RECENT DEEP STOP DATA AND TESTS

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Introduction

The *Deep Stop And Decompression Workshop*, sponsored by the Undersea And Hyperbaric Medical Society (UHMS), Office Of Naval Research (ONR), Divers Alert Network (DAN), NAUI, PADI, and IANTD in Salt Lake City in June, was well attended by contributors and attendees from the technical diving community, training agencies, scientific and medical sectors, US and French Navies, Los Alamos National Laboratory, meter manufacturers, and researchers in related sectors. The focus was deep stops. Some interesting information emerged and readers are directed to the Proceedings for all details. Proceedings should be out in a few months, and will carry not only invited papers, but also ensuing discussions by participants. In another communication, we hope to summarize Workshop viewpoints.

The Workshop got us thinking about deep stops and this article. Many facets of deep stops remain poorly understood and need further elucidation. Yet, building on published work over the years, there is much support for deep stops, testwise and datawise. Readers of SOURCES might find select analyses, spanning recreational to technical diving, pertinent. So in risk analysis framework, here are some cherry picked tests and data, specifically the LANL Data Bank, the Neuman-Linaweaver early deep stop air tests, the Bennett-Marroni recreational deep stop Doppler tests, the NEDU 170/30 deep air schedules, the French Navy deep air Doppler tests, and the LANL C & C Team 450/20 trimix RB trials. All impact NAUI recreational air and nitrox tables, and mixed gas terchnical decompression tables. Analyses such as the following provide insights into the whys and wherefores of deep stops imbedded in all NAUI tables. Specifically, the Bennett-Marroni Doppler tests corroborate the recreational NAUI 1/2 deep stop training protocols for air and nitrox diving, while the others underscore risk factors that enter into fabrication of the NAUI open circuit (OC) and rebreather (RB) mixed gas decompression tables.

Early Deep Stop Air Tests

Back in 1976, a controversial era for deep stops and the enigmatic Brian Hills, Neuman and Linaweaver tested a number of decompression schedules on air, using deep stops and early Doppler. No surprise today, they found that deep air stops lowered Doppler scores in surfacing divers and reduced the incidence of DCS in statistically small trial space. Both the normoxic nitrox profiles tested and the results differ dramatically from the 2007 NEDU air tests for the same exposure, namely 170/30, that is, 170 fsw for 30 min. The DCS hit rate in the NEDU tests was 5%, while 0% in the Neuman-Linaweaver studies, and the run time was also 4 times longer in the NEDU cases. Perhaps some discrepancies relate to the use of normoxic nitrox for the equivalent 170/30 air dive, but that seems a small effect considering the use of equivalent air depths by nitrox divers. In light of present deep stop practices, the early Neuman-Linaweaver studies are congruent with same, while the later NEDU tests leave much to be explained as to rationale for the deep stop profile NEDU tested. As such, the NEDU profile is not of the deep stop genre used today. More will follow on that.

In a nutshell, some results of the Neuman-Linaweaver tests are quoted *[Neuman. priv comm, 2007]* from their published paper. Using traditional (extreme) exposure staging for an air dive to 210 fsw for 50 min, subjects made a deep stop for 3 min at depth 10 fsw deeper than the first USN stop. On the equivalent 170 fsw dive for 30 min, subjects also made a deep stop for 2 min at a depth 10 fsw deeper than the first USN stop. In other words, the deep stops were only 10 fsw deeper than the first decompression stops, but the reductions in Doppler scores and DCS hit rates were statistically meaningful. There were no cases of DCS in subjects performing deep stops on top of traditional staging protocols. Bubble counts on deep stop stagings also dropped by factors of 5 versus counts on traditional stagings. Noticeably of interest are the decompression run times, 46 min in the Neuman-Linaweaver chamber tests, versus 178 min in the NEDU wet pod studies. The NEDU experiment requires run times of 178 min to use shallow stop data as a calibration point (has same run times), but since deep stops always result in shorter overall run times, little to no meaningful comparative data seems the result. Rather than testing deep stops, NEDU likely tested an inadequate multilevel decompression profile. Dive planning and decompression software were not available in 1976 as today, so the contrasts standout more, as witnessed on many blog and technical diving websites.

RGBM Data Bank

Deep stop data is necessary, within the RGBM, as well as all other bubble (dual phase) models requiring deep stops algorithmically. While LANL data is broadbased, we have been able to extract correlation parameters, plus estimate some table, meter, and profile risks. Data collection continues across the gamut of technical, scientific, and research diving. Divers using bubble models are reporting their profiles to a Data Bank, located at LANL (also NAUI Technical Diving Operations). The profile information stored is simple:

1. bottom mix/$ppO2$, depth, and time (square wave equivalent);
2. ascent and descent rates;
3. stage and decompression mix/$ppO2$, depths, and times;
4. surface intervals;
5. time to fly;
6. diver age, weight, and sex;
7. outcome (health problems), rated 1 - 5 in order of poor (DCS) to well.

This information aids validation and extension of model application space. Some 2,879 profiles now reside in the LANL Data Bank. The are 20 cases of DCS in the data file. The underlying DCS incidence rate is, $p = 20/2879 = 0.0069$, below 1%. Stored profiles range from 150 fsw down to 840 fsw, with the majority above 350 fsw. All data enters through the authors (BRW and TRO), that is, divers, profiles, and outcomes are filtered. All data is deep stop data. A summary breakdown of DCS hit (bends) data consists of the following:

1. OC deep nitrox reverse profiles – 5 hits (3 DCS I, 2 DCS II)
2. OC deep nitrox – 3 hits (2 DCS I, 1 DCS II)
3. OC deep trimix reverse profiles – 2 hits (1 DCS II, 1 DCS III)

4. OC deep trimix – 2 hits (1 DCS I, 1 DCS III)
5. OC deep heliox – 2 hits (2 DCS II)
6. RB deep nitrox – 2 hits (1 DCS I, 1 DCS II)
7. RB deep trimix – 2 hits (1 DCS I, 1 DCS III)
8. RB deep heliox – 2 hits (1 DCS I, 1 DCS II)

DCS I means limb bends, DCS II implies central nervous system (CNS) bends, and DCS III denotes inner ear bends (occurring mainly on helium mixtures). Both DCS II and DCS III are fairly serious afflictions, while DCS I is less traumatic. Deep nitrox means a range beyond 150 fsw, deep trimix means a range beyond 200 fsw, and deep heliox means a range beyond 250 fsw as a rough categorization. The abbreviation OC denotes open circuit, while RB denotes rebreather. Reverse profiles are any sequence of dives in which the present dive is deeper than the previous dive. Nitrox means an oxygen enriched nitrogen mixture (including air), trimix denotes a breathing mixture of nitrogen, helium, oxygen, and heliox is a breathing mixture of helium and oxygen. None of the trimix nor heliox cases involved oxygen enriched mixtures on OC, and RB hits did not involve elevated oxygen partial pressures above 1.4 atm. Nitrogen-to-helium (-to-light) gas switches occured in 4 cases, violating contemporary ICD (isobaric counterdiffusion) protocols. Isobaric counterdiffusion refers to two inert gases (usually nitrogen and helium) moving in opposite directions in tissues and blood. When summed, total gas tensions (partial pressures) can lead to increased supersaturation and bubble formation probability. None of the set exhibited full body nor CNS (central nervous system) oxygen toxicity. The 20 cases come after the fact, that is diver distress with chamber treatment. Profiles come mainly from C & C Team operations and some from 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 repetitve dives, deeper than 150 fsw, 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 nature of DCS (hit, or no hit), and the set of bubble model parameters being fit.

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. Fine graining into depths is not meaningful yet, so we breakout data into gas categories (nitrox, heliox, trimix), as tabulated earlier. Table 1 indicates the breakdown.

Table 1. Profile Data

mix	total profiles	DCS hits	incidence
OC nitrox	344	8	0.0232
RB nitrox	550	2	0.0017
all nitrox	894	10	0.0112
OC trimix	656	4	0.0061
RB trimx	754	2	0.0027
all trimix	1410	6	0.0042
OC heliox	116	2	0.0172
RB heliox	459	2	0.0044
all heliox	575	4	0.0070
all	2879	20	0.0069

The DCS hit rate with nitrox is higher, but not statistically meaningful across this sparse set. The last entry is all mixes, as noted previously. To fit this data, we will test both the RGBM (bubble) and ZHL (supersaturation) models using maximum likelihood, or better yet, logarithmic likelihood, as it is called by the statistical folks. Recall that the Buhlmann ZHL model has been a standard for dissolved gas staging, while the RGBM is a modern staging model with deep stops implicit in its formulation, one that has gained widespread acceptance and utility in the past 20 years, or so.

While we cannot recount mathematical details here, we rely upon logarithmic likelihood techniques to match models against the data in Table 1. Three distinct classes of data emerge from Table 1, the set of 2879 individual profiles, the 3 set of nitrox, heliox, and trimix profiles, and the 6 set of OC and RB nitrox, heliox, and trimix profiles, with the 6 set the most comprehensive and the one used for model comparisons. Any good statistics book can recount logarithmic likelihood methods. The logarithmic likelihood, LL, is a rough metric for fits by the RGBM and ZHL models. The canonical value, $LL6$, is the LL for the 6 step RB/OC control set. No fit value, LL, will better the canonical value, $LL6$, that is,

$$LL6 = -112.9$$

$$LL \leq LL6$$

meaning all fits will be more negative (smaller LL). Results are tabulated as follow in Table 2. Put another way, the closer LL is to LL_6, the better the fit.

Table 2. Logarithmic Likelihood And Logarithmic Likelihood Ratio

model	LL	LLR	p
6 step ste	-112.9	0.0	1.000
3 step set	118.4	11.0	0.013
2879 set	-119.2	12.6	0.033
ZHL	-210.6	92.2	0.001
RGBM	-113.3	0.8	0.933

The logarithmic likelihood ratio, denoted LLR, tests two models, and is linked to the statistical chi squared distribution. The chi squared distribution ranges from 0 to 1, and measures goodness of a model to data. As LL approaches LL_6, the chi squared indicator, p, approaches 1. The closer p gets to 1, the better the statistical metrics for the model. Clearly, the ZHL model does not correlate well, compared to the RGBM model. It does not work here in the deep decompression arena, but others have shown it correlates in the nonstop and light decompression limits. In those limits, bubble models and supersaturation models tend to converge, simply because phase growth is minimal.

Bottom line, this analysis suggests that deep stops are both safe and compact statistically for the LANL model and set. Coupled gas transport analysis suggests that deep stops and shallow stops can both be staged safely, but deep stops are more efficient in controlling bubble growth and are usually shorter in overall dive time duration. Any surprise to SOURCES readers? Probably not.

Bennett And Marroni 2.5 Minute Recreational Deep Stop

Deep stops are already mainliners in some training agency protocols for no and light decompression diving on air and nitrox. The prescription is to make a deep stop at half depth for 1 - 3 *min*, followed by a shallow stop in the 15 *fsw* zone for 1 - 2 *min*. In Table 3, we cite bubble surfacing risks for a deep stop at half depth for 1 *min*, 2.5 *min*, and 4 *min*, the middle case suggested by Bennett and Marroni from Doppler scoring *[Bennett, priv comm, 2008]*, followed by direct ascent to the surface. Risks are easily computed within RGBM and/or ZHL models using standard techniques, but are not reproduced here. Interested readers might consult *Basic Decompression Theory And Applications*, Best Publishing Company, Flagstaff, 2008. Surfacing supersaturation risks are tabulated in Table 4 for comparison. Dives are carried out to the (old) US Navy NDLs for easy reference. Deep stops for less than 2.5 *min* reduce recreational risk out to the Navy NDLs in all cases. Bubble risks decrease for short deep stops and then increase as stop times increase. As stop times continue to increase, the dives will require decompression. In other words, with increasing deep stop time, the dives become multilevel decompression dives. Obviously, the playoff of deep stop time against bottom time is a minimax problem. This is traced to bubble behavior with increased gas tensions for increasing deep stop time. In all cases, stop time in the shallow zone was 1 *min*. Longer stop times in the shallow zone had little effect on surfacing risks. Shallow stops in training regimens probably serve better to teach buoyancy control to neophytes.

Table 3. Comparative Bubble Risks For Recreational Deep Stops

depth (fsw)	time (min)	no stop $RGBM$	1 min stop $RGBM$	2.5 min stop $RGBM$	4 min stop $RGBM$
80	40	2.10%	1.93%	1.90%	1.91%
90	30	2.10%	1.87%	1.83%	1.84%
100	25	2.10%	1.74%	1.71%	1.72%
110	20	2.20%	1.65%	1.61%	1.62%
120	15	2.00%	1.50%	1.46%	1.47%
130	10	1.70%	1.29%	1.25%	1.26%

Ascent and descent rates were standard in the analysis, that is, 30 fsw/min and 60 fsw/min respectively. The small risk spread for 1 - 4 *min* accommodates recreational deep stop training regimens, that is, 1 - 3 *min* deep half stop for many agencies.

Corresponding supersaturation risks in Table 4 are seen to increase montonically with length of deep stop. This is to be expected in dissolved gas models, with exposures at increasing depths for increasing times cascading tissue tensions, oblivious to any bubble-dissolved gas interactions tracked in Table 3.

Table 4. Comparative Supersaturation Risks For Recreational Deep Stops

depth (fsw)	time (min)	no stop ZHL	1 min stop ZHL	2.5 min stop ZHL	4 min stop ZHL
80	40	2.10%	2.12%	2.18%	2.26%
90	30	2.10%	2.13%	2.20%	2.29%
100	25	2.10%	2.15%	2.23%	2.34%
110	20	2.20%	2.24%	2.32%	2.41%
120	15	2.00%	2.10%	2.20%	2.38%
130	10	1.70%	1.78%	1.91%	2.13%

NEDU Deep Stop Air Tests

The Navy Experimental Diving Unit recently tested their version of air deep stops *[NEDU, priv comm, 2007]* with a moderate DCS rate. Profiles tested are given in Table 6, along with a suggested LANL deep stop profile. Profile NEDU 1 incurred a 5.5% DCS hit rate, while NEDU 2 1 incurred a lower 1.5% DCS hit rate.

Table 6. Comparative NEDU Air Deep Stop Schedules

depth (fsw)	NEDU 1 time (min)	NEDU 2 time (min)	LANL time (min)
170	30	30	30
120			0.5
110			1.5
100			2.5
90			3.5
80			4.5
70			5.0
70	12		5.0
60	17		7.0
50	15		11.0
40	18	9	14.5
30	23	23	22.0
20	17	52	28.5
10	72	93	59.9
	206	207	195
$ZHL\ risk$	5.6%	2.4%	3.4%
$RGBM\ risk$	10.6%	3.2%	2.6%

Bubble risk is higher in both NEDU 1 and NEDU 2, but large in NEDU 1. NEDU 1 is a multilevel decompression dive with inadequate treatment in the shallow zone. Initial deep stops in NEDU 1 did not control bubble growth, and the length of the stay in 70, 60, and 50 fsw builds up dissolved gas in the middle range tissues, which then diffuses into bubbles causing them to grow. NEDU 2 is classic with no deep stops, and very long times in the shallow zone to effect decompression. The LANL schedule has deeper stops, shorter midzone times, and then shorter times in the shallow zone compared to both NEDU 1 and NEDU 2. One important factor here is the shape of the decompression schedule, that is the LANL profile is shorter overall, with NEDU 1 and NEDU 2 profiles exhibiting supersaturation staging with shallow belly and tail, while the LANL profile is steeper exhibiting bubble staging with deeper stops and steeper ascent rate. Both NEDU profiles are not of the genre typically dived by users of modern deep stop tables, software, and meters.

Gas transport analyses on both NEDU schedules suggests that NEDU 1 produces 15% - 30% larger bubble volumes on surfacing, due to the longer stay in the mid zone, while NEDU 2 produces surfacing bubble volumes 3% - 5% larger than surfacing bubble volumes in the LANL profile. Surfacing bubble volumes in the LANL profile were close to the staging limit point.

French Navy Deep Stop Schedules

The French Navy also tested deep stop air schedules *[Blatteau, priv comm, 2008]*. Three protocols on deep air were employed and none exhibited Grade 4 Doppler bubbles. Analysis centered on just Grade 3 bubbles. For purposes of deep stop analysis, Protocol 1, a dive similar to NEDU 1, is interesting. Protocol 1 is a deep air dive to 200 fsw for 20 min, with ascent staging according to Table 7. Contrasting staging strategies are denoted MN90, the standard French Navy dissolved gas regimen, and LANL. Outside of World Navies, few diving sectors today even contemplate air decompression diving to 200 fsw. Risks in air dives beyond 150 fsw are known to increase by factors of 10 over similar dives at shallower depth. This is, of course, one major reason why trimix and heliox become mixtures of choice for deep and decompression diving worldwide, across commercial, scientific, exploration, and research sectors.

Table 7. French Navy Air Deep Stop Schedules At 200 fsw

	Protocol 1	MN90	LANL
ascent rate fsw/min			
starting at 90 fsw	10	20	30
depth	time	time	time
(fsw)	(min)	(min)	(min)
200	20	20	20
130			0.5
120			0.5
110			1.0
100			1.0
90			1.0
80	1		1.5
70	1		2.0
60	2		2.0
50	2		2.5
40	4		3.0
30	6	3	6.0
20	9	8	7.0
10	22	32	8.0
	78	68	65
RGBM risk	3.9%	2.2%	2.1%

By contrast, LANL staging starts deeper, is shorter overall, and has smaller bubble risk than Protocol 1. Protocol 1, however, tracks more closely with LANL than NEDU 1, and exhibits lower risk than NEDU 1. However, run time for Protocol 1 versus MN90 is longer, unlike conventional bubble model run times. Estimated bubble risks, $RGBM$, are tabulated at the bottom of Table 7.

C & C Team 450/20 Multiple RB Dive Sequence At 1.4 atm

Details of a 16 dive sequence by members of the C & C Team to 450 fsw for 20 min at 1.4 atm follow. Dives were successfully completed in tandem without mishap, and are included in the LANL Data Bank. All dives follow the same schedule, as given in Table 5. Oxtox (both CNS and full body) metrics are included. Diver Tags and Outcomes are tabulated, according to the LANL Data Bank profile schema described previously. Diver Tag 1 is one of the authors (BRW). Risk estimates (both bubble and supersaturation) are noted, along with binomial probabilities for 16 tandem dives within a LANL Data Bank underlying incidence rate of 0.69%. Four additional dives in the same sequence were also performed without mishap, but are not included because of larger fluctuations about 450 fsw. Bottom fluctuations in the 16 dive sequence were ± 5 fsw maximum for longer than a minute.

Diluent is 10/80 trimix with a $ppO2$ setpoint of 1.4 atm. The cumulative CNS clock fractions exceed a (traditional) limit of 1.0, while OTU uptake remains below a (traditional) limit of 650 min. There is likely greater variability in oxtox limit points than decompression limit points. Descent and ascent rates are standard, except in the 30 fsw zone where the ascent rate is 1 fsw/min. The binomial probability of no hits is $P(0)$, while the probability of 1 hit is $P(1)$. The probability of 2 or more hits is vanishingly small for underlying incidence of 0.69%.

Table 5. RB 16 Dive Sequence At 1.4 *atm*.

Dive Tags = 2042 - 2058
Diver Tags = 3,20,5,**1**,9,6,10,2,14,4,15,7,8,11,16,12
Diver Outcomes = 3,4,3,**3**,4,3,4,3,4,3,3,3,4,3,4,3
Underlying Incidence = 20/2879

depth (fsw)	time (min)	CNS clock ($fraction$)	OTU uptake (min)
450	20	.17	32.6
360	0.5	.01	0.8
350	0.5	.01	0.8
340	0.5	.01	0.8
330	0.5	.01	0.8
320	0.5	.01	0.8
310	0.5	.01	0.8
300	1.0	.02	1.6
290	1.0	.02	1.6
280	1.0	.02	1.6
270	1.0	.02	1.6
260	1.0	.02	1.6
250	1.0	.02	1.6
240	1.0	.02	1.6
230	1.5	.03	1.8
220	1.5	.03	1.8
210	2.0	.03	4.1
200	2.0	.03	4.1
190	2.0	.03	4.1
180	2.0	.03	4.0
170	2.0	.02	4.0
160	2.5	.02	4.0
150	2.5	.02	3.9
140	3.5	.03	5.7
130	5.0	.05	9.0
120	5.0	.04	8.5
110	5.0	.04	8.4
100	5.5	.04	9.0
90	6.0	.05	9.8
80	8.0	.07	13.0
70	8.0	.07	12.5
60	9.5	.08	15.5
50	11.0	.10	17.9
40	12.0	.10	19.5
30	8.5	.07	13.8
20	10.5	.09	17.1
10	17.0	.11	25.2
	211.5	1.38	262.2

$$RGRM\ risk = 4.27\%, \quad ZHL\ risk = 12.67\%$$
$$P(0) = 89.4\%, \quad P(1) = 10.4\%$$

Computed bubble risk (RGBM) is below the binomial probability, $P(1)$.

Gas Transport Analysis

With regard to the preceeding dives and schedules, a couple of points are interesting. These follow from a closer look at dissolved and bubble gas phases across the profiles, using LANL tools and selected way points on the dives. These comments also apply to deep and decompression staging using traditional dissolved gas models and tables. Remember these comments are made within the LANL model framework and attendant data correlation:

1. bubble growth in the deep zone of decompression profiles NEDU 1 and Protocol 1 is not constrained in their version of deep stop air tests;
2. deep stops are not deep enough in NEDU 1 and Protocol 1, nor are follow stops;
3. critical phase volume limit points are exceeded in NEDU 1 and Protocol 1 even before the diver exits, in other words, along the decompression glide path underwater;
4. the recreational 2.5 *minute* stop at 1/2 depth within the NDLs of even the old USN tables maintains the phase volumes below limit points;
5. the LANL 450/20 profiles also surface below the phase volume limit point, no surprise because profiles were designed to meet that constraint;
6. supersaturation profiles MN90 and NEDU 2 also do not control bubble growth in the deeper zones, but the separated phase volume is below model limit points, with pressure in the shallow zone sufficient to constrain bubble growth and maintain adequate dissolution, but time consuming because bubbles are now larger in the shallow zone.

Much the same can be said of supersaturation versus bubble staging strategies in general.

Capsule Summary

In addition to the gas transport comparison of dissolved gas staging versus bubble staging, analysis suggests broadly:

1. deep stop data is intrinsically different from data collected in the past for diving validation, in that previous data is mainly based on shallow stop diver staging, a possible bias in data collection;
2. deep stop data and shallow stop data yield the same risk estimates for nominal, shallow, and nonstop diving because bubble models and dissolved gas models converge in the limit of very small phase separation;
3. if shallow stop data is employed in all cases covered, dissolved gas risk estimates will be usually higher than those computed herein;
4. bubble risks estimated herein are higher than risk estimates in other analyses, perhaps a conservative bias;
5. data entry in the LANL Data Bank is a ongoing process of profile addition, extended exposure-depth range, and mixed gas diving application.

Data specifically underscores technical diving trends:

1. pure O_2 or $EAN80$ are standard OC switch gases in the 20 fsw zone;
2. deep stops are standard across mixed gas diving, and DCS spikes are nonexistent;

3. deep switches to nitrogen mixes off helium mixes are avoided by technical divers, instead oxygen fraction is increased by decrease in helium fraction;
4. deep stop dive computers serve mostly as backup or bailout, with tables and dive planning software the choice for deep stop diving;
5. DCS spikes across mixed gas, decompression, and deep stop diving are non existent using deep stop tables, meters, and software;
6. DCS incidence rates are higher for technical diving versus recreational diving, but still small;
7. RB usage is increasing across diving sectors;
8. wrist dive computers possess chip speeds that allow full resolution of even the most extensive bubble models;
9. nitrox diving in the recreational sector is exploding;
10. technical diving data is most important for correlating models and data;
11. technical divers do not dive air, particularly deep air, with trimix and heliox the choices for deep excursions;
12. released deep stop tables, software, and meters enjoy extensive and safe utility among professional divers;
13. technical diving is growing in leaps and bounds, with corresponding data accessible off computers and bottom timers;
14. more cross talk across military, scientific, research, exploration, and commercial diving is desirable.

The operational issue of deep stops and staging is one of timing, with questions of time and depth at all stops only addressed within consistent model and ranging data frameworks. *To that end, we conclude deep stops are not riskier than shallow stops, that both can accomplish the same end, but that deep stops are more efficient timewise than shallow stops.*