

**08-13-2000 Indianapolis IN – Warren Smith – FF PSD Deep Training
Barotrauma**

**Pvt. Warren J.C. Smith
August 13, 2000
Indianapolis Fire Department**

Smith, Warren J.C.

http://www.usfa.fema.gov/applications/ffmem/ffmem_detail.cfm?p_id=736

Age: 28

Rank: Firefighter, Private

Status: Career

Incident Date: 08/13/2000

Incident Time: 13:05

Death Date: 08/13/2000

Cause of Death: Caught or Trapped

Nature of Death: Asphyxiation (includes drowning)

Emergency Duty: No

Duty Type: Training

Activity Type: Other

Fixed Prop. Use: Outdoor Property

Fire Dept. Info:

Indianapolis Fire Department

50 N. Alabama

Suite E 208

Indianapolis, Indiana 46204

Chief: Louis Dezelan



Final Summary:

Private Smith was participating in dive training exercises at a local quarry. Private Smith and his company were simulating the rescue of a drowning child in 70 feet of water. Private Smith had been a certified team diver for 2 years. Private Smith failed to surface with his buddy and rescue attempts were commenced immediately. CPR was started in the water and continued during a boat ride to shore. Paramedics from a local rescue squad provided aid, and Private Smith was transported by helicopter to a local hospital where he was pronounced dead. Private Smith died of barotrauma, a condition caused when a diver rises to the surface of the water too quickly and suffers internal injuries as a result of gas expansion during the ascent.

Pvt. J.C. Smith was a private on Engine 14. While practicing diving maneuvers with three other fire fighters in a 70-foot deep rock pit, Pvt. Smith lost contact with his dive partner. Pvt. Smith was found moments later in cardiac arrest. He was air lifted to the hospital where he was pronounced dead. He was 27 years old.

Warren C Smith

<http://www.thediversassociation.com/index.php/sheets>

Fire-fighter, aged 28, Search and rescue training dive in a lake. Circular search, partner lost the rope and became separated, basic SCUBA gear only, no voice comms. Another diver saw the victim who was distressed and frantically screaming, the victim knocked out the other diver's face piece. The victim, who was entangled in the buoy line was pulled to the surface by the line, given medical assistance and transported to hospital by air ambulance where he was pronounced dead. The cause of death was stated as pulmonary barotrauma. NIOSH report

Diving crew at Southwestside quarry was practicing how to save a child.

http://www.starnews.com/news/articles/0814_IFD.html

August 14, 2000 By Sally Falk Nancrede Indianapolis Star

An Indianapolis firefighter died Sunday afternoon after a simulated drowning rescue apparently went tragically wrong.

Pvt. Warren J.C. Smith, 28, was pronounced dead at 2:14 p.m. at Methodist Hospital. He was taken there by Life Line Helicopter after the accident, which occurred about 1:18 p.m. on the Southwestside.

He had been practicing the rescue of a drowning child in a gravel pit at Epler Avenue and Ind. 37. Smith was part of two teams of divers practicing the simulated recovery in the quarry, according to Capt. Mario Garza, public information officer for the Indianapolis Fire Department.

The officers were retrieving a child-sized mannequin, Garza said. "The dummy child was in 70 feet of water, and something went wrong," said Garza. "We don't know exactly what went wrong. Right now we have more questions than we have answers."

Several other divers were in the area at the time, said Indianapolis Fire Chief Louis Dezelan. "He was an experienced diver," Dezelan said. "They're all professionals. They take this stuff very seriously."

Smith, who was not married, was a five-year veteran of the Fire Department. For two years, he had been a certified rescue diver, which is a rigorous certification to obtain.

Garza said there are many questions about the incident, including whether Smith had problems because of the depth of the dive.

The Marion County Sheriff's Department will lead an investigation into the accident, and the Indianapolis Police Department's dive team will assist, Garza said.

They will check the equipment, see if Smith ran out of air and complete a list of other checks to determine what happened. "Until they do a thorough investigation, which could take a week or more, we don't know what happened," said Garza.

Dezelan said he had spoken with some of the other divers, but at this point could do little more than mostly offer support. "We have an affection for each other because of this business we're in," Dezelan said. "It's my obligation to help them get through it."

Rapid Ascent Caused Indianapolis Rescue Diver's Death

http://www.firehouse.com/lodd/2000/in_aug13.html

08-13-00 HEATHER CASEY - Firehouse.com News

Firefighter Warren J.C. Smith of the Indianapolis Fire Department died Sunday afternoon after a simulated diving rescue of a child in a gravel pit on the southwest side of the city.

He died from a condition known as barotrauma, caused when a diver rises to the surface too rapidly, said Frances Kelly, Marion County chief deputy coroner. Gases in the body, such as oxygen and nitrogen, contract when divers descend and expand when they rise, Kelly said. If they rise too fast, the lungs can over-inflate, rip, and spill out air that can cause air clots. Air clots were found during Smith's autopsy Monday, Kelly said.

"They were searching for a child dummy in about 70 feet of water," as part of a monthly training session, said Roger Birchfield, assistant PIO.

Smith, 28, was a five-year veteran of the department and a member of station 14.

Smith and his partner entered the water at about 1 p.m., followed by a second team. They had been in the water about five minutes when Smith's partner surfaced and another diver arose, yelling for help, Birchfield said.

One diver cut off Smith's weight belt while others pulled him from the water and launched a boat to carry him the 100 feet to shore. The rescuers started CPR as soon as they had Smith on the boat.

At 1:41 p.m. Life Line Helicopter air-lifted Smith to Methodist Hospital where he was pronounced dead at 2:14 p.m. "They shocked him about three times and brought him back once, but he went back under," Birchfield said.

The divers first knew there was a problem when one of them encountered Smith thrashing under the water.

Officials said additional causes of the tragedy will be examined, such as whether Smith ran out of air or had equipment problems.

The joint investigation is being headed by the Marion County Sheriff's Department, in conjunction with the state police, the Department of Natural Resources and the Indianapolis Police Department dive team.

Smith is survived by his father, Birchfield said.

Services will be held Friday afternoon August 18th at Saints Peter and Paul Cathedral 1400 N. Meridian St.

Internment will be at Washington Park North

Diver suffered oxygen deprivation

<http://www.all-links.com/cgi-bin/newscentral/frameit/FrameIt.pl?url=http://www.starnews.com/>
August 15, 2000 By Tonya Maxwell Indianapolis Star

Autopsy suggests firefighter surfaced too rapidly, triggering deadly reaction.

An Indianapolis firefighter diving in about 70 feet of water during a training exercise Sunday died after changes in the pressure created a condition that starved his lungs and heart of oxygen, the Marion County coroner said Monday.

Investigators are still trying to determine what happened at the bottom of a Southwestside gravel pit where Pvt. Warren J.C. Smith and three other divers were practicing the rescue of a drowning child.

The four firefighters were diving in about 70 feet of water at a quarry at Epler Avenue and State Road 37.

When Smith, 28, didn't respond to radio calls, divers began searching the murky water, said Detective Sgt. Michael Turner of the Marion County Sheriff's Department.

Smith was found within minutes and was pulled to the surface, where other firefighters tried to revive him. Smith, however, likely was dead before he was taken out of the water, Turner said. "We don't know if there was a problem with his air or if something went wrong in the training scenario," Turner said.

Smith's equipment will be inspected for flaws, and investigators are looking into the possibility that Smith died because of mistakes he made. Turner said Smith's air tank was empty and he was not wearing his full-face mask when divers lifted him from the water.

Smith's accident, which occurred just four months after his mother's sudden death, has left the congregation of St. Andrew the Apostle Catholic Church in disbelief, said Diane Orr, director of religious education.

During his teen years, Smith regularly attended St. Andrew with his mother, Sharon, who was active in the church.

At his mother's wake in April, Smith told Orr that his mother had been nervous about his plans five years ago to become a firefighter. " 'I told her not to worry,' " Orr remembers Smith saying. " 'That, just as she felt called to teach and volunteer at St. Andrew's, I felt called to serve on the Fire Department.' "

Smith also promised his mother that he would be careful and safe in his job. Looking back Monday, Orr said that maybe Sharon Smith's untimely death was a blessing in disguise. "I don't think Sharon could have handled it," Orr said. "They were so very close. Although Sharon was strong, she would have been devastated."

Smith died from barotrauma, a condition usually caused when a diver rises to the surface too rapidly, said Coroner John P. McGoff. As a diver descends gases in the body, such as oxygen and nitrogen, contract. Those gases expand when a diver rises, and a quick ascension can cause the lungs to overinflate.

If that over inflation is severe, the lungs can rip and spill air into the body, causing air clots, McGoff said.

An autopsy conducted Monday found air clots around Smith's lungs, under his skin and in his bloodstream. Air clots can block arteries, depriving the heart, lungs and brain of oxygen and causing death.

For safe ascensions, experts recommend that divers rise 30 to 60 feet a minute, said Jason Roney, a dive instructor at Indy MPH Watersports Inc., in Fishers in Fishers.

Surfacing faster than that can cause barotrauma and force the lungs to tear. "They're like a balloon," Roney said of a diver's lungs. "If you overinflate it, it pops with a pretty good force. If you put too much air in the lungs, it has to go somewhere."

Smith, a 1990 graduate of Chatard High School, received his diving certification two years ago. He graduated from dive school alongside Cpt. Mickey Radez, who saw Smith at the training site hours before his death. He

wished Smith -- known among fellow firefighters as J.C. -- a good dive. "If we had advertisements, J.C. would have been the poster boy for the department," Radez said, remembering Smith as a dedicated, hard-working and well-trained firefighter.

"Not to sound too dramatic, but we really lost a brother."



NIOSH
Fire Fighter Fatality Investigation
and Prevention Program

Death in the line of duty...

A summary of a NIOSH fire fighter fatality investigation

May 3, 2001

<http://www.cdc.gov/niosh/fire/reports/face200038.html>

Fire Fighter/SCUBA Diver Dies During Training Evolution—Indiana

SUMMARY

On August 13, 2000, a 28-year-old male fire fighter/self-contained underwater breathing apparatus (SCUBA) diver (Diver #1 [the victim]) died during a training evolution. The victim was a member of the career fire department's Dive and Rescue team. The victim and other team members gathered at the site of the incident and prepared to complete training evolutions, which involved search and recovery. After a short class covering vectors for the last known location and a pre-dive briefing of the training evolution, a weighted baby doll was placed in the water, approximately 100 feet from the shore. The victim and his dive partner (Diver #2) entered the water and followed vector points (visual line of site) based on the location where the baby doll was released. Reaching the area where the baby doll was released, they dropped a buoy marker and returned to the shore. After splitting up into two teams, the victim and his partner and two other divers (Diver #3 and Diver #4) entered the water and swam to the buoys, which they had placed earlier to perform underwater search patterns. Divers #3 and #4 descended their buoy line first, and the victim and his partner descended their buoy line shortly after. As both teams performed their search patterns at a depth of 70 feet, the divers from both teams eventually became separated from their partners. Diver #4 searched for his partner (Diver #3) as Diver #2 surfaced to locate the victim's air bubbles and relocate his position. As Divers #2 and #4 searched for their partners, Diver #3 came in contact with a distressed diver whom he determined to be the victim. Diver #3 tried to calm the victim as he frantically screamed and moved around, knocking off Diver #3's facepiece. After re-donning his facepiece, Diver #3 attempted to surface to get help. Diver #3 became entangled in the search lines and eventually received assistance from Diver #2 to get free. Divers #2 and #3 surfaced and reported to the dive instructor that the victim was distressed and was still on the bottom. The dive instructor swam out to the location and the instructor, Diver #3, and Diver #4 pulled up the buoy line that the victim and Diver #2 had descended. The victim, who had become entangled in the buoy line, was pulled to

the surface by the buoy line. The victim was unconscious and had red froth near his mouth and nose. En route to the shore (via boat), the victim received medical assistance which continued on the shore. He was then loaded into a helicopter and transported to a nearby trauma center where he was pronounced dead.

NIOSH investigators concluded that, to minimize the risk of similar incidents, fire departments should

- *ensure that positive communication is established among all divers and those personnel who remain on the surface*
- *ensure that underwater searches are completed individually to avoid possible rope entanglement*
- *ensure that equipment checks are performed before each dive*
- *consider that appropriate medical fitness evaluations for SCUBA work are obtained and updated on all divers*
- *ensure that all divers record each dive in a dive log*
- *ensure that divers are trained to perform rescue operations for other divers who may be in distress*
- *consider developing a pre-dive checklist for all diving situations, including training*
- *consider supplying divers with an alternative air source*
- *consider upgrading their diving standard operating procedures (SOPs) and include the 29 Code of Federal Regulations (CFR) 1910 for commercial diving operations*
- *consider upgrading manual underwater communication devices with hands-free underwater communication devices.*

INTRODUCTION

On August 13, 2000, a fire fighter/SCUBA diver (the victim) died while performing a training evolution. During the evolution the victim became distressed and did not surface. Other divers pulled the victim to shore and administered emergency medical treatment. The victim was transported to a trauma center where he was pronounced dead. On August 14, 2000, the U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this incident. On September 27-29, 2000, two safety and occupational health specialists from the NIOSH Fire Fighter Fatality Investigation and Prevention Program investigated this incident. Meetings and interviews were conducted with the Chief, Deputy Chiefs, District Chiefs, the Director of Special Operations and Training, fire fighters and divers who were on the scene, the dive

instructor, and representatives from the International Association of Fire Fighters (IAFF). NIOSH obtained copies of the fire department's Standard Operating Procedures (SOPs), the dive training manual, the victim's training records, photos of the incident site, a copy of the victim's autopsy report, and drawings of the incident site. Investigators were unable to examine the victim's SCUBA gear due to external testing which was being completed. The equipment was tested by the Department of Navy at the request of the local coroner.¹ The victim's mask, which incorporated the breathing regulator, had a positive pressure system which causes a slight free-flow when the mask is not firmly strapped to an individual's face, which is normal. The victim's mask tested to have a slight free-flow when the mask was tightly sealed, which does not meet the manufacturer's specifications. The victim's buoyancy compensator (BCD) was also tested by the Navy and appeared to perform as desired. "The Navy report concluded that the complete diving system appeared to have been maintained properly and functioned as designed. It would not have been a factor in this accident."¹ There was no direct evidence to support that the victim ran completely out of air underwater. However, if the victim checked his SCUBA cylinder air pressure with the mask attached to it earlier that morning, and if he did not shut off his air supply, the mask's free-flow would have reduced his air pressure. If this occurred and the victim never checked his air pressure at the dive site, he could have had a reduced air pressure reading, limiting his air supply. Calculations provided by the fire department and the Department of Navy demonstrate that based on the approximate time the victim would have checked his air pressure the morning of the incident, and the time that they began the dive, the victim could have possibly descended with approximately 2,100 psi of air in his cylinder. The victim and the other divers stated that they had approximately 3,000 psi of air in their cylinders when they descended. However, the victim did not record his air pressure level. The victim's gear consisted of the following: dry suit, full facepiece with a built-in electronic communication device and air source, buoyancy control device (BCD), hood, weight belt, fins, knife, and rope. *Note: The communication device incorporated a manual button which has to be pushed to send communications.*

The fire department involved in this incident is comprised of 744 uniformed personnel. The department serves a population of approximately 399,000 in a geographical area of 93 square miles. The department requires all new fire fighters to complete Fire Fighter Level I and Level II certification. Upon entering the department, all fire fighters must pass an annual physical examination which consists of medical screening, psychological evaluation, personal fitness evaluation, blood work, physiologic evaluations, random drug testing, and a flexibility test. Fire fighters on the Dive and Rescue team must pass the above evaluations, along with additional evaluations which include endurance tests, body fat analysis, ear checks, blood pressure, and other general medical checks to obtain their SCUBA dive team membership. The fire department requires all fire fighters who are on the SCUBA Dive and Rescue team to achieve Basic and Advanced National Association of Underwater Instructors (NAUI) certification. The fire fighters are required to complete six dives a year of which three of the dives must be completed with the dive instructor to maintain their certification. The victim was certified as a Basic and Advanced SCUBA diver. The victim's training records were reviewed by NIOSH investigators and appeared to be sufficient. The victim's dive log was reviewed and the last dive logged by the victim was on May 28, 1998, with no apparent problems noted.

All comments and notes recorded in the victim's dive log were positive, with encouraging remarks by the victim's instructor. Although his last dive was logged on May 28, 1998, he had completed additional training and was an active diver in the department. *Note: According to one of the dive instructors, since May 28, 1998, the victim completed the once a month dives to retain his diving certification. However, these dives, along with others, were not recorded by the victim in his dive log.* The Standard Operating Procedures for the departments' SCUBA Dive and Rescue team were reviewed and appeared to be up to date and complete. The body of water in which the incident took place was a large, open lake with depths near 100 feet ([see Photo](#)). The weather on the day of the incident was reported to be sunny, with the temperature in the mid-80 degrees, and calm winds. The water's visibility was reported to range from 0 to 10 feet. The water temperature was not recorded, but it did not appear to be a factor in the diver's performance. *Note: Although the water temperature was not recorded, interviews revealed that the water temperature was approximately 55 degrees.*

INVESTIGATION

On August 13, 2000, at approximately 1100 hours, a crew from the fire department's Dive and Rescue team met at a nearby lake to perform a required training evolution. The crew of 10 (Diver #1 [the victim]; Divers #2, #3, and #4; a safety diver (dive master); a dive instructor; a boat operator; a paramedic and two additional support staff) gathered at the site, where the dive instructor went over the scenario for the training evolution. The evolution consisted of releasing a weighted baby doll in the lake and then completing search-and-rescue operations based on the last known visible location of the doll. Once the location was established, the fire fighters would set up vectors (reference points) to guide them to the location. *Note: Prior to the briefing, the dive instructor and the safety diver swam approximately 100 feet from the shore to evaluate an area for the search.* The divers would then place buoy markers at the vectored location, exit the water, partner up (buddy system), reenter the water, descend on the buoy line, and complete a search pattern sweep. After receiving this instruction, the divers set up their equipment on the shore, and the dive instructor and safety diver entered the water again and were guided by other divers to the same approximate location as before. After establishing their vectors, they exited the water. The victim, his dive partner, and the instructor then swam out to the same approximate location with the weighted baby doll. They dropped the doll and returned to shore. After exiting the water, the instructor told the fire fighters to swim out to the location, based on the vector points, and place a buoy marker to establish a reference point for their search. The instructor also stated that a crew who was performing training evolutions previously lost a flashlight approximately 30 feet south of the baby doll. At that time they decided that they would drop two buoys in separate locations and perform search patterns ([see Diagram](#)) to search for the flashlight and doll. The victim and his dive partner (Diver #2) entered the water wearing life jackets and followed the vector points to the last known visible location of the baby doll. They dropped a buoy at that point and swam back to the shore. Divers #3 and #4 donned their gear and entered the water with another buoy and search rope as the victim and Diver #2 donned the rest of their gear. Both crews completed an equipment check and the victim

stated that he had approximately 3,000 psi of air in his cylinder. The victim's air pressure was recorded by the dive master, as reported by the victim. *Note: All of the divers, except for Diver #2 who was wearing a wet suit, were wearing dry suits and their full array of diving gear. All divers except for the victim's dive partner (Diver #2) were equipped with full facepieces which incorporated an electronic communication device with their air supply regulator. Diver #2 was equipped with a conventional regulator and had no electronic communications with the other divers (his full facepiece was being repaired).* As Divers #3 and #4 dropped their buoy approximately 30 feet south of the other buoy, the victim and Diver #2 entered the water and swam toward the buoy they had placed in the water. Divers #3 and #4 descended their line and reached the bottom of the water at a depth of approximately 70 feet. They completed a circular pattern sweep by attaching the line to the anchor, establishing physical contact with each other, and swimming side by side in a circular pattern around the anchor line, releasing additional rope on each completed evolution. The victim and his partner reached the buoy they had placed in the water and descended the line to a depth of approximately 70 feet. They completed a fan (180-degree pattern) search pattern by having the victim stay at the anchor base, and his dive partner completed the fan search patterns. After each pattern, the victim (pivot diver at the anchor's base) would give two tugs on the line, letting Diver #2 know that the pattern was completed and that additional rope was being released. *Note: There is no required procedure to complete the patterns. The divers decide which pattern they will use.* As Divers #3 and #4 completed their evolutions, Diver #4 stated that he encountered Diver #2 approximately 13 minutes after he and Diver #3 had descended the line. The divers stated that the visibility underwater at this depth was approximately 3 feet. Diver #4 and Diver #2 made visible communication signs with their hands, signaling that everything was OK. *Note: It is unclear if any of the lines had become entangled at this time. However, it is very possible that the two different search lines could have become entangled during the search. Diver #3 recalled releasing approximately 40 feet of rope line during their circular sweeps. The buoys were set up approximately 30 feet from each other.* Diver #4 looked back but could not see Diver #3. Diver #3 became separated from Diver #4, and Diver #2 lost the line that he and the victim were using to complete their patterns. Diver #2 attempted to use his compass to locate the victim while Diver #4 attempted to locate Diver #3. Diver #3 started to reel in his search line and follow it back to the anchor base, where he could relocate the buoy line and follow it to the surface. *Note: If the divers become separated, they are trained to briefly search for their partner. If the divers cannot locate each other underwater, they are to surface and regroup.* Diver #3 attempted to contact Diver #4 and the victim several times through his facepiece communication device and received no response. Diver #3 checked his air supply and noted that he had approximately 1000 psi of air left. *Note: If the victim had descended with the air pressure that was calculated by the fire department and the Department of Navy, he could have had approximately 100 psi of air pressure in his cylinder at this time. However, the victim did not record his air pressure before his descent, but did report to others that he had approximately 3,000 psi of air in his cylinder before descending.* He then began to reel in the search line to go back to the buoy and felt two tugs on the other end of it. Shortly after, he heard a loud scream which sounded like it was emitting through a mask. He quickly reeled the line in and found the victim frantically screaming. The screaming lasted for approximately 10 seconds. *Note: It is*

believed that the victim could have been entangled in the search lines at this time, because he was located on the end of Diver #3's search line. Diver #3 grabbed the victim from behind and attempted to calm him down. At this point, Diver #2 had surfaced, and saw air bubbles close to one of the buoys. He assumed the air bubbles were coming from the victim. He swam to the buoy and descended to relocate the victim. Note: Divers stated that the buoys had moved from their original placement to a closer proximity with each other.

Diver #3 stated that he was able to calm the victim for approximately 5 seconds before the victim started thrashing around and frantically screaming again. As Diver #3 attempted to locate the victim's weight belt to release it, the victim tightly grabbed around Diver #3. Diver #3 was able to break free from the victim and calm him again for a short period of time. Diver #3 then reached again for the weight belt, and the victim began to scream and thrash around. The victim grabbed around Diver #3, restricting his movement. As Diver #3 successfully broke free from the victim, the victim knocked off Diver #3's facepiece, which contained his air source. Diver #3 was able to locate his facepiece and re-don it. *Note: Diver #3 could not determine if the victim knocked off his facepiece by accident or if the victim was out of air attempting to use Diver #3's air source.* Knowing that he was low on air and the victim was in distress, Diver #3 decided to surface and get assistance. *Note: SCUBA divers trained for search-and-rescue are trained to assist others who may be in distress. Training emphasizes that any time divers who are assisting those in distress are restricted in movement or lose their air supply, they should immediately free themselves, find their air source and surface to request assistance.* As Diver #3 attempted to surface, he became entangled in the search lines, which began pulling him back down. Diver #3 stated that he was approximately 15 feet above the victim (approximately 55 feet under water) when he became entangled.

Diver #2 had reached the buoy by this time and descended the line a second time. As he descended the line, he came into contact with Diver #3. Diver #3 gave Diver #2 the out of air sign and pointed down. *Note: Diver #3, in a state of panic, was attempting to explain to Diver #2 that the victim was possibly low on air and he (Diver #3) was entangled.* Diver #2 then realized that Diver #3 was entangled. He pulled out his knife and cut Diver #3 free of the search line, and the two divers ascended. At approximately 1300 hours, the divers surfaced, and Diver #3 told Diver #2 that the victim was in distress. Diver #2 immediately yelled to shore, "NAUI, NAUI, NAUI," which means a diver is in distress. The dive instructor immediately swam out to their location as the boat operator, the safety diver, and the paramedic responded in the boat. Prior to their response, they radioed dispatch for an ambulance and the life-flight helicopter. Diver #4, who had surfaced away from the buoys, saw the boat responding and immediately swam toward Divers #2 and #3. Diver #2 checked his gauges and noted that he had approximately 1000 psi of air left. He decided to descend the line and attempt to locate the victim. He descended approximately 40 feet and became entangled in the search line, but was able to ascend and surface without assistance. The dive instructor, along with the other divers, started pulling up the buoy line (the line which Divers #1 and #2 were on) and felt that they had snagged the victim. *Note: It is believed that the two search lines became entangled during the two different search patterns. No divers recalled seeing or making contact with the victim from the time his partner started the search pattern to the time*

Diver #3 came into contact with him. As they pulled the line up, Diver #2 descended the line and was able to locate the victim, and remove his weight belt. Diver #2 stated that the victim's facepiece was not on his face and that he was unconscious. Diver #2 could see a red froth around the victim's nose and mouth. Diver #2 ascended to the surface, and the divers pulled the victim to the surface at approximately 1307 hours. They removed the victim's gear as the dive instructor began to give the victim mouth-to-mouth resuscitation in the water. They loaded the victim into the boat, and the safety diver took over the resuscitation efforts. The boat operator started the boat; however, the propeller was entangled in the line. Diver #2 was also entangled in the line, which kept pulling on him. The dive instructor was able to free the propeller and Diver #2 from the line, and the boat proceeded to shore. As the boat arrived on the shore, advanced life support was started, the ambulance arrived on the scene, and emergency medical personnel continued treatment to the victim. The medics could not locate a pulse and decided to use a defibrillator in an attempt to regain a pulse. The medics were able to get a pulse and then lost it. They shocked the victim a second time and received a pulse, which they eventually lost again. They attempted to shock the victim a third time but could not regain a pulse. The life-flight helicopter had arrived on the scene, and the victim was loaded into the helicopter and transported to a nearby trauma center. The victim received additional medical treatment at the hospital, but the victim was pronounced dead in the trauma center at 1414 hours.

CAUSE OF DEATH

A complete and detailed post-mortem examination was performed by a forensic pathologist. The cause of death was stated as [pulmonary] barotrauma. Findings were extensive air emboli (air bubbles in lung, brain, and heart blood vessels), subcutaneous emphysema (air under the skin), and alveolar hemorrhage, as well as pulmonary edema with pink foam in the airways. There was no pneumothorax. No other primary lung abnormalities were noted, including under microscopic examination, and no other significant abnormalities were noted in the post-mortem exam. Toxicology reports listed no finding which contributed to his death. The manner of death was listed as an accident.

NIOSH investigators followed up on additional concerns that a medical condition could have occurred prior to pulmonary barotrauma. Although a medical condition cannot be completely ruled out, information obtained from the autopsy report supports that it is unlikely.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Fire departments should ensure that positive communication is established among all divers and those personnel who remain on the surface.²

Effective underwater communication is imperative. Specifically, diver-to-diver and diver-to-surface communications should be established and maintained during the entire dive(s). Underwater electronic devices are available to establish diver-to-diver and diver-

to-surface communications. Some of the divers involved in this incident were equipped with underwater electronic communication facepieces during this diving incident. Additionally, the fire department involved in this incident was equipped with an electronic surface monitor, which allows surface personnel to monitor the underwater communications. However, the electronic surface monitor was not being used during this incident.

Recommendation #2: Fire departments should ensure that underwater searches are completed individually to avoid possible rope entanglement.

Any time rope lines are used underwater during SCUBA activity, the risk of entanglement is present. Rope lines used underwater should be kept at a minimum to avoid possible entanglement. When two different search patterns are being performed in close proximity, it is possible that the search patterns can overlap one another and cause the ropes to become entangled. If two different searches take place, they should be at a safe distance from each other and the proper staff should be assigned to oversee each individual dive operation. It is unclear that the search patterns were overlapped in this incident. However, Diver #3 located the victim underwater on his (Diver #3's) search line, which indicates that they had become entangled at some point underwater. Diver #3 recalled releasing approximately 40 feet of rope line during their circular sweeps. The buoys were set up approximately 30 feet from each other. Additionally, it was stated that the buoys were dragged from their original placement closer together during the operations, which also indicates entanglement of the two lines.

Recommendation #3: Fire departments should ensure that equipment checks are performed before each dive.³

Using the buddy system, divers should develop the habit of inspecting each others' equipment for correct positioning, adjustment, air pressures, and function before entering the water. Whenever divers are using underwater electronic communication devices, all divers should ensure that the devices are working properly and have fully charged batteries. The divers should attempt to establish communication with each other on the shore and remain in communication throughout the dive. Any problems (e.g., low air, broken weight belt, broken straps, etc.) should be reported to the dive instructor, logged, and repaired or replaced before the dive takes place. During this incident, none of the divers could recall if the victim's underwater electronic facepiece was in working order. Diver #3 attempted to establish underwater electronic communication with the victim several times but was unsuccessful. The victim's dive partner was equipped with a conventional diving mask and regulator and was also unable to establish underwater electronic communications with the victim.

Recommendation #4: Fire departments should consider that appropriate medical fitness evaluations for SCUBA work are obtained and updated on all divers.⁴⁻⁶

Underwater diving with SCUBA involves a number of known and potentially serious risks. One of the more important concerns is the risk of pulmonary barotrauma, which can occur when pressure stresses on lung tissues. This can lead to rupture of lung tissues and air entering blood vessels (air embolism), the pleural space (pneumothorax), or other body tissues (as in chest tissues or under the skin). The air bubbles in air embolism may be carried to all parts of the body and can block normal blood flow; this can be particularly dangerous if it involves the brain (seizures, stroke) or the heart (heart attack).

Medical fitness for SCUBA activities is intended to detect those who may have predisposing health factors that would increase the risk of diving injuries, including pulmonary barotraumas. Although research is continuing, there are currently no screening procedures that completely eliminate the risk for this problem.^{5,6} In this incident, there was no evidence suggesting a lung disease in the victim, either from a routine physical exam or history, an old chest X-ray, or post-mortem examinations. The lack of a pneumothorax also suggests that pleural blebs (a known contraindication to SCUBA) were likely not present. The finding of alveolar hemorrhage without other anatomic abnormalities suggests that the pulmonary barotrauma may have been caused by a breath-holding maneuver while ascending; however, apparently spontaneous pulmonary barotrauma has also been reported. The victim's apparent pain, confusion, and subsequent cardiac arrest were all likely secondary manifestations of pulmonary barotrauma.

Recommendation #5: Fire departments should ensure that all divers record each dive in a dive log.⁶

A detailed log book is the proof-of-experience documentation for any diver. It is important to document all parts of each dive for future reference. The documentation should consist of the dive location, the date, weather conditions, water temperature, air temperature, time of dive, type of dive (e.g., training, rescue, recreational, etc.), equipment being used in the dive, dive partner or other divers, air pressure at the beginning of each dive, air pressures at the end of the dive, water visibility, maintenance, dive or site maps, personal information, emergency information, dive details (e.g., minutes of dive, dive depth, surface time, etc.), a summary of the dive, and a witness (dive partner or other diver) signature. The dive log provides an excellent means to recall diving experiences, document diving history, and note details that may otherwise be forgotten. Additionally, it can help the diver(s) remember to complete tasks which may be overlooked during a routine dive (e.g., check air pressures before and after each dive, equipment checks, etc.).

Recommendation #6: Fire departments should ensure that divers are trained to perform rescue operations for other divers who may be in distress.^{3,7}

Divers who perform rescue operations are generally trained to deal with distressed victims. However, the divers should also be trained to deal with any distressed divers

who may be performing the rescue operations. The training should be in a controlled environment (e.g., swimming pool) and cover all possibilities which divers may encounter in a rescue situation. Underwater management should also be included in the diver training. For example, some underwater problems divers encounter, which are pointed out in the PADI Open Water Dive Manual are overexertion, running out of or low on air, regulator free-flow, and entanglement. A diver experiencing or about to experience a problem, will generally be anxious with rapid and shallow breathing. The diver will generally pay no attention to his or her buddy or others and will make quick, jerky movements. The buddy should assist by trying to slow down and calm the overexerted diver. Then the buddy should assist the overexerted diver in a controlled ascent to the surface. If a diver is running out of air, the buddy should provide an alternative air source (buddy breathing or extra cylinder). Then the buddy should maintain calm and assist the diver in a controlled ascent to the surface. The same practice should take place for a diver who has experienced a problem with a free-flowing regulator. A diver who becomes entangled in debris or rope should be assisted in the same way as an overexerted diver would be. Calm the diver to prevent overexertion and slowly remove the diver from the debris. A diver in distress who is entangled could possibly cause both divers to become entangled if the diver is not immediately calmed. When this training takes place, divers should go through the exercises with their buddies and perform each part of the training. The training should be supervised by a certified dive trainer and a safety diver. Backup divers should also be in the water to assist in the training. This type of training allows divers to become familiar with each other's actions or reactions in these types of situations. It is important that the divers know as much as possible about each other's action underwater.

Recommendation #7: Fire departments should consider developing a pre-dive checklist for all diving situations, including training.³

When divers arrive on the scene there are many tasks that need to be performed. The majority of the tasks are brief and require only seconds. These tasks could include evaluating the site, developing site diagrams, preparing equipment, checking equipment, checking their buddy's equipment, reporting recent health or medical problems, interviewing witnesses, and recording pertinent information in the dive log. A checklist could be developed to ensure the completion of all tasks. This checklist should be signed by the dive instructor or supervisor and kept on file for future reference. A sample checklist can be viewed in the PADI Open Water Dive Manual.

Recommendation #8: Fire departments should consider supplying divers with an alternative air source.²

Divers should always pay close attention to their air supply while underwater. Should a diver become low on air for some reason, an alternative air source should be near. Divers should always dive with a buddy. In certain situations, the diver's buddy can supply the alternative air source, by "buddy breathing" or providing an extra second stage regulator,

also known as an "octopus." Since divers can become separated and cannot always rely on their buddies as an alternative air source, they can be equipped with an extra small air cylinder. The small air cylinder is equipped with a mouthpiece and can be attached to the diver's primary cylinder. Should a diver run completely out of air, the diver could use the spare cylinder to ascend to the surface. The breathing time allowed will vary, depending on the depth of the diver, cylinder size, and the diver's breathing pattern. Full facepieces require special attention. The full facepiece incorporates the air source and must be completely removed to use this type of alternative air source. There are modifications which allow this type of alternative air source to be used with full facepieces. However, it is recommended that the manufacturer be contacted before adding new equipment or making any modifications to new or existing equipment.

Recommendation #9: Fire departments should consider upgrading their diving standard operating procedures (SOPs) and include the 29 Code of Federal Regulations (CFR) 1910 for commercial diving operations.⁷

The fire department involved in this incident did have SOPs in place at the time of the incident. The standard for commercial diving operations, 29 CFR Part 1910.401 applies to every place of employment within the waters of the United States where diving and related support operations are performed. However, this standard does not apply to any diving operation performed solely for search, rescue, or related public safety purposes by or under the control of a government agency. This standard covers the basis for dive operations and fire departments should consider incorporating this standard into their diving SOPs as a reference.

Recommendation #10: Fire departments should consider upgrading manual underwater communication devices with hands-free underwater communication devices.

There are different types of underwater communication devices which can be used to establish a link of communication between divers. There are two different ways communications can be sent through these devices, by manually activating the device or voice activation. Manual activation consists of the diver pushing a button to communicate a message. Voice activated devices are activated when the diver speaks. The voice activated system makes it easier for divers to communicate since they are not required to push a button. When divers are performing search-and-rescue dives, they could possibly have a rope line in one hand and a compass in the other. Using the voice activated device would allow divers to speak freely without having to use their hands to activate the device. Additionally, if a diver would become entangled underwater, his or her hands may not be free to activate the manual device to call for assistance.

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INVESTIGATOR INFORMATION

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Photo. Incident Site

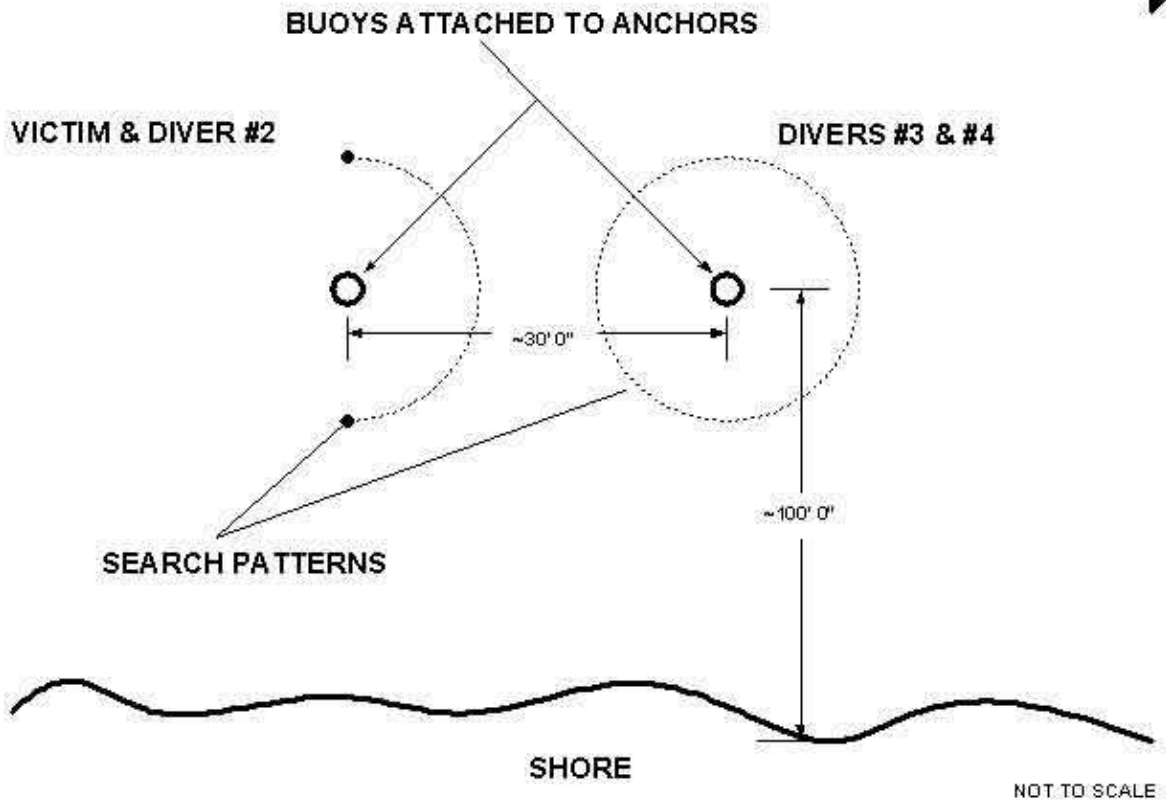


Diagram. Search Patterns

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