

ON CORRELATION OF POPULAR DIVING MODELS WITH COMPUTER PROFILE DATA AND OUTCOMES

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ABSTRACT

A diving protocol is a safe combination of model and data to efficiently and safely stage diver ascents following arbitrary underwater exposures. In an earlier publication, we correlated two models with the LANL Data Bank using coarse grain correlation functions, namely a constant surfacing bubble volume for the dual phase bubble model (RGBM) and a fixed supersaturation ratio for the standard dissolved gas model (Haldane). A finer correlation analysis, consistent with computer, table, and software real world implementations of popular models, is of interest in the diving community and important. To that end, we analyze four popular ones, namely the USN, ZHL16, VPM, RGBM algorithms, their dynamical principles, and correlations with the LANL Data Bank. Table, profile, and meter fit and risk parameters are obtained in statistical likelihood analysis from profile data and DCS outcomes. In this analysis, permissible supersaturations are limited by model specific staging constraints, not uniform across the whole dive profile. Such correlation is more stringent. The LANL Data Bank is described, and the methods used to deduce risk are detailed. Risk functions for the four models are summarized. Parameters that can be used to estimate profile risk are tallied. To fit data, a modified Levenberg-Marquardt routine is employed. The LANL Data Bank presently contains 2994 profiles with 23 cases of DCS across nitrox, trimix, and heliox deep and decompression diving. This work provides needed comparisons between global mixed gas diving, specific models, and deep stop data. Our objective is operational diving, not clinical science. The fit of models to data is chi squared significant as follows, using the logarithmic likelihood ratio of null set (actual set) to fit set:

$$\text{USN} - (\chi^2 = 0.081)$$

$$\text{ZHL16} - (\chi^2 = 0.131)$$

$$\text{VPM} - (\chi^2 = 0.717)$$

$$\text{RGBM} - (\chi^2 = 0.861)$$

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Introduction

A diving *algorithm* is a combination of model, data and ascent staging procedure that can be safely used across commercial, sport, technical, research, and scientific underwater operations [1-13,15-22]. Accordingly, this work analyzes four popular algorithms against actual diver profile data and DCS outcomes. The models are the USN [21], ZHL16 [3], VPM [22], and RGBM [20]. The USN and ZHL16 models are dissolved gas models [1] that ultimately require decompression stops in the shallow zone to eliminate dissolved nitrogen and helium. The VPM and RGBM are coupled bubble-dissolved gas models [9] that require deeper decompression stops to control bubble growth and dissolved gas elimination. The efficiency of shallow stops versus deep stops is one of current interest [11-13,18], and this study further suggests the utility of coupled deep stop model and data as a useful and safe diver staging tool. Many protocols are based on shallow stop data which focus on just dissolved gas buildup and elimination. Both are used today.

Collecting real world diving data is a global alternative to differential wet and dry testing, a very precise but limited statistical procedure. The approach here [18,20] for technical, mixed gas, and deep decompression diving parallels the Project Dive Exploration (PDE) and Diving Safety Laboratory (DSL) efforts at DAN [16] for recreational air and nitrox diving, but does not overlap significantly. As will be seen, the deep stop models (VPM, RGBM) correlate well with the LANL Data Bank, while the shallow stop models (USN, ZHL16) do not. Turns out that both shallow and deep stops can be made at the same relative risk level, but deep stops usually admit shorter overall decompression times [5,12,13,20,22], an important aspect of operational diving when mission objectives are folded over diving requirements, including diver safety.

To correlate hundreds of *gbytes* of downloaded dive computer data (commercial and specialized meters) supercomputing power here at LANL is requisite in performing maximum likelihood analyses of data and model. Using powerful software, the transitions from microprocessors to parallel processors are seamless.

Staging Models

All models use the tissue tension equations for dissolved gas buildup and elimination, p , for initial tissue tensions, p_i , at ambient pressure, p_a , with tissue halftimes, τ ,

$$p - p_a = (p_i - p_a) \exp(-\lambda t)$$

for exposure time, t , and,

$$\lambda = \frac{0.693}{\tau}$$

Sets of tissue halftimes, τ , vary across models but differences are not important, with an approximate range,

$$1 \leq \tau \leq 720 \text{ min}$$

Tissues with small τ are termed fast, while tissues with large τ are termed slow. In mixtures of inert gases (nitrogen and helium usually), the total tissue tension, Π , is the sum over mixture constituents,

$$\Pi = \sum_{j=1}^N p_j$$

with p_j the tension of the j^{th} gas component and N the number of gas components in the mixture, usually just nitrogen and helium. After this, models diverge in their diver staging regimens, with dissolved gas models (USN and ZHL16) limiting dissolved gas buildup, Π , and bubble models (VPM and RGBM) coupling dissolved gas buildup to bubble growth and limiting bubble volumes, Φ . In all models, a permissible supersaturation, G , can be defined at each point of the dive, and this is the parameter that will be correlated with data. This correlation parameter, G , is discussed next for each of the four models.

1. USN Model (Workman 1965)

In the Workman USN approach, the permissible gas tension, Π , is limited by,

$$\Pi \leq M$$

with M critical tensions listed in Table 1 for depth, d ,

$$M = M_0 + \Delta M d$$

where depth, d , is the difference between total ambient pressure, P , and surface pressure, P_0 ,

$$d = P - P_0$$

Table 1. USN M-Values

nitrogen			helium		
τ_{N_2} (min)	M_0 (fsw)	ΔM	τ_{He} (min)	M_0 (fsw)	ΔM
5	104	1.8	5	86	1.5
10	88	1.6	10	74	1.4
20	72	1.5	20	66	1.3
40	56	1.4	40	60	1.2
80	54	1.3	80	56	1.2
120	52	1.2	120	54	1.2
160	51	1.1	160	54	1.1
200	51	1.1	200	53	1.0
240	50	1.1	240	53	1.0

Corresponding permissible gradients, G , then satisfy,

$$G = \Pi - P \leq M - P = (M_0 - \Delta M P_0) + (\Delta M - 1)P$$

with P_0 ambient pressure at the surface as noted,

$$P_0 = 33 \exp(-0.0381h)$$

for elevation, h , in multiples of 1000 ft.

2. ZHL16 Model (Buhlmann 1990)

The Buhlmann ZHL16 approach is similar to the Workman USN approach, that is, the permissible gas tension, Π , is limited by,

$$\Pi \leq Z$$

with critical tensions, Z , given by,

$$Z = a + \frac{P}{b} = a + \frac{P_0 + d}{b}$$

so that,

$$G = \Pi - P \leq a + \left[\frac{1}{b} - 1 \right] (P_0 + d)$$

for constants, a and b , defining Z at sea level, in Table 2.

Table 2. Buhlmann Z-Values

nitrogen			helium		
τ_{N_2} (<i>min</i>)	$a + 33/b$ (<i>fsw</i>)	$1/b$	τ_{He} (<i>min</i>)	$a + 33/b$ (<i>fsw</i>)	$1/b$
4.0	106.2	1.91	1.5	134.5	2.36
8.0	83.2	1.54	3.0	102.4	1.74
12.5	73.8	1.39	4.7	89.4	1.53
18.5	66.8	1.28	7.0	79.8	1.38
27.0	62.3	1.23	10.2	73.6	1.32
38.3	58.4	1.19	14.5	68.2	1.25
54.3	55.2	1.15	20.6	63.7	1.21
77.1	52.3	1.12	29.0	59.7	1.17
109.2	49.8	1.09	41.1	57.1	1.14
146.0	48.2	1.08	55.2	55.1	1.12
187.0	46.8	1.07	70.7	54.0	1.11
239.0	45.6	1.06	90.3	53.3	1.10
305.0	44.5	1.05	115.3	53.1	1.09
390.0	43.5	1.04	147.4	52.8	1.09
498.0	42.6	1.04	188.2	52.6	1.08
635.0	41.8	1.03	240.0	52.3	1.07

3. Varying Permeability Model (Yount 1986)

The tissue compartments in the Yount VPM for nitrogen consist of the set,

$$\tau_{N_2} = (1, 2, 5, 10, 20, 40, 80, 120, 160, 240, 320, 400, 480, 560, 720) \text{ min}$$

with the helium compartments scaling,

$$\tau_{He} = \frac{\tau_{N_2}}{3}$$

Tissues slower than 320 *min* are used for saturation exposures in the original VPM, and the reduced set of faster compartments is sufficient for our purposes of correlation with the LANL DB. In gel experiments, Yount divided gas diffusion across bubble interfaces into permeable and impermeable regions. For dive model applications, the regions separate around 165 *fsw*. Bubbles of nitrogen and helium are excited into growth by pressure changes during the dive from

some minimum excitation radius, ϵ , in the $0.5 \mu m$ range, with nitrogen bubbles slightly larger than helium bubbles and the excitation radius decreasing with increasing absolute pressure, P . The radial bubble distribution, n , in the VPM is given by,

$$n = n_0 \exp(-\beta r)$$

with n_0 an experimental normalization factor for gel sample size, and β on the order of $1/\epsilon \mu m^{-1}$ for diving applications. The staging protocol in the VPM limits the permissible supersaturation, G to prevent bubble growth on ascent,

$$G = \Pi - P \leq \frac{\gamma}{\gamma_c} \left[\frac{2\gamma_c}{\epsilon} - \frac{2\gamma}{\epsilon_0} \right]$$

with γ the usual bubble surface tension, and γ_c the crushing bubble effective surface tension, roughly 20 dyne/cm and 150 dyne/cm respectively [23]. The radius, ϵ_0 , is an experimental metric, somewhere near $0.7 \mu m$. For diving, VPM ascents are limited by G at each stage in the decompression and staging profiles iterated to convergence across all stops.

4. Reduced Gradient Bubble Model (Wienke 2008)

Nitrogen tissue compartments in the Wienke RGBM range,

$$\tau_{N_2} = (2, 5, 10, 20, 40, 80, 120, 160, 200, 240, 300) \text{ min}$$

with helium compartments,

$$\tau_{He} = \frac{\tau_{N_2}}{2.65}$$

using the ratio of the square root of atomic weights as the scaling factor. The bubble dynamical protocol in the RGBM algorithm [20] amounts to staging on the seed number averaged, free-dissolved gradient across all tissue compartments, G , for P permissible ambient pressure, Π total inert gas tissue tension, n excited bubble distribution in radius (exponential), γ bubble surface tension, and r bubble radius,

$$G \int_{\epsilon}^{\infty} n dr = (\Pi - P) \int_{\epsilon}^{\infty} n dr \leq \int_{\epsilon}^{\infty} \left[\frac{2\gamma}{r} \right] n dr$$

so that,

$$G = (\Pi - P) \leq \beta \exp(\beta \epsilon) \int_{\epsilon}^{\infty} \exp(-\beta r) \left[\frac{2\gamma}{r} \right] dr$$

for ϵ the excitation radius at P . Time spent at each stop is iteratively calculated so that the total separated phase, Φ , is maintained at, or below, its limit point. This requires some computing power, but is attainable in diver wrist computers presently marketed, with the same said for the VPM. The USN and ZHL16 models are less complex for computer implementation. The limit point to phase separation, Φ , is near $600 \mu m^3$, and the distribution scaling length, β , is close to $0.60 \mu m^{-1}$ for both nitrogen and helium. Both excitation radii, ϵ , and surface tension, γ , are functions of ambient pressure and temperature, and not constant as assumed in many analyses. The EOS assigned to the bubbles renders the surface tension below lipid estimates used previously, on the order of 15 dyne/cm , and excitation radii are below $1 \mu m$ [18].

LANL Profile Data Bank

Divers are reporting their profiles to a Data Bank, located at LANL. The profile information needed is simple and comes from dive computer downloads. Computer downloads are then processed for entry into the LANL Data Bank. Some profiles (not downloaded) are transcribed into requisite data format. Powerful software translate dive computer (microcomputer) downloads into meaningful data for maximum likelihood analyses on the LANL Blue Mountain machine (massively parallel supercomputer). An earlier publication [19] describes profiles in the LANL Data Bank, as well as broader field testing reported to us. Profiles come from seasoned divers using wrist slate decompression tables with computer backups, and directly as computer downloads, which we software transcribe to the requisite format. Profiles span the technical diving community at large, essentially mixed gas, extended range, decompression, and extreme diving. Profiles from the recreational community are not included, unless they involve extreme exposures on air or nitrox (many repetitive dives, deeper than 150 *fsu*, altitude exposures, etc). This low rate makes statistical analysis difficult, and we use a global approach to defining risk after we fit the model to the data using maximum likelihood. The maximum likelihood fit links directly to the binomial probability structure of DCS incidence [14,17] in divers and aviators. Consider it briefly, and the likelihood maximization technique.

Probabilistics And Data Correlation

Decompression sickness is a hit, or no hit, situation. Statistics are binary, as in coin tossing. Probabilities of occurrence are determined from the binomial distribution, which measures the numbers of possibilities of occurrence and non-occurrence in any number of events, given the incidence rate. Specifically, the probability, P , in a random sample of size, N , for n occurrences of decompression sickness and m non-occurrences, takes the form,

$$P(n) = \frac{N!}{n! m!} p^n q^m$$

with,

$$n + m = N$$

p the underlying incidence rate (average number of cases of decompression sickness), and q ,

$$q = 1 - p$$

the underlying nonincidence. For large sample sizes, $N = n + m$,

$$\ln P(n) \approx N \ln N - n \ln n - m \ln m + n \ln p + m \ln q$$

The likelihood of binomial outcome, Φ , of N trials is the product of individual measures of the form,

$$\Phi(n) = p^n q^m = p^n (1 - p)^m$$

given n cases of decompression sickness and m cases without decompression sickness, and,

$$n + m = N$$

The natural logarithm of the likelihood (LL), Ψ , is easier to use in applications, and takes the form,

$$\Psi = \ln \Phi = n \ln p + m \ln (1 - p)$$

and is maximized when,

$$\frac{\partial \Psi}{\partial p} = 0$$

The multivalued probability functions, $p(x)$, generalize in the maximization process according to,

$$\frac{\partial \Psi}{\partial p} = \sum_{k=1}^K \frac{\partial \Psi}{\partial x_k} \frac{\partial x_k}{\partial p} = 0$$

satisfied when,

$$\frac{\partial \Psi}{\partial x_k} = 0 \text{ for } k = 1, K$$

In application, such constraints are easily solved on computers, with analytical or numerical methods. The likelihood, Ψ , is typically a function of 2 - 3 parameters over the whole set of profiles, requiring computing power coupled to sophisticated numerical techniques and software.

To perform risk analysis with the LANL Data Bank, an estimator need be selected. For both dissolved gas and phase models the permissible supersaturation, G , is useful. As detailed earlier, the permissible supersaturation, G , is cast into normalized risk function, ρ , form,

$$\rho(\kappa, t) = \kappa \left[\frac{\Pi(t) - P(t)}{P(t)} \right] - \kappa \exp(-\omega t)$$

with $\Pi(t)$ and $P(t)$ total tissue tension and ambient pressures in time, t . The asymptotic exposure limit is used in the likelihood integrals for risk function, r , across all compartments, τ ,

$$1 - r(\kappa) = \exp \left[- \int_0^\infty \rho(\kappa, t) dt \right]$$

with *hit - no hit*, likelihood function, Ω , of form,

$$\Omega = \prod_{k=1}^K \Omega_k$$

$$\Omega_k = r_k^{\delta_k} (1 - r_k)^{1-\delta_k}$$

and logarithmic reduction, Ψ ,

$$\Psi = \ln \Omega$$

where, $\delta_k = 0$ if DCS does not occur in profile, k , or, $\delta_k = 1$ if DCS does occur in profile, k . To estimate κ in maximum likelihood, a modified Levenberg-Marquardt [14,19] algorithm is employed (*SNLSE*, Common Los Alamos Applied Mathematical Software Library) [20], a nonlinear least squares data fit (NLLS) to an arbitrary logarithmic function (minimization of variance over K data points with $L2$ error norm).

We assign numerical tasks to processors on the LANL Blue Mountain Machine, a massively parallel processor (MPP) with 2,000 nodes according to tissue compartments and the 3 (nitrox, trimix, heliox) data sets. Risk estimates emerge and only maximum tissue risks are finally averaged and variance computed. In diver staging, certain tissue compartments control the exposure, This is true within dissolved gas algorithms, as well as bubble algorithms. Finally, we fit across the partitioned depth data structures:

$$\begin{aligned} \text{USN} - \kappa &= 0.45 \pm 0.16 \text{ min}^{-1}, \omega = 0.82 \pm 0.09 \text{ min}^{-1} \\ \text{ZHL16} - \kappa &= 0.56 \pm 0.23 \text{ min}^{-1}, \omega = 0.89 \pm 0.16 \text{ min}^{-1} \\ \text{VPM} - \kappa &= 0.83 \pm 0.17 \text{ min}^{-1}, \omega = 1.02 \pm 0.29 \text{ min}^{-1} \\ \text{RGBM} - \kappa &= 0.96 \pm 0.13 \text{ min}^{-1}, \omega = 0.91 \pm 0.18 \text{ min}^{-1} \end{aligned}$$

The data is relatively coarse grained, making compact statistics difficult. The incidence rate across the whole set is small, on the order of 1% and smaller. Consistent with a permissible supersaturation risk function which varies with depth over range, we divide the 2994 profiles into 200 *fsw* increments for nitrox, heliox, and trimix, OC and RB entries. The tabulation follows in Table 3, with DCS hits, ι , and total of category dives, σ , denoted ι/σ in the Table.

Table 3. Profile Data

mix	0- 199 <i>fsw</i>	200- 299 <i>fsw</i>	300- 399 <i>fsw</i>	400- 499 <i>fsw</i>	500- 599 <i>fsw</i>	600+ <i>fsw</i>	total
OC nitrox	5/268	3/76					8/344
RB nitrox	0/213	1/246	1/91				2/550
OC trimix	0/10	2/388	0/226	1/26	0/4	1/2	4/656
RB trimix	0/22	0/393	1/291	2/118	1/5		4/819
OC heliox		0/42	2/49	0/25			2/116
RB heliox	0/12	0/215	1/163	1/117	1/2		3/509
total	5/525	6/1350	5/820	4/286	2/11	1/2	23/2994

In the above set, there are 35 *marginals*. Marginals are often entered with statistical weight of 0.5 in likelihood analysis, but we do not include them. The profiles the 500+ *fsw* category are record attempts on OC and RB systems and are not part of operational diving in the broad sense.

The logarithmic likelihood (LL), Ψ , is a rough metric for fits to bubble and supersaturation risk estimators. The canonical value, Ψ_6 , is the LL for the 6-step depth control data set. No fit value, Ψ , will better the canonical value, Ψ_6 , that is,

$$\Psi_6 = -124.86$$

$$\Psi \leq \Psi_6$$

meaning all fits will be more negative (smaller LL). Results are tabulated as follow in Table 4. The 36 nitrox, trimix, and heliox set is called the null set by statisticians, but we will employ the 6-step depth set across all gases and breathing systems as the null set. The 36 step set is not dense. The 3-step set is all nitrox, heliox, and trimix profiles across all depths and breathing systems. The 1-step set is just all profiles across depths, breathing mixtures, and breathing systems.

The logarithmic likelihood ratio (LLR), denoted Γ , tests two models, and is χ^2 distributed,

$$\Gamma = 2(\Psi_6 - \Psi)$$

for Ψ the bubble and supersaturation estimators in Table 4. The percentage point, α , is the area under the χ^2 curve, from $\chi^2_{\alpha,\nu} = \Gamma$ to ∞ , measuring the goodness of fit, ranging 0 to 1,

$$\int_{\chi^2_{\alpha,\nu}}^{\infty} \chi^2(x,\nu) dx = \alpha$$

for ν the degrees of freedom (6 - the number of USN, ZHL16, VPM, RGBM, 3, or 1 step degrees of freedom). Here, ν will vary between 5 and 3, that is, for the USN, ZH16, VPM, and RGBM correlations, $\nu = 4$, while for the 3-step correlation, $\nu = 3$, and for the 1-step correlation, $\nu = 5$.

Table 4. Logarithmic Likelihood And Logarithmic Likelihood Ratio

estimator	LL	parameters	LLR	α
6 step set	$\Psi_6 = -124.86$	$p = 0.0095, 0.0044, 0.0061, 0.0140, 0.1818, 0.5000$	$\Gamma_6 = 0$	1.000
3 step set	$\Psi_3 = -133.71$	$p = 0.0112, 0.0054, 0.0080$	$\Gamma_3 = 16.7$	0.031
1 step set	$\Psi_1 = -134.86$	$p = 0.0077$	$\Gamma_1 = 20.0$	0.027
USN	$\Psi_{USN} = -133.0$	$\kappa = 0.45 \pm 0.16 \text{ min}^{-1}$ $\omega = 0.82 \pm 0.09 \text{ min}^{-1}$	$\Gamma_{USN} = 8.3$	0.081
ZHL16	$\Psi_{ZHL16} = -128.3$	$\kappa = 0.56 \pm 0.23 \text{ min}^{-1}$ $\omega = 0.89 \pm 0.16 \text{ min}^{-1}$	$\Gamma_{ZHL16} = 7.1$	0.132
VPM	$\Psi_{VPM} = -126.9$	$\kappa = 0.83 \pm 0.17 \text{ min}^{-1}$ $\omega = 1.02 \pm 0.29 \text{ min}^{-1}$	$\Gamma_{VPM} = 2.1$	0.717
RGBM	$\Psi_{RGBM} = -126.1$	$\kappa = 0.96 \pm 0.13 \text{ min}^{-1}$ $\omega = 0.91 \pm 0.18 \text{ min}^{-1}$	$\Gamma_{RGBM} = 1.3$	0.861

Capsule Summary

The USN, ZHL16, VPM, and RGBM protocols were statistically analyzed for correlations and data linkage within the LANL Data Bank. The Bank stores technical, mixed gas diving profiles with outcomes. Some 2900+ deep stop profiles reside within the Bank, with 23 cases of DCS. Parameters within models analyzed were fixed for comparisons and were representative of values used popularly in decompression meters, dive tables, and dive planning software. No attempts were made to optimize these parameters for correlation with data. The correlation functions were the model constrained permissible supersaturations. The USN and ZHL16 models do not correlate, with statistical significance:

$$\begin{aligned} \text{USN} - \chi^2 &= 0.081 \\ \text{ZHL16} - \chi^2 &= 0.131 \end{aligned}$$

while the VPM and RGBM models correlate well:

$$\begin{aligned} \text{VPM} - \chi^2 &= 0.717 \\ \text{RGBM} - \chi^2 &= 0.861 \end{aligned}$$

This work reports further correlations between global (OC and RB) mixed gas diving, specific models (USN, ZHL16, VPM, RGBM), and deep stop data. Our objective is safe operational diving, not clinical science which is well beyond this profile correlation.

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AUTHOR SKETCH

Bruce Wienke is a Program Manager in the Nuclear Weapons Technology/ Simulation And Computing Office at the Los Alamos National Laboratory (LANL), with interests in hydrodynamics, applied mathematics, particle and nuclear physics, numerical methods, parallel computing, thermonuclear burn, decompression phenomenology and models, radiation and gas transport, bubble dynamics, and phase mechanics, publishing some 240+ technical and research papers in related Journals. He contributes to underwater symposia, educational publications, technical periodicals and decompression workshops, authoring eight monographs (*Hyperbaric Physics With Bubble Mechanics And Decompression Theory*, *Reduced Gradient Bubble Model In Depth*, *Technical Diving In Depth*, *Physics, Physiology And Decompression Theory For The Technical And Commercial Diver*, *High Altitude Diving*, *Basic Diving Physics And Applications*, *Diving Above Sea Level*, *Basic Decompression Theory And Applications*). Diving experience includes the Caribbean, South Pacific, Asia, inland and coastal United States, Hawaii, and polar Arctic and Antarctic on OC and RB systems in technical, scientific, military, and research exercises. He functions as Team Leader for the C & C Dive Team.

Wienke is Workshop Director/Instructor Trainer with the National Association Of Underwater Instructors (NAUI), and served on the Board Of Directors (Vice Chairman for Technical Diving, Technical and Decompression Review Board Member). Wintertime he hobbies ski racing, coaching, and teaching. As a Racing Coach and Instructor, he is certified United States Ski Coaches Association (USSCA) and Professional Ski Instructors of America (PSIA), and competes in the United States Ski Association (USSA) Masters Series, holding a 8 NASTAR racing handicap while winning NASTAR National Championships in his age class over the past 15 years, and Rocky Mountain SL, GS, SG, and DH Masters titles over the past 5 years. He quarterbacked the Northern Michigan Wildcats to an NCAA-II National Championship in 1963, winning All American Honors. Other pastimes include tennis, windsurfing, and mountain biking.

Wienke received a BS in physics and mathematics from Northern Michigan University, MS in nuclear physics from Marquette University, and PhD in particle physics from Northwestern University. He belongs to the American Physical Society (APS), American Nuclear Society (ANS), Society Of Industrial And Applied Mathematics (SIAM), South Pacific Underwater Medical Society (SPUMS), Undersea And Hyperbaric Medical Society (UHMS), and American Academy Of Underwater Sciences (AAUS). He is a Fellow of the American Physical Society, and a Technical Committee Member of the American Nuclear Society.

Wienke advises on decompression algorithms across exploration, recreational, technical, commercial, scientific, and research sectors, and developed the reduced gradient bubble model (RGBM), a dual phase approach to staging diver ascents over an extended range of diving applications (altitude, nonstop, decompression, multiday, repetitive, multilevel, mixed gas, and saturation). Many modern dive computers incorporate the modified and iterative RGBM into staging regimens for OC and RB mixed gas diving. In lock step, computer software and platforms offer RGBM for technical dive planning and profile analysis. A number of Training Agencies employ RGBM tables, software, and meters for hands on training and education within their Standards and Procedures.

Wienke serves as Reviewer Editor for the *Journal of Computational Physics*, *Physical Review*, *Transport Theory And Statistical Mechanics*, *Applied Physics*, *Nuclear Science And Engineering*, *Nuclear Fusion*, *Journal Of Quantitative Spectroscopy And Radiation Transport*, *Nuovo Cimento*, and *Journal of Applied Physics*. He is also an Associate Editor for the *International Journal Of Aquatic Research And Education*, a Contributing Editor of *Sources*, the NAUI training periodical, and a Contributing Editor of *Advanced Diver Magazine*, a trade publication for technical diving.