Career Part-Time Fire Fighter Dies After Being Struck by Pressurized SCUBA Cylinder — Ohio

Executive Summary

Close-up photo shows broken cylinder valve and neck area of SCUBA cylinder that struck the 33-year old fire fighter. ***(NIOSH Photo)***

On June 24, 2018, a 33-year-old male career part-time fire fighter (Fire Fighter 2) died after being struck in the head by a pressurized compressed-air self-contained underwater breathing apparatus (SCUBA) cylinder. Fire Fighter 2 was working his regular shift at Station 22 and was assisting Fire Fighter 1 and an off-duty captain with the inspection of a lot of 22 used SCUBA cylinders. The SCUBA cylinders had been recently privately purchased by members of the fire department's dive rescue team. The cylinders were all used and all had expired hydrostatic retest dates stamped on the cylinders. The fire fighters were draining the air from the cylinders and removing the cylinder valves so that the cylinders could be sent out to be hydrostatically retested and requalified. Some of the cylinder valves were stuck shut preventing the fire fighters from bleeding off the cylinders' contents through the cylinder valve. In order to bleed off the cylinder contents from the cylinders with the stuck valves, Fire Fighter 1 was instructed to loosen the pressure-relief burst disc plugs on the cylinder valves approximately 1 ½ to 2 turns, while Fire Fighter 2 assisted the captain in removing cylinder valves from the empty cylinders. During this process, one of the pressure-relief plugs separated from the valve body which created an unrestricted oriface through which the cylinder contents vented. The unsecured cylinder began to spin, rotate and bounce off the engine bay floor until it became an airborne projectile. The airborne cylinder struck a concrete block wall, causing the cylinder valve body to shear off, resulting in a larger oriface for the cylinder contents to vent through. The cylinder was projected off the concrete block wall diagonally across the engine bay where it struck the right rear corner (officer side) of the engine, then glanced off the engine striking Fire Fighter 2 in the head. The other two fire fighters immediately began to administer first aid to the fallen fire fighter. Fire Fighter 1 called dispatch for an air medic helicopter and an ambulance. Within minutes, Fire Fighter 2 was transported via helicopter to a regional trauma hospital where he was pronounced dead.

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Contributing Factors

- *Unsecured pressurized SCUBA cylinder*
- *Unknown hazards associated with old, out-of-date cylinders with stuck valves*
- *Limited training and experience on the task*
- *Non-routine maintenance on pressurized SCUBA cylinders*
- *Selection, care and maintenance of SCUBA equipment*
- *Inadequate risk versus gain analysis.*

Key Recommendations

- *Fire departments should ensure that pressurized cylinders of all types are properly stored, handled and maintained in a safe manner following the manufacturer's recommendations and industry best practices by qualified and properly trained individuals.*
- *Fire departments should follow guidance provided by NFPA 1852 Standard on Selection, Care, and Maintenance of Open-Circuit Self-Contained Breathing Apparatus (SCBA) and apply it to self-contained underwater breathing apparatus (SCUBA).*

Additionally, federal, state, local, and municipal governments, standards-setting organizations and authorities having jurisdiction should:

- *Consider developing and adopting a national standard on public safety dive teams and public safety dive operations including guidelines for the selection, care and maintenance of SCUBA equipment.*

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Introduction

On June 24, 2018, a 33-year-old male career part-time fire fighter died after being struck in the head by a pressurized compressed-air self-contained underwater breathing apparatus (SCUBA) cylinder. On Monday, June 25, 2018, the Director of the Ohio Public Employment Risk Reduction Program contacted the National Institute for Occupational Safety and Health and requested NIOSH assistance. That same day the fire department directly contacted the NIOSH Fire Fighter Fatality Investigation and Prevention Program to request assistance with an investigation. On June 26, 2018, the U.S. Fire Administration notified NIOSH of this incident.

On June 28, 2018, a safety engineer with the NIOSH Fire Fighter Fatality Investigation and Prevention Program traveled to Ohio to initiate an investigation and to inspect the incident scene at the fire department's Station 22. The NIOSH investigator met with the fire chief, fire department's Human Resources manager, the fire department's officer responsible for training activities who was also an officer of the International Association of Fire Fighters local union, a representative of the State of Ohio Bureau of Workers' Compensation, Public Employment Risk Reduction Program, and a representative of Ohio Department of Commerce, Division of State Fire Marshal. The incident scene was inspected and photographed. The NIOSH safety engineer and the two Ohio state employees then traveled to the local county sheriff's office to inspect two cylinders and cylinder valve components involved in the incident that were being held in custody by the sheriff's office.

On July 2, 2018, the safety engineer returned to Ohio to continue the investigation, along with the Medical Officer from the NIOSH Fire Fighter Fatality Investigation and Prevention Program Medical Component located in Cincinnati, Ohio. The NIOSH investigators obtained copies of the fire fighter's training records, fire department standard operating procedures, the dispatch audio records for the incident and county coroner's reports. Interviews were conducted with the fire fighters directly involved in the incident.

Fire Department

This combination fire department provides fire suppression and emergency medical (EMS) services across parts of two counties where it serves a population of approximately 41,000 residents across a geographical area of about 362 square miles. The daytime population increases to over 75,000.

The fire department operates as a joint emergency medical services (EMS) and fire protection district. The joint EMS/fire district is governed by a board of directors. The fire chief, a fiscal officer, and the human resources director report to the board of directors. The fire department employs an assistant fire chief and a fire safety inspector. The fire department operates three shifts with a minimum staffing level of 11 career (full and part-time) fire fighters per shift. Each shift is supervised by a shift captain and a shift lieutenant. The fire department currently operates out of four stations across the district. Table One lists the apparatus and equipment housed at each station.

Table One

Station 10	Station 21	Station 22	Station 23
Tender 212 Utility 248 Medic 226 Brush 247	Engine 201 Rescue 234 Medic 220 Medic 221	Engine 202 Medic 222 Brush 245 Boat 200 4-wheel ATV	Engine 203 Tender 214 Rescue 232 Tower 236 Brush 246 Medic 223 Medic 224 Medic 225 UTV 200 FEMA trailer Utility 249

Table Two highlights the number of emergency calls that the fire department responded to over the past three years.

Table Two

Year	2015	2016	2017	2018*
Fire	480	590	557	318
EMS	4,428	4,516	4,870	2,817
Total	4,908	5,106	5,427	3,135
				*through 7/23/2018

At the time of the incident, the fire department was in the process of re-establishing a fire department dive rescue team that had been disbanded under a previous fire chief. The current chief had been working with fire department members (both career and volunteer) over the past year to re-establish the dive rescue team. In order to be a member of the fire department dive team, the individual fire fighter is responsible for obtaining their Open Water certification. After that, the department covers the cost for the additional trainings such as Advanced Open Water, Rescue Diver, and Recovery Diver. At the time of the incident, the fire department had not established standard operating procedures or guidelines covering the dive rescue team. The fire department did have a set of draft standard operating procedures that were in the process of being reviewed and adopted as official standard operating procedures.

Training and Experience

The state of Ohio has three certification levels for fire fighters: Volunteer, Fire Fighter Level I, and Fire Fighter Level II:

- Volunteer Fire Fighter requires 36 hours of training in basic concepts, equipment, and techniques. This training does not include live fire training. After successful completion, the student may take the state certification examination.
- Fire Fighter I requires a minimum of 156 hours training that includes a comprehensive introduction of basic fire-fighting concepts and skills and permits the students to practice the skills, including live fire training.
- Fire Fighter II requires a minimum of 104 hours of training that includes additional practice of skills on advanced rescue and prevention concepts, including participation in live fire training evolutions. Level II certification is required for full-time paid (career) fire fighters.

With the exception of full-time career fire fighters, the state of Ohio permits the authority having jurisdiction to determine the level of fire fighter certification. The state also requires continuing education credits after certification. For Fire Fighter I and Fire Fighter II, any certification after 2012 requires 56 hours of continuing education every 3 years.

Fire department records showed that the fire fighter killed during this incident had received state certification in Volunteer Firefighter, Firefighter I, Firefighter II, Emergency Medical Technician, Advanced Emergency Medical Technician and Fire Instructor. In addition, fire department records showed that the fire fighter had 1,555.50 hours of on-duty activity and fire service training from December 2015 through June 2018.

Incident Location

This incident occurred inside the north engine bay at the fire department's Station 22. In addition to existing work benches, fire fighters had set up a table near the Side B wall to hold assorted tools, SCUBA cylinders, and cylinder valves (see Photo 1). The fire fighters were also working on the engine bay floor. The station did not have a cylinder containment vessel or system to contain cylinders.

Photo 1: Photo shows the North engine bay at Station 22 where the incident occurred.
Photo courtesy of the State Fire Marshal's Office.

SCUBA Cylinder

The cylinder involved in this incident was a U.S. Department of Transportation (DOT)-approved model 3AL flat-bottomed aluminum cylinder manufactured in June 1991. The cylinder was designed to be filled with compressed gas to a maximum pressure of 3000 pounds per square inch (psi). The cylinder was used as a self-contained underwater breathing apparatus (SCUBA) air cylinder by a commercial fisherman in saltwater conditions for several years. The cylinder had been hydrostatically retested, in accordance with DOT requirements four times with the most recent hydrostatic retest conducted in September 2011. *Note: Aluminum cylinders including the 3AL model cylinder are required to be hydrostatically retested every 5 years per DOT regulations found in Title 49, Code of Federal Regulations (CFR) Section 180.205*. At the time of this incident, members of the fire department's dive team had recently acquired a lot of 22 used 3AL aluminum cylinders. All the cylinders in the lot of 22 had been used for SCUBA diving in salt water conditions. All the cylinders had expired hydrostatic test dates so fire fighters were working to remove the cylinder valves from the cylinders so that the cylinders could be hydrostatically tested and requalified.

As part of the NIOSH investigation, the cylinder valve was sent to an engineering laboratory for a metallurgical analysis to help identify why the cylinder valve was stuck shut. Based upon the laboratory's visual inspection and tests conducted, chloride-induced corrosion was the root cause of the failure of the regulator valve's normal operation. Corrosion locked the regulator valve in the "closed positon", and did not prevent compressed gas escaping elsewhere from the valve body at full pressure. See Appendix One for the laboratory conclusions and summary page. The full laboratory investigation report is available upon request.

Weather Conditions

The weather on June 24, 2018 at approximately 1354 hours (the day and approximate time of the incident) was mostly cloudy. The temperature was approximately 78 degrees Fahrenheit with 64 percent relative humidity and winds from the west / northwest at 13 miles per hour. Barametric pressure was recorded at 28.8 inches water column [Weather Underground 2018]. The weather was not considered to be a contributing factor in this incident.

Investigation

On June 24, 2018 at approximately 1410 hours, a 33-year old part-time career fire fighter was critically injured when he was struck in the head by a pressurized self-contained underwater breathing apparatus (SCUBA) breathing air cylinder. The cylinder experienced an uncontrolled leak and became an airborne projectile.

On the day of the incident, two career fire fighters were working their normal shift at Station 22. Fire Fighter 1 was a full time employee of the fire department. Fire Fighter 2 was a 33-year-old career part-time employee. Fire Fighter 1 was also a member of the fire department's dive rescue team, having just joined the dive rescue team in the past year.

Members of the fire department's dive rescue team had recently privately purchased a lot of 22 used self-contained underwater breathing apparatus (SCUBA) air cylinders. All of the cylinders had expired hydrostatic test dates and all the cylinders were reported to be full of air. *NOTE: At the time of this investigation, the fire department did not own or supply any dive rescue equipment to the dive rescue team members. All dive rescue team members were required to obtain their own protective equipment and dive gear.*

The fire department's captain in charge of the dive rescue team (off duty on this day) brought the lot of 22 cylinders to Station 22 in his personal vehicle so that he could train Fire Fighter 1 on how to inspect SCUBA cylinders. Since all of the cylinders had expired hydrostatic test dates and would need to be requalified by an authorized test facility, it was decided to drain the air from each cylinder and remove the cylinder valve so that the inside of each cylinders could be visually inspected.

Both Fire Fighter 1 and Fire Fighter 2 assisted the captain in draining the SCUBA cylinders and removing the cylinder valves. The ambulance normally parked in the North engine bay was moved outside the station so that the captain's personal vehicle (containing the 22 SCUBA cylinders) could be backed into the north station bay (see Photo 1 and Diagram 1). The cylinder examination and inspection work was done on a table in the engine bay and also on the engine bay floor. Some of the cylinder valves were difficult to remove from the cylinder so the fire fighters would lay a cylinder on the engine bay floor so that a fire fighter could hold the cylinder while another fire fighter used wrenches to unthread the cylinder valve from the cylinder neck. *NOTE: Station 22 did not have any type of cylinder containment system to secure compressed gas cylinders. Station 22 also did not have a table vise or similar device to securely hold and restrain a cylinder.*

During this process, the fire fighters noticed that a number of the SCUBA cylinders could not be drained of air because the cylinder valve hand wheels were stuck and could not be turned to open the valves. It was decided to drain the air from the cylinders with non-functioning (stuck) valves by loosening the pressure-relief disc plug slightly and allow the air to drain off through the threaded port.

Fire Fighter 1 was instructed to loosen the pressure-relief burst disc plugs on the cylinder valves approximately 1 ½ to 2 turns, while Fire Fighter 2 assisted the captain in removing cylinder valves from the empty cylinders. Fire Fighter 1 began to drain the cylinders with non-functioning (stuck) cylinder valves by loosening the pressure-relief disc plugs with a 3/8-inch socket wrench and turning the plug approximately 1 ½ to 2 turns until the air began to bleed off through the treads. Once the cylinder began to bleed off air, the cylinder was placed upright on the engine bay floor. *Note: 3AL cylinders have flat bottoms so the cylinders would stand upright. It was reported that this process took 60 to 90 seconds for the air to bleed off until the cylinder was empty. SCUBA cylinders do not have pressure gauges on the valve body so the exact cylinder pressure was unknown.* Three cylinders were drained in this manner. During this process, one of the pressure-relief plugs separated from the valve body which created an unrestricted orifice through which the cylinder contents (compressed air) vented. While working to drain the air from a fourth cylinder, Fire Fighter 1 observed a cylinder begin to spin around and bounce on the floor due to the pressure escaping from the burst disc plug port. The spinning cylinder struck another empty cylinder (blue in color) that had already been drained of air and had its cylinder valve removed. The empty blue cylinder was projected across the engine bay where it struck the passenger side of the engine (see Diagram 1), bounced up toward the ceiling, struck an overhead pipe and came to rest on the engine bay floor.

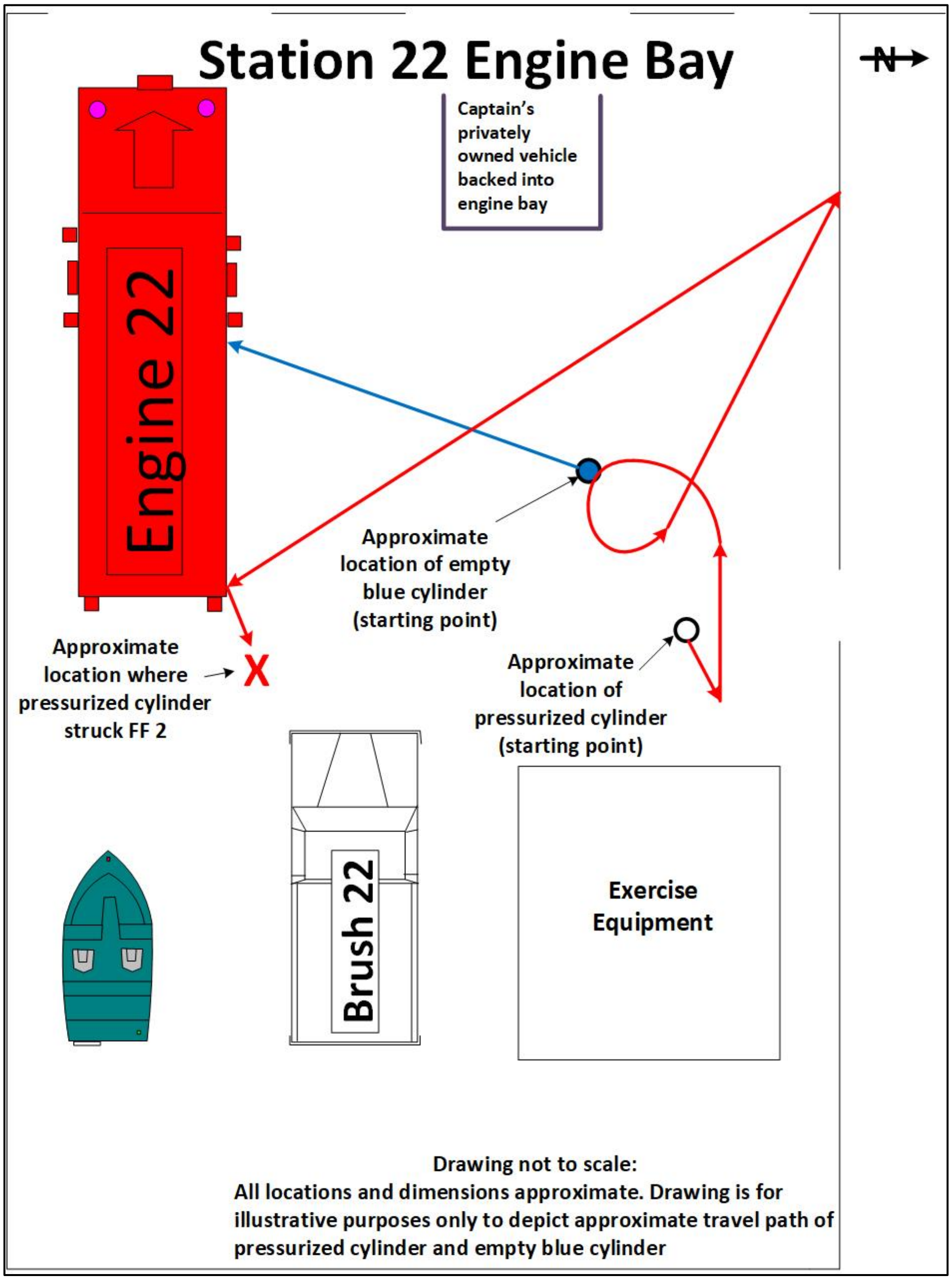

Diagram 1. Diagram shows the approximate travel paths of the pressurized SCUBA cylinder and the empty blue cylinder which became airborne after being struck by the unrestrained pressurized cylinder.
NIOSH Diagram.

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Hearing this commotion, the three fire fighters began to move out of the way to find cover. Fire Fighter 1 quickly moved to his left away from the cylinders while the captain and Fire Fighter 2 moved to take cover behind the brush truck parked behind Engine 22 (see Diagram 1). After striking the empty blue SCUBA cylinder, the leaking pressurized SCUBA cylinder was launched in the opposite direction across the engine bay and struck the concrete block wall approximately 7 feet above the floor (see Photo 2 and Photo 3). When the cylinder struck the wall, the cylinder valve was sheared off at the cylinder neck (see Photo 4, Photo 5 and Photo 6). The valve body came to rest on the floor near the man door entrance to the engine bay. The valve hand wheel separated from the valve body and came to rest on the floor near the work bench. The cylinder was then projected at an angle back across the engine bay where it struck the rear corner (passenger side) of Engine 22 before glancing off the engine and striking Fire Fighter 2 in the head (see Photo 7 and Diagram 1). The cylinder landed on the engine bay floor and continued to expend energy as the remaining air was depleted, before coming to rest near exercise equipment located at the rear of the engine bay (see Photo 10).

Photo 2. Hole in engine bay wall caused by SCUBA cylinder (valve end) striking the wall after the cylinder became a projectile.
NIOSH Photo.

Photo 3. Exemplar SCUBA cylinder valve is held up against wall where the incident SCUBA cylinder struck the engine bay wall, creating a hole in the wall. Note how the shape of the cylinder valve matches the damaged area on the wall
NIOSH Photo.

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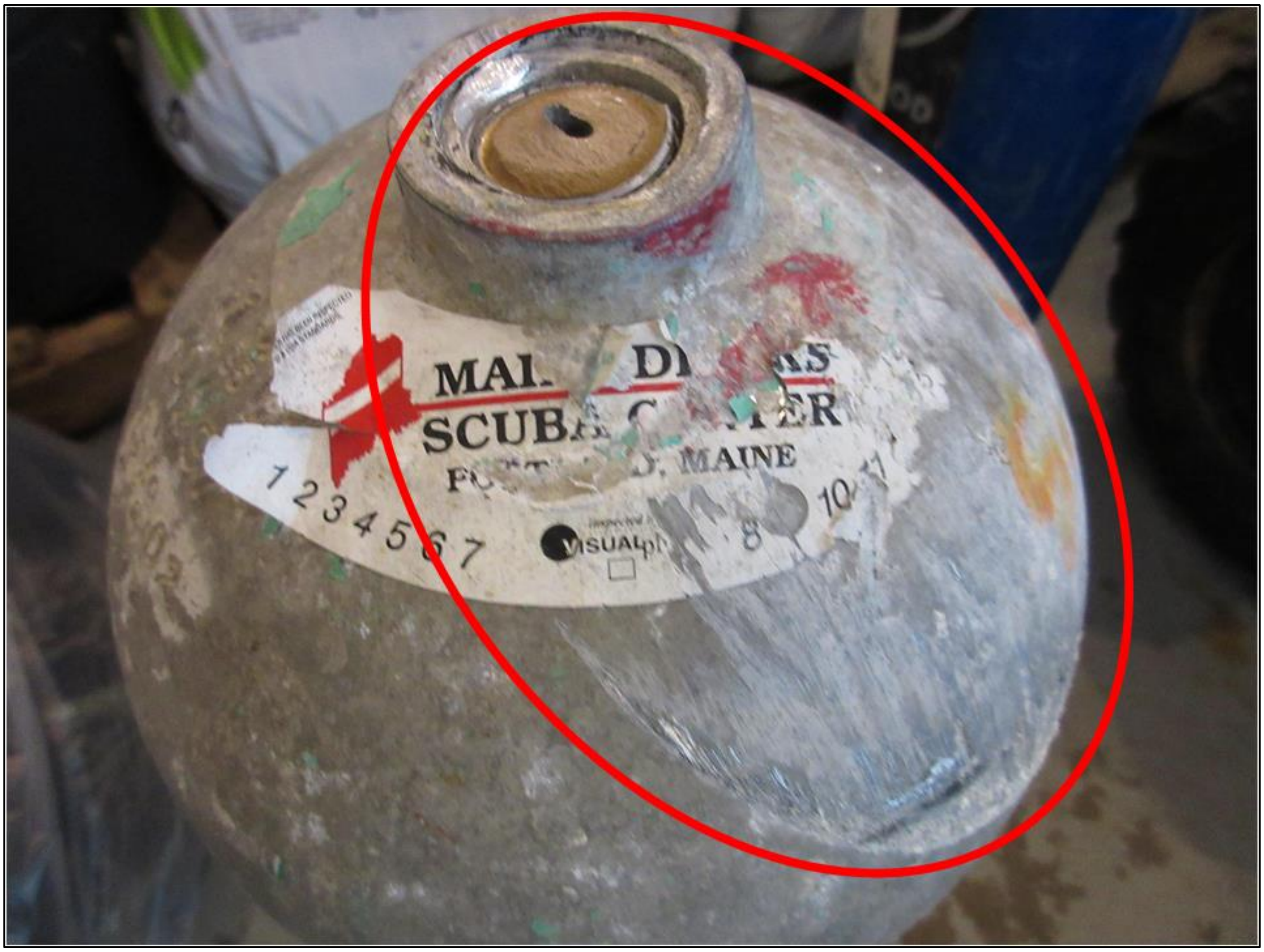

Photo 4. The SCUBA cylinder involved in this incident. Note the scuff marks on the cylinder caused by the cylinder striking the engine bay wall (see Photo 2 and Photo 3). The area highlighted in red is the area that impacted the wall.
NIOSH Photo.

Photo 5. SCUBA cylinder valve involved in the incident. This cylinder valve was broken off from the SCUBA cylinder when the cylinder struck the engine bay wall. It is believed that the valve handwheel (left side of valve in Photo above) also broke off when the cylinder struck the wall. See Photo 4.
NIOSH Photo.

Photo 6. Photo shows how cylinder valve broke off the SCUBA cylinder when the cylinder impacted the engine bay wall. Also see Photo 2, Photo 3 and Photo 4.
NIOSH Photo.

Photo 7. Close-up view of the dent on the rear of Engine 22 (officer side) where the pressurized cylinder struck the engine before glancing off engine and striking Fire Fighter 2.
NIOSH Photo.

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The Captain and Fire Fighter 1 immediately began to administer first aid to Fire Fighter 2. Fire Fighter 1 called dispatch for an air medic helicopter and also requested an ambulance. Within minutes, the fire fighter was transported via helicopter to a regional trauma hospital where he was pronounced dead.

Photos 8 through 10 as well as Diagram 1 depict the estimated travel path of the airborne pressurized cylinder. State Fire Marshal's Office investigators and local deputy sheriffs investigated the incident scene immediately after the incident and were able to estimate the likely travel path of the cylinder.

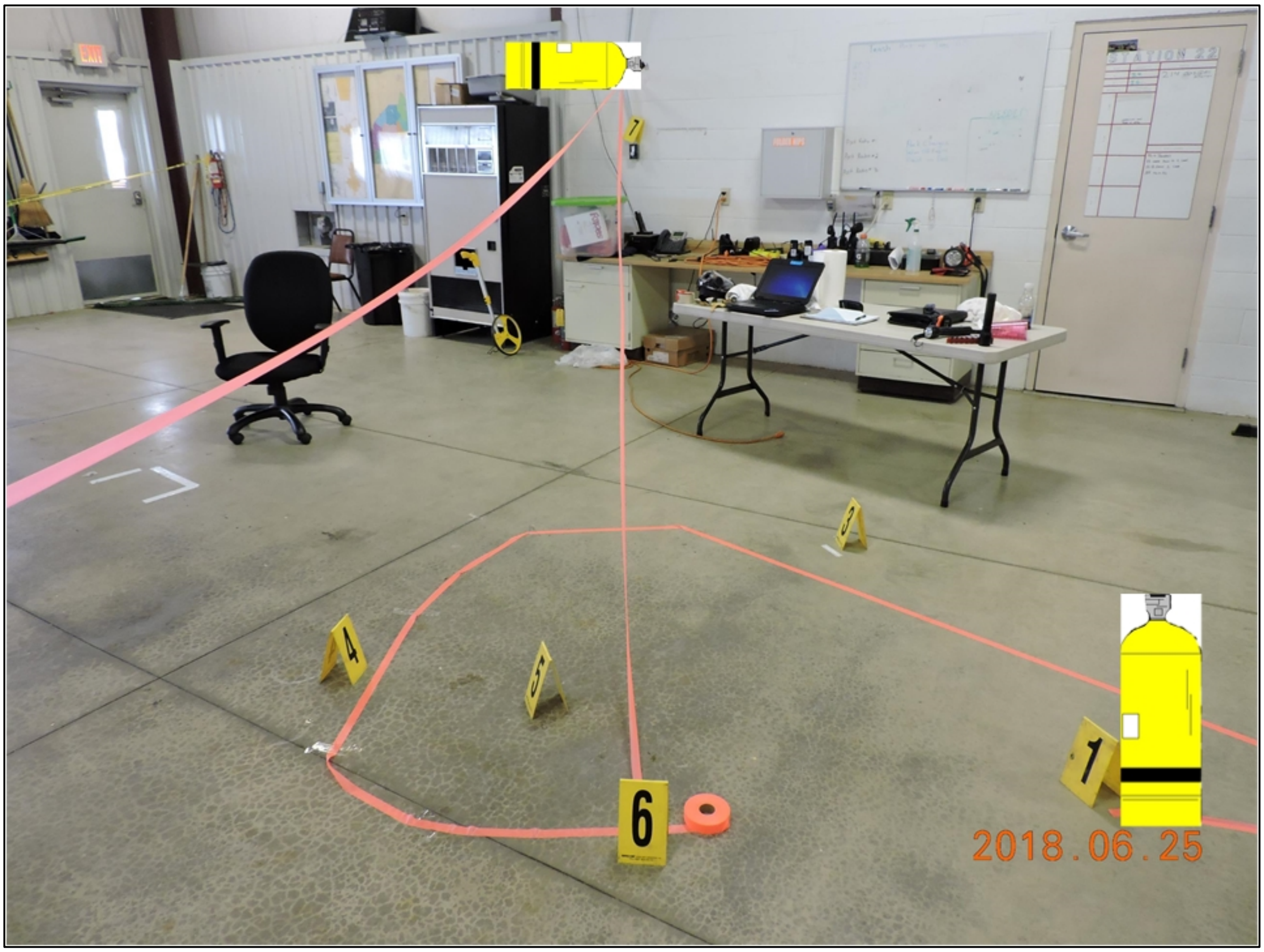

Photo 8. Photo depicts estimated path of cylinder after compressed air was released through pressure relief burst disc orifice. Cylinder was standing on end at Position 1 when it began to spin and rotate due to the escaping air pressure. The orange tape marks the cylinder's travel path estimated by State Fire Marshal's Office investigators and County Sheriff's Deputies. Cylinder is believed to have become airborne at Position 6 and traveled in a spinning motion until it struck the engine bay wall at Position 7. Also see Photo 9 and Photo 10.
NIOSH graphic using photo supplied by State Fire Marshal's Office.

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Photo 9. Photo shows estimated travel path (estimated by State Fire Marshal's Office investigators and County Sheriff's Deputies) of the cylinder after it struck wall and the cylinder valve broke off. This caused the air to escape the cylinder at an increased rate. The cylinder bounced off the wall and was projected across the engine bay where the cylinder struck the right rear corner of Engine 22 (Position 8), then struck the Fire Fighter 2. The step ladder at Position 9 marks the approximate location of Fire Fighter 2 who was moving to take cover behind the brush truck. After striking Fire Fighter 2, the SCUBA cylinder fell to the floor and continued moving along the path indicated by the orange tape from Position 10 to Position 15 where the cylinder came to rest near the exercise weight equipment. Also see Photo 8 and Photo 10.
Photo courtesy of State Fire Marshal's Office.

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Photo 10. Photo shows estimated travel path (estimated by State Fire Marshal's Office investigators and County Sheriff's Deputies) of the cylinder after it struck the rear corner of Engine 22 (point 8), then struck the fire fighter at approximately Point 9 before falling to the engine bay floor (point 10) and expending energy as it moved across the engine bay floor before coming to rest at Point 15 near the exercise weight equipment. Also see Photo 8 and Photo 9.
Photo courtesy of State Fire Marshal's Office.

Contributing Factors

Occupational injuries and fatalities are often the result of one or more contributing factors or key events in a larger sequence of events that ultimately result in the injury or fatality. NIOSH investigators identified the following items as key contributing factors in this incident that ultimately led to this fatality:

- Unsecured pressurized SCUBA cylinder
- Unknown hazards associated with old, out-of-date cylinders with stuck valves
- Limited training and experience on the task
- Non-routine maintenance on pressurized SCUBA cylinder
- Selection, care and maintenance of SCUBA equipment
- Inadequate risk versus gain analysis.

Cause of Death

According to the County Coroner Office death investigation report, the Fire Fighter 2 died due to blunt force trauma to the head and the manner of death was accidental.

Recommendations

Recommendation #1: Fire departments should ensure that pressurized cylinders of all types are properly stored, handled and maintained in a safe manner following the manufacturer's recommendations and industry best practices by qualified and properly trained individuals.

Discussion: Fire departments should ensure that pressurized cylinders of all types are properly stored, handled and maintained in a safe manner following the manufacturer's recommendations and industry best practices by qualified and properly trained individuals. NFPA 1500 *Standard on Fire Department Occupational Safety, Health and Wellness Program* [NFPA 2018] outlines the general requirements for the safe handling, storage, and use of SCBA cylinders in Chapter 7.15. Fire departments should apply these requirements to self-contained underwater breathing apparatus (SCUBA) cylinders as well. Chapter 7.15.6 states that during the filling of SCBA cylinders, all personnel and operators shall be protected from catastrophic failure of the cylinder, except during specific rapid refilling processes which the fire department risk assessment process has identified and for which standard operating procedures have been incorporated [NFPA 2018].

There are a number of hazards associated with the handling, use and storage of compressed gases, depending upon the type of cylinder and the contents. Some of these hazards include:

- Pressure Hazards: All compressed gases are hazardous due to the high pressure inside the cylinder. Damage to the cylinder valve can result in a rapid release of the high pressure gas propelling the cylinder causing personal injury and damage to property.

- Fire and Explosion Hazards: Flammable gases such as acetylene, butane and hydrogen can burn or explode under certain conditions. If flammable gases are allowed to accumulate until their concentration is between their defined Lower Explosion Limit (LEL) and Upper Explosion Limit (UEL), an explosion may occur if there is an ignition source present.

- Health Hazards: Many gases are toxic and can cause serious health problems dependent upon the specific gas, its concentration, length of exposure, and route of entry. Health symptoms of exposure to gases can be immediate, or delayed.

- Chemical Burn Hazards: Some compressed gases are corrosive. They can burn or damage skin on contact, burn the eyes or lungs if inhaled, as well as attack and corrode metals.

- Asphyxiation Hazards: Asphyxiation is the main hazard associated with inert gases such as helium, argon, and nitrogen. If these gases escape undetected into the atmosphere, they can quickly reduce the oxygen levels below concentrations necessary to support consciousness and life.

- Physical Hazards: Compressed gas cylinders are large, heavy and awkward to handle. Improper handling, or not properly securing cylinders while in use, can cause cylinders to fall causing injury to workers.

Many sources of safe handling procedures for compressed gas cylinders are available through an internet search. One such example is a fact sheet provided by the Texas Department of Insurance, Division of Workers' Compensation Resource Center. This fact sheet states "The use, storage and handling of compressed gas cylinders presents two types of hazards. First is the chemical hazard associated with the cylinder contents (corrosive, toxic, flammable, etc.). Second is the physical hazard represented by the cylinder being under pressure. Mishandled cylinders may rupture violently, release their hazardous contents or become dangerous projectiles." This fact sheet, Compressed Gas Cylinders: A 5-Minute Safety Training Aid can be found at the webpage https://www.tdi.texas.gov/pubs/videoresource/t5compressedgas.pdf [Texas TDI, 2006].

Another source of safe handling procedures is the Texas A & M University at Galveston Compressed Gas Safety Program manual [Texas A & M, 2015]. Page 11 of this manual states "If the cylinder's valve does not operate properly, do not attempt to force the valve to turn. The cylinder should be returned to the vendor. Employees must not attempt to repair cylinders or cylinder valves or to force stuck or frozen cylinder valves." This Compressed Gas Safety Program manual is available at the webpage http://www.tamug.edu/EnvironmentalHealthSafety/NO_Menu_Important_Files/Compressed%20Gases%20Safety%20Program%2010-2015.pdf.

A number of additional internet sites devoted to compress gas safety stressed the point that when a compressed gas cylinder is encountered having a damaged or corroded valve, the user should contact the cylinder supplier or vendor for instructions and not attempt to repair or remove the damaged valve themselves.

During this incident, pressurized SCUBA cylinders were being handled in a station that did not have a cylinder containment system. Fire department members were in the process of draining the air from SCUBA cylinders so that the valves could be removed from the cylinders. Some of the SCUBA cylinder valves were stuck and could not be opened. Since the valves were stuck shut, fire fighters were loosening the pressure-relief burst disc plugs to allow the compressed air to bleed off. Performing this work in a cylinder containment system may have resulted in a different outcome.

Recommendation #2: Fire departments should follow guidance provided by NFPA 1852 Standard on Selection, Care, and Maintenance of Open-Circuit Self-Contained Breathing Apparatus (SCBA) and apply it to self-contained underwater breathing apparatus (SCUBA).

Discussion: NFPA 1852 *Standard on Selection, Care, and Maintenance of Open-Circuit Self-Contained Breathing Apparatus (SCBA)* establishes requirements for the selection, care, and maintenance of self-contained breathing apparatus (SCBA) as required by the respiratory protection program in NFPA 1500: Fire Department Occupational Safety and Health Program to reduce health and safety risks associated with improper maintenance, contamination, or damage [NFPA 2019]. While NFPA 1852 specifically covers self-contained breathing apparatus (SCBA), self-contained underwater breathing apparatus (SCUBA) are very similar in function to SCBA. Since many fire departments provide public safety dive teams as part of their response coverage, fire departments should evaluate the guidelines and requirements found in NFPA 1852 and apply these applicable guidelines and requirements to SCUBA equipment.

For example, NFPA 1852, Chapter 7 covers maintenance. Chapter 7.1.3.4 states “Users shall not perform work beyond the limits of the organization’s SOPs and their training and shall not exceed what is allowed by the manufacturer’s written instructions.” This practice should be applied to both SCBA and SCUBA equipment. Chapter 7.2.3.8 states “Cylinder repairs shall be limited to only those conditions specified by the SCBA manufacturer. [NFPA 2019]. As noted, these guidelines and requirements, while developed for SCBA, could be easily adapted by fire departments to cover SCUBA equipment.

NFPA 1852, Chapter 7.3.5 states “Where filling breathing air cylinders during routine maintenance, all operators and personnel shall be protected from catastrophic failure of the cylinder by a SCBA fill station that meets the requirements specified in Section 24.9 of NFPA 1901 [NFPA 2019]”. NFPA 1901, Section 24.9 covers *SCBA or SCUBA Air Cylinder Fill Station* requirements. Additional design requirements for SCBA and SCUBA air cylinder fill stations are also included [NFPA 2016]. *Note: While NFPA 1901, Section 24.9.1.1 which states “The fill station shall fully enclose the cylinder during filling to contain the fragments if a cylinder ruptures,” applies to fill systems mounted on fire* *apparatus, good safety and health practice suggests that all cylinder fill stations should fully enclose the cylinder being filled.*

During this incident, fire fighters were performing not-routine maintenance on used SCUBA cylinders with stuck valves that were pressurized. A cylinder fill station or a means to fully enclose the cylinders was not available at the fire station. Non-routine maintenance should only be attempted by qualified and trained individuals following the manufacturer's guidelines and specifications. If fire departments do not have the prerequisite training, knowledge, and skills to perform the maintenance required, the fire department should seek assistance from the manufacturer or a manufacturer-qualified vendor.

Recommendation #3*: *Fire departments and authorities having jurisdiction (AHJ) should conduct a hazard identification and risk assessment analysis of their response areas and incident scenes to determine what resources are needed to conduct technical search and rescue operations in accordance with NFPA 1670 and NFPA 1500.

Discussion: Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. Technical rescue incidents are "low frequency/high risk" events. The primary purpose of risk assessment is to focus on incidents that might not occur very often (low frequency) but that could have severe consequences associated with them (high risk). The reason for the focus on low frequency/high risk incidents is that since they do not occur on a frequent basis, responders might not be as prepared to deal with them, and the outcomes can be harmful or detrimental to fire fighters (see Diagram 2).

According to NFPA 1670 Standard on Operations and Training for Technical Search and Rescue Incidents, Chapter 4.2.1, states, "The AHJ shall conduct a hazard identification and risk assessment of the response area and shall determine the feasibility of conducting technical search and rescue operations." Chapter 4.2.2 states, "The hazard identification and risk assessment shall include an evaluation of the environmental, physical, social, and cultural factors influencing the scope, frequency and magnitude of a potential technical search and rescue incident and the impact they might have on the ability of the AHJ to respond to and to operate while minimizing threats to rescuers at those incidents" [NFPA 2017b].

According to NFPA 1500 Standard on Fire Department Occupational Safety, Health and Wellness Program, a risk management plan serves as documentation that risks have been identified and evaluated and that a reasonable control plan has been implemented and followed [NFPA 2018]. Determining the frequency and severity of occurrence of risks will serve as a method for establishing priorities.

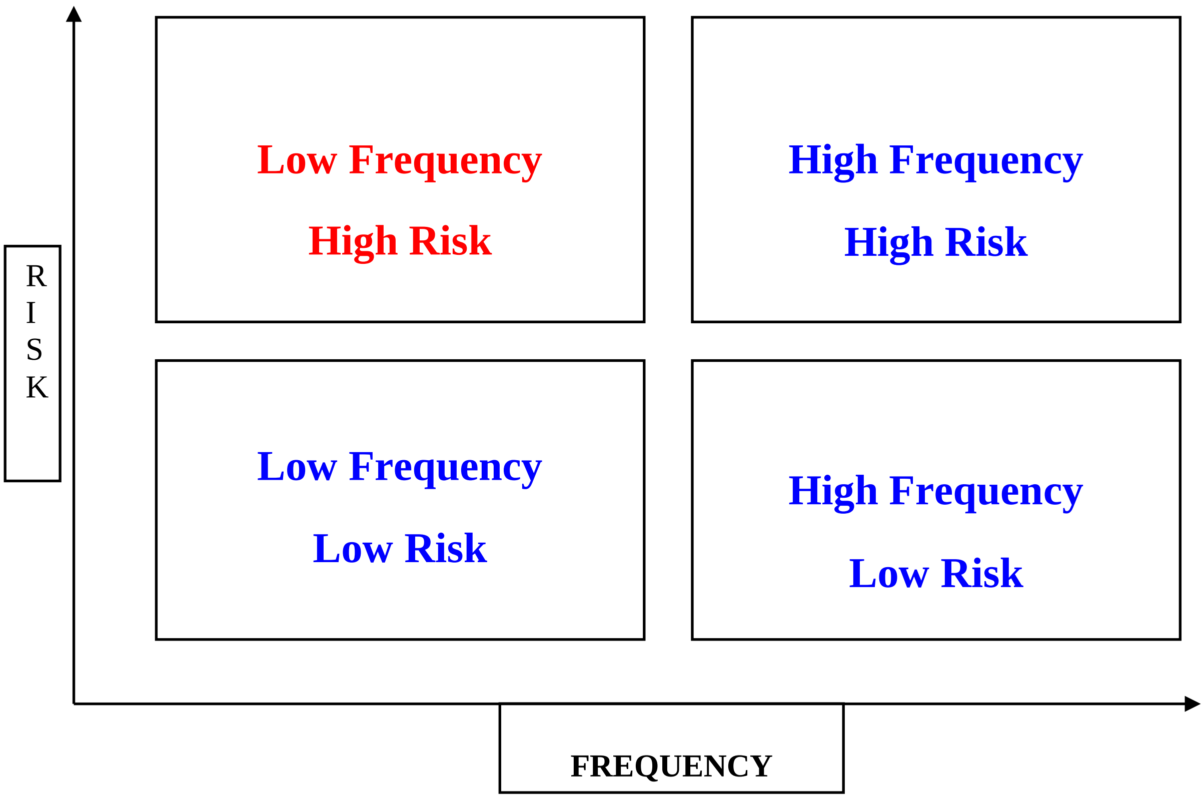

Diagram 2

The hazard identification and risk assessment determines "what" can occur, "when" (how often) it is likely to occur, and "how bad" the effects could be. In other words, the hazard identification and risk assessment is necessary in order for fire departments and AHJs to determine what the hazard is, how often it is likely to occur, the location it is likely to occur, and what actions are necessary to mitigate the threats.

Fire departments and authorities having jurisdiction at the local, state and federal level can help ensure the safety of emergency responders who must respond to drownings and other incidences where public safety dive rescue teams are needed by conducting hazard identification and risk assessment surveys within their response areas. These surveys should include both existing water hazards (lakes, rivers, streams, reservoirs, and standing bodies of water) and anticipated flood-prone areas based upon historical data. The survey should also include flood maps and identify other site-specific hazards. These survey plans should also identify the specific personal protective clothing and equipment necessary to respond to the different hazards identified by the survey.

Once the hazard identification and risk assessment is developed, fire departments and AHJs can use this information to ensure that all fire fighters and emergency responders are trained and properly equipped to address all potentially dangerous areas of concern during dive rescue operations and other types of water rescue, following the requirements outlined in NFPA 1670.

Recommendation #4: Fire departments and authorities having jurisdiction should ensure that they identify the operational level for technical search and rescue they are capable of providing.

Discussion: Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. As previously noted, fire departments and authorities having jurisdiction are required by NFPA 1670 to identify the operational level for technical search and rescue that they are capable of providing, based upon hazard identification, risk assessment, training level of personnel, and availability of internal and external resources. Fire fighters should be trained to the appropriate operational level based upon the requirements of NFPA 1006 *Standard for Technical Rescuer Professional Qualifications* [NFPA 2017a]. NFPA 1006, Chapter 18 covers dive rescue operations. Additionally, NFPA 1006, Chapter 16 covers surface water operations; Chapter 17 covers swiftwater rescue; Chapter 19 covers ice rescue; Chapter 20 covers surf rescue; Chapter 21 covers watercraft rescue; and Chapter 22 covers floodwater rescue operations. Each rescue discipline is covered at the awareness level, operations level and technician level.

The ***Awareness Level*** represents the minimum capability of organizations that provide response to technical search and rescue incidents. ***Operations Level*** represents the capability of organizations to respond to technical search and rescue incidents and to identify hazards, use equipment, and apply limited techniques specified in this standard to support and participate in technical search and rescue incidents. The ***Technician Level*** represents the capability of organizations to respond to technical search and rescue incidents and to identify hazards, use equipment, and apply advanced techniques specified in this standard necessary to coordinate, perform, and supervise technical search and rescue incidents" [NFPA 2017b]. NFPA 1670, Chapter 4.1.3, states, "In jurisdictions where identified hazards might require a search and rescue capability at a level higher than awareness, a plan to address this situation shall be written." Chapter 4.1.3.2 further states, "Where an advanced level of search and rescue capability is required in a given area, organizations shall have a system in place to utilize the most appropriate resource(s) available, through the use of local experts, agreements with specialized resources, and mutual aid. [NFPA 2017b]"

During this incident, the fire department involved was in the process of re-establishing a fire department dive rescue team. At the time of the incident, the fire department had draft standard operating procedures covering dive rescue operations. These draft SOPs had not been finalized by the fire department. NFPA 1670 requires that rescuers expected to enter water for search and rescue operations operate at the technician level and be trained to the requirements of NFPA 1006 *Standard for Technical Rescuer Professional Qualifications*.

Recommendation #5: Fire departments should ensure that fire fighters who engage in water rescue operations are properly trained and equipped for the assigned task as outlined by NFPA 1670 Standard on Operations and Training for Technical Search and Rescue Incidents.

Discussion: Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. Virtually every jurisdiction in North America has the potential for water rescue and recovery operations. These situations can occur in swimming pools, ponds, lakes, rivers, streams, drainage canals and other bodies of water [Dodson 2007, IFSTA 2008]. Water, the very ingredient that fire fighters regularly use to extinguish fires has caused numerous fire fighter injuries and deaths [Dodson 2007, NIOSH 2002, NIOSH 2010, NIOSH 2011].

National Fire Protection Association (NFPA) 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents* was developed to define specific levels of preparation and operational capability that should be achieved by any authority having jurisdiction (AHJ) who has the responsibility for conducting technical rescue operations. The purpose of this standard is to assist the AHJ in accessing technical search and rescue hazards within the response area, to identify the level of operational capability, and to establish operational criteria [NFPA 2017b].

NFPA 1670, Chapter 4.1.1, states, “The authority having jurisdiction (AHJ) shall establish levels of operational capability needed to conduct operations at technical search and rescue incidents, based on hazard identification, risk assessment, training level of personnel, and availability of internal and external resources.” Chapter 4.1.2 states “At a minimum, all technical search and rescue organizations shall meet the awareness level for each type of search and rescue incident for which the AHJ has identified a potential hazard. Chapter 4.1.4 of NFPA 1670 identifies the following operational levels for technical search and rescue and as noted, requires that standard operating procedures be established. Quoting NFPA 1670, Chapter 4.1.4:

> “The AHJ shall establish written standard operating procedures (SOPs) consistent with one of the following operational levels for each of the disciplines defined in this document.
>
> (1) ****Awareness Level***. This level represents the minimum capability of organizations that provide response to technical search and rescue incidents.
>
> (2) ****Operations Level***. This level represents the capability of organizations to respond to technical search and rescue incidents and to identify hazards, use equipment, and apply limited techniques specified in this standard to support and participate in technical search and rescue incidents.
>
> (3) ***Technician Level***. This level represents the capability of organizations to respond to technical search and rescue incidents and to identify hazards, use equipment, and apply advanced techniques specified in this standard necessary to coordinate, perform, and supervise technical search and rescue incidents.” [NFPA 2014b].

Chapter 4.1.5 states that it is not the intent of this document to have an organization deem itself capable of an advanced skill level in any of the disciplines defined herein simply by training or adhering to the requirements set forth. Maintaining an operations- or technician-level capability in any discipline shall require a combination of study, training, skill, and frequency of operations in that discipline [NFPA 2017b].

Chapter 4.1.6 states that the AHJ shall establish operational procedures consistent with the identified level of operational capability to ensure that technical search and rescue operations are performed in a manner that minimizes threats to rescuers and others [NFPA 2017b].

Chapter 4.1.8 states that operational procedures shall not exceed the identified level of capability established in 4.1.4. Annex A of NFPA 1670 contains additional information to clarify this point. According to Annex A4.1.4(1), the "awareness level" can involve search, rescue, and recovery operations. Members of a team at this level are generally not considered rescuers. Annex A4.1.4(2) states the "operations level" can involve search, rescue, and recovery operations, but usually operations are carried out under the supervision of technician-level personnel [NFPA 2017b].

Chapter 4.1.10 contains information that fire departments and authorities having jurisdiction can use to develop training programs for technical search and rescue operations. This chapter requires that the training be commensurate with the operational capability of the organization. Chapter 4.1.10.4 states, "The AHJ shall evaluate its training program to determine whether the current training has prepared the organization to function at the established operational level under abnormal weather conditions, extremely hazardous operational conditions, and other difficult situations" [NFPA 2017b].

NFPA 1670 focuses on water search and rescue that includes six separate water-related disciplines at both the operations level and technician level including dive rescue (Chapter 18), as well as surface (Chapter 16), swift water (Chapter 17), ice (Chapter 19), surf (Chapter 20), watercraft search and rescue (Chapter 21), and flood water (Chapter 22) [NFPA 2017b]. NFPA 1670 includes detailed requirements for the standard operating procedures to be developed and implemented and the type of personal protective equipment and clothing to be worn during all levels of water search and rescue [NFPA 2017b].

At the time this incident occurred, the fire department was in the process of re-establishing a public safety dive rescue program. The fire department was in the process of developing standard operating procedures (SOPs) and guidelines (SOGs) to cover the public safety dive rescue program. Eight to 10 fire fighters had expressed an interest in being part of the fire department's public safety dive rescue program. A volunteer fire department member who was also a certified Dive Instructor was responsible for providing all dive rescue team training. The fire department's draft SOPs covering dive rescue operations did not address SCUBA equipment maintenance or cylinder safe handling procedures.

Recommendation #6: Fire departments should develop, implement, and enforce standard operating procedures for water search and rescue operations including dive rescue operations.

Discussion: Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. NFPA 1670 *Standard on Operations and Training for Technical Search and Rescue Incidents*, Chapter 4.1.4, requires the authority having jurisdiction (AHJ) to establish standard operating procedures that are consistent with each of the awareness, operational, and technician operational levels. Chapter 4.1.6 states that the AHJ shall establish operational procedures consistent with the identified level of operational capability to ensure that technical search and rescue operations are performed in a manner that minimizes threats to rescuers and others. Chapter 4.1.8 states, "Operational procedures shall not exceed the identified level of capability established in 4.1.4" [NFPA 2017b].

In addition to other fireground operations, standard operating procedures (SOPs) pertaining to water rescues should be developed to standardize practices and techniques used by fire departments. These SOPs should also be tailored to meet the specific needs and conditions within a response jurisdiction. SOPs should outline, at a minimum, the following: mandatory appropriate PPE, equipment or apparel likely to endanger personnel if they fall into the water or attempt a rescue, upstream safety spotters, personnel staged at downstream points, only properly trained personnel staged in the danger area, standard communications, waterway rescue preplans, and safety consideration for rescuers.

At the time this incident occurred, the fire department was in the process of re-establishing a public safety dive rescue program. The fire department was in the process of developing standard operating procedures (SOPs) and guidelines (SOGs) to cover the public safety dive rescue program. Eight to 10 fire fighters had expressed an interest in being part of the fire department's public safety dive rescue program. A volunteer fire department member who was also a certified Dive Instructor was responsible for providing all dive rescue team training. The fire department's draft SOPs covering dive rescue operations did not address SCUBA equipment maintenance or cylinder safe handling procedures.

Recommendation #7: Fire departments should recognize public safety SCUBA diving as a high risk/low frequency event and ensure that public safety divers are properly trained, equipped, and supported to perform public safety diving responsibilities and integrate the training and SOPs with regional dive and water rescue team(s) who they regularly respond with.

Discussion**:** Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. Fire departments should recognize public safety SCUBA diving as a high risk/low frequency event and use a risk assessment program to determine the level of involvement they are able to participate in (see Diagram 2). During this assessment, departments can decide if they want to accept the risk (fully committed to equipping and training their own team), share the risk (integrate with other teams in a mutual aid or regional team) or decline the risk (using a program risk analysis to transfer SCUBA duties to other agencies).

There is no standard scale to measure and evaluate frequency and severity of risk for the fire service. It is imperative that a fire department develop a risk management program that is based upon the process of identifying, evaluating, prioritizing, and controlling risk. The risk management plan incorporates a full range of control measures that may be used to limit, reduce, or eliminate the probability that an undesirable outcome will occur.

An important factor is that the fire department should prepare and maintain a written statement or policy that establishes the existence of the fire department, the services the fire department is authorized and expected to perform, and the basic organizational structure. This will be basis for the development of the risk management program. The frequency and severity of risk starts with a thorough community risk assessment [NFPA 2018].

Some fire departments will have a greater or lesser degree of tolerance for risk than others. The intent of the risk management process is for a fire department to develop a standard level of safety. This standard level of safety defines the parameters of the acceptable degree of risk for which members perform their job functions. There is no single method or solution for effectively managing risk. Determining how to manage risk is a decision each individual fire department must make based on the risk management model [VBFD 2016].

A fire department's leadership should have a covenant with their public safety dive team through the governing body's risk manager (or risk management structure) to make diver safety their top priority by managing the risk. The risk manager should focus on sound resources based on research, training and experience. The leadership should consider sound risk management if they are going to commit their people to an underwater environment. The department has an ethical, moral, and legal duty to prepare them to be effective public safety divers. There is no greater responsibility [in public safety SCUBA diving] than safety [Orusa 2017].

Fire departments should prepare and maintain written policies and standard operating procedures that document the organization structure, membership, roles and responsibilities, expected functions, and training requirements, including the following:

- The types of standard evolutions that are expected to be performed and the evolutions that must be performed simultaneously or in sequence for different types of situations

- The minimum number of members who are required to perform each function or evolution and the manner in which the function is to be performed

- The number and types of apparatus and the number of personnel that will be dispatched to different types of incidents

- The procedures that will be employed to initiate and manage operations at the scene of an emergency incident [NFPA 1500].

Fire departments that decide they want to accept the risk and perform technical rescue water operations, including SCUBA diving and water rescue, need to ensure that personnel receive the proper initial training, advanced training, repetitive skills training and interagency training with mutual aid or regional dive teams that they regularly respond with. Fire departments must also understand that the commitment will involve a continuing commitment to advanced and recurrent training and also equipment and marine apparatus purchasing and maintenance.

Managing risk includes mandatory continuing education and skills documentation programs. Steve Orusa, Fire Chief of Fishers Indiana Fire Department and national expert and author of *Dive Rescue Specialist, Operational Training for Public Safety Divers* [Orusa 2007] notes a lack of basic diving skills has been statistically identified as one of the leading causes of public safety diving fatalities. With 86% of the fatalities occurring in training and recovery modes (as was this incident), managing the components of rescue and recovery mode and the risk/benefit analysis in water rescue operations and training are critical. There is overwhelming documentation that provides evidence of serious safety concerns when relying solely on recreational training for public safety dive teams [Orusa 2017].

The advanced SCUBA training needs to be consistent with national consensus standards and agencies that provide recognized, advanced levels of certification to safely perform this level of emergency service capability. Although recreational SCUBA diving certification programs provide a level of training that is fine for the recreational SCUBA diving community, these programs are not commonly designed for the extreme hazards regularly encountered with public safety water rescue and diving. According to NFPA 1006 *Standard for Technical Rescuer Professional Qualifications, 2017 edition, Annex A* [NFPA 2017a],

> "The committee is of the opinion that Advanced Open Water certification provided by most nationally recognized certifying agencies (agencies associated with the Recreational SCUBA Training Council) build an acceptable foundation for the basic SCUBA skills required for dive technical rescuer. These courses do not, however, offer all of the skills required to meet these standards, and further training and experience in special hazards expected to be encountered in the AHJ's territory should be sought."

Chief Orusa has taught the importance of advanced repetitive skill dive training beyond recreational dive skills for many years. Public safety SCUBA diving is a technical skill that greatly exceeds recreational SCUBA certification levels. He notes: "Recreational diving agencies provide safe and effective dive training for the enjoyment of the public. The business model of a recreational SCUBA agency is to teach the client to have fun underwater. John Q. Public is not performing dives in zero visibility, dives with prolonged bottom times, dives with entanglement hazards, dives requiring heavy physical exertion, dives at all times of the day and night, and dives in extreme weather conditions. That is public safety diving." [Orusa 2017].

In his book Chief Orusa notes: "Inadequate SCUBA skills may be the leading cause of public safety diver accidents. In many cases, a problem developed that the diver was unable to solve due to a basic skill level. In most cases, divers had received either insufficient or nonexistent SCUBA skills refresher training after initial certification." Public safety divers should have training and experience in a variety of environments likely to be encountered in rescue operations, such as deep water complex dives, limited visibility, cold water diving, ice, current, contamination and hazardous materials, dry suit, and lifting operations.

Annual confirmation of these skills should be performed to ensure continued competency. Dive team(s) need to stay current on training and annual skills evaluation. An example of an evaluation form to assess skills of public safety divers is provided in Figure 1.

The level of knowledge, skills, ability, equipment and support required for a public safety SCUBA diver are outlined in NFPA 1006 [NFPA 2017a] and NFPA 1670 *Standard on Operations and Training for Technical Search and Rescue Incidents* [NFPA 2017b]. Throughout NFPA 1006 and

1670, hazard analysis and risk assessment is addressed. One of the most hazardous events a diver can encounter is not being able to solve problems or make decisions underwater. The typical chain of events in a public safety diving accident is as follows:

- The public safety diver becomes cold and/or tired
- Their stress level which is already high under such circumstances, increases
- The public safety diver encounters a problem or makes a mistake they cannot solve
- Panic ensues
- Death or serious injury results [Orusa 2017].

Public safety diving requires emergency response teams with specific knowledge, skills, ability, equipment and continued support beyond basic fire fighter or emergency responder requirements to resolve unique or complex rescue situations. Additionally, when the team is faced with complex, deep, highly technical recovery dives, it is important to realize the team's limitations and when the team needs assistance and call additional resources (mutual aid). Some jurisdictions utilize regional teams to meet the goals of risk management for a specific risk (shared risk).

A key part of an overall rescue strategy should be mutual aid. The use of formal or informal mutual aid can help share the risk by providing additional experience, equipment, personnel and other resources to a public safety diving event. Other benefits include, greater levels of coverage and redundancy, building trust between organizations and leadership benefits that can ultimately make for a safer dive environment. Additionally it can remove destructive competitiveness and rivalries between departments and/or agencies.

Since the resource requirements and commitments are very high, a shared risk approach may work for some jurisdictions. Regional or mutual aid teams need to train together (if they are going to work together) so they can recognize and work together and have a level of coverage and/or redundancy that they may not have otherwise. If regional teams are going to work and train together, they should consider integrating their standard operating procedures (SOPs) and standard operating guidelines (SOGs). The difference between SOPs and SOGs is the difference between a procedure, which must be followed, and a guideline, which is more flexible and allows the responder to tailor his/her actions to fit the situation. A set of SOPs would include any rules that should be inviolable. For example, a public safety diver should always end his/her dive with 1,000 psi remaining for emergency reserve air (3,000 psi per 80-cubic-foot cylinder). The 1,000 psi rule should not be broken and is a good example of an SOP [Hendrick et al. 2000].

Fire department SCUBA dive teams need to stay current on new equipment available such as "in mask" air supply status or heads up display (HUD), communications and protective gear such as dry suits and redundant air supply options. Also, new high definition sonar systems are available that can reduce a dive teams exposure to blind diving, by working to locate and isolate a dive target to within feet. Blind underwater searches using search ropes and gridding-off areas are very task-oriented and time-consuming (underwater time) and therefore could require a significantly greater resource commitment for a significantly longer period of time. Reducing your exposure to the hazard is a recognized risk management principal. Dive teams should consider reducing the risk by reducing the exposure to the hazard (underwater) by spending more time and resources when they can on surface operations and technology to locate and mark targets with extreme accuracy.

Continued support for the team is an important component of the leadership of technical rescue teams. Once a team is properly trained and equipped, the organization must continue to provide support to maintain the technical rescue team's operational readiness through continued training and review of program goals and needs. Inadequately trained divers should not be allowed to participate in technical rescue SCUBA diving incidents beyond their level of training (see Figure 1).

Recommendation #8: Federal, state, local, and municipal governments, standard-setting organizations, and authorities having jurisdiction should consider developing and adopting a national standard on public safety dive teams and public safety dive operations.

Discussion: This recommendation focuses on the need for a national standard covering public safety dive rescue operations. Currently, a national standard covering public safety dive rescue operations does not exist.

"We should require standards that increase the safety and effectiveness of fire *department public safety SCUBA operations*. A root cause analysis identifies that public safety dive-specific training and equipment, standardization of training and equipment, SOPs, skills maintenance requirements, best practices, and consistency must be implemented. The result of these professional qualifications will be the prevention of injuries and the loss of personnel in the line of duty [Orusa 2019]."

Career Part-Time Fire Fighter Dies After Being Struck by Pressurized SCUBA Cylinder — Ohio

I.A.D.R.S. Annual Basic Scuba Skills Evaluation

Diver's Name: ______________________ Department: ______________________

Air Consumption: Start ________psi / Finish _________psi Time: Start _______/ Finish ________/ Total ________

Water Depth: __________Pool / Open Water (circle one) Examiner: ______________________

Task grading: S = Satisfactory N = Needs Improvement (specify) N/A = Not Applicable (use for equipment only)

Equipment Handling and Set-Up

__________- properly assembles equipment (basic gear / specialty gear)
__________- shows familiarity and comfort with equipment
__________- properly protects equipment (i.e. tank valve / regulator)
__________- review (line & hand signals / air consumption rates / buddy awareness / emergencies / diver log)

Watermanship Skills

__________- 500 yard continuous forward stroke swim - no swim aids for time (refer to grading criteria)
__________- 15 minute tread / last 2 minutes with hands out of water (refer to grading criteria)
__________- 800 yard snorkel swim (refer to grading criteria)
__________- 100 yard inert diver rescue tow (refer to grading criteria)

Skin Diving Skills

__________- mask clearing
__________- snorkel clearing (popping & expansion)
__________- snorkel without mask (led by partner, 1 lap)
__________- fin kicks (flutter / dolphin) one length each, using mask and snorkel
__________- in water surface dives (head first / feet first)

SCUBA Diving Skills

__________- entries (giant stride / seated or controlled entry)
__________- neutral buoyancy control (oral / power) inflation
__________- dry suit buoyancy control and emergency procedures (i.e. hose disconnect or flooding)
__________- regulator clearing (blowing / purging) and retrieval
__________- regulator without mask (led by partner, 1 lap)
__________- full face mask (removal / switch to regulator / clearing full face mask / replace full face mask)
__________- descent procedures (signal / check time & air / raise inflator hose / feet first descent / clear ears)
__________- ascent procedures (signal / check time & depth / + buoyancy / raise inflator hose / ascend @ 20ft/min)
__________- air sharing at depth and during ascent
__________- buddy breathing at depth and during ascent
__________- emergency swimming ascent procedures (simulate out of air / signals / ascends / continuous exhaling / surfaces / inflates BC orally using bobbing technique)
__________- emergency buoyant ascent procedures (simulate out of air / signals / drops weights / ascends / continuous exhaling / surfaces / inflates BC orally using bobbing technique)
__________- weight belt (removal / replacement) on surface and bottom
__________- buoyancy control device (removal / replacement) on surface and bottom
__________- OPTIONS: Blackout Mask / Night Dive / Navigation / Confidence Obstacle Course

Performance Comments: ____
____

Equipment Care and Storage

__________- properly disassembles equipment
__________- cleans and restores equipment properly

Additional copies available at no charge via the International Association of Dive Rescue Specialists webpage. Visit www.IADRS.org

Figure 1. Sample SCUBA basic skills evaluation checklist.
(International Association of Dive Rescue Specialists: www.IADRS.org.)

References

49 CFR [2018]. U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, Title 49, Code of Federal Regulations (CFR), Section 180.250. General requirements for requalification of specification cylinders. https://www.gpo.gov/fdsys/pkg/CFR-2010-title49-vol2/pdf/CFR-2010-title49-vol2-sec180-205.pdf. Date accessed: September 2018.

Dodson D [2007]. Fire department incident safety officer. 2nd ed. Clifton Park, NY: Thompson Delmar Learning.

Hendrick W, Zaferes A, Nelson C [2000]. Public safety diving. Saddle Brook, NJ: PennWell.

IFSTA [2008]. Essentials of fire fighting. 5th ed. Stillwater, OK: Oklahoma State University. International Fire Service Training Association.

NFPA [2013a]. NFPA 1001 Standard for fire fighter professional qualifications. Quincy, MA: National Fire Protection Association.

NFPA [2015]. NFPA 1521 Standard for fire department safety officer professional qualifications. Quincy, MA: National Fire Protection Association.

NFPA [2016]. NFPA 1901 Standard for Automotive Fire Apparatus. Quincy, MA: National Fire Protection Association.

NFPA [2017a]. NFPA 1006 Standard for technical rescuer professional qualifications. Quincy, MA: National Fire Protection Association.

NFPA [2017b]. NFPA 1670 Standard on operations and training for technical search and rescue incidents. Quincy, MA: National Fire Protection Association.

NFPA [2018]. NFPA 1500 Standard on Fire Department Occupational Safety, Health and Wellness Program. Quincy, MA: National Fire Protection Association.

NFPA [2019]. NFPA 1852 Standard on Selection, Care, and Maintenance of Open-Circuit Self-Contained Breathing Apparatus (SCBA). Quincy, MA: National Fire Protection Association.

NIOSH [2002]. A fire fighter drowns after attempting to rescue a civilian stranded in flood water—Colorado. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2001-02, http://www.cdc.gov/niosh/fire/reports/face200102.html.

NIOSH [2010]. Two career fire fighters seriously injured during swiftwater rescue training at a low-head dam—Ohio. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2007-11, http://www.cdc.gov/niosh/fire/reports/face200711.html.

NIOSH [2011]. Volunteer fire fighter drowns after being thrown from his swiftwater rescue boat—West Virginia. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2010-09, http://www.cdc.gov/niosh/fire/reports/face201009.html.

Orusa S [2007]. Dive rescue specialist, operational training for public safety divers. 3rd ed. Fort Collins, CO: Dive Rescue International.

Orusa S [2017]. NIOSH LODD report F2016-09 subject matter expert technical review comments. June 2017.

Orusa S [2019]. NIOSH LODD report F2018-10 subject matter expert technical review comments. January 2019.

Texas Department of Insurance [2006]. Compressed Gas Cylinders: A 5-Minute Safety Training Aid. HS94-046E(1-06). Texas Department of Insurance, Division of Workers' Compensation. Date accessed: September 2018. https://www.tdi.texas.gov/pubs/videoresource/t5compressedgas.pdf.

Texas A & M [2015]. Compressed Gases Safety Program. Texas A & M University at Galveston, Office of Environmental Safety and Health. Date accessed: September 2018. http://www.tamug.edu/EnvironmentalHealthSafety/NO_Menu_Important_Files/Compressed%20Gases%20Safety%20Program%2010-2015.pdf.

VBFD [2016]. Risk management plan. Virginia Beach, VA: Virginia Beach Fire Department, https://www.vbgov.com/government/departments/fire/Pages/default.aspx.

Weather underground [2018]. Historical weather data for June 24, 2018. Date accessed: July 2018.

Investigator Information

This incident was investigated by Timothy R. Merinar, Safety Engineer, with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH located in Morgantown, West Virginia. Dr. Wendi Dick, Medical Officer, with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Medical Component, in Cincinnati, Ohio assisted with the interview process. An expert technical review was provided by Fire Chief Steven Orusa, Fishers Fire Department, Fishers, Indiana. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division.

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Appendix One
Laboratory Analysis of SCUBA Cylinder Valve
NIOSH Investigation F2018-10 OH

Based upon the laboratory's visual inspection and tests conducted, chloride-induced corrosion was the root cause of the failure of the regulator valve's normal operation. Corrosion locked the regulator valve in the "closed positon", and did not prevent compressed gas escaping elsewhere from the valve body at full pressure.

The full laboratory investigation report is available upon request.