Journal of Hazardous Materials, 36 (1994) 45–53
Elsevier Science Publishers B.V., Amsterdam

Deadly rescue: The confined space hazard

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(Received February 10, 1993; accepted in revised form April 6, 1993)

Abstract

Rescue operations in confined spaces can expose the person(s) attempting rescue to hazardous atmospheres or to physical hazards such as engulfment, which are potentially fatal. Two sources of data in the United States on work-related fatalities — the National Institute for Occupational Safety and Health (NIOSH) National Traumatic Occupational Fatalities (NTOF) surveillance system and investigations performed under the NIOSH Fatality Assessment and Control Evaluation (FACE) program — were used to examine confined space-related deaths. For the years 1980 through 1988, there was an average of 89 work-related deaths in confined spaces per year, and approximately 23 (25.5%) of those who died were persons attempting rescue. Asphyxiation by atmospheric hazards was the primary cause of death of those persons attempting rescue. Those persons who were attempting rescue and who died were more likely to be co-workers than public safety or emergency medical service (EMS) personnel. Since rescue operations in confined spaces present unique hazards, proper training of personnel and the availability of specialized equipment are required to protect persons attempting rescue from injury and death. Safety supervisors and public safety and EMS personnel should be familiar with the recognition of confined space hazards and the use of appropriate rescue techniques.

1. Introduction

The term "confined space", as defined by the National Institute for Occupational Safety and Health (NIOSH), refers to a space which by design has limited openings for entry and exit; unfavorable natural ventilation which could contain or produce dangerous air contaminants, and which is not intended for continuous employee occupancy [1]. Confined spaces include, but are not limited to, tanks, process vessels, pits, silos, vats, degreasers, boilers, utility vaults, and pipelines. Workers are required to enter confined spaces for tasks such as repair, inspection, and maintenance, and are often exposed to multiple hazards. Fatal injuries which occur in confined spaces are most likely to be from atmospheric hazards [2]. The types of atmospheric hazards in confined spaces can be quite varied — some examples are shown in Table 1. The vapors of substances not normally thought of as toxic, such as fuel oil or gasoline, can build to high concentrations

SSDI 0304-3894(93)E0051-3

TABLE 1

Examples of atmospheric hazards in confined spaces

Type	Example
Toxic gas	Hydrogen sulfide, carbon monoxide, hydrogen cyanide
Inert gas	Argon, helium, nitrogen
Simple asphyxiant	Nitrogen, methane, carbon dioxide
Oxygen deficiency	Oxygen in air consumed or displaced
Solvents	Freons, other chlorinated hydrocarbons, gasoline
Explosive mixtures	Methane/air, toluene vapor/air

in confined spaces and cause asphyxiation. Certain confined spaces are subject to changing atmospheric conditions and may have been entered safely in the past but may suddenly contain air which is toxic or which is unable to support respiration. Sewers, manholes, and pits below ground level are known to quickly change air composition during times of low barometric pressure [3, 4], when the surrounding soil may release toxic gases into the confined space.

Physical hazards are also an important cause of injury in confined spaces. Loose granular materials, such as sand or grain, can engulf a worker in cavities or voids within the material. A worker standing over such a void can sink in and be engulfed in the loose material and asphyxiated, much like engulfment in quicksand.

Rescue attempts in confined spaces can expose the unprepared rescuer to the risk of asphyxiation in an atmosphere unable to support respiration. In 1986 the National Institute for Occupational Safety and Health (NIOSH) issued an "Alert" requesting assistance in preventing confined space-related fatalities. This Alert, based on investigations conducted under the NIOSH Fatal Accident Circumstances and Epidemiology (FACE) program (name changed in 1992 to Fatality Assessment and Control Evaluation) cited eight incidents with 16 fatalities, ten deaths of which were persons attempting rescue [5]. Subsequent NIOSH reports re-emphasized the danger to persons attempting rescue [6, 7] and called attention to specific atmospheric hazards in confined spaces such as chlorofluorocarbon F-113 in degreasing tanks [8] and hydrogen sulfide and methane [9] in manure pits.

A study of Occupational Safety and Health Administration (OSHA) investigations of asphyxiations in confined spaces that occurred from 1984 through 1986, reported that only 12% of those who died were persons attempting rescue [10]. However, OSHA does not have jurisdiction over state and municipal workers in many states, nor over most agricultural workers, which may have resulted in OSHA not investigating some deaths involving rescuers, with consequent underreporting. Also, deaths of non-employee rescuers would not be counted by OSHA.

In 1993, OSHA promulgated "Permit-Required Confined Spaces" regulations (29 CFR 1910.146) for work in confined spaces in general industry and addressed the need for rescue procedures for confined spaces [11]. The regulations attempt to establish criteria for rescue which would protect co-workers or other rescuers from injury or death. OSHA estimated that over 1.6 million U.S. workers enter "permit-required confined spaces", that is, confined spaces which would require entry permits under the OSHA regulations. However, the OSHA confined space regulations would not apply to workplaces with fewer than 11 employees, federal workers, state and municipal employees in the 24 states under federal rather than state OSHA jurisdiction, self-employed persons, and workers in the construction, agriculture and shipyard industries. The OSHA preamble to the standard also noted that many confined space-related injuries resulted in multiple fatalities, and that in most of those cases, persons attempting rescue died trying to rescue the initial victim who had entered the confined space [11].

The present study was done to estimate the number of confined space-related fatalities that occur at work in the United States each year, and the number of persons who died attempting rescue.

2. Methods

NIOSH has established the "National Traumatic Occupational Fatalities" (NTOF) surveillance system to enumerate traumatic work-related fatalities occurring in the United States. The NTOF data base is a census of traumatic, work-related fatalities based on all U.S. death certificates for 1980 through 1988 in which the "Injury at Work?" box on the death certificate is marked "Yes", the external cause of death was an injury (International Classification of Diseases, 9th revision (ICD-9) E800-E999), and the victim was 16 years of age or older [12, 13]. One of the advantages of NTOF over other sources of mortality data is that in addition to containing the underlying and contributing causes of death (ICD-9), each record contains the written description from the death certificate of the causes of death, and the comments made by the certifying coroner, medical examiner, or physician. The NTOF data base was used as a surveillance tool for counting confined space-related deaths by reviewing these narrative descriptions.

NIOSH also investigates selected workplace fatalities, including confined space-related deaths, through the FACE project. NIOSH is voluntarily notified of such fatalities by cooperating organizations and agencies [7]. On-site, research investigations are conducted by NIOSH to study and evaluate the working environment, the worker, the energy exchange resulting in fatal injury, the role of management, and the interaction between these factors. The goal of the FACE project is to prevent future deaths by identifying potential risk factors and recommending strategies to reduce the risk of fatal occupational injuries. Although not all states report and not all confined space-related deaths are reported or investigated by NIOSH, FACE investigations provide detailed information describing the environment and circumstances of fatality incidents. Fatalities investigated under the NIOSH FACE program from 1982 through 1991 which involved confined spaces were included in this analysis.

3. Results

3.1. Death certificates

Death certificate data from NTOF identified 803 deaths in 681 incidents in confined spaces for the nine-year-period, for an average of 89 deaths per year and 1.2 deaths per fatal incident. The average victim age was 35 ± 14 years, with a range of 16 to 86 years. Of the 803 deaths, atmospheric hazards caused 499 (62%) and mechanical suffocation caused 223 (28%). Eighty-one victims (10%) died from other causes of injury.

There were 584 incidents in which a single victim died, and 97 multiple-fatality incidents with a total of 219 victims. Victims of multiple-fatality incidents were significantly more likely to die from an atmospheric hazard (89%) than those who died in single-victim incidents (50%, $p = 0.05$).

The employment of victims by industry is shown in Table 2, with the manufacturing industry ranking the highest in the number of victims in both single- and multiple-fatality incidents — 141 (24%) and 51 (23%), respectively.

TABLE 2

Industry of employment for confined space victims who died in work-related incidents during 1980–1988[a]

Industry division	Deaths in single-victim incidents	Deaths in multiple-victim incidents	Total
Agriculture/forestry/fishing	108	23	131
Mining, including oil & gas	50	30	80
Construction	80	27	107
Manufacturing	141	51	192
Transportation/communication/public utilities	58	42	100
Retail and wholesale trade	46	5	51
Services	33	13	46
Public administration	10	11	21
Not classified	54	17	71
Total	584	219[b]	803

[a] Source: NTOF data [12], 1980–1988.
[b] 97 incidents.

TABLE 3

Occupation of victims employed in public administration who died in confined spaces at work during 1980–1988[a]

Occupation	Deaths in single-victim incidents	Deaths in multiple-victim incidents	Total
Police officer	1	3	4
Fire fighter	1	2	3
Paramedic	1	1	2
Other government service	7	5	12
Total	10	11	21

[a] Source: NTOF data [12], 1980–1988.

Death certificates identified only 21 of 803 victims (2.5%) as working for government agencies and 10 of them were identified as police, fire, or EMS personnel (Table 3). As death certificates record the "usual occupation", and "usual industry" of the victim rather than the occupation and industry at the time of death, volunteer EMS or safety personnel, or those who worked part-time, might not have that occupation recorded on the death certificate. The information available concerning details of the fatal injury varied.

3.2. FACE investigations

During 1982 through 1991, the NIOSH FACE program investigated 62 incidents in confined spaces, with 97 fatalities. Thirty-five persons (36%) died attempting rescue, and three firefighters died in one incident fighting a fire in a silo, rather than attempting rescue. Only four of the 35 persons attempting rescue were police, fire, or public safety personnel, while 31 were co-workers.

All of the persons attempting rescue identified by FACE who died, except one who died in an explosion, were overcome by atmospheric hazards: One death from a flammable/explosive atmosphere containing toluene, two deaths from asphyxiation by natural gas, eight deaths in oxygen-deficient air, and 24 deaths from various toxic gases (Table 4). Inadequate or inappropriate respiratory protection was a major factor noted in the FACE investigations. In only six of the 62 incidents was there a self-contained breathing apparatus (SCBA) accessible for rescue at the worksite. Six of the 97 fatalities involved the use of inappropriate respiratory protection, such as using a respirator with organic vapor cartridges in an oxygen-deficient atmosphere, instead of an air-supplied respirator or SCBA. A standby person was used during the confined space entry in only eight of the 62 incidents.

TABLE 4

Atmospheric hazards which overcame 35 rescuers in 97 fatal incidents investigated by FACE (1982–1991)

Source of incident	Number of incidents
Flammable atmospheres	1
Simple asphyxiants	2
Oxygen-deficient	8
Toxic gases	
carbon monoxide	3
hydrogen cyanide	4
hydrogen sulfide	13
chlorine	2
trichloroethylene	2
Total	35

4. Discussion

There is no single coding scheme or definition which allows us to accurately count all deaths which occur in confined spaces in data sources such as death certificates. The physician or coroner who fills out the death certificate may not include sufficient description of the death to allow its occurrence in a confined space to be identified, therefore, judgements were made as to whether deaths from asphyxiation, suffocation and drowning occurred in a confined space. Furthermore, there is no unique code for asphyxiations in confined spaces among the external cause codes (E-codes) of the ICD-9 system. In addition, perhaps only 85% of the death certificates recording work-related deaths are filled out with the "Injury at Work?" box marked "Yes" [14].

Death certificate data in NTOF identified 89 confined space-related deaths per year. The proportion of confined space-related deaths that occur among persons attempting rescue can be estimated. However, any scheme for estimating the upper and lower bounds of the rescuer-to-overall-death ratio is subject to many confounding factors. A reasonable assumption is that it is not less than 15%, which is the proportion of deaths identified from NTOF who were the second, third, fourth or fifth victims in multiple-victim incidents. As for an upper limit, the nine-year series of FACE investigations identified that 36% of persons who died in confined spaces were attempting rescue. FACE investigations may be more likely to be conducted for multiple-victim than for single incidents. However, the actual proportion is unknown. There were incidents in which initial victims survived and the rescuer died, which would be reported in NTOF as a single fatality. There were also incidents in which two workers died together in a confined space and neither was a rescuer. No evaluations have been conducted on the amount of overcounting or undercounting that might be involved. Thus, a reasonable estimate for the proportion of confined space-related deaths involving rescuers would be approximately 25.5% (the median value between 15% and 36%), or approximately 23 rescuer deaths per year.

4.1. Rescue in confined spaces

Persons attempting rescue who die in confined spaces most often succumb to atmospheric hazards such as oxygen deficiency or a toxic gas exposure. It is not our purpose in this article to describe at length the proper means of rescue in confined spaces. However, we would like to briefly discuss recognition of confined space hazards and provide references which discuss requirements for effective rescue. The main characteristics which a rescuer should be able to recognize about a confined space are that it [1]:

(1) has limited openings for entry and exit
(2) has unfavorable natural ventilation which could contain or produce dangerous air contaminants, and
(3) is not intended for continuous human occupancy.

Previous research indicates that most confined space fatality incidents are characterized by lack of recognition of the hazards associated with confined spaces, failure to follow existing, known procedures for safe confined space entry, and incorrect emergency response [7]. Successful, safe entry into a confined space may require the use of engineering controls such as mechanical ventilation [15], administrative controls such as entry permits [16], standby personnel [17], and atmospheric testing [18], and personal protective equipment such as a positive pressure SCBA [8]. The NIOSH criteria document on confined spaces discusses requirements for these types of rescue [1]. The NIOSH Guide to Industrial Respiratory Protection covers the selection, use, and maintenance of respirators with a decision logic for proper respirator selection [19]. OSHA has also promulgated extensive requirements for working in confined spaces [11].

5. Conclusion

Better awareness of confined space hazards is urgently needed. The first step in preventing confined space-related fatalities is enabling workers to immediately recognize that an area is, in fact, a confined space and therefore a potentially deadly area that should not be entered unless appropriate safety measures are taken. Such recognition of confined spaces and their hazards can prevent initial confined space deaths and subsequent risk to rescuers.

Fatal injuries in confined spaces are most likely to occur from: (1) atmospheric hazards, (2) entry without testing the atmosphere, (3) failure to properly ventilate the confined space, (4) failure to recognize the hazards of a confined space, (5) failure to train employees on safe entry procedures and hazard awareness, (6) lack of a proper rescue plan, and (7) lack of appropriate personal protective equipment.

Prevention of fatalities in rescuers who attempt to aid victims in confined spaces should focus on the "first responder". In most cases this will be a co-worker. Prevention efforts should be aimed at educating employers and workers about confined space hazards and ensuring that employers provide SCBA and other rescue equipment at a site accessible to the confined space, as well as training in confined space rescue procedures. Prevention of deaths in public safety and EMS rescuers should be aimed at enabling them to quickly recognize the types of confined spaces which might contain air unsuitable for breathing. Clearly labeling areas as confined spaces by posting warning signs near entrances may reduce the risk to non-employee by-standers, who are not subject to confined space training and employer policy, but who may attempt rescue of confined space victims.

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