LANG

AAUS POLAR DIVING WORKSHOP

PROCEEDINGS OF

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THE AMERICAN ACADEMY OF UNDERWATER SCIENCES

MAY 20 - 21, 1991

SCRIPPS INSTITUTION OF OCEANOGRAPHY, CALIFORNIA

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Scripps Institution of Oceanography
La Jolla, California

May 20 - 21, 1991

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American Academy of Underwater Sciences
Polar Diving Workshop

Editors

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and
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Preface

The fifth major AAUS Workshop addresses the complexities of performing underwater research in the polar regions under the auspices of the National Science Foundation, Division of Polar Programs. The information contained in these proceedings is the result of the combined knowledge of nearly thirty recognized polar diving experts. Their expertise covers a variety of scientific disciplines and different methods and techniques of underwater research. The discussions reflect some differences of opinion with regard to the options available to the scientist working under the ice. The message from these experts is, however, quite clear. There is a risk associated with cold water, under ice diving. That risk is managed by appropriate training in the type of diving equipment to be used before deployment to the ice environment. Equipment used in polar diving activities requires special design and maintenance considerations. Careful attention must be paid to dive plans and the management of emergencies due to the remoteness of polar regions.

We are indebted to a group of experienced, dedicated scientific divers who gave of their time and energy to discuss their polar diving experiences that represent the state-of-the-art in the understanding of the complexities and preparation of Arctic and Antarctic scientific diving operations. As a result of this workshop, we have a mechanism for the review, update and dissemination of polar diving information that should provide guidance for AAUS and DPP training programs and challenges for future polar scientific divers.

Finally, on behalf of the U.S. scientific diving community, I extend our greatest appreciation and indebtedness to James R. Stewart, Diving Officer Emeritus - S.I.O., who has dedicated his career to the advancement and practice of scientific diving. For over twenty years, Jim's pioneering efforts in Antarctic scientific diving and as DPP Diving Officer, have essentially made the use of scuba a valuable, scientifically accepted tool for the performance of our underwater research as we know it today.

Michael A. Lang
President
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About AAUS

The American Academy of Underwater Sciences (AAUS) is a non-profit, self-regulating body dedicated to the establishment and maintenance of standards of practice for scientific diving. The AAUS is concerned with diving safety, state-of-the-art diving techniques, methodologies, and research diving expeditions. The Academy's goals are to promote the safety and welfare of its members who engage in underwater sciences. These goals include:

* To provide a national forum for the exchange of information in scientific diving;
* To advance the science and practice of scientific diving;
* To collect, review and distribute exposure, incident and accident statistics related to scientific diving;
* To promote just and uniform legislation relating to scientific diving;
* To facilitate the exchange of information on scientific diving practices among members, and;
* To engage in any or all activities which are in the general interest of the scientific diving community.

Organized in 1977 and incorporated in 1983, the AAUS is governed by a Board of Directors. An Advisory Board of past Board of Directors members provides continuity and a core of expertise to the Academy. Individual membership in AAUS is granted at the Member, Associate Member, and Student Member categories. Organizational membership is open to organizations currently engaged in scientific diving activities. Maintenance of membership is dependent on a continued commitment to the purposes and goals of the Academy, compliance with the reporting requirements and payment of current fees and dues.

* For the diving scientist, AAUS provides a forum to share information on diving research, methodologies and funding;
* For the diving officer, AAUS provides an information base of the latest standards of practice for training, equipment, diving procedures and managerial and regulatory experience, and;
* For the student, AAUS provides exposure to individuals, agencies and organizations with on-going programs in undersea research.

Scientific diving means diving performed solely as a necessary part of a scientific activity by employees whose sole purpose for diving is to perform scientific research tasks. Scientific diving does not include tasks associated with commercial diving such as: rigging heavy objects underwater, inspection of pipelines, construction, demolition, cutting or welding, or the use of explosives.

Scientific diving programs allow research diving teams to operate under the exemption from OSHA commercial diving regulations. This reduces the possibility of an OSHA fine and some concern regarding civil liability. Civil suits examine whether the "standards of practice of the community" have been met. Diving programs which conform to AAUS standards reflect the standard of practice of the scientific diving community and allow divers from different institutions to perform underwater research together. This reciprocity between programs is the product of years of experience, trust and cooperation between underwater scientists.

Acknowledgements

We thank the workshop participants for providing their time and energy and sharing their polar diving expertise in this forum. An extra measure of appreciation is extended to Bill Van Dorn, George Simmons, Jeff Bozanic and Jim Mastro for providing papers for inclusion in this document. Special thanks is due Bob Stinton and Dick Long for sharing their knowledge of dry suits.

We also thank Kimbra Cutlip of the Smithsonian Institution for her effective assistance in the management of this workshop. Laura L. Runyon, Encinitas Court Reporting, provided a transcript of the workshop and Julie T. Olfe provided editorial services for portions of these proceedings.

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I. Advances in Equipment and Technology

1. Thermal and Hand Protection - Bob Stinton, Diving Unlimited International.

For the thermal protection of a diver operating in cold water, passive systems consist of a suit and underwear. These systems can keep the core and skin temperatures up for extended periods of time, such as up to six hours in 35°F water, for divers at rest or doing moderate work like taking photographs. The type of underwear is a little bit heavier than what we currently have. These are composite garments of 800 or 600 weight in which the joints have less insulation than the arms, to give some flexibility. With effective insulation and a dry suit that maintains its insulation with depth, it is only necessary to add a little air as one descends, to compensate for the squeeze. The biggest problem that remains is the thermal protection of face, hands, and feet.

If a full face mask is used, the face is not a problem, because there is no exposed skin. One problem with the hands is because suit systems are expensive, the gloves are often neglected. The geometry of the hand limits the amount of insulation that can be used; layering insulation quickly gives a baseball-glove effect so there is no dexterity for picking things up. The thumb is the main problem, and there is wide individual variation.

The navy standard states that working divers should not let their hands get colder than 15°C. At 10°C your hands begin to hurt. They feel like somebody is working on the knuckles with an ice pick. If you maintain 8°C for 30 minutes, you will develop a nonfreezing cold injury. To recognize a nonfreezing cold injury, get out of the water and warm up. Your fingers will tingle and be numb, and your joints will not work properly for a couple of days. If you prolong the exposure, you will develop something akin to trench foot, which is the ultimate injury. Tissue will start sloughing off as in a typical freezing injury. If skin or digit temperature reaches 6°C at any point, the nonfreezing cold injury occurs without the time parameter. There is a 2-degree yield and a wide individual difference. A glove that works perfectly for one person, may not be right for the next person. One variation may result from susceptibility you were born with. It might also be that as a child, riding a bicycle in Kansas delivering newspapers in the freezing rain, you developed a nonfreezing cold injury. That nonfreezing cold injury increases your susceptibility to repeat injuries. In air, if your fingers are cold with gloves, you add mittens. In water, adding more levels of insulation, merely reduces the rate of cooling. The person who has not had a nonfreezing cold injury is just as susceptible, but it takes a few minutes longer. A person who is more adapted still winds up at a certain point, and the cooling curves look exactly the same.

For dives of one hour or less, there are glove systems that will protect divers' hands with no problem, although in the general population there are probably a few individuals who can develop a nonfreezing cold injury within 30 minutes. We used a glove box for a series of tests in which we chilled the water and had people submerge their hands. Some people responded so quickly to the cooling of their hands that one person actually fainted from the experience. And this was in a warm environment. Other work on gloves and hand protection is being done at the Naval Experimental Diving Unit and Naval Medical Research Institute. The issue is important, and has been ignored for too long. The British have done some tests and concluded that whether the hands are wet or dry, they still get freezing cold. If they are wet, you can cover them with enough insulation to go around and club things, but you cannot do any precision work. My personal experience is that whether I wear a five-fingered glove with two wool liners or a mitt, my hand tests out exactly the same; it does not make any difference. I have higher dexterity with the five-fingered glove. With a mitt, the thumb still gets cold. One would expect the fact that the thumb has a little more muscle mass to be the limiting factor, but it seems to be the blood flow. Blood flow to the hand decreases to about 25 cc a minute as the blood cools. That is not much capacity to carrying blood out on the hand. Once vasoconstriction occurs in the hands, hardly any blood flows into them. We have not tried pouring hot water into the gloves and slipping them back on while running the tests. I would, however, assume - based on the idea of filling the suit full of hot water - that would decrease the cooling rate. For short dives this might buy some time. For longer duration, we are investigating heating the hands with immersible electric gloves, and other strategies to provide some heat. The two tools a diver has are mind and hands. As the mind sees an action, the hands need to be able to do it.

The toes are somewhat similar. They are essentially put into a one-pocket mitt, and the amount of insulation can be increased if bigger fins and ankle weights are used. The cooling effect is not as drastic as with the fingers because at least the feet are inside the suit.

The face needs attention as well. Divers wear hoods and hold regulators in their mouths. The upper part of the face is completely exposed. There are strategies to prevent that. If you cannot wear a full face mask, which is not the most desirable thing to wear, there are hoods with cutouts for the regulator. You have to learn to slip the regulator through the opening provided for it. This type of hood provides a minor level of insulation. For Peggy Hamner I put together an item that looked like a wrist seal cone stuck on the end of the regulator. When she pressed it into her mouth, it covered the lips as well, which is where the nonfreezing cold injuries of the face can develop.

Diving Unlimited International (DUI) has guidelines that are designed so that divers can look up the kind of dive they are going to do - light work, heavy work, photographic work - the depth and the water temperature and develop a strategy for how much insulation is needed. The guidelines are set up with what we call plus ratings. As we sit here in this room, some people are cold and while others, wearing short pants and short-sleeved shirts, wonder when we will turn the heat off. There are such individual differences and they must be adjusted for. You cannot put every person in a dive team in the same configuration and expect the same results. A person who always wears a sweater inside, probably has a lower set point and will require a little bit more insulation in the water. A person who is always in shorts and a T-shirt may be that way because that is the only thing he can afford or because he has a warm thermostat. The DUI guidelines also talk about weight, so that weight belt strategy can be planned ahead of time.

People try to get more insulation with less weight by using other inert gases in the suit. The questions have not all been answered on the use of argon. Cave divers, after they make a long dive, are using it in the decompression stop and actually flood their suits with it. One question that is not answered is whether it affects decompression from a long or deep dive. Some people have theorized that the skin does not perspire sufficiently for enough argon to be absorbed to make a difference, but nobody has really tested it. I have experimented by switching from air to helium which unfortunately cancels 75 percent of the insulation. When you push the inflator button, the helium comes into your suit, and it feels like cold water is being poured down the front of you, it is that dramatic. Switch back to air, and it feels like you just spilled coffee down your front side. Carbon dioxide has been proposed, because it can be carried in liquid form and it provides more volume. But some investigators have found that carbon dioxide forms carbonic acid when exposed to moisture. You are very moist around membranes, so it eats away at you. We do know that at one thousand feet, if you are surrounded by air and breathe helium, there is nitrogen in your exhausted breath. The skin perspires enough nitrogen to be detected in a gas chromatograph when you exhale. The theoretical advantage of using gases to insulate an undergarment is that a diver who goes somewhere cold could change gas to have a garment rated for a colder temperature. This has not been thoroughly tested, but probably deserves further investigation.

There are guidelines for selecting underwear. The dry suit is only a shell; insulation comes from what is worn underneath it. Not every person is the same, so one set of underwear does not offer everybody the same level of protection.

Some work is being done with heat-piping in gloves to try to increase blood flow in the upper arm. The problem is that heat-pipe technology is not sophisticated enough yet. In a passive situation, to keep your hands warm, you need 20 watts per hand in a five-fingered glove with two pairs of heavy wool liners in 35°F water. If you start sucking up 20 watts from your body and pumping it out through your hands, you may lose in the long run. That is a lot of dissipating heat, similar to adding a radiator to yourself. For a short-term dive, maybe it has an advantage. Heat-pipe technology is not the leading research topic; nobody is really interested. NASA is willing to spend $16 million to cool a robotic arm, but no one is willing to pay $16 million to help a diver transfer heat to the end of his finger.

Some divers insert heat packs in their gloves. But there are only 100 Btu's per pound if it is good material. At 20 watts of dissipation, that does not last very long. In addition, heating the hand does not heat the tip of the finger. I can heat my hand or my body up to 100°F, until I am nauseated from the heat, but the tips of my fingers will still be cold. The difference is so dramatic that you can lose 10°F per knuckle from the palm temperature, back-of-the-hand temperature, to the tip of your finger.

Heat-providing breathing gases, such as the hydrogen catalytic, were experimented with in the past. I am not sure that they offer anything in terms of providing heat. If you plug all the heat leaks, the body is still generating heat, and if there is no place to dissipate it, you overheat and die. You can die from that a lot faster than from getting cold, and there are fewer warning symptoms.

Another thing to be careful of is underwear with a radiant barrier. This reflects 90 percent of the heat back to your body. The first thing you need to know is that the radiant heat loss from your body is not that great, maybe 10 percent. When you are immersed in water, it is probably zero. It is said that the barrier reflects 90 percent of that 10 percent. As a demonstration, right out of the NASA astronautics handbook, a flare provides 100 percent radiant aspect to the environment. A rolled tuck provides 70 percent, in which case you do not feel that much warmer.

The small diver, a person of about a hundred pounds, is probably at the greatest risk, because if that person loses heat at the same rate as everybody else, the core temperature is dropping faster and he or she has to wear more insulation. A small diver is going to require more protection than a big one, who may lose a lot of heat, but who has got a lot of mass to give it up, so the core temperature will not drop.

In a diving situation it is important not to precool the hands and feet. If you get into the water with hands that are already cold, you are starting further down on the cooling curve. Your feet will get cold because they perspire a lot, and the insulation there gets wet. You can pretreat your feet with Mitchum's antiperspirant for a couple of weeks, which cuts your perspiration to almost zero. Or you can just wrap your feet in Saran wrap and a plastic bag to keep the insulation from wetting by condensing on the inside of the suit. Wet thinsulate underwear takes about 20 to 30 minutes to dry on low heat in a dryer. Be careful to keep the synthetics on low heat or the fabric will melt. Hanging in an engine room, thinsulate takes about two days to dry out.

Surgical gloves underneath gloves help a diver who is out for a long time. Depending on the duration of the dive, the amount of protection is very, very important. We ran tests with mitts over our five-fingered gloves. Once the hand got too cool, taking the overmitts off did not make any difference. Once the hands got cold, they were cold, and once the stability points were met, all that extra bulk did not add anything. Dexterity is most important at the beginning of the dive. As your hands begin to get cool, you will lose dexterity.

If you take your gloves off after the dive and your hands hurt, you are approaching a nonfreezing cold injury. If they are still tingly or numb the next day, you have got it, and once you have it, you cannot get rid of it.

Heat from inside the suit can be pumped to the hands, as a sort of air shunt system. Reaching up reinforces the insulation effect. Raising the hand makes about a two-foot difference, a one psi pressure differential. Lowering the hand changes it from one positive psi to one negative, a total two psi differential. Almost all of the insulation is compressed at about 0.5 psi differential so just that simple motion changes the insulation of your glove. Some people suit up and keep the thumb loops on with their hands in the gloves. This provides a channel for warm air to pass. I left the thumb loop on in one test, and within 10 minutes my thumb felt about ready to fall off. I retracted my hand, working to get the loop off, and this warmed the thumb back up. Anything that impairs circulation can have a drastic effect.

Thermal creams were investigated in the 1950s. Pilots were to smear the creams on their bodies to keep warm. The cream was a skin irritant, caused vasodilation, and gave the feeling of warmth. In reality, it caused heat loss. The Canadians made some reactants of magnesium and iron called tea bags. When the two parts were mixed together, compressed, and dropped into seawater, they made a dead-shorted sea battery, which could be inserted in the back of the glove. Unfortunately, the heat being applied to the back of the hand also produced blisters.

Without a wet glove to carry the warm water out to the fingertips, the tips of the fingers are almost impossible to insulate. To insulate a cylinder, one considers the log mean area; take the inside diameter and the pressure ratios go way out. Spheres - the tip of the finger - are even worse. It is very difficult to put the heat where it is needed - out on the fingertips.

Discussion

M. Lang: Does face protection interfere with handling out-of-air emergencies such as buddy breathing?

B. Stinton: There are two strategies. A conical piece of neoprene, locked into your face, can be pushed up into your face to breathe. The hood has the same problems because you have to go in from the side with the regulator which does not work for buddy breathing, so you wind up using an alternate air source. The other item is a hood with eyes, nose and mouth. It is an arctic face protector that is usually used with seals; you seal your mask to it and swim about. The other piece is a hood with eyes and a mouth hole through which you have to slip the regulator. You could opt to just cut the hole bigger, but then you have lost the point of it; the upper lip, which is vulnerable to nonfreezing cold injuries, is exposed again. The cone was the best. At least if it was aimed in the right place it could get there, but the possibility of snagging or hang-up were present. This is specialized equipment, and you have to be trained to use it. Do not assume that your other skills will carry you through.

J. Stewart: Let me describe the hydrogen breathing device that we came up with 30 years ago. It did solve the core temperature problem. We obtained premixed hydrogen (3 percent) in air, which is noncombustible. We took a 72-cubic-foot tank in which we filled 750 psi with 3 percent hydrogen. We topped it off to 2250 psi with air, bringing the hydrogen level effectively down to 1 percent. We used a standard single-hose regulator. We built a catalytic converter, just like on a car, with platinum-coated aluminum pellets. For the second stage we simply made a neoprene sleeve and then insulated it. One percent hydrogen in air wields an effective 120°F air temperature that can be breathed along with moisture to eliminate the dehydration problem; as the hydrogen is catalyzed, heat and moisture are produced.

B. Stinton: Jim said it produced 120°F. We must remember that there is a distinction between temperature and heat. When something is heated, its temperature goes up, but does it have any heat capacity? When you investigate some of the claims that a system will keep your hands at 110°F, you may discover a great difference between theoretical and actual heat delivery. In areas where respiratory heat loss becomes a big factor, similar strategies or techniques are used to provide respiratory protection against heat loss in an emergency.

D. Long: We can bring the inhaled gas to 100 percent humidity and 150°F, but a diver can die breathing that kind of temperature. Some of the advanced work done on hypothermia shows that breathing enriched oxygen gas that is 100 percent humidified still does not put enough volume of heat into the body to raise the temperature significantly. But it can stop someone from losing consciousness in the case of a severe hypothermic event. We talked earlier about making the back of the hands so warm that they are burned, while there can still be a cold injury at the fingertips. I would suggest that breathing an elevated temperature, putting the heat into the lungs, and trying to pump it out to the fingertips, will not work. Furthermore, I think it is more dangerous than it is worth to mess around with the central system. We already have a passive insulation system that works rather well. We also have breath-regeneration systems. We are working on some systems to actively heat the hands. We do not believe that we are going to be able to solve your problem of spending time in cold water without addressing the hands. And we are not talking about the back of the hands; we are talking about the fingers. Unless those fingers can be kept warm, we cannot give you any realistic work capability in the Antarctic or Arctic.

2. Buoyancy Compensation and Dry Suit Use - Dick Long, Diving Unlimited International.

I believe in what is called management by walking around. Several times a day I walk through the factory, past the glue tables and the testing platforms, and I know that one of the suits I am looking at will come back in a body bag. If I knew which one it was, I would take it out of the line. After a tragedy has occurred and we go through all of those questions to see what I could have done to make things come out differently, I try to make sure I have done everything I can. That is why I welcome the opportunity to participate in a workshop like this.

At DUI our policy is that safety is a noncompetitive issue; therefore, you are welcome to anything we know that could make your operation safer. You are also welcome and encouraged to disseminate it to others. The only thing we ask is that whenever you can, you give us feedback, because what we give you will not be the purest possible. Second, when you develop any kind of information that may be of some value, please make it available to us, because all we will do is turn it around and feed it back into the system. Our manual is just for generic DUI dry suits, but most important, from your standpoint, is that it is filled with warnings. You are faced with the same liability crisis that is pressing the nation, and the manual contains many warnings that you might find useful in preparing your literature or your training material.

We have also drafted a course outline for teaching dry suit diving. The course only covers diving in water 40°F and warmer. We consider anything below 40°F ice diving. The thermal guidelines were developed for sport dives that are longer than 20 minutes but less than an hour. The guidelines cannot be directly applied to an ice diving situation. Think of this as our mathematical model, developed to determine the loss of heat and the correct amount of insulation to use in differing circumstances. If these determinations are not done well, what we call the misery index comes into play; it can tell you how cold you are going to be in advance. The difference between a small diver and a big diver can be as much as if they are using the same equipment but the small diver is diving in water up to 20°F colder. Their cooling rates will be about the same.

From my perspective, sharing information is the only way that we are going to make divers safer in the water. Diving will never be safe. It will always be an adventure, whether on a professional level or on a recreational level. The danger can be elevated dramatically by sea conditions or by colder water. It can also be elevated dramatically when a diver does stupid things, and our job is to make diving safer. We do that by giving divers knowledge about what is going on. They can then make their own decisions based on the skills that they have developed and the application of their knowledge. I know of no other way to do it, because once divers enter the water, they are on their own. They must make their own decisions and take their own actions to take charge of the situations they find themselves in. Only perfect practice makes perfect, and therefore the type of training we do is equally important as the fact that we do any training at all. We simply do not have people in the field who have the knowledge or the skills to be able to train divers adequately in the use of dry suits. Therefore, we are using a small percentage of the capacity of this very powerful piece of equipment. I try to get this information out into the field, to develop these skills, and at least to make people aware that they do not have all the answers to all the problems, nor do we.

I view the diving that you are doing in Antarctica, through the ice, as a totally different class of diving. Therefore, the preparation for such a diver is obviously different; we all agree on that. What we need is a partner system where the partner is, in fact, the backup system. The partner knows everything about your equipment, and you have both trained and practiced various kinds of emergency skills that may be required at the dive site.

One thing that concerns me about insulation is that, as a manufacturer, we have developed insulation strategies so powerful that rather than keeping divers in thermal equilibrium, we can easily drive them into hyperthermia. Hyperthermia is far more dangerous than hypothermia, because cold hurts but heat kills. With the hot-water system in the early days we actually had people, because they had been cold for so long, keep turning the water temperature up then put on breathing gas heaters. We would bring divers up, who would report dizziness, take off the mask, take one breath, and pass out. It is possible in very cold water to actually go into hyperthermia, so I simply raise the flag of caution, particularly for some of the insulation strategies that we now have.

A wet suit's ability to keep you warm is controlled more by water depth than by water temperature. Any dry suit's insulation ability to keep you warm is controlled more by your exercise rate than by the water temperature. Therefore changes in insulation will be more predicated upon a diver's work rate than upon water temperature. In most cases people think of it the other way around: the colder the water, the more insulation they put on. As we begin to learn more about how to apply this science of what we call insulation strategies to the work at hand, we will find out that we will really have a lot of valuable tools. What we want to do is employ simplification times three.

Thermal insulation strategies vary, beginning with the workload, the water temperature, and the individual. The insulation is, in fact, trapped air, so all the insulation equates to buoyancy. Therefore we do not end up issuing a 40-pound weight belt to each diver. Divers have to be able to change their weight every time they change their insulation systems. We are learning to use zone insulation instead of solid insulation. For instance, we do not use the same insulation over the chest as over the arms and legs; we need more movement in the arms and legs. In the muscles - the heat generation system - the circulating blood moves the heat around. So for most divers doing any form of work at all, we use less insulation in the arms and legs than in the torso. If we are going to change this insulation a bit, we usually change it on the torso and not on the arms and legs. But we know of no way to insulate the arms and legs enough to be able to run the hands out there bare. We are going to sacrifice the hands, the tools with which we do the work. Actually, all we need for a diving system is something that holds two eyeballs and a pair of hands.

We want to be able to change the insulation system inside, and therefore we are going to change the lead we use to counterbalance it. The whole idea for controlling buoyancy control is to have the least possible amount of air floating around inside that dry suit. The number one cause of problems with divers in the water is overweighting. They just throw on enough lead to make sure they go down. Then they put in air to compensate for the lead. As they begin to roll, the air starts rolling around to the feet. The actual process of learning to gauge how much lead you need is almost a science. One can change the ordinary underwear and take a lot of the buoyancy out of it. If you take the pockets out, you take out some insulation that is not necessary, and therefore you can reduce the amount of lead you are carrying. The leg can be modified to use less insulation, but then it has to be custom-fitted because the leg is a taper. When I raise my arms in a one-piece suit, my legs have to come up to accommodate the changed arm length. Therefore I have to make sure I do not make the calf so tight that it stops me from lifting my arm. We have a set of exercise tests in our literature.

We often find that when someone is restricted in a dry suit, the restriction is in the underwear, but they do not understand it until they get into the water and the underwear collapses around them. Just before going into the water, a diver should take the excess insulation material that is down around the ankles and pull it up in between the knee and the hip bone so that the material is already up there and it's possible to bend the leg when necessary. That is a very simple thing, but it can make a big difference. If the diver is just going to go down, look at something, and come back, there is no problem. The margin may not seem like much, but if there is a problem and a diver has to fight for life, it may make the difference in whether he or she can shimmy out of that hole or not.

Training disciplines are important. As the water gets colder, we put more things around the hands and face. My suggestion would be to say that below certain water temperatures buddy breathing is not realistic, because you cannot get the mouthpiece out of your mouth and into another person's mouth. In 29°F water, you cannot orally inflate buoyancy compensators as you could in 40°F or 70°F water. It is important to understand that the emergency procedures we are used to are not applicable in such cold water.

The amount of insulation a diver wears can change from day to day, from job to job. Therefore the amount of lead changes from job to job, depending on the amount of insulation. We have worked out a system for taking insulation into a pool or somewhere else to identify how much lead a particular piece of insulation requires. A diver can carry a chart and know ahead of time what will happen.

Once in the water, we want to use the amount of air carried on our back. If a diver is wearing a single 80-cubic-foot tank, that tank has six pounds worth of positive buoyant weight of air, so the diver must enter the water six pounds heavy to achieve neutral buoyancy at the end of the dive. A diver who wears a set of twin 80's on the bottom must carry 12 pounds of lead, and that amount of weight has to be compensated for.

As manufacturers, we insist that people wear buoyancy compensators not for compensation under water, but as a surface flotation device. In case all else fails, there must be a backup system. Therefore, we change the requirement in the water by virtue of using air in the suit, not by putting air in outside bladders. The reason for this is that any inexperienced diver, regardless of age, with two bladders containing buoyancy who suddenly loses buoyancy control may begin punching buttons and pulling things, trying to figure out what is going on. Some tragedies have resulted from this. Therefore, we want you to use a buoyancy compensator as an emergency backup. Divers are supposed to change their neck seals regularly, just like spark plugs in a car, but often they do not. A diver could 'blow-up'. We have seen one case where a diver was wearing a suit a little smaller than he should have been and had a full zipper failure on the back.

We have some real problems with people wearing big weight belts and then dropping them. A lot of the deeper wreck divers have died of air embolism. They wear a big weight belt and drop all the weight at one time. They probably have some air in the suit, and by the time they have 40 pounds of positive buoyancy when they are coming up, they have extra air in the suit because they probably were overweight to start with. That extra air in the suit is trying to expand out through an exhaust valve, but there are harnesses going over the body as well, and it is hard for the air to transfer from one side to the other. The diver is probably not lifting an elbow on the way up, which means all the air in one arm is expanding and creating positive buoyancy. Over 300-foot-per-minute ascents are made, and a diver who passes through that last 33 feet at a velocity of 300 feet is going to be hard-pressed to exhale enough air not to embolize. This issue of weighting and buoyancy control is really important. The best thing we can do is keep the amount of lead a divers has to carry to a minimum, so that the amount of air carried in the suit is down to a minimum, so there will be the least possible amount of expansion to begin with.

Just how deep does a diver wearing a foam suit have to get before that foam suit is no longer in and of itself, without any air inside, positively buoyant? With some of the very soft materials, it can be as little as 80 or 90 feet. But even in the best G231N material, you can get down to around 130 or 140 feet before it will be neutrally buoyant. If a diver loses the neck seal and gets all the air out of the suit, then - added to that the negative buoyancy with tank and all the other things - there is trouble. Therefore, with a foam suit our strong recommendation is to use a buoyancy compensator as standard policy, although many divers use it only for surface flotation or emergency backup.

I want to finish by saying that as a company we have berated the training agencies about as much as we can to start teaching their dry suit instructors. I think it is a tragedy that all someone has to do is send in a course outline, indicate he has been an instructor for two years, say he knows how to use a dry suit, and then the agency will send out a rubber stamp. Nobody has ever evaluated this person, or ever seen this person in a dry suit. Therefore, we have taken an unusual step in going out and soliciting diving instructors to participate in a research program. We have dry suit systems out now with instructors across the nation. Each quarter those instructors pick out an area of personal interest - what they feel they are the best in - and send us back a report of what they tried, what worked, and what did not work. Then we, in turn, put that information into a newsletter.

Discussion

M. Lang: Which type of buoyancy compensators are most appropriate for use with dry suits?

D. Long: I think a lot of that has to do with the type of scuba cylinders a person is wearing, the size of the person, the type of work being done, the type of suit being worn, and the location of the valves. The buoyancy compensator has to fit your needs. It must not cover the valves.

B. Hamner: Horizontal trim is important to talk about.

D. Long: Most scuba divers look like scallops out bobbing on the bottom. We came up with buoyancy compensators so that when people were neutral, they were not swimming around like big plows, with their heads up and fannies down. They plow a lot of water in front of them wherever they go. We have been experimenting a lot with what we call zero-G diving. We want to be able to go anywhere in the water and lie in whatever attitude and stay there without moving. We want to make the divers neutrally buoyant. Now they slowly begin to take a position so that the heaviest part is down and the lightest part is up. So we have designed a buoyancy system in which we can move the amount of lead up or down. When you wear an ankle weight, you have to kick it up and down, and that is tiring. There is also the laminar flow of water going down on the end of that leg and which is disturbed by that kick up and down. The knee moves only about three or four inches, six inches at the outset if someone really puts power into it. We put the lead on the top of the thigh. It has got to be high enough up that it cannot get down over the top of the knee. Then you can change those weights, going from a couple of pounds to three or four pounds depending on what you want to do.

After years of saying otherwise, I am now going to heavier tanks, because the tanks are naturally negatively buoyant in the backpack and they lie in the middle of the shoulders. By minimizing the amount of insulation and only using it where it will do some good, then knowing how much lead to carry for it, a diver can put the lead in places so that the body comes out in trim. There is an immense amount of life between zero and 30 feet in a kelp bed. When the dive computer says you have got to come up, but maybe you had better slow down, you may come up and spend 10 or 15 minutes floating around in that upper level. When you are in proper trim, you will be surprised at how fast you can swim. By simply choosing where you put your weights, for instance, even to the point of taking the weights out of thigh pockets, and putting them in BC pockets, you can easily change attitude. When you drop lead, you can drop only part of it, not all.

B. Hamner: There is an additional advantage to horizontal trim that we have used for years, because we do primarily blue-water diving. We never really get cold, even in the Antarctic when we blue-water dive, because when we are horizontal, the air is uniformly distributed throughout the suit. If we are vertical or on the bottom and our hands are down, those parts of the suit are compressed. If we are horizontal in the water, the suit pressure is uniformly distributed, and the air moves easily.

D. Long: We have found that one-half psi makes a big difference in the thermal insulation available in a given insulation. There is also another consideration. With pile, where all the hair sticks straight up, you get a certain spring effect from each hair as you compress it. Therefore, as you are going up and down in the new pile system, particularly the heavier piles, you can get a change of buoyancy by virtue of the attitude of your body. That is why we like thinsulate so much. Once it goes down, it does not change much.

3. Thermodynamic Model for Coldwater Survival - William G. Van Dorn, Scripps - UCSD

Starting from first principles, an approximate thermodynamic heat flow equation for the human body is proposed, assuming whole-body specific heat and thermal conductance to be independent of time. Solutions to this equation are nested curves giving expected survival time as a function of water temperature and equivalent fat thickness. The curves are consistent with survival records, and the equation can also be used to estimate supplemental body insulation necessary for survival for an arbitrary period in water of any temperature. Although formulated for passive survival in a vasoconstricted state, the equation unexpectedly predicts well the hypothermal endurance of active swimmers. This is shown to result from the fact that whole-body thermal conductance increases in proportion to heat production, so that their respective effects on the heat-flow equation tend to offset one another.

Present Status

The two principal data bases for current cold water mortality models date from World War II:

1. Nazi experiments with Dachau volunteers, dressed in flying attire and immersed in ice water, suggest that "...death impends at core (rectal) temperatures $T < 30°C$."(Alexander, 1945);
2. Molnar's (1946) empirical curve of immersion time versus water temperature T_w for wartime ship-sinking survivors (Fig .1).

Both data sets suffer from inadequate medical and physical documentation; the former having been questioned as fraudulent and the latter because of other possibly life-threatening circumstances. Nevertheless, lacking better evidence, death in both categories is generally considered to have resulted from hypothermia - the physiological response to cooling of body tissues that leads progressively to muscular paralysis, mental disorientation, coma, and cardiac or respiratory arrest.

Since 1945, despite extensive study of the body's physiological responses to cold, there is still no generally accepted prescription for survival time in terms of relevant variables such as internal heat production, body mass and area, and internal and external insulation. Such a prescription is the object of this paper.

Background

After Rennie (1987), consider the human body as a thermodynamic engine, comprised of a liquid core, surrounded by a musculo-skeletal framework, and bounded exteriorly by a fat layer of thickness, σ (mm). The body has mass, M (kg), and area A (m^2) - assumed independent of σ. The fat layer is assumed to have a constant thermal conductance $C_t = 0.21$ kW.m^{-2}.°C mm^{-1}, while the muscle layer acts like a counterflow heat exchanger, whose thermal conductance changes with vascular perfusion so as to regulate heat flow from the body and stabilize its core temperature near $T = 37°C$. Over a limited range of water temperature T_w, a motionless body is able to maintain its core temperature within a fraction of a degree by automatic vaso-constriction (thermoregulation).

Because both muscle and fat thickness are series impedences to heat flow, the lowest (critical) temperature T_{cw} at which the body can stabilize itself by thermoregulation varies with the individual. If the body is placed in water colder than its critical temperature, it can only attempt to stabilize its core temperature by additional heat production, either involuntarily (shivering), or by physical exercise. However, Rennie notes, a motionless body's stability range appears to diminish slowly with time, and involuntary shivering may commence after several hours exposure to a nearly thermoneutral environment.

Exercise produces metabolic heat at a rate of about three watts per watt of mechanical power; but it also greatly augments heat loss through convective cooling. Moreover, exercise perfuses the muscles with blood, thus increasing their heat conductance. Thermoregulation now depends upon whether heat production exceeds heat loss. If the former prevails, equilibrium will be achieved with the skin at water temperature, the fat-muscle interface near T_{cw}, and the core near 37°C. With net heat loss, despite the body's attempts to conserve heat by muscular vasoconstriction, core temperature will fall exponentially toward T_w. Death is presumed to occur when rectal temperature has dropped to $T_r < 30°C$ (Hayward *et al.*, 1975).

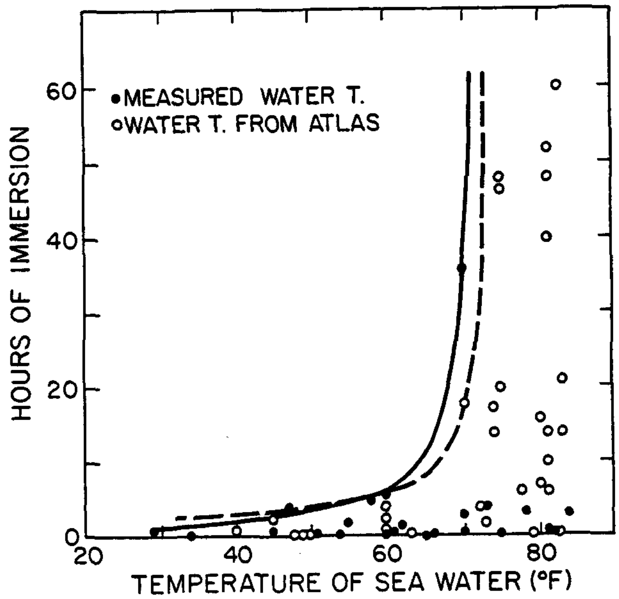

Figure 1. Duration of shipwreck survivors in ocean waters of diverse temperatures (from Molnar, 1946); dashed curve is a plot of equation [1] (from Hayward, *et al.*, 1975)

Numerous tank experiments under controlled conditions have convinced physiologists that physical activity among average subjects always leads to a faster rate of body heat loss than does passive cooling (Keatinge, 1969; Hayward *et al.*, 1975). Further, passive experiments indicate that even shivering cannot produce thermoregulation in lightly-clothed subjects in water colder than 25°C. By a large, linear extrapolation of rectal cooling rates, averaged among 12 subjects, Hayward, *et al.* (1975) proposed the following survival time equation for passive cooling:

$$t = 0.25 + 0.12/(.0785 - .0034T_w) \text{ hours} \quad [1]$$

which says nothing about the physiology of the test subjects, and is invalid for $T_w > 23°C$. A dashed curve computed from [1] is shown in Fig. 1, and bears a qualitative resemblance to Molnar's empirical survival curve, although less favorable interpretations are possible within the authors' stated error bounds. Figure 2 is a later representation of [1] to which shaded bands have been added (Hayward, 1986): "...representing mean attempts to indicate a portion of the large amount of individual variation that exists in cooling rate and predicted survival time." Various other interpretations of Fig. 2 have received wide distribution in aquatic publications, including the National Search and Rescue Manual (NASAR, 1986), which is distributed to all branches of the Armed Forces. All carry the adjurement against exercise as deleterious to survival.

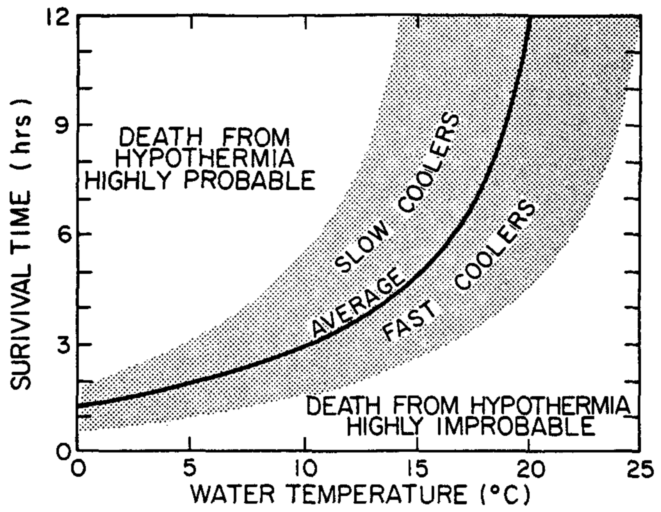

Figure 2. Widely circulated representation of passive cooling model (Hayward, 1986). Heavy curve is same as dashed curve in Fig. 1. Shaded band is estimated area of uncertainty.

Transient Heat Flow Model

In the above work, physiologists have specifically exempted from consideration conspicuous examples of protracted cold water activity. The physiology of channel swimmers and Korean sponge divers have been examined (Pugh *et al.*, 1960; Rennie, 1987), but excepted for: "excess fat and endurance heat production" (Hayward *et al.*, 1975). We shall return to this question in the next section, but consider now only (nearly) passive cases of transient heat flow.

In a thermodynamic sense, [1] is not an appropriate cooling law, because the cooling rate is independent of time. Instead, one expects the cooling rate of a solid body with an insulating layer to be proportional to the temperature difference across the layer, which leads to an exponential decrease in the temperature gradient with time. Any internal (metabolic) heat being generated within the body must also be considered. The appropriate transient cooling rate equation has the form:

rate of heat change = heat produced - heat lost

$$MC_p dT/dt = E - AC_e (T-T_w) \qquad [2]$$

where, in addition to quantities already defined, dT/dt is the differential rate of body core cooling (°C.h^{-1}), E = metabolic heat generation (W), C_p = mean specific heat = 3.9 kJ.kg^{-1}.°C^{-1}, and C_e = 11.4/(1 + 0.1σ)W.m^{-2}.°C^{-1} is effectively Rennie's algebraic approximation of whole body heat conductance for passive, vasoconstricted Korean sponge divers in stirred cold water (Rennie, 1987). Both C_p and C_e are assumed independent of time.

Separating variables, and integrating between the limits T = 37 °C at t = 0 and T = 30°C at t=t_s, we obtain for the survival time expectancy

$$t_s = \frac{MC_p}{AC_e} \log_e \frac{E - AC_e(37 - T_w)}{E - AC_e(30 - T_w)} \quad \text{hours} \qquad [3]$$

Evaluation of [3] requires specification of A and M, which cannot be conveniently generalized. However, I have found that their ratio $M/A = 40 \pm 1$ kg.m^{-2} applies to a wide spectrum of aquatic individuals, including female sponge divers (Rennie, 1987), channel swimmers (Pugh *et al.*, 1960), and military SEAL trainees (H. Bradner, pers. comm.). Equation [3] can be put in this form simply by dividing both numerator and denominator of the logarithmic argument by M, and defining $Q = E/M$ = metabolic heat per unit mass (W.kg^{-1}).

The test of this model is that it reasonably simulates Molnar's survival curve (Fig. 1) for an appropriate average fat thickness, and is also consistent with other relevant data. For Molnar's victims, I have taken $\sigma = 6$ mm, obtained from body-weight and percent fat for 1,010 U.S. Army personnel (Vogel *et al.*, 1986), assuming neutral density for the fat layer and, again, $M/A = 40$ kg.m^{-2}. Having σ, eq. [3] was then normalized to Molnar's curve by iterating Q until a best-fit was found. The dashed line in Fig. 3 is the solution of [3] for $\sigma = 6$ mm, $Q = 1.8$ Wkg^{-1}, which coincides everywhere with Molnar's curve within 0.2 hr. Indeed, one could hardly hope for better agreement.

The solid curves in this figure correspond to 6 mm increments of fat from 0 to 30 mm. Energy-wise, for a 70 kg man, $Q = 1.8$ W.kg^{-1} of metabolic heat corresponds to about 42 W of mechanical power, equivalent to dog-paddling or treading water, and seemingly attainable by anyone in normal health.

A second, and critical, test of this survival model is provided by the sudden capsize and sinking of the dive boat Santa Barbara at 3:30 a.m. on Jan. 1, 1990, off Guaymas, Mexico. Five survivors clung to a wooden door, four clad only in pyjamas, and one (Opha Watson) in a full wet suit, which had fortuitously bobbed up beside him. A sixth survivor, crewman Vincente Mancilla, unbeknownst to the others, clad in sweatshirt and Levi's and wearing a Kapok life vest, swam for 35 hours in 16.7°C water to intercept the Guaymas - Sta. Rosalia ferry, which alerted a rescue boat to the accident scene. It found only Watson, the others having slipped away at intervals chronicled by Watson's diving watch.

From interviews with Watson and relatives of the deceased, I have assembled the data and survival predictions in Table 1. Percent body fat was computed from height and weight (McCance *et al.*, 1951), and converted to thickness assuming $M/A = 40$ kg.m^{-2}.

Table 1. Dive boat Santa Barbara accident statistics.
Calculated values are underlined. * denotes survivors.

Name	Age	Height	Weight		Fat	Survival time	
		cm	kg	% std	mm	obs.	calc.
Opha Watson	62	178	91	1.23	26	38*	∞
V. Mancilla	29	175	100	1.56	10	35*	18
John Ream	63	183	83	1.41	9	14	13
Jerry Lyons	35	180	86	1.41	9	12	13
Janet Ream	56	168	73	1.25	8	11	10
Norma Malloy	45	164	68	1.09	7	9	8

For the deceased, computed survival times agree with those observed within one hour, which is better than might be hoped, considering the many assumptions involved. For example, there is no specific evidence that the victims core temperatures had dropped to 30°C, but assuming a terminal temperature of, say, 34°C reduces their survival expectancy to only 3 - 4 hours. I conclude that Fig. 3 is a fairly reliable guide for search and rescue operations.

Because of his thick wetsuit (8 mm fat + 6 mm neoprene = 26 mm equivalent fat thickness), Watson is predicted to have achieved thermoregulation (infinite survival) at $T_1 = 16.7$°C. However, without food or water for 48 hours, he was suffering from exhaustion and thirst, and felt that he might not have survived another night.

Mancilla's height and weight, estimated from opinions and photographs, lead to a calculated 10 mm fat thickness and a predicted survival time of 18 hrs. But, if we credit him with an additional millimeter of insulation for his sweatshirt and Levi's, the prediction increases to 36 hrs, which agrees well with his observed survival and shows the effect of a relatively small amount of insulation in the region of Fig. 3 where the relevant survival curve is steep.

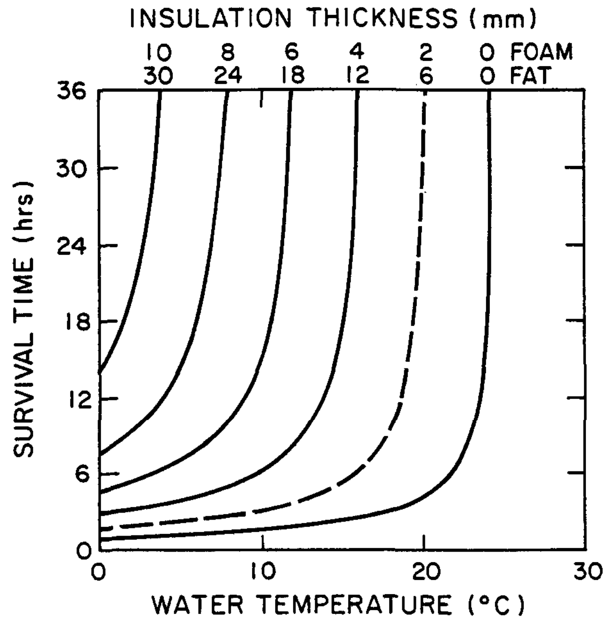

Figure 3. Proposed survival model. Curves were computed from eq. [3] for 6 mm increments of body fat = 2 mm neoprene foam, any combination of which can be combined to give total whole-body insulation. Although intended for passive survival, curves also provide reasonable estimates for onset of hypothermia among expert swimmers.

Steady-State Heat Flow

Mancilla's survival is remarkable, not only because of his long exposure, but also because he was swimming strongly, which would be expected to have significantly reduced his effective whole-body insulation. But swimming would also have increased his metabolic heat production, tending to offset his enhanced heat loss, and suggesting that eq. [3] may have wider application than to purely passive survival.

This hypothesis is tested in Table 2, which shows comparative physiological data for five English Channel swimmers (Pugh *et al.*, 1960), together with their respective water temperatures, exposure times, survival times calculated from [3], and rectal temperatures taken immediately after swimming.

We note immediately that the calculated passive survival times of the first two swimmers exceed their actual times of immersion, whereas the reverse is true for the latter three. Second, rectal temperatures decrease in almost the same order; Guiscard finished in a hyperthermic condition, *i.e.*, he was fully thermo-regulated. Heif, the winner, was almost neutral, but beginning to fade, while the latter three were all hypothermic (Park had to be helped from the water).

Table 2. Channel Swimmer Statistics (England - France), from Pugh *et al.* (1960). Calculated "survival" times were obtained using equation [3].

Name	Age	Ht. cm	Wt. kg	Fat mm	Water Temp°C	Survival time Obs.	Survival time Calc.	Rectal Temp°C
G. Guiscardo	25	172	82	8.5	18	14.5	23.5	37.8
A. Heif	26	179	86	7.4	18	11.7	13.9	36.1
T. Park	31	173	82	6.2	18	12.1	9.7	34.0
B. Pereira	34	160	77	7.5	16	12.5	8.0	35.5
E. Soussi	27	170	87	10.9	16	18.0	17.8	34.8

Lastly, we cite the well-documented case of an Icelandic fisherman with an equivalent fat thickness of 14 mm, who swam vigorously in thermal equilibrium for over five hours in 5.6°C water (Keatinge, 1986), and for whom equation [3] predicts a 5.2 - hour survival.

From these comparisons it appears that, in addition to forecasting the survival expectancy of passive subjects, eq. [3] can also be used to estimate the onset of hypothermia in active swimmers, and that Sr. Mancilla would be a likely candidate for a new Channel record.

Discussion

This study was undertaken with the objective of finding a practical formulism for estimating passive human cold-water endurance that was substantially in accord with observation and physical and physiological principles. While reasonably succeeding in the former, eq. [3] does not take into account two well-recognized physiological responses to cold water immersion:

1. I have assumed constant heat production (Q), whereas the body attempts to stabilize Q at a level proportional to the temperature gradient $T-T_w$, presumably until lapsing unconscious (Hayward, 1986).

2. I have assumed constant muscle conduction, whereas it is observed to decrease with falling shell temperature and to increase exponentially with increasing physical activity (Rennie, 1987).

But the model's successful extension to channel swimmers suggests that these oversimplifications may not be as significant as one might suspect. To quote Rennie (1987): "...insulative resistance is progressively reduced as voluntary exercise intensity increases to (about) three times resting metabolism, almost exactly offsetting the increased heat production, and leaving the insulating fat alone as the sole barrier to heat loss in the heavily exercising subject."

As a relevant example, consider channel swimmer A. Heif (Table 2), who was in nearly thermal equilibrium, so that heat production equalled heat loss. During time trials in a 50 m pool, his energy production is given as $E = 15.4\ kcal.min^{-1} = 797\ W$ (Pugh *et al.*, 1960), of which 75 percent is expended as metabolic heat: $Q = .75 \times 797/86 = 7.0\ Wkg^{-1}$. His whole-body heat conduction is approximated by: $C_e = (QM/A)/(T-T_w) = (7x86/2)/(36.1 - 18) = 16.5\ W.°C^{-1}.m^{-2}$. This is to be compared with the (passive) value used in eq. [3]; $C_e = 11.4/(1 + 0.1 \times 7.4) = 6.55\ W.°C^{-1}.m^{-2}$. The ratio of active to passive heat conduction is, then, 16.5/6.55 = 2.50, which is to be compared with their corresponding ratio for heat production: 7.0/1.8 = 3.89.

Thus, Mr. Heif's increase in heat production by swimming far exceeded his increased conductivity, which explains why he was able to maintain nearly normal core temperature for almost as long as his passive survival expectancy. Is Mr. Heif an exception? Not by present standards. The current Channel record stands at 7.7 hours (Penny Dean, USA, 1978). We note that Jerry Lyons (Table 1) had a physiognomy and passive endurance potential very similar to that of Heif, and regularly swam five to ten miles per week. By Coast Guard report, the Santa Barbara sank about 44 km from its port of destination - approximately the width of the English Channel. Given these circumstances, he might better have elected to swim for it.

Applications

Equation [3] can also be used to make estimates of supplementary insulation required for fixed-term immersion at any temperature; *e.g.*, the design of wet suits for special applications. All that is necessary is to change the terminal rectal temperature fro 30°C to 36°C, a thermal depression that most individuals can sustain without shivering. Such a calculation, for example, shows that Opha Watson's 8 mm fat thickness plus his 6 mm neoprene suit would presumably have enabled him to spend an hour in freezing water. In fact, before the advent of dry suits, wet suits made of 6 - 9 mm foam neoprene were routinely used in the Scripps Institution's diving operations around Antarctica.

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4. Scuba Cylinders - Jim Stewart, Scripps Institution of Oceanography - UCSD

One question that has come up over the last several years with the evolution of the new compressed gas cylinders is, what do we need to dive with, considering the kinds of diving suits that we are using in cold water? The heavier the cylinder, the less weight you have to carry on your person to compensate for the buoyancy of your suit.

Historically, we have used twin steel 72's at McMurdo. We have broken some of those out and used them as singles. This year for the first time we had steel 95's with slingshot valves. I would like to get a response from those of you who worked with these cylinders. Are they more or less appropriate than the doubles we have been using?

J. Mastro: We had nine steel 95's this last season, and judging from how much they were used, they were quite popular. They offer more flexibility for air than a single 72, yet less weight and less air than a set of twin 72's. They are also heavier than a single 72 so a diver needs to wear less weight on the belt.

J. Bozanic: The slingshot valves will not accommodate Royal Aquamasters with any other backup regulator because of the bulk of the housing on the canister.

L. Austin: Do the heavier cylinders make divers feel top-heavy when swimming horizontally?

J. Stewart: Not in my experience.

D. Long: The distribution of the weights has more to do with it that than the tank being positive or negative.

B. Stinton: The only experience I have had with the 95's is that when I enter water through the surf, I feel that the center of gravity is a little high. You do not have surf in Antarctica, but there is a higher center of gravity out of the water.

J. Bozanic: For my diving outside the polar environment, I find the stability and the comfort of twin tanks more pleasant than a large single cylinder.

J. Mastro: John Oliver pointed out one advantage. We have boxes for transporting cylinders by helicopter, and they fit a set of double 72's. If you can only take two or four of these boxes on a helicopter, you can choose between taking two or four sets of twins or four to eight single 95's. With the singles, the number of dives can increase. We found that to be very advantageous sometimes.

J. Stewart: For years the cylinders of choice were the twin 38's. Unfortunately, they were a little buoyant at the end of the dive, so we floated tail up, but they worked well.

5. Regulator Function in the Antarctic - Jeff Bozanic and Jim Mastro, McMurdo Dive Locker

Single and double-hose regulators were evaluated during use under actual field conditions through the 1989-90 and 1990-91 austral research seasons at McMurdo Station, Antarctica. A total of 1191 dives were conducted using eleven different regulators. Single-hose regulators were found to be more reliable (6.8% failure incidence) than double-hose regulators (17.4% failures), challenging conventional views. Single-hose regulators with the highest reliability include the Poseidon Cyklon 300 (4.0%) and the Poseidon Odin (5.3%). Given specified regulator models, proper care and maintenance was felt to be the most significant factor in operational reliability.

Introduction

The harsh nature of Antarctic diving challenges both divers and their equipment. This is particularly true of diving operations in the vicinity of McMurdo Station, Ross Island, the site of the most southerly - and coldest - water in the world. The -1.8°C temperature of McMurdo Sound stresses equipment to a point unmatched elsewhere, including the slightly warmer, but still frigid, waters on the Antarctic Peninsula.

In any environment, it can be argued that the regulator is the most critical piece of equipment the diver has, for without a reliable supply of air there is no dive. In the icy waters of McMurdo Sound, the regulator also takes on the distinction of being the one piece of equipment most strongly and adversely affected by the cold.

For many years, the double hose Royal Aquamaster was considered the only regulator reliable enough to be used in the polar waters (Jenkins, 1976; Bozanic, 1991). Its design, with both first and second stages contained in the same housing, theoretically made it resistant to free-flow failure. Single-hose regulators were considered inappropriate for the Antarctic environment, both because they allowed moisture-laden exhaled air to cross the second stage mechanism, and because the high pressure reduction spring was not protected from the ambient aqueous environment.

A few single-hose regulators, primarily Poseidon Cyklon 300s and Poseidon Odins, have been used since the 1984-1985 austral season in McMurdo to provide a redundant capability to the standard issue U.S. Divers Royal Aquamasters (RAM). It had become clear to many divers that a single RAM was insufficient for safety, but attaching two RAMs was impractical. Unfortunately, Poseidons exhibited a tendency to spontaneously malfunction, particularly after prolonged periods of disuse.

A small variety of other single-hose regulators were also used to provide redundancy, with divers reporting mixed effectiveness with regard to free-flow failures. Verbal dissemination of experience with such failures and occasional references to regulator reliability (Sharkey and Griffin, 1987) were communicated within the scientific diving community, but the validity of such reports could not be reliably established. This led Harbison (1988) to conduct a limited study evaluating eight different single-hose regulator models in waters of sub-zero temperatures in the Arctic. However, he did not include in his evaluation a comparison with the reliability of double-hose regulators in the same environment.

In the New Zealand Antarctic Research Program, several regulators were evaluated for use, with only one regulator being approved (Mercer, 1989). However, testing protocols, quantitative data, and specification of types of regulators evaluated were not provided. This significantly reduced the utility of that study.

This study was initiated to provide quantitative data on effectiveness of both single and double-hose regulators utilized in actual field conditions. It was specifically intended to examine the traditional views of the superiority of double-hose regulators in polar diving conditions, as well as identify single-hose regulators with acceptable performance history.

Methods

Antarctic Services, Inc. employed a full-time Dive Technician for the first time during the 1989-90 season. This provided the mechanism to collect the necessary data to evaluate regulator reliability.

Diving researchers and technical personnel were provided regulators from the diving locker on-site, or used regulators they had brought with them as part of their personal gear. Initial issuance of the type of regulator was based on specific request of the diver. However, late in the season designated researchers were requested to dive with specific regulators selected to broaden the results of the study. Regulators used included: U.S. Divers Royal Aquamaster, U.S. Divers Conshelf Supreme, Poseidon Cyklon 300 with environmental cap on the first stage, Poseidon Odin with environmental cap on the first stage, and ScubaPro G200. All dives were conducted normally; no special procedures were implemented to bias the performance of the regulators.

Regulator maintenance was provided by the Dive Technician as part of his normal duties, minimizing skewing of results by varying maintenance procedures. However, by the end of the season lack of specialized equipment and spare parts for particular regulator models had forced the cannibalization of regulators to provide a minimum stock of operational units. Because regulators were placed in service containing previously used parts, some minor proclivity towards higher failure rates may be inferred in the later seasonal data. This pertains primarily to the Poseidon models.

All divers were required to submit dive logs to the Dive Technician on a regular basis. As part of the logs submitted, information on duration of dives, depths, types of equipment used, and failures was collected. This included specifically the type of regulator utilized as the primary breathing source and description of any regulator malfunctions. In addition, predive handling of equipment was summarized, as was categorization of the dive sites. Information from the dive logs was reviewed by the Dive Technician, clarified if necessary, and computerized for later analysis.

Because analysis of various regulators was not planned until arrival on the ice, no special attempts were made to evaluate representative units of particular manufacturers. All regulators utilized were already in inventory on-site at McMurdo, or were provided by individual researchers. Thus, many manufacturers' models are not represented in this study.

Prior to the 1990-1991 austral season, the regulators of one manufacturer were singled out for testing, with the intention of testing the products of other manufacturers in subsequent seasons. The purpose was to find reliable replacements for both the RAMs and the Poseidons. The manufacturer selected was ScubaPro. Three models were chosen which spanned the scale in cost and sophistication. These models were: Mk 200/G200, Mk 10/G200 and Mk 10/D350.

In addition, a complete servicing capability for the Poseidon regulators was established prior to beginning research diving for the 1990-91 season. All malfunctioning Poseidon regulators could then be overhauled using new replacement parts and proper tools.

During the 1990-1991 austral season, research divers were given their choice of single or double-hose, Poseidon or ScubaPro. Where no preference existed, regulators were issued according to available stock or the needs of the study. Divers were asked to note on their dive logs several factors pertaining to regulator function, including model of regulator used, whether the regulator malfunctioned, type of malfunction, and elapsed time of dive before malfunction occurred. These records were maintained in another database.

Results

During the 1989-90 research season, 532 scientific and technical dives were conducted by twenty divers. During the 1990-1991 season, the McMurdo Diving Locker supported 659 recorded individual dives. Two major variables changed between the 1989-90 and 1990-91 research seasons. These were an improved regulator servicing capability for 1990-91, and a personnel change in the Dive Technician position. Therefore, the data have been presented individually by season (Tables I, II), as well as in combination (Table III).

	Dives	Failures	Percent
Double Hose:			
RAM	133	10	7.5
Single Hose:	399	15	3.8
Cyklon 300	226	4	1.8
Cyklon/AGA	3	0	0.0
Odin	164	8	4.9
Conshelf Supr	5	2	40.0
Mk200/G200	1	1	100.0
Total:	532	25	4.7

Table 1. Regulator Failure Data 1989-90

	Dives	Failures	Percent	Time to failure
Double Hose:				
RAM	126	35	27.8	1
Single Hose:	533	45	8.4	
Single Hose*:	439	45	10.3	
Cyklon 300	201	13	6.5	15
Cyklon/Odin	87	1	1.1	15
Odin	99	6	6.1	10
Pro Diver	3	2	66.7	4.5
Mk200/G200	7	7	100.0	10
Mk10/G200	121	13	10.7	14
Corrected*	27	13	48.1	14
Mk10/G250	1	1	100.0	10
Mk10/D350	14	2	14.3	12.5
Total:	659	80	12.1	
Total*:	565	80	14.2	

* During 94 of the Mark 10/G200 dives, the first stage remained on the surface as discussed in the text. Thus, these figures more accurately reflect the performance of this regulator combination.

Table 2. Regulator Failure Data 1990-91

	Dives	Failures	Percent
Double Hose:			
RAM	259	45	17.4
Single Hose:	932	57	6.1
Single Hose*:	838	57	6.8
Cyklon 300	427	17	4.0
Cyklon/Odin	87	1	1.1
Cyklon/AGA	3	0	0.0
Odin	263	14	5.3
Conshelf Supr	5	2	40.0
Pro Diver	3	2	66.7
Mk200/G200	8	8	100.0
Mk10/G200	121	13	10.7
Mk10/G200*	27	13	48.1
Mk10/G250	1	1	100.0
Mk10/D350	14	2	14.3
Total:	1191	102	8.6
Total*:	1097	102	9.3

* Using corrected figures as defined in Table 2

Table 3. Regulator Failure Data 1989-91

	Number of Dives:		Percent Failure:	
	Huts	Open	Huts	Open
RAM	94	39	7.4	7.7
Single Hose:	147	252	0.0	6.0
Cyklon 300	119	107	0.0	3.7
Cyklon/AGA	0	3	N/A	0.0
Odin	28	136	0.0	5.9
Conshelf Supr	0	5	N/A	40.0
Mk200/G200	0	1	N/A	100.0
Total	241	291	2.9	6.2

Table 4. Failure information by site type, 1989-90

During the 1990-91 season, 94 dives were conducted by Kooyman, *et al.* at Cape Washington using the ScubaPro Mark 10/G200. All of these dives were of short duration (10 minutes or less) and shallow (3 msw or less). In addition, the first stage of the Mark 10 remained on the surface, with the diver supplied by a G200 second stage at the end of a 8-meter intermediate pressure hose. These divers experienced no free-flow failures. However, we feel these conditions do not provide adequate information on the true performance of the regulator. For this reason information and comparisons in Tables II and III show lines for both total dives and dives as corrected by omitting the Cape Washington dives.

Research diving in McMurdo Sound is conducted from heated huts as well as from open sites exposed to ambient weather conditions. During the 1989-90 season, the type of dive site was noted, and later correlated with regulator failure data. These data are summarized in Table IV. The total number of dives performed using each type of regulator in each of the two types of site is listed in the first two columns of this table. The adjoining columns specify the failure rates for each regulator as a function of the type of site.

During the 1990-91 season, all regulator service information and details on specific malfunctions were maintained. Functional performance of each individual regulator was tracked. Table V summarizes this data.

Model	Percent of Total Dives	Number Used	Number Failed	Problem (%) Free Flow	Other
RAM	19	9	8	91	9
Cyklon 300	31	17	4	12	88
Cyklon/Odin	13	4	1	Insufficient Data	
Odin	15	5	4	38	62
Pro Diver	0.5	1	1	100	0
Mk200/G200	1	2	2	100	0
Mk10/G200	18	10	9	100	0
Mk10/G250	0.2	1	1	100	0
Mk10/D350	2	1	1	100	0

Table 5. Regulator Service Data

Discussion

Our data indicate that certain single-hose regulators are between two and three times more reliable than the double-hose Royal Aquamaster. The difference in reliability between single-hose models, however, is considerable (see Table III). Of all regulators evaluated, the Poseidon models were the most reliable. This data agrees with the results of Harbison (1988) and the recommendations of Mercer (1989).

The reliability of RAMs may have been superior when they were initially introduced for use in Antarctic diving. However, since no early quantitative data exist it is impossible to determine the degree of deterioration in performance through time, if any. We do feel that the age and condition of these regulators, all manufactured in excess of twenty years ago, plays an important role in their current dependability.

Past problems with Poseidon regulators may be attributable to poor servicing by scuba equipment repair companies. We found that Poseidon regulators repaired in New Zealand or the U.S. showed a tendency for spontaneous failure, while the same regulators repaired or serviced by the Dive Technicians in McMurdo experienced fewer failures, and no spontaneous failures at all. We attribute this to the intermediate stage pressure setting. We consistently fixed the pressure at 130-135 psi while the manufacturer recommends setting it just below that which causes the second stage to free flow. However, other factors may be involved.

It became necessary at one point during the 1990-91 season to attach Poseidon Odin second stages to Cyklon 300 first stages. This combination proved extremely reliable. For reasons that are still unclear, the Odin second stage seemed less prone to free-flow than the Cyklon when dives were conducted through fresh water lenses. The Odin first stage proved to be somewhat less reliable than the Cyklon first stage under normal diving conditions.

A recurring problem with the Poseidon environmental caps was noted. These caps are highly exposed, leading to their frequent puncture. While this was never a dive-threatening problem, it did lead to the need to replace these caps on a constant basis. At McMurdo, an average of two replacements per season per regulator was necessary. We feel this problem can be minimized with proper regulator handling, but an adequate supply of caps and glycol should be maintained on-site where their use is required.

Use of the AGA full-face mask with second stage attached to a Cyklon first stage worked as designed. This mask is designed to be a positive pressure system, and continually free-flows. Because of this, a discussion of free-flow failure with this regulator combination is not applicable.

Most ScubaPro models did not fare well. The Mk 200/G200 proved itself to be completely inappropriate to the Antarctic environment. All Mk 200s free-flowed on the first and every subsequent use. The Mk 10/G200 fared only slightly better. While this regulator combination functioned well at first, it demonstrated a tendency to free-flow after about 14 minutes. Once a free-flow failure had occurred on one dive, it had a tendency to repeat on subsequent dives.

The ScubaPro Mark 10/D350 proved to be more reliable. This regulator was used by one diver, and it functioned almost without mishap. On the two occasions where free-flow occurred, it was slight and was directly attributable to water introduced into the second stage mechanism during rinsing. Once the regulator was cleaned and dried, it did not fail again. We hasten to note, however, that this positive assessment is based on only one regulator and 14 dives. In addition, the regulator was never used in a repetitive dive situation. Because it shows promise, this regulator should be tested further.

A number of personal regulators were used on occasion. These include the U.S. Divers Pro Diver, U.S. Divers Conshelf Supreme, and ScubaPro Mk 10/G250. While all of these regulators experienced free-flow failures and their use was ultimately abandoned, insufficient data exists on their use to draw any final conclusions.

Many of the free-flowing single-hose regulators we serviced had water present in either the first or second stage, or both. Elimination of this water often solved the problem. It seems clear to us that proper attention to the details of regulator care may prevent failure in regulators that are normally reliable. This agrees with the findings of Somers (1987) in his work on under ice diving. Additional discussion of the causes of free-flow in single-hose regulators and ways to minimize or prevent it are contained in Appendix I.

Many of the scientists deploying to the ice in the 1989-90 season had no previous polar diving experience. In this group, regulator failures reached almost 100% during the initial dives of the season, regardless of regulator utilized. Instruction in proper care eliminated this problem.

Data compiled in Table IV indicate that regulator failures tended to occur with greater frequency when diving from open sites. Often compounding this problem was the manner in which the regulators were transported to the dive site. Equipment was generally transported on the back of open vehicles, such as tractors or snowmobiles. When exposed to these conditions, the regulators were pre-chilled, and had a higher incidence of failure.

Another environmental consideration involves diving through fresh water lenses. These lenses develop later in the austral season, as the sea ice surface melts. Divers passing through these lenses reported a higher frequency of failures in some regulator models. In this situation the Cyklon first stage with an Odin second stage provided the highest reliability in regulator performance.

Table V demonstrates that failures were not attributable to specific regulators, but were inherent in their design. Had failures been specific to one or two particular units, then they could have been removed from service. However, of the units evaluated during the two seasons, nearly all of them exhibited problems at one time or another.

Conclusion

Appropriate single-hose regulators are demonstrably more reliable than the RAM double-hose. Of the single-hose regulators evaluated, only the Poseidon Cyklon 300 and Odin have sufficient history and reliability to be recommended for polar diving.

Effective maintenance increases the reliability of all regulators. On-site repair by a technician familiar with the regulator and the environment seems a key factor in preventing problems. This rationale is not new - it is the same one used to support the RAMs for so many years.

Equally important in maintaining regulator reliability is proper pre- and postdive care. In particular, small amounts of moisture in the regulator mechanism, while unimportant in temperate waters, become critical in the polar environment. Divers must be made aware of the importance of regulator care and trained in the special procedures necessary to keep regulators performing in a consistent manner during Antarctic diving operations.

This study included regulators from only a few manufacturers. Other makes and models of regulators designed for cold water should be evaluated in polar environments. Future developments in regulator design may reduce free-flow failures. Baz, *et al.* (1986a, 1986b) have proposed the design of self-heating first and second stages. Stewart (1989) has suggested the use of a hydrogen/air breathing mixture combined with a catalyst in the second stage to pre-heat the breathing gas. As these and other new regulator designs are developed, their reliability in actual scientific diving should be monitored to ensure the highest possible reliability for these operations.

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Appendix A - Regulator Care in the Antarctic

The Problem

The harsh nature of Antarctic diving makes proper equipment care much more critical than in other environments. At -1.8°C (the prevailing water temperature), people and equipment are operating at the very edge of safety and reliable function. With regulators, the most frequent problem is freeze-up with subsequent free-flow. These free-flows can be minor, such as a slight trickle which does not adversely affect the course of a dive, or major - in which case a full set of twin 72s can be emptied in seconds. Obviously, a major free-flow can present a serious safety problem.

The Theory

The prevailing theory as to the cause of regulator freeze-up and free-flow is the following:

Air expands as it leaves the cylinder and passes through the regulator. The expanding air supercools the regulator, which is already at the freezing point because of the surrounding water. This supercooling effect encourages ice formation both in and around the regulator.

a. Ice forming around the first stage may impede the action of the pressure adjusting spring.
b. If water is present inside the first stage, the resulting ice may prevent a positive seal at the high pressure seat.
c. Ice forming in the second stage may block the action of the second stage seat.

Any of these conditions can and will cause a free flow.

The addition of environmental protection to the first stage (the glycol-filled cap of the Poseidons and the silicone-retaining "boot" of the ScubaPros and the Conshelf Supreme) prevents ice from reaching the pressure adjusting spring. Except in cases where the protection has been compromised, this system generally solves a good part of the freeze-up problem.

A major cause of free-flow then becomes the presence of water, either in the first or second stage mechanism. Any water, but especially fresh water, which is present inside the first stage will freeze quickly when the regulator is used. This ice may block the piston and cause free-flow. Once an ice crystal has formed at the high pressure seat, the resulting free-flow and rapid expansion of air will cause more cooling, moisture release, condensation, and a likely further growth of ice. The free-flow can quickly become total and disastrous. In our experience, free-flows generally start small and almost always become worse as time goes on.

Similarly, water present in the second stage mechanism will freeze and may block open the second stage seat.

It is likely that there are other factors which can precipitate free-flow failure in a regulator. Regulators also differ in their susceptibility, which may indicate design strengths or flaws, or differing tolerances to ice intrusion. However, most of the free-flowing regulators we repaired, double- and single hose, had water present inside when taken apart. Water is, we believe, the prime culprit.

The Water

A. First Stage

Water can be introduced into the first stage in one of four ways:

1. Through the air inlet nozzle.
2. Through an improperly tightened plug or hose.
3. Through a compromised o-ring seal.
4. Backflushed through the LP hose from the second stage.

B Second Stage

Water can enter the second stage mechanism in four ways:

1. From the exhaled breath of the diver.
2. Leaks in the diaphragm or diaphragm seal.
3. Faulty exhaust valve seals.
4. During post-dive rinsing.

Moisture from exhaled air is inescapable. As previously mentioned, some regulators may be more susceptible to this than others. Introduction of sand or bottom sediment may affect the integrity of the exhaust seals or diaphragm, and should be avoided by properly stowing alternate air sources during a dive. Water enters during postdive rinsing when the purge button is depressed while the regulator is being rinsed (and the regulator is no longer under pressure).

C. The Scuba Cylinder

Moisture contained in the compressed air of the tank, though extremely low, can still pose a problem. Rapid expansion of this air will cause any moisture present to condense and freeze. Therefore, running air at high volume through a regulator, such as to fill a lift bag, greatly increases the probability of a free-flow failure.

The Solution

Keeping water, salt or fresh, out of the first and second stages is the single most effective method for preventing free-flow in an otherwise reliable regulator. This requires a certain amount of careful attention both before and after a dive. These are the guidelines:

1. Before the Dive
    - Keep regulators warm and dry during transport.
    - Before attaching the regulator to a cylinder, the valve on the cylinder must be blown free of collected water or snow.
    - Avoid breathing from the regulator before diving.

2. During the Dive
    - NEVER use a regulator, either primary or backup, to fill a lift bag! Pony bottles are a safer alternative.

3. After the Dive
    - After the dive, the regulator should be carefully removed from the cylinder and the protective cap blown dry and replaced.
    - Blowing air at the unprotected nozzle accomplishes no good and may force water into the regulator.
    - DO NOT toss the regulator in the snow without replacing the protective cap!

- DO NOT place the regulator in a wet bucket without replacing the cap.
- If the regulator has been removed from the tank, make sure the protective cap is firmly secured BEFORE rinsing the regulator.
- NEVER depress the purge button while rinsing the regulator. (Unless the regulator is still under pressure.) (This is where extra attention to detail is required. It can be very easy to depress the purge button accidentally while handling the regulator.)
- Dry the regulator completely between dives.

Caveat

Following the above guidelines will not guarantee that a regulator will not free-flow. As stated before, it is very likely that other factors are involved. However, experience has shown that following these guidelines will make a free-flow less likely.

Discussion

D. Bresnahan: Do you have any data on the time of the season?

J. Bozanic: No data have been compiled.

J. Pearse: These are all free-flow failures? You did not have any failures of air stopping?

J. Bozanic: Not that I remember from the data.

D. Long: Could you determine whether the freezing occurred in the first stage or the second stage?

J. Bozanic: We have cases of both.

S. Bosch: Do you have any way of estimating whether the failure in the double-hose regulator was due to actual freezing conditions or just adjustment problems? I found on some dives that the free-flow occurred with increased pressure. I did not necessarily try to attribute those failures to temperature problems, whereas the single-hose regulator, the Conshelf, would start to free-flow right in the middle of a dive .

L. Quetin: Did you see any relationship between descent failure and the weights used?

J. Bozanic: Jim talked about the particular types of failures when he talks about the maintenance.

J. Pearse: It looks like eight of the nine failures for the RAM (Royal AquaMaster) are from design.

J. Mastro: For the most part, the failures are inherent in the design of these regulators. Almost all the RAMs failed. The only one that did not fail across the board was the Cyklon: only 4 out of 17 failed. The rest never failed or free-flowed.

J. Stewart: It looks like we had a bad set of springs down there this year. John Cronin, of U.S. Divers, and other manufacturers said that getting a complete shipment of bad springs is not unusual. We have had really high reliability on the RAMs in the past. When we set them at 2250 psi they worked fine. If you adjust them to 2400 psi, they free-flow.

L. Somers: What was the primary source of the water that you identified in the regulators?

J. Mastro: I think it came from careless handling of the regulator.

L. Somers: Postdive washing?

J. Mastro: Between dives. Sometimes regulators are used on more than one dive in a single excursion. I saw regulators tossed into the snow without their caps replaced. Snow would get into the nozzle area, be put back onto the tank, and be blown into the regulator. In some regulators you depress the purge as you are rinsing and get water into the mechanism.

S. Bosch: Do you have any feeling for the extent of the failure, double-hose versus single-hose? I think it is important in terms of finishing a dive that a free-flowing single-hose regulator is very difficult to use, whereas with the double-hose, there might be a minor free-flow which still leaves them functional.

J. Mastro: I cannot draw a firm conclusion either way.

P. Dayton: In defense of the Royal Aquamaster, it was absolutely fail-proof through the 60s. My program made several hundred dives with them, and we never maintained them. We treated them terribly, and maybe only four or five times experienced a slight, perfectly workable free-flow, which was always accompanied with ice particles, so we knew it was coming. The regulators currently in use all have parts that have been recycled several times over.

J. Mastro: In fact, we do not even consider that we have 17 distinct regulators. We have parts for 17 regulators, and we rebuild them until they work. If they do not work, we replace parts. Our only point here is that single hoses are at least as reliable as RAMs, or in our case, more reliable.

B. Hamner: Paul's point is very well taken. You are comparing used cars with new ones.

J. Mastro: Correct, and different technology as well. I did record the time to failure on these regulators. The average time to a free-flow failure for the double-hose was one minute; in the single-hose it was usually more than ten minutes and sometimes as much as fifteen minutes.

J. Bozanic: There were many failures early in the season before people were briefed on how to care for the regulators, so proper care and maintenance are very important. Regarding the reliability of the double-hose regulators in the 1960s, we do not have any data. However, the original canisters and housings on the regulators themselves are significantly bent along the rims and edges where the diaphragm seals. We frequently found salt water behind the diaphragm in the second-stage area in that regulator. The supposition is that it entered from the housing deformation on the canister itself, so it is a function of the fact that we are using 20-year-old regulators.

6. Surface-Supplied Diving in Freshwater Lakes - George M. Simmons, Virginia Polytechnic Institute

Introduction

The purpose of this paper is to summarize the methods and experiences of our research dive teams during the Antarctic austral summers between 1979-1988. The objective of these research dives was to explore, define, and conduct experiments beneath the ice-covered lakes in Taylor and Wright Valleys in Southern Victoria Land, Antarctica (Simmons, 1981; Simmons *et al.*, 1985; Wharton *et al.*, 1989). During this period five lakes were studied and several hundred dives logged. The methods that were developed to accomplish these tasks permitted us to dive beneath ice covers 10 to 20 feet thick, to depths over 100 feet, and occasionally in near zero visibility.

Training and Equipment

There is no way that one can adequately train and prepare for Antarctic research diving in temperate latitudes. The best that a dive team leader can do is rely upon an applicant's diving experiences and dive with the applicant under a variety of adverse conditions to evaluate this person's level of self confidence and water skills. Because Virginia Tech is located west of the Blue Ridge Mountains, this meant that we put our divers on the bottom in the cold, dark reservoirs, and we subjected them to the effects of swift currents in the New River. Not that we expected to encounter such currents in Antarctic Lakes, but observing the applicants under such conditions provided valuable insight into their level of ability.

Most teams were also taken offshore for oceanic diving as part of another research project. These diving activities were either off Wilmington, NC or Key Largo, FL. These dives were deigned to incorporate night diving, as well as diving in swells and surge. The open ocean dive sites were always in water of about 100 ft depth and usually 7 - 23 miles offshore.

Our training program began in the local campus swimming pool to test basic swimming, skin diving and scuba skills. The exercises then moved to the reservoirs and rivers where the divers used standard scuba equipment and wet suits, and progressed to the equipment that would be used in Antarctica.

We originally began using custom made cold-water wet suits, double hose regulators, and U.S. Divers Professional face masks. This system did not work well. Although the suits were expertly made, they contributed to a high degree of hypothermia and were expensive, in that divers had to each have their own suit. We did experience a couple of freeze-ups with the double-hose regulators when they were used immediately beneath the ice. While easy to clear in normal diving conditions, they were excessively cumbersome in the heavy wet suits, weights, and other equipment used to collect samples. The masks also left much to be desired. Part of the problem was that we rigged the masks with a communication system. They were inherently difficult to clear and with the communication system in place, there was a considerable amount of water that had to be constantly flushed from the masks.

At the end of our first diving season, it was apparent that a different system would have to be developed. We finally decided on KMB-10 diving masks, Unisuits and U.S. Divers Cold-water regulators. This system allowed the diver to remain dry, the mask provided for communication and easy clearing, and the regulators never failed in several hundred dives. We continued to use this system for the remainder of our diving operations. Divers preparing to go to Antarctica used this system in as many different diving conditions as possible before leaving the United States. In addition, considerable time was spent tending and communicating with divers underwater.

The Antarctic Diving Environment

We usually arrived in Antarctica in October which is the beginning of the austral summer. The air temperature was usually -20°C and there was always wind. The average wind speed was 20 mph. We began the season by testing everything in McMurdo Sound from the warmth and safety of a fish hut. These huts had already been erected over a large diving hole. Moreover, the water temperature in McMurdo Sound was -2°C and if equipment was to malfunction, this would probably be the place where it would occur. Interestingly enough, the single hose regulators worked well with the KMB-10's, even in this environment. The dives in McMurdo Sound also provided the opportunity for the new divers to become exposed and acclimated to the Antarctic diving environment under very controlled and highly supervised conditions. These dives allowed us to dive in buddy teams so that experienced divers could observe and evaluate the new divers underwater. When we were satisfied that everything was working, and our research equipment and supplies were ready, we were moved by helicopter to our field camp(s) in Taylor Valley. During the last several years of the project, we had a permanent camp located at Lake Hoare in Taylor Valley.

There are several differences between diving in McMurdo Sound and diving in the dry valley freshwater lakes. Even though the water is slightly warmer, 0°C, there is no benefit of a warm shelter over the dive site while diving in a very remote location. In most instances, McMurdo was approx. 80 miles or more by air from our camp. Moreover, poor radio communication and bad weather could prohibit immediate rescue and evacuation in the case of an accident. When diving in McMurdo Sound, divers had the benefit of track vehicles to carry them and their equipment from the dive locker to the dive site. At the lakes, divers and their tenders had to either carry or haul by sleds, all diving and research equipment from their camp to the dive hole. This distance was usually several hundred meters, and in nearly all cases across broken ice surface. Once at the dive hole, the dive was conducted without benefit of a shelter which put a premium on having the dive plan executed without difficulty. A delayed dive due to forgotten times or equipment malfunction could contribute to hypothermia and cause the dive to be aborted.

Even though the weather at the beginning of the season was severe, it is only fair to say that most diving was conducted when air temperature was in the 10's and wind velocity was < 20 mph.

Under Ice Diving

We studied conventional ice diving techniques before beginning this scientific endeavor, but very little of this information applied to our particular diving situation. We melted our holes through the thick ice covers with a flat copper coil connected to a steam generator (Love *et al.*, 1982). These holes were approximately 4 ft in diameter and required 24 hrs to complete. We originally started diving in buddy pairs tethered to the surface, but quickly discovered how easy it was for the divers to become entangled in their own dive lines. Moreover, one or more additional lines were usually down the hole for research equipment which exacerbated the situation. The problem was that it would have been impossible for two divers to surface together in the same hole in an emergency situation. Because there were no underwater obstructions in these lakes, and because the divers usually conducted their research activities in the vicinity of the hole, we finally decided that single, tethered divers with underwater communication to a surface tender was the safest approach. A stand-by diver was ready to assist if necessary.

The thick ice covers, coupled with their sediment load absorbed about 99% of the light which impinged on the lake's surface. It would seem that there would be relatively little light under the ice and we originally carried the best underwater lights we could afford. We realized early on that these lights tended to become tangled in other lines, left on the bottom, and were generally, and otherwise useless. One's eyes can adapt quickly to such low light environments, and the training in local reservoirs became very important when we had to work in anaerobic zones where light levels were reduced to zero.

In most cases our divers did not use fins, but relied on canvas boots and ankle weights. This approach prevented the diver from inadvertently stirring up the bottom - and destroying the habitat we were trying to study - and provided more mobility on the bottom with research equipment. The flotation of the dry suit was used to assist with recovery off the bottom.

A crevasse ladder was used to assist divers exiting the water. A gas stove was kept operable at the dive site to provide initial warm water for the gloves, and to melt ice around connections and carabineers. Upon surfacing, the diver's equipment was quickly removed, the diver evaluated, and then escorted back to the tent or Jamesway and assisted with the removal of the dry suit. A more complete dive debriefing followed soon thereafter. We did not conduct decompression dives, nor did we dive deeper than 100 ft. We used standard U.S. Navy No-Decompression Tables with the "next greater depth and time" principle. Our emergency dive accident management system was an oxygen cylinder equipped with a tight-fitting mask. In several hundred dives, we did not have any diving accidents, and our system, simple though it was, suited our research objectives quite well.

Summary

There is very little difference between diving in Antarctica and diving in any other inhospitable environment. The differences which do exist center around remoteness of the diving operation. Because of this factor, it is very important that the divers are well trained and mature. Considerable time must be spent in preparation for such an expedition, and the dive team leader should be prepared to adjust the diving system, if necessary, to provide for the safest possible conditions for his divers.

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Discussion

M. Lang: How long did it take to melt down through 12 feet?

G. Simmons: We can melt at about 9 to 12 inches per hour, depending on the amount of set depth in the ice. If there was a sand layer, we had a graduate student go down with a brush. We had to shut the system down, sweep up, wash the hole down, and then melt again.

L. Somers: It seems like George and I stand pretty much alone in tether diving and tethered surface-supply diving. At the University of Michigan we acquired commercial diving equipment to accomplish much of our work, including DUI's hot-water system, and we were extremely satisfied. To this day, we have remained with the tethered diving system. We have tethered diving with the air on the diver's back, tethered scuba with communication lines to the surface, full face mask, and provisional surface-supplied diving where the air is supplied from the surface and the diver wears a bailout bottle for emergencies.

Our major consideration was for single-diver deployment. We find that most tasks can be performed by a single diver, and that a buddy on the surface is probably in a much better position to help the single diver on the bottom than a diver who is down beside him. Of course, this relates to environments with extremely poor visibility. We use the tethered system where we are doing primarily vertical drops with a limited amount of lateral swimming, and where we need to have good communications back to the surface.

I cannot stress enough the importance of communication back to the surface for monitoring the diver. I know far more about the status of a diver who is many feet below me when I am listening to that diver breathe and talking with that diver than I could ever know as a buddy. We do have standby diver capability in the event of diver distress, but in more than 20 years of doing it, we have never had to deploy a standby. One diver in rapid deployment with minimal equipment and a surface supply of air seems to be an excellent method for vertical under-ice diving.

I will add that many people are put off by surface-supplied diving because they identify it with large diving systems, large compressors, large air tanks, and so forth. But some of the modern equipment being marketed by Diving Systems International and Amron includes very compact consoles to which you hook up scuba tanks or double scuba tank systems. We find these systems are very easy to deploy in the field. One of the papers I wrote describes this compact diving system for rapid deployment using the console and a very lightweight tether, and we have enjoyed working with it for years.

G. Simmons: I do not want to call it solo diving; it is tethered diving. We realized very early on that although we were used to diving as buddies, the other person under water could not help the first and was usually very cold. Two people could not get up through the hole at the same time. So we went to tethered diving, and that system seems to me to be safest. I think that in any remote situation, the diving supervisor has to assess the situation, make a decision, and go with it.

L. Somers: We have tried to put our components together now so that when a team gets to the field, it has the option of scuba diving, tethered scuba diving, or surface-supplied diving, all with a compact system.

L. Quetin: With surface supply or light tether, what kind of hose are you dragging around?

L. Somers: We are now using a hose with quarter-inch inside diameter. This is not what a commercial diver would use, but I find it quite adequate for short umbilical links, particularly if we kick up the first-stage pressure. I have removed the strength member and gone with a combination strength and communication line and replaced the pneumofathometer hose with laboratory tubes that are almost weightless.

J. Bozanic: What do you consider to be a short umbilical?

L. Somers: I very seldom work with more than 150 feet.

7. Diver Recall Systems and Sonar - Jim Stewart, Scripps Institution of Oceanography - UCSD

Diver Recall Systems

One of the problems we have had in the Antarctic is communicating with divers when they are not on a hard line. In Phoenix, Arizona, Screamer makes a handy little recall device, about the shape and size of a flashlight, that emits a high-frequency sound. It is a prototype we have been working with, and it seems to have a lot of potential. Additionally, they now make one about the size of a baseball. This unit will not go through a kelp plant, but otherwise it works pretty well. The range is only about 25 feet. They make them in colors other than hot pink as well.

G. Simmons: NOAA had some sort of siren device that ran off the ship's generators. They kept it on the fantail, and when they wanted you back in, they lowered it over the side and turned it on. If you were in the ocean, you would come up.

J. Stewart: You can use a swimming pool speaker, too. You can also turn on the ship's bottom sounder, and change frequencies and scales so that every diver around can hear it. But you do not have those on 16-foot outboards. There is always the option of putting a scuba cylinder in the water and banging on it.

Sonar

The first edition of ScubaPro's sonar gave a single-shot reading. The second edition will scan, so if you are looking for an object or the bottom, you can get a continuous reading by holding the button. The last point it reads is maintained for 10 seconds. The first version had a pretty broad cone. If you stick it down in an ice hole for a reading, it beats using a lead line. That is really what I was after. The other advantage I see for this second-generation scanning sonar is its use with a triplane in turbulent waters where you hang it below the ice and can scan with it. Of course, the next generation will have a little compass in the back so you can also take a bearing.

C. Mitchell: I installed a flasher fathometer in an underwater housing twenty-five years ago. You can now get fathometers with digital displays for $150, put them in a case with the transducer out one side, and add a 12-volt dry-cell battery to make a scanning sonar.

8. Shelters - Jim Stewart, Moderator.

J. Stewart: Historically we have used Scott huts and Jamesway huts as shelters. Now, we have the apples and that new zip-up hut, which looked like it was going to be an answer to a number of things. It has a zip-up door with ventilation, windows, and a good floor. It looked like it would be a good diving locker. I would like to record some things here about what you found most successful for your diving operations in remote areas.

J. Pearse: We usually just use those little fish huts.

D. Bresnahan: We use them for a fixed site where we are going to stay for a couple of weeks. A fish hut is a 12-by-20-foot building that has a hole in the floor. We dive from a 60^0 environment right into the water. That is probably the ideal situation.

J. Stewart: Jamesway offers the same thing, but more for when you are going to go out for just a day or two.

J. Pearse: For one day, going out in the hovercraft is by far the easiest. You can carry everything out, dress in the craft, and get into the water.

P. Ponganis: Gerry and I have found one small fish hut that is very easy to drag around. It does not cover the dive hole. We take that hut out, dress in it, and turn on the heater to get warm. That worked very well for a one-day trip.

J. Stewart: I was just wondering if those Weatherports could not be used like the fish huts. They are much more mobile, it seems to me. One would go up in a hurry, and you would have a hole in the floor like in a fish hut.

P. Dayton: For single-day trips out of a helicopter, there is little time to put things up, so the Scott tent is probably the easiest to put up and take down and still get your dives in. It goes up and warms up fast. They are not bad for dressing, but if I were going to live out there for several days or several weeks, I would like a little more.

J. Pearse: We used a Scott tent like George did, over a hole.

P. Dayton: You used it to get dressed?

S. Bosch: For a longer-term operation, a week's time, there are two ways to go about it. You can use one of those apples, which can be transported by helicopter and placed on the site or on the heliport, which is really ideal, except we have to come up with a better way to transport it. It takes nearly a helicopter flight to get it out there. It is very cumbersome.

P. Dayton: How heavy are they?

S. Bosch: They are not necessarily heavy, just bulky.

P. Dayton: You do not fly the apple around casually. It is a big operation.

D. Bresnahan: But the Weatherport does not fly around constructed. It flies around broken down.

S. Bosch: I think the consensus is that the Weatherport is easier in the long run. In the summertime there is no need to dive from a shelter as long as you have a place to dress out of the wind. Once you are ready, you just jump into the water.

D. Bresnahan: A shelter should be one that you can comfortably stand up in and that is easy to assemble.

S. Bosch: The problem comes when you want to dry your gear, for example. If you are going to be out for any extended period of time, there is not really a good way to put a heater in the Weatherport. We had a portable heater, which tends to build up fumes.

P. Ponganis: At Cape Washington, the Weatherport was our main laboratory and living hut for two months. We had a kerosene heater that worked quite well, and we were able to hang the suits from the poles on the inside on the roof and dry them overnight.

S. Kottmeier: The portable structures you are talking about tend to prolong the diving season on the ice. Larry Basch was able to dive into February. We have to pull other structures off the ice by mid-December. The more portable structures like apples, Weatherports and small tents help prolong the season.

9. Transportation - Jim Stewart, Moderator.

J. Stewart: How about transportation? We have trucks, helicopters, hovercraft, and small boats for diving. Obviously, the hovercraft is the vehicle of choice for one-day trips. Some of you worked out of trackmasters and a personnel carrier that had a gasoline-powered heater in the back. You would get in the back of that and suit up.

S. Bosch: We found the closed sprites to be really very good.

J. Pearse: They are almost as good as a vehicle. The enclosed space that we had was fine for one day.

D. Bresnahan: Did you ever use a tucker?

J. Pearse: No. They are much too high to work with.

P. Dayton: The most dangerous day-to-day problems we had were dragging tanks and weight belts from wherever we had to store them to the hole. We ended up putting tents near the hole, but we still had to keep the tanks somewhere. It would be nice to have a way to deal with the rotten ice on the other side of the sound. A big-wheel or an ATC could get over that rotten ice, or maybe a super banana sled that would not lose the tanks every time it hit a bump. I do not know how we managed to do our work without breaking legs.

D. Bresnahan: We are considering a John Deere product. It has four wheels in the back, one wheel in the front with a ski, and it can carry two people. You can put a small cab or roll bar on it. It has a flat bed and carries 600 pounds; you can trailer it and carry an additional thousand pounds. I am not sure that anything is going to go over an irregular surface that is really a deteriorated ice surface.

P. Dayton: You fall through those little ponds. I do not know how we got through. My legs are certainly scarred up and bruised. All of us were battered. It would be nice to develop something for that area.

K. Dunton: In the Arctic we have about 12 years of experience on the ice. We have used a vehicle from Crowley Marine a lot. It is a big rolligon. Some are 40 feet long. They are articulated, and have maybe 8 to 10 huge tires about 6 feet high, with low pressure (4 to 6 psi). Each tire is driven independently from a spindle above the tire. These vehicles are great for going to the tundra, and are the only ones allowed there during the summer, because they do not affect the vegetation. They will go through a slight bit of slush and through rivers as long as they are not too deep. They will not go through very rough ice. They take us through the small pressure ridges, and we have been out there when the rivers start to break up and there is fresh water under the ice. We use a Parcoll that we can put up in about four hours to use as our diving hut and lab. That has been very convenient for us over the years. We can get it out of the ice and pack it on the rolligon and go home. We cannot use explosives up there, but we do everything ourselves. By the way, we have no logistical support in the Arctic. We use a tackle to pull the ice block out with the rolligon. The rolligons are expensive, but would be very handy for Antarctic operations.

10. Making Entry Holes for Ice Diving - Jim Stewart, Moderator.

J. Stewart: How about making holes? We have the melter, augers, chain saws, blasting, and that instrument of torture called a handsaw. Any problems with these, other than the fact that the auger bends once in a while?

D. Bresnahan: We like the auger, which gives us a 42- or 48-inch-diameter hole when it is running properly. It goes through nine feet of ice in half an hour and makes a nice clean hole. We do not like to drag that over to the other side of the sound, 50 miles away, because invariably the trailer breaks down, and the auger is a high-demand piece of equipment. On the western side of the sound, we have been using explosives, and we would like to find another system. We would rather do something else, and the environmental people are biting us up about using explosives. We had a lot of deaf seals. We are trying to come up with something else that is a take-off of a melter system or a steam-generator system, but something that we could pull in on a lightweight, five-ton sled.

J. Stewart: What you can do is get one of Dick Long's hot-water suit steam operations and attach it to George Simmons' melter.

D. Bresnahan: In George's case we have a controlled system since we do not want to ruin anything in the lake.

G. Simmons: On the ice, it does not matter if we introduce some fresh water into the water column. We have a lot of flexibility with what we can create, but we really have not come up with anything.

B. Townsend: We use augers in the Arctic.

D. Long: What is your maximum weight requirement? How big is too big?

D. Bresnahan: I would like to be able to pull them with a Piper Snowcat if I can stay within 2,000 - 3,000 pounds.

P. Dayton: You are going to have to fly them then. You will not be able to drive.

D. Bresnahan: Then 2,000 pounds, or multiple trips. We are making multiple trips now with explosives. I just do not want to bring somebody home in pieces.

D. Long: How fast?

D. Bresnahan: When we blow a hole with explosives, we have many hours of very painful, slow, tedious work to clean the hole out. If we can melt or auger and we do not disturb hundreds of yards of ice underneath the surface, we do not have this big hole to clean.

D. Long: How fast would you have to dig a hole or how big around would that hole have to be?

J. Mastro: 42 inches at 9 inches an hour.

P. Dayton: I would make it really big. It is nice to have two divers in the hole.

D. Long: How big does a hole have to be for two divers?

P. Dayton: Five or six feet.

J. Pearse: That is rough on the auger.

G. Simmons: I was going to say at least six feet would be big enough to get two divers into the hole. If it is conical, it probably melts a little faster. With all that sediment in the ice, we can melt close to a foot an hour with the little steam generator we have. That was just a modest commercial model, nothing heavy-duty. One of the nice things about having a flat unit is that we can get down into the hole fairly easy. When we were interested in the stratigraphy of the ice, we could ride the melter down and sample the ice column.

J. Stewart: Those of you who have not had the pleasure of coming back to a hole and having it filled with a Weddell seal, might not realize that it is always nice to have at least two holes. Those animals spend a good deal of time at a depth of perhaps a couple of thousand feet. When they get back to your hole, they hyperventilate. There is no way in the world you can get them out of there.

II. Document and Case Reviews

1. Review of UNOLS Shipboard Diving Safety Workshop - Chuck Mitchell, M.B.C., Moderator.

The two-part workshop centered around a problem that UNOLS (University National Oceanographic Laboratory System) and the operators of their vessels were having. Work on board big ships at sea usually entails a conflict of some sort between the master and staff of the vessel and the scientific staff. The conflict changes character from time to time and centers around different subjects, usually who is responsible for what, who is going to do which activity on certain days, and so on. Another problem arises when people arrive from other institutions to dive on the ship and no one is sure of their diving capabilities. This almost basic state of distrust between the masters of the vessels and the scientific staff interfered with the whole process. Of course, the National Science Foundation - which funds many of these research projects, including the operation of the vessels - was caught in the center.

As a result, a group was invited to address these conflicts over a period of about six days, followed up with a lot of correspondence back and forth. A list of recommendations covered a variety of subjects such as conflicts over authority and responsibility, conflicts between the scientific party versus the ship's party, multi-institutional cruises, whose dive manual and operational protocol should prevail and small boat operations. If a launch is put over the side to support divers in the water, what are the minimum criteria for its operator? What kinds of protocols are brought forward in an emergency situation? Is diver skill evaluation commensurate with their degree of expertise and training? Emergency planning for ships at sea is complicated. Some are more remote than in the Antarctic, but the same kinds of problems exist. Is medical expertise available by telephone? How are people transported out? Are there written instructions? Does everybody know what to do? There was also quite a bit of discussion about recompression chambers. Should there be one on-site or not? These are the issues that were addressed during that workshop. Even though it was designed for shipboard operations, I think that the general protocols and the issues are generic enough that they could be applicable to the Antarctic land-based operation, as well as shipboard diving.

M. Lang: One of the reasons I sent the Shipboard Diving Safety Workshop proceedings out is because they are fresh off the press but also because I felt most of the issues addressed here are very applicable to diving off the Polar Duke or any other polar research vessel. This document points out that the most potentially dangerous part of your entire dive is moving people on and off the research vessel. On the Polar Duke, everything is loaded into the Zodiac. The crane operator puts the Zodiac overboard. Divers in their dry suits climb down the chain ladder into the Zodiac. They dive while the tender stays in the boat, surface, climb aboard the Zodiac and head back to the chain ladder. Then, tired and with cold hands, they have to climb up an 18-foot chain ladder and avoid being smacked up against the ship.

L. Quetin: We have our divers ride down in the Zodiac. That seems to work out very well for putting divers on ice off the Polar Duke. We get into the Zodiac and harness up to a safety belt, are swung over the rail, dropped down onto the ice, detach ourselves and away we go. It is really quick and safe.

C. Mitchell: How do you work the safety belt arrangement for detaching? As soon as you hit the water, you want to bust loose.

L. Quetin: We just take the Zodiac and set it on the ice. At the same time the ship is breaking a lead for us to dive through. Then the ship backs up and we have a nice edge. We tie off to the Zodiac with our down line, which goes to a float - a typical blue-water rig. We harness with safety belts in case the bridle for the Zodiac breaks. It works really well, much better than climbing down a ladder. In open water, it would be a little trickier. But if it is fast ice, we are being put on a float, it works well.

B. Hamner: We did not ride the boat down like Langdon, because we were out in the open sea. If a ship has any roll on it, then you are out there on a big lever arm swinging back and forth, and it is not attractive.

C. Mitchell: Other than being knocked off balance as you are buffeted against the side of the ship, there was probably a reduced hazard of having your knuckles caught between the gunwale and the ship.

B. Hamner: When we were in quieter waters, we used Langdon's procedures - just got into the boat. One issue is that generally those boats are picked up by a bridle, and if your weight is distributed peculiarly, that boat can flip. So you need a really long bridle arrangement, but then it swings badly too.

C. Mitchell: You can use what is sometimes referred to as a strong back, a kind of rigid framework that holds the boat straight down. It offers some additional stability, but then there is a problem with having people in the boat. Once it hits the water, the cable slacks and that framework goes up and down and back and forth. That is probably much more dangerous than loading people down the ladder.

The only other method I can think of is used for offshore oil platforms. It is something equivalent in diameter to a tractor tire and has a steel platform and a large, nylon net cage. It looks like a big bird cage made of nylon strapping. You literally leap onto that when it drops onto the deck, grab onto the outside of the netting, and the crane operator then snatches you off the deck. You go straight up at high speed and are deposited on the platform, which can be 80 feet above the water.

L. Austin: At the Farallon Islands, we go in from a crane with a large truck tire. We just hold on to the line and stand on the tire, which is lowered into the water. Then we get into the boat.

C. Mitchell: So you go directly into the water and then into the boat.

M. Lang: In a cold environment, you climb down the ladder into the Zodiac. You are still warm when you make your dive. Then you come up and get the evaporative cooling effect and are absolutely frozen by the time you get back to the mother ship. Some models of dry suits do not hold as much water on the outside so they do not cool you down as fast. Vulcanized rubber blows dry quickly, or you can have the tender wipe you down.

B. Langley: The Navy does it basically the same way. The diver wears a safety harness attached to a pulley and a line. That could provide a degree of safety, especially coming up, when divers are cold.

D. Bresnahan: Divers coming onto the ship after several hours out on the islands are drenched and wet, and cannot get back on ship. They cannot take hold of the ladder in the swells and then have the physical strength to arm themselves up. We have had to haul people up.

G. Simmons: For emergency recovery at sea there is a sling that is put under the arms. Something simple like that to slip around divers to help them get back to the ladder and steady them as they make their way up might be the easy, simple solution.

D. Long: In the offshore oil industry, collars are used through which people put their arms and are then hoisted up. I think big baskets are just too big for the type of vessels you are using, but I see nothing wrong at all with just throwing down a horse collar as a safety precaution, and having divers put their arms through it and being hoisted up. Using cold hands on something like a chain ladder should be avoided after a person comes out of the water, since that person is already a thermal casualty. Helping divers up like this should probably be just a matter of routine, as opposed to waiting until they cannot make it.

C. Mitchell: The diver's body strength at the end of a couple of dives has decreased significantly, and the upper body strength needed to get up and down those ladders is frequently just not there anymore. We tend to overestimate our capabilities.

C. Mitchell: Who has authority and responsibility for operations that take place on the shoreline and for diving from huts?

G. Simmons: The helicopter pilots are in charge of getting us there. Once at the camp, the senior person - either I or someone I designate - has responsibility for moving people from the hut out onto the ice. In case of accident, there are certainly protocols from the Navy's point of view, but from our point of view, the worst thing that could happen would be for someone to fall down and get cut on the ice, break a leg, or pull a ligament. Other than general first aid procedures, it is a matter of getting back in touch with McMurdo and having a helicopter pick us up. We had general guidelines for what to do if something went wrong, and we discussed them from time to time, but we did not have anything formally written down.

J. Bozanic: For McMurdo station, there is a diving accident management plan that was originally generated by Jim Stewart and worked on by Steve Kottmeier, Jim Mastro and me. I think that information is not widely enough disseminated early in the dive program; the divers need to be more aware of what the procedures are. The plan needs continual review to make sure that it meets the conditions under which people are diving each year.

C. Mitchell: That is similar to the general consensus at the UNOLS workshop. There was some confusion about who was going to do what in case of an accident and in some incidents where it the whole process significantly slowed down while people were interfering with one another because the pathway of authority and responsibility was not clear.

D. Bresnahan: I would disagree with Jeff. I think the bigger problem is not with the divers not knowing what is going on; it is with the people who respond to the accident, . Those are the people who really need to know, when a diver or a party in the field calls in to report an accident, what the appropriate response should be.

C. Mitchell: When you call the Coast Guard for help, the person who answers the radio starts asking a series of questions. He will not initiate any kind of response until he gets his questionnaire filled out. We found it helpful to go through the whole process with our staff and field personnel so that they know what the questions will be and already have the answers formulated in their minds.

M. Lang: Urgency and the quality of medical care in diving-related accidents are very important. The outcome is contingent upon the learned skills of the scientific divers in recognizing any kind of barotrauma and rendering immediate aid, in addition to having a standing plan in effect. Is there such a plan for Polar Duke operations at Palmer Station? No?

The other question is the recompression chamber issue. We had heated debates about recompression chambers on ships. As you know, the only reason we can perform our science is because we are able to convince the Department of Labor that we have a safe and effective way of doing it. One of the requirements we were exempted from was having a recompression chamber on-site. My question is, if the chamber at McMurdo at some point becomes inoperational, does that mean scientific diving can no longer take place? Can you only dive so far away from the chamber?

D. Bresnahan: You are correct. If the chamber is down, the diving program is suspended.

J. Heine: What about at Palmer, where there is no chamber at all?

D. Bresnahan: There is a chamber at McMurdo.

J. Heine: Why is that different? People dive at Palmer all the time without one.

L. Quetin: That is a liability.

D. Bresnahan: Palmer is not within reasonable reach of McMurdo. It would take a day and a half to get to McMurdo from Palmer.

M. Lang: This is a real problem for remote polar operations. We send K-cylinders of oxygen, regulators and masks with Smithsonian scientific divers working in remote sites and still request that they dive safely.

G. Simmons: We had sort of a remote situation there in McMurdo, and the phone system was not always working. There was a dilemma about what to do, because we wanted to be as safe as possible. The other side of the coin is that if we do not get our work done and get some data, because we have such a narrow time frame, the whole season collapses, and then we will not be back next year. Jim Stewart said the best thing to do is to dive safely, follow the U.S. Navy diving tables, and do not do any decompression time. The best thing to do is take a tank of oxygen out with you and a regulator for greater percentage of oxygen delivery. We would try to inform McMurdo when we were diving, to make sure that at least people back in town knew what was going on. I do not know what to do above and beyond this.

L. Somers: In Europe, the average delay in getting to a recompression chamber is 10 hours. Consequently, they developed the protocol of using oxygen and adequate hydration of the patient. Oxygen is the key. Hydration has to be considered, and if you are going to hydrate a person who has experienced decompression sickness paralysis, someone on the team should know how to insert a catheter. That system can be put into a pretty small packet in the field. One area we have not explored is moving into closed-circuit oxygen rebreathers for emergency use.

C. Mitchell: How long would it take to get someone from a site back to a recompression facility if McMurdo was down?

D. Bresnahan: To take them to Christchurch, New Zealand, in an ideal situation would be 12 hours. In a less than ideal situation or in bad weather, then would take an undetermined length of time. And, that means that the weather must be good enough to bring them back in to McMurdo. If people dive at McMurdo in September, it would take more than 72 hours to get to Christchurch, because the aircraft are gone.

D. Divins: If we are going to administer oxygen, we should have enough to last until we can get to a chamber. Having a small bottle on the ice and feeling that we are safe is not really sufficient. It will definitely reduce symptoms, but once the oxygen runs out, the symptoms of decompression sickness will come back. The rebreather that Lee was talking about delivers 10 or 12 hours of oxygen as opposed to 30 or 40 minutes. How much oxygen do we have to have? We cannot keep people on pure oxygen for 72 hours and have them develop oxygen toxicity.

C. Mitchell: You should have enough oxygen to get you from the dive site to McMurdo.

L. Somers: I might add that approximately 72 percent of the European cases were resolved or nearly resolved before recompression. This is a major or total reduction of symptoms.

M. Lang: For type I DCS, right?

L. Somers: And type II.

D. Long: I am sure most of you have seen the new type of one-man recompression chamber that virtually folds up and fits inside a trunk. Problems with any kind of recompression chamber are a nauseated patient and knowing how to operate the chamber. A 40-inch double lock chamber is very different from a one-man chamber where you cannot get to him. However, considering the number of times chambers are used, and considering the problems of instructing someone and keeping skills current, it is almost better not to have a portable chamber. But the decision must be made and not let slide. If you are trying to address decompression sickness problems per se, then you can reduce your exposure with your diving procedures and the equipment. In the case of an air embolism, the problem can be severe. There does come a time when you simply will not be able to take enough with you, and you will have to accept a certain risk. Having knowingly done so and having the divers understand ahead of time and sign releases, "I understand that where I am going there is not a chamber available nor will one be immediately available," simply puts that risk up front. You can end up with so much equipment trying to cover all the potential possibilities that you endanger your mission.

C. Mitchell: Very valid points.

G. Staffo: The difficulty is that it really calls for a lot of preplanning. You have to have a good program. Then you have to be willing to stick with it or you have to have a mechanism in place for changing it, so appropriate people can make adjustments. In Antarctica, the frequency of change is probably the hardest thing to handle, with the limited resources we have there. To some extent, we can raise our standard and have a greater planning effort. But then we will probably lose some flexibility in our ability to make changes.

C. Mitchell: Within the scientific diving community, we have come to a general consensus. Not having a chamber on-site is an acceptable risk in most cases if people are trained adequately and there are procedures in place to provide emergency transport to facilities. Some of these facilities are so complicated and take so much support personnel to run that it would be almost impossible to have them on-site.

J. Mastro: I agree with that. At McMurdo we are all involved in dry suit diving, with the potential risk of blowup and rapid ascent, so subsequent embolism is a major problem. It is a good idea to have a chamber there for that reason, as opposed to for DCS. The chance for DCS is not great. In fact, the one fatality we had was caused by an embolism.

L. Austin: Are any people doing decompression diving in the Antarctic?

J. Mastro: Not legally.

D. Bresnahan: Not once they go under the water.

J. Bozanic: There were at least two decompression dives in the logs that I received two years ago.

J. Mastro: They are against guidelines.

J. Bozanic: Neither one was a planned decompression dive. They were emergencies that happened at the surface.

D. Bresnahan: At McMurdo we are dealing with a thousand people in the summertime. We have a full eight-bed emergency facility. The chamber is attached to the medical facility and is a medical treatment facility. We have full-time medical officers. We have been able to operate the chamber with a trained crew. That same level cannot be put in at Palmer Station, which has a peak population of 43. I dragged my feet for a year to try to avoid a chamber, because now that we have one, all these people are squawking about how much it costs to keep. But if we are going to have it, it has to be ready to run. I cannot see us in a position to do that on the ships or on Palmer.

M. Lang: Diving safely obviously comes way up front. That is why we have scientific diving programs with standards well beyond those of recreational programs. On the other hand, when we as a Diving Control Board track Smithsonian dive plans, there is no way we can allow people to dive if the nearest chamber location and method of transport is not contained in that dive plan, and is not within some reasonable distance or capability.

D. Bresnahan: What is reasonable at Palmer?

M. Lang: That is the question. The proposed UNOLS emergency maps had concentric circles outside of which there could be no diving, period.

B. Hamner: If those criteria apply to Palmer, there can be no diving there.

G. Simmons: I do not think we should overlook the fact that we have had a pretty good safety record of diving in cold-water environments. I do not think we should minimize the level of training and leadership that we have for younger people who are coming on board. You cannot operate your research program to suit every level of emergency that could arise. My experience out of McMurdo is that there are two extremes: you either do not have an emergency, or whatever facilities you have will not do any good; it is all over. There is no way to plan for a graded emergency series. Eventually you reach a point at which you say you are either going to do the work or you are not. If you decide to do it, then you accept a certain amount of risk and go ahead and get the job done. You take as many precautions as you can, and you carry a reasonable amount of oxygen, but that is about all you can do.

D. Long: I recommend that further investigation be made into the closed-circuit oxygen rebreathing system as treatment device.

B. Langley: In the Navy we do not require a recompression chamber on scene for all types of dives, only for dives that are considered extremely hazardous. In the naval special warfare community, some submarine-lockout free ascents are considered hazardous by some people, but even there we do not have a blanket requirement to have a chamber on scene; it is left to the commander's discretion. If our people are trained properly, then the likelihood of an accident is greatly minimized.

C. Mitchell: I summary, our general consensus appears to be that we are not particularly in favor of, or do not see the need now for having a recompression chamber on-site to accomplish most of our tasks.

D. Nagle: One of the statements that was used a lot in the rescue community was that backup systems will proliferate until the entire operation is paralyzed or until somebody decides to get some work done - one or the other. It comes down to the original core system that selects good people, gives them the best training possible within reason and budget, and sends them out to use their good judgment to make their own decisions about what is occurring.

S. Jewett: In Alaska and throughout the polar areas work has been shackled by our risk management department's requiring an Emergency Medical Technician (EMT) on location for any remote operation. I do not think they would say that simply having a CPR and a first aid card is sufficient for remote diving operations.

C. Mitchell: Is this for shipboard or land-base operations?

S. Jewett: This is for setting up camps in remote locations on the ice pack. In order to carry out an operation a couple of months ago, we had to go to the local fire department and hire a man for a month and a half to take him out on the ice. He sat there and read books all day.

D. Nagle: On the other hand, you can pick up that training in a hundred hours, and programs are available. There is also a risk assessment that determines what level of safety is will deal with what percentage of risk that could occur in the scenarios that you are going into. How much more safety will diminish that risk by what percentage, and at what point does it cost more to create this level of safety than it does to get the work done? It is a judgment call. What for you is too expensive, might be perfectly reasonable for someone else.

S. Jewett: Unfortunately, the ice core project went along with it, so the precedent has been set. I just hope it does not come back to haunt us.

C. Mitchell: That is a problem for a small ship like ours. The consensus has been that we must have the basic first aid supplies, a radio backup, and access to a physician on call 24 hours a day.

L. Austin: This is really important in terms of the requirement of having something like a recompression chamber or an EMT. We went through all of this in the late seventies, and we convinced the federal government that we really were safe and that we would pick the proper kind of coverage when we needed it. We should be very careful before ever saying that we require anything, because it will come back to haunt us.

D. Bresnahan: We put a recompression chamber in at McMurdo, and now that we have the chamber, if it is not up, there can be no diving. We will never convince people on the upper level that before, when we never had it, we were safe.

B. Hamner: There should be some requirements. All the remote diving operations should have oxygen.

J. Stewart: That is required anyhow.

B. Hamner: We only have the little units that last 20 minutes.

C. Mitchell: During the UNOLS workshop we asked who had the responsibility for oxygen. If people are going to be at sea, we suggested that they make checklists of all these items for the precruise plan and that there be a firm and clear distinction of who will provide what.

L. Somers: In the records for the last two years of polar diving, how many out-of-control ascents or overinflation of suits or BC's have you recorded?

J. Mastro: No data have been recorded. There are a few anecdotal stories.

G. Staffo: We do not have formalized reporting in place for that, so we are in the position of having to make policies without a good database for some of the risk management decisions. In some aspects, management has decided to err on what they consider to be the overly conservative side, and such was the policy made only two years ago for the recompression chamber. Antarctica's unique remoteness and sometimes unreliable communication tends to make us err on the side of conservatism. What we look for with increased technology is a better risk management system and having better assessments on which to base decisions.

C. Mitchell: Scientists have been diving in Antarctica for 30 years now. The accidents have been relatively few and far between. Many thousands of dives have been made without any difficulty at all. We have to keep that in mind.

M. Lang: I organized the AAUS Repetitive Diving Workshop at Duke University this year. We discussed multilevel diving and how many dives per day could be made for how many days without taking a break in between. It turns out there are no hard data to say when you should take a day's break from diving. I just want to read one paragraph of the session summaries: "Although diving is a relatively safe activity, all persons who dive must be aware that there is an inherent risk to this activity. Currently, the risk of decompression illness in the United States is estimated as one incident per 1,000 dives for the commercial diving community, two incidents per 10,000 dives for the recreational diving community, and one incident in 100,000 dives for the scientific diving community." That is a definite plus for continued education, training and controlled diving programs.

D. Divins: We were talking about a conscious victim and rebreather. Embolism seems to be the major concern rather than decompression sickness, in which case you might have an unconscious victim, and the rebreather is not going to be sufficient. You have to have some means of positive pressure inflation. The rebreather would be nice for the conscious person.

M. Lang: Most people cannot distinguish between a type I and type II case anyway, because they have never been trained to do field neurologicals. By using the term "decompression illness" they cover both arterial gas embolism and bends.

C. Mitchell: A physician once described air embolism to me. There are two kinds of embolism: one that gets you - within 30 seconds you are dead; and then the other kind that you recover from.

J. Mastro: We did have an embolism case last season at McMurdo, which we treated. Had we not had the recompression chamber there, this fellow would have been in serious shape by the time we got to Christchurch. It is a small risk in hundreds and hundreds of dives, and he was not a scientific diver, either. But if the chamber is easily supportable, it is worth having, even if you save only one person.

D. Divins: There is an Australian unit called a paracell that will fit in a fixed-wing aircraft. It runs off of scuba tanks and is big enough for a tender to enter. It could be made to lock onto a standard chamber so you could transfer a person straight through. A helicopter could fly to the scene, and you could put a victim under pressure, transport under pressure, and administer oxygen inside.

B. Langley: We have one of those at the Experimental Diving Unit. It is a two-man chamber to which you can attach a one-man lock, so you can actually put three people in there. It has two sections, and six average men can pick either section up. That is how heavy it is. It costs about a quarter of a million dollars for the package.

B. Townsend: In emergency situations that were not diving related - an amputation and a massive coronary - we found that even though we had taken so much trouble to get all the sophisticated hardware on site, people had forgotten the basics - treatment for shock, and upper-airway management. All of our welding oxygen is medical grade oxygen. Our preplanning and also our sensitivity to prevention are good for major emergency contingencies, but the basics, we found, cannot be neglected.

M. Lang: Most of the treatment for a diving accident, once the diver is on the surface, would be no different than for any other medical emergency (First aid, CPR, oxygen, treatment for shock, hydration, evacuation, etc). If you are on the ship, you have to have an emergency plan.

2. Review of 1987 AAUS Cold-Water Diving Proceedings - Michael Lang.

This document was the first attempt to assimilate some of the polar diving experiences in one place. It does not really lend itself to "review", since it is a historical document and was sent to you with the intent of disseminating information as a starting point for further discussions. We feel that the information is current, but I think it would probably be more beneficial to go right on to the blue-water diving guidelines.

3. Review of 1986 Blue-Water Diving Guidelines - John Heine, Moss Landing Marine Labs, Moderator.

I am not sure there is anything about doing blue-water work in polar waters that needs to be discussed. Perhaps Bill Hamner or Langdon Quetin might discuss any particulars they have experienced using blue-water diving techniques in cold water .

L. Quetin: We modified the technique a bit. We put our down line to about 10 to 15 feet. On the end of that is the 'u' with two loops to hold the diver lines. As the divers swim under the ice, this allows the lines to go up so they do not get caught on the ridges and protuberances under the ice. We do not use a safety person, but send two divers down. After trying lots of different systems, I gave up using a half-inch tether per person. Half-inch-thick braided nylon worked okay and floats at the surface. But we went to quarter-inch because there was too much drag with the half-inch. The quarter-inch gives us enough communication that if people on the boat see something changing, they can signal divers.

J. Heine: Without a safety diver, do you have any problem with large predators?

L. Quetin: Not at all. We have never had a problem at sea with leopard seals and have never seen a killer whale.

B. Hamner: I agree that you can probably dispense with the safety diver in the Antarctic. I would not recommend it in the tropics, because the safety diver looks out for sharks, and it turns out that is nice.

J. Heine: Did you have any dexterity problems or problems with handling your shackles that were any different from when you dive right out here offshore? No? Are the environmental conditions - the constraints of wind, current, swells, and visibility - similar everywhere you were?

B. Hamner: The weather changes so radically and quickly in the Antarctic, that we have to be really careful.

L. Quetin: Communication from the surface is more important than having safety divers. That is why we went to a tethered system.

C. Mitchell: At the UNOLS workshop, a number of situations were discussed that revolved around the communication between the person in the inflatable and someone on the mother ship. There were two instances where there was a lot of confusion about what to do next and whether the person in the boat was supposed to recall the divers. There was a conflict of responsibility in which the crew on the mother ship felt that the situation required recalling the divers and then had to convince the person in the inflatable. Anything that we could do to avoid such situations would be helpful.

J. Heine: It is standard procedure for the person in the inflatable to have the radio on and be able to effectively communicate to the people underwater.

C. Mitchell: In one case the person in the inflatable apparently did not have the radio on. The ship wanted to recall because there was an iceberg floating down onto them. The support vessel had to steam up to the inflatable, with the divers still down and say, "Get out."

D. Bresnahan: Perhaps an alternate means of communications in addition to the radio would be good.

G. Staffo: It is important that you do not just put anyone on as a tender. The tender has to be a trained person with a very serious understanding of his responsibility.

B. Hamner: In one case, the second mate was running the boat. The wind came up, and he could not start the engine. Then he threw his oar overboard. Not very competent.

L. Quetin: It can be more subtle than that. On one of our windier cruises we had tenders trained, and things were going very smoothly. Two new tenders got fed into the system at the same time, and we did not catch it. They did not know the routine, and it threw us off a bit. There was no incident, but the situation did bring home the fact that you can get into a routine and become a little casual about it.

J. Stewart: I should also point out that in addition to the kind of blue-water diving that most of you people do, and the type of diving for which this guideline was written, there are additional kinds of blue-water diving. Such as when you step off into a water column to recover an instrument, meet a submarine, or chase our bottom controller around and meet it in the open sea at two o'clock in the morning. That diving is not addressed in the guideline, and for it, you really do not want to wear a tether. You want to be able to work in the environment and have a person in the boat who really understands what you are doing. You have to have faith in that person; when you step off into the open sea out there, he has to know where you are and what you are doing.

J. Heine: The bottom line is that you do not want to be learning what you are doing down there. You should be trained in exactly what you are going to do, and everyone should be experienced before you go down.

4. Review of Antarctic Diving Accidents

Jim Stewart

I want to report on the accident we had at McMurdo in 1987 and review for you some of the causes we think contributed. It might be also appropriate for Jim Mastro to fill you in on the Coast Guard diver accident.

In 1987, Mark McMillan came to us from University of California, Santa Cruz. He had a research diver certification and landed a volunteer position with Bill Stockton. He was trained and certified in dry suit diving. He went south and was given a series of check-out dives by Bill Stockton and Steve Alexander. On his twenty-first dive, he was asked to carry a small light, weighing about 40 pounds, out under the ice in New Harbor, about 50 miles from McMurdo. He entered the hole. The array was a little bit heavy. Apparently the lift device that he had on it was not enough to handle the weight. He went to his dry suit for a lift bag and the senior divers told him at that point that he couldn't do that. He got out, added an appropriate amount of lift on the device, and dropped back into the hole.

Alexander apparently was under Mark McMillan swimming out, and as they approached the site - about 125 feet from the hole - Alexander dropped down, looked up, and saw McMillan coming down, took two pictures, and looked around. He saw the array on the bottom, and McMillan up in the overhead. Alexander went up. The regulator was out of McMillan's mouth, and he was ballooned up under the ice. Alexander had trouble letting enough air out of his suit to move him and not sink him. He took him back to the hole with great effort. He got him up out of the hole, gave him mouth-to-mouth resuscitation, and put him on oxygen. They radioed for the helicopter.

I had arrived on the ice the day before and had just gotten back to my room after overhauling some two-hose regulators when I saw the emergency team in the helicopter. About that time there was a knock on the door, and the people in charge of the chamber had it up and running at the time the doctors were there. The corpsman on the helicopter was giving McMillan CPR and oxygen. The doctors worked on him for about 40 minutes and did everything they possibly could without any result. Ultimately they took a sample out of the heart, and it was pure froth. We pulled the people in, talked to them, went through the equipment, but found nothing that had contributed. He still had significant air in his tanks. We pulled the valves out of the suit and examined them. There was no problem with the valves.

We attributed the accident to a couple of things. First, he was working hard to tow that array. Second, he had to put air in his suit when he went down. He had a five-gallon Nalgene bottle on the light array, which would give him plenty of lift. When he went down,he must have put more air into his suit, because the array was on the bottom and he was in the overhead. Had he not put air in his suit, he would have compressed at the same rate the bottle did, and he would have been on the bottom. All we could attribute the accident to was addition of air. The minute he let go of that array, he was up, and away. We have to suspect that as he came up, the suit collar lifted, gave him a carotid sinus squeeze, and he embolized, because he was too good of a diver not to have taken a means of exhausting air. This is the only accident of that type that we have had happen.

Jim Mastro.
The other case involved a Coast Guard diver. I think the techniques used for the dive were inappropriate to the environment. The diver was relatively new, just out of diving school. But he was the divemaster because he was of senior rank on the vessel. It was his first dive in a Viking dry suit - he had been using a Unisuit. It was also his first dive under the ice.

Apparently they went in on a T-shaped tether system. The line from the surface came down to a cross, with one diver on each end. As they descended in an inverted orientation, one diver began losing his fins, which were being blown up by his suit. My suspicion, and I cannot corroborate this, is that he was using his Unisuit weight belt, so he was about 20 pounds too heavy and pumped up with air. His buddy helped him replace the fins. In the course of the loss and replacement, the divers became tangled in the tether line. The tether line ultimately knocked off one diver's mask so that he could not see, and shortly after that knocked out his regulator. Ultimately he was rendered helpless, tangled up without regulator or mask.

At this point, there are two stories. The diver claims that he decided to shoot to the surface. He admits he exhaled some air and then held his breath to the surface for 17 feet. His buddy says that the victim went catatonic, as though he decided he was going to die, so the buddy assisted him forcefully to the surface. The buddy corroborated that the victim exhaled some air and held his breath to the surface. When he got to the surface, there were no outward symptoms. He claimed he was all right. There was an initial call to the recompression chamber by a team member who was listening to the radio at the time. We assembled in the chamber, and the doctors told us there was no problem, he was asymptomatic.

An hour later we assembled at the chamber for the yearly cleaning, and at that point the victim was in the hospital. The story that I heard from the doctors was that he was taken aboard the Coast Guard vessel. He exhibited some confusion, inability to make simple decisions like which side of the passage to walk on, and at that point admitted that he had had a serious headache since he surfaced. The doctors and recompression chamber crew decided that this indicated a possible embolism, especially since he admitted holding his breath to the surface, so we pressurized him on a Table VI-A. His symptoms cleared after 28 minutes. I believe it was the very short period of time at 165 feet. When we finished with the VI-A, he came out without symptoms. A couple hours later he developed pain in the right leg - pain in the joint and numbness in the foot. We repressurized him again, almost immediately after a call to NEDU doctors in Panama City for advice. We pressurized him on Table VI, and after a few minutes, he resolved completely, came out without symptoms, and went away fixed.

G. Simmons: Did anyone try just putting him on pure oxygen before putting him in the recompression chamber?

J. Mastro: I do not know why the medical staff did not have him on oxygen.

J. Stewart: Utilization of surface oxygen was one of the significant points that came out of the repetitive dive workshop we just had. On a large diving vessel, some 77,000 dives were made in one year. They used oxygen prophylactically for about 50 cases in which there was some slight indication of a problem. They put the divers on oxygen immediately and took them back to the ship. By the time they got there, they were asymptomatic and were not treated.

III. Tables and Dive Computers.

1. Review of AAUS Dive Computer Guidelines - Michael Lang, Smithsonian Institution

Because of the need to provide training and input for our diving scientists, and to keep pace with technology and safety, we investigated the plethora of new dive computers that suddenly came onto the market. We had to promulgate some guidelines for training and use. We started off with two and a half days of workshop time that resulted in the following specific recommendations.

1. Only those makes and models of dive computers specifically approved by the Diving Control Board may be used.

2. Any diver desiring the approval to use a dive computer as a means of determining decompression status must apply to the Diving Control Board, complete an appropriate practical training session, and pass a written examination.

3. Each diver relying on a dive computer to plan dives and indicate or determine decompression status must have his or her own unit.

4. On any given dive, both divers in the buddy pair must follow the most conservative dive computer.

5. If the dive computer fails at any time during the dive, the dive must be terminated, and appropriate surfacing procedures should be initiated immediately.

6. A diver should not dive for 18 hours before activating a dive computer to control his or her diving.

7. Once the dive computer is in use, it must not be switched off until it indicates that complete outgassing has occurred or until 18 hours have elapsed, whichever comes first.

8. When using a dive computer, non emergency ascents are to be at the rate specified for the make and model of dive computer being used.

9. Ascent rates shall not exceed 40 fsw/min in the last 60 fsw.

10. Whenever practical, divers using a dive computer should make a stop between 10 and 30 feet for 5 minutes, especially for dives below 60 fsw.

11. Only 1 dive on the dive computer in which the NDL of the tables or dive computer has been exceeded may be made in any 18 hour period.

12. Repetitive and multilevel diving procedures should start the dive, or series of dives, at the maximum planned depth, followed by subsequent dives of shallower exposures.

13. Multiple deep dives require special consideration.

2. Repetitive, Multiday, and Computer Diving in Antarctica - Jeff Bozanic and Jim Mastro.

Dive profiles were collected for 42 scientific and technical divers working under actual field conditions through the 1989-90 and 1990-91 austral research seasons at McMurdo Station, Antarctica. A total of 1191 dives were conducted, 410 of which were repetitive dives. Six models of dive computers were utilized during 576 dives, 232 of which were repetitive dives. The greatest uninterrupted run of diving involved 13 days of diving. The greatest sustained density of dives was 2.9 per day, with a maximum time of 3 hours, 44 minutes of bottom time on a single day. No incidents of decompression sickness were reported, which is within predictions for scientific diving operations (Egstrom, 1991). Three computer models were used during a minimum of fifty dives without experiencing mechanical failures. These were the Orca Skinnydipper (392 dives), Orca Edge (88 dives), and Beuchat Aladin Pro (54 dives).

Introduction

Scuba diving is frequently utilized in the McMurdo Sound region of the Ross Sea, Antarctica by scientists conducting biological and oceanographic research. Funding for this research is provided the National Science Foundation Division of Polar Programs. Environmental conditions are extreme, with air temperatures dipping below -100°C with wind chill, and water temperatures approximating -1.8°C. Diving beneath fast ice is common, as are repetitive and multiday dives.

The safety of divers working in these conditions is a primary concern. A major consideration is the prevention of decompression sickness caused by hyperbaric exposure. As such, the reliability of dive timing devices, depth gauges, and dive tables is an important factor.

For almost thirty years, use of the U.S. Navy diving tables has been the accepted standard for diving operations based at McMurdo Station. However, the safety of the USN tables has recently come into question (Graver, 1988; Bozanic, 1990), resulting in the New Zealand Antarctic Research Program approving only the Canadian Defense and Civil Institute of Environmental Medicine (DCIEM) tables for Antarctic diving (Mercer, 1989). The proliferation of dive computers in the market place has further confused the issue, as many of these devices are being used to replace the USN tables.

Some models of dive computers allow researchers to concentrate more diving in a shorter time frame compared to standard USN dive tables, because they integrate actual depth through time and penalize the diver only for the nitrogen uptake actually occurring during the dive. Although these dive computers generally use more conservative nitrogen loading models than the USN tables, as reflected by the M-values utilized in the algorithms, Huggins (1987) states that the computers eliminate safety margins implicit in the tables due to exact integration of multi-level profiles. Further concerns with dive computer use stem from the fact that computers model only two variables, time and depth, leaving others unaddressed. Additional variables considered significant, such as cold and exertion experienced by the diver, are ignored (Loyst, 1991; Huggins, 1987).

Diving in Antarctica involves exposure to risk factors considered by many to contribute to the incidence of decompression sickness. These risk factors include environmental cold, repetitive diving, multi-day diving, and heavy exercise during the dive (Edmonds, *et al.*, 1983). Bennett, *et al.* (1991) noted that a high percentage of persons reporting decompression sickness to the Divers Alert Network exhibited one or more of these risk factors in their immediate dive history. Most common were multi-level dives (45% reporting), multi-day diving (50%), and repetitive diving (65%). Edmonds (1989) stated that dive computers were less safe than U.S. Navy dive tables, and that their use should be restricted to single dives and maximum depths of 120 fsw.

In contrast, Gilliam (1991) reported that divers utilizing dive computers in tropical waters exhibited a reduced incidence of decompression sickness. These divers consistently were conducting multilevel and multiday diving, but were exposed to warm waters with only light to moderate work loads.

Information on the use of dive computers in polar environments is limited. Sharkey (1987) described the use of the Orca Edge during a research cruise during which more than 450 dives were made north of the Arctic Circle. Stewart (1989) recounted anecdotal problems with computers used in the Antarctic.

This study summarizes information compiled during the 1989-90 and 1990-91 austral seasons, during which six models of dive computers were used by scientists diving at McMurdo Station, Antarctica. Quantitative data on repetitive diving, multiday diving, and dive computers is provided. Descriptions and functions of the models of dive computers used may be found in Loyst, *et al.* (1991).

Methods

A full-time Dive Technician was employed by the NSF contractor for the United States Antarctic Research Program for the first time in 1989. Staffing this position provided the manpower necessary to collect data needed to systematically examine the use of new equipment in polar conditions. Though there was a change in personnel for the 1990-91 research season, data collection protocols were continued with no alterations.

Some diving researchers and technical personnel provided dive computers as part of their personal equipment. Models included the Orca Edge, Orca Skinnydipper, Beuchat Aladin Pro, and Oceanic Datamaster Sport. In addition, an Orca Delphi was brought to McMurdo Station for evaluation by the NSF-DPP Dive Officer, and two Dacor Microbrains were available from the contractor's dive locker for use by divers.

It was assumed that divers providing personal computers had the necessary training and expertise to use them properly. Instruction on the use of the contractor's dive computers was available from the Dive Technician. The manuals for these computers were also available for perusal. No modification in diving practices were instituted as a part of this study, thus all data reflects actual field use with no mitigating influences.

Data for the study was collected from dive logs submitted by the divers to the Dive Technician. These required logs contained data on date of the dive, depth, bottom time, type of computer used (if any), and any problems experienced with the computer during the dive. Incidents of decompression sickness or suspected decompression sickness were reported separately. Information was reviewed by the Dive Technician for completeness, clarified if necessary, and collated for later analysis.

For the purposes of this study, a repetitive dive was considered to be any dive which followed within twelve hours of a previous dive. This was true even for dive computers which utilize models containing tissue compartments of greater than 120 minutes half-time.

Results

From 1989 through 1991, 1191 scientific and technical dives were conducted by 42 divers. 576 of these dives (48.4%) were conducted using dive computers. Repetitive dives comprised 410 dives, or 34.4% of the total diving conducted. 232 (56.6%) of these were regulated using dive computers. These results are summarized in Table I. Use of the Oceanic Datamaster Sport is included in the data on dive table use, as this model does not integrate depth through time as do the other dive computer models.

Computer Model	Number Dives	Repetitive Dives
Microbrain	19	3
Edge	88	20
Delphi	23	7
Skinnydipper	392	195
Aladin Pro	54	7
Computer Dives	576	229
Table Dives	615	178
Total Dives	1191	410

Table 1. Dive computer use 1989-91

Computer Model	Number Used	Number Failed	Percent Failed	Type Failure
Microbrain	3	3	100	Quit operating, no discernable cause
Edge	3	0	0	
Delphi	1	1	100	Low battery warning Quit operating, no discernable cause
Skinnydipper	8	0	0	
Aladin Pro	2	0	0	
Datamaster Sport	1	1	100	Quit operating, low temperature related

Table 2. Dive computer reliability 1989-91

Maximum Depth (fsw)	Number of Dives Initial	Number of Dives Repetitive
0-30	61	88
31-60	109	58
61-90	313	153
91-130	298	111
Total	781	410

Table 3. Maximum diving depths for initial and repetitive dives 1989-91

Consecutive Diving Days:	1	2	3	4	5	6	7	8	9	10	11	12	13
Number of Occurrences:	211	68	22	16	14	11	6	5	2	2	1	2	1

Table 4. Multiday diving 1989-91

Information concerning the numbers of dive computers used, along with failure information, is contained in Table II. This table includes the performance data for the Oceanic Datamaster Sport, which was used on a single dive.

Table III details the maximum depths of initial and repetitive dives engaged in during the 1989-91 seasons. Of the repetitive dives, 65 were reverse profiles, *i.e.* the repetitive dive was to a depth deeper than the earlier dive.

Duration of multiday diving is summarized in Table IV. The number of consecutive days over which diving for a given individual was conducted is on the upper line, and the number of series falling into that time frame is on the lower line.

The greatest concentrations of diving occurred during series which included 26 dives over a nine day period (2.9 dives per day), and 31 dives over a twelve day period (2.6 dives per day). The most bottom time on a single day totalled three hours, 44 minutes. This was accrued during six dives, with maximum depths ranging from 43 fsw to 63 fsw.

Discussion

The data show that repetitive diving is routine in Antarctic research. While this is not surprising, the fact that much of the repetitive diving was conducted at relatively deep (>90 fsw) depths is of interest. Deep repetitive diving is considered to entail a greater risk than repetitive dives to shallow depths, and requires special consideration (Lang and Hamilton, 1989). Many of these multiple deep dives would not have been allowed according to the US Navy repetitive diving tables, as the accumulated residual nitrogen times would have precluded the divers from reentering the water.

In addition, 65 of the dives were reverse profiles, which are also considered to carry an increased degree of risk. Because of this risk the American Academy of Underwater Sciences recommends that repetitive dives be conducted at progressively shallower depths (Lang and Hamilton, 1989).

Multiday diving was also routine, with up to 13 consecutive diving days occurring on one occasion. While the exact effects of multiday diving are not currently well understood, many authorities are recommending that a break from diving be taken every three to five days. During this study, 12% of the diving series lasted five or more consecutive days.

Despite the unavoidable risk factors inherent in Antarctic diving, as well as the avoidable additional risk taken by some research divers (as described above), no cases of decompression sickness were reported. One test of pressure was conducted during the 1990-91 season, but when the shoulder pain did not resolve at depth it was attributed to a strained muscle.

These results are within those which would be expected based on data presented by Egstrom (1991), indicating a decompression sickness incidence rate of 1:100,000 for scientific diving. Given this incidence rate, there is a 1.2% chance of one or more cases of decompression sickness in 1191 dives, with a probability of 0.988 that the divers would be incident-free. Even if a rate of 1:2,000 was assigned (the estimated rate for commercial divers stated by Egstrom), the probability of zero incidents is still 0.551.

It is reasonable to assume that the incidence of decompression sickness for scientific polar diving would fall between the two end points presented above. Those incident rates were based on empirical data, and were not calculated on the basis of risk assessments. It is impossible at this time to assign any concrete probability of incidence of decompression sickness for Antarctic research diving, because no cases of decompression sickness have been reported. The incidence rate cannot be interpolated because the relative importance of the various risk factors is not sufficiently understood.

Further clouding the issue is the lack of data on dive profiles. No record of actual profiles was collected during the 1989-91 seasons. Thus, the dives may have been conducted as square-wave profiles, or as true multilevel profiles. A complete analysis of both decompression sickness incidence and of dive computer effectiveness cannot be determined without dive profile information. In particular, it is difficult to evaluate dive computer effectiveness without exposures that approach the limits of the computer's algorithm. Some of these questions would be ameliorated by utilizing computers which incorporate data loggers.

Operational performance of dive computers varied significantly between models. The Orca Skinnydipper had the greatest history of use during the 1989-91 seasons. Eight units were used during 392 dives, with zero failures. Other models with zero failures included the Orca Edge (3 units/88 dives) and the Beuchat Aladin Pro (2/54).

Three Dacor Microbrains were used for 19 dives, with all of the computers ultimately failing. No discernable cause was seen for the failures. The malfunctions included two cases where the units quit operating completely, and one case where the unit continued to read a depth of 14 fsw for a period of months after the dive was completed.

One Orca Delphi was used for 23 dives. On all of the dives, a low battery state was indicated by the unit, even if new batteries were installed immediately before the dive. This was true with both lithium and alkaline cells. The warnings displayed were equally split between "LOW LOW" and "LOW LOW LOW." This unit failed completely on the last dive, with no discernable cause. This malfunction appeared to be unrelated to the battery. Failure of this unit is of special concern, as it also provides scuba cylinder pressure. Thus, once failed, the diver has no indication of remaining cylinder pressure.

Poor battery performance has been noted by Somers (1986) and Sharkey (1989) while using the Orca Edge in polar conditions. However, this problem was not related by any of the research divers during this study. It was noted that battery changes were made more frequently, with battery performance being 50-66% of that expected for temperate waters.

Faint and/or sluggish LCDs were reported in some Skinnydipper and Edge units, but in all cases the screens remained readable throughout the dives. The Beuchat Aladin Pro functioned without either battery or LCD problems.

One Oceanic Datamaster Sport unit was used during the course of activities. It consistently ceased operating as it became chilled, and resumed operation when rewarmed. The instruction manual for the unit cautions that the unit should not be used in temperatures below $0^{o}C$. Our experience indicates this is true.

During the 1989-90 season approximately 24 new mechanical depth gauges and submersible pressure gauges were placed in service. An initial failure rate of 25% was noted in these units during the first six dives in which they were used. The failure noted was leakage of water into the housings, presumably bypassing the face plate o-ring. Once these units were removed from service, no further failures were noted in the remaining units. Four new gauges were placed into service during the 1990-91 season. No mechanical gauge malfunctions were reported for this season.

Conclusions

While repetitive diving is common in the Antarctic environment, it is not possible to assign risk with any degree of confidence. Continued collection of diving history will be necessary to define a decompression sickness incidence probability. At this time, it does not appear that Antarctic divers exhibit a greater incidence of decompression sickness than scientific divers working in other environments. While Antarctic researchers are routinely exposed to a variety of risk factors thought to increase the probability of decompression sickness, in thirty years of Antarctic diving no incidents of decompression sickness have been reported.

This data suggests that some models of dive computers may be used successfully from an operational standpoint in polar diving conditions. However, the validity of the algorithms upon which the computers are based can not yet be reliably determined. Further data collection is necessary. Particularly, data should include an increased number of dives on all models, use of additional units of each manufacturer's model, and the use of data loggers to record dive profiles for which the computers were used.

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Discussion

B. Hamner: Putting a statistic of 100 percent in your table is not helpful, because you had only one Datamaster.

J. Bozanic: One Datamaster, three Delphis, two Microbrains, and between six and twelve EDGEs.

M. Lang: What do you recommend for batteries?

J. Bozanic: We used both lithium and alkaline cells, and neither worked in the Delphi. We did not have low-battery problems with the EDGE, or at least none that were reported. In Antarctica there will be a real problem, so there will have to be a prepared policy. A new battery will only be exchanged for an old one; they will be treated as a controlled substance.

L. Quetin: Do you have any data on how long the batteries lasted in the EDGE?

J. Bozanic: No, I do not.

J. Heine: We noticed no big differences between battery life in SkinnyDippers in California and in McMurdo. When I talked to the people at ORCA Industries, they figured the batteries might last about 25 percent of their lifetime in that cold, and they were more concerned about them in the air than in the water, because the air gets quite a bit colder. We were very careful to keep them warm except when they were out in the water. They lasted about the same time there - about three weeks.

B. Stinton: Has anyone encountered frozen LCD displays?

J. Bozanic: None that were reported to me.

J. Heine: The LCDs were quite a bit slower. In fact, at some points, if they got really cold they started to disappear, so it was a little tricky to read them sometimes.

L. Austin: What parts of the gauges failed?

J. Bozanic: The failures were primarily leakages, apparently through the face plate o-rings.

G. Staffo: Would you suggest they should be environmentally tested, prior to initial failure of the units?

J. Bozanic: Yes, if there were a practical way of using some sort of pressure pot or something that could be chilled.

S. Jewett: We have been told by a few people in Alaska that the lithium battery will not be made anymore.

J. Bozanic: I have heard rumors that someone else will manufacture them or that Kodak found a new source of supply.

3. Review of AAUS Biomechanics of Safe Ascents Recommendations - Michael Lang, Moderator.

We held the Biomechanics of Safe Ascents Workshop at Woods Hole Oceanographic Institution in September of 1989. I organized that workshop to follow up on some of the questions that were left unanswered by the AAUS Dive Computer Workshop, part two in a series. We were very fortunate in that we have been able to address a lot of these questions from an academic standpoint and have gotten a lot of input and support from the manufacturing communities, the training agencies, and various sectors of the diving community. Therefore we feel confident about the following recommendations:

It has long been the position of the American Academy of Underwater Sciences that the ultimate responsibility for safety rests with the individual diver. The time has come to encourage divers to slow their ascents.

1. Buoyancy compensation is a significant problem in the control of ascents.
2. Training in, and understanding of, proper ascent techniques is fundamental to safe diving practice.
3. Before certification, the diver is to demonstrate proper buoyancy, weighting, and a controlled ascent, including a "hovering" stop.
4. A diver shall periodically review proper ascent techniques to maintain proficiency.
5. Ascent rates shall not exceed 60 fsw per minute.
6. A stop in the 10-30 fsw zone for 3-5 min is recommended on every dive.
7. When using a dive computer or tables, non-emergency ascents are to be at the rate specified for the system being used.
8. Each diver shall have instrumentation to monitor ascent rates.
9. Divers using dry suits shall have training in their use.
10. Dry suits shall have a hands-free exhaust valve.
11. BC's shall have a reliable rapid exhaust valve which can be operated in a horizontal swimming position.
12. A buoyancy compensator is required with dry suit use for ascent control and emergency flotation.
13. Breathing 100% oxygen above water is preferred to in-water air procedures for omitted decompression.

Discussion

M. Lang: Does anyone feel the need to discuss the necessity of wearing a BC with a dry suit?

L. Quetin: I wonder about ascent control. I encourage divers who are coming up to use the suit, because going back and forth between BC and dry suit just leads to trouble.

M. Lang: In the dry suit, putting air in eliminates the squeeze; it does not really control buoyancy.

S. Bosch: Can you see any use for using the BC with a ceiling, if you use a dry suit for control?

M. Lang: I would say that in case of a catastrophic failure there would still be some way of maintaining positive buoyancy with a BC.

L. Austin: You need surface flotation in the hole, do you not?

S. Bosch: We usually hang a down line.

D. Nagle: Catastrophic failure is the point, particularly in regard to the type of tank being used. The additional weight that divers have to carry initially to be able to perform a stop at the end of the dive leaves them unable to maintain even neutral buoyancy without the BC if there is a failure at the neck seal. In other words, they go out heavy because of how light their tanks are going to be at the end of the dive so that they can make a stop.

S. Bosch: We have standard precautions to hang a down line from the hole with a heavy weight on it so divers can hang onto it while making a stop. In a catastrophic failure situation, I do not see making that stop with that cold-water rush.

D. Nagle: That would be your choice.

J. Bozanic: One thing that should be noted is that adding a BC as a mandatory piece of equipment increases the chances for failure in another piece of equipment. From my notes, there were three failures of inflation valves on BC's in the 1989-90 season and two additional ones on the dry suit inflation valves themselves. The need for a BC in under-ice situations should be balanced against the increased possibility of blowup failure in the BC itself.

D. Long: Can I ask the nature of the failures?

J. Bozanic: Freeze open.

D. Long: Were the divers using short bursts to put in air or holding down the button?

S. Bosch: Short bursts would do it. I have had a failure going into the water from a hut. At about 20 feet of water, the valve stuck open. It was a Viking valve that stuck using short bursts and I resolved the problem. I floated up under the ice quickly, but the valve still pumped air in if I kept hitting it. There was probably an ice crystal in there.

D. Long: Did the valve activate as soon as you hit the button the first time?

S. Bosch: I do not recall.

D. Long: The purpose of the rapid exhaust valve in the BC is to get the air out as fast as you pump it in. That is no factor with freezing; just get rid of all the air if the inflator freezes open. In the case of dry suit valves, freeze-ups often occur when people do not check the valve before going into the water or if there is water in it. The first time they hit the inflator it freezes. Hitting it again once or twice will usually break the small crystal. That is why people ought to hit that inflator a couple of times before they start down. If a freeze-up is going to happen, our limited experience tells us that is when it will happen.

M. Lang: This goes back to training; whenever you hear air involuntarily flowing, you should disconnect the inflator. ScubaPro's Air II units had a defective batch of poppets on the back of the inflator button last year. The rubber o-ring came unbonded and would unseat itself from the metal. The first time a diver hit the inflator, the free-flow would not stop, and entry-level divers were on their way to the surface without knowing what happened. The problem will be either with the inflator of the BC or the inflator of the dry suit. This information should be incorporated into the initial training.

J. Bozanic: A lot of inflator valves on the BC's are not easily operated with mitts on.

J. Mastro: Actually, pulling off the inflator device is really easy.

J. Bozanic: Some inflators have wings on them.

L. Austin: Putting them on is hard.

D. Long: I would like to hear further discussion on the problems that Jeff brought up regarding the BC when a diver goes in under ice. I do not see this as such a problem. Of course, once a diver is underneath an overhead such as ice, or in a cave, and has runaway air in the BC, there is a problem, and I understand that. But I still think a diver is better off with a BC than without one. I would like to hear people present the case for not having a BC and what the considerations are in making that evaluation.

J. Bozanic: At this point we do not have enough information to say a diver should or should not have a BC, because we do not have failure incidences recorded. I did not want this to go through without people thinking about the down side of requiring BC's. I am not recommending that we need to use BC's with dry suits.

J. Mastro: With a solid ice cover, flotation is not really necessary in the hole, because there is a rope or a ladder. I am not saying it is rational, but there was a lot of resistance to using BC's with ice. A BC was felt unnecessary because there was never a problem of going to the surface and floating or maintaining positive buoyancy. If divers had to tow themselves up the down line, that is what they did.

M. Lang: The wreck diving community and the cave diving community also have an ascent to the surface on a line at some point. Now you say they would not need a BC? What about catastrophic failure of the suit?

B. Stinton: Whenever you are hanging onto a line, you become a one-handed diver. If you can float in a hole and have two hands free, you can do something. The minute you have to hold onto something permanently it compromises what you are doing if you are not paying attention.

J. Bozanic: Regarding practices in the cave and wreck diving communities, a lot of those people now wear two BC's in case they have a catastrophic failure with their dry suit and their BC. The reason is significant. These people are swimming considerable distances over very silty areas. If they disturb the bottom they have to be able to maintain an effective rate of exit from the environment that they are working in. This does not pertain to McMurdo because everyone is working within a short distance of their access holes.

P. Dayton: I will speak for the anti-BC position. A diver who has a catastrophic failure, has a buddy there. The diver does not need to float in the hole. When you get up into the hole, you are giving things to the tender and the catastrophic failures do not happen very often. I can see a situation in which a neck seal or zipper goes out, and a diver is in a hurry to come out. There are more hoses to get in the way, and it just seems like an unnecessary hassle for someone who does not want to go up anyway. Unless you can see your down line, you cannot find the hole. You need to be at least 40 or 50 feet down to see the hole. Being up is not what you want.

G. Simmons: I was going to agree with Paul. We have tried it both ways, using the standard harness for the tanks that came out of the McMurdo dive locker. Somebody brought a BC down and it wound up on the ice. Because of the hose and the connections and worrying about the CO_2 inflator and accidentally pulling the lanyard, we finally went back to the standard harness. That decision should be made by the diving supervisor on the scene. If there is a diver who feels more comfortable wearing a BC or a diving supervisor who, under the conditions, thinks it is safer to use a BC, then that is what should be done. In our situation, where we are using tethered divers it is safer to keep it as simple as possible and keep people on the bottom until they are ready to come up.

J. Mastro: The inflator freeze-up is not likely to happen if you use the BC only as a surface flotation and emergency backup, because then you are not inflating it. Also, I think there are two situations in the Antarctic when you ought to have a BC. One is in blue water, because if you blow your suit, it is all over, unless you are tethered

J. Heine: You had better be.

J. Mastro: The second is in open water when the ice breaks up. Then you may need surface flotation.

P. Dayton: One suit failure was mine. My inflator stuck. Getting up was not the problem; I got up in a hurry. I got up just fine without any neck seal.

J. Heine: I was amazed to see the harnesses that some people wore to get the weights off their hips. There is no way that I could see to ditch those at all. In the case of a catastrophic suit failure and not being able to ditch your weights, I think you would be in a world of hurt as far as trying to get to the surface. We do not go anywhere near those harnesses.

L. Somers: We just had a case up in Michigan that settled out of court where the fellow had a scuba tank attached to his suit by the hose. The tank was hanging below him, he was floating, feet up, and the shoulder harness weight belt was hanging from the tank. That proved to be quite a disastrous situation. Henderson was sued because they said he could not release his air hose from his suit. They figured that was the least of his problems.

M. Lang: If you cannot disconnect your inflator hose, should you be diving with that kind of system?

P. Dayton: Sometimes a tender cannot take that thing off you. We have a terrible time.

S. Bosch: The problem is even worse when there is a ring to pull. It is very close to the valve, so you cannot get your glove in there. We do need to come up with a system for pulling that off.

D. Nagle: I have noticed that, particularly if the unit is going in and out of the water, ice crystals will form up under the ring. That is why neither the tender nor anyone else can get up underneath it. It is frozen in place.

D. Long: Sitech makes the valves for Viking. One has a ring around it, a larger knob so one can get two fingers in and pull. The other is a T-bar. One of the problems with a T-bar is that it can quick disconnect by accident. Sitech also built a support inflator which is shoved in; by simply grabbing the hose and pulling on it hard enough, you can dislodge it from its connector. As a manufacturer, I can tell you that the issue of that disconnect is not a small one in our failure mode analysis. When we look at what can happen if the air inflation coming into the suit is lost, then we find a whole set of problems. What happens when a diver cannot disconnect if there is a free-flow? We do not have what we consider to be a good answer to all the scenarios we can run through. We simply have picked what we thought was the least difficult of all of them. There is nothing absolute; there should never be an absolute rule made.

Therefore, to say one must dive with a BC with a dry suit in any and all circumstances is ridiculous. But I still think the need here is for buoyancy control, not emergency ascent, and you do need to have buoyancy control at all times. As a manufacturer of dry suits, I say that a dry suit is not enough for buoyancy control. If you choose, though, to not wear a BC under the ice, that is up to you. We have a number of dead divers right now were not wearing buoyancy compensators. There is a case being made by their lawyers right now, saying they would be alive, had they had buoyancy compensators on. All of you here are subject to that group of people. The diving industry is a target for the Trial Lawyers Association. We do have examples in which not having a BC has created a problem, and I would not want to underestimate the jeopardy that all diving is under, including scientific diving, from the legal community. If I were a diving officer who had told my diver not to wear a BC when the argument could be made that had he worn a BC, he would have had buoyancy control and therefore made it back, I would be in a very uncomfortable position, because the data suggest BC use with a dry suit.

G. Staffo: You really have to have a good understanding and plan for your dive and realize which are the greater hazards for your diving situation. I agree with what George says. It has to be looked at case by case basis as to where the greater hazard lies.

D. Long: Sure. With communications and a tethered diver, just reel the guy in. But if he is out there by himself, you make the judgment call because you will be judged by it.

G. Staffo: You must identify which hazardous conditions justify the buoyancy compensator and which ones present a greater problem for having one. Therein lies the challenge.

D. Long: Just understand that the manufacturers collectively have said, "Thou shalt." If you err, that is what they are going to throw up against you.

B. Langley: We talked about using rebreathers for diving under ice. It is not possible to hook up some of these buoyancy compensators to your system, so you will either have to carry another system down with you (which is more gear) or you will have to consider using the life vest inflator-type of system. We did a study at NEDU (Navy Experimental Diving Unit) on one particular type of life vest emergency ascent with a dry suit. One thing we found is that a diver should not drop the weight belt. Every time divers dropped their weight belts, they floated up and ended up floating face down. Make sure you test these systems and know what is going to happen after dropping the weight belt.

M. Lang: Is the weight belt permanently attached, or do you still give divers the option, but tell them not to drop it?

B. Langley: It is not part of the emergency ascent procedure, because an unconscious diver goes face down.

J. Pearse: If the harness belts are really that dangerous, we should make a decision. I understand that the harness used in McMurdo was initiated by Ted DeLaca, who is certainly an experienced diver. One of our first really dangerous accidents happened when Sid lost his belt accidentally and was instantly up under the ice. We were asked by DeLaca and Stockton: "Why would you ever want the take your belt off, because all you are going to do is come up underneath the ice?", and we agreed. Since then, we have been much more comfortable.

M. Lang: What about a situation in which you have to assist your buddy and have to dump much of his weight to get him up?
B. Hamner: All of these harnesses could also be hooked up with quick release.
S. Bosch: Shoulder releases.
J. Heine: A portion release, anyway.
L. Somers: You are doing both open-water and under-ice diving down there.
D. Long: We are working on a system in which you only drop part of your weight. We are talking about points of control. If you dump a big belt, I think you are just asking for it. Even in open water, there is no way to control 40 pounds of positive buoyancy underwater. A human being is not able to do that. Even swimming upside down at full speed, you cannot do that. I think this is an issue for which we in the diving industry have not found a total solution.
D. Divins: The possibility of dropping some weight while still maintaining some gives a bit better weight distribution, according to an article in *NAUI Sources*. Has anyone experienced two belts?
D. Long: Put weights in your BC pockets maybe?.
M. Lang: The Zeagle type of design.
D. Long: The SeaQuest is a better system, where you put up to 20 pounds in the backpack itself, which is not droppable. You can then put on up to 20 pounds that are droppable.
D. Divins: You can drop a portion out of the Zeagle, which has a rip cord, parachute-type of operation. You can split the weights that way and not drop everything.
M. Lang: Part of the issue is having the ability to achieve positive buoyancy. But there is an enormous difference in attaining 5 to 10 pounds of positive buoyancy versus 40 to 45.
D. Long: We also want to have buoyancy control.

M. Lang: Dick Long and Lee Somers wanted to address the group with some other pertinent ideas.
D. Long: I saw the new Spirotechnique arctic regulator and thought that the mechanism in the second stage was worth investigating. I have not seen test results. In all of the regulators that I have seen, the lever on the mechanism that activates the valve sits on the same side of the regulator as the valve does - the right-hand side. In the Spirotechnique, the levers are on the left-hand side and a plastic connector crosses in the second-stage valve, so therefore the valve itself is made of plastic. All the ports around it are plastic, and the mechanism itself is out of the range where it would be affected by the refrigerating effect of the expanding gas. U.S. Divers Company is now importing the regulators.
B. Townsend: We have been trying some of them at Resolute Bay. Also, DCIEM (Defence and Civil Institute for Environmental Medicine) has contracted with a Toronto consulting company to make a cold-water regulator.
L. Austin: We have been using those regulators and went through the U.S. Divers overhaul program on them. They are complicated to overhaul. The nylon piece, the valve seat carrier has to be thrown away when it is overhauled. So far, we have not found them to be an easy-breathing regulator.

L. Somers: I am interested in your thoughts, as polar divers, about air supply redundancy. I have heard you mention the slingshot, and I also wonder if you use a dual scuba system like the pony bottle. Many of our cold-water divers in the Great Lakes have gone to the pony bottle system rather than the slingshot valve.
J. Heine: We often would hang a pony bottle with regulator at the bottom of our line. If we buddied together, we did not carry it with us.
L. Somers: Do you still rely on conventional buddy breathing techniques or do you go totally self-sufficient?
J. Heine: We buddy breathe or octopus breathe.
L. Somers: I assume there are very few full face masks?
J. Heine: That is right.
L. Somers: I think that will filter into our areas and completely negate all the original concepts of buddy breathing.
D. Nagle: But that can be dealt with just by putting on a little hose with the quick snap-in's.
L. Somers: With cold hands and big gloves?

D. Nagle: It plugs straight into the hole.

L. Somers: Being totally self-sufficient to turn the valve on the manifold to switch to the other supply?

L. Austin: Dick Moe said that octopus breathing in low-air situations in the Antarctic really does not work. The air flow rates are so poor, and the need is so great that the divers end up coming up. He came up without air so his buddy could breathe with 300 psi left in the cylinder.

L. Somers: Lloyd, would that be the same if they were using the slingshot, drawing off of both regulators?

L. Austin: I do not think so.

J. Stewart: Using a regulator with an AIR II in this case, or with an octopus, works fine at 1,000 pounds or 2,000 pounds. But at about 400 or 500 pounds, if both divers inhale on each regulator from the same first stage, neither one gets a discrete breath. We felt that if you use buddy breathing in that situation, each person at least gets a discrete breath. If both people get a little apprehensive and are coming up and get nothing, the ascent gets riskier.

J. Mastro: This is one reason why at McMurdo we require two regulators. In one instance my buddy had two regulators free-flow completely, and we ascended on my tank.

L. Somers: Are your able to get around and turn off the free-flowing regulator?

J. Mastro: The buddy has to do it.

D. Long: For diving under an overhead, cave divers have an excellent rule: one-third of the air going in and one-third of the air coming back. This leaves one-third of the air in reserve. At times they go into fifths when they have a lot more air for supply. Air is the cheapest thing we have around here; to run out of it would be ridiculous. We should have plenty of air when we crawl out of the hole. It is just too easy and cheap to take with us. We have not yet solved the water-breathing problem. A diver who is down to 300 pounds is already a casualty.

G. Staffo: We are working towards a pre-cruise dive plan. I thought it was interesting to hear some of the comments today about the conditions in the areas, visibility during various times of the year, currents, even the frequency of predators. That information has not really been collected anywhere. From my point of view - having to look at diving safety and try to make an initial assessment of the risk in the dives - some collection format would really be useful. It would also be useful for the people who might be planning dives for the first time.

S. Bosch: Absolutely. We have recognized that need for many years. A lot of information has been gathered by many people. But it never gets written down, and every new group has to learn the same thing over again. It would save a lot of time.

L. Quetin: But I think there is no substitute for learning from somebody who has been there before you. When I first started diving, I learned from Hamner's group. The apprentice system is fundamental, and if at all possible, the best method.

M. Lang: How many absolute new groups are going down who have not been connected with folks who have been down there in the past?

D. Bresnahan: Maybe one every three or four years, but they are an exception. You can say the same thing for all the science groups. It is fairly rare that a principal investigator comes into the program without having been affiliated with somebody else in the past.

S. Bosch: I would agree with that, but we have been the exception twice. In 1984, except for John having been there in the 1960s, we had not dived McMurdo. Now I am going to Palmer Station, and I have never dived there.

IV. Training and Certification Requirements - Michael Lang, Moderator.

The approach is to review the adequacy of current polar diving training requirements and to identify where divers can go or what additional training might be provided to them before leaving for the Antarctic. Obviously, dry suit training/experience is a mandatory requirement. There is no place one can go for a formalized dry suit training course. Guidelines promulgated by the manufacturers are available and D.U.I. in particular has been supportive in providing audiovisual and training materials to scientific diving programs in need of established dry suit training courses.

The AAUS manual specifies medical examinations at two year intervals (> 40 years of age) and three year intervals (< 40), based on the opinion of hyperbaric experts that it was not necessary to undergo an annual physical examination. This helped many programs financially and alleviated some of the burden of diver certification.

The second item is a swimming evaluation. A prospective diver has to be able to swim before learning to scuba dive. Some of the recreational scuba training agencies do not believe it is necessary, but we do. The actual scuba training incorporates some of the very basic scuba skills.

The theoretical knowledge evaluation is in the form of a written examination. The AAUS also feels that initial CPR certification is a mandatory requirement and must be kept current. There are two national organizations that certify individuals in cardiopulmonary resuscitation, the American Heart Association, and the American Red Cross. In some states the certifications are valid for up to two years. Most scientific divers obtain a recertification on a yearly basis.

Standard first aid certification is recommended, but not required.

Undoubtedly, the critical item of the entire certification matter is the open water evaluation. A diver demonstrates his underwater abilities by diving with someone who is qualified to evaluate his diving skills (*i.e,* diving officer or diving instructor).

Having successfully accomplished the aforementioned items, a diver is then certified by the institution's diving control board to a certain depth, based on his or her experience and skill. An entry-level diver in a scientific diving program is usually issued a 30-foot card. After completion of 12 dives within the 30-60 ft. range and a check-out dive at 60 ft., a 60-foot card is issued. There is a progressive accumulation of experience under a "supervised condition", diving with someone who is certified to a deeper depth.

When scientists are sent to polar regions, the personalized indoctrination they receive with an experienced group is very beneficial in order to learn the methods and techniques within the group they will be working with. On the other hand, the diver has to meet some minimal skill and knowledge level to be able to take advantage of the scientific methodology and expertise that the principal investigators are providing.

L. Austin: We feel that people should be thoroughly trained and experienced in dry suit use (*i.e.,* diving with a dry suit for at least one year). To send someone down who is putting on a dry suit for the first time in a training session just before they go is ridiculous; it takes so long to convert from the attitude of using a wet suit to a dry suit.

G. Simmons: Over the years that I was working in Antarctica, I always felt very comfortable having our students go through Jimmy here at Scripps. We finally evolved to the point that Jimmy trusted my judgment. I think somewhere along the line, even though the local instructors or diving certification boards will approve people, I as an investigator, would feel more comfortable if there were one or two places in the country, maybe a place on the West Coast or a place on the East Coast, where we could send our people for final approval. That way, someone like Jim at Scripps or Michael at the Smithsonian, has a much better overview of the quality of diver performance, in general, on a broad scale, than an individual investigator would see at a local level. There may be new items that should be emphasized that an individual investigator had not thought about. There ought to be some sort of last level of approval from the National Science Foundation, much as we have had in the past.

J. Stewart: The American Academy of Underwater Sciences has this system in place, where all of the major campuses working in the Antarctic have scientific diving programs. We have a Diving Officer on each campus. That Diving Officer's responsibility is to get that person trained and certified to their own and the campus' satisfaction, in the use of the equipment they are going to use in the Antarctic. The OSHA exemption and the AAUS manual says the diver must be trained and competent in the mode of diving that they pursue wherever they are going to dive. It does not say certified. You do not certify the diver in a wet suit, you train him in a wet suit until he is competent. Dave Bresnahan sends a form to the PI's that has to be signed originally by the campus Diving Officer and then by me for final concurrence. I know that the Diving Officer is going to give me a quality product. If there is something on that application that I do not like or understand, I pick up the phone and talk to him. We have never had any problem with that.

M. Lang: I agree with George that there has to be some place where you can send people who do not have that experience. Not all diving officers are qualified or have the experience to teach dry suit diving. We should follow up on George's recommendation and evaluate some appropriate places to be able to acquire dry suit training.

L. Somers: I have always been concerned about putting divers into a rigorous environment without having some previous exposure in a similar environment. My concern is finding some place here in the States through workshops where the person could operate in the cold environmental conditions. It is a lot different diving in dry suits from Scripps pier or from a boat in southern California versus actually having to dress in and execute a complete dive under conditions where your ambient temperature is 30 below with wind chill factor.

J. Bozanic: That idea parallels the New Zealand Antarctic program for diving where they perform all their training in the mountain region. Regarding Lloyd's comment about one year's worth of experience, a certain minimum number of dives experience would make this requirement a performance criterion. That is important because a few people down there have relatively few dives or limited exposure with dry suit training. Likewise, Jim's comments about the mode of diving are important. If people expect to use the same equipment they are normally used to, great. But, if they have never used a double hose regulator or tethered diving system, it is important that they get adequate experience in those modes of diving as well, along with any particular tasks they are going to be doing underwater. It requires a certain amount of skill in getting their equipment up and down through a hole, and water column. If they have not done those kinds of tests before in relatively benign conditions, that places an added stress and potential problems in the environment.

J. Stewart: I agree with the comments on the performance criteria. You are setting the stage for certification. Anybody who goes through dry suit training gets that certified on their card as a specialty. If you have clear and concise objectives that you can be evaluated against, that is basically a certification.

J. Bozanic: Working in the environment before deployment would also be very beneficial in terms of the equipment care issues we reviewed yesterday with the regulators. Divers then have the opportunity to use their equipment in an environment where they can experience those types of failures.

L. Austin: In response to your comment, it would be unwise to certify somebody as an "ice diver", without ever having been there, who had just gone through the dry suit training and so forth. Maybe it should indicate that they have had the training with the equipment, but they really should not be certified as an "Antarctic diver".

J. Stewart: They provide evidence that they have the skills to be able to properly use a dry suit. That is what we have evaluated thus far.

G. Staffo: The skills that you test for in this environment are applications for cold water, such as the difficulties and problems with manual dexterity and being able to disconnect the inflation hoses.

Those are key distinctions that have to be made that are specific to the environment that you are planning to put these people in.

L. Quetin: I notice the importance of buoyancy control, and dry suits are all that different. It is a matter of going slow and learning how to control buoyancy. You do not need to dive in a dry suit for a year. When you get to the field with your divers, there is some training that you have to do there. We need the flexibility. If you set up something where people have to go to a course at a specific location, it really cripples the program.

D. Bresnahan: That was not the intent. The diving officer from the institution has to sign off that the individual is competent to use the equipment they are going to use in the field (*i.e.*, a dry suit). For the institution that does not have the capability to do that, we are just looking for a resource, someplace else to send the individual. I am concerned about the impact on the research community if we have a requirement of a year or a certain number of dives.

L. Quetin: There is a lot of variability in individuals; if you start requiring a certain number of dives, some people may need more and others will not.

D. Bresnahan: It is the Diving Officer's responsibility, and we should try to dictate the details to each institution. The Diving Officer whose name appears on the bottom of that sheet of paper has to realize that if something happens, we are all going down together. We are too connected.

J. Pearse: The training is still going to occur on the ice and it is going to be a collaboration between the certifying diving officer and the P.I. who has had experience down there. I would be worried about a whole new group going down there with no one having experience, but the P.I. has to have someone there who has enough experience to take the person down on the first couple dives.

J. Stewart: I look at an individual's comfort level in a pool with a dry suit, and on a number of dives off the pier. I want a person who is competent in that equipment. When it comes to the environment, that is why we now fortunately have an on-site person at McMurdo. The rationale behind that was once the diver got down there, he would be given a series of dives in the immediate area of downtown where he could make his mistakes, if any, in very shallow water. Then he would go out with the principal investigator, make a couple of 'follow-me' dives so he learned the environment. After he is comfortable in that environment, then you let him go to work.

D. Long: A diver needs to be mentally and physically fit to dive and has to have proper skill training. Then and only then, does he need the proper equipment. We have had cases where people on their way to Antarctica stop by DUI to pick up their dry suit. It was the first dry suit they had ever seen. Equipment is third in line, not first in line. Having the equipment does not mean that a diver has the capability. The diver needs to insure that this equipment is in proper working condition. He also needs to be experienced in that particular equipment in an area similar to where he will be operating. That experience needs to be current, not five years ago or even a year ago. The length of time of dry suit ownership is not important; the number of dives is. In dry suit diving, we have seen that divers can have a lot of one form of experience, that may or may not be applicable to the situations under which they will be diving in Antarctica. A dry suit diver needs to have experience in changes in insulation and changes in lead requirements as a result of that. Therefore he must be able to demonstrate buoyancy control under a wide variety of circumstances. The skills involved in the kind of diving they will be doing need to develop here. For instance, to come up under the ice at 500 psi is unwise. If divers are going to dive under the one third rule in Antarctica, then they should start diving here under the one third rule even though they do not have the overhead environment.

We need some policies and practices that go beyond what we currently have. We have some of them, such as wearing a buoyancy compensator, but we do not have all of them yet. A person needs to be able to demonstrate zero G diving or neutral buoyancy and trim. The best way we have found to develop these has been to take away their wet suit. You can always step down in technology, and the military is always a prime example of this. All their training is done in wet suits here in San Diego. When the time comes to carry out the mission, they put their dry suits on and find they have not been properly maintained and leak. In addition, the divers have buoyancy control problems. If they were to do all of their training here in San Diego in dry suits, then any time they need to downscale in technology, such as go to a wet suit, that is easy to do. If their everyday mode of practice is to use the most sophisticated equipment they have, their instincts are in the right order and they know and understand it. The organizations that do this as a matter of routine we have found to be the most successful, with the least amount of down time and aborted dives. So take away their wet suits, put them in the dry suits as a matter of routine, even though they may not require that level of thermal exposure and protection. The lack of buoyancy control skill is the problem, not the temperature or the water.

M. Lang: Some divers entering programs have only been through that weekend dive store course. They cannot even spell buoyancy much less having done any exercises to try to master those skills. Compare that course with our 100-hours course where we drill them on buoyancy control every time they get into the pool. If buoyancy skills have been learned, then you are absolutely right. It is very simple to get into the dry suit from a wet suit.

L. Somers: Over the past few years I have seen some changes in direction of many of the divers coming into the program. Many of the scientists that I have to deal with say, "I do not have time to waste by going diving. I want my certification to go out and dive in my dry suit. I want to go do my job but do not bother me with training." I know the dive program system works, but the different level of person coming into programs now has a whole fast-food philosophy of acquiring their experience. I want to make sure we do not lose direction.

S. Bosch: I agree with you. We have to recognize the restrictions that we face in terms of getting a program established, in this case, in Antarctica. In our case, we are looking for someone who is willing to stay down there for five months. It is hard to come up with an individual who will do that. Not all universities have a diving program they can put their students through. For example, we are dealing with U.C. San Francisco which doesn't have a dive program.

J. Stewart: What we have done in the past is pick an institutional program close to you, and put you through their training. That institution's diving officer then signs off as having evaluated you and that he is comfortable with your performance. We all have similar certification requirements, and I know that if the diver is going to be certified, it is basically done the same way I do it.

S. Bosch: This diver is then sort of the responsibility of that diving officer at that neighboring university.

M. Lang: It is not always that simple because not all diving control boards or institutions will take responsibility for someone not associated with them. The problem people come from institutions without scientific diving programs. Someone is going to have to certify them somewhere. Some institutions will do that, but others absolutely refuse to certify or evaluate someone else who is not an employee of that institution.

J. Stewart: I was talking about evaluation, not certification.

M. Lang: But you still put your name down on the bottom of the sheet, stating: "Yes, he has met all the performance criteria." You can play with the semantics of it, but you are essentially saying, "I will let this person dive." If this person does dive and things do not quite turn out the way they were supposed to, you are still stuck.

L. Austin: UC Berkeley will contact your risk management people and your chancellor and tell them what we are doing. They have to decide then whether they are willing to accept it on their liability.

D. Bresnahan: Ultimately, if your institution will not affiliate locally, NSF has a standard arrangement with Scripps. You can arm wrestle to get some more money and basically pay to come down to Scripps and go through the training program right here. That is what we did with George Simmons' people when we started out without an equivalent system. They all came to southern California.

L. Quetin: This money comes out of science?

D. Bresnahan: It all comes from the National Science Foundation. It just buys you a few less pieces of science equipment.

D. Long: There is a population of divers in the diving community where the standards are far less than yours are now. Some of those divers will feed into your systems. The search and rescue community divers get very little time in practice. They do dives under very adverse conditions. We are now seeing and will continue to see their high accident rate. Because of the length of term of the diving officers, the science community has maintained a very high safety record. I suggest that because diving is getting a much broader level of exposure, and more people want to be divers, you simply need to be on guard that these individuals are going to start filtering into your system. Certainly, if you were to advertise in Underwater U.S.A. that you are looking for people with some kind of a degree who are willing to go to Antarctica for five months, you would be deluged with applicants. That is going to make your problem worse, not better, because you have no mechanism of screening these applicants. I am making a case that AAUS has to continue in the manner that it has as far as setting the example to which the rest of the diving industry can look to see how it could and should be done. Understand that there is a population of divers out there who do look to you for that, and understand that they will take what you say and publish here today and apply it. Therefore, to whatever extent you are comfortable with sharing your knowledge and expertise, I encourage you to do so.

D. Bresnahan: To give you an idea of what NSF demands from our people, everyone who comes to McMurdo to be involved in field activities has to go through a hands-on training program. If that individual is a repeat customer, they get to go through it again. If they do not want to go through the program, they can get on the airplane and go home. NSF has the same attitude about the diving requirements. We have had individuals in the past who have tried to slide through the program and they have not gotten through. We had people at McMurdo who were there and wanted to dive. They put a lot of pressure on because they were already in the field. But we did not let them. NSF recognizes that it has to have a very tight program, because if we have failures, it is going to impact everybody.

J. Stewart: I concur with Dave and that is the attitude we have taken over the years. You say no. It is really very simple. We cannot afford the type of people that Dick was alluding to in any of our programs, let alone polar programs.

J. Bozanic: At a minimum, training on the ice should review emergency procedures in the area, use of the oxygen kits, use of the diver lift devices for getting people out of the holes when diving from within fish huts, on-site dive management, use of the radio systems, evacuation, and on site treatment of air embolisms in particular.

L. Quetin: I agree with that. At Palmer we can certainly improve on emergency measures. Oxygen administration is one of them. We also need to talk about who is responsible. I am still in favor of divers bringing their own equipment in. For our program, the pool training with the equipment that we will use is important. I do not really like the idea of having to pull regulators off the shelf at Palmer and use them. I want the divers very familiar with their equipment before we go down. You might want to have training sessions with the oxygen equipment there.

J. Mastro: I agree wholeheartedly with Jeff, but there are certain restrictions in terms of the compliance factor. I would not issue any equipment to any dive group until I had gone through the dive accident management plan, the recompression chamber and other procedures with them. There was some reluctance on the part of some groups who just did not have time for that. They were too busy getting ready for their project.

S. Bosch: The problem is that the standard NSF policy is not in writing. Everyone going down there should know that they have to do this before they can dive.

J. Mastro: I think the NSF policies ought to be in the guidelines.

S. Bosch: As should the field training.

L. Somers: If they were responsible divers, they would not be bucking the system.

C. Mitchell: I would just like to make the comment that these are the exact issues that came up during the UNOLS discussion. Principal investigators show up with people and equipment they haven't worked with before. The Diving Officer of the host institution asks whether they have had a practice session to operate this equipment. and they answer that they can't afford the ship time. The Diving Officer responds that they need to dedicate a half day to get this stuff all together. The investigator now complains he can't afford the time since it was not in the budget. As Sid pointed out, in may places these rules are not in writing and where they are, are not broadcast with enough emphasis that the principal investigators get it. There are instruction manuals to fill out your NSF grant request. There should be another manual that outlines these procedures and necessary documentation before you leave.

G. Staffo: The dive plan should incorporate the practice dives and the equipment familiarization, and the p.i. held accountable for it. If the dive plan isn't filed, approval to proceed is denied. This aspect needs improvement, and to a certain extent it is part of the condition of the grant.

G. Simmons: The rules are very simple. Before you set foot on a ship, you have to have demonstrated that you have certain water skills and you have gone through the appropriate training program in the diving mode you are going to use. The outcome is equally simple - if you haven't done it, you just don't go. You either fulfill these requirements before you go or you fulfill them when you get down there in some organized way, whatever seems to be acceptable and appropriate, or you do not dive. That is just all there is to it.

L. Quetin: This is a curious conversation because it feels very confrontational between the PI's and support personnel, and I don't think that's really the issue. The more we can get away from these confrontations, the safer it will be because one confrontation spoils the whole batch of interactions. If you're in a confrontational environment on the ice with diving, people will fight it, that's human nature. If the perception is that we are trying to do research and get people in the field, the scientists will respond more favorably. I agree with George. The time for most of the training is back here, because field time is very valuable. You cannot get completely away from on site training, you have to go through it, and we do. We dive off the dock at Palmer just to see how people like the cold water. We do that until they get it right and then we go out to sea. That costs ship time, but it is important. We minimize on site training because we have had a lot of pool sessions. Setting up long periods of training in the field is not the way we want to go. The idea of working it out together eliminates the feeling of confrontation.

D. Bresnahan: The critical point that Chuck was talking about is people have to know in advance that there are going to be some requirements that they have to factor in. If they know this well in advance, the confrontational attitude is greatly reduced. These requirements will detail what will happen to you, including the checkout orientation for divers. So, if the science party has that material and did not read it, sorry. The problem is compounded when upper management rotates through McMurdo. When you talk about diving to mountaineers or glaciologists, it is foreign to them. A document that lays out the ABC's becomes a lot easier when you address the next level of management that doesn't understand some of the unique requirements.

L. Somers: Unrelated to NSF, I have seen several cases where there have been administrative overrides of the diving person on site. For example, the diver will simply get on the radio or telephone and get an administrative override of what the diving supervisor might say.

D. Bresnahan: Our problem is when we get some congressman who wants to dive in the Antarctic.

D. Divins: In the past, everybody has spent the first day in the field doing some type of training. With increased litigation and decreased money, people are being forced into shorter windows. That half-day training session really hurts because half a day in 10 rather than half a day in 20 is lost. There will likely be a bit more confrontation if requirements and expectations aren't spelled out in advance. With the regulations in hand in advance, the opportunity is there to get much of it done before they get there and save themselves time and money on the ice. In addition, we should let the divers know what they will still have to do when they get there. In general, we can sell the program a bit better and make it more palatable.

D. Nagle: If the Diving Officers at the home institutions are involved and help facilitate and prepare the people going to the ice, then that same sense of helping to get ready, helping to be prepared can carry right on down to the support people that exist there. Everybody is then seen as a facilitator of the activity and there is a desire on the part of the researchers to have the information that those people have because they know it will help them dive safer, dive more effectively, and be able to get their work done. A lot of it boils down to attitudes, and it starts at home.

D. Divins: One of the things that makes it work so well in California is that everybody knows each other fairly well. The importance of this meeting and possibly others is that when Langdon and I talk about Antarctica, I have no idea who is connected on the other end in Washington. I have not had enough contact with people running Polar Programs to really know who to call. This has been a beneficial meeting and if we can open up these lines of communication, it can simplify a lot of the problems for the support staff there because we can solve the problems in advance. Communication between the Diving Officers and campus community is as important as communication among universities as part of the diving regulations.

L. Quetin: With diving safety, the attitudes, communications and the people are as important as having a list of rules and hoops that you have to go through.

J. Stewart: NSF holds an orientation meeting every year for those scientists going south. It has always seemed to be appropriate to get together with those people at that session. The document resulting from this workshop, with participants representing the many facets of the community, will be a consensus document. We are solving many issues here and will have a presentation for people at an orientation meeting long before they go, making them aware of what is expected of them.

M. Lang: At what point does NSF review not only the science aspect or merit of the proposal but also the operational aspects? If a proposal were presented to make eight dives per day under the ice for 25 days straight, when is that determined not to be a good idea?

D. Bresnahan: When the original proposal comes in for the next season, 18 months in advance, in addition to the standard peer review for the sciences, there are some logistics realizations which take place to see whether it is a feasible thing for us to do. Later, the PI is required to submit, in detail, the diving project plans.

G. Staffo: We have a very brief safety department health checklist that asks basic questions. We also have them address some measures of how they plan to deal with the risks involved there.

J. Stewart: Some years ago on one of our UC campuses, one of the faculty was able to write a grant, have it funded, conduct a total diving operation, ultimately kill one diver, bend another, and the first we heard of it was when we received a call from New Guinea saying, "somebody died and another guy is in real trouble." There was absolutely no place in any grant proposal form to account for diving activities as there is for human subjects or radiation. No one caught it, that was an eye-opener to all of us. We need a total dive plan that can be evaluated by Polar Programs before a program dives.

K. Dunton: I was trying to stay out of it, but the principal investigator must be given some credit. We are funding science. I do not hire support divers. The people I bring to the Arctic are scientists. Diving is a tool. It is just like any other tool in my lab and that is all it is ever going to be. One of the worst things that can happen is for that tool to be compromised by many regulations that make it impractical to further use diving as a tool. We go through an entire procedure of open water checkouts in advance, either in Puget Sound or locally. Then we go up to the Arctic in the summertime. We make the dives and practice the kind of measurements we are going to be collecting and then we start doing it. We have oxygen on board, of course, NSF provides no logistics in the Arctic. We check with the emergency people since there is no Coast Guard up there. So we work pretty hard at it and we are on our own. It has worked remarkably well over 13 years with no accidents or even close accidents. If I am going to work up there, I want my program to continue unimpeded, and I am going to work very, very hard to make sure that we do everything as safe as we can do it. I do not advertise in the paper that I need a diver. My divers are all students - Ph.D. or M.S. students, and if I need some help, I call on someone. Steve Jewett has done it too. He called Langdon and they put together a fantastic crew of experienced divers to work with him in Southeast Alaska.

M. Lang: In support of Ken, the diving regulations come from the working underwater scientists. The researchers at this workshop are members of their home diving control boards. You are all directly involved with the promulgation of the scientific diving regulations at your campus. I have always viewed a scientific diving program as a research support activity.

B. Hamner: Overplanning can be a little misleading, too. In general, on a research project, I have never done what I claimed I was going to do. You get in the field and you find new things. If you were not finding new things, you would not be doing good work, so you adjust your plans. You may be certified to 60 feet but as you go down, find out the animals are at 120 feet, so you have to restage. You do not come back to California and enlist in the dive program again.

V. Standardization of Dive Procedures - Jim Stewart, Moderator.

J. Stewart: The next segment of the program is dedicated to standardization of diving procedures. Diving procedures in the antarctic are defined by the area in which we work. There are procedures for diving in the open, diving out of huts, through Scott tents, etc. The main issue is the discussion of buoyancy compensators use with dry suits. That seemed to be the most discussed portion of yesterday's session. I open that topic again so that we can conclude something as a consensus.

D. Long: There will always be sessions when the diving supervisor of the season will have to make a judgment call because of the specific circumstance the divers find themselves in. There should always be a caveat in all rules that covers that aspect. All of you represent institutions that are considered to be deep pockets, even though your budgets do not represent that. Whenever I take any action or make any decision, the simple reality of life today is that at some time there may be a lawyer making the judgment that had I as the manufacturer done something differently, this person would still be alive. Because I did not, I will now be responsible for that person's death and for their bill. As scientific divers, the issue of BC's with dry suits is a judgment call you have to make. As a manufacturer, I say that divers are using my product that is not designed to be a buoyancy compensator or lifesaving device. We are required by public policy to have made failure mode analysis and to have gone through what could happen and how we would address the problem if that did happen. We have some of the issues covered, others we do not. For instance, we do not have a good solution for the disconnect issue. If you have something that disconnects too easily, it can be knocked off. The 'T' bars can be disconnected if you are rummaging around on a wreck get hung-up. On the other hand, if the connector is too small or people have gloved or cold hands, they cannot disconnect it. That is the risk the diver must take.

Should one use a buoyancy compensator? We have seen torn neck seals come in, and for any one of a variety of reasons, the diver had lost his capacity to control buoyancy and as a direct result of that, drowned. Therefore, for a buoyancy compensator to be worn as a backup system, understanding all of the fallacies of backup systems in general, the person has to use it at the appropriate time. Most recovered bodies still have their weight belts on. From my standpoint, for the protection of the system, if I had to make a statement that covered all people at all times, I have to say use a buoyancy compensator because the device we manufacture cannot guarantee that under any and all circumstances you will have buoyancy control. From the practical standpoint, to inflate your suit enough to hold your head high out of the water puts all the weight on the top of the shoulders, brings the shoulders up, and pushes the head down. If you are using an inverted neck seal, it puts a tremendous amount of pressure on the neck, none of which is going to help the diver. You want flotation under the arms, to lift the diver high enough out of the water to keep the head up. In a dry suit, floating on the surface like this is difficult, and swimming back to the boat, with air in the suit flooding to the arms is also difficult. A buoyancy compensator is the preferred device.

J. Stewart: Now would you address the question of working under ice and coming up through a hole where you do not have to swim? You simply have to come up and get out, as opposed to open water.

D. Long: Let's take the umbilical diver out of the discussion. If a diver has an umbilical, he can pull himself in or have someone reel him in. If you have a down line coming through your hole but cannot get up to it because you are negatively buoyant you have problems. The strongest fins can create about 40 pounds of lift at maximum output. Most divers cannot maintain a 40-pound weight with their lift. Therefore, if they lose their buoyancy control and have no method of neutralizing that buoyancy, they have to ditch their weightbelt. Ditching a weight belt under ice is just as dangerous as being negative. You would almost be better off to walk up under the hole, drop the belt and hope you hit the hole on the way up. You are the experts at diving under ice. I am not and want to underline that. So I have to leave that one to you.

J. Bozanic: The problem of getting to the down line, strung from the hole to the bottom, is not pertinent at McMurdo.

D. Long: Again, as an equipment manufacturer, I have a much different vested interest than you do, and I think you need to understand that when we speak.

M. Lang: Most people have no appreciation for the manufacturer's issues. This was brought to light with the talk you gave at the 1990 DEMA show regarding the fate of Chouinard.

D. Long: Chouinard, the parent company of Patagonia started in the mountain climbing business because Evan Chouinard was a mountain climber. They were the premier company in mountain climbing equipment. There was a a young lawyer with a family who decided to take up mountain climbing. He went to a licensed guide who gave the group instructions and put a harness on him that was made by Evan Chouinard's company. He tied him into the harness, and they went up the mountain. They stopped for a break and the lawyer went off to the side to relieve himself. It is assumed that he untied the knot in front of him in the process and then tied it back incorrectly, but no one caught it. He went up the mountain, made one slip and fell, and apparently the knot inverted. The next time he slipped and fell, he came out and hit the deck. He, of course, was killed. The law firm he belonged to, saw the connection between Chouinard and Patagonia, and immediately filed suit against Chouinard. Because that suit was filed, other suits were also filed behind it. The case never got to court because the cost of litigation was so great that Chouinard had to declare bankruptcy. So they never got into court to prove whether the man was negligent. We now live in a society in which fault is no longer the basis of liability. We have a strict liability law that says if someone is hurt, someone pays. The mountain climbing industry was brought to its knees because it no longer had access to liability insurance of any form. The diving industry is about to face the same situation. Lawsuits have increased 30 percent. Some of the big claims being made are just astronomical - an understatement. Therefore, I would encourage anyone in the diving business to never use the word "best". How are you going to be able to prove it was best? What's the independent documentation you have and how can you prove that that device was best as opposed any other devices that are being made? Another word is"safe." Diving is not safe. If it were safe, my client would not be dead. My client is dead. Therefore, it obviously wasn't safe. End of discussion. You must portray diving as an adventure sport or say it is risky or has certain inherent risks that cannot be reduced or eliminated. Everything can be done right and you might still get killed. Use those kinds of words and the manual I gave you. Use the word "death" often in what you say so the people understand that it could happen to them.

D. Nagle: Diving is a discipline that requires a maintenance of your skills. Some UCSC divers had been using dry suits for a long time, but they were working hard at something and not necessarily as efficiently as they could. After trying different techniques in a pool session in dry suits, they were amazed at the difference in dry suit performance. I want to encourage divers not to assume that just because they have been using a piece of equipment for a long time they necessarily know how to use it.

J. Stewart: What are your feelings about buoyancy compensators?

D. Nagle: They have to be in the recommendations. The dry suit is not equipped to vent as fast as a BC. You are really behind the curve if you try to use the dry suit as a buoyancy compensator and you need to get air out of it in a hurry. You could open your seals, but that is not the recommended use, and it could be counterproductive in an antarctic situation.

C. Mitchell: The dry suit's purpose is thermal protection, not that of a buoyancy compensator. However, buoyancy changes as a function of the suit compressing, so air is added, but only to the maintain the suit's insulating capability.

L. Quetin: I thought Dick said not to use the buoyancy compensator except at the surface or in case of a failure with the suit. The inherent nature of the suit is that it is buoyancy compensating.

M. Lang: The only reason you put air into your dry suit is to alleviate the squeeze. As a result, some buoyancy is obtained. The BC is not inflated until you are at surface, because if your dry suit is used there as a BC, the will feel choked and cannot move your arms.

P. Dayton: Where did you get your compensation at 60 feet?

D. Long: The key word here is "compensator" because the device was made to compensate for the changes in buoyancy of a wet suit. In a membrane-type dry suit, made by any manufacturer, that element disappears because there is no compression of the suit occurs. The squeeze is equalized on descent to maintain the same volume of air inside the suit. Therefore, if used properly, the suit does not change buoyancy in the vertical water column. The need for buoyancy compensation, therefore, does not exist. However, because of improper weighting or lack of full understanding of the application of the science and technology of a dry suit, problems have occurred. People grossly overweight themselves. Then they resort to buoyancy compensation to compensate for this excess lead. The issue then becomes understanding insulation and weighting at the same time because they are inevitably linked. When those two issues are understood, one does not use the suit as a buoyancy compensator, because properly weighted, air never has to be put in the BC underwater except in an emergency situation.

P. Dayton: We wear a fair amount of underwear, so at the surface we need to expand our suits to be able to move. At depth, the underwear compresses - as a wet suit would - so some air has to be injected into the dry suit. You keep putting air in as you go down, in order to maintain the same volume in the water column. Upon arrival on the bottom, you still have not used your buoyancy compensator.

D. Long: Affirmative.

P. Dayton: Now you ascend, and you have a buoyancy compensator. Whether you use it or not, you have to vent the air.

L. Quetin: Do not forget the additional change in buoyancy occurring as the tank air is used.

P. Dayton: You are weighted properly to get down. You have to be able to get down far enough so you can swim around, and as you do that, you are going to be putting air in your suit. You want to be neutral on the bottom.

D. Long: So you do not want to be negatively buoyant on the bottom. In reality, all you are doing is neutralizing the squeeze on the way down. When you come back up, all you need to do is vent the air as it expands. Use of an automatic exhaust valve - located on the upper arm - is called passing gas. The valve is adjusted to the completely open position; upon ascent, the elbow is slightly raised to vent, then lowered again.

P. Dayton: I have yet to hear a need for the buoyancy compensator under the ice.

D. Long: What if something occurs that violates the watertight envelope of the dry suit?

P. Dayton: The explosive neck seal, or the horror story of the zipper coming undone could happen. Those are the two events that will ruin your dry suit and give you trouble getting up. You have about 40 pounds of weight on the belt. We have logged many dives in the Antarctic; I know of only one neck seal that blew up, and no massive zipper failures. The zippers sometimes leak, but they do not explode. That seal failure was on my neck and I was flooded with cold water. I was uncomfortable, but came up through the water column fairly easily.

J. Stewart: Did you come up the rope or did you come up quickly?

P. Dayton: I did not have an ascent-limiting nitrogen problem, so I came up as fast as I could. The key thing Dick said yesterday is that we do not want to have an absolute rule that applies to everyone at all times. I am arguing against the idea to have an obligatory buoyancy compensator rule. Coming up under the brash ice - instead of the hole - is a very serious mistake. At some point divers are going to use BCs and a mistake will occur. The regulations cannot state "do not use BCs under any conditions", but I would like to have the regulations state that BCs are not recommended under the ice. I am probably the first minority.

S. Bosch: Second.

L. Austin: Third.

P. Dayton: I would like to take a stand on paper recognizing that going up is a real problem and should be discouraged. If somebody really likes their compensators, fine, let them wear it around.

S. Bosch: I agree with everything you said. The real problem with diving in any kind of cold water is that you already have too much equipment, so I have to see a really concrete reason for adding another piece. In my experience down there, I only know of one person who has had a massive flooding of his suit, and there he is right there. Every season I hear of several people whose buoyancy had failed or experienced a free-flow of air into their suit or BC.

P. Dayton: The free-flows of air happen very commonly. Unfortunately, those inflators do not come off. It sometimes takes two tenders to get it off when they are jammed.

S. Bosch: That is more of a risk than the occasional major suit failure. We have to weigh the major pros and cons. It seems that under the ice it does not make a whole lot of sense to have the BC.

M. Lang: We all have to wear a safe-second regulator (octopus) in entry-level training. It is fairly simple for the lawyer to convince the jury that it did not matter if there was air in the tank or not. Had this shiny safe-second regulator been hanging off that tank, that person would be alive today. Eventually that worked itself into the A.N.S.I. entry-level scuba training standard. So, whether we want to or not, we end up with another piece of equipment. If your BC free-flows under ice conditions, dump the air and come up. Throughout your diving career you were trained to do that on scuba. The other issue is that most of the work under the ice at McMurdo is benthic work, right?

P. Dayton: That is the history of it, but there was Harbison's group that was in the water column.

M. Lang: So there is both mid-water and benthic diving in dry suits. From the point that you descend through the hole in the ice sheet, it does not matter if your work is benthic or mid-water, until you make the ascent. The only BC issue we are talking about here is associated with the ascent. Otherwise, diving in an overhead environment is no different. It seems to me that we should focus on the ascent procedure, so your problem of getting caught under the brash ice does not occur.

Having dived in California for 12 years, I learned quickly that you could either drop anchor and swim 500 yards in one direction and then have to crawl back through the kelp canopy or, you could devise the dive plan to go down the anchor line through a minimum of kelp canopy, work in a circular pattern and come right back up the anchor line. Diving under the ice sheet could be handled the same way.

P. Dayton: In favor of the equipment, I love that octopus. I carry mine under my arm. I am not opposed to additional equipment. All the same, we have got clubs for hands and we are trying to do some work down there. We cannot do it under the hole, it is unrealistic. We have to plan our dives so the dive always finishes under the hole. We have a basket on the bottom to put in as much as we can so our hands are free. We may want to hang onto a light, sometimes a camera. We have two regulators, one in our mouth, one hanging over the shoulder. We have a line to hold on to and some stuff in our hands, and the buoyancy compensator has two more hoses flapping around. The BC has one hose that goes into the compensator from the regulator and a tube that you dump air out of. It has other gadgets, too. When you have tubes flopping around, cameras with neck straps, transect lines, and baskets to carry, you have enough junk that unless it serves a purpose, I would just instinctively want to get rid of it.

M. Lang: To put this topic in perspective, this BC requirement with the dry suit has now been reiterated in several workshops with different groups in the diving community. If we are going to endorse a variation from the standard requirements for a specific situation, we have to justify and document it. If we deviate, the question arises "why do we need to wear a BC on the dry suit anyway?" I have yet to hear a valid reason for not wearing a BC under the ice. Free-flow of air into the BC can be easily dealt with by dumping the air, and "just another piece of equipment" is unfortunately not convincing enough of an argument for not wearing one. I caution that if we make this deviation from what is already an accepted standard of practice in the entire diving community, then we have to be able to document that.

J. Bozanic: One problem was the use of the BC in tethered diving systems where you do not necessarily have a low pressure air source for inflation, in addition to Paul's concern of having that extra hose on the BC getting tangled up. Instead of a low pressure inflator, a small bottle could be used to inflate the BC. A bottle with a simple on - off valve as opposed to something that could stick. That is another potential solution we have not discussed yet. How we can we modify this equipment to match the environment we are working in and still maintain the safety considerations that Dick and Mike have raised.

J. Stewart: I had never hit the inflator button and emergency dump on the BC at the same time to see exactly what would happen. This morning I hooked up my regulator to a stabilizing jacket BC, turned the tank on, hit the inflator button and pulled the automatic dump. I got absolutely no buoyancy (air) in the BC whatsoever. So when you get a runaway BC, all you have to do is grab the emergency dump and you have already solved the problem.

M. Lang: Your point, Jeff, is dead on. Certain equipment designs are more appropriate under certain conditions than others. Dave Duggins' (Friday Harbor Marine Labs) main objection against the BC use with a dry suit was the extra hose. If you streamline the equipment, have a low pressure inflator and alternate breathing source combined in one unit, you have eliminated one hose with an octopus that could free-flow anyway. Nothing needs to flop around. The inflator unit meets with a velcro patch on the BC. The buoyancy compensator issue is important enough to warrant a bit more thought about the appropriateness of equipment designs for the kind of diving environment.

D. Long: As a rule, all the inflator devices I have seen freeze when you try to activate them. As long as you do not touch them, they do not inflate. If you get pinned underneath the ice, all modern BCs have a venting valve in their backside. You can vent in any direction. So an inflated BC is not that big an issue when you get down to it. Besides, you should never use it, unless you need it. If you need it, then you have another problem altogether.

A.P. Valves in Britain makes a variety of BCs, some of which have a high pressure bottle, as an independent inflation source. There is no low pressure mechanism on some of these systems at all. You inflate the BC with a high pressure valve, and the chance of a freeze up is very unlikely. So there are alternatives and you should ever say lightly "this is something that you have to do." It is also something that we need to work out the procedures for, better than we have done so far. Ultimately, if you were caught underneath the ice and did not have a buoyancy control device with you, you might wish you had one.

J. Mastro: Much has been said about diving under the ice sheet, and I can see both sides of the argument. What happens when the ice sheet breaks up and becomes open water?

J. Stewart: That is essentially the same as diving at Palmer Station and warrants the use of a BC. If you have a problem and put air in the suit, you will get a carotid squeeze and terminate yourself. These are two different environments in the Antarctic. I am for the use of the BC in open water. The main problem we are addressing here is what happens when you come up underneath the ice. Is it at the discretion of the diving officer? There has to be a mechanism that we can spell out as a policy opinion.

K. Cutlip: I understand the importance of a BC as a flotation device at the surface. Certainly in open water, flotation is going to be necessary if you come up away from the boat, but if you only have one very small point of entry and exit, is there no longer a need for surface floatation? Presumedly, you have somebody assisting you at the surface, and if that system fails, you have more problems than just the absence of a BC. So when diving through a hole in the ice, what is the advantage of wearing a BC?

D. Nagle: The purpose for wearing the BC under the ice is its function as a backup if you lose your ability to control buoyancy with the dry suit, period. That is why it is there. I would suggest a small project be put together with the intention of forming a consensus on the advantages and disadvantages of different types of BCs with dry suits.

J. Stewart: I would point to possibility and probability. With the numbers of logged dives conducted by the people sitting in this room, we have demonstrated that we are safe and effective using the technology we have today. There is always a possibility something might happen. I am not sure that using the buoyancy compensator under the ice does not create more problems than it solves. You can always come back to the hole and come hand over hand up the down line.

P. Dayton: And you have a buddy with you.

C. Mitchell: Traditionally we have mandated within the AAUS standards and the Scripps standards, that the diver have some method of attaining or maintaining positive buoyancy. It was assumed by some institutions that if the diver had a wet suit, all he had to do was drop his weight belt to attain positive buoyancy. How do we accomplish that with the dry suit? We have heard the horror story of an overinflation and suddenly finding yourself in the brash ice. That is a worst case scenario. What happens when a neck seal blows and now the diver is standing on the bottom, 'x' number of feet from his hole, 50 pounds negative?

J. Heine: He would not be that negative.

P. Dayton: You have not heard us talk about that. You can take your weight belt off.

C. Mitchell: But that has not helped your buoyancy. You have not provided positive buoyancy yet.

M. Lang: Especially not with the types of weight harnesses used at McMurdo.

P. Dayton: You have a buddy and the down line, and my horror story only happened once; I swam up.

J. Pearse: You will be just about neutral and if you take your weight belt off, you will not have to make a great effort to get up. You have to climb up lines, but if you take off your weight belt, you can swim up.

P. Dayton: You are very enthusiastic when a neck seal blows, and you swim up.

C. Mitchell: I suppose that you are in a slightly more stressed situation than you would be under normal circumstances. All of a sudden you feel 28-degree water and I cannot believe that people act normally and rationally when being suddenly emerged in that water.

P. Dayton: But if your response is going to be to pull your parachute cord and inflate, then you are going to die. Why have that action available?

G. Simmons: My dry suit zippers has failed. In fact, I knew it would fail and I still wore the dry suit because I liked it, an old-time Unisuit. When I got in it, we pushed the zipper back together and I walked out to dive for about 55 or 60 minutes under the ice in shallow water. When these things happen, it is not like someone ripping your wet suit open, tearing your lungs out and putting extra weights on you. I was working on the bottom, fairly heavily weighted, and suddenly I could feel a little cold water slipping down my back. I said, "my zipper has failed and I'm through, let's get off the bottom." I stood up and the tender pulled me back to the hole. I walked to the hole, with my back arched of course, and went up. At least when we are planning these dives, every piece of equipment that is on that diver, whether a knob or a valve, has have some function to it. I worry about things hanging there that could inadvertently pin a person beneath the ice.

J. Heine: Steve Barsky and I published a study in the proceedings of the 1988 AAUS Symposium here at Scripps. In a pool in shallow water, we took a number of different dry suit and underwear combinations and purposely flooded the suit to document the changes in buoyancy. In no circumstance was the diver unable to simply swim to the surface. It is a fallacy to think that with a totally flooded suit you are negatively buoyant, unless you are in much deeper water where you are going to lose a lot of air. Just because you are wet does not mean you will be negatively buoyant.

D. Long: I am involved with two lawsuits in which divers did not have buoyancy compensators on and are dead. The assumption is that if they had had buoyancy compensators on, they would be alive. So I can only tell you we have honest to God dead bodies with honest to God American trial lawyers behind them. As a manufacturer, I will say that under such circumstances, whoever made the decision not to wear a BC was in error. I would prefer not to see you get caught in that position.

M. Lang: What we are not interested in is to go back and re-validate why we wear a BC with a dry suit in the first place. If diving under ice is truly perceived as such a unique circumstance, a special operating procedure for exactly that kind of dive, could be considered.

J. Mastro: Until this last season, BCs did not even exist at McMurdo for use as standard equipment. I have dived with and without a BC under the ice. It's a pain in the neck to have a BC on under the ice. It is just extra equipment. It gets in the way. I understand what Dick is saying, too. There is a good reason to want positive buoyancy if your dry suit fails. But, as we have heard, that is not necessarily a major consideration. There are a couple of cases when I think under the ice use should be mandated. For instance, we dived through a natural crack and followed it along for a couple of hundred yards as the bottom dropped away. It was basically a blue-water dive. There are lots of access holes along the crack, but getting back to the down line was not an option. In a situation like that, even though it is a pain in the neck to have on, it's a good idea to have that BC. Mandating BCs for all under ice use is not necessary, only in certain situations.

M. Lang: What kind of BC were you using? Why is a BC such a pain in the neck?

J. Mastro: It was a Dive-Right back inflation unit. Well, agreed, it did not get in the way that much, but it was just an extra piece of equipment with two extra hoses banging on the side of your head; it was just more than I thought was needed down there.

D. DeMasters: I spoke with someone yesterday who suggested that the new NOAA regulations will not require the use of a BC with dry suits. He has done a lot of surfacing with dry suits from 100 feet with no problems. In open water diving specifically, they will not require BCs with dry suits because of the trouble with covering the valves. So there are at least one set of regulations that will not require a BC.

M. Lang: Qualify the type of dry suit. NOAA's standardized equipment program specifies the use of a foam suit. That entails a certain amount of inherent buoyancy.

D. DeMasters: That is true. That will be the standard, but that will not be the only dry suit used on all NOAA dives.

M. Lang: Not all BC designs are compatible for use with dry suits. There are many BCs however that do not cover valves, are not a pain in the neck, provide great backup, float you waist-high out of the water without choking side effects, and are affordable for you and your buddy.

W. Langley: The Navy requires buoyancy compensators on all dives. We do not do very much ice diving, but we do a lot of diving with wet suits and dry suits. Buoyancy compensators, as Mike said, come in different models and maybe you have chosen the wrong models. You can get the models that Dick was describing with high pressure inflation. It is safer and you will not have the free-flow problems that you had with the other types of BCs. Whatever you decide, my recommendation would be to neither eliminate the BC nor make its use a hard and fast requirement. In some situations it might prove more hazardous to have the piece of gear than not to have it. But there are circumstances when you should have it. Think about the type you buy and get ones without hoses that do not hook up to your air source for your breathing.

D. Long: "Under normal circumstances, a BC is recommended to be worn with a dry suit. It is recognized that conditions may exist when, in the judgment of the dive supervisor, the diver would be more at risk with a buoyancy compensator than without one. Under those circumstances, the use of a BC will be at the discretion of a dive supervisor."

L. Quetin: We have to get the individual back into that discussion. The good thing about not having a hard and fast rule is that for every dive there will be a discussion as to whether this is a good idea. Each individual diver will then be better educated. The dive supervisor might recommend it or ultimately the individual diver will. If I decide for blue-water dives that buoyancy compensators will be used, then I will recruit divers who are comfortable using them. But in some instances, it is not always a clear-cut case and it becomes a matter of individual preference since there is no data, regardless of the liability problem.

J. Bozanic: We need to collect more failure data on this issue. I am not so sure that the responsibility lies with the dive supervisor to the extent it does with the scientific diver. Because at least in the way scientific diving was regulated by OSHA, assumption of safety remains with the individual diver, and that general overall view should be reflected.

D. Nagle: It is reflected in the proper training and selection of divers who understand the concepts and are able to make solid judgments themselves. There is that ending quote about good judgment being based on experience and experience frequently coming from bad judgment. Here we have collective experience and that gives us good judgment. There has to be some margin of trust in the orientation and preparation given to the diver at the home campus. The individual, in the end, has to have the resources to develop an objective awareness and to be able to analyze the situation and the equipment. The responsibility lies with the individual, who is hopefully prepared with the best information available.

M. Lang: Our objective was to attempt to standardize dive procedures. To state that it is an individual's choice whether or not to wear a BC, could result in two incomparably equipped buddies, unless they have to make the same decision on BC use. I would rather encourage a standard operating procedure for optional BC use at specific sites.

P. Dayton: That should not be a concern right now. Buddies can use all sorts of different equipment. As long as they dive together, they should be happy.

J. Bozanic: Nobody contests the use of the BC under most scientific diving conditions. The only environment where BC use is contested is underneath the ice, relatively close to the hole, where there is a bottom for the diver to stand up and climb up the down line. That is the only situation we are talking about. We should make BCs optional based on the judgment of the individual diver if those conditions and criteria are met.

D. Long: We do not want to look for an engineering solution to a training problem. There is no question that within the diving community, less than 10 percent of the people utilizing dry suits fully understand how to use them. In the scientific community that probably goes up to 20 percent, which means that 80 percent of the people who are using dry suits do not understand all of the aspects. This is a multi-faceted problem of which training is a major component. If all we had were well-trained, experienced divers, the possibility of an accident would not be as great. But the divers do not always have the best training circumstances. We have to work on solving that problem, but make our decisions today based on the fact that adequate training is not always a part of these divers' experience.

J. Bozanic: The standards for the New Zealand Antarctic diving program require all research divers to be individually man-tethered from the surface. Most under ice diving procedures in this country have the same standard. Yet the standard of practice at McMurdo does not call for the use of a manned tether, primarily because of the exceptionally good visibility and the lack of opportunity to lose that visibility in a hurry. This topic should be at least briefly discussed here.

P. Dayton: I have fought the tether from the very beginning; it wrecks my habitat. But there are times when you do need something. Some words need to be written down such that if you cannot see the hole from your planned dive, you really should use a tether. You cannot see the hole in shallow water because of the parallax problem. Those holes are not very big and at a 30-foot distance, you might lose it.

J. Stewart: When diving under ceilings, where there is low visibility or shallow water that restricts the diver's ability to see the entry hole, or the danger of tidal currents, the use of a manned tether is necessary.

J. Bozanic: There are no such provisions under standard practices in other communities that, should a conflict arise, we would be compared to. Are you allowed to dive in Michigan underneath the ice without a tether if you are able to see the hole from where you are?

L. Somers: No.

J. Bozanic: Also, under the New Zealand diving program guidelines, nobody is allowed to make a dive at any time without the use of a manned tether, even when they are diving in the same environment we are. Our practice is not bad. I like the way it is worded in the diving manual.

J. Pearse: I like the way it is phrased and I like to be able to dive without being tethered. On the other hand, we are worrying about litigation. We have often been in the situation, even in very clear water, when the hole cannot be seen while diving some distance from it. You are looking around to find it, and that is litigation just waiting to be had. It is a real can of worms and something we are setting ourselves up for.

D. Divins: When the hole is not found, is the down line not visible and is it not possible to put a strobe or light on it so the hole can be seen?

J. Pearse: We always hang a strobe and flags. If you are very far away, those can be indistinct, so you are talking about the distance as opposed to visibility.

D. Bresnahan: That is another problem with the dive plan and how far you have gone from the hole.

J. Pearse: While swimming around the bottom it is easy to get disoriented.

D. Divins: Are you dealing with a one-thirds air provision in that situation?

P. Dayton: Yes, I usually try to do that, too.

J. Bozanic: Our dive manual states that we should terminate the dive with 500 psi, or sufficient quantity to reach the surface safely. There is no thirds provision. If we are going to have an air standard - aside from the tethered issue - it should be based on some volume of air instead of some pressure which is tank dependent. I have made the same proposal to the cave diving community which is most analogous to our under-ice diving, still within sight of the exit point.

L. Quetin: That is a good idea if it is related back to some pressure and tank size, because that is what you see.

J. Bozanic: Once you have a volume, you need some idea of the pressure in your tank. The standard should be written in a volume with maybe a table or something.

J. Stewart: I have already done that.

M. Lang: What are the average diving depths at McMurdo?
J. Pearse: About 80 feet.
M. Lang: Do all divers make the safety stop?
J. Mastro: Yes.
J. Stewart: I hope so.
P. Dayton: Our usual at McMurdo is 100 feet because that is where the sponges I work on occur. The routine procedure is that you are supposed to come up and make your stop, which is where you start having these buoyancy compensator problems.
M. Lang: You are not inflating air, you are dumping at that stage.
P. Dayton: Anyway, the procedure is to hang for a little while.
J. Stewart: Anything else? Think about wording recommendations for these items during our final session.

J. Pearse: One other item needs clarification. If we do not want to have harness weights, we should remove them from McMurdo because they are down there right now.
J. Mastro: You have the option.
J. Pearse: Is it an option right now?
J. Mastro: Oliver's group uses single weights with two buckles.
M. Lang: Could you describe the harness weight?
J. Mastro: It is a wide weight belt with a different kind of quick release, and two straps that go under the shoulders to the tank. I am trying a quick release system with an arrangement of two 'D' rings, a snap shackle that drops the belt when yanked.
D. Bresnahan: So you yank both of those and the straps that are underneath your tank. Do you then have to lift the whole tank up to get this harness to come down?
J. Mastro: I cannot answer that because I have not tested the quick release yet, but if you have 30 to 40 pounds on the belt, it should pull those straps out.
J. Stewart: Just remember that in the horizontal position, the belt is not going to drop at all. You have to be in a vertical position.
D. Long: We have a new weight system that allows you to redistribute the weight to different parts of the body. Weight can be dropped in parts, so it is never dropped all at once.
J. Mastro: Dropping weights is always a serious problem. As Paul pointed out before, dropping your weight under the ice is usually the last thing you would ever want to do, which is why we wear the harnesses. Dick's adjustable system sounds very good.
D. Long: Accidental dropping of weight belts occurs frequently; it is a disaster waiting to happen.
J. Pearse: It is very dangerous in the Antarctic. That is why I like to wear the harnesses. On the other hand, I have been trained well enough. I know that you have to be able to get rid of those weights, so I always feel uncomfortable wearing the harnesses.

W. Langley: I noticed one thing that was not mentioned in the UNOLS publication that I was sent for review. In the military, we give briefings for everything and I did not see anything about pre-dive briefings for the divers.
J. Stewart: It is a stated practice in the AAUS manual (Sec. 2.61 - Lead Diver) that you always brief people before going in the water. UNOLS requires adherence to the AAUS Manual.

B. Hamner: Just as point of information, I have never dived like Paul has at McMurdo, but I gather that only one diver can come up that hole at a time, is that not right?
J. Mastro: The standard procedure now is to drill two big holes right next to each other, so two divers can come up.
P. Dayton: There should be room for two divers to come up.
J. Bozanic: There are times when two holes are not used, and it does provide an interesting safety problem.

S. Bosch: Diving through Harbor Branch Oceanographic Institution, we are not allowed to dive on any sort of dive computer system. We have to follow D.C.I.E.M. tables and it is required that no matter where we go or who we dive for, when representing Harbor Branch, we use our own table system. If I dive with someone who has a dive computer, how do you standardize that?

M. Lang: I talked with John Reed recently about that who said that the Harbor Branch diving control board had never been requested to authorize dive computer use.

J. Stewart: Any decompression table or device must be at least as safe as the U.S. Navy diving tables.

L. Somers: How do you determine that?

J. Stewart: Theoretically, the Navy has the least safe diving tables around, according to the philosophy of the day. A set of appropriate diving tables must be available at the dive location. These tables must be at least as safe as the U.S. Navy diving tables.

S. Bosch: That essentially means everything.

J. Stewart: It is not a problem. Look at the number of dives on that particular table over the years. Scripps has over 200,000 logged dives with only one case of decompression sickness. When we approached federal OSHA for our exemption, we were able to document almost a million dives in the scientific community. Our incident rate was .0037. So we have no problem with the U.S. Navy tables.

M. Lang: On certain tables you can over-conservatively limit yourself so that you cannot get any work done. Trying to dive 4 dives per day in the 50-60 foot range on Huggins' no-bubbles tables is almost impossible. Working on the bottom under ice, the dive computer will not give you much advantage because a square-wave dive profile is approximated. D.C.I.E.M. and British Sub-Aqua Club tables, are just very conservative and limit your work capability.

J. Stewart: I point out that while we are allowed 25 minutes at 100 feet, the new ScubaPro computer gives you only nine minutes. Each computer is more restrictive than the last one and it is all couched in terms of safety. Pretty soon we will all just be sitting here and will not be able to dive.

D. Nagle: We can talk about it.

D. Divins: AAUS adopted three-year physical intervals for anyone under 40 and two-year physicals for anyone over 40. What will the recommendation from Polar Programs be for physicals? Currently, you need a physical within six months of going to the ice. In Langdon's situation, he will have had three physicals in an 18-month period. Will the AAUS physical standards be adopted by Polar Programs for people who come on and off the ice a lot?

D. Bresnahan: No, but our own standards are being adjusted to take into account people like Langdon. For example, the chest x-ray is going to be required once every five years.

L. Quetin: You never want to get over 40.

D. Divins: It is becoming more frequently accepted by physicians that once you have had the initial chest x-ray - PA and lateral - that there is very little chance of a problem occurring, so there is really no reason to have follow-up x-rays. However, Dr. Linaweaver in Santa Barbara finds a number of cases of tuberculosis showing up. The amount of radiation from an x-ray is less than what you get in a day out in the sun; the fear of chest x-rays is somewhat unfounded.

J. Mastro: Nothing is written down about exactly what type of tether system should be used. Most people have been using, and I recommend, an L-shaped tether where your tender at the top has a positive pull on that tether. It is a positive communication link connected to one diver who is connected to another diver. One diver controls the tether lines and keeps them from becoming entangled.

L. Quetin: It very much depends on what you are doing.

J. Mastro: This refers strictly to under ice diving.

L. Somers: In this book, there is very little addressing surface-supplied diving. For example, there is nothing in here relative to backup air sharing at the bottom. And, obviously, to date, very little full-faced masked diving has been done in your arena. Consider that if divers start full-face mask diving, the conventional air-sharing techniques are invalidated, so that will have to be addressed at that time.

J. Stewart: That is why this is continually updated. I want to discuss the concept of dive plans, and essentially overall safety of any diving site and diving program.

VI. Dive Plans and Safety: McMurdo/Palmer Station/Arctic - Jim Stewart, Moderator.

J. Stewart: From a dive plan standpoint, Dave, can you give us an idea of the proposal procedure once you receive it?

D. Bresnahan: In the proposal we require, in addition to the science justification, a clear indication of what is required logistically. In fact, for those of you who are interested in going next year, this has been put together in a booklet format. So there are lots of forms to fill out that you are all painfully aware of. It is not an effort to know exactly what you're going to do and nail you down. It is an attempt to gather the basic information so we can look at it from a logistics standpoint and determine whether or not it can be done, while the other part of the agency is peer-reviewing it in terms of the science. We do not want to get in the position where we fund something and then say "we can't do that, it's not safe." After those decisions are reached and the funding decision is made, then we seek a lot more detailed information on requirements. Pete has a new program now, a rather voluminous package we are trying to streamline that requests a lot more detail. The request is also for specifics on who the divers will be. There is a sheet for each diver, who they are and what their qualifications are. The institutional diver has to sign that form before it comes to us. In addition, we request a dive plan, a basic idea of what your program will entail. That tends to be very general and would not restrict anybody once they got there, if they find that sponges are at 100 feet versus 60 feet. It is general information and gives the contract people an idea of what specific support you require.

J. Stewart: Any comments or criticisms of the policies now in place or the paperwork?

D. Bresnahan: We have tried to keep it very, very simple. We could demand a lot more detail on the dive plan, but we have not done that.

J. Stewart: How about the safety aspects? What would your recommendations be for any changes in the way things are running now?

L. Quetin: Safety is a problem. It is not that we can necessarily make it safer, but refers to getting information to divers about what is and is not possible. In the case of Palmer Station, it would be nice to go through some scenarios just to give researchers some idea. People need a better briefing on the safety procedures that would be employed, especially on the Polar Duke.

D. Bresnahan: In the last few years at McMurdo, in addition to the drills with the chamber, we exercised mass casualty drills. That has been of real benefit. The hierarchy needs to be more aware of what is going on.

L. Quetin: Right now, if we had a dive accident on the Polar Duke, the first thing I would say is we should steam for Tierra del Fuego. I do not know what else we could do.

J. Mastro: I agree. We worked on development of a master plan. Do people know how to use the oxygen system that we have? Do they know what the dive accident management plan is before they get there? J. Pearse, S. Bosch and L. Basch were involved in one of the recompression chamber drills. That helps the grantees understand how it works and helps refine the system. There should also be someone with a bit of oversight authority as to how the diving operation is done. Currently, the grantees are the diving officer and dictate procedures for their groups, and it has worked well in the past. But there are occasions when an oversight capability by someone involved in the program might be useful.

L. Quetin: For Palmer Station, I disagree.

M. Lang: It is unclear, from what Dave has said, who actually reviews the dive plan.

J. Stewart: I get the document to sign-off, but sometimes I do not get the dive plan at all.

M. Lang: Who determines how many dives per day to what depth, etc? Somebody has to review the dive plan somewhere, right?

J. Bozanic: The PI does that.

D. Nagle: It has not been clear to me that that is the case.

M. Lang: That should be very clear because this is where things fall through the cracks. It does not matter where our people dive, as the diving officer, I get a dive plan to review for the diving control board. If they plan to dive in the Antarctic and the dive plan needs to be sent to Jim after my review and approval, fine.

D. Nagle: I agree as well. The point that does not seem to be clear is who gives the approval at the home institution? The dive plan is a framework for discussion for the diving officer.

L. Quetin: The responsibility should be with the dive officers who should determine their ability to evaluate the dive plan and then defer to Jim. We will get more information out quicker than if it goes to NSF and comes down. They are pretty remote from the diver and remote from one-to-one discussion. So the best evaluator is the dive officer and he will know whether to defer to somebody else.

D. Divins: It would be beneficial to have a list of equipment that is provided made available to the individual campuses to help with pre-planning and training. For instance, if we are aware of what equipment is available at the different stations, then I can demonstrate to divers before they leave "this is what we have here, but this is what you are going to see down there." It will save some complications at the stations.

L. Quetin: At Palmer, probably the doctor on station would be the ideal person to be responsible for running some of the oxygen systems. That does not cover the Polar Duke as far as on-station demonstrations.

D. Nagle: There is no discussion of requirements before proceeding with the dive in terms of availability of transportation by helicopter or lack of communications or weather precluding emergency transportation. There should be some clearly defined set of requirements that must be in place before even thinking about proceeding with diving. Is that in the emergency plan for out-of-town diving?

J. Mastro: You have to have enough oxygen and a delivery system to deliver 100 percent to the patient.

J. Bozanic: Dave has brought up a more general aspect. Requiring a chamber at McMurdo before you can dive, for example, is of no benefit if you cannot transport the victim to it because the weather is such that the helicopter cannot take off.

D. Bresnahan: The weather may be good at New Harbor and bad at McMurdo so I cannot launch a helicopter.

J. Bozanic: And you have a remote camp at New Harbor where people are living for weeks at a time.

P. Dayton: And you want to dive. That is why you are living there.

D. Bresnahan: If the weather is good, I have a S.A.R. helo crew that I can land 24-hours-a-day, seven days-a-week, but if the weather precludes me from launching, should that not preclude Paul from diving at New Harbor?

P. Dayton: No.

P. Ponganis: I am involved in some of these remote operations and it would totally defeat the purpose of your project. It is logistically impossible to completely eliminate diving at a remote site when the weather is not perfect. It just reinforces the need for training and safety preparedness of the divers that are at that site. At Cape Washington, we are in a position that if something happened, we probably could not bring enough oxygen. The divers that are going into that situation have to realize the position that they are voluntarily putting themselves in, and if they accept that and are prepared as much as we require them to be, so be it. Otherwise, remote diving is going to be eliminated.

L. Quetin: The divers have to be informed of the situation.

J. Bozanic: In regard to the issue of the hyperbaric chamber being required for diving operations and scientific diving around McMurdo, is New Harbor close or not close to McMurdo by definition? If it is required in one part of the DPP's program, why is it not also required at Palmer or up in the Arctic or on any of the research vessels from which diving is being conducted? This is essentially a double standard here that is not accepted by the scientific diving community, was specifically exempted by OSHA, is not necessary and, in fact, detrimental to some of the operations we have discussed. That one requirement will affect the kind of work that Paul would have been involved with at New Harbor. This should be readdressed or reevaluated.

L. Somers: If you cannot launch a helo, do they stop all mountain climbing and all activities of that nature that are considered high risk?

D. Bresnahan: No.

L. Somers: Because that could have as great a requirement for professional service at McMurdo as diving accidents would.

D. Long: If we dive, we have to go in the water. The water will always be wet. We cannot change that. There is this certain inherent risk we deal with for which we cannot cover all bases. We can easily get ourselves into the "safety hazards of safety devices syndrome."where a greater possibility of having an accident is created. There is also the issue of informed risk. It is absolutely imperative that if you point out that those risks are there, that by some mechanism within your association you enter the element of informed consent. Inform divers of the risks they are facing and have them sign off in such a manner that they know what the risks are. In clear, simple English: "this is the risk you are taking; do you still want to do it? If you still want to do it, then by all means."

J. Mastro: There are constraints imposed with the environment and additional risk in the Antarctic, but you have to be willing to accept those if you want to get any work done. You cannot be constrained by whether or not a helicopter is going to be able to get off the pad.

D. Long: What I suggest is not a policy of whether you do or do not make a dive, whether you can or cannot launch a helicopter, but how you logically and legally inform people of the risks and then move forward in the process.

J. Bozanic: A chamber for a certain amount of diving activity in any remote location is definitely something that increases the safety of that entire group.

J. Stewart: I wish I could agree with you.

D. Bresnahan: I have argued with folks in our office for years about the chamber issue. We are at the point now of arguing about flying helicopters in McMurdo in September, where we have to have an aircraft standing by in Christchurch to evacuate victims, because of a potential helicopter crash due to the inherently dangerous nature of aviation.

P. Dayton: Is that all because of the litigation?

G. Staffo: There is a changing attitude towards acceptable risk, and anytime a change occurs in the program, the question arises "are we increasing or decreasing the risk?" That is how some of these issues have been viewed. Jeff said that his opinion was that having a recompression chamber has a positive increase, so therefore some people have viewed that when you do not have it you have a decrease. The challenge is in trying to identify the interest factors that define an acceptable level of risk and how each of those factors contributes; which ones can we do something about to make a significant improvement. There have been fatalities and since the Safety in Antarctica report, greater sensitivity towards acceptable risk.

J. Stewart: Just out of curiosity, in the last 10 years, how many fatalities overall have we had in the Antarctic?

D. Bresnahan: Probably 10.

J. Stewart: One diving fatality and nine others?

D. Bresnahan: Two guys fell in a crevice and died; another guy was intoxicated and choked to death in the middle of the night; yet another was electrocuted on a ship and two guys were killed in an aircraft crash. It has been a board spectrum.

G. Staffo: Part of the problem we have to deal with is how to compare these different scenarios in terms of some common denominator. What is an equivalent diving risk? Normally the risk is related to some element of exposure, for example, for aircraft it is numbers of passengers and hours of flight.

D. Bresnahan: The Navy says aviation is inherently dangerous once you start the engine. There are too many things that you have no control over, and as such, we are prepared to medevac people from Antarctica if there is going to be aviation. That is how conservative the viewpoint is right now.

J. Stewart: For the first time, since Jim and Jeff have been at McMurdo, we have received dive data back at the end of each year. I have asked all PI's who have worked there to give me that dive data so we can put that in one area to give us the number of exposures per number of incidences. We do not have that. We can get it and I will.

G. Staffo: As a PI you should certainly realize that as our society accepts less and less risk, the requirements are likely to get more stringent and the hoops we have to jump through will probably increase. They will increase unless we are willing to accumulate a strong data base and paper trails. That includes having the training and certification to support that we believe this diving risk is acceptable.

C. Mitchell: It is generally accepted that you reduce the number of accidents through training and planning. Once the accident occurs, the recompression chamber and oxygen kits, etc., are all in the treatment mode. Once the accident occurs, the management is no different from any other accident. It becomes part of the big accident pool. The question then is what level of treatment you respond with. Some people may feel that a chamber must be on site for treatment, but on the other hand, there is no cardiology unit for people that may have a heart attack. Are we responding in an equal fashion to all accidents?

G. Staffo: No. Throughout society, our response to mishaps is not very logical. It results from the way we give different values to the victims depending on whether it is a child or a young person or even a citizen. We give certain acceptance to people who have chosen to take the risk. The critical aspect is to try and do some analysis to minimize that sequence of events which result in the mishap occurring. That is what we can successfully do here because you have a general understanding of how the mishap occurs and can try to prevent that sequence. The other aspect was that after the incident occurs, then you have to address it in terms of the mitigation and the ability to which you can ameliorate that condition. Certainly in the situation of some diving mishaps, there is very little that can be done. We did talk about some of them: oxygen, recompression chamber.

C. Mitchell: These are all first aid treatments.

G. Staffo: Exactly. Most of them are also time-critical. It is something that still needs further work.

D. Long: Within the area of risk management we also have the legal implications and lawsuits that follow training, prevention, accident, first aid treatments and evacuation. What appears to be a defendable method of managing this legal risk, is creating a document that the diver signs stating that he has been informed and knows the risks in no uncertain terms. When you have the diver agree in advance to arbitration, it is very unlikely that a personal injury lawyer will pick up the case because they must go through arbitration before they can sue. This has been a very effective defense in the management of risk of litigation.

J. Stewart: For years, the University of California has carried an extra hazardous policy on all of us. From the early days through today it costs exactly the same for our secretaries as it does for those of us who are working underwater. There is no difference.

D. Long: In the industrial environment it can cost 250 percent of payroll for the insurance. Two and a half times the amount of money the diver is paid is paid into insurance so that when someone sues, that is where the money is collected from. There are limits to those pools of money which most people are not aware of. The fact that you have insurance does not mean all of you are covered.

VII. Review of DPP Dive Manual - Jim Stewart, Moderator.

J. Stewart: Our task is to review and update the Division of Polar Program's "Guidelines for Conduct of Research Diving."

D. Long: It does not address thermal protection at all.

J. Stewart: No. That was not the original intent of the manual. It is just an administrative document.

M. Lang: In that case, I would like to see a mechanism incorporated for the review and approval of dive plans and diver certifications.

J. Mastro: I have a recommendation about that politically sensitive matter of an on-site dive officer. I think it is useful to have someone in that position of responsibility with certain authority. I am not really suggesting a position to dictate policy.

D. Bresnahan: I have the authority to pull the plug on anyone who is down there. The NSF is ultimately responsible for the conduct of anyone in the field and has the authority to pull the plug on any program and send people home if that is deemed necessary; for example, if a person does not reasonably accept a decision about diving safety.

J. Mastro: In a university situation there are people with that type of authority. Below them are people involved in specific aspects of the program, like the dive officer. I do not understand why it is not the same way in the Antarctic.

G. Staffo: Part of the problem is that we do not have enough resources, but we have to try to bring specialists to every issue. We cannot address them all. Are we going to have an aviation safety specialist? A specialist in radiation? A chemical hazards specialist? All we can do is try to have a reasonable person there who is willing to listen to the people who have the expertise and then make a decision. That is what the NSF person has to do. We are working to improve that. In the last year we have instituted a safety environment health council to address problem areas.

S. Bosch: Part of the problem is continuity of the dive locker technician position. We have no way of knowing the diver who will be doing that job from one year to the next. Sometimes we have someone who does not know the situation and lays down laws or rules that are absolutely preposterous. Their role should be very well defined for anyone who goes into that position and there should be an attempt at continuity from year to year.

L. Austin: Do you have some diving orientation in Washington, D.C., for these people?

G. Staffo: We have a general orientation conference.

D. Bresnahan: The time for that conference has been cut back from five days to one and three-quarters days, and it is difficult to include any specific meetings. Everybody wants to add meetings, but nobody wants to add time.

J. Bozanic: The issue of formal status or formal interaction between these agencies has been addressed in the academic community before. There is no reason that you cannot put the diving technicians on the NSF Diving Control Board for the period of time in which they are associated with the contractor. That solution would also effect a formalized means of communication for some of the groups that are outside of NSF or research diving in general, a liaison member for the Coast Guard.

D. Bresnahan: The Coast Guard and the Navy will dive in the Antarctic anyway. They are not going to abide by any DPP regulations concerning diving. They are not within our purview.

J. Mastro: The concept of upgrading or altering the position to include these other responsibilities and authorities must be addressed.

J. Stewart: Part of my recommendation last year was that the position be evaluated. I think the person there for the diving program should be experienced and have knowledge of the chamber operation and of search and rescue; that makes it a little more than a technical position. It is a supervisory position that at least gives you a speaking acquaintanceship with your peers. Formalizing this recommendation, of course, has to be evaluated by Dave Bresnahan and Steve Kottmeier.

J. Bozanic: I would recommend placing the dive technician on the Diving Control Board and stating that in the manual.

M. Lang: On whose diving control board?

J. Stewart: We do not have a diving control board.

M. Lang: The ideal situation would be for DPP to hire a full-time diving officer, an NSF employee, and establish a diving control board.

J. Bozanic: On page 2, the last paragraph says "the exemption from OSHA is based on a history of safe and effective self-regulation, including the diving control board, diving officer, and a diving safety manual. DPP has only a diving safety manual.

J. Stewart: I have been functioning as the diving officer.

J. Bozanic: There ought to be an effective diving control board as called for by the DPP manual.

M. Lang: Realize that the people that you are overseeing here with your "Polar Program Diving Control Board" are not employees of NSF. They are employees of other universities. I think there could be only a peer review of dive plans that are submitted and of certification criteria, versus actually certifying somebody.

C. Mitchell: As Jim indicated, this is an administrative document; a little short in the beginning, a little short at the end. We need some more material to make it a useful document. When a principal investigator wants to initiate a dive program down there, this manual contains almost no means for him to evaluate protocol and procedures and what he is going to have to accomplish before he is allowed to undertake the tasks that he is proposing.

L. Austin: These PI's have diving programs where they come from, so they have a diving control board and a diving manual. Jim's suggestion of a guideline is probably better because these people all end up reporting under federal OSHA rules to their own diving control boards. The difference is that people like Jim are on the site with these responsibilities, while the diving control boards and the campuses are on another planet.

J. Stewart: The foreword says: "The Division of Polar Programs provides a means of conducting underwater research to those members of the scientific community who have a research diving program in place which meets the requirements set forth in the exemption for scientific diving, from subpart T of the commercial diving standards of federal OSHA. This document, as indicated, is drawn from the American Academy of Underwater Sciences Guidelines for Research Diving. These guidelines were created by synthesizing the diving standards of various universities, agencies, and organizations...."

L. Austin: The problem is, though, that the diving control board on the campus or institution back in the United States may not really understand the problems that people like Jim and Jeff face out there in trying to help people get their diving done. They have to be given some kind of standing so that the PI's will respect their opinions, because they know a lot about what is going on. Back on our campuses we do not know anything about that.

J. Stewart: This will be a continuing problem as long as we have the kind of turnover we have had in the last couple of years. The one advantage we have is a continuing series of programs. The PI's who are operational down there now have been operational for a long time, and they really provide the expertise to get a program going and get it done properly. We are a support group and are there to make science happen safely and efficiently.

J. Bozanic: A recommendation was made some time ago for line-tended diving to take place underneath ice with use of a secured tether and hard-wired communication that would require the diver and tender to remain in voice contact under conditions deemed reasonable and necessary by the PI and the dive technician on the ice.

G. Simmons: I would certainly feel a little more comfortable if a paragraph was included to cover tended diving with voice communication and full face masks. In the dry valley lakes, in my opinion, it is more dangerous to have two people simultaneously out under the ice than to have one person.

J. Stewart: I agree with you 100 percent.

K. Dunton: On page 4 the solo diving prohibition requires effective communication with at least one other comparatively equipped certified research diver in the water. We never have two divers in the water simultaneously in the Arctic. We have a backup diver fully equipped on the surface, and we wear redundant systems. We can never put two divers under the water at once.

J. Stewart: That is fine. This prohibition only applies to open-circuit scuba.

L. Somers: There is a statement that all surface-supplied diving shall be accomplished in accordance with all scuba procedures in this manual (Sec. 2.40, page 6).

J. Stewart: That was an error on my part.

J. Bozanic: Instead of paragraph 2.40 about surface-supplied diving, I would recommend "line-tended diving may take place under the following conditions: one, a tether securely attached to the diver; two, hard-wire communication to enable the diver and tender to remain in voice contact with each other; and three, under circumstances deemed necessary by the researcher and diving officer."

Under paragraph 2.21, solo diving, add a phrase at the end that says, "except as provided in paragraph 2.40."

L. Somers: Let us make the distinction that there are two types of tethered diving. In one, the divers wear the air supply on their backs (tethered scuba). In the other, the air supply comes from the surface, and the only air supply with the diver is a very small emergency system. Some people are confusing that.

L. Austin: In the past there have been unsecured lines or tethers at the surface, such as a spool sitting on the ice. Has that been resolved in practice?

J. Stewart: I was not aware that it occurred. Is there a person topside?

J. Bozanic: But the end of the line is not attached to anything.

J. Stewart: We addressed that by putting a screw into the ice.

J. Bozanic: Under "termination of dive," subparagraph c says that no dive shall be longer than 60 minutes. This rule is based on thermal considerations, I suppose. Yet several people have snorkelers in the water for several hours at a stretch.

J. Stewart: I am not really concerned about the snorkelers. This particular document does not address them at all.

J. Bozanic: My recommendation is that a dive shall be terminated when the diver is no longer comfortable.

J. Stewart: No longer able to get out of the water. I used the longest period for which I could foresee a diver working under the ice.

J. Bozanic: On some dives I was very uncomfortable after 50 minutes, and on others I was still completely comfortable at 55 minutes. Oliver's group was diving for more than 60 minutes, and one assumes that they were doing it because they were comfortable in the water at the time. A hard-an-fast limit like this may not necessarily be the best way of going about it. I do not know what dive times one faces in the Arctic.

K. Dunton: They vary from 15 minutes to an hour and 15 minutes.

P. Dayton: We have all gone over an hour several times.

J. Stewart: I just picked a number because it seemed like a good one based upon what was going on.

J. Bozanic: Paragraph a, under termination of dive, states that diving should be terminated, usually, at 500 psi. I would prefer to see that changed to a volume standard. I would recommend something like 20 cubic feet, which in a single 72 would be the equivalent of 700 psi.

L. Quetin: In our experience, diving blue-water systems at an ice edge, we work at probably 30 or 40 feet. Terminating the dive at 700 psi really is not necessary. We cannot stay in that long, but we may want to leave flexibility in the system for dive planning rather than writing a hard rule.

J. Mastro: Dick Long made the point that for every rule there is a caveat. Hard-and-fast rules are not going to apply to every situation.

J. Stewart: Just put in "normally."

J. Mastro: Why not terminate a dive at 700 psi and then decide you want to sit right under the hole at 15 feet for five minutes?

J. Bozanic: There is a section in here that says diving should be conducted in accordance with accepted DPP guidelines, and, as discussed earlier, accepted DPP guidelines do not exist for specific modes of diving. Such guidelines probably ought to be developed.

J. Stewart: The modes were not included because they were not in existence. They were not being used.

L. Quetin: Regarding tethered diving, is there anything regarding the blue-water setup?

J. Stewart: The manual specifies that blue-water diving will be conducted in accordance with the blue-water guidelines accepted by AAUS.

L. Quetin: I have not been able to find it, but it must be included.

J. Bozanic: On page 3, there is a statement that diving equipment must be used under standards established by the AAUS. It does not specifically talk about blue-water diving from the regulations standpoint.

J. Stewart: We can certainly cite the literature and the means of conducting business. In section 1.22, I referenced the AAUS standards because those standards cover everything.

L. Somers: Is any semi-closed or closed-circuit system being used down there?

J. Stewart: No, but it is getting close.

L. Quetin: I would like to see some way that we could treat each dive program as a custom program in the sense that it receives review and help from the collective knowledge from previous programs, to assist in the design and make it better. We might implement that through the diving control board, especially for a new program coming on-line. Even older programs could be updated periodically if we had some way to distribute the collective information.

G. Staffo: From my previous experience at NASA, that is how we approached all projects. We called it a safety review process. The question here is are the PI's willing to do that review? The first phase is the proposal process, in which you submit your initial plan on your dive. The second phase would be upon approval. Then you would update and revise that plan. The third phase would be the review before deployment; this might be the orientation, whether it is at McMurdo, Palmer Station, or on the Polar Duke.

L. Quetin: We do that informally now. I have a sense that there is a lot of new information coming out, and it would be nice to find a better way to distribute it and look at the new equipment. Right now it is very difficult to incorporate new equipment into our dive programs because of the three-year funding cycle. For me to retool based on some of the findings of regulator performance would take a lot of money. I would be hard-pressed to do that. At the same time, we are not having any problems, so we have to see that point of view, too.

D. Bresnahan: Why should you do that on your science project? No one else buys regulators on a science project. They buy suits because they are tailored to the specific individual, but nothing else at McMurdo.

L. Quetin: Do they get to take their regulators home and practice with them?

D. Bresnahan: No.

L. Quetin: If I train graduate students to dive in the Antarctic, I like to train them in the equipment they are going to use. I like to train them in dry suits in a pool until they get it right.

L. Austin: With the actual equipment they are going to use in the Antarctic?

L. Quetin: Right. That is mandatory, or you have to spend a week on-site doing the same thing.

P. Dayton: At least at McMurdo, the existing pattern has been that if divers have not used double-hose regulators and dry suits, Jim takes them for several dives in the pool with the equipment that they will be using.

J. Stewart: That has always been the case. We have that written right into the statement that the campus diving officer fills out. The prospective Antarctic diver will be checked out and competent in the use of dry suits and double hoses, if necessary.

J. Bozanic: In the same section of the manual, it says that all equipment to be used in these places must be inspected by the DPP-approved NSF diving contractor, but that does not hold true in the Arctic, and it does not necessarily hold true at McMurdo. In addition, the manual states that the inspection should take place every six months.

J. Stewart: On long-term projects a diver should not spend more than six months in this environment without having gear checked by the on-site diver, if there is one. Obviously, it was also meant that at the start of the next austral diving program, the equipment should be inspected.

J. Bozanic: This will also pertain to Ken Dunton's situation in the Arctic, where there is no one to do that kind of inspection work.
J. Stewart: That is true. I did not know he was up there.

S. Bosch: Regarding diving under ceilings (sec. 2.22), it says that all dives outside of a shelter must be tended. Does this mean that dives within a shelter are not necessarily to be tended? It could be interpreted that way.
J. Stewart: You must have a tender wherever you are, but it is really necessary outside. A lot of people diving through a hole felt they did not need personal help getting in and out of the water. This could just be interpreted as that.
J. Bozanic: Perhaps we ought to change it to say that all dives should be tended by a surface tender.
J. Stewart: I think that happens anyhow.
J. Pearse: I do not know of anybody who cannot get gear in and out of the hole.
L. Austin: If the weather is a problem, the tender might be watching for changes in weather outside.
D. Bresnahan: Weather is more of a problem for the tender.
J. Bozanic: Should the diver-recall mechanism be included in the dive manual as a requirement?
J. Stewart: Sure. We always just stick a tank in the water and beat on it. That sound travels pretty well. Something more sophisticated just costs money.
J. Bozanic: A number of AAUS procedures have been promulgated that are not reflected in the DPP diving manual: the safety stop for 3 to 5 minutes at 10 to 30 feet, and the use of a BC with dry suits. Do we want to include those requirements as part of the diving guidelines for DPP, or should we include them by reference in the back, saying these guidelines should be followed until they are amended by other organizations?
J. Stewart: I have forwarded the conclusions and recommendations from each of the previous AAUS workshops so they would be available on-site.
J. Bozanic: In this manual, do we want to include those recommendations as separate appendices, since they did not exist when this manual was first written?
J. Stewart: I would think so.

J. Bozanic: Elements that are necessary for a dive team to know before they actually begin operations should be added to the on-site orientation for safety programs, regardless of whether the dive site is included as part of the predive approval process. Evacuation procedures vary when conducted in the Arctic versus McMurdo or Palmer Station.
L. Quetin: I would include that in a wider arena than just diving. Inform people what is possible.

J. Bozanic: There is one more issue that I personally do not approve of but that ought to be considered because, if it is a standing policy, it belongs in the manual. It regards having an operational chamber at McMurdo as a prerequisite for scientific diving. If that fact stands as a recommendation or a policy of the NSF, then it should be written into the guidelines as well.
J. Stewart: You mean that they are limited to diving only when that chamber is up and running?
J. Bozanic: That is what I understand the requirement to be.
M. Lang: Then you cannot dive at Palmer Station anymore.
J. Bozanic: If it is true for McMurdo, it should be stated in the DPP diving guidelines. The only written information that people receive when diving down there are these guidelines, and that needs to be stated in writing.
G. Simmons: None of the universities require an on-site operational chamber, and by virtue of reciprocity it is a moot issue.
J. Stewart: Who disagrees with no diving allowed if the chamber is not operational? (Unanimous show of hands by workshop participants).

M. Lang: One of the key missing items in this manual is the statement "The ultimate authority in the program..." It still is not clear who is in charge here. Is it Gary Staffo? Is it Jeff Bozanic? Or Jim Stewart? Every campus defines an ultimate authority, usually a dean or president. The DPP manual states nothing about authority. Without lines of authority, there is no accountability, etc.

J. Bozanic: I will argue that we can make recommendations, but the person who actually needs to make the revisions is the DPP diving officer, in conjunction with the diving control board.

M. Lang: Final approval and responsibility is still going to be by the final authority. Our expert recommendations to DPP will be more precise and applicable once that entity is identified.

G. Staffo: We are here to listen to the best advice you have to offer and to put forth recommendations to ensure safe diving in Antarctica. From this we will see which final result we can produce.

S. Kottmeier: My understanding is that each dive program is actually operating under a DPP reciprocity agreement with its home institution, much the same way a group using radioisotopes is using its university's license in the Antarctic to conduct experiments with those materials. Is that true?

J. Stewart: That is my understanding.

M. Lang: It is not that clear; Steve is asking if there is a written reciprocity agreement with another program.

S. Kottmeier: If Jim Stewart is evaluating each program, assuming that each dive officer and each institution has the expertise to evaluate a diver's ice diving skills, then he is deferring to that expertise, acknowledging that. He then extends privileges of that program to the antarctic program.

J. Stewart: That is exactly what I am doing by knowing all of the diving officers and how they conduct their programs. For years I did not have that prerogative. I had to interview each individual. Now most of the diving officers who are knowledgeable about this program are sitting in this room.

VIII. General Discussion - Michael Lang, Moderator.

L. Somers: I would almost rather see the discussion of closed-circuit and semi-closed circuit scuba left out here; instead we should include a simple statement that the subject will be addressed in a separate guideline. If the subject is put into this program, it will have to be redefined, because there are going to be some major changes.

B. Hamner: For blue-water diving operations, I think a sling might be useful on the Polar Duke for lifting injured or cold people out of small boats instead of trying to physically haul them up the ladder. It would not cost anything. It could be hooked up to one of the cranes. I also think the marine technician on the Polar Duke ought to have medical training of some sort.

D. Bresnahan: Is that because there is no one else on the Polar Duke who has adequate medical training or because the technician is an additional person who speaks English?

L. Quetin: Traditionally, the second mate is responsible for medical matters on the ship.

D. Bresnahan: Let us address the problem, then: the second mate's training is not adequate.

L. Quetin: If we had oxygen aboard the ship based with the second mate, the second mate would have to come up to speed on that. If we put it in ASA's province, the responsibility would be with the marine coordinator or the marine technician.

B. Hammer: If it is the second mate's responsibility, then NSF should require that person to be familiar with oxygen.

D. Bresnahan: The medical providers on the Polar Duke and the Nathaniel Palmer have to be trained for this additional requirement.

L. Quetin: Especially because I do not think you can expect divers going to the ship to be familiar with a particular system unless they have been trained on it ahead of time. We have to also think about how much oxygen is available on board a ship that is four and a half days from a chamber.

J. Stewart: There is a small rebreather that extends the oxygen life by large numbers.

D. Divins: That would entail a lot more medical considerations. Keeping a person on pure oxygen for three or four days creates some problems. For long-term oxygen in medical situations, they do not use over about 60 percent O_2 to get about the same effect. The importance of having additional medical training on board the Polar Duke probably applies here also.

L. Somers: When breathing O_2 for long periods, we take air breaks just as we would in the hyperbaric chamber.

P. Ponganis: To monitor somebody on long-term oxygen therapy, there are devices, fairly simple to operate, for monitoring oxygen saturation through a finger. The FiO_2 can be dialed down for correct oxygenation. For long-term situations such a device might be worthwhile to have. It would cost several thousand dollars.

D. Bresnahan: Are we in the realm of reality? The second mate of the ship is going to manage this?

P. Ponganis: The device works by itself, anybody can handle it.

C. Mitchell: The Merchant Marine and the Coast Guard provide medical consulting services via single sideband radio. It is handy to have some rudimentary facilities for treatment even if people on the vessel may not be specifically trained to use them. The physician on the radio can provide guidance. Medical Advisory Services (MAS) is one such support group.

B. Hamner: I think we all agree on the issue, and it is up to Dave Bresnahan to implement.

D. Long: Divers preparing to go to Antarctica should plan for adequate thermal protection, especially adequate hand protection. We have five-fingered gloves with woollen liners. People who do not smoke or drink much coffee do not have a lot of vasoconstriction in their hands, so their hands stay warm a long time. With respect to an engineering design for a human hand, we have created a human club. Yes, we can do it, but only because we survived the experience, not because it is an adequate solution. You might very well be satisfied with that particular solution, but I would not. I do not think we have yet dealt with realistic work capability of the individual. If your hands were warm, I accept they were warm.

J. Mastro: On occasion hands get warm under the circumstances. Keeping them dry is a major factor, and more dexterity would be useful. A lot of divers purposely use wet mitts or mitts that just do not stay dry. John Albers used mitts that were purposely wet. He put hot water in them before he got started, and was happy with that.

L. Somers: Pictures that I have seen of polar divers, as well as all of my search and rescue background point up the importance of predive management. I see too many exposed hands and too many people who have a thermal problem with their hands before going into the water.

D. Divins: Predive thermal protection in general should be carefully addressed.

D. Long: "Divers in polar regions should be proficient in the use of dry suits, thermal insulation strategies, and weighting, and they should be highly experienced with the particular system they are going to be using.

M. Lang: Taking everything into account that you have heard here, and considering your personal observations and experience, do we need to put something in writing about the issue of using a BC with a dry suit?

J. Bozanic: I would recommend two things. First, that the AAUS recommendation on using dry suits and BC's be endorsed for polar diving in general. Second, that in the particular circumstances of diving under solid ice with a down line to the bottom, the BC may be dispensed with based on the individual assessment of the diver involved.

M. Lang: Please rephrase the second recommendation; there is unanimous agreement on the first one.

J. Bozanic: As a special procedure for diving under fixed ice with limited excursion distance from the access hole and with a down line to the bottom, the BC requirement could be dispensed with, based on the judgment of the diver involved.

D. Long: I can think of several other circumstances in which you might want to eliminate the BC, not just that one. Tether diving all by itself would qualify well. "It is recognized that conditions may exist in which by the judgment of the diving supervisor or principal investigator, the diver would be more at risk with a buoyancy compensator than without one. Under these circumstances, the use will be at the discretion of the diving supervisor, diver, or principal investigator." Simply leave it open so that we have recognized in advance that conditions could exist in which a diver will not want to use a BC with a dry suit, and then allow the individual on the scene to make that judgment call. At least this gives the authority to make that decision.

J. Stewart: There is a statement in our AAUS manual: "Each diver shall have the ability to achieve and maintain positive buoyancy." Is this not what we are after?

D. Nagle: We do, though, have some statements in our other documents stipulating the use of a BC with a dry suit. What I like about Dick Long's statement is that it makes the individual responsible for the decision. The decision is not based on convenience, but on the diver's judgment. It is actually less safe down there with the BC than without it.

M. Lang: The question then arises as to the responsibility of the Diving Officer.

D. Nagle: If I have done a good job in training the divers to use their own judgment, the responsibility is exactly where it should be, on them.

L. Quetin: I see one practical problem with that. In writing a grant and requesting funds for diving, when I submit a proposal and a budget, do I include buoyancy compensators?

D. Nagle: The recommendation is in two parts. Generally, we recommend using BC's with dry suits, but under some circumstances, you may choose not to use a BC. You should be prepared to use both.

L. Quetin: In other words, write BC's into the budget. Another problem is that different people require different size buoyancy compensators. Should I recruit scientific staff based on the size BC that is available?

L. Somers: There are many ways to handle that now, with some of the new systems.

M. Lang: Dick, will you please reread your statement and fill in the blanks?

D. Long: "It is recognized that conditions may exist in which in the judgment of ...

M. Lang: Judgment of whom?

P. Dayton: Why not just leave that without anything? In the end it is pretty obvious diver are responsible for their own safety.

M. Lang: "It is recognized that conditions may exist in which the diver would be more at risk with a BC than without one."

P. Dayton: In which case the diver would not wear one.

K. Cutlip: In which case the BC is not required. That way you are not giving anyone responsibility; you are not pointing the finger at anyone who does not wear one.

P. Dayton: The way the whole game is played, it is the diver who has responsibilities all along.

C. Mitchell: But when he dies, the responsibility is no longer his; it is yours and the institution's.

J. Stewart: Our manual already specifies a lead diver. The lead diver is the senior diver on each dive. It seems to me he is the obvious choice if you have to put a name on it.

P. Dayton: Not unless it is, for some reason, legally necessary to put one there.

K. Cutlip: "It is recognized that conditions may exist in which the diver may be more at risk with a BC than without one, in which case a BC will not be required."

J. Stewart: That sounds good to me.

C. Mitchell: That does not really make it clear who is making the decision. It is just recognizing that the diver may be put at risk. Somebody has to be responsible for that.

J. Stewart: I still think it is the lead diver on a particular dive who should have that authority and responsibility.

C. Mitchell: Rather than the individual?

J. Stewart: That is why there is a lead diver.

C. Mitchell: I have a problem with that.

L. Austin: The lead diver makes all the decisions, so you do not have to put it down.

K. Cutlip: An individual diver may really feel comfortable going without a BC, so it should be his decision.

L. Quetin: Then he does not dive.

C. Mitchell: We have always made the point that a scientific diver who feels the conditions are not safe has the option of not making a dive. He has not generally been given the responsibility of choosing and collecting the gear, deciding how it will be used, etc. We are now proposing to deviate from that to some extent.

P. Dayton: Not very far though.

M. Lang: Yes we are. If I want to use a single-hose regulator that free-flows, would I now be able to, according to this line of thought?

C. Mitchell: Exactly right. Suppose I do not want to use swim fins, and I think I will just use a wet suit rather than a dry suit. A diver might go to NSF: he does not want to use these jackets and boots; he has got some other things from Patagonia.

L. Austin: It is always assumed that the diver is really the one who is in charge of his equipment and himself in the final analysis. People in the system are helping him, training him, and so forth, but the diver makes many decisions on a moment-by-moment basis as to what he wears and what he does.

K. Cutlip: The lawyers will be the ones who decide whom they are going to sue. Why should we give them a name to start with?

J. Bozanic: How about adding a recommendation under BC's and dry suits, something along the lines of "It is recommended that continued data be collected on the performance of BC's and dry suits in polar conditions."

D. Long: That would need another workshop for sure.

D. Divins: The way the recommendation is worded, it sounds as though the diver would be at more risk with the BC. Does that mean he is at risk without it? Is he still at risk every time he goes in the water?

P. Dayton: When he flies in the airplane to get there, he is at pretty serious risk.

J. Mastro: What is the risk of wearing a BC that has no air in it?

L. Quetin: Parasitic drag or entanglement.

P. Dayton: We do not have to make litany of all the risks.

D. Long: I have been studying the liability issues. Wherever you can, state that diving is a risky venture. Use the word risk; use the word death. Use those words as often as you can. By doing so, you will have said up front that it is there. The more often you write it down, the less likely it will be that someone says, "you didn't tell me", because it is right there in black and white. The more often you state it, the more defensible a position you will have. That is why I gave you those manuals, for the warnings they contain. If any apply to what you are doing, please feel free to use them.

M. Lang: "It is recognized that conditions may exist in which the diver would be more at risk with the BC than without one. In such case, a BC will not be required."

J. Stewart: Are there any recommendations regarding diving cylinders or valves that we should consider?

L. Somers: I did not see anything in these guidelines referring to the redundant systems that we have talked about, such as dual regulator systems or slingshot valves. Should there be some statement in the guidelines about that?

L. Austin: I would think so if we are going to use redundant systems. They were not discussed until this workshop and the DPP manual was written a year ago.

J. Bozanic: "When scuba systems are used, redundant air supply mechanisms should be included as part of that system." In other words, a dual valve manifold or a slingshot valve for a pony bottle, sufficient to get the diver back to the surface.

D. Nagle: Maybe we should add a statement to the effect that "Due to the tendency for scuba apparatus to free-flow under polar diving conditions, it is recommended that redundant systems be employed." Then, maybe state that a minimum redundant system consists of two complete regulators.

P. Dayton: Or you will die.

S. Kottmeier: "Due to the tendency for scuba apparatus to free-flow." Are you talking specifically about first or second stages?

M. Lang: "Due to the tendency for scuba apparatus to free-flow under polar conditions, a minimum of two full regulator systems is recommended."

P. Dayton: Is that necessary out in the blue water?

L. Quetin: No.

P. Dayton: I think we need it under the ice.

L. Quetin: We are shallow and we are over 20 and 30 feet away from getting to the surface.

J. Stewart: Then we state that as "under-ice diving conditions.

S. Kottmeier: Do you want to use the word <u>tendency</u> versus <u>potential</u>? <u>Tendency</u> indicates that this will happen all the time.

D. Nagle: It does happen all the time.

S. Kottmeier: In which case, would a redundant system be of any use?

G. Staffo: We certainly do not want a single-point failure that results in a catastrophe. Secondly, we do not want common cause failure. We do not want two of the same systems that will fail in the same manner; so we really would not have redundancy. We ought to have something independently redundant. How to achieve that and to what extent, I leave to the experts.

D. Divins: To have a redundant system, we will have to change all of the valves at Palmer Station.

M. Lang: No recommendation for the cylinders. Anything else on regulators?

S. Jewett: Are there any regulators that are not approved?

J. Stewart: Rich Harbison indicated that the Sherwood Blizzard free-flowed every time he used it.

C. Mitchell: Bozanic and Mastro showed many 100 percent failures of regulators when used only three or four times yet free-flowing every time.

J. Bozanic: Harbison's data on that particular regulator were called into question by some of the other people on that cruise. I would be hesitant to state that something is not recommended as a result of a study citing evidence from only three dives. For our study, we did not have enough diving history for some regulators to be able to make any kind of recommendations. There were none we could recommend not to use. There has to be more evaluation of all regulator systems in the polar environment.

B. Hamner: If a regulator does not work, do not use it.

M. Lang: One thing we did not cover in great depth is regulator maintenance and use, for example, "do not exhale into the regulator before immersion or do not dip it into fresh water." I am looking for a recommendation to minimize the risk of freeze-up.

J. Bozanic: "To minimize the possibility of failure of regulators in polar conditions, proper care and maintenance should be provided."

L. Somers: I think that keeping the regulator dry before and after a dive has to be specifically stated.

M. Lang: "To minimize possibility of regulator freeze-up, proper predive and postdive care should be adhered to."

L. Austin: For a recent expedition of 12 people to the western Pacific, we had accepted four regulators that had been overhauled by sources outside the university. All four of those regulators failed on the trip. If we can say something to the effect that regulators should be completely cleaned and overhauled, before they are sent to the Antarctic, I think it might help.

J. Mastro: Our experience was that regulators that came from outside sources failed more often than the ones we repaired or maintained on-site. Our recommendations are contained in the paper that we have submitted to you for these proceedings.

L. Austin: Would you not rather have them completely cleaned and overhauled before they come to you?

J. Mastro: Absolutely not.

J. Bozanic: Absolutely yes. I would much rather have a regulator with new parts arrive at McMurdo.

J. Mastro: I am saying that if it does malfunction, I do not want to send it out for repair; I want to repair it myself.

L. Austin: Would you not want to receive one that is overhauled by a university laboratory, in perfect condition, with the intermediate pressure tested?

L. Quetin: At Palmer Station regulators are bought on a polar grant. They are about five or six years old. We do not get new ones there.

L. Austin: Don't you have to completely tune the regulators and work with them if they are brand-new?

J. Mastro: When they come in new, we test them. If they work, we issue them. But, we find that the new ones fail more frequently. Of course, there is no point in taking a regulator completely apart and putting it back together if it is working.

M. Lang: Are there any specific recommendations for surface-supplied systems?

G. Simmons: Perhaps only to modify the DPP dive manual to accommodate tether and surface-supplied diving.

J. Bozanic: The performance standards presented here for single-hose regulators are on a par with double-hose regulators and should be approved or acceptable for regular use in polar diving.

M. Lang: Shall we list name brands or models?

J. Bozanic: I would just leave it as is.

S. Bosch: I think we should qualify that conclusion, because the failures that you have referenced in the double-hose regulator system can be attributed not necessarily to weather or cold. Clearly, they happen within the first minute, and the same problems could occur in the tropics.

J. Bozanic: I am not saying that double-hose regulators can no longer be used, but the prevailing thought is that double-hose regulators are better than single-hose for polar diving.

S. Bosch: But they are better in terms of the design themselves.

L. Somers: No more double-hoses are being manufactured so it is a moot point.

L. Quetin: I recommend that we just forget the whole issue.

P. Dayton: As long as we do not legislate them away. We treated them poorly in the 1960s, and no wonder they are worn out now. They worked beautifully. The ones we are using now are fragile. In principle, Sid is right. When they were really new, the double-hose regulators were resilient, good pieces of equipment and much better than the fragile ones we have now. But they are not available anymore, so it does not matter.

K. Dunton: Should there be a requirement for some predive suggestion of what communications will be?

J. Stewart: Theoretically, that happens in the briefing phase. When you brief people before the dive, that is one thing that you should talk about.

K. Dunton: If I do underwater ice work, I consider it critical. It should be mentioned that that specific topic was discussed. If there are wire communications, fine. What if they break down? What is the backup? They break down all the time; so does wireless communication. If you do not know your line signals, then you are very inefficient.

M. Lang: "Dive team leaders shall brief divers on alternate methods of communication."

J. Pearse: It could be inserted on page 7, Sec. 2.51(2).

M. Lang: For shipboard diving operations in the Antarctic, we have discussed some of the UNOLS materials. Bill Hamner also made two recommendations that, at the least on Polar Duke, a sling be installed to hoist divers to the ship, and additional medical training be required for the second mate.

L. Quetin: I would recommend that particular attention should be given to discussing and integrating the dive plan and the shipboard operations with the captain, possibly involving the lead diver.

C. Mitchell: The UNOLS materials contain a detailed discussion, a checklist of what goes on between the lead divers and the ship's operational personnel.

L. Quetin: I am a little concerned about the setup on the Polar Duke, in that we have a marine coordinator on board. I consider it important to make sure that the chief scientist or the lead diver deals directly with the captain and does not go through another step. Usually when I go on board, I talk about that with the marine coordinator. We want to keep the lines of communication as short as possible, for speed and accuracy. "The lead diver should deal directly with the captain of the vessel in developing the dive plan for a cruise."

M. Lang: Are there concluding thoughts on the blue-water diving guidelines?

J. Heine: I do not feel that anything additional needs to be written.

M. Lang: Are there comments about methods of transport?

K. Dunton: "A more efficient means of transportation, *e.g.*, rolligons, should be investigated for transportation across rough ice, rotten ice, or thin fast ice."

M. Lang: The next topic concerns training and certification requirements.

J. Stewart: "Divers shall be trained and experienced in the equipment to be used during their polar dives."

L. Quetin: "Before deploying to the Antarctic," because training somebody in gear down there is difficult.

J. Stewart: That is already covered by the fact that the campus diving officer certifies that divers are trained and competent in the use of whatever equipment they will use down there.

M. Lang: "Divers shall be trained and experienced in the particular dry suit they will be wearing for polar diving."

D. Long: There are numerous course outlines around, including one of our own for training divers to use dry suits. DUI's course is not designed for training divers for the Antarctic or for any ice diving. To my knowledge, there is no course outline for truly training divers who are switching from a wet suit to a dry suit, all the way up to ice diving. It might be a project for someone in the AAUS to come up with such a course outline.

M. Lang: That is a good point. We do not have anywhere, really, a training outline. The DPP policy manual includes nothing about training. I think workshop participants agree that we should recommend that a course outline be developed specifically for polar diving training.

L. Austin: Absolutely.

J. Stewart: I agree.

D. Long: Lee Somers has got the closest thing to it, but I do not know how Lee feels about its completeness.

L. Somers: It is not complete for the polar region, but it is a start.

D. Long: Dry suit certification, at least as far as I know, is a nonspecific issue. It is very vague and nebulous and could entail five minutes in a swimming pool or a 50-hour program. I would like to see a sharper focus than that.

J. Bozanic: "Before beginning diving operations at McMurdo, all dive team members should participate in an on-site diving orientation." I am talking about a program to be developed for the diving group by some person on-station. I am talking about a general, overall briefing for the dive teams before they deploy to the field.

G. Staffo: There should be training for tenders about their responsibilities: communications, line tending, and emergency response are probably the key ones.

J. Mastro: We had a requirement that all tenders be certified divers, whether or not they were approved to dive in the Antarctic. We felt more comfortable with that.

D. Bresnahan: I do not think you can require that.

J. Stewart: That is not really necessary.

B. Hamner: We often use shipboard personnel as dive tenders in small boats. I would rather have an experienced seaman than a diver up there.

L. Somers: I have always felt that any tender has to be qualified to properly administer aid to a diver who might be injured, so tenders must be versed in appropriate first aid procedures. They should also be able to identify and deal with equipment problems. I heard complaints about using a tender who is a boat operator but has no knowledge of diving and no first aid capability. Is there any comment on this?

P. Dayton: That is adequate because divers have buddies who have been through all of the rest of it. The boat operator needs to get the boat back, and my buddies do not know how to drive that boat. They can take care of an injured diver.

J. Pearse: All dives conducted outside a shelter must be tended. From a shelter, two people can go diving.

P. Dayton: Having a tender is a good idea, but I do not think that the tender needs to have a number of qualifications.

D. Bresnahan: That question has been batted around a lot. Should it be allowed for two people to drive out to their hut and both jump in to the water to go diving, with nobody on the surface?

B. Townsend: No.

P. Dayton: I think we changed it. How much authority must we write into this, and how much common sense can we allow the dive team?

M. Lang: What we are really looking for is any new or additional information for a concrete recommendation. Some of these things are straightforward and are done anyway.

L. Austin: Historically, the tender was another diver who was going to be underwater on the next dive, when the first diver would be topside manning the pump, so there was good reciprocity between the two people. We need a competent tender, someone who really understands diving problems, so the people below are not at risk because somebody is not looking or thinking.

C. Mitchell: In the Arctic you will need a large brown dog to keep the bears away.

B. Townsend: You have to make sure that the dog does not come to you when the bear comes to him.

J. Mastro: How does everyone feel about under-ice diving in McMurdo? If a tether is used, should it be an L-shaped system? One diver communicates directly with the surface, controls the tether line, and prevents it from getting wrapped up. The other diver does the main work.

K. Dunton: So you are working at 50 percent efficiency? One diver watches; the other does the work. Why can a diver not handle the tether and do his own work? We have done it that way for a long time and never had a problem.

L. Somers: We are talking about two different types of diving here. One team has full mask and hard-wire communications and redundant scuba, and works independently. The other group is a scuba buddy team.

L. Quetin: I want to say something recognizing the unique needs of each scientific project, and that the development of each project should somehow take advantage of the collective knowledge of other polar divers.

G. Staffo: What concerns me here is that I put a lot of faith into planning the dive and assessing the hazards ahead of time. Then right before the dive these specific safety precautions have to be included. Risks have to be assessed based on the nature of each day's dive plan.

K. Dunton: Each method is developed because of different research needs on the bottom. Normally we cannot work together because of problems with visibility and stirring up sediments. We are doing rather sensitive work.

L. Quetin: Those conditions are known before a person ever goes to the Arctic, so that if there is some way of developing a dive plan, money would be available for Ken to get together with Jim and your diving officer.

G. Staffo: You can plan ahead, and say you are going to do this dive during this period, expect these water conditions, this visibility, and these currents and this is the method you plan to use. But when you arrive there and go into the hole, you find that those are not the conditions. Then what do you do: how do you change the plan, and who approves it? Nobody.

L. Quetin: The diver who is there can say he will not dive or it is too risky. I think if we have collective knowledge based on many different opinions instead of going down there relatively blind, a diver can make a better decision. But at the site you have to depend on the divers.

S. Bosch: Are we recommending tethering for every under-ice dive?

J. Pearse: When you cannot find the hole, you put a tether on.

P. Dayton: There are times at McMurdo when the current is strong enough that you do not dive.

J. Pearse: When you look at an area where there might be a current, you put a line down.

P. Dayton: Sometimes you abort your dive.

L. Quetin: There has got to be a way for such knowledge to be transferred to a new group going down there.

L. Somers: "If you are deploying a diver to work independently, then that diver shall be equipped with full face mask, voice communications to the surface, and redundant air supply capability."

J. Stewart: How about dive plans and safety recommendations?

J. Bozanic: "Although recompression chambers are beneficial and add a margin of safety to diving operations, the immediate presence of an operational recompression chamber should not be required for conducting scientific diving."

C. Mitchell: A chamber provides a treatment, but it does not add a margin of safety.

J. Stewart: I would agree with that.

M. Lang: "Although recompression chambers are beneficial, the immediate presence of an operational chamber should not be required for scientific diving."

J. Mastro: "The dive management accident plan and emergency response system should be exercised with regular drills."

J. Bozanic: How about the assumption of risk waivers for NSF/DPP divers or research divers?

D. Bresnahan: If we are talking about asking a diver to sign a form that absolves anybody of responsibility, the lawyers will laugh at you hysterically as they throw you out the door, because you cannot sign away the rights of your estate. After you die, anybody in the line can sue anybody else, regardless of what you sign.

D. Long: That is accurate, but not anybody can sue anyone for anything. Whether or not you win is not the story. The issue is not can you sign away your life; you cannot. But you can establish whether a person has or has not been informed of a risk and the right to accept the risk. Have the person made an informed decision? Then you can agree by contract what will be done if something does happen, and in this particular case, we recommend arbitration as a viable alternative approach. Can anyone sue you? Yes, they can. Will they laugh at you? Of course they will. But they will do so at their own risk. Most lawsuits that are filed do not win. We do. It is simply the small percentage that win and get big awards that we hear about.

D. Bresnahan: When someone declines to sign, is he or she not allowed to dive?

L. Somers: A person who is not willing to accept the risk should not dive.

J. Stewart: We have a "court-tested waiver" that was used by the University of California two years ago. That particular document was upheld in court. A person had been informed of the hazards and the inherent risks in diving. The diver died, and somebody sued and lost. The judge concluded that this person was fully apprised of the inherent dangers of the sport, and threw out the case.

G. Staffo: How many universities represented here require their divers to sign such forms?

L. Austin: If that is our standard waiver, employees cannot be asked to sign. They will throw you off the campus.

M. Lang: In the federal government you cannot either. The only divers the Smithsonian asks to sign waivers are outside people who are not federal employees.

C. Mitchell: We do not have employees sign a form, but we do have guests that come aboard the ship sign it.

B. Townsend: We make graduate students and visiting scientists sign a waiver at Fisheries and Oceans in Canada.

G. Staffo: We do it in the form of medical waivers. We notify that they are assuming a risk, ask them to sign, and notarize it.

J. Stewart: Would that be appropriate for us to ask our diving group to do?

G. Staffo: We can do this in almost every instance of what we do in general for going down to the ice.

D. Bresnahan: This goes back to the old Air Force hold-harmless agreement that you signed before getting onto the airplane.

D. Long: The legal environment that exists today is very different than it was five years ago or even three years ago. Things that were thought true then got thrown out because judges in the state of California chose to make law as opposed to having it come through the normal system. Because the tort system is what it is, other decisions were made that reversed some of the earlier ones. I only know that waivers have held up, and the key appears to be that informed consent did exist. Did the person know and understand what the risks were? Did the person willingly accept those risks? And did the person sign a waiver including gross negligence? Those waivers have held up in court in diving situations. With the addition of arbitration, at least so far, this has been a good deterrent. If you do nothing but deter a lawsuit, you have won.

D. Bresnahan: If the workshop wants to add that as a recommendation for NSF/DPP to pursue with legal counsel, fine.

D. Long: I suggest not putting it in as a recommendation. I would say it is in this group's interest to put some background information together, develop it, and take it to somebody after we have developed it.

G. Staffo: I believe that to a certain extent that should be part of the first statement here. "I have read this, I am aware of this, I am cognizant of the risks, I sign this off and date and notarize it". People could not dive until they did that. I am not ready for that route now, because I am already having trouble getting basic information from the principle investigators about just what they are going to do. But from the point of view of risk mitigation, that is what your legal people like you to do.

M. Lang: Are we creating legal waivers for NSF's Division of Polar Programs? That is something that has to be generated by DPP's general counsel.

J. Stewart: I recommend that there be an addition to the foreword of the manual stating that there are inherent risks in antarctic diving.

P. Ponganis: The single diver regulation relates directly to our project. I would not like to see this prevent us from doing our cage dives, as limited as they are. Is there a way to provide an exclusion for them? We are making leopard seal observations from a cage about 10 to 15 feet deep. The diver is inside the cage and using a surface supply of air. There is a line tied to the diver.

J. Stewart: That is communication.

P. Ponganis: I do not want to be running into problems with this in the future.

M. Lang: You are approved in the Scripps diving program.

J. Stewart: I do not think there is a problem with the kind of diving you are doing, while somebody is standing there looking at the top of your head.

G. Staffo: "Defining the authority, responsibility, review and approval of dive plans shall be specified in the guidelines for conduct of research diving."

S. Kottmeier: Do we have a date in mind for the revised DPP dive manual?

M. Lang: The proceedings of this workshop will be separate from revisions to the dive manual. Whoever is in charge of that manual should consider the recommendations from this group.

S. Kottmeier: Will the manual be revised for use in the coming season?

J. Stewart: Yes, it will. As soon as I receive recommendations to be included in it, I will incorporate them.

G. Staffo: I would like to see a recommendation addressing the panel of experts or diving review board, and the composition and establishment of such.

M. Lang: Currently, NSF/DPP does not have one, as required by OSHA for scientific diving.

J. Stewart: The diving control board shall be instituted under DPP in accordance with the criteria set forth in the manual. Since you are going to appoint the board, Gary, I will send you my recommendations.

D. Bresnahan: I recommend that this forum become an annual, but somewhat downscaled, meeting. The best time would be after the austral summer.

J. Stewart: I agree with that. The other thing I would like to see happen is that the cognizant diving officer, including the diving safety panel, be allowed to go down to the Antarctic to look at things.

G. Staffo: I would also like to see some recommendations about the scope of the panel's coverage. I need to know how this panel relates to the individual institutions and to the diving safety officers.

D. Divins: It seems that most of the folks who are here have been at McMurdo. Someone could be brought in from Palmer Station to provide more input on what should be done there.

L. Quetin: For instance, a lab manager from Palmer.

D. Bresnahan: Normally, we have enough of an operation for a full-time person at McMurdo, but not at Palmer.

L. Quetin: I would bring a marine coordinator and a lab manager. We had some problems with the marine coordinator on the ship last season. He thought the diving operations were his responsibility, so we had to work that out. If he were aware of the process here, then the lines of authority would become clear. The more familiar these people are with this operation on the ship or at the station, the better the communication.

D. Bresnahan: The Polar Duke and soon the Nathaniel Palmer are supposed to be operated under UNOLS guidelines.

M. Lang: Is that fact? From UNOLS we understood that they had nothing whatsoever to do with Division of Polar Programs, that the operations were totally separate . That is one of the main reasons I sent all participants the UNOLS Shipboard Diving Safety Proceedings to evaluate how applicable they would be to polar diving.

G. Staffo: In about two weeks we are going to have the first preseason peninsula/Palmer Station conference, and one issue that will be discussed is the UNOLS diving workshop. This will give us an opportunity to raise some of the questions and concerns I have heard here about the authority and the diving operations.

J. Bozanic: Jim Stewart has raised the question both in the past and at this meeting of having an operational meeting of applicable dive officers down on the ice to review procedures and training. Should we add a recommendation for a project like that?

D. Bresnahan: The Division of Polar Programs would be glad to entertain that request if Jim wants to organize it and send us a letter. We will be glad to put it in the pile with the thousand other people who would like to visit McMurdo. We will see what we can do. We have to organize a few things to get us into position so that when Jim retires, we will not have lost the on-site expertise of people who know how the infrastructure works in the Antarctic.

J. Stewart: The AAUS dive computer guidelines, safe ascent recommendations and repetitive diving guidelines will become appendices in the DPP dive manual.

D. Bresnahan: The DPP manual is a guideline. ASA has been tasked to develop a manual. If we try to incorporate too much material in a guideline, it becomes a manual.

M. Lang: ASA is developing a training manual?

D. Bresnahan: Not a training manual, a procedures manual similar to Lee Somer's handbook.

L. Quetin: We should add something to address the development of dive plans for new projects, to incorporate the collective expertise in the area. Currently, we do not have a good system for getting information from Paul Dayton and John Pearse about what they encounter. Their experience could make a difference to somebody new who is going down to dive. There could be a workshop format such as this.

J. Stewart: That issue will fall into place with the review process we are talking about. A new kid on the block can be sent to a person who has been there before for review and comment, which would simplify the process.

G. Staffo: How many of the PI's are using laptop computers at their dive locations and find them amenable not only for recording their scientific data but also for dive logs and other information?

J. Stewart: Last year I recommended that we explore the possibility of dumping dive log information right back into the central computer, wherever that may be. As people complete their dives at end of the day or week, they could just enter data and not have to file a piece of paper.

J. Mastro: I agree with the idea, but I also think a hard copy is a good thing to have, because magnets can erase a lot of data.

D. Bresnahan: There should be no reason why the dive technician could not have an electronic mailbox at McMurdo so that any investigator could submit that information.

IX. AAUS Polar Diving Workshop Recommendations

1. The importance of predive thermal and hand protection should be carefully considered during polar diving activities.

2. Divers in polar regions should be proficient in the use of dry suits, thermal insulation strategies and weighting, and should be highly experienced with the particular system they are going to be using.

3. The AAUS recommendation that a dry suit be used with a buoyancy compensator is endorsed for polar diving in general. It is recognized that conditions may exist in which the diver would be more at risk with the buoyancy compensator than without one. In such cases, a buoyancy compensator will not be required.

4. It is important that continued data be collected on the performance of regulators, buoyancy compensators, and dry suits in polar conditions.

5. Due to the tendency for scuba apparatus to free-flow under polar conditions, a minimum of two full regulator systems is recommended.

6. To minimize possibility of regulator freeze-up, proper predive and postdive care should be followed.

7. Dive team leaders must brief divers on alternate methods of communication.

8. A sling should be installed on deck, capable of hoisting a diver from small craft to the research ship.

9. Additional medical training and proficiency in oxygen administration should be required of the second mate aboard polar research vessels.

10. The lead diver should deal directly with the captain of the vessel in developing the dive plan for a cruise.

11. A more efficient means of transportation (*e.g.*, rolligon) should be investigated for transportation across rough ice, rotten ice, and thin fast ice.

12. A course outline must be developed specifically for polar diving training.

13. Before beginning diving operations at McMurdo, all dive team members should participate in an on-site diving orientation.

14. A tethered diver who is deployed to work independently, must be equipped with full face mask, voice communications to the surface, and redundant air supply.

15. Although recompression chambers are beneficial, the immediate presence of an operational chamber shall not be required for scientific diving.

16. The dive management accident plan and emergency response system should be practiced with regular drills.

17. The foreword of the DPP dive manual will include the statement that there are inherent risks in antarctic diving.

18. The authority, responsibility, review, and approval of dive plans shall be clarified in the DPP Guidelines for Conduct of Research Diving. A DPP Diving Control Board shall be composed with an established charter and defined charge and scope of authority to review and approve polar diving projects.

19. This polar diving forum should become a down-scaled, annual meeting, convened after the Antarctic austral summer season.

20. The AAUS dive computer guidelines, safe ascent recommendations, and repetitive diving guidelines should become appendices to the DPP dive manual.

21. A mechanism should be established for developing the dive plan for new projects to take into account the collective operational expertise in that area for that particular project.

22. A few scientific diving programs should be evaluated for their capability of providing cold water and dry suit diving training for USAP participants who lack this experience.