PART I

CONFINED-SPACE-RELATED FATALITIES

OVERVIEW OF CONFINED-SPACE HAZARDS

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NIOSH defines a confined space as one which, by design, has limited openings for entry and exit; unfavorable natural ventilation which could contain or produce dangerous air contaminants, and is not intended for continuous employee occupancy.[6] Confined spaces include but are not limited to storage tanks, compartments of ships, process vessels, pits, silos, vats, wells, sewers, digesters, degreasers, reaction vessels, boilers, ventilation and exhaust ducts, tunnels, underground utility vaults, and pipelines.[6] Confined spaces can be found in many industrial settings, from steel mills to paper mills, from shipyards to farms, and from public utilities to the construction industry. The hazards associated with confined spaces can cause serious injury and death to workers. Two major factors lead to fatal injuries in confined spaces: 1) failure to recognize and control the hazards associated with confined spaces, and 2) inadequate or incorrect emergency response. The emergency response is usually a spontaneous reaction to an emergency situation, and can lead to multiple fatalities.[8]

Confined spaces may be classified into two categories: 1) open-topped enclosures with depths which restrict the natural movement of air (e.g., degreasers, pits, selected types of tanks, and excavations), and 2) enclosures with limited openings for entry and exit (e.g., sewers, tanks, and silos). **Figure 1** illustrates examples of common types of confined spaces.

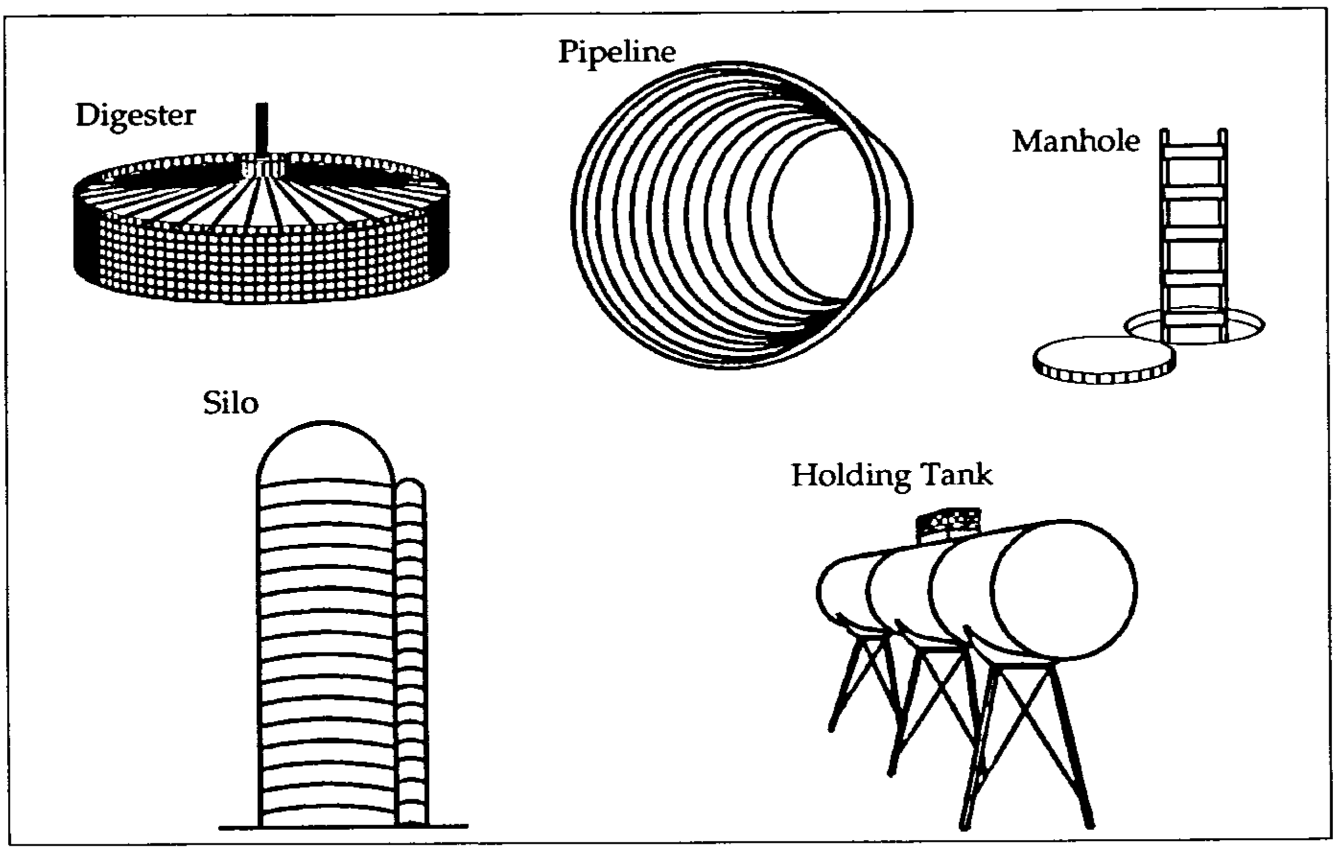

***Figure 1.** Types of Confined Spaces*

The hazards found in any confined space are determined by the material being stored or used, by the process taking place inside the space, and by the effects of the external environment. Worker entry into confined spaces may occur during construction activities or during frequent necessary functions such as inspection, repair, or maintenance. For purposes of discussion, we will separate hazards in confined spaces into atmospheric hazards and physical hazards.

ATMOSPHERIC HAZARDS

Oxygen deficiency

Oxygen deficiency occurs from chemical or biological reactions which displace or consume oxygen from a confined space. The consumption of oxygen takes place during combustion of flammable substances, as in welding, cutting, or brazing. A more subtle form of consumption of oxygen occurs during bacterial action, as in the fermentation process. Oxygen deficiency can result from bacterial action in excavations and manholes which are near garbage dumps, landfills, or swampy areas.[11] Oxygen may also be consumed during slow chemical reactions, as in the formation of rust on the exposed surface of metal tanks, vats, and ship holds.

Ambient air has an oxygen content of 21%. When the oxygen level drops below 17%, the first sign of hypoxia is a deterioration of night vision, which is usually not noticeable. Physiologic effects include increased breathing volume and accelerated heartbeat. Between 14% and 16% physiologic effects are increased breathing volume, accelerated heartbeat, poor muscular coordination, rapid fatigue, and intermittent respiration. Between 6% and 10%, the effects are nausea, vomiting, inability to perform, and unconsciousness. At concentrations less than 6%, there is rapid loss of consciousness, and death in minutes.

Oxygen displacement: Inert gases and simple asphyxiants

A simple asphyxiating atmosphere contains a gas or gases that are physiologically inert and which do not produce any ill effects on the body. However, in sufficient quantity, a simple asphyxiant will displace oxygen and may result in an atmosphere unable to support respiration. The ambient, or normal, atmosphere is composed of approximately 21% oxygen, 78% nitrogen, and 1% argon with small amounts of various other gases. For example, if 100% nitrogen—a non-toxic, colorless, odorless gas—is used to inert (displace oxygen in) a confined space, it will cause immediate collapse and death to the worker if the confined space is not adequately ventilated before worker entry. Other examples of simple asphyxiants which have claimed lives in confined spaces include carbon dioxide, argon, and helium.

Flammable atmospheres

A flammable atmosphere generally results from vaporization of flammable liquids, by-products of chemical reaction, enriched oxygen atmospheres, or concentrations of combustible dusts. Three components are necessary for an atmosphere to become flammable: fuel and oxygen in the proper mixture, and a source of ignition. The proper mixture of fuel and oxygen will vary from gas to gas within a fixed range and is referred to as the lower flammability limit (LFL) and upper flammability limit (UFL).

These terms are synonymous with the lower explosive limit (LEL) and upper explosive limit (UEL). For example, the explosive range for methane is between 5% and 15% in air.[12] Concentrations below 5% methane are below the explosive range, and concentrations above 15% are too rich to support combustion. If a confined space contains 27% methane and forced ventilation is started, the introduction of air into the confined space may dilute the methane in air, taking it into the explosive range.

Toxic gases

Toxic gases may be present in confined spaces because:

1. The manufacturing process uses toxic gases. For example, in producing polyvinyl chloride, hydrogen chloride is used, as well as vinyl chloride monomer.

2. There are biological or chemical processes occurring in the product stored in the confined space. For example, decomposing organic material in a tank or sump can liberate hydrogen sulfide.

3. The operation performed in the confined space can liberate a toxic gas. For example, welding can liberate oxides of nitrogen, ozone, and carbon monoxide.

Some toxic gases such as phosgene or carbon monoxide are particularly insidious because of their poor warning properties. Toxic gases which have been reported to cause death in workers in confined spaces include carbon monoxide, hydrogen cyanide, hydrogen sulfide, arsine, chlorine, oxides of nitrogen, and ammonia.[9]

Toxic gases may be evolved when acids are used for cleaning the interior of a confined space. For example, hydrochloric acid can react chemically with iron sulfide to produce hydrogen sulfide. Hydrogen sulfide is heavier than air and will settle out at the bottom of a confined space. Hydrogen sulfide is extremely toxic and exposure can cause paralysis of the olfactory system (making the victim unable to smell the gas), loss of reasoning, respiratory failure, unconsciousness, and death.[6,13]

Solvents

Hydrocarbon solvents are frequently used in industry as degreasing agents. These agents can cause unconsciousness by depressing the central nervous system.[14] Some chlorinated hydrocarbon solvents, such as chloroform, have been used as anesthetic agents. In addition, certain chlorinated or fluorinated hydrocarbon solvents are toxic to the heart[15] and have been associated with sudden death in confined spaces. The solvent methylene chloride can be toxic in confined spaces both because of its solvent properties and also because it is metabolized in the body to carbon monoxide.[16]

The National Institute for Occupational Safety and Health (NIOSH) developed a classification scheme for atmospheric hazards in confined spaces which is based on the oxygen content of the air, the flammability characteristics of gases or vapors, and the concentration of toxic substances that may be present in a confined space (**Table 1**).

Listing a particular confined space as class A, B, or C is determined by the most hazardous condition present. The usefulness of this classification is that it provides a framework upon which recommendations for work practices and rescue procedures can be made. A detailed listing of safe work practices and procedures for confined-space work is given in the NIOSH criteria document.[6]

Table 1. *Confined-Space Classification*[6]

CHARACTERISTICS		
CLASS A	**CLASS B**	**CLASS C**
Immediately dangerous to life	Dangerous, but not immediately life threatening	Potential hazard
OXYGEN		
CLASS A	**CLASS B**	**CLASS C**
16% or less *(122 mm Hg) or greater than 25% (190 mm Hg)	16.1% to 19.4% * (122-147 mm Hg), or 21.5% to 25% (163-190 mm Hg)	19.5%-21.4% * (148-163 mm Hg)
FLAMMABILITY CHARACTERISTICS		
CLASS A	**CLASS B**	**CLASS C**
20% or greater of lower flammable limit (LFL)	10-19% LFL	10% LFL or less
TOXICITY		
CLASS A	**CLASS B**	**CLASS C**
IDLH**	Greater than contamination level, referenced in 29 CFR Part 1910, Subpart Z (IDLH**)	Less than contamination level referenced in 29 CFR Part 1910 Subpart Z

* ***Based upon a total atmospheric pressure of 760 mm Hg (sea level)***
** ***Immediately Dangerous to Life or Health***

PHYSICAL HAZARDS

In addition to the atmospheric hazards in a confined space, physical hazards must also be addressed. Physical hazards cover the entire spectrum of hazardous energy and its control. These hazards include those associated with mechanical, electrical, and hydraulic energy; engulfment; communication problems; noise; and size of openings into the confined space.

Engulfment

Engulfment in loose materials is one of the leading causes of death from physical hazards in confined spaces. Engulfment and suffocation are hazards associated with storage bins, silos, and hoppers where grain, sand, gravel, or other loose material are stored, handled, or transferred. The behavior of such material is unpredictable, and entrapment and burial can occur in a matter of seconds. In some cases, material being drawn from the bottom of storage bins can cause the surface to act like quicksand. When a storage bin is emptied from the bottom, the flow of material forms a funnel-shaped path over the outlet. The rate of material flow increases toward the center of the funnel. During a typical unloading operation, the flow rate can become so great that once a worker is drawn into the flow path, escape is virtually impossible.

Loewer and Loewer reported that a typical flow rate for a bin unloading auger is 1000 bushels per hour. This is equivalent to 1350 cubic feet per hour or approximately 21 cubic feet per minute. A person 6 feet tall displaces about 7.5 cubic feet, assuming an average body diameter of 15 inches. From the time the auger starts, there would be perhaps 2 to 3 seconds to react. In 4 to 5 seconds a person could be trapped up to his knees, and in 22 seconds, completely covered in grain.[17]

A condition known as bridging can create additional hazardous situations. Bridging occurs when grain or other loose material clings to the sides of a container or vessel that is being emptied from below, allowing a hollow space to be created. The bridge of material over the space may collapse without warning, entrapping workers who are standing below or on top of the bridge and who are unaware that the surface is unstable. Bridging can occur in storage bins, silos, and hoppers that contain ground grains, soybean meal, or other meals, or other loose materials such as cement, limestone, coal, or sawdust. The diameter of the storage vessel and moisture content of the stored materials are factors that contribute to bridging.

Other physical hazards

The nature of confined-space work may make it difficult to separate the worker from hazardous forms of energy such as powered machinery, electrical energy, and hydraulic or pneumatic lines.

Examples of physical hazards often encountered in a confined space include the following:

1. Activation of electrical or mechanical equipment can cause injury to workers in a confined space. Therefore, it is essential to de-energize and lock-out all electrical circuits and physically disconnect mechanical equipment prior to any work in confined spaces.

2. Release of material through lines which are an integral part of the confined space pose a life-threatening hazard. All lines should be physically disconnected, blanked off, or should use a double block and bleed system.

3. Falling objects can pose a hazard in confined spaces, particularly in spaces which have topside openings for entry, through which tools and other objects may fall and strike a worker.

4. Extremely hot or cold temperatures can make work inside a confined space hazardous. If a confined space has been steam cleaned, for example, it should be allowed to cool before any entry is made.

5. Wet or slick surfaces can cause falls in confined spaces. In addition, wet surfaces can provide a grounding path and increase the hazard of electrocution in areas where electrical equipment, circuits, and tools are used.

6. Noise within confined spaces can be amplified because of the design and acoustic properties of the space. Excessive noise is not only harmful to the worker's hearing, but can also affect communication and cause shouted warnings to go unheard.

CONCLUSIONS

Confined spaces can be hazardous, and they can be hazardous in varied ways. Oftentimes the confined space will not appear to be hazardous; it may have been entered on prior occasions without incident, and may give no apparent sign of danger. At other times there may be ready indications of danger: the distinct odor of irritating or toxic atmospheres, the presence of arcing electrical equipment, continued mild shocks, or flowing grain or sand. By their nature, confined spaces concentrate hazards: atmospheric hazards, in that certain gases will displace breathable air, or that the confined space will allow the accumulation of toxic hazards or flammable or explosive atmospheres; and physical hazards, in that confined spaces limit the ability to avoid contact with electricity, moving mechanical components or machinery, or unstable substances. Recognition of the inherent capacity of these spaces to harbor hazardous agents is a significant element in any workplace hazard assessment. When confined spaces are recognized to be hazardous, provisions for minimizing the need for entry and for use of appropriate work practices and equipment can be made.

EPIDEMIOLOGY OF CONFINED-SPACE-RELATED FATALITIES

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The danger of work in confined spaces has been written about since Roman times, when the Emperor Trajan was noted to have sentenced criminals to clean sewers, an occupation considered one of the worst.[18] Agricola recorded that stagnant air in mines produced difficulty breathing, and that fires in mines soon brought death to those who worked there.[19] Alice Hamilton wrote that decomposing organic matter in vats, tanks, and manholes emitted hydrogen sulfide and cited several examples of how this had caused death from asphyxiation.[20] Asphyxiation at work in specific industries such as steel-making was studied early in this century as part of the Pittsburgh Survey.[21]

The NIOSH criteria document on confined spaces presented an analysis of 276 confined-space incidents, with 193 fatalities.[6] Atmospheric hazards accounted for 78 (40%) of the deaths. This report included a discussion of fatalities due to falls, explosions, fires, and contact with electrical energy which occurred in confined spaces.

A review of confined-space deaths investigated by NIOSH from 1983-1989 as part of the FACE program analyzed 88 deaths in 55 incidents.[10] Only 27% of the employers involved had any written confined-space-entry procedure. Only three of the 88 victims had received any training in confined-space entry.

In a study of asphyxiation and poisoning which was based on OSHA investigations conducted in 1984 through 1986, 188 deaths in confined spaces were identified: 42 were from mechanical hazards such as engulfment in loose materials, and 146 were from oxygen-deficient air or poisoning by gases or chemicals in confined spaces.[9] The 188 deaths made up 4% of fatalities investigated by OSHA during the 3 years. Not included in the confined-space category were 190 deaths from trench cave-ins which OSHA investigated. This study did not include electrocutions, or deaths from explosions which occurred in confined spaces. In 1989 OSHA proposed to establish safety requirements, including a permit system, for entry into confined spaces. OSHA stated that asphyxiation was the main hazard in confined spaces, and that atmospheric hazards were the leading cause of death. The California Department of Labor Statistics and Research reported that in 1981 through 1982, 21 of 1011 (2%) work-related deaths were confined-space-related.[22] For the period 1967 through 1977, OSHA researchers estimated that 5% of injuries in the shipbuilding industry involved confined spaces.[23] For 1979 through 1981, OSHA estimated that 174 fatalities per year occurred in confined spaces.[9]

Epidemiologic studies attempting to assess deaths in confined spaces have been hampered by the lack of data sources which specifically identify this type of fatality. A review of confined-space-related fatalities investigated by the NIOSH FACE program found that when the NIOSH investigation report was matched to death certificate information, none of the death certificates specifically stated that the incident had occurred in a "confined space."

There are epidemiologic data pertinent to deaths in confined spaces which focus on specific hazards or substances rather than on the confined-space environment. In the oil and gas industry, hydrogen sulfide (H_2S) is a particular hazard for workers in areas such as Texas, Oklahoma, and the Rocky Mountain states where crude oil is "sour" and contains considerable H_2S. A review of several sources of data on work-related injury in Alberta, Canada, reported 221 cases of poisoning by H_2S from 1969 through 1973, of which 14 (6%) were fatal injuries.[24] Most of the injuries occurred in enclosed spaces and were among oil and gas workers.

A study of workers overcome by solvents reported that fatal injuries occurred more frequently among young workers.[25] Deaths from solvents in confined spaces that were investigated by OSHA also occurred more often among younger workers than other types of confined-space events.

METHODS

NIOSH has assembled the National Traumatic Occupational Fatalities (NTOF) surveillance system consisting of all U.S. death certificates for 1980-1989 in which the "Injury at Work?" box on the death certificate was marked "Yes," the external cause of death was an injury or poisoning, and the victim was 16 years of age or older.[26] Causes of external injury are coded according to the International Classification of Disease, 9th revision.[27] Confined-space deaths cannot be identified from coded data. One of the advantages of NTOF over other sources of mortality data, however, is that, in addition to containing coded data on the causes of death, each record in the database also 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. This allows researchers to make computerized searches for certain words or phrases on death certificates. Because of this feature, the NTOF database can be used as a surveillance tool for counting deaths in silos, bins, vats, sewers, and other work locations likely to have been confined spaces.

Confined-space-related deaths were ascertained from NTOF using a two-step process. All deaths from certain external injury causes were first selected, and then each of these was individually reviewed to ascertain whether the fatality occurred in a confined space. All deaths in which the external cause of injury was asphyxiation (E911-913), poisoning (E850-858 or E860-869), and drowning (E910) were first selected for review. Each of these was then examined for mention of a confined space such as a vat, pit, bin, tank or silo. In addition, deaths caused by poisoning from gases such as methane, hydrogen sulfide, and sewer gas, and deaths resulting from engulfment in grain, were included if the location of injury was unspecified. Deaths from carbon monoxide (CO) poisoning were included only if the death certificate indicated that it occurred in a confined space. Deaths from CO poisoning in automobiles, garages, or repair shops were not considered confined-space-related deaths. Deaths from mine roof falls and mine cave-ins were also excluded. Deaths in confined spaces from electrical energy, explosions, machinery and other physical hazards, except for engulfment in loose materials, were not included because few death certificates for these types of fatalities included a description of the location of death sufficient to determine if it occurred in a confined space.

Deaths from trench cave-ins differ somewhat from other types of mechanical asphyxiation. According to OSHA, a trench or excavation which was 5 or more feet deep would be considered a confined space. Some reports have included trench cave-ins when counting confined-space fatalities,[22] while others have not. Deaths from trench cave-ins have some features in common with deaths caused by engulfment in loose materials such as grain or sand. Deaths from trench cave-in were not included in the case definition of a confined-space death for this technical report. However, they were tabulated separately to allow comparison with other studies.

Deaths from trench cave-ins were first selected by reviewing all deaths from asphyxiation (E911-E913) as described above for mention of a trench cave-in. In addition, a key word search for "trench," "cave-in," "excavation," and "ditch" was done for all other causes of death in the NTOF database, and these records were then reviewed for mention of a trench cave-in.

Confined-space deaths per 100,000 workers were calculated using employment data from the Bureau of the Census' County Business Patterns (CBP).[28] CBP is a census of workers based on payroll records. Because CBP data do not include employment data for government and agricultural workers, CBP data were supplemented with data on government employees from the Current Population Survey[29] and agricultural workers from the Census of Agriculture.[30]

Because the amount of detail provided on death certificates is variable, the number of confined-space and trench cave-in deaths identified in NTOF must be considered as a minimum number of deaths occurring under these circumstances. There were undoubtedly additional deaths which could not be identified because of a lack of detail on the death certificate. A detailed description of the methods and limitations of the NTOF surveillance system has been reported previously.[26]

RESULTS

NTOF Data

There were 585 separate fatal incidents in confined spaces for the 10-year period, claiming 670 victims. Seventy-two (12%) of the fatal incidents involved multiple victims. The distribution of multiple fatality incidents by the number of victims is shown in **Figure 2.**

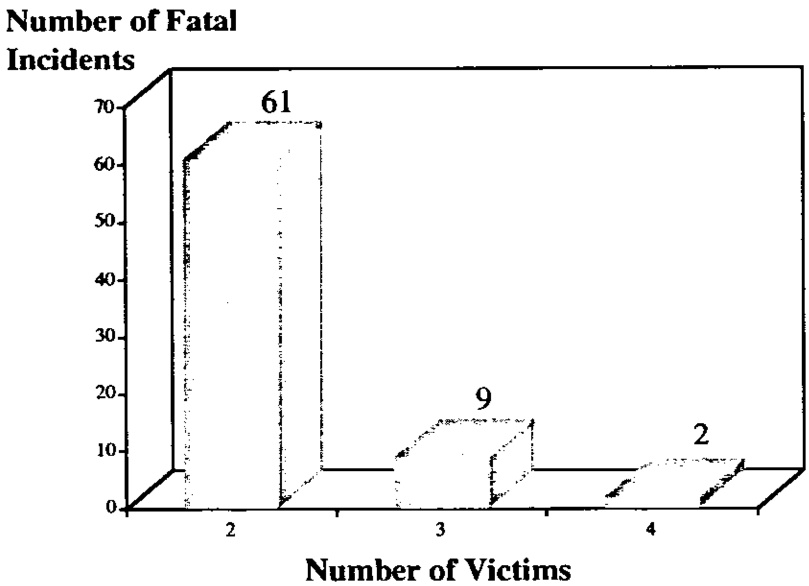

Figure 2. *Number of Victims in Multiple Fatality Confined-Space Incidents Identified by NTOF, 1980-1989 (N=72)*

Figure 3 depicts the frequency of confined-space deaths by year. There was an average of 67 deaths per year, with an average rate of 0.08 per 100,000 workers per year.

Victims ranged in age from 16 to 86 years. The average age (± standard error) was 35 ±19 years. Six hundred sixty victims were male and 10 were female. The race/ethnicity of the victims is shown in **Figure 4**.

The number of fatalities was highest in manufacturing (152), followed by agriculture (128), construction (90), transportation/communication/public utilities (77), and mining/oil/gas (63). Fatality rates are shown in **Figure 5**. Rates were highest in mining, oil, and gas with 0.69 deaths per 100,000 workers per year.

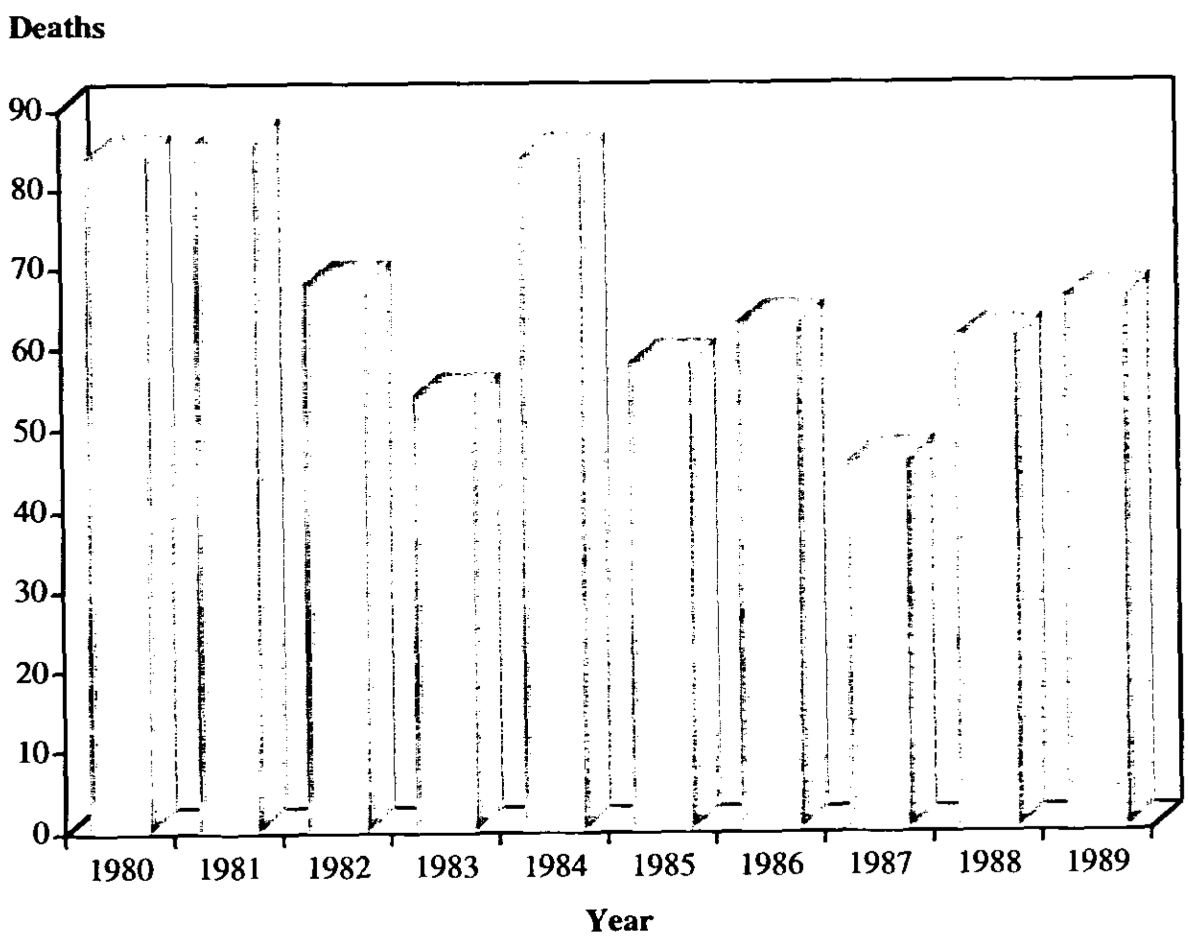

Figure 3. Deaths in Confined Spaces Identified by NTOF by Year, 1980 -1989 (N=670)

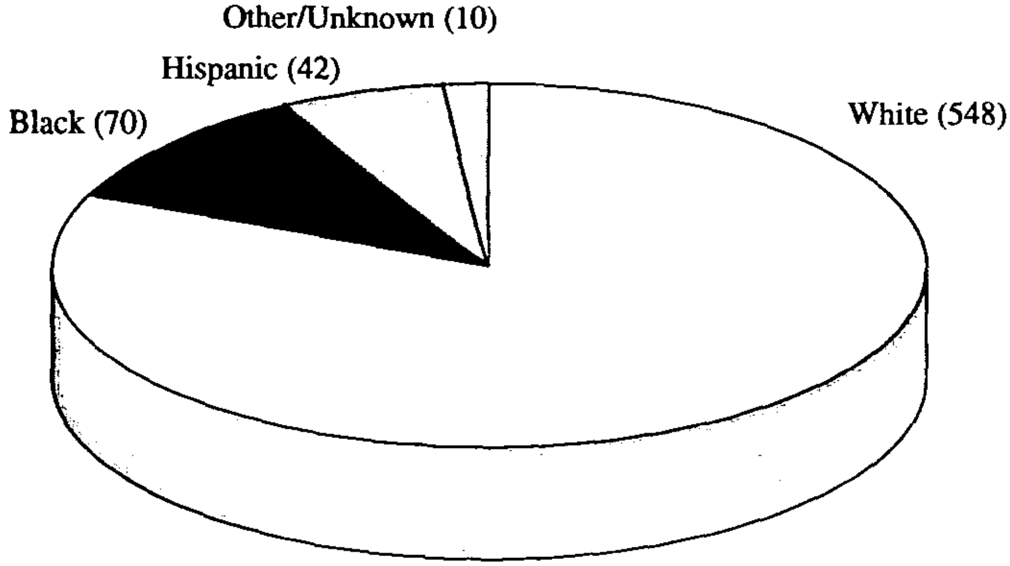

***Figure 4.** Race/Ethnicity Noted on Death Certificates for Deaths in Confined Spaces Identified by NTOF, 1980-1989 (N=670)*

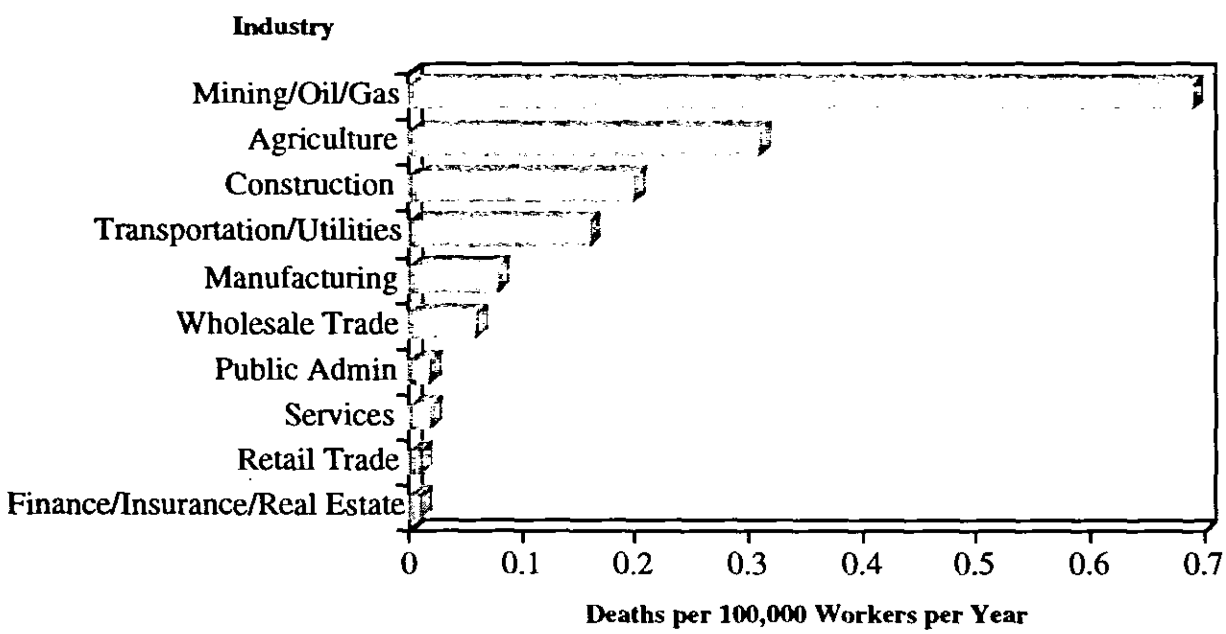

***Figure 5.** Rates of Confined-Space Deaths Identified by NTOF by Industry, 1980 -1989* (N=670)

The distribution of confined-space-related fatalities according to the external cause of death (E-Code) is shown in **Table 2**. Asphyxiations accounted for 305 deaths (45%), poisonings accounted for 274 deaths (41%), and drownings accounted for 91 deaths (14%). Within specific groupings of E-Codes, the proportion of deaths which could be determined to have occurred in confined spaces varied. For poisoning, NTOF reported 1018 deaths in 1980 through 1989, of which 274 (27%) were in confined spaces. For asphyxiations, NTOF reported 1218 fatalities, with 305 (25%) in confined spaces. Only 91 (10%) of 947 drownings were in confined spaces.

The circumstances of fatal injury in confined spaces are shown in **Figure 6**. Atmospheric conditions, such as presence of toxins, or lack of oxygen, contributed to over half of the confined-space-related deaths. Engulfments in loose materials were the causes of death in about one-third of the cases. The remaining 10% of the deaths were drownings and engulfments in other materials (i.e., sludge and manure), in which it was not possible to determine from the death certificate if atmospheric conditions contributed to the death.

Atmospheric conditions noted on the death certificate are shown in **Figure 7**. Hydrogen sulfide claimed 51 victims; methane, 38; inert gases, 32; and carbon monoxide, 25. Sewer gases were reported to be the cause of death for 25 victims. There were 62 deaths in which the death certificate stated that the victim was in an oxygen-deficient area, but did not specify that any particular toxin or gas was also present. For another 78 victims, the death certificate did not provide enough information to determine the type of atmospheric condition which contributed to the death.

Table 2. *E-Codes Assigned to Death Certificate Diagnoses for Deaths in Confined Spaces Identified by NTOF, 1980-1989 (N=670)*

GROUP	NUMBER (% of TOTAL)	
Poisoning (E850-858, E860-869)		274 (41%)
Drowning (E910)		91 (14%)
Asphyxiation (E911-913)		305 (45%)
(E911, 912-Obstruction of Respiratory Tract)	31	
(E913-Mechanical Suffocation)	274	
TOTAL		**670 (100%)**

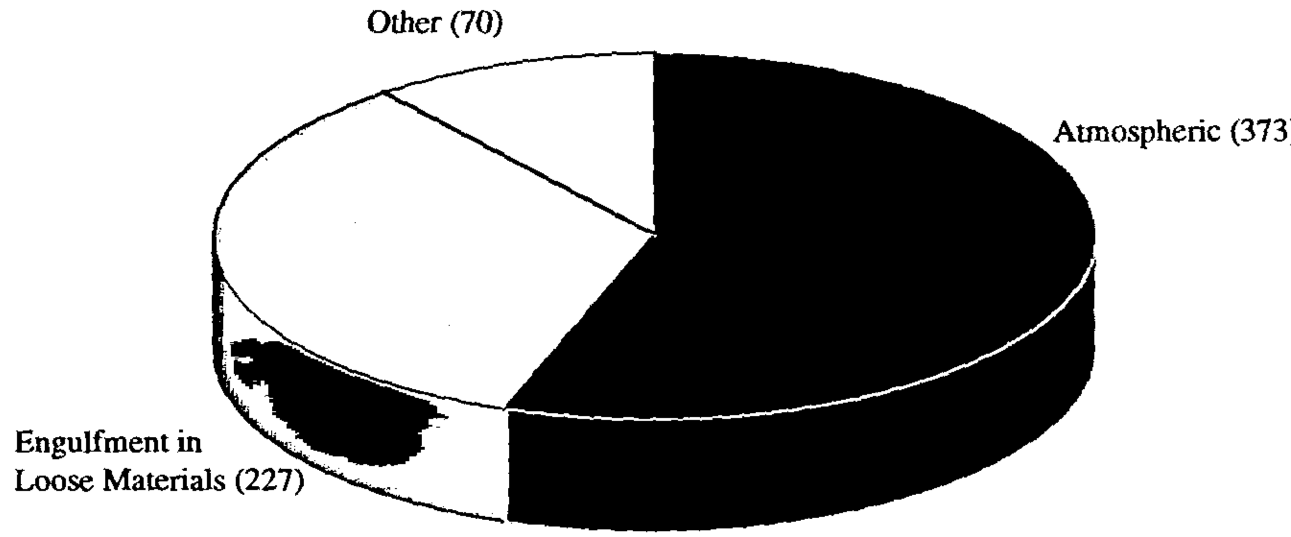

Figure 6. Circumstances Noted on Death Certificates for Deaths in Confined Spaces Identified by NTOF, 1980-1989 (N=670)

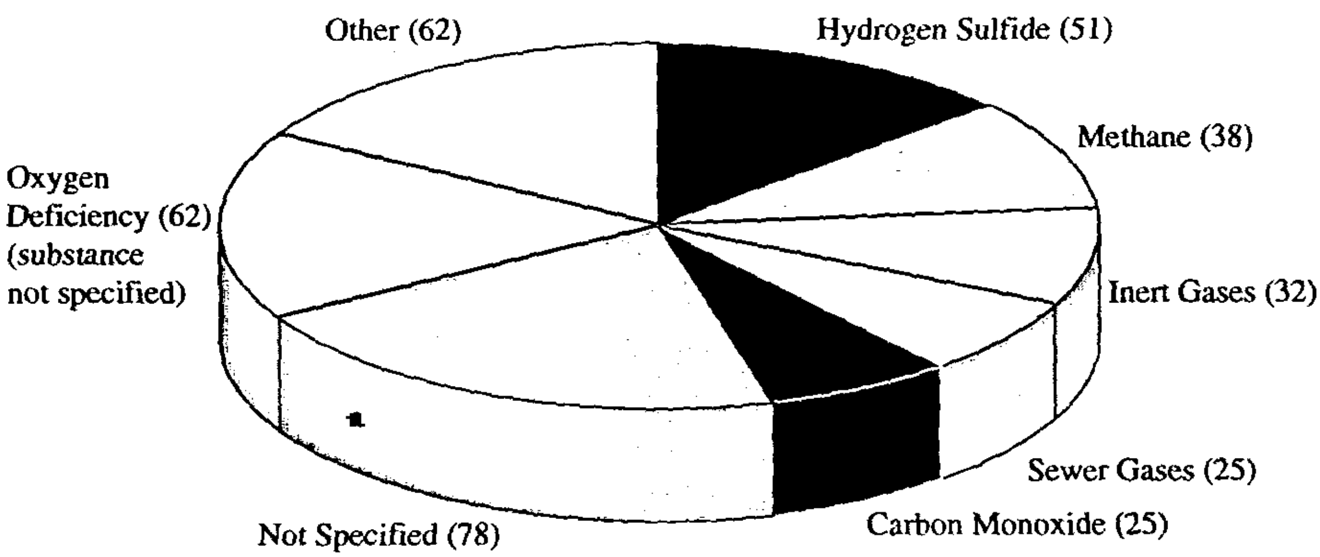

Figure 7. Atmospheric Conditions Noted on Death Certificates for Deaths in Confined Spaces Identified by NTOF, 1980 -1989 (N=373)

Tanks were the most common location of confined-space-related deaths from atmospheric conditions, accounting for 109 of the deaths. Sewers were the location in 61 of the deaths, pits in 32 deaths (16 in manure pits), and silos in 27 deaths. For 71 of the victims, the confined space was not reported on the death certificate but the deaths were assumed to have occurred in a confined space because of the type of gas (i.e., methane or hydrogen sulfide). Confined spaces reported in the remaining 75 deaths were diverse and included vats, wells, bins, pipes, and kilns.

Of the 373 confined-space-related deaths resulting from atmospheric conditions, 85 of the victims worked in the manufacturing sector, 59 in construction, 57 in the transportation/communications/public utilities sector, and 48 in agriculture/forestry/fishing. Industry was not listed on 35 of the death certificates.

As noted, mechanical asphyxiation by engulfment in loose materials claimed 227 lives (**Figure 8**). Entrapment in grain caused 124 deaths, and agricultural products other than grain, such as silage or fertilizer, caused 26 deaths. There were 25 deaths from engulfment in sand, and 22 deaths from engulfment in other building materials such as gravel, cement, and clay. Engulfment in sawdust claimed 11 lives. For 8 victims, the type of material was not denoted on the death certificate, but was assumed to be a loose material because of the location (i.e., silo or hopper).

Silos, bins, hoppers, and grain elevators were the locations of most fatal engulfments, accounting for 158 deaths. There were 13 deaths in pits and 17 in other locations. For 37 of the engulfment fatalities, the death was assumed to have occurred in a confined space even though location was not specified.

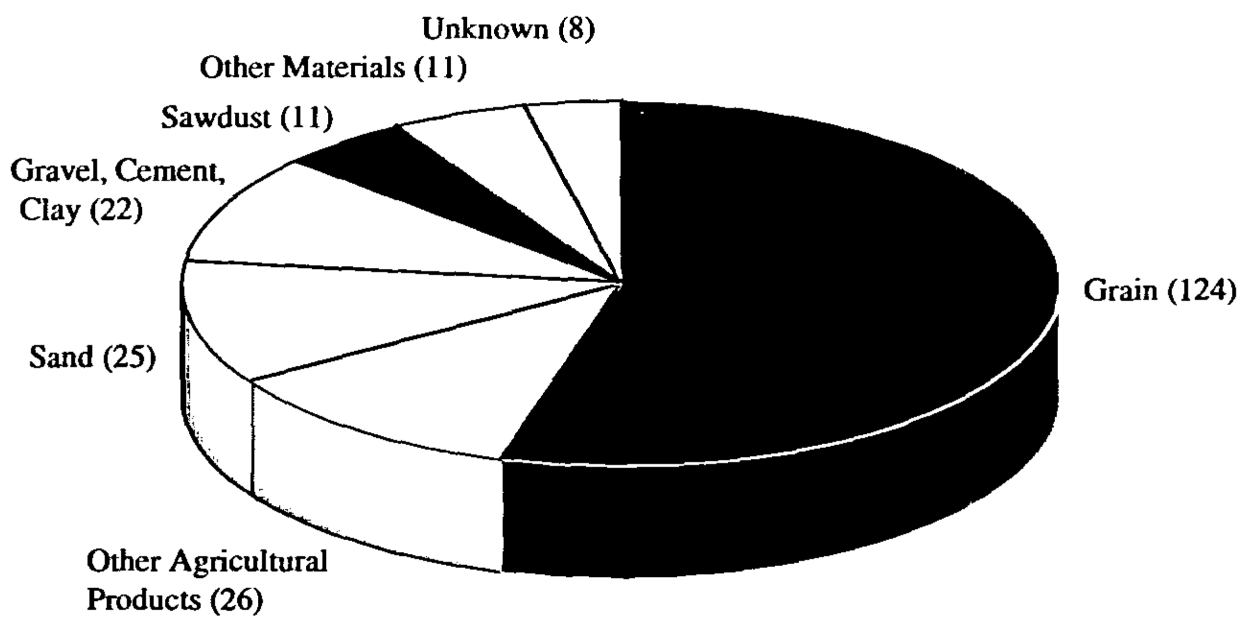

Figure 8. Loose Materials Involved in Mechanical Asphyxiations in Confined Spaces Identified by NTOF, 1980-1989 (N=227)

Nearly one-third (74) of the confined-space-related deaths from engulfment in loose materials were in the agriculture/forestry/fishing sector. Fifty-seven of the victims worked in the manufacturing sector, 24 in wholesale trade, and 24 in construction. There were less than 15 deaths in the remaining industry sectors. Industry could not be determined for 19 of the deaths resulting from engulfment in loose materials.

Trench Cave-ins

For the years 1980 through 1989, there were 606 fatal injuries due to trench cave-ins identified in NTOF, resulting in an average of 61 per year (**Figure 9**). The 606 deaths occurred in 572 incidents. The construction industry accounted for 468 deaths (77%); no other industry had more than 28 deaths (5%) during the 10-year period. Using U.S. employment data for the construction industry as the denominator, the average fatality rate for the construction industry was 1.05 per 100,000 workers per year.

The average victim age was 35 years, with a range of 16 to 72 years. Only one victim was female. Whites were the largest racial/ethnic group, with 454 deaths (75%), followed by blacks with 77 deaths (13%), Hispanics with 64 deaths (11%), and other/unknown with 11 deaths (1%).

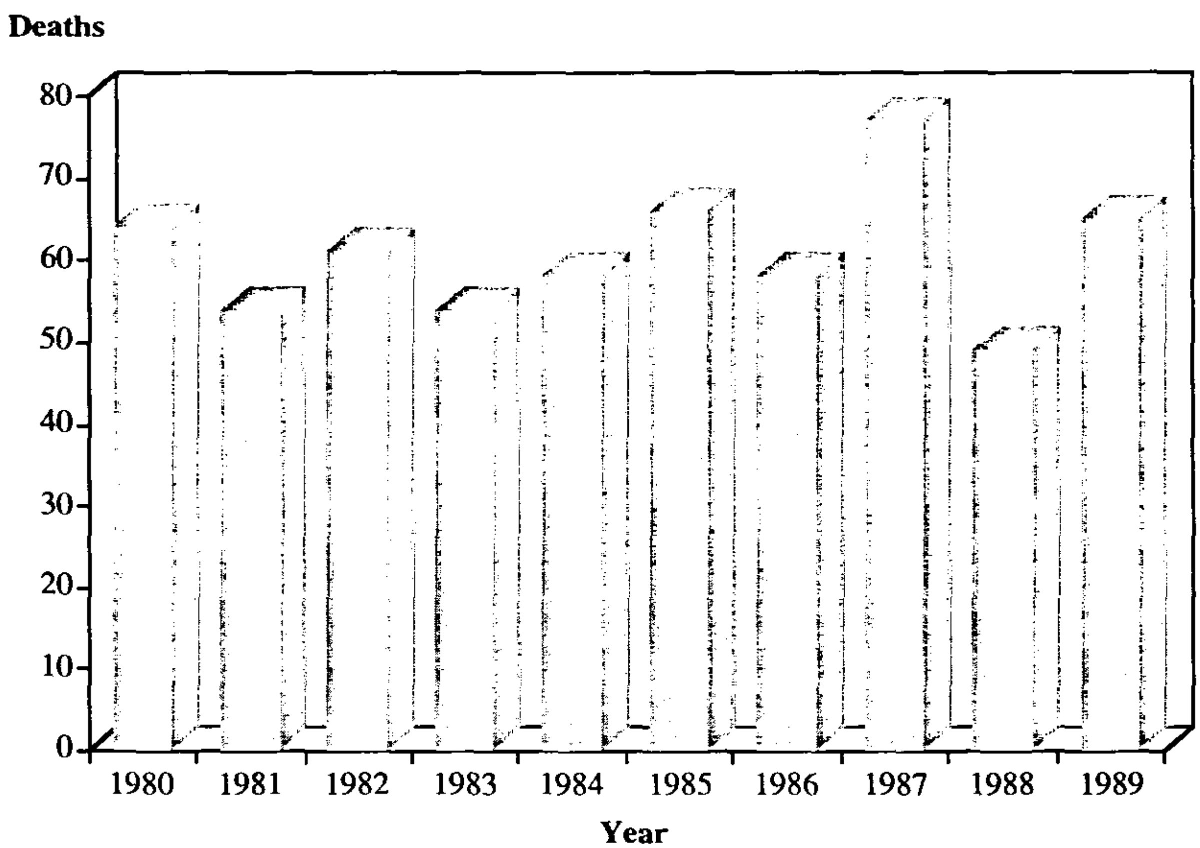

Figure 9. Trench Cave-in Deaths Identified by NTOF by Year, 1980-1989 (N=606)

FACE Investigations

During the period from December 1983 through September 1993, NIOSH conducted 70 onsite FACE field investigations of fatal work-related incidents in confined spaces. There were 109 deaths in the 70 incidents. Three industries accounted for over 62% of the incidents—construction (18, 26%), public administration (13, 19%) and manufacturing (12,17%). Description of these investigations by industry group, hazard type, and other factors is provided below. Case reports for each incident are provided in Part II of this report.

Incident-specific Information

Nearly two-thirds (72) of the confined-space-related fatalities occurred in the months of May through August and one-quarter (26) occurred in July. Forty-five of the incidents (64%) involved only 1 victim and 13 of these were in the construction industry. An additional 24% of the incidents involved at least two victims. The overall victim-to-incident ratio was 1.56:1, with the manufacturing and public administration industries experiencing the highest ratios; 1.75:1 and 1.69:1, respectively **(Table 3)**.

Eighty percent of the confined-space incidents had hazardous atmospheres (43% were oxygen-deficient, 29% were toxic, and 7% were flammable). The remaining 21% had some type of physical hazard present at the time of the incident **(Table 4)**. Fifty-six percent of the construction industry incidents and 46% of the public administration industry incidents involved oxygen-deficient atmospheres.

Forty-seven (67%) of the employers involved in confined-space incidents provided safety training to their workers. In only 28 (40%) of the 70 incidents did the employer have written safety procedures. None of the employers used a permit system for confined-space entry and warning signs were rarely used. A standby person was used in 26 (37%) of the 70 incidents. Industry differences on safety issues are provided in **Table 5**.

***Table 3.** Fatal Confined-Space Incidents Investigated by FACE, by Industry and Number of Victims per Incident, 1983-1993 (N=70)*

Industry	Number of Victims					Total
	One	Two	Three	Four	Five	
Agriculture/Forestry/Fishing	8	3	0	0	1	12
Construction	13	4	1	0	0	18
Manufacturing	8	1	2	0	1	12
Transportation/Utilities	6	3	0	0	0	9
Trade	0	1	0	0	0	1
Services	3	1	1	0	0	5
Public Administration	7	4	1	1	0	13
Total	45	17	5	1	2	70
(% of Total)	64.3	24.3	7.1	1.4	2.9	100.0

Table 4. Fatal Confined-Space Incidents Investigated by FACE, by Industry and Type of Hazard, 1983-1993 (N=70)

Industry	Hazardous Atmospheres			Physical Hazards	Total
	Oxygen Deficient	Toxic	Flammable		
Agriculture/Forestry/Fishing	5	2	0	5	12
Construction	10	5	0	3	18
Manufacturing	2	8	1	1	12
Transportation/Utilities	5	1	1	2	9
Trade	0	0	1	0	1
Services	2	0	1	2	5
Public Administration	6	4	1	2	13
Total	**30**	**20**	**5**	**15**	**70**
(% of Total)	**42.9**	**28.6**	**7.1**	**21.4**	**100.0**

Table 5. Fatal Confined-Space Incidents Investigated by FACE, by Industry and Training Procedures Implemented, 1983-1993*

Industry	Training Procedures Implemented				
	Training	Written Safety Procedures	Permit	Stand By	Warning Posted
Agriculture/Forestry/Fishing	1	0	0	4	4
Construction	11	8	0	4	0
Manufacturing	11	6	0	4	1
Transportation/Utilities	9	5	0	3	0
Trade	1	0	0	1	0
Services	2	1	0	2	0
Public Administration	12	8	0	8	0
Total	**47**	**28**	**0**	**26**	**5**
(% of Total)	**67.1**	**40**	**0.0**	**37.1**	**7.1**

*** One incident may involve more than one category**

Victim-specific Information

Thirty-seven percent of the victims were less than 30 years of age and two-thirds were less than 40 years of age (**Figure 10**). The average age of the victims in the FACE investigations was 36 years (range 15 to 73), which was similar to that found on death certificates from NTOF.

Fifty-eight (53%) of the victims worked for the private sector, 25(23%) were employed by state or local governments, and 26 (24%) were self-employed. Industry differences in employment are described in **Table 6**.

The most common reason for entry into a confined space was repair/maintenance, with 44 victims (40%), followed by rescue, with 39 (36%). Of the 39 victims whose reason for confined-space entry was to attempt to rescue someone, only four were emergency responders (i.e., police, fire, or public safety personnel). Tanks, vats/pits, digesters, and sewer manholes were the most frequently encountered types of confined spaces undergoing repair and maintenance or involved in rescue operations (**Table 7**).

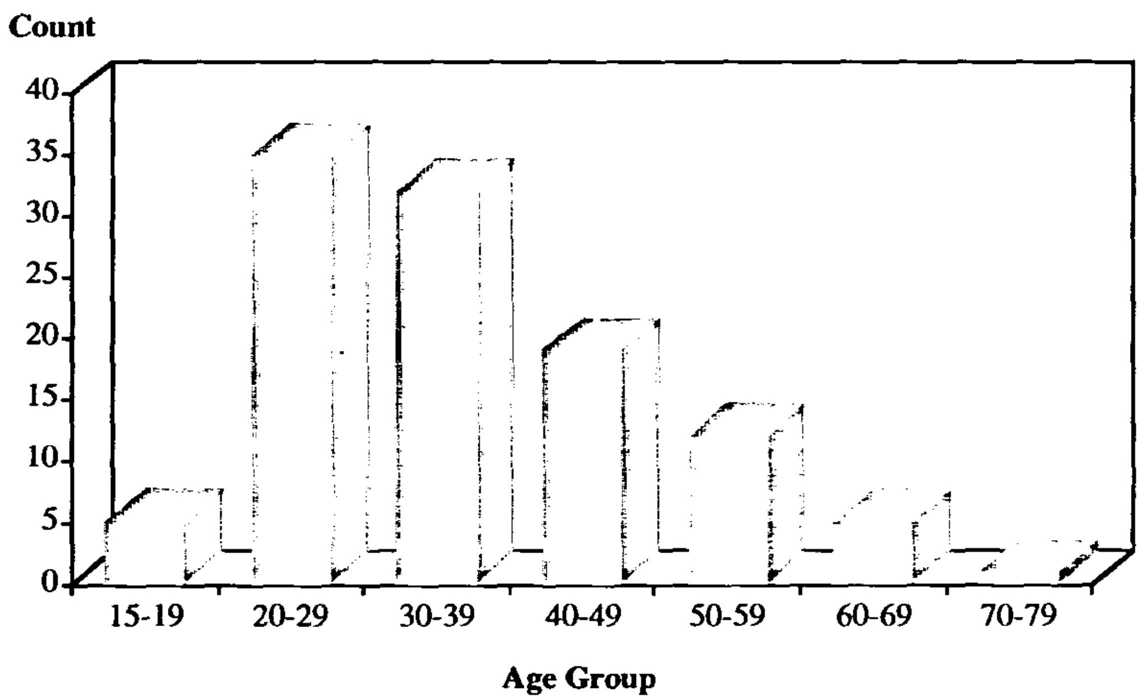

Figure 10. *Confined-Space-Related Fatalities Investigated by FACE, by Age Distribution of Victims, 1983-1993 (N=109)*

Table 6. Confined-Space-Related Fatalities Investigated by FACE, by Industry and Employment Sector of Victim, 1983-1993 (N=109)

Industry	Employment Sector			Total
	Private	Government	Self-Employed	
Agriculture/Forestry/Fishing	6	0	13	19
Construction	17	1	7	25
Manufacturing	21	0	0	21
Transportation/Utilities	10	2	0	12
Trade	2	0	0	2
Services	2	0	6	8
Public Administration	0	22	0	22
Total	58	25	26	109
(% of Total)	53.2	22.9	23.9	100.0

Table 7. Confined-Space-Related Fatalities Investigated by FACE, by Confined Space Type and Reason for Entry, 1983-1993 (N=109)

Type	Reason for Entry							Total
	Const.	Insp.	Repair/ Maint.	Rescue	Retrieve Object	Dislodge Material	Unknown	
Tank	0	5	14	11	1	0	0	31
Pipeline/Tunnel	1	0	1	1	0	0	0	3
Tanker Truck	0	0	3	0	0	0	0	3
Utility Vault	0	1	3	0	0	0	0	4
Vat/Pit Digester	0	0	10	14	2	0	0	26
Silo/Bin	0	1	0	0	0	5	1	7
Sewer Manhole	4	3	10	10	0	0	0	27
Well	0	1	3	3	1	0	0	8
Total	5	11	44	39	4	5	1	109
(% of Total)	4.6	10.1	40.4	35.8	3.6	4.6	0.9	100.0

Few of the victims had received formal safety training, as shown in **Figure 11**. Thirty-seven (34%) had received no training at all, while 45 (41%) had received on-the-job training only. Formal safety training in the form of classroom instruction or manuals was received by 21 victims (19%). Only six (6%) of the victims received safety training specifically oriented toward confined spaces.

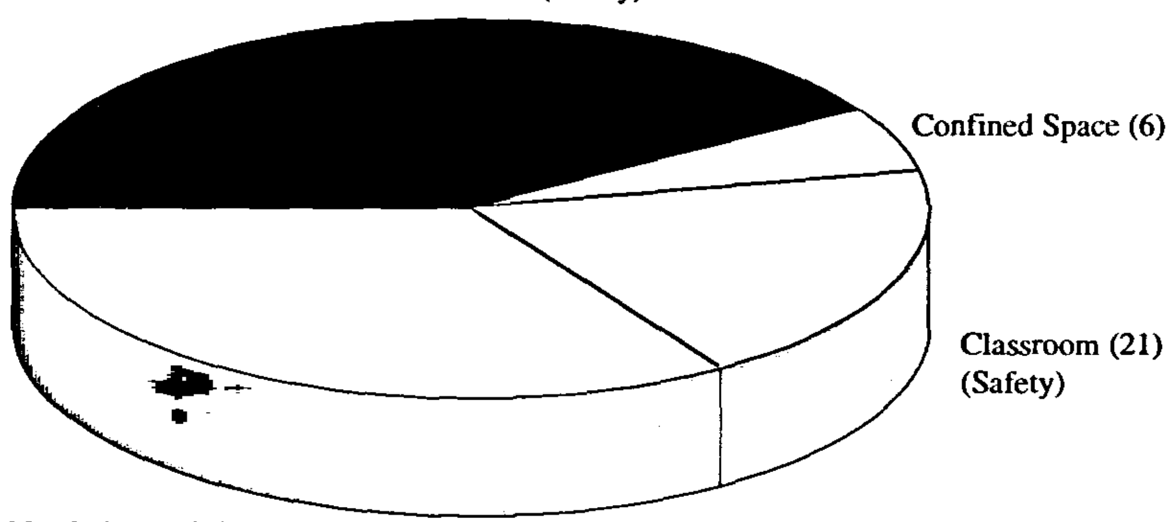

Figure 11. *Confined-Space-Related Fatalities Investigated by FACE, by Type of Training Received by Victim, 1983-1993 (N=109)*

DISCUSSION

The death certificate data from NTOF help to illustrate the magnitude of the confined-space problem nationally and allow a comparison of the risks in various industries. The information from FACE investigations allows for the identification of more detailed information on confined-space hazards, such as, the lack of a permit system, standby person, written warnings, and other measures needed for proper confined-space work. In addition, the FACE investigations provide information on fatalities among rescuers.

OSHA estimates that 238,853 establishments employing 12.2 million workers, have permit-required confined spaces.[31] These establishments employ approximately 1.6 million workers, including contractors, who enter approximately 4.8 million permit-required confined spaces annually. 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 transportation, construction, and shipbuilding industries.[32]

FACE reports and death certificates in NTOF identify many of the same hazards for confined-space-related fatalities. The largest numbers of deaths are in manufacturing, construction, and agriculture, with the highest fatality rates in the mining industry (including oil and gas) and in agriculture. Atmospheric hazards cause the largest number of confined-space-related deaths. However, if one were to include trench cave-ins as confined-space-related deaths, then mechanical hazards would be the largest group.

Confined-space-related deaths from mechanical asphyxiation occurred primarily in silos, bins, hoppers, and grain elevators. Those due to atmospheric hazards occurred in a variety of structures and settings; no single structure type was predominant. Sewers and manholes were involved in 61 (9%) of the 670 confined-space-related deaths identified from NTOF and 20 (18%) of the 109 deaths investigated by FACE. The atmospheric hazards in sewers and manholes range from toxic gases like hydrogen sulfide and carbon monoxide, to oxygen deficiency due to the action of bacteria in sewage or soil. Manholes in low-lying or swampy areas may present a particular problem in that the air inside may be depleted of oxygen only under conditions of low barometric pressure, when air is drawn out of the surrounding soil into the manhole.[33] These types of manholes may have been entered many times in the past without difficulty, lulling workers into a false sense of security.

There was a slight downward trend from 1980 to 1989 in confined-space-related deaths but not in deaths due to trench cave-in. All work-related deaths in the U.S. have shown a decline since the early 1980's.[26] The actual number of confined-space-related deaths is probably more than the 67 per year identified on death certificates, as many death certificates lack details as to the manner and location of death. In addition, the "Injury at Work" box is not marked "Yes" in all work-related deaths, and this means of identifying workplace deaths finds perhaps 81% of such deaths.[34]

Rescuers accounted for 39 of 109 deaths (36%) in confined spaces which were investigated by the FACE program. It is difficult to count the number of rescuer fatalities in the NTOF data because the death certificates often lacked detail concerning the victim's activity. However, it should be noted that in NTOF, 23% of confined-space deaths were in multiple-victim incidents. Whatever the true proportion of rescuer fatalities may be, these data indicate the need for recognition of confined-space hazards and the need for established rescue procedures prior to confined-space entry.

PREVENTION: ELEMENTS OF A CONFINED-SPACE PROGRAM

Ted A. Pettit, M.S., R.E.H.S.

The worker who is required to enter and work in a confined space may be exposed to a number of hazards, ranging from an oxygen-deficient or toxic atmosphere, to the release of hazardous energy (electrical/mechanical/hydraulic/chemical). Therefore, it is essential for employers to develop and implement a comprehensive, written confined-space-entry program. The following elements are recommended as a guide in developing a confined-space program.

A confined-space-entry program should include, but not be limited to, the following:

- identification of all confined spaces at the facility/operation
- posting a warning sign at the entrance of all confined spaces
- evaluation of hazards associated with each type of confined space
- a job safety analysis for each task to be performed in the confined space
- confined-space-entry procedures
  - initial plan for entry
  - assigned standby person(s)
  - communications between workers inside and standby
  - rescue procedures
  - specified work procedures within the confined space
- evaluation to determine if entry is necessary—can the work be performed from the outside of the confined space
- issuance of a confined-space-entry permit—this is an authorization and approval in writing that specifies the location and type of work to be done, and certifies that the space has been evaluated and tested by a qualified person and that all necessary protective measures have been taken to ensure the safety of the worker
- testing and monitoring the air quality in the confined space to ensure that
  - oxygen level is at least 19.5% by volume
  - flammable range is less than 10% of the LFL (lower flammable limit)
  - absence of all toxic air contaminants

- confined-space preparation
  - isolation/lockout/tagout
  - purging and ventilation
  - cleaning processes
  - requirements for special equipment and tools

- safety equipment and protective clothing to be used for confined-space entry
  - head protection
  - hearing protection
  - hand protection
  - foot protection
  - body protection
  - respiratory protection
  - safety belts
  - lifelines, harness
  - mechanical-lift device—tripod

- training of workers and supervisors in the selection and use of
  - safe entry procedures
  - respiratory protection
  - lifelines and retrieval systems
  - protective clothing

- training of employees in confined-space-rescue procedures

- conducting safety meetings to discuss confined-space safety

- availability and use of proper ventilation equipment

- monitoring the air quality while workers are in the space.

The NIOSH criteria document, *Working in Confined Spaces*,[6] was developed to provide the user a means for significantly reducing worker injury and death, associated with entering, working in, and exiting confined spaces. This document will provide more detailed information in developing a comprehensive confined-space-entry program. Additional information on confined-space safety is available from other NIOSH publications and journal articles.[2-10]

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