DIVER EDUCATION SERIES

Under Ice Scuba Diving

Lee H. Somers

Michigan Sea Grant College Program

MICHU-SG-86-500

DIVER EDUCATION SERIES

Under Ice Scuba Diving

Lee H. Somers

Michigan Sea Grant College Program

MICHU-SG-86-500

This publication is the result of work sponsored by the Michigan Sea Grant College Program with grant NA85AA-D-SG045 from the National Sea Grant College Program, National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, and funds from the State of Michigan.

Ordering information for additional copies of this publication can be obtained from: Michigan Sea Grant Publications, 2200 Bonisteel Boulevard, The University of Michigan, Ann Arbor, Michigan 48109; 313/764-1138.

Dr. Lee H. Somers is Assistant Professor, Division of Physical Education, and Associate Research Scientist, Department of Atmospheric and Oceanic Science, The University of Michigan. He is also Michigan Sea Grant's Extension Specialist in diver education, diving technology, and aquatic accident management. Dr. Somers' 30-year diving career has included commercial, saturation, research, polar, cave, and ocean diving, and directorship of a hyperbaric chamber facility. He is a certified diving instructor, including Ice Diving Specialty Instructor rating. His research and travels have taken him from the Canadian Arctic to the Mediterranean and Africa to Central and South America and the Caribbean.

TABLE OF CONTENTS

UNDER ICE SCUBA DIVING

Lee H. Somers, PhD

SECTION 1

INTRODUCTION

Scuba diving under ice has become a popular winter time activity for many cold climate recreational divers. In addition, there is an increasing interest in cold water and under ice aquatic science research. The ever increasing interest in "frozen lake" recreational activities such as ice diving, ice fishing, snowmobiling, ice boating, skating, and cross-country skiing has also developed new response requirements for the **public safety or dive rescue teams.** The potential survivability of a person submerged in very cold water has been well documented. Children have been successfully resuscitated with no apparent neurological damage following 30 minutes or more of complete submergence. Many **dive rescue teams** now operate in a **rescue mode** for up to one hour following the known or suspected time of victim submergence.

Ice diving, whether for recreation, research, or rescue/recovery, is certainly not without some added risk factor in comparison to conventional open water scuba diving. The inherent complications associated with extreme surface exposures, thermal stress on the divers, equipment function/malfunction under extreme cold conditions, ice cover, cold climate logistical support, and so on place unusual demands on the dive team. Of increasing concern is that **over enthusiasm** on the part of "macho" divers and instructors tends to lure unsuspecting novice divers into situations beyond the capability of their equipment, training, skill, and experience. Public and departmental "pressures" may force the poorly equipped and untrained public safety diver into unacceptably **high risk** situations.

In my previous technical publication on this subject, <u>Cold Weather and Under Ice Scuba Diving</u> [1], I stated that I **do <u>not</u>** advocate ice diving as a recreational activity. This is simply a matter of "risk benefit!" I personally do not feel that the reward is worth the risk. However, I must continue to accept the realities of the "world of sport diving" and the desire of the individual diver to participate in "high-risk" adventure sports. Furthermore, I recognize the **need** for improved training and operational requirements for **public safety divers.** Consequently, I hope that the knowledge gained from my personal experience and research will be beneficial in the promotion of safer ice diving practices.

DIVER QUALIFICATIONS

All scuba divers should follow a **logical progression** in the acquisition of advanced training and diving experience. In order to **qualify for ice diving** training, I feel that the recreational diver should hold at least an Advanced Openwater Scuba Diver Certification and have completed no less than 50 openwater scuba dives under a variety of environmental conditions. Public safety divers should have completed Level III training and have a similar experience record. I recommend that the diver acquire initial experience in warm weather diving and progress through a series of more demanding "cold weather" open water diving exposures prior to ice diver training. I am well aware of the fact that the waters of the Great Lakes area are extremely cold below a depth of 30 to 60 feet even during summer months. However, the diver must also acquire **progressive experience** in dealing with **cold surface conditions.** I suggest that the greatest potential cause for an ice diving accident **originates** at the surface during pre-dive preparation and exposure of the divers and equipment to thermal stress.

I am an advocate of reasonable levels of **physical fitness** for all divers, regardless of diving conditions. However, the cold weather diver can be placed under unusually high physical, emotional, and thermal stresses. A "physically fit" diver can generally deal with stressful situations better than an "physically unfit" diver. I recommend that the diver maintain an **minimum** fitness level of Catagory III (Fair) on the "Cooper 12-Minute Aerobic Swim Test" [2]. This means that the male diver (age: 20-29 years) must be able to swim at least 500 yards in 12 minutes; 400 yards for female divers. All divers and applicants for training must be medically qualified for diving in accord with state occupational health and safety standards (where applicable) or accepted standards for scuba diving [3]. The nature of ice diving also requires a careful analysis of the diver's emotional, tempermental, and intellectual fitness. Recklessness and emotional instability are serious liabilities for both the diver and other members of the team. Individuals who tend to panic or become confused in stressful situations may find ample opportunity to do so under the ice; claustrophobic tendencies are certainly not compatible with ice diving.

TRAINING

Even the highly experienced open water scuba diver must have specialized training in ice diving techniques and participate in properly supervised ice dives. Ice divers must be familiar with specialized equipment, the nature of equipment malfunctions resulting from exposure to extreme cold, the physiological implications of cold stress, first aid for those injuries characteristic to operating in sub-freezing environments, and maintenance of thermal comfort both underwater and on the surface.

Recreational and scientific divers can enroll in speciality courses conducted under the standards of the National Association of Underwater Instructors (NAUI), Professional Association of Diving Instructors (PADI), or equivalent organizations. The "sample" course outline that I prepared for NAUI which required 12 hours of classroom, 3 hours of pool, and 16 hours of actual ice diving training is included in this manual (Section 8) [4]. Instructors and prospective ice diving trainees are encouraged to review this course outline which may be acquired from NAUI. Scientific divers will generally receive special training through their university diving safety program, especially if they intend to work in polar region.

Public safety divers can enroll in special programs designed for rescue/recovery personnel and conducted by Dive Rescue International of Ft. Collins, Colorado. This program generally consist of two phases. The first phase, **Ice Rescue**, emphasizes surface rescue techniques and equipment; ice safety; knowledge of ice; operational planning; and field rescue exercises. This course is designed to train both divers and non-divers in safe procedures for rescuing persons who have fallen through the ice, but, still remain at the surface. Phase two, **Ice Diving**, is a comprehensive course designed for experienced public service divers who may be called upon to rescue/recover victims submerged under the ice, locate/recover crime investigation evidence, and recover submerged vehicles.

SECTION 2

EQUIPMENT FOR UNDER ICE DIVING

Most divers and dive teams will be equipped with conventional open water scuba diving equipment. This equipment can also be used for ice diving; however, there are some special requirements and additional items that must be considered for diving under ice and working in cold environments.

BASIC EQUIPMENT

The selection of mask, fins, and snorkel is a matter of personal preference. Keep in mind that fins with extra large foot pockets may be required in order to fit over the dry suit boot and several layers of socks without cramping the toes or restricting circulation in the foot. Fin straps must be properly adjusted and secured with tape or a retainer before committing to the ice diving operation. Strap adjustment or replacement can be quite difficult during the operation; a broken or dislodged strap could increase the risk to the diver. Keep in mind that this applies to all adjustable straps, including the mask strap.

Although most sport divers continue to wear a snorkel attached to their mask strap for all diving, I personally **discourage** this practice for ice diving. The risk of entangling the snorkel in a safety line and dislodging the diver's mask is of great concern. Some divers advocate that a flexible hose snorkel can be inserted through a small hole cut through the ice with a knife and used in an emergency to draw air from the surface. This procedure is difficult and limited by physiological capability because of the water pressure on the submerged diver's chest. If you elect to include a snorkel in your ice diving outfit, I recommend that it be secured elsewhere on the diver such as on the underside of the buoyancy compensator (BC), in a BC pocket, under the knife straps, etc.

All ice divers should carry a sharp knife secured to the leg, BC, scuba harness, or arm. Some divers carry large sheath knives on the inside of their leg in order the minimize the possibility of snagging on the safety line. Others prefer to carry compact knives attached to equipment or the arm. Regardless of the type and size of knife selected, carry it in a position where you can get to it **with either hand.** Some public safety divers who frequently work in limited visibility carry two knives at different locations on the body. I personally secure a sharp, compact knife to the front portion of my BC or scuba harness.

I must again emphasize that surface temperatures may be sub-zero, thus complicating equipment adjustments and donning. Keep in mind that some rubber products become stiffer and have slightly less stretch under sub-zero conditions than at room temperature. Weight belts must have the appropriate amount of weight for a given dive; adjustments on the ice or in the water can be very difficult. Attempting to adjust or "fix" equipment by cold divers or surface personnel on site increases the possibility of **life-threatening mistakes**!

SELF-CONTAINED UNDERWATER BREATHING APPARATUS

Most recreational, research, and public safety divers will use the same scuba for all diving, both open water and under ice. The most common scuba in use at the present time includes a single 71.2 or 80 cubic foot scuba cylinder; a single hose regulator equipped with an "octopus" and a pressure gauge; and a backpack/BC combination unit. A decade ago, the use of double-hose regulators was recommended by most ice diving authorities because single-hose regulator malfunction was relatively common under ice diving conditions [1]. U. S. Navy Oceanography Office personnel experienced a 48.6% single-hose regulator "freeze-up" malfunction rate during one series of dives [5]. The experiences of various ice diving groups and the mechanism of regulator "freezing" is discussed in detail by Somers [1] and Fullerton [6].

Over the past decade the single hose regulator has almost completely replaced the double-hose regulator for **all** diving, including under the ice. Although regulator "freezing" still occurs, the frequency of such malfunctions has been greatly reduced largely through better "management" of the regulator prior to and during diving operations. Regulator design improvements may also have been significant in reducing the frequency of regulator "freezing." Furthermore, double-hose regulators have all but disappeared from the American diving scene. To my knowledge, they are no longer manufactured or sold in the United States and most dive shops do not stock parts to service these older model regulators.

Most modern single-hose regulators are now designed with **protected** first-stages. The "ambient pressure chamber" is sealed and filled with air, silicone, or an anti-freeze solution in order to protect the internal components from water and debris. Consequently, water which could freeze under the right set of conditions is no longer in contact with "moving" components. Probably many, if not most, regulator "freezing" malfunctions occur in the **second-stage** assembly. Following hard inhalations and/or depressing the purge button to activate high air flow, moisture in the second-stage housing apparently forms ice crystals in the second-stage valve assembly. At least one manufacturer has designed a regulator with Teflon (DuPont trademark) coated components and a "heat retention" unit in the second-stage assembly in an attempt to reduce the potential of regulator "freezing."

At this point I must emphasize the the potential for regulator "freezing" still exists in all scuba regulators available on the market today. Fortunately, the "freezing" almost always results in a second-stage **free flow.** This enables the diver to return to the surface for corrective measures **without** having to rely on a buddy to supply air. In the event of a free flow malfunction you must **terminate the dive immediately and return to the surface.** Continued use of the regulator for a short period of time is possible, and preferable, to buddy breathing. However, continued free flow will cause additional moisture to freeze on the enlarging ice crystal(s), hold the second-stage valve open, and increase the rate of air flow.

Common precautions used by cold weather/ice divers to reduce the possibility of regulator freezing include: (1) keeping the interior of the second-stage completely dry before entering the water; (2) **not** breathing from the regulator until underwater; (3) allowing little or no water to enter the second-stage chamber during or between dives; (4) **not** depressing the purge button for more than 5 seconds prior to or during the dive; (5) **avoiding** heavy work loads that would significantly increase the breathing rate and volume of air moved through the valve with each breathing cycle; and (6) assuring that the scuba air is moisture-free.

Langerman has minimized regulator freezing by being certain that the regulator is thoroughly dry several days in advance of the dive and then not using (breathing from) it until just before entering the water. Just before the diver leaves the surface, he warms the regulator by pouring hot water over it. Divers are reminded to breath slowly and easily [7].

Langerman also suggest that "the single most important factor which correlates with under ice free-flow problems appears to be surface temperature. When the air temperature is well below zero, we experience many problems; when the air temperature is above 15°F, the problem seems to disappear" [7].

The use of an "octopus" is becoming a "standard" in the scuba diving community today. Although I feel that there are better emergency air alternatives for ice divers, general public acceptance of the "octopus" has made it the primary system used by most ice divers. Keep in mind that the two second-stage assemblies (the primary and the "octopus") are both attached to the **same** first-stage. Consequently, the diver cannot isolate the free flowing second-stage. This means that the "octopus" is of little or no advantage in resolving the problem independently. In the event that two divers must breathe from a single scuba, the higher air flow through an **unprotected** first-stage might increase the possibility of **first-stage freezing.** Langerman finds that the removal of the "octopus" reduces the incidence of free-flows ("regulator freezing") underwater [7]. In any event, if a diver's scuba malfunctions in a fashion that restricts or eliminates air flow, "octopus" breathing is an acceptable alternative. However, the dive should be terminated immediately.

The use of a **dual outlet manifold** and **two independent single-hose regulators** is possibly a better alternative for dealing with regulator malfunction. The dual manifold is available for both single and twin cylinder scuba. In the event of a "free flow" malfunction of the primary regulator, the diver can exchange it for the "secondary" regulator and isolate (or turn off) the free flowing regulator provided that the diver or buddy can reach the valve/manifold assembly. Many divers prefer the use of a compact 15 cubic foot scuba (or "pony" unit) as an emergency air supply alternative. Either of these systems allow for an "independent" resolution of the problem, especially for public safety divers using the "single diver down" mode. Keep in mind that the divers must train and experiment with equipment positioning under controlled conditions in order for any of these alternatives to work properly under actual field conditions.

Do keep in mind that the independent "controlled emergency swimming ascent" option is still available to the ice diver in the event of complete loss of air supply. It is a common practice to limit under ice penetrations to less than 100 feet by controlling the amount of safety line fed to the diver(s). A skilled, experienced diver should be able to successfully complete such an emergency ascent to the hole on a diagonal path. This ascent, to be used as a last resort alternative, can be tested and practiced in a confined water situation by having the diver make an exhaling emergency ascent following his/her safety line from the deep end of the pool to a "simulated" hole at the shallow end of the pool. All emergency ascent alternatives should be practiced under controlled training conditions.

The use of a **buoyancy compensator** (BC) with a dry suit is becoming a standard practice, especially with the increasing popularity of the "thin fabric" dry suit. Many foamed-neoprene dry suit (i.e., air suit) divers used their suits for "buoyancy compensation" and, thus, did not wear a seperate BC. However, an increasing number of divers and instructors are concluding that the dry suit should not be used as a substitute for a BC. Keep in mind that a **properly weighted** thin fabric suit diver should not experience the significant buoyancy loss with increased depth common to foamed neoprene suits and that supplemental buoyancy compensation should be minimal.

The most popular BC currently in use at present is the "vest or jacket" style in contrast to the "collar" style of earlier years. However, some divers still prefer and use the "collar" style BCs. The pros and cons of BC styles will not be addressed in this paper. Regardless of individual preference, select a BC **and/or** position the dry suit inflation/deflation valve(s) so that the BC will not interfer with the operation of these valves.

Buoyancy compensator and dry suit inflation/deflation valves are subject to potential malfunctions. These may be induced thermally or otherwise. Malfunction of a BC inflation unit resulted in an "uncontrolled, full BC inflation" ascent for one diving instructor [8]. Inspection of both BC and dry suit exhaust valves following seperate diving accidents revealed that the valves malfunctioned in an "open" position. Consequently, the divers apparently could not maintain air in the BC or dry suit for compensation or emergency flotation. There is the significant likelihood that poor/inadequate maintenance was a factor in these alleged malfunctions.

Andersen reports on "suit blow-ups" resulting from dry suit inlet valves "sticking in an open position" [9]. Continued manipulation of the valve did not stop the flow of air into the suit and the divers were forced "uncontrolled" to the underside of the ice. The only method found to resolve the emergency was to immediately disconnect the inflation hose. If this "disconnection" is not accomplished immediately, the rapid over-inflation of the suit will cause the diver's arms to become immobile or restricted in movement.

THERMAL PROTECTION

The foamed-neoprene, wet suit was the primary suit for recreational, research and public safety divers for nearly two decades. In the late 1960's a variable volume foamed-neoprene, dry suit fitted with a **waterproof/airproof zipper** and manufactured in Sweden was introduced to the American market under the tradename UNISUIT. During the 1970's this and similar foamed-neoprene dry suits (often referred to as "air suits") began to replace the wet suit for serious cold water diving. These suits provided the diver with an air inflatable, waterproof thermal protection suit that could be worn over a variety of undergarments or, in some designs, without undergarments. The primary advantage was that they kept the diver dry. However, since the suits were constructed of foamed-neoprene rubber, the insulation properties and buoyancy characteristics of the suit did vary with depth and, in some cases, an exceptional amount of weight was required to off-set the buoyancy of the suit and contained air. The suit could be "inflated" with air from the diver's scuba cylinder or a small independent cylinder. These suits provided major advancements in thermal protection and diver comfort. However, bulk, insulation/buoyancy variation with depth, and, in some cases, sizing continued to be a problem, especially for smaller and female divers.

In the early 1980's new technology in waterproof materials and seam construction led to the development of a new breed of "thin fabric" suits. The materials resembled waterproof nylon fabrics that had been used in the construction of outer garments and outdoor equipment such as packs and tents (e.g., 420 Denier urethane sealed nylon). These suits were less bulky, lighter in weight, easier to put on and take off, and more comfortable to wear both underwater and on the surface than their predecessors. The neck and wrists seals were constructed of very thin latex rubber for improved watertightness and added comfort. Some authorities suggest that these new suits have a higher reliability factor for dryness. Other "thin" materials include rubber-coated tricot (e.g., Viking suits) and "crushed" foamed-neoprene (e.g., DUI CF200X suits). The nylon materials do not stretch and the suit must be "sized" so that there is sufficient material to slide over the undergarments and not restrict diver movement. The tricot and crushed neoprene suits do have some degree of elasticity.

All scuba diver dry suits are fitted with air inflation and deflation valves. The various designs are too numerous to be discussed here and new/improved models are being marketed each year. The inlet or inflation valve is generally located in the diver's chest area and connected to a low pressure outlet on the scuba. Exhaust valves may be positioned on the chest, upper arm, or lower arm. At least one manufacturer features an adjustable "automatic buoyancy control" outlet valve which can be activated by changing arm position and will automatically discharge excessive air during ascent. Another manufacturer has introduced an "air control" valve which allows the diver to inflate and "vacuum" deflate the suit through a single valve [10].

Unlike conventional foamed-neoprene wet and dry suits, the thin fabric suits offer little or no thermal insulation. The key to versatile thermal protection is in the selection of appropriate insulating undergarments. The thin fabric suit can be used throughout the year under climatic conditions and water temperatures ranging from tropic to polar. The diver may select from a wide range of undergarments depending on water temperature, climatic conditions, and personal preference. For summer diving in warmer northern quarries or "polluted" waters the diver many choose to wear only the heavier weight polypropylene underwear similar to that worn by mountain climbers. Colder water divers can select heavier pile or Thinsulate (trademark of 3M) undergarments and wear several insulating layers.

Undergarments are available in various weights (or thicknesses) of synthetic "fleece" (i.e., polyester pile or "fur"; "bunting" fabric), open cell polyester foam, and Thinsulate. All of these materials have performance, insulation, and physical comfort characteristics that can vary with moisture content (e.g., from leakage or perspiration) and compression. One manufacture combines a foil radiant film between a polyester insulating material and a nylon taffeta shell. Undergarments are available in one-piece "coverall" or "jumpsuit" models, jackets, pants, vests, and socks.

Unfortunately, a very limited amount of test information is available on the comparative effectiveness of various insulating garments for divers. One manufacturer has published comparison charts depicting the relative thermal resistance vs. thickness for pile, foam, and Thinsulate [10]. Thinsulate exhibits the highest thermal resistance factor for a given thickness of material. Furthermore, Thinsulate appears to have superior insulation qualities over the other materials, especially when wet. In one U. S. Navy study of M-400 Thinsulate undergarments worn under a "crushed foam" dry suit it was concluded that this undergarment "provides adequate thermal protection during air diving and conditions of moderate, intermittent work for up to 6 hours in water as cold as 35°F" [11]. The M-400 Thinsulate tested by the Navy is apparently the same 1/8-inch Type-B Thinsulate used in the current DUI C-4 undergarment [12]. This material resists compression and retains approximately 80% of its insulation capacity when wet. The Thinsulate used in the construction of diver's undergarments is much more effective, less compressible, and less flexible than that used for ski wear and outer garments. The U. S. Navy study also reported, "Depth dependent degradation of undergarment insulation was not observed between depths of 10 and 70 FSW (feet sea water), and is not anticipated at depths deeper than 70 FSW" [11].

Most thin fabric dry suits are constructed with a "neck seal" collar and without a hood. Most divers apparently prefer the added comfort (physical, not thermal) and suit donning convenience of suits without attached hoods. Suits can be constructed with or without hoods based on the diver's personal preference. One experienced polar scientific diver selected a hood that "attached" to the suit with a special neck ring. This allowed him to use the suit with a dry hood, a neck seal, or a surface-supplied helmet attached directly to the suit [13]. Most divers use a foamed-neoprene, wet type hood specially designed to seal securely against the latex rubber neck seal of the suit.

Most dry suit divers currently use foamed-neoprene, wet type three-finger mittens with snug fitting wrists seals. One manufacturer has designed a mitten constructed of 3/16-inch thick material over the palm/finger area and 3/8-inch thick material over the back of the hand where the greatest heat loss occurs. The hand still represent one of the most difficult areas of the body from a standpoint of functional insulation. Filling the mittens with warm water before and after the dive is a common practice to extend thermal comfort. At least one manufacturer provides as special "ring and rail" option for attaching dry gloves or mittens directly to the suit. Wool or synthetic liners can be worn under the dry gloves/mittens.

The new thin fabric/insulating undergarment diving suits have several advantages over the foamed-neporene suits. In addition to those advantages already mentioned, these suits can be more comfortable when worn for long durations on the surface because of low bulk and loose fit. A special plastic neck ring is available which allows the diver to relieve the potential discomfort of the neck seal and increase suit ventilation during surface wear. In the event that the diver becomes too warm on the surface, the suit can be unzipped for ventilation or partially removed to expose and cool the upper body. The suits are also very easy to take off between dives.

The light weight suits are very versatile for other diving and aquatic activities. Recreational enthusiasts will find the suits useful for other cold weather/water activities such as boardsailing, rafting, kayaking, and boating. Boaters and adventurers can carry the suit (including mitts and hood) in a small duffel bag for use in the event of an emergency. The suit can be rapidly pulled on over standard clothing to significantly extend the survival time of a person immersed in cold water. Naturally, the suit must be donned before immersion.

Scientists and public safety personnel find that the suits do significantly increase comfort and safety when working from small, exposed vessels under cold and adverse conditions. A special Gore-tex laminate dry suit fabric which is waterproof and "breathable" was developed for military special forces. This suit is also available to civilian personnel to provide long term protection on the surface and during intermittent shallow immersion.

Selecting and learning to use a comfortable, versatile, and adequate thermal protection system is not an easy task. Although many divers and public safety dive teams still advocate use of the foamed-neoprene wet suit, some authorities suggest that its use should be limited to water temperatures above 60°F. Air suits are still in use, but the popularity of thin fabric suits is increasing significantly. Divers are encouraged to take advantage of "dry suit" clinics conducted by many local diving equipment suppliers in order to learn about the most recent developments in thermal protection and to "swim" various suit and undergarment combinations.

Once you have selected a thermal protection system, learn to use it properly and safely. Many experienced divers do not appreciate the different "characteristics" of dry suits compared to wet suits. I recommend that divers make no less than 10 "training dives" under controlled conditions before they venture into more adverse environmental conditions. The fact that you apparently "master" the use of the suit on the first or second dive is no assurance that you will be able to respond properly under stressful conditions. Divers who use wet suits in the summer or for tropical diving and switch to a dry suit for a ice dive are probably at more risk of accident than a diver who uses the same suit for all diving. This is due to the fact that they may not be able to use the dry suit proficiently and may be unable to manage themselves or others in a stressful situation. They may be better off if they simply use the wet suit and accept the added cold discomfort and limitations.

Proper dry suit training is necessary for safe and efficient use of these suits. The National Oceanic and Atmospheric Administration Diving Office conducted a series of tests on various dry suits and developed a variable-volume dry suit diver training program [14]. The course includes instruction in suit selection; dry suit "dangers"; blow-up prevention and recovery methods; selection and use of weight belts and ankle weights;

selection and use of accessories such as fins, fin straps, and underwear; and suit maintenance.

Many instructors and diving equipment suppliers conduct special dry suit training workshops. Divers must learn special procedures and precautions for dressing and undressing. One criticism of the thin latex rubber neck and wrists seals is that they can easily be torn through careless handling. The diver may select from several inflation and exhaust valve combinations and must learn the operational characteristics of the valves. Although most dry suits are relatively simple to "patch", the replacement of neck and wrists seals and boots requires special techniques. Finally, the diver must "swim" the suit under controlled conditions in order to learn internal air and buoyancy adjustments, swimming characteristics, and emergency procedures to follow in the event of valve malfunction, suit flooding, or over-inflation.

WEIGHT BELTS AND ANKLE WEIGHTS

Standard scuba diving nylon web belts fitted with quick release buckles and lead weights are most commonly used by ice divers. However, the use of special compartmented belts filled with lead pellets is increasing in popularity. These pellet belts are generally more comfortable and less abrasive on thin fabric dry suit material.

Some divers, especially ones using bulky foamed-neoprene dry suits (i.e., Unisuits), have developed weight belts with shoulder harnesses. The shoulder harness prevents accidential loss of the belt underwater and is more comfortable for divers who require very heavy weight belts. NOAA published the following statement regarding the use of shoulder harness weight belts [14]:

> Test were inconclusive in determining if a shoulder harness should be worn. If it is worn, a diver must be fully trained in ditching procedures, as test results did indicate that the belt can hang up. Test results indicate even a shoulder harness that was put on carefully can move around on the diver while he is working in different positions. This causes the harness to hang up and become difficult to remove, especially with scuba back pack.

It appears that the use of shoulder harness weight belts for scuba diving is of limited popularity at the present time. I discourage its use. If the diver feels that he/she needs this type of weight belt, be certain that the shoulder harness is equipped with quick-release devices.

The weight requirements for a dry suit are based on the buoyancy of the suit (for foamed-neoprene suits) and the amount of insulation worn under the outer suit. As with wet suits the weight requirements for a foamed-neoprene dry suit will vary with depth and suit compression. The weight requirement for a thin fabric dry suit will remain approximately the same for any depth. As you gain experience with a thin fabric suit, you will generaly be able to reduce the amount of weight since your inflation techniques will improve. It is advisable to start your buoyancy evaluation with 10% to 15% of your body weight plus a 2.5 pound ankle weight on each leg.

Ankle weight are generally lead pellet filled nylon or 1/8-inch neoprene tubes or pouches fitted with a quick-lock buckle. NOAA researchers [14] found that the use of ankle weights kept the diver's feet in a better swimming position and allowed more air to be placed in the legs for improved thermal comfort. They help keep the fins on because of the restricted air flow into the feet. They enable divers to better control themselves if they lose their weight belts and to recover faster from inverted blow-up positions. However, they will tire the diver more during long swims. Five pounds is approximately the maximum for a diver to wear on each leg; 1.75 to 3 pounds is more reasonable.

In order to test buoyancy, enter the water with all equipment that will be use for normal diving and exhaust as much air from the suit as possible. Add or subtract weight until you are slightly negative buoyant on exhalation.

Keep in mind that proper suit inflation is esssentailly a balance between suit squeeze and a bubble of air in your suit. Inflate the suit only enough to relieve suit squeeze. Overinflation can cause "control" problems and compromiseyour safety.

SAFETY HARNESS

A lightweight, adjustable chest harness constructed of nylon webbing and secured with a locking D-carabiner is used to attach the safety line to the diver (Figure 1). This harness provides a more secure attachment that the scuba harness or BC. The harness is worn over the suit and under other equipment.

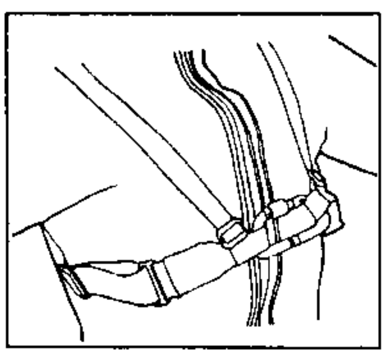

FIGURE 1. Safety harness.

SAFETY LINES

A safety line is the ice diver's only dependable link with the surface. Relocating the entry hole from under the ice is difficult, if not impossible, without this safety line. Most ice diving fatalities have involved situations where safety lines were not used. Based on accident reports, accepted procedures, and **common sense** one can only arrive at one conclusion: **"a safety line is mandatory for ice divers."**

Unfortunately, some ice divers will simply select the nearest and most convenient rope available to use as a safety line. This practice should be avoided. A variety of synthetic ropes are used by ice divers. The rope should be of relatively high tensile strength (over 2,000 lbs.) and large enough for the tender and divers to conveniently handle. Manila rope is less desirable for cold weather work. Manila rope that is allowed to freeze after being water soaked is readily broken and, therefore, can not be trusted for ice diving.

I have selected a **7 mm water rescue rope** constructed of a polypropylene core with a nylon sheath for ice diving. The rope is lightweight, brightly colored (greenish-yellow), and has a tensile strength of 2600 lbs. The multifilament polypropylene core provides a low specific gravity and zero water absorption, enabling the rope to float. The outer sheath increases the strength and abrasion resistance. This rope is flexible under cold temperature conditions to facilitate knot tying and handling.

I use approximately 350 feet of line "stuffed" into a **double-end rope bag** (Figure 2). The bag and rope can be secured at the surface with an ice piton or other security device. A loop is tied in the diver's end of the rope using a figure-8 loop knot. This loop is secured to the diver's safety harness with a locking mountain climber's carabiner or a screw link. When using a single rope/two diver system a second loop is tied about 8 feet from the first one for the second diver. The rope is marked at 10 to 25 foot intervals with self-laminating, write-on rope markers so that the tender will be able to determine how far the diver is from the hole.

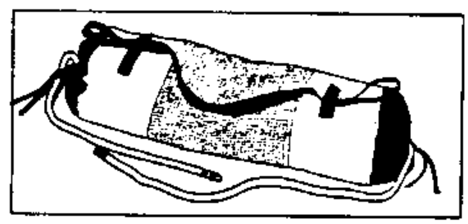

FIGURE 2. Double-end rope bag.

The other end of this long rope is for the safety diver and is prepared in the same fashion. Approximately 100 to 150 feet of line is available for the diver and the remainder is reserved for the safety diver. Consequently, the safety diver is equipped with a rope that is approximately twice the length of the primary diver's line. The entire rope/safety line system can be carried and stored in a single bag.

Rope bags are recommended for easy storage and quick drying of rope. The rope is "stuffed" into the bag, not coiled. This facilitates rope deployment and handling.

Another excellent method of handling ropes is to "stuff" (not coil) the rope in a bucket or similar plastic container [15]. The container can be placed on the ice in front of the tender or secured to the tender on a belt. The rope is fed to the diver as needed and placed back in the container as it is retrieved. This avoids the accumulation of a pile of tangled rope at the tender's feet. Small holes in the bottom of the bucket facilitate drainage.

There are several different ice diving safety lines configurations used throughout the country. Some instructors/ice divers prefer to use a **seperate safety line** and tender for each diver under the ice. This is certainly a "safe" procedure; however, it can involve some rope tangling if the tenders and/or divers cross lines several times. The **single line/two diver** configuration has gained in popularity over recent years. Some dive teams use a single safety line securely attached to a large heavy-duty aluminum or stainless steel ring approximately 10 inches in diameter (sometimes referred to as a "bridle" system). Two lines approximately 6 feet in length are attached to the large ring at one end and the diver's safety harness at the other. Each diver holds the large ring in one hand. This enables the divers to stay close together and both "feel" signals from the surface.

Ropes used for ice diving safety lines should be reserved specifically for that purpose. Keep the ropes clean and free from chemicals. Never overload the rope by using it for towing a car out of the snow, etc. Check the ropes frequently and guard against abrasion. Avoid direct exposure to hot objects such as shelter stoves or placing in the trunk of a car directly over the exhaust system. Synthetic rope fibers may break down or even melt when exposed to excessive heat, thus reducing the strength of the rope significantly. Dry and stow ropes in a cool, well-ventilated place. Examine ropes, carabiners, and other components of the safety line system frequently and replace if they show signs of excessive wear or damage.

COMMUNICATIONS/SAFETY LINE SYSTEM

Many public safety dive teams deploy only a single diver under the ice at a time. This procedure in gaining popularity and is considered "safe" by many authorities. A unique diver communications systems has recently been introduced that makes the single diver technique significantly safer. This system includes a combination safety/communications line, a diver-to-tender electronic communications unit, and a diver's transducer.

The combination **safety/communications line** is constructed of 7 mm nylon static kernmantle rope with a tensile strength of 3000 lbs. The communications wires are woven inside the rope. This rope is fitted with electrical connectors at each end. It has the strength and handling characteristics of ordinary safety rope. Tying knots in the rope apparently has no adverse effects on the communications wires.

The topside **communications unit** is a small, lightweight metal box which may be hung from the tender's neck and conveniently positioned on his/her chest. The tender wears a headset with earphones and a boom microphone and presses a "speak" button located on the front of the unit to talk to the diver. The line from the diver is always open except when the tender is pressing the speak button.

The diver is equipped with a **transducer** or bone-oscillating ear-piece/microphone. This transducer can be placed behind or in front of the diver's ear; either under or outside the hood. Placing the transducer under the hood reduces "bubble noise." Voice transmission from the tender to the diver is excellent. However, the diver to tender communications is less satisfactory because of the difficulty of articulating with a scuba mouthpiece in place. Several full-face masks that are compatible with scuba have been used to significantly improve diver to tender communications. Separate microphone and earphone diver components are available for use with different mask systems and special connectors can be manufactured upon request [16]. Both the communications unit and the transducer are fitted with "break-away" connectors.

The combination communications/safety line adds a new dimension of safety to ice diving. I recommend that all divers and teams seriously consider this system as a replacement for conventional safety lines.

Some divers are concerned that the use of "full-face" masks will complicate or eliminate the possibility of using an alternate air source. Andersen recommends that the divers back-up system consist of a secondary air cylinder/regulator **and** that the diver wearing a full-face mask carry a spare standard mask that can be used with the back-up regulator [9]. Several very compact models that can be carried in the BC pocket or a small "pouch" attached to the scuba harness are available.

DIVER INSTRUMENTATION

The diver will generally be equipped with a dependable waterproof watch/dive timer, depth indicator, and compass. The use of a **console unit** which includes a combination depth gauge/automatic activating timer, compass, and scuba pressure gauge is extremely advantageous for diver equipment management and donning purposes. Consider a depth gauge with a "maximum depth" indicator since a chilled diver is less likely to properly monitor and remember depth. Also, the use of the automatic activating timer eliminates the problem of pushing tiny buttons or rotating watch bezels with gloved hands **and** remembering to do so.

Remember that the compass is used only for survey and relative position determination purposes and **never** as a substitute for a safety line. The console must be properly secured in a position where the diver can monitor the instruments. Do not simply allow the console to hang freely at the diver's side. This increases the possibility of damaging the instruments both underwater and on the surface or entanglement in a safety line. Special care must be taken in handling all instruments since the adverse effects of extreme cold can cause "brittleness" and increase the possibility of breakage or malfunction. Monitor all battery powered instruments carefully since some batteries do not perform adequately under conditions of extreme cold.

Do not encumber the diver with equipment that is unnecessary for safety or task accomplishment. For example, if I am working a dive team under the ice in a relatively shallow, constant depth lake I will often measure the depth by lowering a marked line through the ice hole and checking survey charts to determine if any significant depth variations occur in the area. Dive time is monitored by the tender or a timekeeper at the surface. Dive termination is designated by line signal or voice communication. Consequently, the divers need not be required to wear the timing and depth monitoring devices.

The use of electronic decompression/dive status monitoring devices is increasing in popularity for all diving activities. Be certain to read the manufacturer's instructions booklets for these instruments and pay particular attention to information relative to cold environment diving. Battery performance and power drain has resulted in significant reduction in "battery life" under extremely cold diving conditions [13].

COLD WEATHER CLOTHING AND OTHER PERSONAL EQUIPMENT

Each diver and support person is responsible for providing a complete outfit of cold weather clothing. The selection of cold weather clothing will be discussed later. In addition to thermal protection equipment, it is desirable for each person to use "ice creepers" attached to the bottom of their boots. The ice surface can be very slippery and falls, especially with diving equipment, can cause serious injury.

All persons working on the ice must have a pair of high quality **sunglasses.** Eye fatigue and injury from sun glare can be painful if not temporarily disabling; permanent eye damage is possible. Some "dime store" and "fashion" sunglasses are completely inadequate for protecting the eyes in snow or ice glare conditions. Be certain that the sunglasses you select filter out most, if not all, of the ultra-violet and infra-red radiation. Side shields are useful on some types of glasses in order to prevent excessive light from entering around the sides.

Many dry suit divers wear their **dive undergarments** to the site and home after the dive. This is an acceptable practice; however, always bring a complete set of dry clothes in a duffel bag in the event that your suit floods.

TEAM EQUIPMENT

The diving supervisor or a designated assistant is generally responsible for assembling **and** inspecting all team equipment prior to the diving operation and transporting it to the dive site. As with each individual diver's equipment, the team equipment must be assembled and inspected several days prior to the diving operation. The supervisor should prepare a complete checklist. The group equipment should include, but not necessarily be limited to, the following:

* Safety lines in bags;
* Ice pitons (a sufficient number for securing safety lines and shelter) and a ice hammer for placing pitons;
* Shore shelter and ice shelter;
* Snow shovel;
* Chainsaw, hand-type ice saw, and auger;
* Ice thickness measuring rod;
* Weighted descent line and a sounding line;
* Heaters for both shore and ice shelter;
* First aid kit complete with oxygen delivery system and backboard or stretcher;
* Blankets or sleeping bag and ensolite pad (to preserve body warmth of an injuried diver);
* Containers for hot water (used to warm hands, thaw frozen regulators, and treat frostbite);
* Containers for hot, sweet drink (for general use and emergency warming of distressed person); and
* Thermometer (for checking air temperature; also mandatory to insure that the proper temperature water is used in first aid for frostbite).

SECTION 3

ORGANIZING AND PLANNING AN ICE DIVING OPERATION

Instruction in dive organization and planning is frequently "minimal" in sport diver training programs. Since ice diving operations must be conducted at the highest level of efficiency and safety, it is necessary for all personnel to have a complete working knowledge of organization, planning, and procedures. The information presented here is intended to provide the diver/instructor with a greater insight into the requirements of an ice diving operation. For additional information consult Somers [1] and Jenkins [17].

PERSONNEL

Someone must take charge of the ice diving operation - a **diving supervisor** (i.e., divemaster, instructor, coordinator, or commanding officer). This individual should hold an Ice Diving Certification; persons giving instruction must hold an Ice Diving Instructor Certification. The diving supervisor is in complete charge of the diving operation. His/her primary function is to organize, plan, and **manage** the diving operation. This responsibliity includes selection/approval of dive site, personnel, equipment, and procedures. The diving supervisor is **in charge of the dive and site** and is responsible for maintaining safety standards. This individual must have the authority to control all personnel participating in the diving operation and must not tolerate violation of accepted/established diving procedures and safety standards.

The diving supervisor's usual post is on the surface where he/she is in a position to direct tenders, stand-by divers, and other support personnel. In the event that the designated diving supervisor chooses to dive, an individual with proper qualifications and a complete understanding of the operation must temporarily assume diving supervisor responsibilities until the original supervisor can resume **complete** responsibility. The diving supervisor should not be burdened with added responsibilities such as dressing divers, tending, timekeeping, and so on. The supervisor will direct tenders and diver aides and inspect each diver before he/she enters the water.

The **tender**, one for each safety line, must be qualified to independently tend divers and operate surface support equipment. He/she must be a **qualified ice diver** or a diver specifically trained in the theory and operational aspects of ice diving. Some teams use non-divers who have been specifically **trained as tenders.** These individuals must have a complete working knowledge of scuba diving, diving equipment, and ice diving. Keep in mind that the knowledgeable tender can be the final and most significant "link" in the chain of dive safety "checks and balances." The alert tender is often the first to detect silent hypothermia; emotional, physical, or cold stress; improperly fitted equipment; and so on. Avoid the temptation to let untrained relatives, friends or bystanders serve as tenders!

Diver-aides may be used for such tasks as time keeping, helping divers dress, and handling equipment. This is an excellent way to involve persons with too limited experience or training to participate as divers. I discourage the use of persons who are non-divers since they are assuming some responsibility for the preparation of the diver and his/her equipment. A "pre-dive" instruction session for aides can be very beneficial and improve the general overall safety and efficiency for an operation. Some teams assign an "aide" to each ice diver and tender. However, avoid an excessive number of aides and bystanders, especially if the ice is thin.

A **stand-by diver** team is required for all under ice operations. The diver must be fully dressed for diving with the exception of scuba, weights, fins, and mask. This equipment must be "laid out" in a fashion which will facilitate rapid donning and deployment. The stand-by diver's **tender** remains immediately adjacent to that diver with the safety line in a "ready" position. With practice a good tender-diver team can generally deploy within one minute. Some teams actually place the diver on site completely equipped with the safety line attached. In this case the diver can be in the water within a few seconds. This practice, however, can be awkward and cold and is often abandoned in reality.

The **ice divers** are individuals who hold specific Ice Diver Certification or are undergoing training for ice diving. It is the responsibility of the individual diver to present himself/herself at the dive site fully equipped and prepared to dive at the discretion of the diving supervisor. Any individual who is experiencing the adverse effects of thermal stress, illness, emotional stress, excessive fatigue, alcohol, drugs or other disorders that may influence their safety must notify the diving supervisor immediately and withdraw from the dive operation.

DIVE SITE SELECTION

The dive site for recreational diving and training exercises should be selected on a basis of satisfactory water/bottom conditions, accessibility, exposure protection, shore support facilities, and ice conditions. Ideally, the site should be familiar to all of the divers based on previous open water diving experience. The diving supervisor should select or approve the site at least several days prior to the dive. The supervisor or a person designated by the supervisor is responsible for compiling information on the site including the type of shore, access point(s), expected underwater visibility, water depth, distance from shore, bottom type, and ice thickness. Charts of many inland lakes and quarries are available from state agencies such as the Department of Natural Resources. If access is to be gained through private land or "closed" public facilities, permission must be obtained well in advance.

Ice thickness and condition should be evaluated several days in advance, especially during early winter and spring months. The ice should be at least 4 inches thick for even small groups and no less than 5 to 6 inches thick for larger groups and snowmobiles. Do not take vehicles onto the ice unless it is more than 8 inches thick (preferably 12 inches).

You can check the ice thickness by measuring through a small hole cut with an ice chipper (spud) or auger. Be especially careful early in the season. **Approach new ice and snow or slush covered ice with extreme caution.** I recommend that a team of two or more individuals conduct the ice "reconnaissance." One person dressed in a dry suit and equipped with a safety harness/line can proceed on to the ice 50 to 75 feet ahead of a safety person. Ideally, the safety person should also be dressed in a dry suit and the safety line secured to an object on shore. If the ice starts to crack or appears "weak" the advance person can retreat. If the advance person falls through the ice, he/she can be pulled from the water by the safety person.

The advance person may also wish to carry two "ice picks" to facilitate recovery. The ice picks can be constructed from ordinary ice picks by cutting the pick portion to a length of 2-inches and repointing. Protect each pick with a cork pushed securely onto the pick point. A line approximately 4 feet long should be strung between the two pick handles so that the user can carry the picks around his/her neck for immediate availability. For further information on ice thickness, formation, strength and rescue techniques consult Linton and Rust [18].

The advance person will prepare the measurement hole at the anticipated dive location and check the ice thickness using a measuring rod. This rod can be constructed from a piece of light steel or aluminum stock approximately 3 feet long. The lower 2 inches of the rod is bent 90° to form a hook that can catch on the underside of the ice when the rod is inserted through the test hole. The rod is marked in inches. A wood handle can be placed on the other end of the rod to facilitate handling and reduce the possibility of accidentally dropping it through the test hole. Knowledge of ice thickness is extremely valuable for determining hole cutting procedures.

Under ice visibility can be estimated by lowering a "secchi" disc through the hole. This is a small disc approximately 4 inches in diameter (smaller than the one used by scientists in order to use through a hole cut with a small auger). The disc can be constructed of metal or weighted plastic. The disc is divided into quarter pie shaped sections and the sections are painted alternately black and white. An eye is placed in the center of the disc for attachment of a measured line marked in feet. The disc is lowered into the water until it "disappears" and then pulled upward until the observer can again see it. The distance to the disc is a measure of visibility. **I personally discourage recreational and training dives in water where the visibility is less than 30 feet.** If not previously known, the depth under the hole should be determined with a sounding line. A **sounding line** is simply a line marked in feet with a 2- or 3-pound weight secured to one end. The weight is lowered until it makes contact with the bottom.

Several test holes may be used in order to select the best possible dive location(s). The "recon" team should mark each hole with a flag in order to facilitate relocation on the day of the dive. Ideally, someone should check the site the day before or early in the morning of the dive day to assure that the markers are still in place.

Upon arrival at the dive site most groups will establish a **shore base.** The shore base should provide heated facilities to accommodate both divers and support personnel. These facilities may be in the form of a cabin, building, camping trailer, pick-up mounted camper(s), van(s), or a large tent. Heat can be provided by an appropriate camping-type tent or shelter heater. Precautions must be observed to eliminate fire hazard, stove/fuel explosion, and contamination of the interior with toxic fumes (e.g., carbon monoxide). Several small shelters may be used.

All possible measures must be taken to provide the diver with a warm, sheltered place to dress and undress. The diver must avoid unnecessary exposure prior to the dive since pre-dive chilling will accelerate the onset of cold stress. The shelter is also necessary for the care of potential accident victims and persons who may exhibit symptoms of cold injury.

It may be difficult if not impossible to establish an adequate shore base at some dive sites. Some teams rent near-by motel rooms for dressing/undressing and transport divers to the dive site by vans, 4-wheel drive vehicles, or snowmobiles. Only "necessary" personnel will be at the actual dive site at any given time and a vehicle will **always** be available to transport injured or cold individuals back to the motel base. Ideally, radio communication should be maintained between the motel base and personnel on the ice.

Public safety divers must be prepared to respond to any location within their jurisdiction. Unfortunately, opportunity for pre-dive reconnaissance and extensive site preparation is usually not possible. For a potential **rescue,** response must be immediate and a diver may be deployed under the ice within minutes of arriving at the site. **Consequently, pre-season dive planning and organization must be undertaken in anticipation of possible emergencies at high activity locations.** A prudent and well-organized team will assemble charts and maps of all bodies of water within its jurisdiction and select access locations during summer months. A survey of winter recreational activity sites and review of past winter water-related accidents can provide the team with considerable insight into locations and conditions that might be anticipated for a winter emergency response.

I recommend that the dive team plan and conduct both summer and winter training dives at **priority** locations and assemble data on these locations. Consequently, when an emergency call is issued the **site file** can be immediately pulled and the team briefed enroute or at the site. Through prudent organization the team will know approxmiate depth, bottom conditions, potential underwater hazards, access points, and so on. Ideally, a heated dive support van should be available for dive preparation and command support. Failure to "prepare for" winter emergency response and haphazard deployment of rescue divers can constitute **unacceptable risk situations.**

PREPARING THE DIVE SITE

Once the shore base has been established, the dive site is prepared. Whenever possible, the ice hole should be cut in advance by support personnel rather than the divers. The **hole cutters** should be dressed in waterproof clothing and boots since they will generally be exposed to considerable splashing during the latter stages of cutting. Many individuals wear divers' dry suits. The ice hole should be as close to the shore base as possible.

Triangular shaped holes are the most popular among ice divers. They are easier to cut and have the advantage of being much easier to exit. Although seldom used, a specially constructed ladder secured to the ice with lines tied to ice pitons can be very advantagous for entering and exiting the water.

Cutting ice holes has always been a problem. Northern lakes may be covered with more than a foot of ice and polar ice cover can exceed 6 feet in thickness. For cutting holes in ice less than 18 inches thick, you can use ice augers, ice saws, or chain saws. Ice chippers (spuds) can be used, however, this method is very time consuming and fatiging. I find the "axe" to be least satisfactory of all tools and discourage its use because of the potential danger in the hands of an unskilled person. For cutting a triangular hole with an ice saw, simply drill the points of the triangle with an ice auger and cut the sides of the triangle with the saw. The method can, however, be difficult and time consuming.

Langerman prefers the use of gasoline powered **chainsaws.** Keep in mind that water entering the carburetor can cause malfunction and require a complete field overhaul of the engine. In order to reduce or avoid splashing many experienced ice divers will use the chainsaw to cut through about 90% of the thickness of the ice and then complete the hole with a hand ice saw. If you cut through the ice at the beginning of your cutting procedure, you will always be cutting in water and splashing water on yourself and the chainsaw [7].

Chain saws can be hazards, especially for the inexperienced user. When selecting a chainsaw, consider a direct drive model. Clutch models get wet and can malfunction. Always read the instructions and safety precautions provided with the saw and/or acquire instruction from the seller or renter. Many divers elect to rent both power augers and chainsaws.

The hole size is a matter of team/diver preference. It should be large enough to comfortably accommodate two divers with equipment. Many teams use a hole that is 4 to 5 feet on a side. The ice block is stored under the ice during the dive and placed back in the hole at the end of the dive. Some divers fear the possibility of the block of ice being accidentally pushed back into the hole while they are underwater. This is unlikely and, in the event that it does happen, the tenders and stand-by diver can immediately correct the situation. Remember that ice is extremely heavy and that it would be difficult, if not impossible, to pull a large block of ice on to the surface. Brusate [16] expresses concern about catching a diver's safety line on the ice block, especially in the event that a circle search pattern might be used to search for a lost diver. He has successfully removed relatively large blocks of ice from holes and placed them on top of the ice during diving operations. Ice block removal is facilitated by attaching a line to a ice piton that have been screwed into the ice before the hole is cut. The ice block is tilted by pushing down on one side and pulling from the other; several persons may be required to pull the block from the hole. For information on cutting holes in extremely thick ice consult Somers [1] or Jenkins [17].

Except under relatively warm, windless conditions, some sort of shelter should be set up over or immediately adjacent to the hole in order to provide protection for tenders and support persons. A variety of huts and self-supporting frame tents have been used for this purpose. The shelter must be large enough to comfortably accommodate a supervisor, two divers, one or two tenders, and aides. Benches add to comfort and convenience. Because of availability, low cost, portability and relative ease of erection many divers use large tents similar to those used for family camping with part or all of the floor removed. The interior of the tent can be warmed to some degree with a catalytic tent heater. The tent can be protected from high wind damage by securing guy lines to large ice pitons. Snow can be placed around the bottom to provide added protection.

For long exposures under extreme conditions and at highly used training sites, a heavy-duty double walled tent or insulated plywood or metal hut with a heater is required. The floor of the shelter may be decked with sheets of styrofoam insulation and covered with plywood for added insulation. Prefabricated modular structures can be either assembled on shore or on the ice. Properly designed structures can be erected and stabilizied in one to two hours; some self-supporting tents in a matter of minutes. The interior of the structure should be furnished with benches and a storage rack (or hooks) for clothing and support equipment. In solid walled shelters, a substantial ring should be securely mounted on the wall for attachment of safety lines. Andersen and Jenkins discusses the selection of shelters for polar diving operations [9, 17].

Whenever a stove or heater is used indoors, the danger of **carbon monoxide accumulation** always exists. Even tent heaters that are designed to produce little or no carbon monoxide under optimum conditions may produce high levels of contamination if they malfunction or if there is incomplete combustion of fuels. Always use and maintain heaters in accord with manufacture instructions and safety recommendations. It is always best to provide adequate fresh air ventilation. Deadly carbon monoxide is odorless and can render a person unconscious with little or no warning.

Fire is another hazard associated with the use of tent heaters. Be certain to place the heater in a location where it will not be tipped or accidentally come into contact with the shelter material or support personnel clothing. The use of flame retardant tents is highly recommended.

As an added safety precaution when diving under snow covered ice, a diver orientation pattern can be shovelled in the snow. A standard procedure is to shovel 8 to 10 lines radiating outward from the hole for a distance of 100 to 150 feet. A circular path connects the ends of these lines to form a large wheel-like symbol. Arrows pointing toward the hole are shaped at 10 to 20 foot intervals along the radiating lines. This pattern can generally be seen quite well by the divers under the ice. A lost diver could, in this case, easily find his way back to the hole. However, this procedure should not supersede the use of diver safety lines and a stand-by diver.

MAINTAINING THERMAL COMFORT ON THE SURFACE

Each individual diver and surface personnel is responsible for providing adequate protective clothing for anticipated surface conditions. Many individuals, especially city dwellers, are not schooled in the art of cold weather dressing. All dive team members and support persons must be prepared to deal with low air temperatures, wind chill, precipitation (freezing rain, sleet, and snow), handling wet lines and equipment, long period of inactivity on the ice, and so on.

Clothing should be worn in layers starting with wool or polypropylene **long underwear.** Over clothes, from the inside out, include wool or synthetic pile **pants** and **shirt(s), jacket(s), and/or sweaters**, a **hooded** down or synthetic fiber-filled **parka** and a windproof/water resistant **outer shell garment.** A wool or polypropylene **watch cap** and **scarf** or **balaclava** is recommended for head and face protection. Waterproof **boots** with wool socks and liners are also recommended. Wool or pile **mittens or gloves** are absolutely necessary. For extreme conditions, windproof/water resistant **overmitts** are desirable.

The use of **vapor barrier** garments should be considered for extremely cold conditions where long period of limited activity exposure is anticipated. Vapor barrier **shirt** and **pants** are worn over the polypropylene underwear, and normal outer garments are placed over the vapor barrier layer. A vapor barrier foot protection system consists of a thin polypropylene sock next to the foot with a waterproof vapor barrier sock next. One or more insulating sock layers (wool or pile) are placed over the waterproof sock and a second waterproof sock is pulled over the insulating socks. The foot is then placed in a boot. Foot perspiration will "wet" the liner sock; however, the insulating socks will be protected from both external and internal wetting. Since perspiration is trapped in the polypropylene underwear and not transfered to the insulating garments when a vapor barrier system is used, completely waterproof outer shell garments can be used without fear of perspiration soaking. Vapor barrier is not recommend for persons who are highly activity or for use at temperatures above freezing. The system appears to be most effective for sub-zero temperatures and sedate activities.

Tenders must stay dry and maintain proper thermal balance. Keep in mind that a cold individual undergoes mental changes. The mildly hypothermic tender may be easily distracted from his/her duties, slow to comprehend and respond to an emergency situation, and forgetful. Line and equipment handling is extremely difficult and uncomfortable with cold, wet hands. Most tenders will wear waterproof shells over mittens or gloves. Some prefer foamed-neoprene wet suit gloves and may select a size that enables them to wear a polypropylene or wool liner. The vapor barrier system also works for hands. Tenders should always include one or two pair of extra gloves/mittens in their pockets. **Pocket-type hand warmer heating units** are also valuable.

When working on exposed ice surfaces in the winter, air temperatures will frequently be below 0^{o}F and wind can exceed 20 miles per hour. This combination can produce a equivalent **chill temperature** of -35^{o}F (Figure 3). Keep in mind that exposed flesh can freeze within one minute at -25^{o}F. Remember that tenders and support personnel are inactive much of the time, thus producing little heat from exercise as compared to active persons such as cross-country skiers, hikers, and workers. I **recommend that recreational and training dives be limited to wind chill temperatures above -25^{o}F unless a heated shelter can be provided for protection on the ice.**

COOLING POWER OF WIND EXPRESSED AS "EQUIVALENT CHILL TEMPERATURE"																						
WIND SPEED		TEMPERATURE (F)																				
CALM	CALM	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	40	-45	-50	-55	-60
KNOTS	MPH	EQUIVALENT CHILL TEMPERATURE																				
3-6	5	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-65	-70
7-10	10	30	20	15	10	5	0	-10	-15	-20	-25	-35	-40	-45	-50	-60	-65	-70	-75	-80	-90	-95
11-15	15	25	15	10	0	-5	-10	-20	-25	-30	-40	-45	-50	-60	-65	-70	-80	-85	-90	-100	-105	-110
16-19	20	20	10	5	0	-10	-15	-25	-30	-35	-45	-50	-60	-65	-75	-80	-85	-95	-100	-110	-115	-120
20-23	25	15	10	0	-5	-15	-20	-30	-35	-45	-50	-60	-65	-75	-80	-90	-95	-105	-110	-120	-125	-135
24-28	30	10	5	0	-10	-20	-25	-30	-40	-50	-55	-65	-70	-80	-85	-95	-100	-110	-115	-125	-130	-140
29-32	35	10	5	-5	-10	-20	-30	-35	-40	-50	-60	-65	-75	-80	-90	-100	-105	-115	-120	-130	-135	-145
33-36	40	10	0	-5	-15	-20	-30	-35	-45	-55	-60	-70	-75	-85	-95	-100	-110	-115	-125	-130	-140	-150
WINDS ABOVE 40 HAVE LITTLE ADDITIONAL EFFECT.		LITTLE DANGER					INCREASING DANGER (Flesh may freeze within 1 minute)						GREAT DANGER (Flesh may freeze within 30 seconds)									
		DANGER OF FREEZING EXPOSED FLESH FOR PROPERLY CLOTHED PERSONS																				

FIGURE 3. Wind chill index.

All surface personnel must maintain proper thermal balance. During periods of high activity avoid overheating and excessive perspiring by removing hood, opening parka, or loosening cuffs for ventilation. Keep in mind that exposed ears can freeze (frostbite) within a few minutes in extremely low temperatures, and protect them accordingly. As you cool, replace hood or close garments to maintain thermal comfort. Remove some outer clothing when working in heated shelters.

If divers must travel some distance to the dive site on foot or snowmobile or remain inactive and exposed at the surface, they should wear an insulated parka or exposure suit and insulated boots over their diving suits. Heat lose can be considerable, especially in a wind, and pre-dive/post-dive chilling can result in significantly increased risk of injury or mishap.

PERSONAL PREPARATION

Cold water divers must have adequate pre-dive rest and nutrition. In general, divers will perform better if they are in good physical condition and have adequate rest and nutrition for a week or so prior to the diving operation. At least 6 to 8 hours of sleep and a high caloric intake is recommended for the day before the dive. Some authorities suggest that caloric intake be at least 5000 calories per day for the normal size male.

Breakfast on diving days should consist of food with high carbohydrate content but low amounts of residual because defecation is rather difficult for the suited-up diver. Intake of candy, honey, and sugar-sweetened fluids may be beneficial; however, avoid foods and eating habits that might produce nausea. Divers are warned against radical changes in eating habits and food consumption on diving days without prior experimentation.

Divers must maintain a proper fluid balance. Breathing cold, dry air can cause significant dehydration. Consumption of large quantities of caffein-containing liquids (e.g., coffee, tea, and cocoa), breathing from scuba underwater, and immersion in cold water all tend to induce diuretic effects (e.g., increase urination). Consequently, dehydration is not uncommon. Water and warm fruit juice are most effective for oral fluid replacement; balanced electrolyte fluids (i.e., Gatorade) should be considered if an individual is seriously dehydrated.

SECTION 4

THE UNDER ICE DIVE

The diving supervisor coordinates the establishment of the shore facility, selection of the hole site, cutting of the hole, erection of the ice shelter, and all other pre-dive activities. Generally, these tasks have been assigned and discussed prior to arriving at the dive site. Once he/she is satified that all preparations have been completed, the entire team is assembled for final briefing. This briefing will include, but not necessarily be limited to, the following:

* Objectives and scope of the dive operation;
* Conditions of the dive site;
* Dive plan, schedule, and diver/tender/aide teams;
* Other personal assignments;
* Safety precautions and review of environmental/cold hazards; and
* Special considerations.

Many diving supervisors prepare a dive preparation checklist and briefing outline. At the briefing, the supervisor should evaluate all personnel to assure that they are fit to dive or undertake assigned responsibilities. Surface personnel clothing and health status should be evaluated at this time as well as continuously from the time they arrive at the site until they leave. These are the people at greatest risk of frostbite and hypothermia.

Generally the divers will be required to terminate their dive when they experience a regulator freeze-up, begin to shiver, reach the specific time limit established for the dive, or reduce their air supply to approximately 900 psig (when using a full 3000 psig cylinder). Some teams are more conservative and require termination of the dive with more air held in reserve. This is up to the discretion of the diving supervisor/instructor and can vary with dive sites and conditions.

The divers proceed to dress with the assistance of their aides. The tenders may proceed to the hole site/ice shelter for any final placement or check of safety lines. The divers are escorted to the hole by their aides with all equipment in place except for mask and fins. If the distance from the shore base to the dive site is great, scuba may be transported on a sled or snowmobile and donned at the site. The aides assist the divers in donning the mask and fins and the tender secures the safety line to the diver's harness. The tenders, aides, and divers complete a final equipment and status check. The supervisor will also complete a final check and, when satisfied, permit the divers to enter the water. If the divers have been properly outfitted and checked before they leave the shore site this final preparation and evaluation procedure should take only a few minutes.

The comfort and safety of the divers is the primary concern. Take note that almost everything is done for the diver by an aide or tender once the diver is on the ice. Just before entering the water, warm water is injected into wet suits. If a dry suit diver is wearing unattached gloves, hot water is injected into the gloves.

Generally, most divers prefer to sit on the ice and slip slowly into the water. This is much better for purging air from dry suits. As previously mentioned, some authorities suggest that the diver not draw a breath from the regulator until submerged in order to reduce the potential for freeze-up. The diver or aide can hold the regulator clear until just before the diver submerges, insert the regulator into the diver's mouth, and the diver then submerges and draws the first breath. Langerman recommends that the diver not breathe from a cold regulator until just before entering the water. He also recommends pouring hot water over the regulator housing just before the diver leaves the surface [7].

As the diver submerges he/she holds on to the descent line, adjusts suit air level, adjusts buoyancy, and quickly checks the buddy diver's equipment and status. When both are satisfied, they signal the surface to give them slack by pulling twice on the safety line, and they descend. Breathing slow and easy will minimize the potential for regulator freezing.

Some divers prefer to use a weighted vertical line to facilitate descent and buoyancy adjustment. They proceed down the line to "swimming depth" and then swim laterally. Once they have reached the extent of their safety line allowance or underwater objective they can swim arc or circle patterns. Some divers are concerned about the possibility of tangling their safety lines with the descent line. This is a minimal probability for a good dive team and tender. In the event that the lines do tangle, surface personnel can quickly retrieve the descent line and release the safety line. Or the descent line can be easily removed from the water once the divers have started their swim. Keep in mind that most ice divers do not use the descent line. However, I find it to be a significant aid, especially for trainees.

Each diver is responsible for maintaining the buddy system. Even in good visibility I prefer to see divers no more than 8 feet apart. The divers should keep a light but steady strain on the safety line. If there appears to be a significant amount of "slack" signal the tender to take in the slack by pulling three times on the line. Excess line under the ice increases the possibility of entanglement. A good tender will "feel" the diver's movement and allot the appropriate amount of line. Ideally, the tender will maintain enough strain on the line to "feel" the diver but not restrict his/her movement. The tender will occassionally tug once on the line, a signal which asks if the diver is "OK"; the diver will respond with a single pull to indicate that he/she is "OK." Although the line is secured to the safety harness, the diver should also keep one hand on the line at all times.

Divers should avoid rapid and excessive movements that tend to confuse the tender. Wet suited divers will find that such movements may also increase flushing of water through the suit. Maintaining a moderate level of movement or exercise produces heat and delays the onset of cold stress. Immobility accelerates chilling. Either the divers or the tenders will monitor time and depth in accord with the designated dive plan.

Most lakes and quarries have a thick layer of **slit** (fine-grained sediment) on the bottom. The careless diver can rapidly reduce the usually clear under ice visibility to zero by stirring up this silt. The divers must adjust their buoyancy and body attitude so that they swim above the bottom and do not disturb the silt with their fins. If visibility becomes obstructed, the diver may ascend further above the bottom and swim in clear water to the hole.

In some situations it is possible to encounter **currents** under the ice. This is particularly true where there are restricted bay mouths, straits, or rivers. Winter winds can act on large areas of adjacent open water and create currents which flow under and/or move large units of ice. Tide- induced currents must also be considered in ocean diving. **The diver should avoid diving under the ice in currents if at all possible.**

WHEN TO TERMINATE THE DIVE

Dive termination is determined by one or more of several factors including no-decompression time, cylinder pressure, cold, equipment malfunction, and emotional status. From a standpoint of cold, the diver must terminate with the onset of involuntary shivering and/or diminished manual dexterity. In reality, the diver should terminate when he or she feels uncomfortable or chilled. Generally, the fingers and toes will give the first signs of cold effects. The diver should not prolong the dive exposure to the degree that he/she finds it difficult to handle the safety line or suit/BC valves.

The diver should plan to terminate the dive with approximately 30% of the air supply remaining as a safety factor. Generally, air consumption will increase as the diver cools. Each dive must, however, be planned independently. I always plan to complete my observations, task, or practice near or directly under the hole when my air supply reaches the 40% to 50% level.

Today there is great concern and much discussion about decompression tables and "revised" no-decompression limits. For cold dives the U.S. Navy instructs their divers to use the schedule for the next deeper or longer dive or both. If the diver is following one of the more recently published and more conservative no-decompression schedules **AND** is not cold, a normal no-decompression time can probably be used safely [19]. However, if in doubt or cold, the diver is encouraged to use the more conservative decompression schedule for the next deeper dive (10 feet deeper than the actual dive).

TENDING THE DIVER

Tending is an art! As previously mentioned, tenders should be qualified divers or persons specially trained in tending ice divers. The most effective assistance can only be given by a tender who is familiar with the equipment, procedures, safety precautions, environmental conditions, and difficulities that are inherent in ice diving. It is the tender's responsibility to see that the diver receives proper care while both top side and underwater. The tender must check all equipment and the status of the diver before sending him/her down. While the diver is submerged the tender handles the safety line and maintains communications with the diver.

Tenders and divers must memorize and practice basic line-pull signals so that they can be used easily and safely. The following line-pull signals are used by the U. S. Navy [20]:

Tender to Diver

1 pull..............Are your all right? (When the diver is descending, 1 pull means stop.)

2 pulls.............Go down! (During ascent, you have come up too far. Go back down until I stop you.)

3 pulls.............Stand-by to come up!

4 pulls.............Come up!

Diver to Tender

1 pull..............I am all right!

2 pulls.............Give me slack!

3 pulls.............Take in my slack!

4 pulls.............Haul me up!

Emergency Signals: Diver to Tender

2-2-2 pull series...I am fouled and need the assistance of another diver!

3-3-3 pull series...I am fouled but can clear myself.

These signals have been selected from the U. S. Navy's standard signals for surface-supplied divers. Additional signals are discussed in the section on searching for a lost diver. Additional and special signals may be designated to meet team requirements. Many recreational divers find the U. S. Navy system complex and objectionable. Regardless of the system used, it is the responsibility of the diving supervisor to designate the system and review it in the pre-dive briefing. I recommend standardizing with the U. S. Navy signal system.

When tending a diver do not hold the line so taut as to interfer with the diver's movements. The diver should be given 3 or 4 feet of slack, but not so much that he/she can not be **felt** from time to time. Signals can neither be received or given on a slack line. Consequently, the diver's line must be kept in hand with proper tension at all times.

Line pulls consist of a series of sharp, distinct pulls, strong enough for the diver or tender to feel but not so strong as to pull the diver (or tender) away from his/her position. The tender and diver should not "fight each other!" When sending signals, take the slack out of the line first. Repeat signals until answered. The only signals that do not require an answer is "come up" (delayed until the diver is actually ready) and the emergency "haul me up" signal. Continuous failure to respond to signals may indicate that there is too much slack in the line, the line is fouled, or the diver is incapacitated. If contact with the diver is lost, the following procedures should be followed:

1. If the tender receives no immediate line-signal reply from the diver, he/she should take a greater strain on the line and signal again. Considerable resistance to the tender's pull may indicate that the safety line is fouled. Notify the supervisor and stand-by team and prepare to deploy the stand-by diver.

2. If the tender feels sufficient tension on the line to conclude that the diver is still attached to the line, yet receives no signal, assume that the diver is unconscious. In this event, notify the supervisor and stand-by team and prepare to deploy the stand-by diver.

3. If the stand-by diver is unavailable, or it is considered unwise to deploy one, the diver must be pulled very slowly to the hole. Prepare to administer first aid and transport to a medical facility. Note: If the diver is wearing a dry suit, this procedure is only used as a last resort. Blow-up is almost unavoidable without the assistance of another diver.

The tender is responsible for limiting the diver's lateral distance under the ice. Prior to the dive, the diving supervisor will designate the maximum depth, lateral distance, and line amounts. The supervisor and tender may calculate the amount of safety line (S) required to reach these limits by the formula:

$$S = \sqrt{D^2 + L^2}$$

where D is the diving depth and L is the lateral extent. The following table gives the amount of line required for various depths and a lateral distance of 100 feet:

Depth (D)	Line Requirements
30 feet	104 feet
60 feet	117 feet
90 feet	135 feet

The tender should also monitor the diver's underwater time and signal the diver when the designated time limit is reached. If the diver is equipped with a communications unit, the tender may also maintain voice communications with the diver. In some cases the diving supervisor or a designated "communicator" will manage the communications system and a timekeeper will be designated.

The above water end of the safety line must be secured to a metal stake, ice piton, or other secure object to insure that it is never pulled under the ice. When the diver is submerged the tender must **never let go of the safety line.** The tender skillfully feeds the line to the diver and pulls in slack. The line may be neatly laid in a "figure-8" on the ice surface. Never allow the lines to become tangled.

DIVING UNDER SPRING ICE

The number of fatal ice diving accidents is relatively few. However, most of the fatal accidents in the Michigan and Ohio area have occured during late winter and early spring months when lakes, quarries, and ponds are only **partially** covered with ice. The unsuspecting novice diver, probably trained during the previous winter months, is anxious to start the diving season. A scuba diving team may enter a partially ice covered pond intending to swim only in the open water portion of the pond.

They lose orientation, venture under the ice by accident, and drown when they run out of air. Accident reports show that both novice and highly experienced divers have lost their lives in this fashion.

Do not rely solely on a compass for diving in partially ice covered ponds. Either use standard ice diving procedures or dive with a safety line attached to a boat that will follow the diver. Some divers will elect to tow a **large** float that will catch on the edge of the ice. The float must have sufficient size and buoyancy so that the divers can not pull it under the ice shelf. Do not use the lightweight line generally used for towing surface floats/flags in open water; use a heavy line.

REWARMING THE DIVER

When the diver surfaces, remove breathing apparatus, BC, weight belt, fins, and mask as soon as possible. If the distance to the shore base is short, the diver may carry the scuba and weight belt in place; for longer distances use a sled. Immediate injections of "comfortably" hot water (100 to 110°F) into wet suits and mittens are beneficial; do not remove the mittens or hood in cold air on the ice. Remember that wet flesh can freeze within a few minutes. **Be cautious when applying hot water to exposed skin of divers who have been exposed to extremely cold temperatures.** Brusate describes an incident where the diver experienced severe blistering and peeling of the skin following the application of "too hot" water [15]. The diver apparently did not realize that he was being scalded. If there is to be considerable delay in undressing the diver, remove mittens and hood in a protected location, dry hands and head, and don insulated mittens and hat. Moderate exercise will promote rewarming. Breathing warm air in a heated shelter will also significantly increase the warming rate. The diver should remove the diving suit and don dry clothing as soon as possible. Dry suited divers are at a considerable post-dive advantage compared to wet suited divers. Unless the dry suit has leaked significantly and the under garments are uncomfortably wet, the dry suited diver can simply don additional outer garments without the discomfort of exposing the wet body to "often less than satisfactory conditions."

The preferred method of rewarming a chilled diver is to allow the diver's own biological processes to rewarm his/her body over time with plenty of rest. Drinking warm liquids is considered beneficial. If aggressive rewarming is required in order that the diver may return to diving immediately or conventional rewarming appears to be inadequate, the diver may be immersed in a tub of comfortably hot **circulating** water. Neither showers or still baths appear to be as satisfactory as a circulating tub immersion. The water must circulate around the body to maximize heat transfer. In the absence of a circulating tub, use one of the other methods. Do not remove the diver from the tub until sweat appears on his/her forehead [21].

SECTION 5

DEALING WITH UNDER ICE EMERGENCIES

Ice divers and support personnel must be prepared to resolve under ice emergencies such as breathing system malfunction, suit or BC inflator malfunction, suit flooding, uncontrolled ascent, loss of the safety line and loss of consciousness. Keep in mind that most of the emergencies discussed below can be prevented through the use of proper equipment and procedures, and safety precautions. And those that do occur can generally be easily resolved.

Self-discipline is the key to the diver's safety. The ice diver must "discipline" every move that he/she makes both on the surface and underwater. Many fatal and non-fatal diving accidents occur each year because a diver did not know and observe his/her personal limitations or those of the equipment being used. The ice diver must know when to terminate or abort a dive. A cold diver is at a "higher level of risk" and is less likely to "respond promptly and properly" in an emergency. Personally, I have far more respect for the diver who simply says, "I'm too cold, that's all for me!", than the "thermal macho (or machette)" diver who "guts" it out to the bitter cold end to prove that he/she is a better(?) diver. I know that the first diver will still be of some use in an emergency and will probably end up saving the "better diver" someday. Don't push to the absolute limit in any diving situation, especially under the ice. I have seen some divers go so far that they do not have the physical strength to pull themselves from the water or walk once they are out. Cold can do strange thing to both body and mind.

REGULATOR MALFUNCTION

Regulator malfunction is relatively common and of great concern to all divers. The mechanism, nature, and prevention of regulator "freeze-up" have already been discussed. In the event that the regulator malfunctions, the diver(s) should immediately return to the hole. If the regulator is **free-flowing**, the diver can continue to breath from the regulator. Remember, however, that continuous free-flow will probably increase in rate as the "ice crystal" enlarges and unnecessary delays may result in high flow rate and significant air loss from the scuba. Some divers have discribed the "free-flow" experience as "literally blowing the requaltor out of my mouth" or "painful."

Some divers/dive teams will switch to the alternate (and seperate) air supply immediately and isolate (turn off) the malfuncting regulator. Naturally, both divers in a buddy team will return to the hole. At the hole, air is turned off and the regulator first- and second-stages are thawed with warm water. If sufficient air remains in the scuba, the divers may descend directly below the hole to check the function of the regulator. If the regulator is functioning properly, they are generally allowed to continue the dive. Usually, each instructor and dive team will establish a policy regarding dive continuation.

If the regulator malfunction "shuts-off the diver's air supply," immediately switch to an alternate air source and terminate the dive. Although such malfunctions are rare, the possibility must still be considered. Do not use the regulator again until the cause of the malfunction has been determined and corrected.

BLOW-UP

A diver may lose his/her weight belt, accidentally over-inflate a BC or suit, or experience a suit/BC inflation valve free-flow malfunction. Any of these conditions can result in an **uncontrolled ascent** or "blow-up." The stricken diver must begin exhalation immediately in order to reduce the possibility of pulmonary barotrauma and attempt to discharge excess air from the suit or BC.

If the suit or BC valve is free-flowing, the diver must **disconnect the hose.** If possible, place one hand over head in order to break the impact with the underside of the ice. Above all, remain calm and exhale. Unless the malfunction is corrected immediately, anticipate impact within a few seconds. Even if you resolve the situation, signal the tender to "pull you in" and terminate the dive. The diver must be observed for signs of pulmonary barotrauma.

Many divers fear blow-ups, either in a head-up or feet-up (inverted) position, if they accidentally lose their weight belt. The following information on blow-up was summarized from a NOAA study [14]:

1. The rate of ascent varied by only a few seconds between a diver losing his/her weight belt in a head-up or a head-down position.

2. The rate of ascent resulting from weight belt loss could be better controlled by divers wearing "fabric" suits than those wearing foamed-neoprene dry suits.

3. All attempts to recover from a feet-first blow-up were successful with the first 15 feet after the weight belt was dropped.

4. The use of ankle weights helps the diver get his/her legs down quicker. The ankle weights also apparently reduce the amount and rate of air movement into the foot and, thus, reduces the possibly of fin loss.

5. If the weight belt is lost in water depths of less than 20 feet, the diver must vent air from cuffs and/or neck seal as well as the exhaust valve. The exhaust valve alone cannot expel air fast enough to control the ascent. However, venting from cuffs/neck seals is extremely difficuly for divers wearing the heavy mittens common to ice diving situations.

6. Venting by opening the suit zipper is difficult and almost impossible in the inverted position (and when wearing suits with back-entry zippers.

7. Ascents resulting from loss of the weight belt in depths greater than 20 feet can be controlled by using the exhaust valve; almost normal ascent rates can be maintained.

The following recommendations are based on the NOAA study [14]:

1. Emergency blow-up venting procedures must be taught; however, they must be taught and practiced under very controlled conditions. The diver should be "secured" so that they will not lose complete control and ascend "out-of-control" to the surface.

2. Ankle weights should be worn when possible. They aid in keeping the feet down in blow-ups and help keep the feet in proper position at all times. They give stability and help keep fins on in the event of air getting into the feet.

3. Front-mounted BCs should not be worn with suits that have exhaust/purge valves located in the chest.

4. Divers should not be allowed to use variable volume dry suits until they have had adequate training.

Many foamed neoprene suit equipped-divers have used shoulder harness weight belts in the past in order to increase comfort of wearing extremely heavy belts and reduce the possibility of losing the belt underwater. The use of this type of belt is discouraged. It the diver feel a need for a shoulder harness weight belt, it must be equipped with quick release devices on the shoulder straps and the diver must be trained in releasing the belt in an emergency.

There are two methods of recovering from an inverted position blow-up: the forward roll, where the diver curls inward, and the back roll, where the diver extends and arches his/her back. The back roll is the preferred method for recovery because: (1) it provides the diver with better directional attitude for purpose of recovery of a lost weight belt, and (2) it reduces the ascent time, although not significantly. During the forward or curl roll, the diver loses downward thrust and begins ascending while curling around [14].

The diver can practice blow-up recovery using a descentline and a second safety diver/instructor. The instructor holds the student down and depresses his/her inlet valve to put air in the suit. Be careful to not overinflate the suit during initial practices; use progressively increasing amounts of inflation. The student start to drift (ascend) upward and immediately starts venting and flaring procedures. The instructor holds on to the student with one hand and a decent-ascent line with his other in order to control the student's ascent. Both head-up and inverted blow-up recoveries must be practiced.

LOST UNDER THE ICE

There is simply no reason for a diver to ever become **lost under the ice.** Through the use of proper equipment, procedures, and safety precautions the diver always has a "link" with the surface. A strong and securely attached safety line is **mandatory** even under high visibility conditions. However, all ice divers do agree that there must also be an emergency procedure for such situations. This procedure involves the deployment of a stand-by diver and specific actions by the lost diver.

Let's assume that the diver has become seperated from his/her safety line. Once the diver realizes that he/she is no longer attached to the safety line, he/she should **stop** swimming, listen, and watch for the buddy. Above all, **do not panic** and start swimming wildly around the bottom! This only increases air consumption and will probably complicate rescue. If the buddy, safety line, or hole are not in sight, the diver should immediately ascend to the underside of the ice. If the ice is thin enough, break through and call for help; do not attempt to climb out. When the ice is too thick to easily break through, it is best to not waste time, energy, or air trying to break through. **Simply stay put and relax!**

Once the tender realizes that the life line is no longer attached to the diver or that the line is apparently entangled underwater and signals are not being acknowledged by the diver, he/she will immediately notify the diving supervisor and the stand-by team. The tender should immediately note the amount of line that is under the ice and the direction of the diver at last contact and report this information to the supervisor. This is another advantage of using a measured safety line. The supervisor will quickly analyze the situation and brief and deploy the stand-by team.

Although the situation is critical, the surface group must be maintained under strict control and panicky, irrational actions avoided. The supervisor is in command! The stand-by diver is advised to swim in a direction of about 30^{o} behind the location of last contact and known swimming direction of the ice diver. A compass is necessary for the stand-by diver. The tender is advised to let out enough line to allow the stand-by diver to swim approximately 25 feet beyond the last known distance of the distressed diver from the hole (Figure 4).

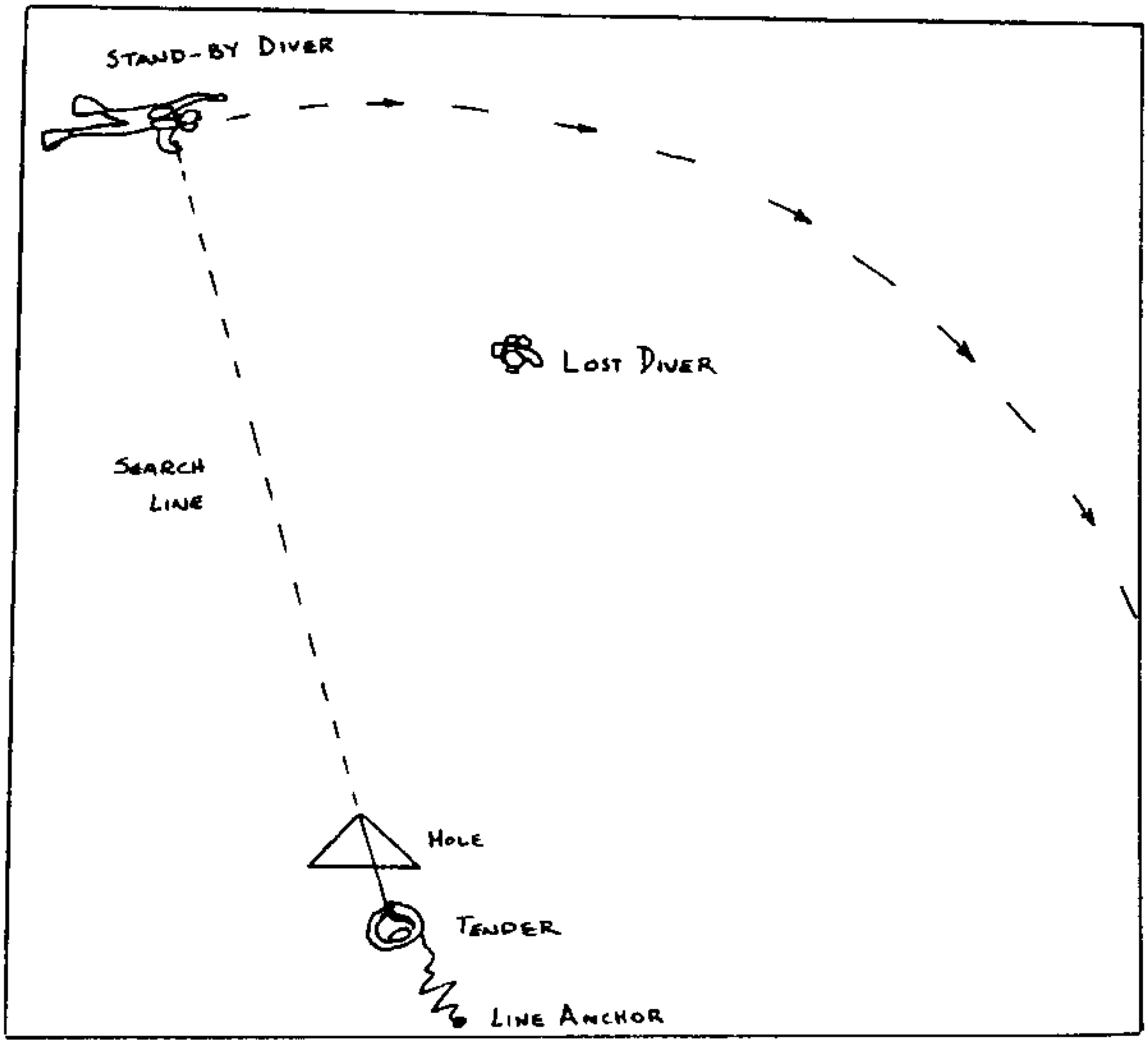

FIGURE 4. Searching for a lost diver under the ice.

The stand-by diver enters the water, stretches out his/her safety line to the designated distance, and starts a clockwise sweep just below the underside of the ice, visually scanning to both sides. Visual scanning is important since an unconscious diver floating under the ice might not be snagged by the rope. The diver and tender must coordinate to keep the line relatively taut at all times. When a full 360° sweep has been completed the tender will signal the diver with two pulls (in this situation meaning, "stop search and go out until I stop you"). The tender will let out more line, the length of which is determined by the diving supervisor based on visibility, and the stand-by diver will make another sweep. Additional sweeps can be made at the supervisor's discretion.

In the meantime, the lost diver must remain calm and hang directly under the surface of the ice in a vertical position. The search line will come across the body or, if a floating line is used, it will pass on the underside of the ice. Keep your hand on the underside of the ice at all times to catch the line and look down in case a non-floating slack line passes below your fins. The divers should be briefed prior to the dive regarding the type of line that will be used for emergency searches. As soon as you have the safety line in hand, secure it to your safety harness or make a loop around your wrist and signal the diver and tender with three pulls (meaning "take in my slack/stand-by to haul me in"). Upon receiving the three pulls, **in a search situation**, the stand-by diver should move to the distressed diver. Once they are united, the divers will signal the tender to haul them in by giving four sharp pulls on the line.

If the lost diver is not located under the surface of the ice after two or more sweeps, the supervisor must assume that the diver is unconscious on the bottom. The rescue diver is signaled back to the hole in order to assess his/her physical status and air supply. If these conditions are satisfactory, the diver is directed to start circular sweeps at a distance above the bottom that allows him/her to see the widest area for a given visibility condition. The supervisor and tender will control the sweep pattern through line signals as above.

In the meantime, additional dive teams are assembled from among the better divers and tenders at the site, briefed, and readied for deployment. The local dive rescue squad should be called to the scene immediately and, upon arrival, will generally assume responsibility for continuing the rescue search. Keep in mind that an unconscious diver may survive extended cold water immersion and rescue attempts should continue for at least one hour after the anticipated time of air supply depletion.

Keep in mind that the stand-by diver will have a long swim if he/she has to complete an entire circle. If the diver is swimming a circle sweep with a radius of 50 feet, the actual swimming distance will be 138 yards (50 feet out, 314 feet circumference, and 50 feet back). One hundred and 200 foot radius searches require 276 and 552 yard swims, respectfully.

ENTANGLEMENT

The stand-by diver may also be deployed if the tender suspects that the diver's safety line is entangled. If the line appears to be "held firm" and signals are not answered, the tender must immediately report the situation to the supervisor. At that point the stand-by diver-tender team will prepare for deployment. If the tender is unable to pull the safety line in with a modest amount of tension and no signals are received, the supervisor will deploy the stand-by diver. This diver will swim down the line and take whatever action is necessary to free the line and diver(s). All divers will then return to the surface and terminate the dive.

If a diver finds his/her line entangled, but, is still in a position to signal the surface, he/she should use a series of line pulls to indicate status. Pulling on the line with a 3-3-3 series indicates "I am fouled (entangled) however, I can free myself!" A 2-2-2 series of pulls indicates "I am fouled and need the assistance of another diver!" If entangled, **do not panic!** Relax, remain calm, and gain control of breathing. If possible, signal your status to the surface. Slowly and carefully feel back along your line and systematically try to untangle it. **Do not cut the safety line!** If you are entangled in another line, attempt to work the line free with your hands. If you cannot free the line and can definitely identify that the line holding you **is not your safety line**, carefully cut away the entanglement. Public safety divers working alone under the ice may find themselves in this type of situation at some time. A few hours spent in a pool or "safe" water practicing solving simulated problems of "entanglement" in fish line, fish nets, wire, and rope with a "black-out" mask could be very worthwhile. The advantages of diver-to-surface communications become very obvious when you consider the possibility of having to resolve an entanglement situation.

SECTION 6

COLD STRESS

The human body is homeothermic, or warmblooded, and must constantly interact with its external environment in a effort to maintain thermal equilibrium. It basically operates in a very narrow temperature range. Slight cooling of the body can produce discomfort, and continued cooling can cause serious, if not life-threatening, physiological changes. Cold induced deterioration in both motor and mental processes is considered to be the major limiting factor relative to diver performance, comfort, and safety. All divers have experienced hypothermia, or a subnormal body temperature, in varying degrees at one time or another.

HEAT LOSS

Thermal balance and immersion heat loss are affected by a number of variables. The first of these is obviously water temperature and the effectiveness of the diver's thermal protection garments. The length of exposure becomes a critical factor, as does the magnitude of metabolic heat generation. The individual's body fat composition, body mass and surface area, and physiological/psychological acclimatization must also be considered. In generalized terms, an individual of large body mass produces more heat and can tolerate longer exposures to cold water than a small, thin individual.

As the body begins to cool there is a mobilization of its heat generation and insulation resources to resist the cold. This response is characterized by peripheral vasoconstriction and increased metabolic activity in an effort to prevent a drop in the body's core temperature. Active movement of body tissues generates heat, carbon dioxide and water. As the body continues to cool the most obvious metabolic activity will take the form of shivering thermogenesis. Thermogenesis is simply the generation of heat.

The first diver evidence of heat loss, just below the comfort level, is **cold sensations.** This is followed by cutaneous vasoconstriction and, then, increased muscle tension, which are not obvious to the diver. Even before a person begins to shiver visibly, muscle tension is measurable on an electromyogram. Normal core temperature is 37°C (98.6° F). At 36°C (97°F) sporadic shivering begins. This initial shivering can be suppressed if the diver makes a conscious effort and, in fact, a working diver may not exhibit shivering at this point because of muscular activity. As the diver continues to cool, shivering increases and causes a further rise in oxygen consumption. As the diver reaches the stage of uncontrollable shivering the oxygen consumption is two to five times the normal [22]. By this time the dive should have been terminated and rewarming procedures initiated.

When the core temperature drops to 35°C (95°F) the diver will experience mental confusion and impairment of rational thought. Death by drowning is a real possibility. A diver should never "push" or "be pushed" to this point. Continued exposure to cold and decreasing the core temperature below 35°C (95°F) causes loss of memory, poor articulation, sensory and motor degradation, and amnesia [22]. Many investigators believe that cold creates a distraction in the diver that interfers with his or her work, and indeed, safety [23]. Childs observes, "distraction due to discomfort may cause the diver to ignore threats to his safety underwater and finally, realizing he is in danger, he may be in further difficulty because of loss of power and dexterity in his hands" [24].

In order to better understand "heat loss" and the use of diver thermal protection systems, it is necessary to consider the areas of the body where metabolic heat is produced. About 16 percent of the metabolic heat is produced in the brain, about 56 percent in the core of the trunk, and about 18 percent comes from total skin and muscle. The remaining 10 percent comes from the total skeleton, connective tissue, and other structures [25].

Divers tend to concentrate their thermal protection around the trunk and often compromise protection to the head. It is interesting to note that the head, a relatively small portion of the body, produces a great deal of heat. Furthermore, the peripheral vasoconstriction effectiveness varies considerably from one part of the body to another. The hands and feet experience considerably high vasoconstriction and cool very quickly [25]. This results in reduced finger dexterity, tactile (touch) sensitivity, and kinesthetic (musculoskeletal) sensation. However, total heat loss in these areas is low. On the other hand, scalp circulation in the head does not experience this vasoconstriction or "shut down" [22]. The amount of continual heat loss can be quite substantial if the head is not properly protected.

SILENT HYPOTHERMIA

Divers have only recently developed an awareness of "silent" or "undetected" hypothermia resulting from long, slow body cooling. Field experience has showed that after several days of work in cold water temperatures scientific divers often neglected to complete their research task and, in some cases, forgot what they were doing underwater. In most cases the divers generally would not indicate that they were cold, just fatigued or unwilling to dive again.

What was the problem? The participants at the "Prevention of Cold Injury" workshop sponsored by the Undersea Medical Society and National Oceanic and Atmospheric Administration reached the following conclusion, "The fatigue and impaired cognition [was] due in large part to the slow body cooling of divers even in tropical waters" [26].

For years scientists failed to make the connection between cold and diver fatigue for three reasons: (1) "thermal macho;" (2) lack of appreciation of the importance of thermal protection equipment; and (3) the insidious nature of "undetected hypothermia" in long, slow body cooling. "Thermal macho" is perhaps best described by Diver/Engineer Robert Stinton of Diving Unlimited International. To quote, "Divers will rarely admit that they are cold. So they become fatigued and are reluctant to dive again. But they will never admit it's because they are cold except in the most extreme situations. Even if they say they're not cold, they pay the price in reduced performance, fatigue, and loss of motivation" [26].

Several authorities on cold water immersion suggest that long, slow cooling of the body does not stimulate the shivering response and thermogenesis. When cooling is encountered by a swimsuit-clad diver immersed in 28 to 33°C (82.5 to 91.5°F) water or dives in a wet or dry suits in 15°C (59°F) or colder water, the mean skin temperature can remain close to the usual comfort zone (33°C or 91.5°F). Consequently, the thermal drain form the body to the water is insidious and hardly noticed by the diver until the core temperature drops 1 to 2°C (2 to 4.5°F) and shivering supervenes [26].

Bachrach considers "silent" or "progressive" hypothermia as "perhaps the major hazard to the diver in cold water" [23]. In commercial diving, investigators have implicated cold as a major cause of diving casualties, particularly the silent, progressive, insidious onset of hypothermia of which the diver is unaware [24, 27].

Divers often disregard the possible cumulative thermal effects of repetitive diving. Following the initial dive the diver returns to the surface where he/she may experience superficial skin rewarming, but little or no recovery of depressed core temperature. Each successive dive creates additional and cumulative thermal drain. This is why many divers are often too fatigued to care for their equipment following a day's diving activities and may be observed to sleep on the way back from the dive site [10]. This "thermal debt" may continue to accumulate over successive diving days. It takes time, rest, food, and, sometimes, aggressive rewarming procedures to replace lost heat energy.

DETERMINING PERFORMANCE DEGRADATION AND DIVER STATUS

One simple method of determining performance degradation is by monitoring the diver's hand writing [21]. Have the diver sign his/her name prior to entering the water. When the diver surfaces, have him/her sign under the first signature again. Repeat this procedure for each successive dive. If the signature shows a continual degradation, this indicates a lack of blood flow to the muscles of the lower arm area and, therefore, the accumulation of a thermal debt. In male divers the testicles will rise to maintain thermal balance as the body cools. One authority suggests that an indication that the diver is completely rewarmed is when the testicles descend to normal position again [21]. This may or may not be a reliable indicator of thermal recovery.

SECTION 7

RECOGNITION AND MANAGEMENT OF HYPOTHERMIA AND COLD INJURIES

Cold stress and hypothermia have already been discussed. In addition to hypothermia, divers and surface personnel must be aware of other potential injuries common to the cold weather environment such as frostbite, snowblindness, and carbon monoxide poisoning. Although snowblindness and carbon monoxide poisoning are not specifically classified as cold injuries, they are both associated with working in cold environments. In addition, the cold environment diver should be familiar with the management of burn injuries that may result from mishandling or malfunction of a shelter heater. Fire hazard is of especially great concern for polar workers and adventurers. Burn management will not be discussed here, but divers/support personnel are encouraged to consult appropriate first aid manuals.

HYPOTHERMIA

Hypothermia is known and feared by all cold weather workers. Anyone working outdoors in severe cold must be aware of the possibility of hypothermia and guard against it. The general physiological effects of decreasing core temperature are summarized as follows:

98.6°F.....................Normal core temperature

98.6 to 96°F..............Shivering begins

95 to 91°F................Violent shivering; speech difficulities

90 to 86°F................Shivering decreases; muscles become stiff; erratic or jerky movements; thinking not clear but maintains posture

85 to 81°F................Victim irrational, loses contact with environment

80 to 78°F................Unconsciousness

Below 78°.................Death

Divers and support personnel must be able to recognize the signs and symptoms of hypothermia in themselves and others. Be alert and constantly evaluate your own condition. If you exhibit any or several of the following symptoms or observe them in other members of the team, take immediate measures to reduce heat loss and provide supplemental heat:

* Intensive shivering
* Severe fatigue or slowing of activity
* Feeling of deep cold or numbness
* Poor coordination and stumbling
* Poor articulation; speech difficulty
* Disorientation, irrationality, and poor judgment
* Decrease in shivering followed by muscle stiffening
* Blueness of skin
* Intense thirst
* No desire for food
* Hallucinations
* Depersonalization

I can not overstress the need for **awareness** of these conditions. The condition can be subtle; silent hypothermia has been discussed previously. Given prolonged exposure, extreme cold, high heat loss, and heavy exertion, an individual can be rendered hypothermic without recognition of the lesser signs and symptoms.

If **mild hypothermia** is suspected, remove the victim to a heated shelter as soon as possible; protect from wind and cold. Replace wet clothing with dry and begin "passive" heating by placing the victim in a sleeping bag or under blankets at room temperature (77-90^{o}F). The theoretical advantages obtained from slow, passive rewarming are avoidance of the rewarming temperature "after drop" and hypotension, and the slow resolution of spontaneous fluid shifts. Slow, passive rewarming is a safe and simple method for mild hypothermia. One should assume that otherwise healthy individuals who are exposed to cold are volume (fluid) depleted. For conscious and cooperative victims, forced drinking in the absence of thirst is recommended. Water and warm fruit drinks are the most effective. Avoid coffee, tea, and cocoa [28].

Slow, passive warming is the best procedure for field management in most diving related situations. Medical assistance is generally available within a few minutes to a few hours. Attempt at active rewarming of severely hypothermic victims in the field is potentially risky and should only be attempted by specially trained individuals. Persons involved in polar expeditions and remote location diving operations must be schooled in advanced methods of hypothermia management.

FROSTBITE

During exposure to cold the body reduces the flow of blood to the surface blood vessels in order to maintain the body's core temperature. The hands and feet are most affected by this reduction in surface blood flow and, due to great skin area, cool rapidly. The ears and nose, although receiving a large amount of blood, protrude from the body and are, therefore, very susceptible to cooling.

As the skin temperature drops below 50°F all sense of touch and pain are lost. If the temperature continues to drop, most circulation to the area will cease and **frostbite** occurs. The water cells in the skin and capillaries freeze and tissue injury results from the expansion of the ice and the resultant cellular chemical imbalance.

Most persons working or playing in cold weather have experienced **frostnip** at one time or another. This is superficial, reversible ice crystal formation associated with intense vasoconstriction. The skin "blanches", and becomes numb with a sudden and complete cessation of cold and discomfort in the affected part. The skin will appear pale, grayish-white in color and feel cold to the touch. As soon as whitening is observed shelter the area from the wind. Cover with dry, insulating, wind proof material. Put you back to the wind or, ideally, find protection in a warm shelter. If possible place the affected area next to a warm area of the body. **Do not rub the area or apply snow!** This only injures the tissue and increases the risk of "tissue death" and subsequent gangrene. A tingling sensation and even some localized pain may occur during rewarming. Once normal color and consistency of the area is obtained normal work can be resumed.

Many persons confuse "frostnip" with **superficial frostbite.** In superficial frostbite the water in the skin and subcutaneous tissues immediately adjacent actually freezes. The frozen part will appear white or grayish-white and be frozen on the surface. When pressed (before thawing) the tissue under the skin will be soft and pliable. Treatment of superficial frostbite involves active heating of the area or affected part. This must be accomplished in a shelter where the victim is warm and protected from the wind. Most of the damage from freezing occurs during the transition from liquid to solid state and vise versa. Rapid thaw decreases the injury by decreasing the amount of time that the cells are exposed to the most damaging conditions. The ideal thawing temperature is somewhere between 37.8 and 43.3°C (100 to 110°F), never to exceed 44.4°C (112°F). The most effective temperature appears to be 42°C (108°F); thawing temperatures above 42.8°C (109°F) can cause increased discomfort [28].

Immerse the affected part in warm water at approximately 42°C (108°F). To measure the temperature accurately a thermometer should be available. Too hot water can cause extreme discomfort and damage the tissue. If a themometer is not available the temperature can be tested with an "unfrostbitten" finger; it should be comfortable to touch and not burn the finger. If the affected area can not be immersed in water, pour water over towels and apply to the area.

The thawing process requires about 30 to 40 minutes and should not be prolonged after complete rewarming. Thawing is judged to be complete when the part is pliable and color and sensation have returned [28].

The diver will seldom be faced with the possibility of **deep frostbite** which involves not only freezing of the skin and subcutaneous tissue but also deeper structures, including muscle, bone, and tendons. Do not attempt to thaw in the field. This condition is critical and requires immediate, rapid evaculation to a medical facility. Incomplete thawing and/or immediate refreezing results in severe damage which may lead to gangrene and subsequent amputation.

During and after rewarming the skin becomes numb; mottled, blue or gray; and it will sting, burn, or swell for a period of time. Blisters may appear within 24 to 48 hours depending on the site and extent of injury. If blisters do appear, do not break them since the possibility of infection is everpresent. Maintain sterile conditions. If the blisters do break, cover with a sterile soft, absorbent dressing and monitor for infection. It is best to consult a physician, even though thawing procedures appear to have been successful.

Heavy breathing resulting from strenuous exercise at temperatures below -25°F can cause "freezing of lung tissue." The victim may experience shortness of breath and cough up blood. This may be followed by a period of asthmatic type breathing. If exercising vigorously at extremely low temperatures and you experience any of these conditions, stop, put your back to the wind, and draw your hood face tunnel over your face. This allows you to rebreath some warmed, humidified, expired air.

SNOWBLINDNESS

Divers and support personnel occasionally work on the ice for long periods of time in direct bright sun. The reflected ultra-violet rays can cause snowblindness. Victims experience a sensation of grit in the eyes with pain in and over the eyes, watering, redness, headache, and intense pain upon additional exposure to light. The symptoms, like those of sunburn, usually do not become apparent for hours following the exposure. Snow blindness will heal in a few days; however, a physician must be consulted. Cold compresses and eye bandages will provide some relief. Avoid ointments and other medications except as prescribed by a physician. Caution the victim against rubbing his/her eyes.

CARBON MONOXIDE POISONING

Whenever a stove or fueled heater is used in a shelter or confined space, the danger of **carbon monoxide accumulation** always exists. Carbon monoxideis odorless and can render a person unconscious with little or no warning. All divers and support personnel must be aware of the symptoms of carbon monoxide poisioning and know appropriate first aid procedures. The symptoms include:

* Headache
* Dizziness
* Weariness
* Nausea
* Yawning
* Ringing in the ears
* Heart beat abnormalities
* Redness of skin, especially nail beds and lips

Victims must be removed from the contaminated environment as soon as possible and administered 100% oxygen. Avoid exercise and sudden exposure to cold since this only increases oxygen requirements and may cause the victim to collapse and even cease breathing. Be prepared to administer resusitation. Immediately transport to a medical facility for treatment and/or observation.

SECTION 8

ICE DIVING SPECIALTY COURSE OUTLINE

The Ice Diving Specialty Course outlined below is a modification of one pubished in NAUI News by the author [4]. This course should only be taught by a **certified** Ice Diving Instructor. The instructor may modify the course at his/her discretion in accord with regional diving practices and the requirements of the sactioning agency.

All participants are to train as both instructors and tenders. The time alloted for open water training sessions is considered as the minimun amount of time required to rotate trainees through the various positions. If the environmental conditions are extreme and/or there is not an adequate shore base facility for the divers to change clothes, one person might have to assume the diver role in the morning and the tender role in the afternoon. In this event each individual would only have one under ice dive for the day and the number of open water days would have to be adjusted in order that each individual will complete no less than **four under ice dives**, serve as a tender no less than **three times**, and as a stand-by diver at least **once.**

SESSION #1: COURSE ADMINISTRATION AND ORIENTATION

(CLASSROOM - 3 HOURS)

Administration

* Verify student certification and experience (minimum Advanced Scuba Diver or equivalent; 50 open water dives)
* Statement of Understanding or Waiver, Release, and Indemnity Agreement
* Medical History Form completion and review
* Collect fees
* Distribute texts, handouts, maps and related materials

Course Orientation

* Introduce instructor/staff and state qualifications
* Student introductions
* Review course content/schedule and objectives
* Overview of cold weather and under ice scuba diving

NOTE: A slide presentation on ice diving may be utilized at this time to enhance interest and participation.

* Review equipment to be provided by student

NOTE: Recommended student equipment includes twin scuba cylinder unit with dual regulator manifold OR dual regulator valve on single cylinder OR auxillary scuba/pony unit with 15 cf minimum capacity (have capability of isolating or turning off free-flowing regulator while diver uses alternate regulator to terminate dive; instructor may elect to provide pony units with regulators); two single-hose regulators (primary with pressure gauge); dry suit recommended; safety body harness (instructor may supply, but recommend that each student acquire personal harness); sharp knife; remaining complete personal scuba diving outfit; Logbook & Training Record; appropriate cold weather clothing/boots for surface wear.

NOTE: The standard octopus regulator may be used as an auxillary breathing unit at the discretion of the instructor. However, the student may lose considerable air unless a free-flowing unit is turned off. The student may terminate the dive while breathing from the free-flowing regulator in any case; although continued use may increase free-flow. Use of octopus eliminates the "independent" option of resolving complete regulator failure.

* Review equipment to be supplied by the instructor

NOTE: Recommended instructor supplied equipment includes pony units with regulators (for students without dual manifolds); safety lines with locking carabiners; large tubular ice screws; emergency/stand-by diver safety lines; first aid kit and oxygen unit; backboard; shelter for protection on ice and heating units (optional depending on condtitions and location); blankets or sleeping bag; ensolite pad; hot, sweet drinks; container of hot water; ice cutting equipment; snow shovel.

Local Dive Area Orientation

* Location and conditions

* Regulations and diver etiquette

* Sources of information

NOTE: Slides of divers, locations, and activities may be used to enhance interest in local diving.

SESSION #2: COLD ENVIRONMENT PHYSIOLOGY AND EQUIPMENT

(CLASSROOM - 3 HOURS)

Cold Weather Environment

* Atmospheric conditions and temperature range
* Wind chill
* Snow and ice conditions; ice thickness/safety
* Sun and reflection

Exposure to Cold

* Heat loss
* Cold stress (physiological and psychological)
* Hypothermia
* Dehydration
* Energy expenditure
* Frost bite
* Eye damage/snowblindness

NOTE: Discuss cause, prevention, symptoms/signs, management/ first aid for above.

Cold Weather/Ice Diving Equipment

* Surface clothing for cold weather ---
    - synthetic vs. down insulation
    - layering and maintaining thermal balance
    - undergarments (natural fibers vs. polypropylene and pile)
    - boots and socks
    - outer garments (windproof vs. waterproof; Gortex or equivalent)
    - vapor barrier principle and clothing
    - hand protection
    - head protection
    - eye protection

* Diving equipment
    - basic equipment
    - scuba
        - regulators (use and malfunction)
        - dual manifold cylinder unit vs. pony unit vs. octopus unit

exposure suits
  wet suits (advantages and limitations)
  dry suits (neoprene vs. waterproof fabric)
  undergarments
  inflation systems
  use and precaustions
safety body harness
safety lines and attachment devices
photographic equipment in cold environments (optional)

SESSION #3: SPECIALIZED WATER TRAINING

(CONFINED WATER - 3 HOURS)

OBJECTIVE: To build the students' confidence in their own ability to use dry suits, handle regulator malfunction, loss of mask in confined area, and line tending.

* Dry suit diving (dressing procedures, inflation/deflation, simulated "blow-up" management, weighting, buoyancy compensation, flooding)

* Line diving and tending

NOTE: Simulate ice diving with entry, exit and line tending at corners of pool deep end (triangular ice hole); students can only surface in "hole"; cover deep end with light weight plastic sheet (sheet can be held up with floats and water polo balls leaving spaces for diver to breath in case of emergency surfacing); reduce light level; use underwater lifeguards.

* Lost mask exercise

NOTE: Under plastic sheet and reduced light conditions; instructor executes surprise mask removal from behind; diver returns to "hole" by (1) line feel and (2) buddy guide.

* Air supply malfunction exercise

NOTE: Under plastic sheet and reduced light conditions; instructor turns air off on primary regulator; student switches to secondary regulator and reaches back to locate primary valve; terminate dive. This exercise is intended to develop students' confidence in managing either an air loss or free-flow by requiring use of secondary air and location of the primary regulator valve which would be necessary in event of a "freeze-up" free-flow. Exercise can be repeated with buddy locating valve.

SESSION #4: OPEN WATER DIVE PLANNING, PROCEDURES, OBJECTIVES, AND DIVE SITE REVIEW

(CLASSROOM - 2 TO 3 HOURS)

Organization and Planning

* Personnel assignment and duties ---
  divemaster
  diver
  tender
  stand-by diver and tender
  diver aides

* Preliminary planning/organization

* Objectives and scope

* Conditions of dive area

* Dive plans and schedules

* Safety precautions

* Special considerations

Maintaining Thermal Balance Above Water

Personal Preparation

* Sleep and diet

* General physical condition

Equipment Selection and Preparation

* Air supply (moisture free)

* Group equipment (provided by instructor)

* Personal equipment selection and preparation

Dive Site Preparation

* Shore bases and shelter

* Ice shelter

* Dive location selection

* Ice thickness requirements

* Snow removal and hole cutting
* Shovel guide pattern on surface

Dress-in and Entry

Under the Ice

* Regulator use and freeze-up prevention
* Suit inflation for thermal comfort; use of BC
* Orientation and descent
* Underwater movement and navigation
* Line handling by divers and tenders
* Termination

Decompression Tables and Safety Procedures

Tending the Diver

* Line handling
* Line signals
* Fouled diver
* Blow-up

Warming the Diver

Hazards Associated with Ice Diving

* Hypothermia
* Cold stress
* Frostbite
* Snowblindness
* Regulator malfunction (free-flow freezing; air delivery failure; auxillary breathing system options)
* Power inflator malfunction (free-flow freezing)
* Blow-up (suit over inflation)
* Lost under ice (line break or release)

* Dry suit flooding
* Partial ice cover
* Silting
* Power saw safety and injuries (recommend use of hand saws by students)

Preparation for Open Water Dive #1

* Description of dive site
* Dive plan and schedule
* Team and personnel assignments
* Inspection of students' equipment
* Emergency plan and procedures

NOTE: A slide presentation illustrating a previous dive at this site would be very helpful.

SESSION #5: ORIENTATION, DIVE, POST-DIVE REVIEW

(DIVE SITE A - 4 HOURS)

Site Orientation

* Review water conditions
* Designate entry/exit point
* Identify natural aids to navigation
* Review emergency procedures
* Review assigned task and dive teams
* Surface cold precautions

Ice Dive #1

OBJECTIVE: Students will make shallow dive with limited horizontal distance in order to familiarize themselves with site organization, hole cutting, equipment handling, dress-in, dive procedures, and line tending.

SECONDARY OBJECTIVE: Allow instructor to evaluate ability and competency of students in diving activites.

Post Dive Review

* Rewarming procedures (as required)

* Review of water conditions

* Discuss problems (if any)

* Logbook and training record entries

* Student dive planning considerations for Dive #2

NOTE: If the students have not previously experienced diving in cold weather and cold water (without ice cover), a dive should be scheduled prior to Session #5 at an open water location in order to familiarize students with the cold weather/water environment and dry suits.

NOTE: If a sufficient number of instructors and assistants are available, more than one ice hole can be used for training divers.

NOTE: Each trainee will serve as both a diver and a tender. If conditions do not allow for this rotation, the trainees will switch roles for the next dive. Consequently, there would have to be a Session 5A & 5B. The same shall be considered for subsequent dive sessions.

Break For Lunch (or Departure)

SESSION #6: ORIENTATION, ICE DIVE/POST-DIVE ACTIVITIES

(DIVE SITE A OR B - 4 HOURS)

Site Orientation

* Review water conditions

* Designate entry point

* Identify natural aids to navigation

* Review emergency procedures

* Designate any changes in specific task assignments

Ice Dive #2

OBJECTIVE: The students will make a dive to not more than 40 feet or 75 feet horizontal distance to practice dive procedures, buoyancy compensation, and line tending.

SECONDARY OBJECTIVE: To familiarize students with the under ice environment.

SECONDARY OBJECTIVE: Further instructor evaluation of student's ability.

Post-Dive Activities

* Rewarming procedures (as required)

* Review conditions and activities

* Logbook and training record entries

Break for Day

SESSION #7: ACTIVITIES REVIEW

(CLASSROOM - 2 TO 3 HOURS)

NOTE: This session may encompass a review of Dives #1 and #2 and include additional information on local dive sites, cold water diving equipment, and so on.

NOTE: Guest speakers may be utilized at this session to relate specific cold environment diving experiences (such as Arctic expedition) and the under ice environment.

* Organization and emergency procedures for OW Dive #3

* Assign dive team tasks

NOTE: Dive #4 may include special tasks such as environmental data collecting, underwater dive site mapping, recovery of lost objects such as ice fishing tackle or snowmobile recovery (for very experienced divers only).

SESSION #8: ORIENTATION, ICE DIVE, REVIEW

(DIVE SITE A OR B - 4 HOURS)

Site Orientation

* Review water conditions

* Designate entry point

* Identify aids to navigation

* Review tasks and emergency procedures

Ice Dive #3

OBJECTIVE: The students will practice management of simulated regulator malfunction with emergency return to ice entry point and lost diver search and recovery.

NOTE: A simulated lost mask exercise may be included at the instructor's discretion.

Post Dive Review

* Rewarming procedures (as required)

* Review of water conditions and dive problems (if any)

* Logbook and training record entries

* Planning considerations for Dive #4

Break for lunch (or Departure)

SESSION #9: ORIENTATION, ICE DIVE, POST-DIVE REVIEW

(DIVE SITE A, B, OR C - 4 HOURS)

Site Orientation

* Review of water conditions

* Designate entry point

* Review emergency procedures

* Special task assignment

* Designate dive teams

Ice Dive #4

OBJECTIVE: Each dive team will complete a special assigned task such as environmental data collecting, underwater dive site mapping, recovery of lost objects such as ice fishing tackle or snowmobile recovery (for very experienced divers only).

SECONDARY OBJECTIVE: The student's pride and sense of achievement are enhanced through completion of the assigned task.

Post-Dive Review

* Rewarming procedures (as required)
* Review water conditions, observations, and problems (if any)
* Review and applaud dive accomplishments
* Students report on data or project
* Logbook and training record entries

Graduation dinner and award C-cards, patches, and certificates.

NOTE: Appropriate time for guest speaker with unique audio/visual presentation.

REFERENCES CITED

1. **Somers, L.:** "Cold Weather and Under Ice Scuba Diving," National Association of Underwater Instructors Technical Publication No. 4 (Montclair, California, 1973).

2. **Cooper, K.:** The Aerobics Way (New York: Bantam Books, 1977).

3. **Davis, J.:** (ed.), Medical Examination of Sport Scuba Divers (San Antonio: Medical Seminars, Inc., 1983).

4. **Somers, L.:** "NAUI Ice Diving Speciality Course," NAUI News (October 1984).

5. **Bright, C.:** "Diving Under Polar Ice," pp. 145-157 in Symposium Proceedings: Equipment for the Working Diver (Washington: Marine Technology Society, 1972).

6. **Fullerton, D.:** "Evaluation of Single Hose Regulators," Defence and Civil Institute of Environmental Medicine, Operational Report No. 930 (Downsview, Ontario, 1973).

7. **Langerman, N.:** "Mountain Divers in Winter," NAUI News (October 1984).

8. **Larry Taylor:** Personal Communication (1985).

9. **Andersen, B.:** "Arctic III Expedition: Diving Equipment and Human Performance During Diving Operations in the High Arctic," Final Report, ONR Contract No. N00014-73-C-0208 (Landover, Maryland: Oceanautics Incorporation, 1973).

10. **Cranston, R.:** Your DUI Diving Guide (San Diego: Diving Unlimited International, Inc., 1984).

11. **Piantadosi, C., et al.:** "Manned Evaluation of the NCSC Diver Thermal Protection (DTP) Passive System Prototype," Navy Experimental Diving Unit Report No. 13-79 (Panama City, Florida, 1979).

12. **Robert Cranston:** Personal Communication (1985).

13. **Phillip Sharkey:** Personal Communication (1985).

14. **Rutkowski, D. and Ruszala, T.:** "NOAA Diving Office Test, Evaluation, and Training of the Variable-Volume Dry Suit," National Oceanic and Atmospheric Administration Diving Office, NOAA Technical Report 80-1 (Rockville, Maryland, 1980).

15. **Wayne Brusate:** Personal Communication (1985).

16. **James Hyde:** Personal Communication (1985).

17. **Jenkins, W.:** "A Guide to Polar Diving," Naval Coast Systems Laboratory (Panama City, Florida, 1976).

18. **Linton, S. and Rust, D.:** Ice Rescue (Fort Collins, Colorado: Concept Systems, 1982).

19. **Karl Huggins:** Personal Communication (1985).

20. **U. S. Navy,:** "U. S. Navy Diving Manual," NAVSHIPS 0994-9010 (Washington: U. S. Government Printing Office, 1970).

21. **Richard Long:** Personal Communication (1985).

22. **Webb, P.:** "Human Tolerance to Thermal Extremes" p. 17-29 in Egstrom, G., (ed.): Symposium Proceedings: Thermal Problems in Diving (Wilmington, CA: Commercial Diving Center, 1977).

23. **Bachrach, A.:** "Cold Stress and the Scientific Diver," p. 31-37 in Mitchell, C. (ed.): Dive for Science 85: Proceedings of the Joint International Scientific Diving Symposium (La Jolla: American Academy of Underwater Sciences, 1985).

24. **Childs, C.:** "Loss of Consciousness in Divers -- A Survey and Review" in Medical Aspects of Diving Accidents Proceedings (Luxembourg/Kirsberg, 1978).

25. **Egstrom, G.:** "Thermal Regulation in Man" p.3-16 in Egstrom, G. (ed.): Symposium Proceedings: Thermal Problems in Diving (Wilmington, CA: Commercial Diving Center, 1977).

26. **Makulowich, G.:** UMS/NOAA Cold Workshop. Pressure 14:4, (August) 1985.

27. **Hayward, M. and Keatinge, W.:** Progressive Symptomless Hypothermia in Water: Possible Cause of Diving Accidents. British Medical Journal 6172:1182 (1979).

28. **Bangs, C. and Hamlet, M.:** "Hypothermia and Cold Injuries" pp. 27-63 in Auerbach, P. and Geehr, E. (ed.): Management of Wilderness and Environmental Emergencies (New York: Macmillian, 1983).