Applied Occupational and Environmental Hygiene

ISSN: 1047-322X (Print) 1521-0898 (Online) Journal homepage: http://www.tandfonline.com/loi/uaoh20

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To cite this article: Anthony Suruda , William Milliken , Dale Stephenson & Richard Sesek (2003) Fatal Injuries in the United States Involving Respirators, 1984-1995, Applied Occupational and Environmental Hygiene, 18:4, 289-292, DOI: 10.1080/10473220301405

To link to this article: https://doi.org/10.1080/10473220301405

Applied Occupational and Environmental Hygiene
Volume 18(4): 289–292, 2003

1047-322X/03 $12.00 + .00
DOI: 10.1080/10473220390115138

Fatal Injuries in the United States Involving Respirators, 1984–1995

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There is little published information concerning the epidemiology of fatal injuries involving respiratory protection. We compiled a case series from U.S. Occupational Safety and Health Administration investigation reports from 1984 through 1995. For the 12-year period there were 41 incidents resulting in 45 deaths due to asphyxiation or chemical poisoning while wearing a respirator. There were 23 deaths related to airline respirators, 17 deaths involving use of negative pressure (air purifying) respirators, and 5 deaths involving self-contained breathing apparatus. Among the 23 deaths involving airline respirators, 15 were associated with compatible connection couplings for breathable air and inert gases. Three workers with beards died who wore tight-fitting respirators in an atmosphere that was immediately dangerous to life and health. Most of the fatalities involved regulatory and procedural violations, and would have been prevented by proper training and compliance with existing regulations. The information concerning the victims was limited but it did not appear that medical screening would have prevented any of the deaths.

Keywords Respirator, Fatality, Inert Gas, Beards, Airline

In a 1999 review concerning medical surveillance for respirator use Muhm[1] noted that there was little published information on the extent of hazardous effects related to respirator use. Hudnall et al.[2] reported 11 fatalities in 1984–1988 involving airline respirators supplied with inert gases. In the 1998 revision of the U.S. Occupational Safety and Health Administration (OSHA) respiratory protection standard 1910.134 OSHA estimated that there were 5 million respirator users in approximately 1.3 million U.S. workplaces.[3] We conducted the present study to examine the number and types of fatal injuries related to improper respirator use.

We chose to review OSHA investigation data because respiratory protection is addressed by existing OSHA standards. If a fatal injury involves a known violation of OSHA standards this will usually be mentioned in the fatality report. Since April 1984 OSHA fatality reports have included narrative text of the compliance officer's report abstract, form OSHA-170, as well as key words that allow text searches. OSHA investigation data are not the most complete source of reporting for fatal work injury and identify fewer fatalities than either the Bureau of Labor Statistics Census of Fatal Occupational Injuries,[4] which is based on reporting from multiple sources, or the National Institute for Occupational Safety and Health's surveillance system, which is based on death certificates.[5]

METHODS

Fatal injuries involving improper respirator use were identified by a review of computerized records from OSHA fatality investigations for a 12-year period. Fatality data were available from OSHA for 47 states for the period from1984–1989 (California, Michigan, and Washington excluded), and for all 50 states for the period from 1990–1995. Records were selected for initial review in two ways: 1) coding for the hazardous substances argon, helium, nitrogen, carbon dioxide, and carbon monoxide, or 2) a keyword search for RESPIRATOR or ASPHYXIA (or portions of those words). The abstracts of the investigation reports were then manually reviewed to identify fatalities where the death was directly related to improper respirator use. Deaths associated with failure to use a respirator were excluded, as were fatalities associated with structural fire fighting while wearing a self-contained breathing apparatus (SCBA). The fire fighting–related deaths were excluded because few of these fatalities appeared to be due to running out of air, improper SCBA use, or malfunction of the SCBA, and because municipal fire fighters are usually government employees who would not be under federal OSHA jurisdiction.

RESULTS

During the 12-year period there were 41 incidents, 4 of which involved 2 fatalities each, for a total of 45 fatalities.

TABLE I
Types of respirators used in cases of fatal injury

Air line respirators	23
Cartridge respirators	17
Self-contained breathing apparatus	5
Total	45

The 11 fatalities previously reported[2] for 1984–1988 are included. The majority of victims were male (97.9%) with a mean age of 33.8 years (range 22 to 56 years). Most of the fatalities involved non-union firms (71%). Eleven fatalities (24%) occurred in small businesses with fewer than 11 employees, which are not subject to routine (general) OSHA inspections. The types of respirators involved are shown in Table I. There were 23 deaths involving airline respirators, 17 deaths involving air purifying (negative pressure) respirators, and 5 deaths associated with the use of SCBAs. Of the 17 deaths involving air purifying respirators, 14 involved cartridge respirators and another 3 were related to the use of an unapproved mask not specifically identified as to type. There were 3 deaths in which workers with beards wore tight-fitting negative pressure respirators in an atmosphere that was immediately dangerous to life and health (IDLH). One individual had a cardiac arrest associated with the application of a fungicide while using a cartridge respirator.

The majority of victims were in the manufacturing industry (44%), followed by construction (27%), services (9%), trade (7%), oil and gas (7%), and the remainder in other industries (6%). Almost all of the fatalities were due to asphyxiation or chemical poisoning. The most frequent agent was nitrogen, with 18 fatalities, followed by various organic solvents, with 10 fatalities; a complete listing is shown in Table II.

Airline delivery of non-breathable air was responsible for 23 (51%) deaths, most of which (15 of 23 [65%]) were due to a coupling compatibility between breathing air lines and other gas sources that allowed the worker to connect the respirator to non-breathable gas such as nitrogen. Of the 8 deaths involving air line respirators in which the connection was thought to be to breathable air, most involved compressor malfunction and/or system design. There were 4 deaths in which breathable air systems backfilled with nitrogen when the main compressor malfunctioned because the system was interconnected with a nitrogen system. There was 1 fatality initially reported to OSHA as a heart attack while using an air line respirator in a new paint booth. The following day the replacement worker lost consciousness when he donned the same respirator, and it was then discovered that the booth had been improperly constructed and the air line had been connected to the plant argon supply. The remaining fatalities were from carbon monoxide poisoning from contamination of the air supply by exhaust from the compressor or from the compressor overheating and catching fire. There were two fatalities associated with the use of air purifying respirators in a nitrogen atmosphere. In another fatality report, an individual was testing a SCBA and accidentally conducted the test using pure nitrogen instead of breathable air.

TABLE II
Fatality distribution by agent

Agent	# of fatalities	% of total
Nitrogen	18	40.0
Organic solvents	10	22.2
Oxygen deficiency	6	13.3
Carbon monoxide	4	9.0
Argon	2	4.5
Ammonia	1	2.2
Freon	1	2.2
Phosgene	1	2.2
H2S	1	2.2
Fungicide	1	2.2

Most of the fatalities occurred in atmospheres immediately dangerous to life or health. OSHA requires workers having the potential for exposure to IDLH atmospheres to be accompanied by one or more persons that can respond to an emergency. In the current study, there were 36 fatalities associated with noncompliance to this requirement. Confined space entry was associated with 27 (60%) fatalities, with 14 of these deaths (31%) related to the improper use of a fitted cartridge-type respirator. For the entire group, OSHA cited 108 violations of the Respiratory Protection Standard and these are shown in Figure 1.

DISCUSSION

The fatal injuries described in this report were preventable and were related to both lack of proper worker training and to deficiencies in equipment.

The largest number (15) were related to coupling compatibility between air line respirators and non-breathable air supplies. Since the original OSHA Respiratory Protection Standard was promulgated in 1974, it has been a requirement that employers insure incompatibility of couplings for breathing air and inert gases. In the 1993 study of air line–related deaths by Hudnall et al.[2] most of the 11 fatalities were associated with a coupling compatibility between breathable air and inert gas or pneumatic tool air systems.

In contrast to connectors for breathable air, coupling incompatibility has been successfully addressed in the United States for electrical power for consumer products and appliances. Outlet receptacles and plugs for 110 volt electricity versus 220 volt electricity are incompatible. One cannot purchase a 110 volt appliance equipped with a connector that will couple with a 220 volt outlet. In the case of air line respirators there are over 50 connector types in use and these are not unique to breathable air fittings. Ensuring a similar incompatibility between breathable and non-breathable air coupling mechanisms would save lives among those workers who use air line respirators.

Since the National Institute for Occupational Safety and Health (NIOSH) prohibits unapproved changes to an air line

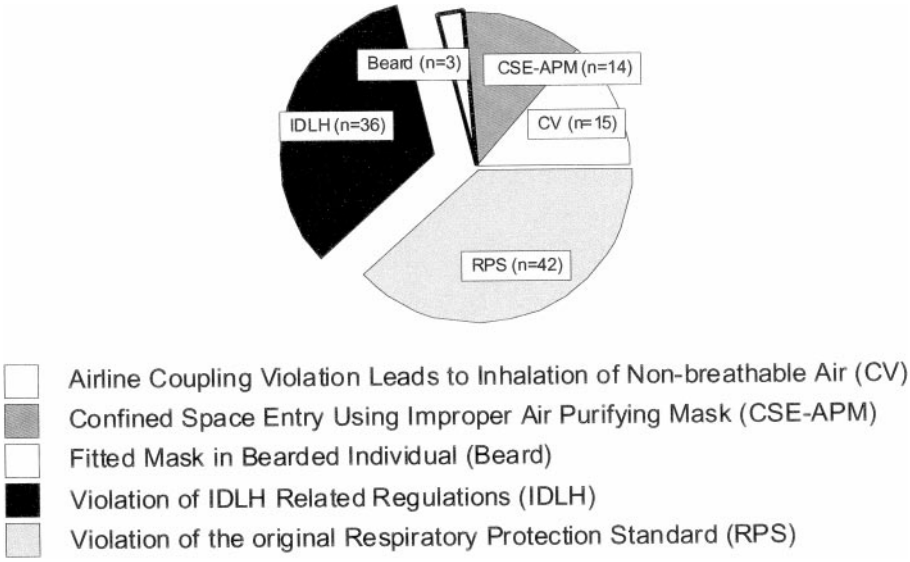

FIGURE 1
Violations cited by OSHA for fatal injuries involving respirators 1984–1995.

respirator,[6] any action taken to ensure coupling incompatibility will require a change in the certification process to designate fittings specially for breathable air. Whether the economic burden of requiring such a change is justified is unknown. Once the change was made there would eventually be a savings of approximately one worker life per year from asphyxiation by non-breathable air sources. A life saved can be estimated to have an economic value in current dollars of $6 million.[7] Assuming that connectors for compressed air have a useful life of 10 years, a changeover to unique fittings for breathable air would be justified on economic grounds if the changeover could be made for $60 million or less.

OSHA requires employers to ensure that compressors used to supply breathing air to respirators be constructed and situated so as to prevent entry of contaminated air into the breathing air–supply system. The standard further requires the employer to ensure carbon monoxide levels of less than 10 ppm if using non-oil–lubricated compressors, and to utilize high temperature or carbon monoxide alarm systems, or both, if using oil-lubricated compressors. If a high temperature alarm is used alone, the employer must monitor the air supply at intervals sufficient to prevent carbon monoxide levels above 10 ppm in breathing air. Compressors are also to be constructed such that crossover contamination is not possible. These requirements were not followed in at least four cases described.

Almost all of the fatalities reviewed in our study were preventable had regulatory guidance been followed. In the majority of cases, appropriate training, supervisory compliance with existing regulations, adherence to confined space entry protocol, and compliance with regulations concerning the safe use of compressors, would have saved lives. There was limited information in the reports concerning the victims, but it did not appear that medical screening would have prevented any of the deaths. The number of fatalities for the 12-year period is probably greater than we report since OSHA does not investigate all workplace fatalities.

The loss associated with respirator related fatalities is, of course, greater than the economic losses alone. Unnecessary loss of life is tragic for coworkers, families, and communities. The occupational and environmental health and safety community should work harder to improve respirator training and safety awareness in workers and supervisors alike. Physicians providing respirator health surveillance surveys and examinations should consider providing preventive education to respirator users in an effort to improve safety. Occupational health and safety professionals must work together with company managers and lawmakers if these unnecessary deaths are to be prevented in the future.

ACKNOWLEDGMENTS

We acknowledge the assistance of Kevin Nechodom and Brian Nordberg in transforming the OSHA data. Brad Whitaker assisted with the initial report review. Fatality reports were provided with the kind assistance of Bruce Beveridge, Sanford Hamilton, and Thomas Tyburski of OSHA Management Data Systems.

SUPPORT

This study was funded by a grant from the Health Research Center, Department of Family and Preventive Medicine, University of Utah, and by Training Grant No. T42/CCT810426 from the National Institute for Occupational Safety and Health.

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