D. Kerem: Not much more than what I have shown. There were people for whom, at 1 atm of air, the $CO_2$ retention was not even in existence. When they were taken to 30 meters, they suddenly showed either a moderate or an extreme retention. You would probably want to say that it was the increased density caused mainly by depth.

D. Vann: Richard, aren't there data from Swedish workers that address that question?
R. Moon: Well, almost all the data in the literature have been based on end-tidal $CO_2$. I think it's the easiest measurement to make, but it's also fraught with a lot of difficulty.

A. Marroni: There is a growing interest in Europe for deep air diving and our multiple agencies are about to start certification at the 50 and 60 meters level on air for deco diving. Do you think that there is a role for a research project to screen for carbon dioxide retention in this kind of deep air diving?
D. Kerem: Probably not, unless you want to start consideration of wash-in and wash-out of gases that could be different with $CO_2$ retention. You have increased $CO_2$ during your dive and less when you are decompressing, nor a narcosis effect. There could be some synergism, but not regarding oxygen toxicity.

B. Hamilton: Dan, if you drew a best fit line through your data points, it would be very close to a 45-degree slope, or slope of one, which is what you would expect. For this particular measurement, air and enriched air, you would expect to see an end-tidal $PCO_2$, wouldn't you? It's going to affect them both in the same way isn't it, as they are the same densities?
D. Kerem: No, the air is at 1 atm and the enriched air at 4 atm. We just wanted to see if we could do a simple air test and predict who is going to be the $CO_2$ retainer. Most of them continued to show the same degree of retention when you took them to depth, but some of them only appeared as retainers at depth.

R. Moon: Dan, what was the $PO_2$ in the group breathing nitrox?
D. Kerem: For this particular one it was 40 percent, so at 4 atm, 1.6 atm.

D. Vann: Alessandro, regarding your question about deep air diving, there are a number of reports in the literature. I have also seen a case in the lab of people just going to sleep at 150 to 180 feet and there have been a number of fatalities there. That's a mighty difficult topic to study in the laboratory for ethical reasons. But I think there are certainly anecdotes.
D. Kerem: Were they resting or exercising?
D. Vann: They were exercising. The one that I'm familiar with personally, divers were swimming in open water. At some point, it might be reasonable to think about switching from nitrogen to helium to get rid of the narcosis and also the increased density, which would appear to increase $CO_2$ retention.

### B. Maximum $PO_2$ Limits Discussion

M. Lang: The next topic under physiology actually provides for a discussion session. It was included because it surfaced repeatedly from several of you as a topic in need of discussion, *i.e.,* the continually shrinking maximum $PO_2$ limit.

B. Gilliam: I've been doing this for a while. When I was a Navy diver, our operational limits were a maximum 2.0 atm and they've been revised downward steadily since then. At 1.6 atm, it seems that we've struck a balance that seems to work overwhelming well in this sport diving population we're addressing here. The database that we presented here today includes nearly 80,000 instructors and divers that were trained under the 1.6 atm rule. Obviously, that $PO_2$ is reduced as the length of the dive dictates, for longer dives it's going to decrease. It's interesting to note again how most of these divers are using nitrox as a technology and performing no-decompression, repetitive diving. If you take even the most liberal algorithm that is in place now, the no-decompression limit on a 32 percent mix (depth limit of 132 feet) still doesn't even get you to 40 percent of the CNS limit. Considering this as an oxygen-dose relationship, I'm trying to understand why there is this continuing resistance to the acceptance of 1.6 atm. We've heard positions that we should go to 1.4 atm. Nobody seems to have any reported oxygen toxicity incidents at all. It's not too likely that we will see any because of the methodology that's being used. The science divers are using 1.6 atm, as I understand it. We've been using it at TDI for nearly seven years now without incident. I can also tell you as the former President and CEO of Uwatec for four years that we shipped every one of our dive computers worldwide with a $PO_2$ alarm set at 1.5 atm. With our software program, the divers could go in and change that set point at will from a high of 1.95 atm to a low of 1.0 atm. When these computers would come back to us for battery changes or other service, about 95 percent of these computers were set at 1.6 atm. This means this diver population has decided that this limit is what they were going to dive at and they were not having problems with it. I would really like to hear from the naysayers as to why we think we need to mess with this limit that's worked well for NOAA, the Navy, the science divers, NASA, and for the largest population of nitrox sport divers who have been trained at this 1.6 atm limit.

D. Rutkowski: There's a lot of myth and misconception out there about the use of oxygen. You hear that commercial divers are routinely using $PO_2$'s of 1.8 atm. Navy SPECWAR are using 1.9 atm. NOAA and some of our training agencies here use 1.6 atm. PADI went to 1.4 atm. Dr. Wells could best explain how this 1.6 atm came up as an administrative appeasement number. It was between the professionals who wanted much higher $PO_2$'s and the recreational diving community. If I dive a $PO_2$ of 1.6 atm for 20 minutes at 130 feet, I'd be using 43 percent of my oxygen toxicity clock. I can dive 1.4 atm and use 100 percent of the oxygen toxicity clock and be in more danger than the individual pushing 1.6 atm. Many people will say that these working divers got to use 1.3 or 1.4 atm. The issue is not the $PO_2$; it's the time at the $PO_2$. If I'm going to make a 20 minute dive at 240 feet, I've got 120 minutes of decompression for which I'm going to need 140 minutes of my CNS clock. If I use a $PO_2$ of 1.4 atm, I will be using 93 percent of that clock. I'd be at much higher risk for a seizure than a diver pushing 1.6 atm and using only 43 percent of the CNS clock would. I could lower my $PO_2$ to 1.3 atm for that 140 minute dive, which would lower my CNS clock to 76 percent of running time rather than 93 percent. You've got to understand that it's the time at these $PO_2$'s that is important, not the $PO_2$ by itself.

B. Bjorkman: We run across this situation in Canada where we're allowed a $PO_2$ of 1.5 atm through DCIEM. Working divers are in very cold water and exerting themselves. We found that wasn't really the issue. The issue was that our divers were forgetting everything they were learning. Our instructors could teach them well for the day, but two weeks later would fail if they were retested. We had to come up with a way for people to remember all the formulas. The only way we could come up with was to develop a table. We found that if we went to a $PO_2$ of 1.2 atm, because keep in mind that our occupational divers in Canada can commercially dive with scuba, we didn't have the problems of tracking OTU's or CNS percentages. Most of the dives are done in relatively shallow water of 60 to 70 feet, perhaps as much as 90 feet. People ran out of air or bladder capacity long before they ran out of bottom time. If you notice on everybody's table or those working with equivalent air depths, down to about 60 feet it's pretty hard to get over a 1.2 atm in any event. For shallow water dives, we found that limiting nitrox to 1.2 atm for occupational scuba divers allowed us to put it all on a simple table that was very easy for people to track. They didn't have to remember any formulas, just looked at the table, and six months post-training could figure out exactly what $PO_2$ to use for the depth and the fraction of oxygen in their cylinder.

D. Rutkowski: Since you're doing shallow work, your $PO_2$ isn't significant. In Key Largo, we have two wrecks that range anywhere from 20 to 40 meters. We give somebody a 32 mix and they're going to go to 130 feet and be pushing a $PO_2$ of 1.6 atm. If we were to lower that to 1.2 atm, there would be no sense in having these artificial wrecks out there. People wouldn't be able to stay on them.

B. Bjorkman: We certainly agree with you on deeper depths. The only problem is if you have to go beyond a 1.2 atm, we have to start getting back into the formulas and this is where we're running into problems. They'll dive regardless, with a lifetime certification, but their knowledge is no longer there.

D. Rutkowski: Dr. Vann did a lot of research in this area. When you came up with some of these numbers you had these people on ergometers, didn't you, working in hot water and cold water?

D. Vann. Right, our 1.6 atm exposures were for divers working in 70 degree water. We were fine at 1.6 atm with working divers and I should say a lot of $CO_2$ retention in the equipment they were using until I got up to 40 minutes, when we had one seizure. We really have very poor data on oxygen toxicity in comparison to decompression where we don't have really good data. One of the things to bear in mind is what is risk? Risk depends upon two things. It depends upon the probability of an injury and it also depends upon the severity of an injury. For decompression sickness, for example, when we're doing altitude studies for the space station, we don't mind 50 to 80 percent incidence of decompression sickness if the symptoms are simply knee pain. If we get into a situation where we get paralysis, then we have to have a very low risk of decompression sickness. One of the things that you want to ask yourself in this discussion of oxygen toxicity it looks like the probability is really low of having a problem at 1.6 atm oxygen partial pressure. The severity of the injury that can occur with unconsciousness underwater is potentially pretty high, which should be considered in your decision about what you want to do.

B. Gilliam: One of the reasons that the 32 percent mix became so popular was because at a 1.6 atm oxygen exposure, it matched up exactly to the traditional training limits and the recommended sport diving limit of 130 feet. It was an easy match for divers to remember their limits. It also gave enough benefits for nitrox that people could maximize what they were trying to do by getting longer bottom times, shorter decompression and shorter surface intervals. I'm certain that everybody in this room understands the difference that Dick was trying to illustrate that it's not the $PO_2$ all by itself that's a problem, it's the dose, the time in minutes at that particular $PO_2$. Trying to artificially limit the sport diver's activities without some reasonable justification is what I'm trying to get at here today. We've seen this data of over a quarter of a million divers trained mostly in the last four years. There have been no oxygen incidents. There are no problems here. I have personally seen people who are incompletely trained and don't understand on the diver level, because the materials are not explaining to them that the dose is the combination of these two effects. I've seen divers who have almost precipitated themselves into panic situations because their computer tells them that they went from 1.4 to 1.45 atm all of a sudden and they think they're going to spontaneously combust. Again, I'm asking for somebody to enlighten me as to why we think we have a problem at 1.6 atm. None of our data shows that we do. I'd like to know why we should be moving in this direction with this discussion. Drew, why did PADI decide to go with 1.4 atm as opposed to a 1.5 or a 1.6 atm?

D. Richardson: We should look at the database and known outcomes to answer that question. For this whole discussion, if you look at Kenneth Donald's work from 1942 to 1945, working with the Royal Navy, they did about 2,000 test dives using oxygen breathing. If you compare that database to NOAA's dose duration, it falls right in between 1.4 and 1.6 atm. PADI had no objection to 1.6 atm. We set it at 1.4 atm for recreational divers as a margin of safety for diver error. However, 1.6 atm fits very nicely under the Donald data set as well. He did make a few mentions in his findings about individual variability. He spoke about temperature being a factor and an increase in susceptibility in 'cooler' water. Generally, the NOAA limits up to and including 1.6 atm at the 45-minute limit, also fall very nicely under Kenneth Donald's work, done so long ago in the war effort.

K. Shreeves: You'll notice that all our tables actually do include numbers up to 1.6 atm; PADI has never been against 1.6 atm. We're thinking more in terms of the recreational versus the technical diver. Speaking of Ken Donald's work, I'd appreciate some feedback from the researchers in this room. We tried to find a correlation between exposure and time to onset of CNS. We're not talking about whole body or pulmonary, but just convulsion and weren't able to find a correlation. I'd like to know where the data is that says there is a tight time-exposure relationship with regard to CNS toxicity.

E. Thalmann: You obviously haven't read Donald's book. First of all, he made a great point of the individual variation to time-quantitative symptoms. There's the classic plot of the diver who was exposed to a fixed oxygen partial pressure day after day and his time quantitative symptoms ranged from five minutes to several hours. What we've got is a bunch of people quoting the literature very superficially without really having spent enough time reading the material in depth to find out where Donald was coming from. The depth-time limits were simply derived from what was considered safe for the majority of exposures for a single bounce dive to that depth for the time as published. If you go back and read Ed Lanphier's original work, he basically did his exposures deep and then extrapolated them shallow to come up with his $O_2$ limits. But the point that Donald made was there was such a wide variation and that's why we can see oxygen toxicity at 20 feet. There have been reported convulsions at 20 feet and some even shallower than that because you have this wide individual variation. That is the problem with oxygen.

B. Hamilton: Donald did all of his studies on pure oxygen, which meant they were all shallow and they didn't have a lot of $CO_2$ retention or breathing gas density factors for what that's worth. On the dose matter that Bret asked about, the curve of susceptibility goes sharply upward a little after 1.6 atm. It's not linear. You can go all day at 40 feet at 1.4 atm. You go until you have a pulmonary problem and you're not going to get a convulsion. Whereas at 1.6 atm, the 45 minute limit is a workable value, but you have to realize that's for a not very hard working diver. That's not very deep in terms of the breathing mix and, we've tried to make the NOAA Manual reflect as much as we could that this 1.6 atm doesn't cover all bases. With regard to the operational data set of numbers, the system is geared to look at decompression sickness. Nothing is there to catch $O_2$ hits. The fact that we didn't show any hits on all those dives doesn't mean there weren't any. In fact, there have been some. The other factor is in supporting what Drew said why PADI sets $PO_2$ at 1.4 atm, because, for one thing, it does deal with the huge individual variability and the variability of the conditions at a very low cost. You don't give up very much when you cut the oxygen limit from 1.6 to 1.4 atm. You do see it somewhat, but it's not a big cost.

M. Lang: Bill, a clarification, please. When you say there have been some hits, what does that refer to? One of the objectives of this exercise is to factually document whether or not there have been documented $O_2$ hits.

B. Hamilton: I know of a couple. These people have taken oxygen hits at 1.6 atm.

M. Lang: Recreational nitrox divers, technical, commercial or military?

B. Hamilton: Technical. One was on the Lusitania that was written up extensively and studied thoroughly.

B. Gilliam: That was not on nitrox.

B. Hamilton: That was a hit after a tri-mix dive breathing pure oxygen at 1.6 atm during decompression.

M. Lang: Those are the kinds of events that we need to clarify for the record. Is there a reference that we can cite?

B. Hamilton: It's written up in *aquaCorps*, if you can call that a reference.

D. Vann: That's not fair because you've got a multi-level oxygen exposure there. When you're talking about a multi-level oxygen exposure as you are after a long decompression dive, it's a whole new ballgame. You can't compare that with a single limit. That's probably what Ed Thalmann was referring to as well. The exposures in which there was a seizure at less than 1.6 atm were all multilevel. I don't know of any others that weren't and I would be very interested in hearing from this group of any oxygen seizures that occurred at 1.6 atm or less without multilevel exposures.

M. Lang: Let's go through that exercise just for the record to document any seizures at 1.6 atm or less on single exposures.

E. Betts: The simple answer is no, I don't have any documented data.

C. Borne: None.

B. Bjorkman: No.

D. Dinsmore: Not that I know of.

B. Gilliam: TDI has none either.

J. Hardy: SSI has none, but also in my legal consulting, I have none.

W. Jaap: AAUS reports zero.

D. Kerem: I'll stress again that with pure oxygen diving, as long as your gear is okay and there is no $CO_2$ buildup in the system, divers routinely dive for hours at 1.6 atm with no incidence of oxygen convulsion.

D. Kesling: None at UNCW.

T. Mount: None at IANTD.
D. Richardson: Zero at PADI.
D. Rutkowski: Hyperbarics zero.
B. Wienke: Zero at NAUI and I would point out that in the last couple of years there's been a lot of decompression diving with $O_2$ washout at 20 feet at 1.6 atm and we've had no problem.

B. Hamilton: Dick, you reported two incidences.
D. Vann: One in the chamber and then one in the DAN data, which was a multilevel exposure. It was 15 minutes on air between 80 and 104 feet with a maximum $PO_2$ of 0.87 atm. The other was 45 minutes on 40 percent nitrox at a maximum depth of 84 feet and that was 1.42 atm. That's a case reported from the field, but the report was actually the most complete that I've seen.
T. Mount: May I comment on that particular one? That case was of a cave diver if I'm not mistaken. When they did his blood gases he also had twice the prescription dosage allotment in his blood and he'd also taken six Advil prior to the dive.
M. Lang: It's duly noted. The conclusion then is that there are no documented oxygen seizures from recreational nitrox diving at 1.6 atm or less on single exposures.

D. Rutkowski: At Ocean Divers in Key Largo, divers are diving air more than nitrox. There are often emergencies that arise with divers offshore. When the rescue people go out there, the first thing I have them ask divers is what drugs they took before diving and how soon before diving. Even the air divers may have what you call drug-drug interaction. If a diver had a tank of nitrox on his back, you could bet they'd call it an oxygen seizure. The $PO_2$ of 1.6 atm only uses 43 percent of its clock. We used to have a NOAA Nitrox II mix of 37.5 percent. At 100 feet that mix would have pushed a $PO_2$ of 1.6 atm. A guy diving at 100 feet on that mix would have a 40-minute no-decompression time limit. That would put him at 96 percent of his CNS clock. Dr. Wells knocked the mix down to 36 percent, which at 100 feet gives a $PO_2$ of 1.5 atm and only 33 percent of the CNS clock. These $PO_2$'s are not just numbers that somebody grabbed out of a hat.
T. Mount: Another important consideration to remember is you're talking about recreational diving not technical diving. Most organizations that do technical diving use 1.4 atm for technical mix because you do spike on multilevel exposures and come back on oxygen. In technical diving, there have been some oxygen seizures, that's undeniable, in recreational diving there have not. Dick uses the example of the two USCG cutter wrecks in Key Largo. Most recreational divers do not go down to a fixed depth and remain there. Most of them either drop to sand beside the wreck at 130 feet, and then swim back onto the deck, which is 110 feet deep. Very few of the people ever actually operate at their maximum $PO_2$'s. The important thing to emphasize is the maximum operating depth, not the dive duration that most people do there.

E. Thalmann: First of all, I know of no regulation or body that is telling the recreational diving community what $PO_2$ they should be diving. If they want to dive 1.6, 1.8, 2.0 atm as far as I know, they're welcome to do it and there's nobody around here that can tell them to do it differently. Second of all, I want to quote something that says that multiple anecdotes do not make data. Here we have got at least a half a million anecdotes if I totaled all those dives up correctly. That does not constitute data. It appears that a lot of individuals are not really willing to look at the data, and number two figure out what the data really say. The U.S. Navy picked 1.3 atm. Why would an organization that has a much higher vested interest in minimizing their decompression time pick a lower $PO_2$ than recreational divers? These guys fight wars and want to get out of the water quickly. The reason is that one $O_2$ incident in the water gets ten million "oh no's", no matter how many "atta boy's" you get. Where did that come from? There were a series of dives done at the Navy Experimental Diving Unit, which is quoted in Donald's book, if you read it carefully. They were all multiple level dives that tended to simulate the kind of oxygen dives that an actual combat swimmer would do. The depths of these dives range from 50 feet to as shallow as 20 feet. What was found was that out to four hours, which was the longest time tested, there were no $O_2$ hits at 20 feet. Therefore, it appeared that not only the lack of convulsions, but the lack of symptoms overall, gave the impression that 1.3 atm was something you could probably breathe forever and not have a problem. There was one documented incidence of an $O_2$ convulsion after 75 minutes at 25 feet. Even so, the Navy picked a 4-hour limit at 25 feet based on operational considerations and based on the fact that all of these other dives were done without incident. The other comment is that I'm glad that the recreational dive community has come up with a nice mathematical way of integrating oxygen exposures for multi-depth dives. The best brains in the U.S. Navy, after a million dollars of funding, have been unable to do that. If somebody could please show me the data on which they based this, I would be happy to bring it to the attention of the Supervisor of Diving so we can catch up with you guys. The point is that the hundreds of dives that were done at NEDU using multiple level techniques were analyzed by the best minds we could find and they were unable to come up with any method of integrating the $PO_2$'s to explain the observed outcome. Now, does that mean that what the recreational people are doing is bad? No, it doesn't. Does anybody want to change that? No. It depends on your philosophy. Nobody is telling the recreational dive community you can't dive 1.6 atm. They turn around to the Navy and ask why they picked 1.3 atm? Because it can be dived all day long. It doesn't impact Navy operations all that much and they don't want any $O_2$ hits in the water. The Navy has within the last month rewritten its helium tables to eliminate 100 percent oxygen in the water. Why? In the last two years there have been two $O_2$ incidents. They don't want any of them, they've eliminated $O_2$ in the water and everybody's happy with that. Looking at this data and trying to draw conclusions about $O_2$ toxicity is much like looking at raw decompression data and trying to decide whether or not the current decompression tables are safe. A classic example: The Navy, in developing a decompression computer, was looking at the shallow air no D limits. I'm sure everybody here would say that these are just fine, we dived them forever. Nobody's having any problem with these NDLs. The Navy did two hundred 40 foot dives for 200 minutes that resulted in two hits. Based on two hits, both fairly mild, they said that's unacceptable. It depends on your philosophy of what you want to do. If you want to be aggressive, fine. 1.6 atm is probably okay as long as you stay within the $O_2$ depth-time limits. The beauty of going shallower is it's almost fail safe. The question is do you want to be fail safe or do you want to have procedures that require a lot of attention on the diver's part. As far as I know, there is nobody here to stand up and tell any recreational diver what $PO_2$ he ought to dive. If you want to cast aspersions on opinions based on data, that's a different story. The point I'm making is that the 1.3 atm comes from looking at real data. This is a recommendation of a $PO_2$ that is almost never going to get you in trouble no matter how long you breathe it. If you want to look at other data, you could say, that's right, there's no data to suggest that 1.6

atm is unsafe. Do you want to make sure a diver can't get in trouble or do you want to have a $PO_2$ that is going to require him to follow a specific procedure to not get into trouble? It all depends on your philosophy.

M. Wells: A lot has been made of the NOAA limits and since they don't exactly match the Navy limits, you ought to understand where they come from. Bret mentioned that a lot of people now have independently discovered that 32 percent at 130 feet yields 1.6 atm. I'd like to point out that's precisely why it was chosen. 1.6 atm was the normal working limit for Navy mixed gas diving when I was doing this in the '70's and 130 feet was the normal scuba limit. If you put that into the equation the Canadian divers can't remember, you come up with 32 percent, which I called NOAA Nitrox I for a very good reason for Bill Hamilton's information. Those tables were designed so that they could be handed to a diver and said, follow these tables. These were NOAA divers and NOAA divers can in fact read and follow instructions. If one followed those tables, the diver would not have to think of oxygen partial pressure limits whatsoever, because they were built into the tables. That build-in is why I called it NOAA Nitrox I, referencing the content of the mix because I didn't want the divers messing around with that. It was all prepackaged and later NOAA Nitrox II came along (36%). The content was non-essential after the analysis was done if you follow these tables. In the late '80's we were presented with a bit of a dilemma caused by the Navy and Ed has mentioned that. We were preparing the third edition of the NOAA Diving Manual, which eventually came out in 1991. The Navy reduced their limits from 1.6 atm. Someone mentioned that this did not have a great impact. It had a great impact on the way NOAA and the Undersea Research Centers were diving. It dramatically reduced the allowable bottom time available for the nitrox divers. Thanks to the fine work of Butler and Thalmann that had been published a couple of years ago, you will notice reference to that publication in that edition of the NOAA Diving Manual: "based on the work of..." I've been asked many times why the Manual doesn't match the numbers in the Butler and Thalmann paper. It was considerably less than they had recommended in their paper. As you remember, the Navy cut back from 1.6 atm for 30 minutes. We wound up increasing it to 1.6 atm for 45 minutes based on Thalmann's work. After consultation with the best experts I could get a hold of and putting our heads together for a consensus opinion, there was a dramatic effect on the effectiveness and acceptable risk we were willing to take at the time. The 1.6 atm for 45 minutes fell within what we considered a quite acceptable risk and that's been in effect now for well over a decade. Judging from what I've heard here today, it is quite acceptable. That 1.6 atm, by the way, was for working dives. People seem to have forgotten that 60 years ago, before I was born, pure oxygen was used for in-water decompression at 50 and 40 feet. They used it heavily throughout my entire lifetime and there have been some incidences, but that's a $PO_2$ well in excess of 1.6 atm. We have a very reasonable number that has been extended from the original Navy limit of 1.6 atm for 30 minutes to 1.6 atm for 45 minutes. That, by the way, was the only significant deviation from Navy policy that NOAA made. I thought, Thalmann, you would be proud of us for doing that based just on your work.

E. Thalmann: This is not really funny, but exactly what should happen. NOAA set its $PO_2$ limits based on two things: Its operational requirement and the amount of risk they were willing to take. The Navy does not canvas the commercial diving industry before it sets its policy. We used to point this out all the time. Someone would invariably get up and complain you guys changed this in your diving procedures and are causing us another heartburn. We'd turn around and say, write your own diving manual, this is the Navy's

Diving Manual. Navy policy is made for Navy divers. All I was doing was explaining why the Navy chose such a conservative limit. What NOAA did is exactly what you're supposed to do. What risks do you want to take and what are your operational requirements? The recreational diving community needs to do the same thing. What are the risks and what are the operational requirements? I would say that the risks-benefit ratio for recreational diving should be as close to zero as you can get because there is no reason that these guys have to get in the water. On any given Sunday, they can stay home and watch football versus commercial divers and military divers who may be required to get in the water, have a mission, or scientists who have an experiment to do. You have to set your risk benefit for the community. NOAA has gone forward and come up with its limits. There is no reason why the recreational divers can't say those are fine. This is a testament to the things you're willing to say. We're willing to recommend that our recreational divers take the same risk as NOAA divers, that's exactly the way it is. You read the data and you make your decision based on them, there's nothing wrong with that

B. Gilliam: We haven't had much comment on this side of the room for a little while. Ed, you've made a bunch of pretty sweeping statements on why the Navy picked 1.3 atm. Obviously the Navy picked that because of their operational tactical requirements. They can't put a combat swimmer in the water and expect him to go over and accomplish a mission in 45 minutes which would be the limit at 1.6 atm. Let's get a grip on the realities of what we're talking about here. Secondly, you've criticized the data that's been brought here today, but absent this data there aren't any other data. This is a relatively new technology. The agencies have been teaching it for less than a decade in most cases and there has been an overwhelming amount of very hard numbers put up here today that are just as hard as anything that DAN has tried to go out and accumulate on their own. A lot of the information that we brought here today has been offered in the past to DAN and in many cases has simply been ignored or distorted. When you say that nobody is trying to tell the sport diving industry what to do, that's really a bit of an understatement, because that is exactly what has happened to us in several situations. That is one of the reasons we're all sitting in this room today. There have been some very speculative and presumptive statements made about the safety of this particular technology in the hands of sport divers that has been flat out wrong. The focus of this workshop has been on what our sport divers are doing with this technology. We can learn a lot from the closest other relative that we've got in this group, the science divers, who have been diving nitrox since the mid '70's with excellent results. We've all been around the room on this 1.6 atm, with no documented oxygen incident. A sport diver using this technology is typified by a guy in a relatively benign environment. He is not threatened, he is not a working diver. In fact, if you take just about any measurable limits of what the performance characteristics of the sport diver are, they're what we would consider to be almost at rest by comparison to a science diver or a Navy tactical diver. Their risk benefit of operating at a maximum $PO_2$ of 1.6 atm is much different than that of diver who's in the water slinging wrenches around or swimming at a sustained speed over a longer distance to perform a work function in a tactical mission. This doesn't add up. There's a bit of resentment when people fail to take fully into consideration what it is the sport diving community is trying to do and how they are doing it. We are doing it with a reasonable degree of responsibility. There are a quarter of a million nitrox divers that have been produced in the last four years. No one is having oxygen problems that any of us can identify. A lot of speculation and presumption has been thrown out there, which if we operated under all of our lives, we'd never get in airplanes or boats. The risk would simply be too great because we don't know what the risk really is. I'm still coming back to the fact that there are an awful lot of good numbers that have been put up here today that suggest that divers using nitrox in the applications that sport divers are using it in, are doing it without problems. Remember as well that most of their equipment packages have a limit to the point that they'll never even get to the no-decompression limit anyway, much less get anywhere close to a threshold of vulnerability on the oxygen-dose exposure. To focus on the real target group we're trying to assess here: It's the Joe Diver with an 80 cubic foot aluminum tank on his back, typically diving in a situation where he's moving around on a reef and perhaps taking pictures. He is not exactly a hard working guy who's at some sort of threat and risk. That's who we should be concentrating on, not on why the Navy did it a certain way, because their mission and goals are completely different than what these people are trying to do. These analogies do not necessarily cross over.

E. Thalmann: First of all, I applaud Mr. Gilliam for being privy to Navy policy discussions, which I obviously missed while I was in the Navy. I don't think he has any idea what went into the 1.3 atm decision. Second of all, what we've seen today is not data, it's anecdote or call it what you will. I think that Mr. Gilliam doesn't know what real data is. Third of all, the Navy is not telling the recreational diving community what to do. If you want your divers to dive 1.6 atm, then why don't you do it? What is stopping you? Why don't you just get up and say I am going to teach it this way? This is the way I want to do it. I have got data to back it up. I can justify it. If called to task, I can produce evidence to say that this should be reasonably safe. Why don't you do it?

B. Gilliam: I think that what we've just seen is exactly why we're in a room like this today because it's that type of attitude, Ed, that gets people pretty upset. Now why is this data that you guys speculatively generate from time to time at DAN any more consequential or any more efficacious than the data that's been put up here today? That data that we put up there today are hard numbers of divers and instructors trained. How many incidents of DCS resulted from that? How many oxygen incidents resulted from that? Those numbers are just as hard as the numbers you guys are trying to assess over at DAN. Remember also that DAN has made sweeping indictments of the nitrox community and have accused us of using a technology improperly at times. You have predicted decompression sickness incidence rates twice that of the air diving community. These statements are largely unsupported by any scientific, medical or anecdotal data. The reason all these people are in this room today is to try to get an objective assessment of what is really going on. Bombastic statements like you've just made are not helping the situation any.

E. Thalmann: Can I separate Thalmann from DAN a minute, please? I've got to make something clear here. Thalmann, 20 years in the Navy, was talking about U.S. Navy generated oxygen exposure data when I talked about data. I don't give any more credence to the DAN data than the data that you've presented. It's still anecdote. It is not based on direct observation and it's not based on controlled conditions. It is still anecdote. When you say me, make sure you understand what me is. I've never made a statement about decompression sickness. If Dr. Bennett wants to get up and say what DAN thinks about it, that's fine. I don't ever recall saying that. Everything that I've ever written or said about oxygen exposure limits has always been referenced to published data and experiments under controlled conditions. If you are you willing to accept that half a million clean dives is evidence that 1.6 atm is okay, you're certainly welcome to do it. I don't think I would particularly object to it. I don't see what the problem is.

## C. Testing Nitrox as a Product

Jon Hardy: I'm now wearing my Rodale's Scuba Diving Magazine hat and also remind you that I am not an employee of any company. I'm an independent contractor to all the people that I work for. About 50 percent of all my work effort goes into testing equipment, procedures or the situations from legal cases. When I talk about the work that I do with Rodale's, please remember that it's as an independent contractor. I'm held at arm's length from the magazine because I have nothing to do with the advertising or marketing.

Given that, every year for the last nine years I have proposed the tests that we do for the magazine. The equipment testing articles are the most expensive articles published in any magazine in the diving field. I've been saying each year that we ought to test nitrox as a product as opposed to a procedure. We finally convinced Rodale's to do it this year and just about the time Michael contacted me we had just started our initial testing. What we do for all our testing and these tests are not just jump in the swimming pool and swim around. The BC, dive computer, and regulator testing is done in labs with breathing simulators and hyperbaric chambers. Then we dive in the ocean and test them with real people. We have logged thousands of dives over the last nine years on these projects.

We went around the nitrox community and asked what human functional aspects we could test and how we should test them. We are not testing DCS or oxygen toxicity. We're talking about those elements that many of us are going to say are urban myths about nitrox.

We have a procedure called the test of the test. Every regulator test, every BC test, every computer test we do has been first tested to see if it is repeatable. That we can follow the scientific method and on a different day can get the same results as we did on a previous day. That 15 different testers can come up with the same result.

The nitrox community offered the following assertions: Diving nitrox causes less narcosis, less fatigue, less gas consumption, and better thermal balance. Those are four areas that some divers believe are true. At this workshop you have heard things said that refute most of these already. These are the four that we found and I am certainly open for any other suggestions. The magazine is going to spend a good deal of time, money and effort for about a three to six month period trying to analyze these. As Michael said, we're going to take a look at some initial results.

We have been testing the gas consumption factor. Of those four human aspects, we know a lot about testing gas consumption because we use it regularly in our controlled swims for testing the efficiency of various equipment. From our initial test, not yet completed or ready for publication, we have found no variation between air and nitrox in the consumption of the gas under the same set of conditions. The numbers are so close that they vary by hundredths