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# Confined Space Emergency Response: Assessing Employer and Fire Department Practices

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*An emergency response plan for industrial permit-required confined space entry is essential for employee safety and is legally required. Maintaining a trained confined space rescue team, however, is costly and technically challenging. Some employers turn to public fire departments to meet their emergency response requirements. The confined space emergency response practices of employers and fire departments have not been previously assessed. We present (1) federal data on the U.S. occurrence between 1992 and 2005 of confined space fatal incidents involving toxic and/or oxygen-deficient atmospheres; (2) survey data from 21 large companies on permit-required confined space emergency response practices; (3) data on fire department arrival times; and (4) estimates by 10 senior fire officers of fire department rescue times for confined space incidents. Between 1992 and 2005, 431 confined space incidents that met the case definition claimed 530 lives, or about 0.63% of the 84,446 all-cause U.S. occupational fatal injuries that occurred during this period. Eighty-seven (20%) incidents resulted in multiple fatalities. Twelve (57%) of 21 surveyed companies reported that they relied on the fire department for permit-required confined space emergency response. Median fire department arrival times were about 5 min for engines and 7 min for technical rescue units. Fire department confined space rescue time estimates ranged from 48 to 123 min and increased to 70 and 173 min when hazardous materials were present. The study illustrates that (1) confined space incidents represent a small but continuing source of fatal occupational injuries in the United States; (2) a sizeable portion of employers may be relying on public fire departments for permit-required confined space emergency response; and (3) in the event of a life-threatening emergency, fire departments usually are not able to effect a confined space rescue in a timely manner. We propose that the appropriate role for the fire department is to support a properly trained and equipped on-site rescue team and to provide advanced life support intervention following extrication and during ambulance transportation.*

**Keywords** arrival time, confined space, emergency response, fire departments, occupational fatalities, OSHA regulation

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## BACKGROUND

### Hazards of Confined Spaces

Many workplaces have confined spaces that are not intended for continuous occupancy by workers. Confined spaces may contain toxic, oxygen-deficient, and/or explosive atmospheres. These conditions can also develop as a result of work performed in the space; high levels of carbon monoxide, for example, may accumulate from the operation of equipment inside a confined space. Confined spaces may contain particular physical hazards, such as contents that can engulf or collapse on a worker, piping and fittings under high pressure and temperature, unguarded machinery, and exposed electrical hazards. By the nature of their design and function, confined spaces may be difficult to enter or exit, and they often have poor natural ventilation.<sup>(1)</sup> This article examines fatal incidents that occurred in confined spaces as a result of toxic and/or oxygen-deficient atmospheres; it does not address fatalities resulting from other physical hazards.

Examples of confined spaces include storage tanks, compartments of ships, process vessels, silos, vats, pits, degreasers, reaction vessels, boilers, ventilation and exhaust ducts, sewers, tunnels, underground utility vaults, and pipelines. Design features that increase risks to entrants include (1) the physical configuration of entry and exit portals; (2) minimal clearances within the space; (3) long distances between entry and exit portals; (4) ineffective means of locking-out electrical and mechanical systems; (5) poor ventilation; (6) structural weaknesses in walls, ceilings, and floors; (7) weaknesses in

pipes and fittings that contain liquids, gases, or pressurized steam; and (8) absence of anchor points necessary for effecting emergency rescue.

### Confined Space Emergency Response

Rescuing a worker from a confined space is a low-frequency, high-risk operation that is both time sensitive and technically challenging. Experience shows that a hastily executed rescue increases the likelihood that would-be rescuers will become victims. Both non-entry and entry rescue approaches have been accepted in current practice.<sup>(2,3)</sup>

In a non-entry rescue, personnel situated outside the space extricate a worker using a tripod hoist or other means of mechanical advantage. Enabling a non-entry rescue requires that all of the following conditions be met before the worker enters the space: (1) a mechanical advantage system rated for life safety purposes is installed outside the space; (2) the worker is roped to the mechanical advantage system and is outfitted with protective clothing and an appropriate harness; (3) the worker is visible from the entry point; (4) there is a means of clear communication between the worker and personnel outside the space; (5) the rescue path is free of obstructions that could entangle the worker during extrication, such as ladders, piping, valves, and equipment; and (6) a vertical—not horizontal—extrication of the worker is possible. If any of these conditions cannot be met, an entry rescue is required.

In an entry rescue, one to two rescuers enter the space to assess, stabilize, and extricate the worker. Adjunct rescue personnel are required outside the space to support the entry team. Entry rescue requires specialized skills and equipment, especially when hazardous materials may be present in the space.

### Epidemiology

In 1994, the National Institute for Occupational Safety and Health (NIOSH) identified 585 separate confined space fatal incidents that claimed 670 lives during the period 1980 to 1989.<sup>(4)</sup> Of these fatalities, 373 (56%) were caused by toxic or oxygen-deficient atmospheres, 227 (34%) by engulfment in loose materials, and 70 (10%) by other factors. NIOSH conducted 70 on-site investigations of confined space incidents that occurred during the period 1983–1993 and that involved 109 fatalities; of these fatalities, 39 (36%) were would-be rescuers.<sup>(4)</sup> Four (10%) would-be rescuers were professional emergency responders, or about 4% of total fatalities investigated. In evaluating data collected over a 5-year period by the U.S. Department of Labor, Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI), NIOSH reported that fatalities attributable to all causes in confined spaces averaged 92 per year, fluctuating from a low of 81 in 1998 to a high of 100 in 2000.<sup>(5)</sup>

### Regulatory History

In response to growing recognition of the unique hazards associated with working in industrial confined spaces, the U.S. Occupational Safety and Health Administration (OSHA) adopted Confined Space Standard 29 CFR 1910.146 for gen-

eral industry in January 1993 (hereafter referred to as the Standard).<sup>(6)</sup> The Standard was intended to protect both workers and rescuers during confined space entries. Under the Standard, a confined space was defined as (1) being large enough and so configured that an employee can bodily enter and perform work; (2) having limited means of entry or egress; and (3) not designed for continuous employee occupancy.

To distinguish spaces that pose unique health and safety risks, a “permit-required” confined space was defined as having one or more of the following attributes: (1) contains or has the potential to contain a hazardous atmosphere; (2) contains a material that has the potential for engulfing an entrant; (3) has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a smaller cross-section; or (4) contains any other recognized serious safety or health hazard. Only permit-required confined spaces are regulated by the Standard.<sup>(7)</sup>

The Standard describes specific responsibilities for an entrant, attendant, and entry supervisor. In emergency response planning, subsection (k) of the Standard requires employers to ensure that (1) the entry supervisor verifies that rescue services are available; (2) the attendant monitors the space at the entry point and summons rescue services if an emergency arises; (3) procedures are in place for summoning rescue services and rescuing entrants; and (4) emergency responders are capable of responding in a “timely manner.”

The interpretation of “timely manner” raised a number of questions in the implementation of the Standard, specifically with regard to if and under what conditions a public fire department could satisfy the intent of the term “timely.” The 1994 National Safety Council’s *Complete Confined Spaces Handbook*, for example, raised concern over the possibility that a fire department might be unavailable to respond to a confined space emergency; the *Handbook* concluded, however, that the Standard allowed employers to rely on the fire department for rescue services, provided that (i) the “rescue service [is] informed of the hazards that may be encountered when responding to a confined space incident; and (ii) responders are provided with access to all permit spaces from which rescue may be necessary so that they can develop appropriate rescue plans and conduct practice operations.”<sup>(8)</sup>

The OSHA Standard posed new challenges for employers in organizing and maintaining an on-site, employee-based confined space rescue team. Team members, for example, required fit-testing and training in the use of self-contained breathing apparatus (SCBA); baseline pulmonary function testing and medical screening; and training in the use of multi-gas detection equipment, high-angle extrication systems, basic first aid, and cardiopulmonary resuscitation (CPR).

The United Steelworkers of America, AFL-CIO-CLC, sought judicial review of the Standard out of concern that subsection (k) did not adequately describe requirements regarding the timeliness or the technical capacity of emergency responders. In its subsequent 1998 Settlement Agreement,

OSHA amended subsection (k) to require that employers match the timeliness and capacity of rescue services with the nature of the hazards present in the space.<sup>(9)</sup> For example, if workers were entering a potentially dangerous space, the employer would be required to provide a technically capable rescue team at the entrance to the space; i.e., one that could reach a worker within minutes in the event of an emergency. The employer could meet this requirement using an employee-based team or a contracted team.

This assessment process was intended to remove the distinction between (and confusion surrounding) on-site and off-site rescue services and to ensure that workers operating in the most dangerous spaces were afforded the highest degree of protection. The 1998 amendments included a new, non-mandatory Appendix F to guide employers in assessing the timeliness and capacity of rescue services vis-à-vis the confined spaces at their facilities.<sup>(10)</sup> Appendix F stipulated, for example, that employers may not rely on the fire department for rescue services if the space might contain a potentially life-threatening hazard.

### Questions Remain

It is unclear how employers have responded to the 1998 revisions to the Standard. Though there are multiple articles in the trade literature on confined space safety and operations, there are no studies in the peer-reviewed literature on confined space emergency response practices by employers. There is some cause for concern, however, given the costs, training requirements, potential risks, and specialized equipment required to organize and maintain an on-site confined space rescue team. It is reasonable to expect that employers—especially those in small and medium-sized enterprises—might be inclined to defer to the fire department in seeking to meet their confined space emergency response requirements, particularly if they are unaware of the confined space rescue practices of fire departments. Funding for the present study, for example, resulted from a legal settlement associated with the deaths of two workers in a confined space at a large heat-treating company. The company's written permit-required entry plan relied on the fire department for rescue services, based on the misperception that a first-responding engine company—which would likely arrive in 5 min or less from the time of dispatch—would have the *capacity*, by itself, to effect a confined space rescue.<sup>(11)</sup> The employer apparently believed that, by relying on the fire department, the company was compliant with the emergency response requirements of the Standard.

In 2009, the American National Standards Institute (ANSI) defined a performance standard for confined space rescue in its *Safety Requirements for Confined Spaces* (ANSI/ASSE Z117.1).<sup>(12)</sup> The purpose of the ANSI standard was “to provide . . . the minimum performance requirements necessary [for] developing and implementing a comprehensive confined space program for the protection of workers.”<sup>(13)</sup> ANSI did not, however, assess how fire departments might—or might not—meet the performance standard, which left open the question of whether, and under what conditions, employers could

rely on the fire department to meet their emergency response requirements under the OSHA Standard. In 2010, following a number of near misses involving U.S. firefighters in confined space incidents, the International Association of Fire Chiefs issued a “stand-down” recommendation on confined space emergency response and urged “fire and emergency leaders to immediately take action to review the dangers and proper procedures for confined space rescue operations.”<sup>(14)</sup>

The present study investigated confined space emergency response practices by employers and the response capacity of fire departments. The study

1. examined federal statistics on the U.S. national occurrence of confined space fatalities that resulted from toxic and/or oxygen-deficient atmospheres between 1992 and 2005.
2. obtained survey data from 21 large companies regarding the role of fire departments in their permit-required confined space emergency response plans.
3. obtained fire department arrival time data for first-responding engine companies and technical rescue units in two large urban areas.
4. obtained estimates from 10 senior fire department technical rescue officers on the time necessary for fire department crews to effect a confined space rescue, from arrival on scene to initiation of advanced life support (ALS), with and without the presence of hazardous materials.

## METHODS

### Confined Space Fatality Case Ascertainment

The U.S. Census of Fatal Occupational Injuries (CFOI) database, compiled since 1992 by the U.S. Bureau of Labor Statistics (BLS), is a collaborative effort among federal and state governments to document workplace fatalities.<sup>(15)</sup> The CFOI is generally considered the most complete database on occupational fatalities in the United States. The CFOI does not include non-fatal injuries, illnesses, or near misses.

To assess confined space fatalities since the 1993 adoption of the OSHA standard, we conducted a keyword search of the CFOI database for the period 1992 to 2005. We narrowed the case definition to fatalities resulting from inhalation of a substance and/or by oxygen deficiency in an enclosed, restricted, or confined space. We included drownings that occurred in such spaces and were attributable primarily to a toxic and/or oxygen-deficient atmosphere. Under a confidentiality agreement with the BLS, we examined each case individually to confirm whether a confined space was involved in the fatality.<sup>(16)</sup> We omitted apparent suicides.

### Employer Practices

To assess employer confined space emergency response practices, we collaborated with a California-based industry trade association and a national industry health and safety consulting firm in administering a survey to 30 large client companies. Twenty-one (70%) companies responded to the

survey. With the exception of one respondent who reported that the company managed hundreds of confined spaces nationwide, the number of permit-required confined spaces at the companies represented by respondents ranged from 1 to 30 at a single site, with a mean of 12. We were not able to gather consistent data on the number of workers employed at these companies; however, both the trade association and consulting firm represent large employers with national and global operations. The survey asked respondents to answer four closed-ended questions pertaining to the role of on-site employees, public fire departments, and off-site private contractors in the company's permit-required confined space emergency response plan. A fifth open-ended question allowed respondents to describe unique challenges in confined space operations at their facilities. The survey required about 15 min to complete.

### Fire Department Arrival Times

We obtained fire department arrival time data from the City and County of San Francisco, California, and the City of San Diego, California, for first-responding engine companies and technical rescue units that were dispatched simultaneously as part of a first-alarm assignment. Both units and others would be required in a confined space rescue. San Francisco (SF) (population 815,358 in 2009) is a densely populated city with minimal outlying suburbs. We evaluated arrival times for the SF Fire Department using data from 1495 first-alarm dispatches that occurred between January 1, 2003, and February 28, 2005. San Diego (SD) (population 1.26 million in 2009) comprises an urban core and outlying suburbs. We obtained arrival times for the SD Fire Department using data from 762 first-alarm dispatches that occurred between January 4, 2003, and December 31, 2005.

We defined the arrival time as the interval beginning with the time of dispatch and ending at the time of arrival on-scene by the first-responding engine and the technical rescue unit. This definition does not include the following time intervals that would occur as part of a fire department response to a confined space emergency: (1) recognition of an emergency condition by workers at the scene; (2) access to means of communication by workers at the scene; (3) transmission of information from the scene to an emergency dispatcher; and (4) access to the confined space entry port by the firefighter rescue team after arrival on scene.

We also gathered aggregate arrival time data for first-responding engine companies in six California municipalities for the period 2001 to 2004.<sup>(17)</sup> The identity of these municipalities was not released; their populations ranged from fewer than 100,000 to over 500,000.

### Fire Department Rescue Estimates

Arrival time data alone cannot capture the potential complications and delays that can occur in a confined space rescue during efforts to (1) assess and mitigate hazards in the space prior to entry; (2) prepare a rescue platform; (3) access, evaluate, stabilize, and extricate the worker; and (4) provide

advanced life support (ALS) intervention. To estimate time ranges for these four phases of a confined space rescue (assessment, rescue preparation, extrication, ALS intervention), we identified 28 urban fire departments in California that maintained both technical rescue and hazardous materials response units, in addition to standard engine and ladder companies. We distributed a closed-ended survey to senior officers responsible for technical rescue operations in each of these departments. Ten (36%) officers responded to the survey. Respondents were employed by 10 different departments in both northern and southern California and, on average, had 24 years of fire service experience. Their average number of years of experience in technical rescue and hazardous materials operations was 12 and 9, respectively.

We asked each participating fire officer to estimate the minimum and maximum times necessary for fire department crews to accomplish each of the four phases of a confined space rescue, differentiating between rescues that involved, and did not involve, hazardous materials. We defined hazardous materials in the survey as consisting of toxic atmospheres as well as oxygen-deficient atmospheres. Respondents were not asked to estimate arrival times to the scene or ambulance transport times from the scene to hospital-based medical services. The survey required about 15 min to complete.

## RESULTS

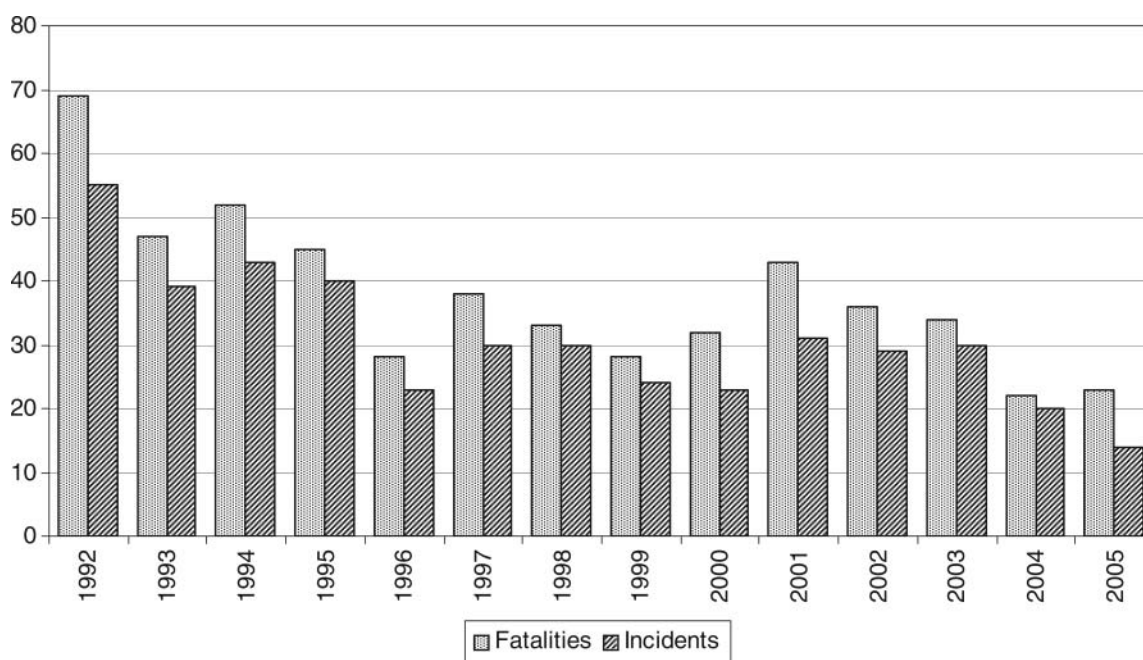
### Confined Space Fatality Statistics

In the CFOI dataset we identified 431 fatal confined space incidents that resulted from toxic and/or oxygen-deficient atmospheres and occurred during the period 1992 and 2005. These 431 incidents resulted in 530 fatalities (Figure 1). The case-level data showed that 87 (20%) incidents resulted in multiple fatalities. The 530 fatalities constituted 0.63% of the 84,446 all-cause occupational fatalities that occurred in the United States during this same period (Table I).<sup>(18)</sup>

The CFOI case-level data provided information sufficient to analyze 514 of the 530 total fatalities; of these 514 fatalities, 397 (77%) resulted from inhalation of a toxic substance, 95 (18%) resulted from oxygen deficiency, 22 (4%) were drownings, and 15 (3%) were classified as "other." Of the 397 involving inhalation of a substance, carbon monoxide accounted for 104 (26%) fatalities; hydrogen sulfide, 44 (11%) fatalities; and methane, 39 (10%) fatalities. The identity of the substance was not stated in 222 (52%) of the 431 incident reports. The case-level information did not provide sufficient information to assess the relative efficacy of on-site vs. fire department-based rescue teams.

Of the 87 (20%) incidents that resulted in multiple fatalities, 77 (90%) involved the deaths of two workers and 9 (10%) involved the deaths of three or more workers. Forty-seven (9%) of the total 530 fatalities were would-be rescuers.

Ninety-nine percent of the 530 fatality cases were male. Workers between the ages of 35 and 44 experienced the most fatalities, followed by those in the 25–34 age group (Table II). Ninety-one percent of companies that experienced



**FIGURE 1.** Annual U.S. occupational confined space fatalities (n = 530) and incidents (n = 431) due to oxygen-deficient and/or atmospheres, 1992 to 2005. (Reprinted with permission of the Center for Occupational and Environmental Health, University of California, Berkeley).

confined space fatality were privately owned. Incidents at companies with 10 employees or fewer comprised 33% of all fatalities; incidents at companies with 100 employees or

more comprised 20% of fatalities. The online supplemental file provides a breakdown of fatalities by U.S. region (Table S-I), occupational group (Table S-II), and industry sector (Table S-III).

**TABLE I. Annual All-Cause U.S. Occupational Fatalities Due to Toxic and/or Oxygen-Deficient Atmospheres, 1992 to 2005**

Year	Confined Space Fatalities <sup>A</sup>	Confined Space Incidents <sup>A</sup>	U.S. Occupational Fatalities <sup>B</sup>
1992	69	55	6217
1993	47	39	6331
1994	52	43	6632
1995	45	40	6275
1996	28	23	6202
1997	38	30	6238
1998	33	30	6055
1999	28	24	6054
2000	32	23	5920
2001	43	31	5915
2002	36	29	5534
2003	34	30	5575
2004	22	20	5764
2005	23	14	5734
Total	530	431	84,446

<sup>A</sup>Reference 16.

<sup>B</sup>Reference 18.

### Employer Practices

Table III provides a description by industry sector of the 21 companies that responded to the survey. Emergency response practices varied considerably among respondents. Twelve respondents (57%) reported that their company relied on the fire department in its emergency response plan, but only four (33%) of these respondents reported that the fire department had conducted a training exercise in the confined spaces at their facility. Six companies (29%) reported that they hired an off-site contractor for permit-required confined space work,

**TABLE II. U.S. Confined Space Fatalities by Age Group, 1992–2005 (n = 530)**

Age Group	Number of Fatalities	Percent (%)
16–19	15	3
20–24	57	11
25–34	147	28
35–44	157	30
45–54	94	18
55–64	44	8
65 and older	14	3

Note: Reference 16.

**TABLE III. Number of Survey Respondents by Industry Sector (n = 21)**

Industry Sector	Survey Respondents
Oil refining	1
Electronics	6
Aerospace	1
Energy	1
Food processing	1
Diversified manufacturing	2
Declined to state	9

and that the contractor provided its own on-site rescue team. Four companies (19%) reported that they maintained their own on-site rescue team for permit-required entries. Some companies reported using both the fire department and off-site contractors. Fourteen respondents expressed concerns about employee-based rescue teams, off-site contractors, and fire departments (Tables S-IV and S-V).

#### **Fire Department Arrival Times and Rescue Estimates**

##### *San Francisco (SF) and San Diego (SD)*

Arrival times varied between first-responding engines and technical rescue units; both of these units, and others, are required at a confined space emergency. Summary data are shown in Table IV. The median (range) arrival times for SF showed that 50% of callers waited  $\leq 4.75$  min (range: 0.33–40.75 min) for an engine and  $\leq 7.5$  min (range: 0.5–120.5 min) for a technical rescue unit. In SD, 50% of callers waited  $\leq 6.5$  min (range: 1.9–31.5 min) and  $\leq 7.25$  min (range: 0.06–60.33 min) for an engine and rescue unit, respectively.

**TABLE IV. Response Times (mins:secs) for First-Responding Engine Companies and Technical Rescue Units for San Francisco, California (n = 1495, Jan 2003–Feb 2005) and San Diego, California (n = 759, Jan 2003–Dec 2005)**

	San Francisco		San Diego	
	Engine	Rescue Unit	Engine	Rescue Unit
n	1495	1495	759	759
Mean	5:15	9:24	7:17	9:11
Median	4:44	7:30	6:29	7:14
Mode	5:00	4:50	5:56	4:06
SD	2:36	7:52	3:14	7:03
Min	0:20	0:33	1:55	0:04
Max	40:42	2:37:57	31:39	1:21:43
90th perc.	7:37	15:46	10:53	18:30
CV	0.4952	0.8370	0.4454	0.7673
Skewness	4.96	6.80	2.32	2.43

Ten percent of SF callers waited  $\geq 7.5$  min for an engine and  $\geq 15.75$  min for a rescue unit; 10% of SD callers waited  $\geq 11$  min and  $\geq 18.5$  min for an engine and rescue unit, respectively. Because of greater travel distances and fewer on-duty crews, arrival times in rural counties would be expected to be considerably longer for both first-responding engines and technical rescue units.

In both SF and SD, the greater range in arrival times for the technical rescue units occurs because these units are responsible for larger geographic areas compared with engines, which are more numerous and distributed more evenly throughout a department's jurisdiction. For the same reason, the range in arrival times of hazardous materials units would be expected to exceed that of both engines and technical rescue units. Many rural areas do not staff technical rescue or hazardous materials units; in those rural areas that do, the range of arrival times for these units would likely be much higher compared with first-responding engines, for the reasons noted above.

##### *Six California Cities*

Arrival times for first-responding engines varied considerably among the six cities. Table V shows arrival times during the period 2001 to 2004 as a percentage of total calls in which an engine arrived on scene in 5 min or less, as measured from the time of dispatch. First-responding engines arrived in 5 min or less between 59% and 78% of the time. For comparison, in SF and SD, 56% and 22% of first-responding engines, respectively, arrived within 5 min from the time of dispatch. Arrival times for first-responding engines in each of the six cities were fairly consistent over time, fluctuating within each city  $< 10\%$  over the period 2001–2004.

##### *Fire Department Rescue Estimates*

Senior fire officers provided estimated time ranges—minimum and maximum times—for fire department crews to complete the four phases of a confined space rescue (assessment, rescue preparation, extrication, ALS intervention). The median time range required to complete all four phases was 48 to 123 min. When hazardous materials were present, the median range increased to 70 and 173 min, respectively. Table VI lists the range, median, and mean time estimates for the four primary operations of a confined space rescue.

**TABLE V. Response Times for First-Responding Engines in Six California Cities, 2001–2004**

Population in 2004	Arrival in $\leq 5$ min (%)
$> 500,000$	59
400,000–500,000	69
400,000–500,000	78
100,000–200,000	50
50,000–100,000	77
50,000–100,000	70

Note: Reference 17.

**TABLE VI. Median (Mean) Confined Space Rescue Times in Minutes for Four Tasks as Estimated by Fire Department Technical Rescue Officers (n = 10)**

	Hazardous Materials			
	Present		Not Present	
	Minimum	Maximum	Minimum	Maximum
Assessment	15.0 (14.5)	30.0 (41.5)	7.5 (8.4)	17.5 (21.8)
Rescue preparation	20.0 (25.5)	52.5 (69.5)	15.0 (18.3)	35.0 (43.5)
Extrication	20.0 (20.5)	60.0 (63.5)	15.0 (16.7)	52.5 (47.5)
Advanced life support	15.0 (18.0)	30.0 (36.0)	10.0 (16.5)	17.5 (27.5)
Total	70.0 (78.5)	172.5 (210.5)	47.5 (59.9)	122.5 (140.3)

## DISCUSSION

Confined space incidents represent a small but continuing source of fatal occupational injuries in the United States. Without an appropriate denominator, and lacking fatality data prior to 1992, it is not possible to assess the trend in these data or the potential effect of the Standard. The data show that 9% of fatalities were rescuers, which is consistent with previous findings of rescuer fatalities in confined space incidents involving toxic atmospheres among U.S. construction workers.<sup>(19)</sup> Twenty percent of fatalities occurred in the construction industry, for which there is no federal confined space standard (Table S-III). Because the CFOI dataset is limited to confirmed fatalities, these results most likely do not capture the full extent of non-fatal worker injuries, acute and chronic illnesses, or near misses occurring in U.S. confined spaces.<sup>(20–23)</sup>

Although the number of employers surveyed was small, results suggest that a sizeable portion (57%) of employers may be deferring to public fire departments to meet their permit-required confined space emergency response requirements. It is likely that dependence on the fire department would be greater among small and medium-sized enterprises. There is a need for additional research to assess confined space emergency response practices among employers, particularly since the introduction of the 1998 emergency response amendments to the Standard.

The fire department arrival time data and rescue time estimates could help inform employers about the nature of fire department operations and the role of on-site confined space rescue teams. The rescue time estimates reported by fire officers illustrate that (1) a confined space rescue requires a substantial commitment of fire department equipment and personnel; (2) the time and resources necessary to effect a rescue increase substantially when hazardous materials are involved in the incident; and (3) fire departments are usually not able to effect a rescue in a timely manner if a life-threatening emergency occurs during a confined space entry. Because rescue estimates were drawn from a small, convenience sample of fire officers located in 10 California cities, and in light of ongoing concerns over near-miss events among firefighters at confined space incidents, these findings warrant further investigation.<sup>(24)</sup>

To meet their requirements under the Standard and to plan appropriately for permit-required confined space entries, it is useful for employers to understand basic fire department operations. Online supplemental Figure S-1 describes the roles of fire department equipment and personnel that would likely be involved in a confined space rescue.

Arrival time data illustrate that if a life-threatening emergency occurs during a confined space entry, a timely rescue can only be achieved by a qualified, on-site rescue team stationed at the entrance to the space. Death occurs within minutes if cerebral oxygenation is compromised, yet survival rates have improved when cardiopulmonary resuscitation (CPR) and defibrillation occur within 3 to 5 min of arrest, followed by ALS intervention within 8 to 12 min.<sup>(25)</sup> Early CPR and defibrillation buys time by maintaining some amount of circulation to vital organs during cardiac arrest; it is only effective, however, if subsequent ALS intervention occurs within the 8- to 12-min window. A properly trained and equipped on-site rescue team should be capable of accessing and extricating a worker and, if necessary, initiating CPR and defibrillation within 3 to 5 min. The fire department arrival time data illustrate that in urban areas, the first-responding engine would likely arrive within 8 to 12 min. In most urban areas in the United States, this unit would be staffed by at least one firefighter-paramedic who could initiate ALS intervention. In this way, the fire department can serve as an effective adjunct to the employer's on-site rescue team.

Rescue time estimates made by fire officers show that a worker who experiences cardiac arrest, deprivation of cerebral oxygen, or some other highly time-critical, life-threatening emergency during a confined space entry will almost certainly die if the employer's emergency response plan relies solely on the fire department for rescue services. First-responding firefighters are not trained or equipped, by themselves, to effect a confined space rescue, and the technical rescue and hazardous materials units capable of doing so will likely arrive too late if they are serving as the employer's primary means of rescue.

Further analysis of CFOI and other data is needed to (1) assess the trend in confined space fatal injuries during the period 8–10 years prior to the OSHA Standard and up to



the present; (2) assess the prevalence of non-fatal injuries and near-miss confined spaces incidents in the United States; and (3) evaluate the performance of on-site rescue teams vs. fire departments in confined space fatal incidents, near misses, and successful rescues.

## CONCLUSIONS AND RECOMMENDATIONS

The great majority of occupational injuries and illnesses can be prevented by incorporating worker health and safety considerations into the design process and by correcting design failures in existing systems. Confined space entry is no exception. At the same time, however, even with the best design features in place, employers are required to implement a confined space emergency response plan for permit-required spaces that matches the timeliness and capacity of the response with the nature of the hazards in the space.

This study presents evidence suggesting that a sizeable portion of employers may be relying on public fire departments to meet their confined space emergency response requirements under the OSHA Standard. This is not surprising considering the costs, training requirements, and specialized equipment required to organize and maintain a confined space rescue team, along with possible misperceptions among employers about the response practices and capacities of fire departments. Under these circumstances, employers—especially those in small and medium-sized enterprises—might be inclined to defer to the fire department in seeking to meet their emergency response requirements. The study points out, however, that first-responding firefighters are not trained or equipped, on their own, to effect a confined space rescue, especially when hazardous materials are present, and the technical rescue and hazardous materials units capable of doing so will likely arrive too late if they are serving as the employer's primary means of rescue.

While additional research will further elucidate the confined space emergency response practices of both employers and fire departments, the study findings may be sufficient to prompt an assessment of employer confined space emergency response practices under the federal OSHA Standard and state OSHA plans.

This study illustrates that it is not consistent with the federal OSHA Standard, nor is it adequately protective of workers, for employers to rely on public fire departments for primary rescue services in their confined space emergency response plans. In the event of a confined space emergency, the appropriate role for public fire departments is to (1) provide on-scene technical support to a properly trained and equipped on-site entry rescue team; (2) provide ALS intervention following extrication by the on-site team; and (3) maintain ALS intervention during ambulance transportation to hospital-based medical services. In these ways, the fire department can play an essential and appropriate role in an employer's confined space emergency response plan.

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