# Confined Space Fatalities in Virginia

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*To better understand the frequency and characteristics of occupational confined space fatalities in Virginia, we reviewed death certificates, workers' compensation files, a Virginia Occupational Safety and Health Administration listing, and medical examiner records for all 50 fatalities (41 accidents) reported during 1979 to 1986. All fatalities were identified in medical examiner records (50), more than in any other source. The majority of decedents were male craftsmen, operators, or laborers less than 50 years old (mean 38). Drug screens of the 43 decedents tested were negative, with the exception of 2 cases where blood alcohol was detected (≥0.06%). Approximately 5% of "at work" civilian deaths (excluding plane, train, and motor vehicle fatalities) were confined space related. Virginia resident death rates per million employees were highest for shipbuilding and repair facilities (23.2), local government (8.9), and manufacturing other than shipbuilding (5.4). Multiple fatalities occurred in 4 (10%) of the accidents, with 3 involving 2 fatalities each, and 1 accident involving 7 fatalities. Three fatalities (6%) were rescuers. Fifty nonfatal injuries of rescuers were known to have occurred in these accidents, 15 of co-workers and 35 of community rescue personnel (firefighters and rescue squad members). Approximately half the accidents occurred during the fourth quarter of the year and on a Thursday or Friday, and about one third occurred at night. The leading accident type was atmospheric condition, most commonly oxygen deficiency (33%) or the presence of carbon monoxide (20%). In 6 (40%) of the 15 accidents involving atmospheric condition, the toxic gas or oxygen deficiency was absent in the confined space at the time of entry. Confined space accidents in the shipbuilding industry occurred exclusively in ship compartments; those in the public sector occurred in manholes and ship compartments. Accidents in the construction, manufacturing, and service industries occurred in a variety of settings, including pressure vessels, stacks, boxcars, and machinery. Entry into any confined space should be viewed as potentially dangerous, and persons who may be required to enter a confined space, including community rescue personnel, should be trained in the specified precautions to be taken. Continuous or repeated monitoring of a confined space atmosphere, rather than preentry testing alone, is advisable when there is a potential for deterioration of the atmosphere during occupancy.*

The Office of Technology Assessment (OTA) has estimated there are around 6000 deaths annually (about 25 deaths per working day) due to occupational injuries.[1] A number of these fatalities occur when workers must enter and work in confined spaces. These spaces, found in essentially any industrial setting, include tanks, vats, pits, boilers, ship compartments, tunnels, utility vaults, ducts, silos, sewers, manholes, and septic tanks, to name a few. Workers usually enter these spaces irregularly and infrequently to clean, repair, inspect, or maintain the space.

The exact number of confined space related injuries and fatalities is unknown, partly because of current data collection methods.[2] There is no known data source that explicitly identifies confined space related cases on a regular basis. In addition, minor injuries that do not result in hospitalization often are not reported or investigated. One study, using two sources of fatality data, found that approximately 2% of occupational fatalities were confined space related.[3] A study of a sample of cases in the shipbuilding industry from 1967 through 1977 indicated that approximately 5% of all injuries involved confined spaces.[4]

Instances of confined space injuries and fatalities have been reported in the literature for at least the last 20 years. As a result of increased recognition of the hazards associated with confined space activities over the last decade, the National Institute for Occupational Safety and Health (NIOSH) has published criteria for a recommended standard,[5] issued an alert,[6] published a training resource manual,[2] published a workers' guide,[7] and included confined space related fatalities in its Fatal Accident Circumstances and Epidemiology (FACE) project. In addition, the American National Standards Institute (ANSI)

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published a voluntary consensus standard in 1977 dealing with confined spaces,[8] and a recently updated version has been published.[9] The Occupational Safety and Health Administration (OSHA) recently published a notice of proposed rulemaking concerning permit required confined spaces.[10] At least 15 states have standards or guidelines concerning confined spaces; Virginia is one of them.[11] However, confined space accidents continue to cause occupational deaths across the nation.

Accurate data are needed to assess the magnitude of the workplace confined space problem, to target prevention efforts, and to assess progress in controlling these confined space accidents. The current study was conducted to address these needs and to further identify those current data sources most useful for case ascertainment and best for obtaining additional information surrounding confined space incidents.

## Methods

All death certificates, excluding motor vehicle fatalities, coded "injury occurred while at work" were initially examined for the period 1985 to 1986. After reviewing these death certificates, subsequent work-related death certificates for preselected International Classification of Diseases (ICD) codes[12] were computer selected for the additional period 1979 to 1984. The following diagnosis codes were selected because they potentially could be related to confined space fatalities: 940–949, 980–989, 994.7, and external cause of injury codes E838, E844, E860–E864, E866–E869, E881, E883.1, E883.2, E883.9, E890.0, E890.3, E891.2, E891.3, E910.8, E910.9, E913.2–D913.9, E918, E919.8, E919.9, E921, E923.2–E923.9, and E924.

The 499 records selected by computer search were manually reviewed to identify fatalities that might be confined space related. Of these, 336 were eliminated as not related to confined spaces, 146 were considered potentially related but required confirmation from some other source, and 17 were considered definite confined space related fatalities (additional details were nevertheless obtained from workers' compensation and medical examiner records). Of the 146 potential cases, 14 were determined to be definite cases through subsequent review of 84 fatalities for which there was both a workers' compensation claim filed with the Industrial Commission of Virginia and medical examiner's records. Fifteen were determined to be definite cases through review of 62 fatalities for which there was a medical examiner record but no workers' compensation record available.

An additional 243 records were identified for further review from computerized workers' compensation claims filed with the Industrial Commission of Virginia from 1979 to 1986. This identification was based on a diagnosis of "injury not elsewhere classified" combined with an accident type of either "fall from an elevation," "radiation/caustics," "caught in/under," or "not elsewhere classified." Manual review of these records along with any available medical examiner record identified 22 confined space fatalities, all but 3 of which had been identified previously in the procedure noted above.

A review of the Virginia Occupational Safety and Health Administration's summary listing of 34 potential confined space fatalities uncovered 25 cases, all but one of which had been previously identified.

Each death certificate, employer's first report of injury, and medical examiner's record was reviewed for the following information, if available: age, gender, race, residence, time, date and place of fatal injury, occupation, industry, circumstances of fatal injury, cause of death, body part injured, confined space type, and accident type. Other descriptive information, such as personal protective equipment available or used, length of employment, time in present position, nonfatalities involved, and toxicological data was also noted. The sole source of toxicological data was the records of the Office of the Virginia Chief Medical Examiner. Newspaper accounts of these accidents were reviewed (when available) as part of the workers' compensation or medical examiner's files.

For the purpose of this study, a Virginia worker was defined as a Virginia resident or an out-of-state resident employed in Virginia. A confined space was defined as a workspace that by design has limited openings for entry and exit, is not intended for continuous human occupancy, and has either an unfavorable natural ventilation (that could contain or produce dangerous air contaminants) or unstable materials or a mechanical or electrical hazard that is exacerbated by the confined nature of the workspace. Accidents related to underground mining, tunneling operations, and trench cave-ins were excluded.

Industry class was coded into categories that corresponded to a four-digit Standard Industrial Classification (SIC) code.[13] Occupation was coded into categories that corresponded to the 13 major occupational groups in the 1980 Standard Occupational Classification of the US Office of Federal Statistical Policy and Standards.[14]

Data on total "at work" fatalities occurring in Virginia for a given year were obtained from unpublished information generated for the National Safety Council by the Virginia Department of Health's Center for Health Statistics. Annual fatality rates per million employed male workers were calculated using industry-specific employment estimates.[15] Because in-commuter employed population estimates were not available by industry, industry-specific fatality rates were estimated only for Virginia residents working in Virginia at time of death.

## Results

A total of 41 confined space accidents involving 50 fatalities was identified. Forty-six fatalities (92%) were recognized or suspected as confined space fatalities from the death certificates, an additional 6% were identified from workers' compensation files, and 2% were identified from a listing at the Virginia Occupational Safety

and Health Administration. Workers' compensation files were available for 27 cases. Medical examiner's records were available and confirmed the confined space related nature of all 50 cases. Nine fatalities involved out-of-state residents employed in Virginia.

## Distribution of Accidents

The distribution of confined space accidents by year of occurrence ranged from one event in 1978 to nine accidents each in 1982 and 1986, with a mean of 4.6 accidents per year (the 1978 fatality was not reported and entered into workers' compensation files until 1980). Multiple fatalities occurred in four (10%) of the accidents, with three involving two fatalities each, and one event involving seven fatalities.

The highest proportion of accidents (49%) occurred during the fourth quarter, October through December, with the remaining accidents being about evenly distributed over the remaining quarters. Most confined space accidents occurred on Thursdays (22%) and Fridays (27%), accounting for approximately half of all confined space accidents. Only one event (2%) occurred on Monday. One third (14) of the confined space accidents occurred at night; the remainder were about evenly divided between the morning (12) and the afternoon (14). The hour of the remaining fatal confined space event was not known. Fourteen accidents (34%) occurred in the coastal, eastern region of the state.

## Fatality Rates

When looking at total "at work" civilian deaths from 1979 through 1986, confined space deaths represent 5.1% (47/922) of the total occupational fatalities in Virginia, excluding plane, train, and motor vehicle fatalities. Using unpublished data from the files of the Virginia Department of Health's Center for Health Statistics, confined space fatalities constituted 0.9% (1/116) of mining deaths, 4.3% (3/70) of transportation/communications/utilities deaths, 6.6% (12/183) of construction fatalities, 9.0% (6/67) of shipbuilding fatalities, 10.2% (6/59) of services related fatalities, 11.7% (12/103) of manufacturing fatalities, 18.2% (2/11) of nonmilitary government fatalities, and 27.8% (5/18) of wholesale and retail trade fatalities.

## Case Characteristics

The median age of workers fatally injured in confined spaces was 38 years (mean 38 ±12). Almost one quarter (24%) were younger than 30 years old and only 12% were 50 years of age or older. Fatality rates for men were highest for those aged 30 to 39 (0.48/100,000) and 40 to 49 (0.69/100,000); rates for younger and older age groups were lower (Table 1). Forty-six (92%) of the fatalities occurred among men; 21 (42%) deaths occurred among blacks and the remainder among whites.

Most fatalities occurred among blue-collar workers; 48% were craftsmen, 40% were operators/laborers, and the remaining 12% were technicians, managers, or professionals. Seven fatalities occurred in workers attempting to unjam materials; five occurred in workers inspecting, ten repairing, and four cleaning.

Asphyxiation was the most common cause of death, accounting for 32% of the total (16 cases), followed by poisoning in another 30% (15 cases). Trauma accounted for 20% of the fatalities (10 cases), burns/scalds for 14% (7 cases), and electrocution and pneumonia for one case each (the pneumonia was apparently a delayed complication of the confined space accident).

Toxicological tests performed by the medical examiner typically consisted of analyses for alcohols, ketones, and drugs. Depending on the conditions surrounding the death, analyses also might have included carbon monoxide, volatile halogenated hydrocarbons, volatile hydrocarbons, argon, and carbon disulfide. In the 43 (86%) decedents tested, two cases had demonstrated blood alcohol levels (0.06% and 0.12% by weight).

## Characteristics of Confined Space Accidents

There were eight confined space accident types observed. The leading type was atmospheric condition, encompassing the greatest number of accidents as well as fatalities and nonfatalities. Fire or explosion, and contact with temperature extremes were the other common accident types.

An examination of confined space accidents due to atmospheric conditions revealed a variety of agents were involved in the 15 accidents (Table 2). Oxygen deficiency (environmental oxygen levels decreased below normal and no significant levels of other gases demonstrated) was the most common cause (33%) of such accidents, followed by carbon monoxide exposure (20%). In six (40%) of the 15 accidents involved atmospheric condition, the toxic gas or oxygen deficiency was

**TABLE 1**
Number of Deaths and Mortality Rates, by Age for Male Workers with Virginia Residence, Confined Space Fatalities, Virginia, 1979–1986

| Age (Y) | Deaths | Men Employed* | Mean Annual Mortality Rate† |
|---|---|---|---|
| 16–19 | 1 | 80,051 | 1.6 |
| 20–29 | 7 | 355,426 | 2.5 |
| 30–39 | 13 | 340,853 | 4.8 |
| 40–49 | 13 | 237,102 | 6.9 |
| 50–59 | 3 | 203,526 | 1.8 |
| ≥60 | 2 | 96,911 | 2.6 |
| Totals | 39 | 1,313,869 | 3.7 |

* Source: US Department of Commerce, Bureau of the Census. *1980 Census of the Population, Detailed Population Characteristics.* Virginia, Employed Males Age 16 Years or Older.

† Rate per 1,000,000 employees.

**TABLE 2**
Atmospheric Condition Types

| Agent | Accidents | Fatalities |
|---|---|---|
| Argon | 1 | 1 |
| Carbon monoxide | 3 | 3 |
| Freon | 1 | 1 |
| Gasoline | 1 | 1 |
| Hydrogen sulfide and carbon disulfide | 1 | 1 |
| Methane | 2 | 3 |
| Smoke | 1 | 2 |
| Oxygen deficiency* | 5 | 5 |
| Total | 15 | 17 |

* Environmental oxygen levels were decreased, but no significant levels of other chemicals were present.

absent in the confined space at the time of entry. It was generated or released by activity of the victim while in the space. In one instance, a worker unclogged a sewer system, which in turn released the toxic atmosphere that killed him. Of the 15 accidents due to atmospheric condition, five were reported to include rescue attempts. Of these, two resulted in the fatality of a potential rescuer. Three (6%) of the 50 fatalities identified in our study were rescuers.

Almost one third (29%) of confined space accidents and one quarter (24%) of fatalities occurred in ship compartments, with rooms/cupola accounting for another 17% of the fatal accidents, and two stack accidents providing a disproportionate fraction (18%) of the fatalities (Table 3). The remaining accidents were fairly evenly distributed among the other confined space types.

The 12 ship compartment deaths were predominantly due to asphyxiation (50%) or to trauma from falls (25%). Over half (7/12) these fatalities occurred to outside contractors who were typically called in for repair, inspection, or maintenance work. Eight of the 12 fatalities occurred aboard Navy vessels, with two occurring to Navy personnel, and six occurring to shipyard workers. In three of these cases, workers entered a compartment or void with a hypoxic atmosphere. In one case a shipyard employee was descending a ladder to inspect a void tank, in which the atmosphere was later shown to contain only 7% oxygen (preentry testing had not been performed). After descending about 4 feet, he became dizzy and fell 30 feet to the bottom of the void. He had no air-supplied respirator, and an appropriate safety harness or retrieval line was not attached. A rescuer was partially overcome.

Nine stack deaths all involved poisoning (smoke inhalation or carbon monoxide). Six trench, tunnel, or pit deaths were the result of asphyxiation (50%) or burn/scald (50%) from steamline ruptures. Three manhole deaths resulted from either asphyxiation (1) or trauma related to falls (2).

The sole cause of death in the four bin/boxcar confined space accidents was asphyxiation. Accidents involving entrapment by unstable materials typically occurred because a worker was attempting to unclog an accumulated deposit of material. These materials included sawdust, cement, and sand. In one instance, the worker was walking on top of the material in a boxcar, whose bottom doors had been opened, when the load suddenly broke loose and entrapped him. In another case, a worker deliberately stepped onto a fully loaded coal hopper to take coal samples when the hopper bottom opened, and he was drawn into the flow path.

Machinery deaths resulted from trauma. In three of the four fatalities, the application of a lockout/tagout procedure was clearly applicable. In each, the fatal injuries occurred when the worker was inside a piece of equipment that was then activated. In one instance, the worker had just finished cleaning a shredding machine when it was activated by another employee. This countermeasure also would have applied in one of the unstable material incidents, in a contact with temperature extremes case, and in an atmospheric condition case. In the temperature extremes case, a steam line was being repaired when it was inadvertently activated by another employee.

In five of the eight accidents related to fire/explosion, welding or the use of a cutting torch was involved. In one case the employee was using a cutting torch in a grain silo, when a flash fire and explosion occurred.

## Nonfatal Injuries

Through workers' compensation claims and newspaper reports, 57 workers were discovered to have sustained nonfatal injuries in eight accidents. These included 40 in accidents

**TABLE 3**
Confined Space Accidents and Fatalities by Industry of Employer and Confined Space

| Industry | Type of Space | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Bin or Boxcar | Machinery | Manhole | Room or Cupola | Ship's Hold | Silo | Stack | Tank or Pressure Vessel | Trench, Tunnel, or Pit |
| Agriculture | | | | | 1/1* | | | | |
| Construction | | | | 2/2 | 1/1 | | 1/7 | | 1/2 |
| Manufacturing† | 3/3 | 1/1 | | 2/2 | | 1/1 | 1/2 | 3/3 | |
| Shipbuilding | | | | | 6/6 | | | | |
| Mining | 1/1 | | | | | | | | |
| Public administration | | | 2/2 | | 2/2 | | | | |
| Retail trade | | | | 2/2 | | | | | |
| Services | | 1/1 | 1/1 | 1/1 | 1/1 | | | | 1/2 |
| Transportation, communication, and utilities | | 1/1 | | | | | | | 2/2 |
| Wholesale trade | | 1/1 | | | 1/1 | 1/1 | | | |
| Totals | 4/4 | 4/4 | 3/3 | 7/7 | 12/12 | 2/2 | 2/9 | 3/3 | 4/6 |

* First number denotes accidents; second number denotes fatalities.
† Except shipbuilding.

due to atmospheric condition, five in accidents involving temperature extremes, and 12 in accidents caused by fire or explosion. Fifteen of these nonfatalities were fellow workers who attempted to assist the index case. Thirty-five were rescue personnel (firefighters and rescue squad members) who were attempting to remove the index case and/or who were fighting an ensuing fire. Thirty-three of these suffered smoke inhalation and heat exhaustion in a single event while attempting index case removal from a foundry smokestack. Seven nonfatalities were workers who were present in the confined space and were directly affected along with the fatally injured workers.

## Characteristics of Industrial Accidents

Confined space accidents and fatalities most commonly involved shipbuilding, other manufacturing industries, construction, and service industries (Table 3). Men employed in shipbuilding and repair facilities had by far the greatest fatality rate, 23.2 per million employees per year, followed by local government employees (involved in sewer accidents in each case), 8.9 per million employees per year (Table 4). Both local government employees were involved in sewer accidents.

Confined space accidents in the construction industry were predominantly atmospheric condition and fire/explosion types (Table 5). Accidents in manufacturing industries other than shipbuilding were mainly due to atmospheric condition and unstable materials. Manufacturing industries, including food and kindred products (SIC 20), tobacco (SIC 21), lumber and wood (SIC 24), furniture and fixtures (SIC 25), chemical and allied products (SIC 28), stone, clay, glass, and concrete (SIC 32), and primary metals industries (SIC 33), involved the widest variety of accident types. Shipbuilding accidents (as in the construction industry) were mainly due to atmospheric condition and fire/explosion. Nonmanufacturing industries (public administration, retail trade, wholesale trade, and services) involved 14 accidents (34%), 15 fatalities (26%), and were most fre-

**TABLE 4**
Number of Deaths and Mortality Rates, by Industry* for Male Workers with Virginia Residence, Confined Space Fatalities, Virginia, 1979 to 1986

| Industry | Deaths | Males Employed† | Mean Annual Mortality Rate‡ |
|---|---|---|---|
| Mining | 1 | 24,489 | 5.1 |
| Construction | 5 | 153,901 | 4.1 |
| Manufacturing§ | 11 | 254,564 | 5.4 |
| Shipbuilding | 6 | 32,263 | 23.2 |
| Transportation‖ | 3 | 117,922 | 3.2 |
| Trade | 5 | 228,926 | 2.7 |
| Services | 6 | 255,116 | 2.9 |
| Local government | 2 | 27,935 | 8.9 |
| Totals | 39 | 1,095,116 | 4.5 |

* Employer's Industrial Classification.
† Source: US Department of Commerce, Bureau of the Census. *1980 Census of the Population, Detailed Population Characteristics.* Virginia, Employed Males Age 16 Years or Older.
‡ Rate per 1,000,000 employees.
§ Except shipbuilding.
‖ Transportation, communication, and utilities.

**TABLE 5**
Confined Space Accidents and Fatalities by Industry of Employer and Accident

| Industry | Type of Accident | | | | | | |
|---|---|---|---|---|---|---|---|
| | Atmospheric | Caught in | Temperature | Electrocution | Falls | Fire or Explosion | Unstable Material* |
| Agriculture | | | | | | 1/1† | |
| Construction | 2/3 | | | 1/1 | | 2/8 | |
| Manufacturing‡ | 4/5 | 1/1 | | | 1/1 | 1/1 | 4/4 |
| Shipbuilding | 2/2 | | 1/1 | | | 3/3 | |
| Mining | 1/1 | | | | | | 1/1 |
| Public administration | 1/1 | | 1/1 | | 2/2 | | |
| Retail trade | 2/2 | | | | | | |
| Services | 2/2 | 1/1 | 1/2 | | 1/1 | | |
| Transportation, communication, and utilities | 1/1 | 1/1 | 1/1 | | | | |
| Wholesale trade | 1/1 | 1/1 | | | | 1/1 | |
| Totals | 15/17 | 4/4 | 4/5 | 1/1 | 4/4 | 8/14 | 5/5 |

* Includes one event or fatality due to implosion (manufacturing).
† First number denotes accidents; second number denotes fatalities.
‡ Except shipbuilding.

quently due to atmospheric condition.

Manhole accidents were observed only in the nonmanufacturing category, and tank/pressure vessel incidents were observed only in the manufacturing industries (Table 3). Bin/boxcar accidents occurred mainly in the manufacturing industries, although ship compartment accidents were distributed among a variety of the industrial categories.

## Discussion

This work underscores a major limitation in the study of occupational fatalities, that is, complete case finding.[16] This is particularly true of confined space fatalities, because there is presently no recognized data base specifically identifying confined space related cases. For this reason, workers' compensation files were used as an adjunct to death certificates for case finding of fatalities. This method only increased the total number of cases by 7% above the number suspected from death certificates alone (from 46 to 49). An additional value of the workers' compensation files was in providing details to assist in confirmation of suspected cases identified from death certificates. The medical examiner's records were an invaluable source for positively confirming the confined space related nature of the fatalities and providing additional information of circumstances surrounding the fatal event. Computerized medical examiner's files, if available, may be a better adjunct data source for case finding than workers' compensation files.

When properly completed, the item of the Virginia death certificate entitled "Describe how injury relating to death occurred," was extremely useful. Indeed, some examples from the death certificates reviewed were "collapsed while working in a void of a barge," "overcome by gasoline fumes in closed space," "working in a closed space with high argon, low oxygen levels," and "unloaded grain barge and collapsed due to oxygen deficiency."

It should be recognized that workers' compensation data do not represent all workers employed in Virginia. Workers employed in the maritime industry, for example, are covered by a federal regulation, the Longshoremen's and Harbor Workers' Compensation Act. Also, OSHA regulations for this industry are enforced by federal personnel, not Virginia OSHA staff.

Because confined space regulations did not take effect in Virginia until January 1, 1988, we anticipated finding no clear temporal trend when accidents were analyzed by year of occurrence. Almost half the fatal confined space accidents occurred in the fourth quarter. The reason for this pronounced seasonal variation is unclear, but it may be related to better ventilation of some confined spaces during the warmer months of the year.

The greatest number of fatal accidents occurred in the Tidewater region of Virginia. This is undoubtedly related to the prevalence of the maritime industry in that region.

A previous study suggested that perhaps 2% of occupational fatalities are the result of confined space related hazards.[3] This number was derived from fatality data gathered from 1976 and 1977 OSHA 36 forms held within the OSHA national office, as well as from occupational death reports available in Safety Services files from previous fatality studies. The present study suggests that although confined space accidents are relatively infrequent, they may account for as many as 5% of occupational fatalities in the civilian work force (excluding those associated with plane, train, and motor vehicle accidents).

Confined space fatalities occurred in workers of all ages but especially those between the ages of 30 and 49. It is not clear why this age group would be at higher risk than are younger workers. In general, older workers are more experienced, mature, and aware of workplace hazards,[17] but this may not hold true for confined space accidents. It is clear, however, that all workers would benefit from increased training in job-specific safety procedures regarding confined spaces, regardless of age. This continuing need for training is most likely because of the typically nonroutine nature of confined space work. Also, the same employees are not always involved in these irregularly performed tasks.

The male to female ratio for occupational confined space fatalities was approximately 11:1. This is probably a reflection of the jobs typically held by women. It is also quite possible that women and men in the same occupational category, for example, laborers and operators, may not have the same degree of hazard associated with their jobs.

As expected, the most hazardous occupations were generally among the blue-collar occupational groups. These were generally the occupational categories involved in inspection, repair, and maintenance work. These types of activities may occur infrequently, and employees apparently do not readily recognize the hazard. Often, the worker who becomes a fatality is the employee of an outside contractor. He may not be totally familiar with the confined space in which he has to work, and he may have received little safety indoctrination.[3,18] Management should be aware that potential safety problems can arise with outside contractors and temporary employees who are called in for repair or maintenance work but who are unfamiliar with the confined space.[18] Proper safety indoctrination and procedures for these individuals should be provided as well as adequate supervision.

It is well established that alcohol intoxication has an adverse effect on job performance. However, in only two cases was alcohol demonstrable in the blood and potentially contributory to the confined space fatalities. Drugs, although a potential problem in the workplace, were not detected in body fluids analyzed and hence were not contributory to the fatalities.

Virginia's confined space fatality experience generally paralleled another study regarding major accident types.[3] In both studies atmospheric condition and fire/explosion were the leading causes of accidents and fatalities. Most of the Virginia confined space accidents involved single fatalities; only three (6%) of the 50 fatalities identified in our study were rescuers.

This is quite low compared with the more than 60% estimate reported by NIOSH.[6] This may reflect a better awareness of appropriate rescue procedures by Virginia workers, a lack of use of the "buddy" system, or it may be an artifact resulting from the overall small number of cases identified.

In almost half the accidents due to atmospheric condition, the toxic gas or oxygen deficiency was absent in the confined space at the time of entry; therefore, prevention plans will need to call for monitoring the atmosphere for oxygen content, combustible gases, and toxic gases both preentry and continuously during use. Because some gases, such as argon, are heavier than air it is necessary to monitor preentry at several levels within the confined space.

Where the potential exists for inadvertently disconnecting an air line or for kinks and pinches to develop in the line, the employee should be provided with a 5- to 15-minute escape respirator containing breathing air[4] (self-contained breathing apparatus). In addition, industry rescue personnel should be adequately equipped and trained to perform emergency rescue. They should be stationed outside the confined space and in contact with the employee at all times. Community rescue personnel should be aware of the hazards associated with confined space rescue operations and the precautions necessary to avoid injury or death among rescuers.

As in other reported incidents involving entrapment by unstable materials,[3, 19] these fatalities in Virginia typically occurred because a worker was attempting to unclog an accumulated deposit of material. Training for workers should emphasize that all stored materials be viewed as having the potential for entrapment. Workers should never enter a storage area from the bottom when material is adhering to the sides of the area, and they should never stand on top of stored material.[19]

In three of the four cases that involved being caught in machinery, the application of a lockout/tagout procedure was clearly applicable. By closing and locking all valves and switches associated with the operation of the confined space, the introduction of contaminants like live steam or the starting of equipment during occupancy would be prevented.[18]

Given that more than half the fire/explosion accidents involved welding or cutting torch use, workers should be made aware of the dangers inherent in welding in confined spaces, and appropriate safety procedures should be developed. These would include inspecting welding hoses for gas leaks and securing gas cylinders outside the confined space where valves could be shut off when not in use.[4]

It is widely recognized that construction is a hazardous industry.[20] This industry, along with shipbuilding, is also an important industry for confined space accidents.[3]

Ship compartment confined space deaths occurred in six industrial categories, the widest distribution of any confined space type. In three of these cases, workers entered a compartment or void with a hypoxic atmosphere. This suggests that preentry testing could have saved lives. There are many direct-reading instruments available in the marketplace that monitor oxygen concentration and common air contaminants.

From the resources searched for this study, we found one area in which relevant information was lacking was personal protective equipment and safety procedures. Detailed accident investigation reports (for example, OSHA reports) should provide this information. Typically, these reports should include whether personal protective equipment and/or safety equipment was used, and if not, why not. They should also indicate whether atmospheric testing had been conducted preentry or continuously, when applicable, and whether mechanical ventilation was used, if needed.

Occupational fatalities are preventable. A first step toward prevention is to consider every confined space as dangerous until proved otherwise. The typical elements of a confined space program consist of permitting, atmospheric testing, ventilation, personal protective equipment, lockout/tagout, safety considerations (safety belts, lifelines, spark-proof tools, explosion-proof fans, etc), rescue procedures and communication, as well as training.[5] A strong safety and health program encompassing these elements, endorsed and enforced by management, is essential to reducing confined space fatalities.

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## Schools That Work

The bad news about American schools today is abundant, but some schools do work. Not many. Not enough. But enough to remind us that we can do it right. A few are widely known. The most famous is Manhattan's LaGuardia High School of Music & Art and the Performing Arts, the model for the movie *Fame.* It earned its reputation the old-fashioned way: hard work. Artistic accomplishment does not easily; even talented kids must put in long hours. And the pace is demanding, from classical ballet students who applaud the ballet teacher to budding playwrights who struggle with syntax and grammar, plot and character development. The North Carolina School of Science and Mathematics (NCSSM), founded by Governor Jim Hunt in 1980, is a statewide residential school for high-achieving (not necessarily gifted) students. Racially and socioeconomically balanced, NCSSM does not require its teachers to hold state credentials or use state textbooks. The result? College professors on the faculty and more demanding, not less demanding, books.

Schools that work are found across the country: New Trier, north of Chicago; the California Academy of Mathematics and Science in Los Angeles; Central High in Philadelphia; Whitman in Montgomery County, Maryland; Lowell in San Francisco; Brooklyn Tech, Stuyvesant, Aviation, and Murry Bergtraum in New York. In addition, most university towns or research centers, like Huntsville, Alabama, and Los Alamos, New Mexico, are proud of their schools that work. What do they have in common? Two things. They have terrific students and demanding staff. It is hard to overestimate how important the raw material is. But it is only part of the story. . . . Teaching matters; curriculum matters; leadership matters. Most important, hard work matters.

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