Confined Space Induced CLAUSTROPHOBIA

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INDIVIDUALS WHO CANNOT HOLD a full-facepiece respirator to their face without hyperventilating, cannot ride in a car without the windows down regardless of the weather, cannot enter storm drains, are terrified of dying and being placed in a casket, cannot be zipped up in a fully encapsulating Level A protective suit, cannot go through a 37x30-in. hatch to a marine vessel, or who refuse a magnetic resonance imaging (MRI) examination are examples of the fear and anxiety caused by exposure to potentially claustrophobic environments. Their fears of restriction and suffocation are the markers for claustrophobic reactions. This article explores confined space-induced claustrophobia and training for desensitization, notes screening standards and available treatments, and offers alternatives to confined space entry.

OSHA's 1910.146 standard defines a confined space as one large enough and so configured that an employee can bodily enter and perform assigned work, has limited or restricted means for entry or exit, and is not designed for continuous employee occupancy. In the preamble to this standard, bodily entry is defined:

> OSHA believes that the [Notice of Proposed Rulemaking] preamble discussion of permit space incidents and of proposed provisions clearly indicates that the proposed rule was intended to cover only spaces that were large enough for the entire body of an employee to enter. (OSHA, 1993b, 4477)

Moreover, the preamble states that "in order for a space to be considered a permit-required confined space, it must first be a confined space" (OSHA, 1993b, 4477).

Hazards associated with confined spaces include "hypoxia and toxic atmospheric conditions, physical injuries, including falling, drowning, collapse, burning, object strikes, [and] electric shock" (Selman et al., 2019). Claustrophobia is the fear of confined spaces, which can be harmful to many employees completing work in these spaces if they develop and react badly to their phobia. This fear can be managed and treated using treatments such as exposure therapy, cognitive behavioral therapy, virtual reality (VR), eye movement desensitization and reprocessing (EMDR), relaxation, visualization and hypnosis (Choy et al., 2007; A. Hardenbrook, personal communication, June 2, 2022).

Research to date has shown that claustrophobia results from two distinct and related fears: fear of suffocation and fear of restriction. Much of the work for assessing persons who might have a claustrophobic reaction came about as a result of patients undergoing MRI scans. Some of these reactions were so severe that the patients could not complete an examination or were aware of the small opening and refused the examination. Rachman (1997) offers:

> The fear reaction resembles the one animals display when their flight is prevented, and it is possible that the human fear of enclosed spaces is a vestigial fear of being trapped in a way that prevents escape when threatened. (p. 164)

Radomsky et al. (2001) offer that "a majority of claustrophobic people express a fear of suffocating while in an enclosed space, and in experimental investigations, this fearful cognition was closely associated with the bodily sensation of shortness of breath" (p. 288).

Wiederhold and Bouchard (2014) note that "claustrophobia is classified as a situational type of phobia, which is a fear of specific situations, that makes people fearful and sometimes panicked in compact places; this includes the fear of confined spaces." Being placed into spaces such as MRI examination equipment or underground tunnels, or activities such as spelunking and underwater diving can trigger an attack. An individual with claustrophobia usually avoids the feared claustrophobic situations or else endures them with intense anxiety, discomfort and a desire to escape. Wiederhold and Bouchard (2014) also note that "to qualify as a phobia, the severity of the avoidance, anxiety or anticipation must interfere significantly with the person's life and the symptoms must have been present for at least 6 consecutive months."

Claustrophobia Historical Information

Rachman and Taylor (1993) published the results of a questionnaire developed to measure claustrophobia from the fear of suffocation and the fear of restriction. They used 179 students who completed five behavioral tests: breathing through a straw, wearing a gas mask, standing in a closet, being tied in a canvas

KEY TAKEAWAYS

- **Approximately 2% to 13% of the U.S. population will experience a specific phobia during their lifetime, including animal phobia, acrophobia, claustrophobia and blood-injury phobia.**
- **Treatments from the medical and psychological fields to reduce claustrophobic reactions have included virtual and non-virtual treatments, cognitive behavioral therapy, relaxation and visualization, and pharmacological treatments.**
- **Occupational confined space exposures include equipment and environments encountered by fire and rescue, search and extrication teams, maintenance personnel, contractors in industrial and commercial employments, and military personnel.**
- **The findings and results of researchers studying how best to reduce claustrophobic reactions in magnetic resonance imaging machines, especially postural positions, has direct relevance to industrial and engineering designers seeking to reduce claustrophobic anxiety in industrial and construction equipment and environments.**

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bag, and lying on a shelf, followed by a structured interview. Adam Radomsky, a core member of the Centre for Clinical Research in Health and psychology professor at Concordia University, aimed to shorten the claustrophobia scale developed by Rachman and Taylor (1993) to test its reliability and validity as a tool for clinical research. Further analysis of Rachman and Taylor's work resulted in the development of two tables reducing the claustrophobia questionnaire from 36 to 26 items (Radomsky et al., 2001).

Later research investigating motion sickness, body movement and claustrophobia during passive restraint found that "claustrophobia occurred during restraint, but only among participants who became motion sick" (Faugloire et al., 2007). Passive restraint (i.e., being unable to move) causes greater claustrophobic severity as opposed to active restraint with muscle control over movement.

Classification of Phobias

Psychologists and others in the medical profession have identified hundreds of phobias. The World Health Organization (WHO, 2022) developed the International Classification of Diseases (ICD) for categorizing individuals with claustrophobia based on the nature of their fears. The ICD-11, effective January 2022, contains an extensive list that defines mental, behavioral and neurodevelopmental disorders by subcategories depending on their relation to anxiety or fear.

WHO classifies claustrophobia as a specific phobia within a broader classification of anxiety or fear-related disorders. Specific phobias encompass:

> Fears of a broad and heterogeneous group of phobic stimuli. . . . Individuals' reactions to phobic stimuli can range from feelings of disgust and revulsion . . . anticipation of danger or harm . . . and physical symptoms such as fainting. (WHO, 2022)

These are sometimes confused with agoraphobia, which "is characterized by marked and excessive fear or anxiety that occurs in response to multiple situations where escape might be difficult or help might not be available" (WHO, 2022).

Stemming from phobic reactions to various stressors, it is estimated that 12.5% of U.S. adults will experience a specific phobia in their lifetime; many, however, do not seek treatment (Ipser et al., 2013). According to The Recovery Village (2022):

> Claustrophobia is relatively common, with a review of specific phobia research estimating that approximately 2.2% of the [U.S.] population experiences a fear of enclosed spaces. Claustrophobia prevalence is higher among women and tends to emerge for the first time in adolescence or early adulthood.

This can be exacerbated by many things though, including MRI examinations where its prevalence may range from 0.7% to 14.0% in patients (Napp et al., 2017).

Statistics for Incidence of Claustrophobic Reactions

Öst (2007) evaluated the claustrophobia scale created by Rachman and Taylor and found it reputable for measures of anxiety and avoidance test-retest reliability, and concurrent and discriminant validity. In a female Canadian sample, Costello (1982, cited in Öst, 2007) found a 4% prevalence, but in a mixed U.S. sample, Kirkpatrick (1984, cited in Öst, 2007) found a much higher prevalence of 13.4%. According to Curtis et al. (1998, cited in Öst, 2007), claustrophobia has a lifetime prevalence of 4.2%, making it the third most prevalent phobia after animal phobia (5.7%) and acrophobia (5.3%). Women are slightly more likely to develop claustrophobia than men (Koh et al., 2017).

To be diagnosed with any form of phobia, the condition must create a significant negative impact on a person's daily life (Watson, 2022). Symptoms of someone having a claustrophobic reaction include:

- shortness of breath
- fast heartbeat
- sweating
- shaking or trembling
- nausea
- dizziness
- dry mouth
- hot flashes
- hyperventilation
- chest tightness or pain
- confusion or disorientation
- headache
- numbness
- choking sensation
- urge to use the bathroom (Watson, 2022)

Usually several of these symptoms occur at once or develop gradually in response to an unsettling environment.

Environments Where Claustrophobic Reactions Often Occur

For individuals experiencing claustrophobia, the common factor between many ordinarily encountered items such as revolving doors or hotel rooms with sealed windows is a perceived threat to their well-being derived from a perceived lack of easy escape from the environment (U.K. National Health Service, 2022). Standards have been established by OSHA and ANSI to help identify these claustrophobic reactions to help create safer working environments.

Standards Addressing Confined Spaces

Krug and Ketchum (2022), chair and vice chair of the ANSI/ASSP Z117.1 committee, report on the committee's analysis of data from OSHA's fatality database, which showed that "asphyxiants and toxic atmospheres are the leading cause of death in confined spaces" (p. 11). In a review of 2018 Bureau of Labor Statistics (BLS) data, Koshy and Presutti (2020) note:

> Fatal occupational injuries involving confined spaces increased 15% from 144 in 2016 to 166 in 2017. Since 2012, the number of confined space fatalities increased by 89% and confined space fatalities in the construction industry increased by 80%, from 41 in 2012 to 74 in 2017. (p. 34)

Appendix C to 1910.134, titled OSHA Respirator Medical Evaluation Questionnaire (Mandatory), addresses fitness for duty. The questionnaire includes a query about whether the employee has ever had any of several conditions, including "claustrophobia (fear of closed-in spaces)" (OSHA, 1998). Current OSHA standards address medical suitability and assessments for claustrophobia during confined space work in 29 CFR 1910.146 through some of the medical and respiratory standards that would be used in confined space entries or retrievals.

Fit for Duty Criteria as Established by NFPA, ANSI & Local Entities

The National Fire Protection Agency (NFPA) and ANSI have published standards addressing workers' fitness for duty and

TABLE 1

NFPA & ANSI CONSENSUS STANDARDS THAT ADDRESS FEAR OF ENCLOSED SPACES & CLAUSTROPHOBIA

Standard	Section or appendix reference
NFPA 1670, Operations and Training for Technical Search and Rescue Incidents (1999-2017)	4.5.4 Fitness: "The [authority having jurisdiction (AHJ)] shall ensure that members are psychologically, physically and medically capable to perform assigned duties and functions at technical search and rescue incidents and to perform training exercises in accordance with Chapter 10 of NFPA 1500." A.4.5.4: "The AHJ should address the possibility of members of the organization having physical and/or psychological disorders (e.g., physical disabilities, fear of heights, *fear of enclosed spaces* [emphasis added]) that can impair their ability to perform search and rescue in a specific environment."
NFPA 350, Guide for Safe Confined Space Entry and Work (2016-2022)	12.18: "The written confined space program should include evaluation criteria for the physical and mental capabilities of personnel assigned to work in confined space operations. The program should consider all actual and potential hazards and operations. The program can reference industry and regulatory medical evaluation procedures, including, but not limited to . . . *physiological and psychological stresses that might be present during confined space entries. Physiological and psychological stresses can include climbing ladders, heat stress, and claustrophobia*" [emphasis added]. A.12.18: "Items to consider as part of the fitness-for-duty evaluation can include, but are not limited to, the following . . . *tight work spaces"* [emphasis added].
ANSI Z117.1, Safety Requirements for Entering Confined Spaces (1977-2022)	16.0 Medical Suitability, 16.1: "Work in confined spaces may involve a variety of stressors which shall be evaluated. This evaluation can be by a team member's medical history questionnaire that is reviewed by physician or other licensed healthcare professional (HCP) against an essential job function-based job description specific to the confined space, as appropriate. It can also be conducted by a physician or other [HCP] as the employer determines is appropriate. "Note: examples include but are not limited to thermal extremes (hot or cold), vertigo, *claustrophobia, and physical and psychological stressors associated with specific confined space environments*" [emphasis added].

Note. Italic text indicates references to claustrophobia, tight spaces or anxiety related to the same.

medical suitability when working in confined spaces. Excerpts from those standards that address fear of enclosed spaces and claustrophobia are shown in Table 1.

Claustrophobia is a recognized issue among naval divers from the U.S. Navy, U.S. Coast Guard and Ireland Navy Divers. Note the following accounts from and about naval divers (italic text indicates references to claustrophobia, tight spaces or anxiety related to the same):

> It is the darkness that gets to people. . . . *That darkness, combined with the claustrophobia of being up to 60m (almost 200 ft) deep* [emphasis added], is the reason the course is considered among the toughest in the Defense Forces and why more than 70% of recruits don't make it to the end. (Gallagher, 2021)

> I have seen rugged football-type fellows sitting on the stool getting suited up and, *when the helmet was put over his head and locked in place, would yell "'get me out of this rig" from claustrophobia.* [emphasis added] (Sears, 2011, p. 17)

> Do you suffer from motion sickness or *fear of enclosed spaces*? [emphasis added] (U.S. Coast Guard, 2019)

The U.S. Navy (2020) Manual of the Medical Department has established standards for physical examinations, enlistment, commission and special duty. The standards applicable to submarine duty include work and duties in an environment "characterized by geographic isolation, austere medical support, need for personnel reliability, prolonged exposure to low level atmospheric contaminants, and psychological stress." Persons deemed most appropriate for this duty will not exhibit "anxiety related to tight or enclosed spaces."

Selected Military Confined Spaces

As seen from the history and relevant standards, claustrophobia has been a recognized phobia for decades and, as such, has been a problem for war soldiers. This was especially true for those navigating the underground tunnels that were a critical part of the Vietnam War (Figure 1). Many who were repeatedly sent into these tunnels experienced a claustrophobic reaction due to the confines of the space through which they were crawling. The military coined the term "tunnel stress" to describe the reactions soldiers experienced.

Tourists who can now visit these tunnels may experience the same fears. The tourist shown in Figure 1c notes that it "was incredible crawling through those tunnels and very tight" (M. Holt, personal communication, Oct. 16, 2022). According to Mangold and Penycate (2005), "Those who attempt to find out for themselves what it was like to exist in the tunnels and make a short journey through soon succumb to claustrophobia.” The 3D model shown in Figure 1a represents the geometry of the tunnels. The approximate dimensions of the tunnels are 31.5 in. (80 cm) high by 23.5 in. (60 cm) wide, affording little room to navigate turns. Anthropometric data for Vietnam military personnel from 1963 and U.S. military personnel from 1966 reveals a marked difference in body sizes between the two military populations at the 5th, 50th and 95th percentiles. Weight, stature and shoulder width, all critical dimensions for tunnel entrance and navigation, had percent greater differences at the 5th, 50th, and 95th percentile ranging from 7.5% to 38% (NASA, 1978).

Military personnel have also experienced instances of becoming claustrophobic when wearing protective gear such as gas masks. E. Cameron Ritchie, a member of the Medical Corps and the Department of Psychiatry at Walter Reed Army Hospital Medical Center, addressed treatment of gas mask phobia occurring in members of the U.S. Army. A 1992 study conducted with military personnel analyzed how adept soldiers were at wearing a gas mask during chemical warfare training. The study concluded that most felt a sensation of claustrophobia and entrapment, but a few had severe reactions to the training. One individual “described a number of episodes of panic and claustrophobia whenever he put on the mask. . . . He could wear the mask no more than 10 minutes inside a building and 5 minutes outside” (Ritchie, 1992). This individual had to be treated for claustrophobia through desensitization methods to be able to wear a gas mask.

Claustrophobia in Industrial Settings & Other Occupations

Claustrophobia also occurs in construction, an industry employing 10.8 million people in 2020 in the U.S. (U.S. BLS, 2020). Of that population, 1.2 million were women, who have a higher prevalence of claustrophobic reactions than men (The Recovery Village, 2022). Researchers conducted an in-depth analysis of common psychological disorders in construction management (Wang et al., 2017). Mental health issues are the second largest category of occupational ill health after musculoskeletal issues (Hunsley et al., 2014). The six most common psychological disorders, including claustrophobia, were analyzed to determine their impact on project performance with the goal of identifying mental health issues in construction (Wang et al., 2017).

Claustrophobia most directly results in significant distress, functional cognition interference, and anxiety and panic in construction. Wang et al. (2017) studied 201 “selected experienced personnel working in construction projects” and examined how mental disorders played a role in their workplace. Analyzing the results, 48% reported symptoms of claustrophobia. In construction management, claustrophobia impacts quality management the greatest, followed by time management (Wang et al., 2017).

OSHA’s Permit-Required Confined Spaces standard final rule presents data for industries affected by the standard, which took effect in 1993. At the time, OSHA estimated that “238,853 establishments employing 12.2 million workers have permit spaces . . . with about 1.6 million workers, including contractors, who enter approximately 4.8 million permit spaces annually” (OSHA, 1993b). Applying this to the statistic that 2.2% of the U.S. population experience a fear of enclosed spaces, it is estimated that 237,600 persons employed in general industry work in 2020 would experience claustrophobia.

Firefighters can also be vulnerable to claustrophobia. An estimated 1.08 million firefighters were employed in the U.S. in 2019, comprising 358,000 career firefighters (uniformed full-time) and 722,8000 volunteer firefighters (active part-time; Fahy et al., 2021). A 12.5% prevalence of specific phobias in this profession yields approximately 135,000 affected firefighters in 2019, while a 2.2% prevalence yields approximately 24,000 affected (Ipser et al., 2013). This 2.2% to 12.5% range verifies that claustrophobia is an occupational risk to the more than 1 million firefighters in the U.S.

A study at the New Taipei Fire Department in Taiwan was undertaken to analyze firefighters through self-reporting surveys and ultimately determine which factors influence their ability to find their way through dark and complex environments (Lin et al., 2021). Results showed that age might be a marginally significant factor, and fear of confinement might be a significant factor that could affect their wayfinding time in dark and complex environments. Additionally, 20.6% of the study’s participants had a fear of confinement corresponding with a wayfinding time of 902.25 seconds, but those without this fear had a wayfinding time of 731.45 seconds. This was significant at the $p = 0.03$ level; the t-test value was $p = 0.03$ (Lin et al., 2021).

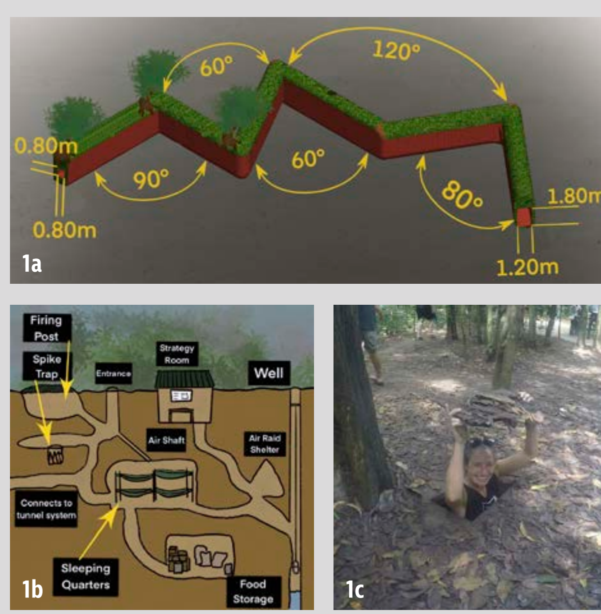
The state of Indiana requires each incoming firefighter recruit to pass a claustrophobia test as a part of the hiring process. In the test, recruits are placed on the first floor of a building wearing “a self-contained breathing apparatus backpack and face-piece with respirator cartridges attached” (Fort Wayne Fire Department, 2010). The applicant must stay on their hands and knees for 1 minute, then crawl on all fours to locate and exit the space. Removing the facepiece, standing or any panic-like behavior during the exercise results in a failure.

A former U.S. Navy diver who performed waterborne repair of U.S. Navy nuclear ballistic missile submarines reports that

FIGURE 1

CU CHI TUNNELS, VIETNAM

Many who were sent into the Cu Chi tunnels during the Vietnam War experienced a claustrophobic reaction. The tunnels that connected the underground buildings were approximately 31.5 in. (80 cm) high and 23.5 in. (60 cm) wide. The tunnels are now open to tourists, who may experience the same fears.



his underwater tasks, which included swimming into a torpedo tube on a submarine, were very confining (B. Everett, personal communication, July 6, 2022). The diver, who was 5 ft, 10 in., had a 42-in. and weighed 205 lb, was in a wetsuit (up to 7 mil thickness) pulling a 3-in. diameter tube that contained a pneumonometer, heated water for extremely cold environments, a breathing tube (airline respirator) and communication cable while so engaged. The shoulder-to-shoulder breadth for this size individual is approximately 17.6 in. The 19-ft torpedo tubes have a diameter of approximately 21 in., giving the diver about 1.7 in. of space on each side of the body.

In a 2020 video, Destin Sandlin, a former U.S. Army missile test flight engineer, enters a torpedo tube on the USS *Toledo* Navy submarine to learn what Navy personnel experience when performing maintenance (Smarter Every Day, 2020). As Sandlin makes his way through the tube, he asks the torpedoman's mate, "You couldn't be claustrophobic and do this, could you?" to which the torpedoman's mate responds, "No, sir."

MRI Machines

Since at least 1984, the medical profession has witnessed patients' claustrophobic reactions to scans involving MRI equipment (Mubarak et al., 2015). The opening of a closed-bore MRI machine, which is about 20 to 24 in. (50 to 60 cm) in diameter, are typically described as an entrance to a long narrow tunnel (Bay Imaging Consultants, 2018).

While undergoing an MRI scan, the patient may be in constant communication with the technicians in case they become uncomfortable and desire to stop the procedure. Facilities may offer comfort enhancements such as music played through headphones, blankets or fans that blow a light breeze (Cleveland Clinic, 2021). If necessary, conscious sedation is an option technicians may consider so that examinations may be completed. However, while sedation and headphones with music may alleviate the anxiety for a patient undergoing an MRI exam, they are not viable options for industrial, construction or military activities or operations.

The patient's position while being scanned can also be a factor to consider in relation to the individual's anxiety in confined spaces. A study measured how anxious individuals would be during their first MRI scans by taking questions from the claustrophobia questionnaire before being scanned (McIsaac et al., 1998).

> The 54 participants who were enclosed head-first in the MRI bore did report more subjective anxiety during the scan (*M* = 2.22, *SD* = 1.02) than the 26 participants who went feet-first (*M* = 1.64, *SD* = 0.95), and this difference was statistically significant. (McIsaac et al., 1998)

The manner in which patients are restrained during a scan may also influence whether they experience claustrophobia. In a study focusing on motion sickness while being restrained, some participants experienced claustrophobia, which increased when being passively restrained (Faugloire et al., 2007).

The usual supine position for examination, with the examinee lying face up, may make individuals experiencing claustrophia more anxious compared to a prone position in which the individual lies face down. When patients were positioned face down, in the MRI machine, termination was less likely to occur. According to Eshed et al. (2007):

> An interesting result is the very low premature termination incidence of breast and pelvis examinations (0.31% and 0.27%). . . . All breast examinations are performed with the patient in the prone position. It was previously described that prone positioning of a patient might alleviate claustrophobic reactions.

These conclusions were also made in a study examining different positions for MRIs. The study found that prone positioning alleviated claustrophobia during a scan as opposed to the usual supine position (Hricak & Amparo, 1984). Of the 18 patients who experienced claustrophobia during the study in the supine position, 11 were then asked to try the MRI examination again in a prone position, which resulted in all patients completing the scan without a claustrophobic reaction (Hricak & Amparo, 1984). These results for postures that reduce or eliminate the anxiety associated with a claustrophobic reaction have great significance for industrial, construction and military applications.

Chemical & Biological Causation of Claustrophobic Reactions From Reduced Oxygen

Oxidation and reduction, also known as redox reactions, are two important factors to consider when examining for oxygen deficient atmospheres and the development of rust in confined spaces. Oxidation is a process that moves electrons from an electron source, such as a metallic substance, to oxygen molecules in the air. The presence of rust on a metallic substance denotes that oxidation has occurred. Reduction is a process that consumes electrons via negative oxygen ions entering a previously oxidized metallic substance, which is now an electron sink. As these ions continue to be absorbed during the reduction process, an oxygen deficient atmosphere is formed, and proper counteractive measures must be taken to make it safe to enter again (Kutz, 2009).

Below water chain lockers have hazards associated with a lack of oxygen as well as rust development. In September 2007, three crew members aboard the ERRV *Viking Islay* off the Yorkshire coast of England died after losing consciousness upon entering a chain locker. According to the investigative report, "One of the seamen entered the chain locker and collapsed. It is probable that the other seaman entered the chain locker in an attempt to help his companion. He also collapsed" (U.K. Marine Accident Investigation Branch, 2008). The

COURTESY BATTLESHIP NORTH CAROLINA

Photo 1: Man inside the barrel of a 16-in. gun. The photo was found in an album aboard the Battleship *North Carolina*.

investigation concluded that "the oxygen deficient atmosphere within the chain locker was caused by natural ongoing corrosion of the steel structure and anchor chain within the space" (U.K. Marine Accident Investigation Branch, 2008). Testing air quality prior to and during entry of confined spaces is required to control this hazard.

In addition, wood pellets pose a risk to individuals working in confined spaces due to carbon monoxide emissions. A study involving five ocean vessel incidents that took place while transporting wood pellets from British Columbia to the Port of Helsingborg, Sweden, in closed cargo hatches. Investigations began after fatalities and injuries occurred in 2006 to those on board a vessel discharging wood pellets in Sweden: "One seaman was killed, a stevedore was seriously injured, and several rescue workers were slightly injured after entering an unventilated stairway next to a cargo hold" (Svedberg et al., 2008). Prior research into the chemical composition of wood pellets showed that "[Carbon monoxide] and other one-carbon compounds, such as methanol, formic acid and formaldehyde, are emitted from wood pellets during storage in warehouses" (Svedberg et al., 2004). Therefore, wood pellets stored as cargo for several weeks aboard sea vessels contaminate the air and make it more difficult for the crew to breathe if in the same space. This investigation concluded that "measurement of both [carbon monoxide] and oxygen levels is essential prior to entry into spaces with air communication with a cargo of wood pellets. Measurement of oxygen alone is not safe. Self-ventilation of stairways is not sufficient" (Svedberg et al., 2008).

Effects of exposure to oxygen concentrations in the 10% to 19% range may include increased pulse and breathing rates, abnormal fatigue upon exertion, impaired respiration that may cause permanent heart damage, nausea and loss of consciousness (Air Products and Chemicals, 2014). These symptoms are similar to those of an individual experiencing a claustrophobic reaction, therefore emphasizing the importance of checking oxygen levels before performing work in such spaces and following OSHA mandated confined space procedures.

Tank & Vessel Openings That May Produce Claustrophobic Reactions

The USS *North Carolina*, a WWII battleship berthed in the Cape Fear River in Wilmington, NC, is a tourist attraction with scheduled and self-guided tours. The gun turrets on the main deck are accessible by a ship's ladder that folds down and allows visitors to climb the ladder to enter the inside of the gun turret through a 37-in. wide, 30-in. high door. Sea vessels contain many tight compartments that must be serviced by crew members. For example, the confined spaces within gun barrels on battleships must be cleaned (Photo 1).

In a firsthand account, Paul Phillips, seaman first class aboard the *North Carolina*, says:

> I was assigned to Turret I as a work station and general quarters station. Several times I was asked to put on a monkey suit (coveralls). I was a gunner's mate striker. The first step was to get two lines from the chamber all the way through the [16-in. gun] barrel. This was done with the gas ejector. We would then use a hammock for me to lie on. We would secure a line to each corner and tie a rag around my head, and I entered the chamber feet first. Someone would pass me a large rag and about a pound or more of grease. When I said ready, men on deck would start pulling me through and I used my hands to spread the grease round and round the barrel. I was glad when my feet came out the other end." (Battleship North Carolina, n.d.)

FIGURE 2
TANK DIMENSIONS

The tight entryway to a petroleum product welded steel tank mounted on a 1955 Marine Corps military surplus trailer.

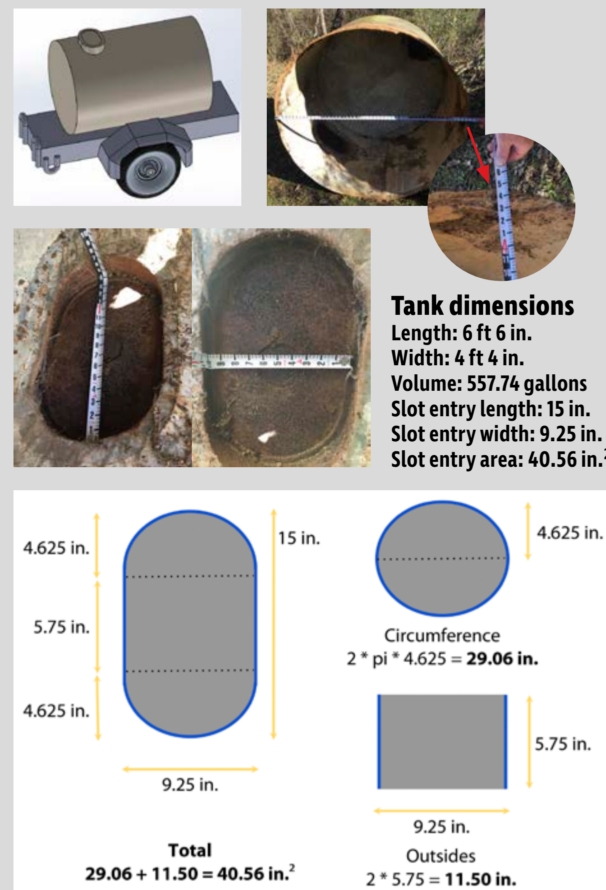


Figure 2 shows how tight the entryway might be to a petroleum product welded steel tank mounted on a 1955 Marine Corps military surplus trailer. An individual weighing 140 lb and measuring 5 ft 8-in. tall with a shoulder width of 15.1 to 15.8 in. used this tank to transport water for agricultural irrigation, a frequent use of surplus equipment for agriculture purposes. Their size placed them at the 5th percentile shoulder breadth. They entered the tank for maintenance purposes but could only gain entry through the manhole slot by rolling their shoulders in toward their chest.

Mechanical Sizing Standards for Storm Drains & Manholes

Storm drains have been a source of amusement especially for the preteen and early teenage year populations. Towns, municipalities and property owners have blocked access to many storm drains now, as drowning and prohibited activities are major property owner liabilities.

Similar to storm drains, manholes are another confined space concern. The American Petroleum Institute (API) has established

TABLE 2
ROOF MANHOLE DIAMETER STANDARDS

Nominal tank diameter (D), m (ft)	Minimum no. of manholes
D ≤ 61 (200)	2
61 (200) < D ≤ 91 (300)	3
91 (300) < D	4

Note. Adapted from "Welded Steel Tanks for Oil Storage (API STD 650)," by American Petroleum Institute, 2012.

FIGURE 3
MANHOLE COVER

Manhole cover with entry diameter shown.

Manhole entry diameter: 38 in.

standards for various diameters of manhole components allowed for official use. Data from API Standard 650, Welded Steel Tanks for Oil Storage, is tabulated in Table 2, which specifies the minimum number of manholes required for given tank sizes.

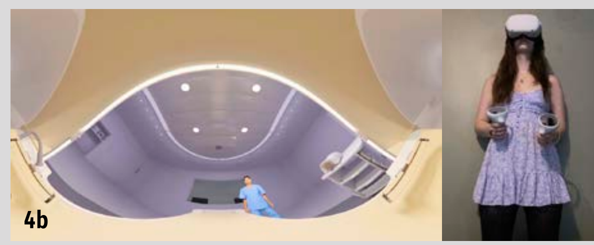
The 40.56-in.^{2} opening for the repurposed military tank shown in Figure 2 (p. 21) is 167% smaller than the 24-in. diameter tank specified by API (Table 2). The 38-in. diameter electrical access manhole cover shown in Figure 3 provides far greater ease of access than the repurposed military tank slot access shown in Figure 2. ASTM C478/C478M-20, Standard Specification for Circular Precast Reinforced Concrete Manhole Sections, states that "the flat slab top access opening shall be a minimum of 24 in. [600 mm] in diameter."

Inspection Technologies to Reduce Confined Space Entries

Technology for flexible fiber imaging devices has been available since the 1950s. This was used for conducting endoscopies where an endoscope enters a patient's body to examine internal organs or cavities (Sivak, 2006). Following this invention, conventional closed-circuit television was used for inspecting pipe interiors, whereby a camera mounted on a tractor is operated via remote control. This allows operators to view "existing defects such as cracks, debris, roots, deflections, etc., and also location and condition of service connections" (Moradi et al., 2019). Using this technology for maintenance and inspection of confined spaces, particularly pipes and tunnels, reduces the risk of individuals having a claustrophobic reaction upon entering the space. Tunnel designs that incorporate adequate lighting may also reduce the risk of having a reaction, as the feeling of being surrounded by darkness exacerbates the tendency to panic. A 2007 report on a replacement transportation bridge

FIGURE 4
VR TREATMENT

Example of VR claustrophobia treatment for MRIs.



being constructed over the Firth of Forth estuary in Scotland notes that "lighting also reduces the claustrophobic effect commonly experienced by tunnel users" (Jacobs U.K. Ltd., 2007).

Since the early 1990s, drones and unmanned aerial vehicles have been available for vertical takeoff and landing, hovering and high-speed horizontal cruise flight (Ebbert et al., 1992). Since at least 1992, unmanned aerial vehicle technology has advanced for many applications, particularly aerial surveillance. Drones are now used for boiler inspections, tanks, vessels and pipelines, eliminating the need for humans to enter some confined spaces.

Medical/Psychological Treatments for Those Who Experience Claustrophobic Reactions

Advancements in the medical community have allowed for various treatments that, over time, may allow claustrophobia patients to function in enclosed environments. The most common include exposure therapy, cognitive behavioral therapy, VR, relaxation and visualization, and medicine (Choy et al., 2007). This could take place with the patient being in a confined space such as an elevator or small closet.

Gas mask phobia is described as "the more extreme reaction of hyperventilation, tachycardia, sweating, fear and inability to keep the mask on" and is considered a "combination of physiological and psychological responses" (Missri & Alexander, 1978, as cited in Ritchie, 1992). Ritchie (1992) discusses the claustrophobia treatment strategy of systematic desensitization, in which a combination of muscular relaxation and deep breathing is incorporated with having the patient imagine the feared stimulus.

> In graded exposure, the patient is actually exposed to the stimulus, but in small increments that allow [them] to overcome [their] anxiety. In flooding, the patient is exposed at full intensity for prolonged periods of time, and so becomes very anxious. However, [they] are forced to remain in that situation until [their] anxiety ebbs. In graded participant modeling, the patient observes a fearless model interact with a phobic stimulus

and gains enough courage to emulate the model. (Fullerton & Ursano, 1990, as cited in Ritchie, 1992)

Technological advancements since 1957 have resulted in VR becoming more prevalent as a form of phobia treatment. Bruce and Regenbrecht (2009) note that "in [VR exposure therapy], a patient is immersed within a virtual environment in which they are confronted with anxiety-provoking stimuli" such as heights, aircrafts or spiders that "should provoke the same psychological and physiological reactions as the real-world situation" (Regenbrecht et al., 2006). Similar to medications, VR treatment is structured to be supplemented by specifically systematic desensitization and exposure therapy.

Figure 4 shows an example of VR claustrophobia treatment for MRIs. VR exposure therapy is conducted with the patient fitted with a headset that can control the environment they see via handheld controller buttons. This allows the person to move closer to the MRI machine and then lie down on its bed, simulating a claustrophobic trigger in a controlled environment. The image on the upper left (Figure 4a) depicts what a patient sees as they walk into the room, and the image on the bottom left (Figure 4b) depicts what the patient sees supine and in the MRI machine while looking up. The engineering and computer science programs of many institutions of higher education include VR labs. Similar technologies such as for gaming applications have been in the marketplace since at least 2006.

Training/Fire Service Published Reports

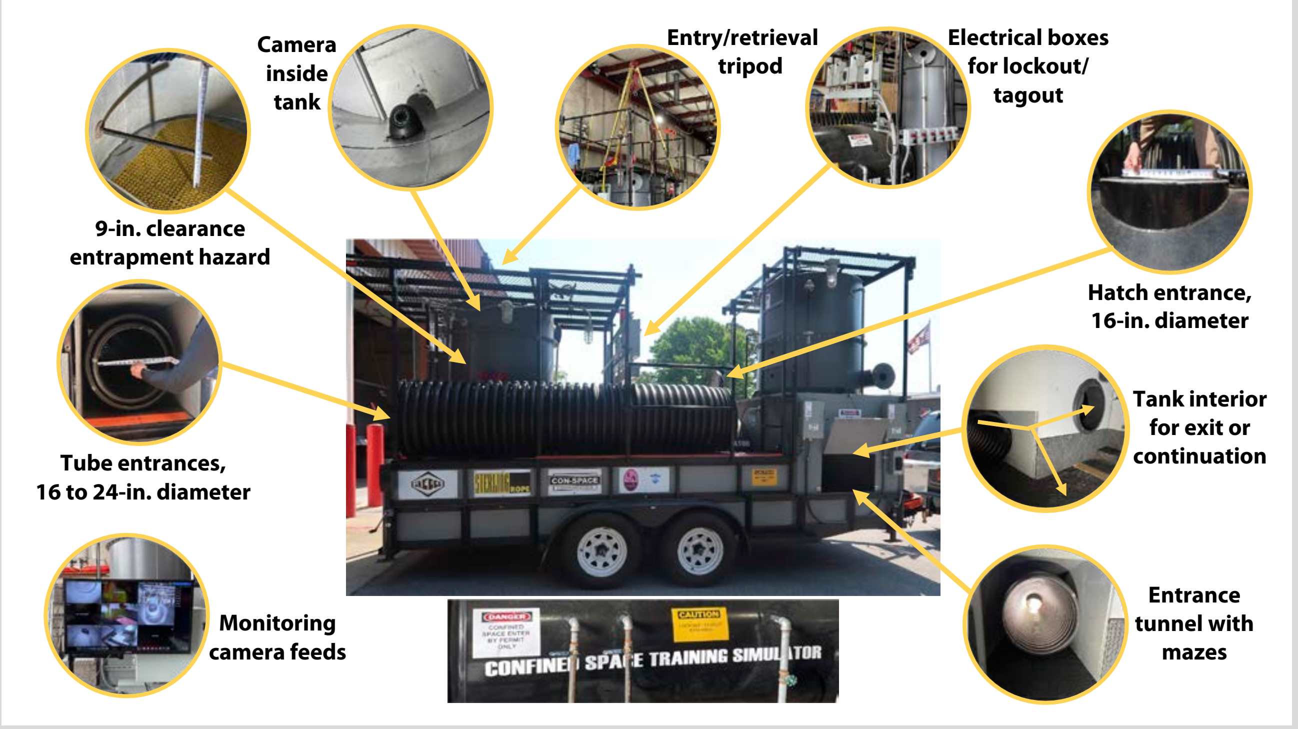
Some U.S. private sector firms provide stationary unit trailers outfitted with mazes and obstacles for training people, primarily self-contained breathing apparatus (SCBA) users. John Griffin, former battalion chief for fire and rescue at the Dallas Fort Worth International Airport, had previously completed training as part of an SCBA confidence maze. One portion of the training certification included entry into a 6-ft long section of 24-in. diameter tubing. At the time, he was 6 ft tall and weighed 240 lb with a shoulder-to-shoulder breadth of approximately 19.4 in., giving him approximately 2.3 in. of space on either side of the body when crawling through the tube. He used the tube in a standalone environment to desensitize and ensure against a claustrophobic reaction before trying to go through a maze containing a series of tubes (J. Griffin, personal communication, June 10, 2022, and July 7, 2022).

Training participants must perform tasks while being mentally and physically stressed. Upon completion of training there should be a developed skill set regarding orientation, communication, rescuing casualties, industrial rescues and nonvisual reactions. A mobile training gallery is one example of this service (Draeger Inc., n.d.). Rescue Extrication Delivery Specialists, a Garner, NC-based technical rescue operations team, built an apparatus on a 16-ft trailer to train people how to move around and operate in a confined space (Figure 5).

Trainees crawl in and up through a tube with an opening of 16, 18, 24 or 30 in. into tanks that may be filled with water. The spaces are small enough that trainees may have to remove their SCBA and push it in front of them to navigate the tubes or openings. They must then perform actions including lockout/tagout, rescuing other persons or climbing a ladder while in tight spaces designed to make them feel uncomfortable. Many of the organization's trainers are fire service personnel.

According to the team chief, the usual trigger for a claustrophobic reaction occurs after donning SCBA while in one of the

FIGURE 5
CONFINED SPACE MOBILE TRAINING UNIT



tubes or tanks. Desensitization is employed by removing tubes from the total system and allowing the entrant to enter and exit those isolated tubes. This prepares the entrant and guards against a claustrophobic reaction when they later enter the couplets ensemble for training (D. Pease, personal communication, June 6, 2022, and July 13, 2022).

Conclusions & Recommendations

In addition to understanding the regulatory and consensus standards that address safe entry and retrieval from confined spaces, OSH practitioners should be aware that claustrophobia is a major deterrent to persons performing confined space entry or retrieval or rescue.

Studies have estimated that approximately 2.2% of the U.S. population will experience a fear of enclosed spaces in their lifetime, while the prevalence of specific phobias in the U.S. population ranges from 2% to 13%. Studies have also estimated that there is a higher prevalence of this occurring with women than men. OSHA, ANSI and NFPA standards and guidelines should be used for assessment of potential claustrophobic reactions. Design engineers, OSH professionals, military staff personnel, physicians and other healthcare professionals should be cognizant of the anxiety triggers associated with claustrophobia. These triggers include a fear of confinement/restriction and asphyxiation. Industrial designers of enclosed environments including storage tanks, walkways, military equipment, manholes, tunnels and shafts should design structures with large enough walking/moving space and appropriate lighting to minimize claustrophobic reactions. Technologies, such as drones equipped with cages or cameras attached to cables and flexible fiberoptic endoscopes can be used for some confined space entries such as internal boiler and sewer line inspections, eliminating the need for people to enter the confined space and should be used to minimize or avoid entries.

Treatment methods delivered by licensed healthcare professionals should be tailored to individuals, which may require a combination of therapies. The MRI postures found to have been most likely to avoid an anxiety or claustrophobic reaction should be incorporated into work procedures and equipment design and redesign. These include prone and feet-first position entries to minimize claustrophobic reactions versus supine and head-first entries. Fire service and emergency responder personnel are parts of the population subject to claustrophobic reactions in confined space environments. Industrial trainers have used training methods that are designed to allow the participant to desensitize by participating in isolated sections of a training maze before going through the entire maze as a means to reduce the incidence of claustrophobic reactions. PSJ

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