60	200	0	0	0	0	0	19	31	44	96	71.00
70	50	0	0	0	0	0	0	0	2	4	1.10
70	60	0	0	0	0	0	0	0	7	9	9.10
70	70	0	0	0	0	0	0	0	13	15	15.10
70	80	0	0	0	0	0	0	0	19	21	19.10
70	90	0	0	0	0	0	0	5	22	29	24.10
70	100	0	0	0	0	0	0	11	24	37	34.10
70	110	0	0	0	0	0	0	18	26	46	44.10
70	120	0	0	0	0	0	5	21	28	56	52.10
70	130	0	0	0	0	0	11	23	31	67	59.10
70	140	0	0	0	0	0	17	26	35	80	65.10
70	150	0	0	0	0	2	22	28	38	92	71.10
70	160	0	0	0	0	5	23	29	41	100	86.10
70	170	0	0	0	0	7	24	30	42	105	99.10
80	40	0	0	0	0	0	0	0	4	6	1.20
80	50	0	0	0	0	0	0	0	11	13	11.20
80	60	0	0	0	0	0	0	0	17	19	18.20
80	70	0	0	0	0	0	0	5	21	28	24.20
80	80	0	0	0	0	0	0	12	22	36	34.20
80	90	0	0	0	0	0	2	19	24	47	47.20
80	100	0	0	0	0	0	9	20	27	58	58.20
80	110	0	0	0	0	0	17	22	30	71	67.20
80	120	0	0	0	0	6	20	25	33	86	74.20
80	130	0	0	0	0	12	21	27	37	99	83.20
80	140	0	0	0	0	16	23	29	40	110	96.20
80	150	0	0	0	0	18	24	30	42	116	110.20
90	30	0	0	0	0	0	0	0	3	5	1.30
90	40	0	0	0	0	0	0	0	11	13	8.30
90	50	0	0	0	0	0	0	0	19	21	19.30
90	60	0	0	0	0	0	0	8	20	30	26.30
90	70	0	0	0	0	0	0	16	22	40	38.30

TABLE 1—(continued)

Depth, ft	Bottom Time, min	Decompression Stop, ft 80	70	60	50	40	30	20	10	Total Ascent Time, min	U.S. Navy Total Ascent Time, min
90	80	0	0	0	0	0	8	18	24	52	54.30
90	90	0	0	0	0	1	17	20	27	67	67.30
90	100	0	0	0	0	9	18	23	30	82	76.30
90	110	0	0	0	0	16	20	25	34	97	86.30
90	120	0	0	0	6	18	22	28	38	114	101.30
90	130	0	0	0	9	19	23	29	41	123	116.30
100	25	0	0	0	0	0	0	0	4	6	1.40
100	30	0	0	0	0	0	0	0	8	10	4.40
100	40	0	0	0	0	0	0	0	17	19	16.40
100	50	0	0	0	0	0	0	9	20	31	27.40
100	60	0	0	0	0	0	2	16	21	41	38.40
100	70	0	0	0	0	0	12	18	24	56	57.40
100	80	0	0	0	0	6	16	20	27	71	72.40
100	90	0	0	0	1	15	18	23	30	89	84.40
100	100	0	0	0	9	17	20	26	35	109	97.40
100	110	0	0	0	15	18	22	28	39	124	117.40
100	120	0	0	2	16	19	23	29	41	132	132.40
110	20	0	0	0	0	0	0	0	3	5	1.50
110	25	0	0	0	0	0	0	0	8	10	4.50
110	30	0	0	0	0	0	0	0	14	16	8.50
110	40	0	0	0	0	0	0	6	19	27	24.50
110	50	0	0	0	0	0	2	16	20	40	35.50
110	60	0	0	0	0	0	12	17	23	54	55.50
110	70	0	0	0	0	9	16	19	26	72	73.50
110	80	0	0	0	6	15	18	22	29	92	88.50
110	90	0	0	1	14	17	20	25	34	113	107.50
110	100	0	0	8	16	18	22	28	39	133	125.50
120	15	0	0	0	0	0	0	0	1	4	2.00
120	20	0	0	0	0	0	0	0	7	10	4.00
120	25	0	0	0	0	0	0	0	13	16	8.00
120	30	0	0	0	0	0	0	1	18	22	16.00
120	40	0	0	0	0	0	0	13	19	35	32.00
120	50	0	0	0	0	0	10	16	21	50	48.00
120	60	0	0	0	0	9	15	18	24	69	71.00
120	70	0	0	0	8	14	17	21	28	91	89.00
120	80	0	0	6	14	16	20	24	33	116	107.00
120	90	0	1	14	16	18	22	28	38	140	132.00
120	100	0	5	14	16	19	23	30	41	151	150.00

TABLE 1—(continued)

Depth, ft	Bottom Time, min	Decompression Stop, ft 80	70	60	50	40	30	20	10	Total Ascent Time, min	U.S. Navy Total Ascent Time, min
130	10	0	0	0	0	0	0	0	0	3	2.10
130	15	0	0	0	0	0	0	0	4	7	3.10
130	20	0	0	0	0	0	0	0	10	13	6.10
130	25	0	0	0	0	0	0	0	17	20	12.10
130	30	0	0	0	0	0	0	6	19	28	23.10
130	40	0	0	0	0	0	5	16	20	44	37.10
130	50	0	0	0	0	6	14	17	22	62	63.10
130	60	0	0	0	7	14	16	20	26	86	86.10
130	70	0	0	7	13	16	19	23	31	112	103.10
130	80	0	6	13	15	18	21	27	37	140	131.10
130	90	0	12	14	16	19	23	30	41	158	154.10
140	10	0	0	0	0	0	0	0	1	4	2.20
140	15	0	0	0	0	0	0	0	7	10	4.20
140	20	0	0	0	0	0	0	0	14	17	8.20
140	25	0	0	0	0	0	0	4	18	25	18.20
140	30	0	0	0	0	0	0	12	19	34	28.20
140	40	0	0	0	0	0	12	16	21	52	46.20
140	50	0	0	0	3	13	15	18	24	76	76.20
140	60	0	0	6	13	14	17	21	28	102	97.20
140	70	0	8	13	15	17	20	25	34	135	125.20
140	80	5	13	14	16	19	23	29	40	162	155.20
150	5	0	0	0	0	0	0	0	0	3	2.30
150	10	0	0	0	0	0	0	0	3	6	3.30
150	15	0	0	0	0	0	0	0	10	13	5.30
150	20	0	0	0	0	0	0	0	18	21	11.30
150	25	0	0	0	0	0	0	9	19	31	23.30
150	30	0	0	0	0	0	3	15	19	40	34.30
150	40	0	0	0	0	7	14	17	22	63	59.30
150	50	0	0	1	11	13	16	19	25	88	88.30
150	60	0	6	12	13	16	19	23	31	123	112.30
150	70	8	12	14	16	18	22	28	38	159	146.30
160	5	0	0	0	0	0	0	0	0	3	2.40
160	10	0	0	0	0	0	0	0	4	7	3.40
160	15	0	0	0	0	0	0	0	12	15	7.40
160	20	0	0	0	0	0	0	4	18	25	16.40
160	25	0	0	0	0	0	0	14	19	36	29.40
160	30	0	0	0	0	0	9	15	20	47	40.40
160	40	0	0	0	3	12	14	17	23	72	71.40
160	50	0	0	10	12	14	17	21	27	104	98.40
160	60	6	11	13	15	17	20	25	34	144	132.40
160	70	7	13	15	17	20	24	30	42	171	166.40

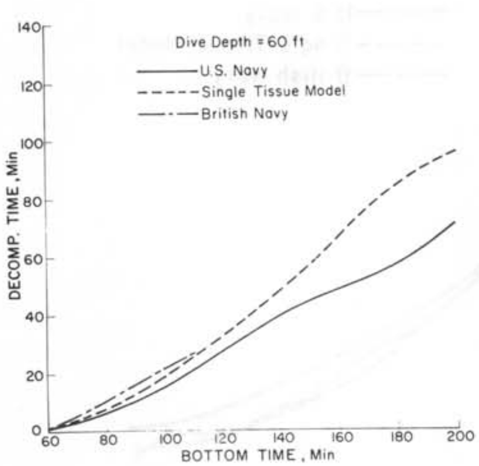
TABLE 1—(Continued)

Depth, ft	Bottom Time, min	Decompression Stop, ft 80	70	60	50	40	30	20	10	Total Ascent Time, min	U.S. Navy Total Ascent Time, min
170	5	0	0	0	0	0	0	0	0	3	2.50
170	10	0	0	0	0	0	0	0	6	9	4.50
170	15	0	0	0	0	0	0	0	15	18	9.50
170	20	0	0	0	0	0	0	8	18	29	21.50
170	25	0	0	0	0	0	4	15	19	41	34.50
170	30	0	0	0	0	2	13	16	20	54	45.50
170	40	0	0	0	11	13	15	18	24	84	81.50
170	50	0	10	11	13	15	18	22	30	122	109.50
170	60	7	12	14	16	18	22	28	39	159	152.50
180	5	0	0	0	0	0	0	0	1	5	3.00
180	10	0	0	0	0	0	0	0	8	12	6.00
180	15	0	0	0	0	0	0	1	18	23	12.00
180	20	0	0	0	0	0	0	12	19	35	26.00
180	25	0	0	0	0	0	9	15	20	48	40.00
180	30	0	0	0	0	8	13	16	21	62	53.00
180	40	0	0	8	11	13	16	19	25	96	93.00
180	50	10	11	12	14	16	19	24	33	143	128.00
180	60	7	13	15	17	20	24	31	43	174	168.00
190	5	0	0	0	0	0	0	0	2	6	3.10
190	10	0	0	0	0	0	0	0	10	14	7.10
190	15	0	0	0	0	0	0	4	18	26	14.10
190	20	0	0	0	0	0	2	15	19	40	31.10
190	25	0	0	0	0	2	13	16	20	55	44.10
190	30	0	0	0	3	12	14	17	22	72	63.10
190	40	0	7	11	12	14	17	20	27	112	103.10
190	50	1	12	13	15	18	21	27	37	148	147.10
190	60	8	14	16	18	22	26	34	48	190	183.10

CONCLUSIONS

The development of a single-tissue procedure that simulates empirical data of the uptake and elimination of inert gases is discussed. The characterization of the model by two fixed values of the uptake and elimination time constants and the supersaturation ratio makes the programmable computation of decompression schedules much simpler than that for multi-tissue models.

Application of the model and the developed optimization procedure to the simulation of U.S. Navy Standard Air Decompression Schedules shows that the model predicts consistently



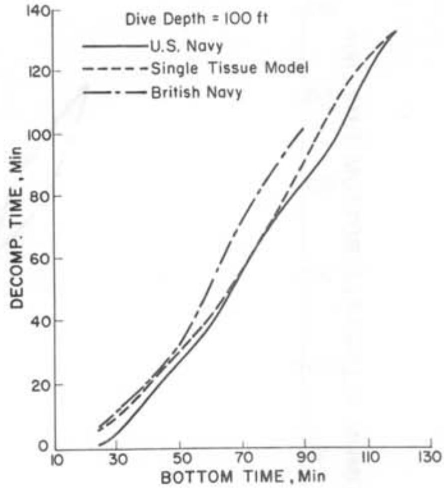
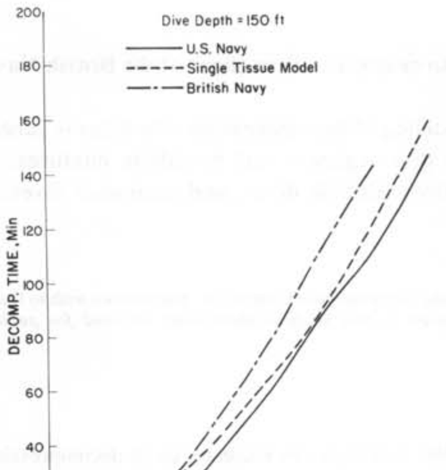


Fig. 4A. Comparison between decompression requirements predicted by the single-tissue model and by the U.S. Navy and Royal Navy for dives of different duration at 60 ft.

Fig. 4B. Comparison between decompression requirements predicted by the single-tissue model and by the U.S. Navy and Royal Navy for dives of different duration at 100 ft.



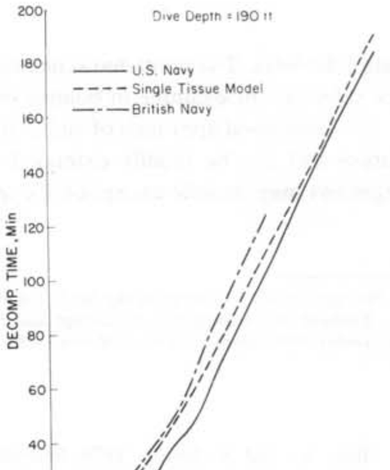


Fig. 4C. Comparison between decompression requirements predicted by the single-tissue model and by the U.S. Navy and Royal Navy for dives of different duration at 150 ft.

Fig. 4D. Comparison between decompression requirements predicted by the single-tissue model and by the U.S. Navy and Royal Navy for dives of different duration at 190 ft.

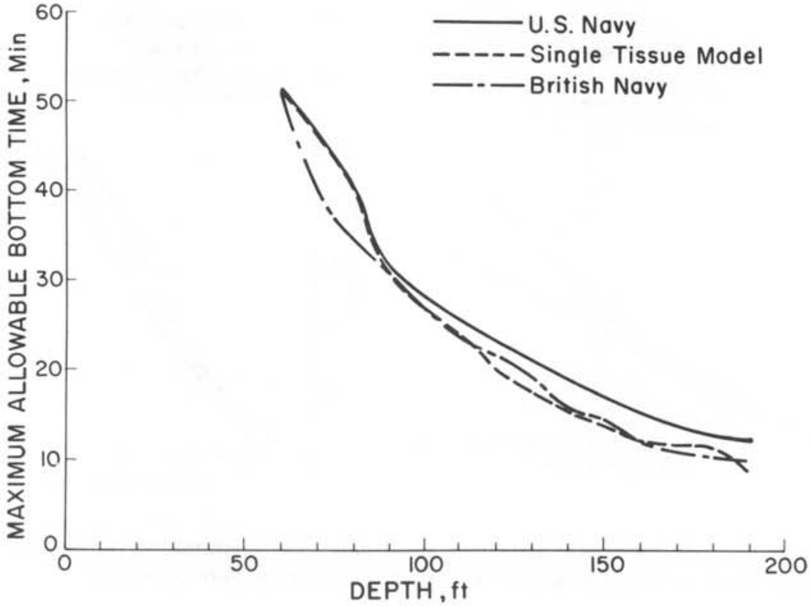


Fig. 5. Comparison between maximum allowable bottom times predicted by the single-tissue model and by both U.S. Navy and Royal Navy for dives limited by a breathing gas supply of 144 cu ft drained at the rate of 1 cfm.

safe schedules. The predicted schedules are also nearly as safe as those of the British Navy, or are safer (as for example in bounce dives).

The developed approach of single-tissue modeling of decompression schedules is general in nature and can be readily extended to other dive regimens and breathing mixtures. Such regimens may include exceptional exposure dives, altitude dives, and saturation dives.

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Baz, A., and A. Seireg. 1979. Faisant un modèle seul-tissu des rouleaux de la décompression. Undersea Biomed. Res. 6(3):217–229.—Cette étude s'addresse au développement d'un modèle seul-tissu qui stimule "l'uptake" et l'élimination des gaz interts par le corps du plongeur. Ce modèle utilise un seul tissu effectif avec des constants de temps différents pour "l'uptake" et l'élimination pour relèver sur le comportement asymmètrique des modèles de tissus multiples du corps humain. Les paramètres de ce tissu effectif sont choisis selon une stratégie qui minimise la déviation sur des exigeants de décompression recommandée par la pratique protective. La stratégie developpée a un caractère général, qu'on peut promptement addresser à la séléction des paramètres optimales pour un modèle seul-tissu convenable à n'importe quel régime de plongée avec l'air ou le mélange du gaz. Par exemple, la procédure est utilisée pour choisir le tissu optimal le plus convenable aux Tables Standares de la Décompression de l'Air conseillées par U.S. Navy.

Les résultats y obtenus sont en accord proche et sur avec les conditions de l'U.S. Navy, et restent conformés à la portée entre de l'U.S. Navy et les tables de la Royal Navy.

seul tissu
parametrès
tables de la décompression
tissu optimal
tables standardes de l'air

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