Update on refuge alternatives: research, recommendations and underground deployment

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Introduction

The U.S. coal mining industry experienced an increase in fatalities during 2006 when 37 miners perished in the nation's underground coal mines. Nineteen miners perished in three disasters: 12 miners perished in a methane explosion at the International Coal Group, Sago Mine, two more miners died in a fire at the Aracoma Coal Co., Alma No. 1 Mine, while another methane explosion resulted in the loss of five more miners at the Kentucky Darby, LLC, Darby No. 1 Mine. This reversed the downward trend of fatalities that had taken place during the previous 21 years (Fig. 1). The causes of all the underground coal mine fatalities in 2005, 2006 and 2007 are listed in Table 1. Table 1 illustrates that fewer fatalities occurred in 2005 and 2007 than 2006 with the goal of zero fatalities as desirable.

The Mine Improvement and New Emergency Response Act of 2006 (MINER Act), PL 109-236, was passed in response to this increase in fatalities resulting from the three mine disasters that occurred in 2006 (United States, 2006). Section 13 of the Act – Research Concerning Refuge Alternatives, specifies NIOSH's responsibilities with respect to refuge alternatives. Section 13, subsection (a) of the Act states that "The National Institute for Occupational Safety and Health (NIOSH) shall provide for the conduct of research, including field tests, concerning the utility, practicality, survivability and cost of various refuge alternatives in an underground coal mine environment, including commercially available portable refuge chambers." Subsection (b)(1) then states that "Not later than 18 months after the date of enactment of this Act, the National Institute for Occupational Safety and Health shall prepare and submit to the Secretary of Labor, the Secretary of Health and Human Services, the Committee on Health, Education, Labor, and Pensions of the Senate, and the Committee on Education and the Workforce of the House of Representatives a report concerning the results of the research conducted under subsection (a), including any field tests." This document summarizes NIOSH's refuge alternatives research that was included in the report to the U.S. Congress.

The concept of utilizing refuge chambers dates back as far as 1912 when the U.S. Bureau of Mines advocated the building of refuge chambers to fight mine fires (Rice, 1912) in the main sections of mines (Paul et al., 1923). In the late 1930s and early 1940s, some small refuge chambers had been established in some coal mines in the central states and these chambers saved lives (Harrington and Fene, 1941). In addition, the Harwick Coal and Coke Co. built a number of large refuge chambers in the Harwick Mine. These chambers were 23-m- (75-ft-) long, 2.4-m- (8-ft-) high and 3.3-m- (11-ft-) wide, cut out of the coal and connected to the surface by two boreholes to provide air, communications, food and water (Harrington and Fene, 1941).

More recent research efforts were completed under contract for the U.S. Bureau of Mines starting around 1970 and extending into the mid-1980s. Five major contract efforts were completed between 1970 and 1983 that addressed mine rescue and survival, the design of explosion-proof bulkheads, post survival and rescue research needs, and guidelines for rescue chambers. As a result, one refuge chamber was constructed and is still located in NIOSH's Bruceton Safety Research Coal Mine (Fig. 2). In general, these contract efforts did not point to any one specific component that would ensure survival during a mine disaster but stressed that survival is a collaboration of subsystems. The subsystems that make up the overall survival strategy include escape, rescue, communications, breathable air and barricading (refuge).

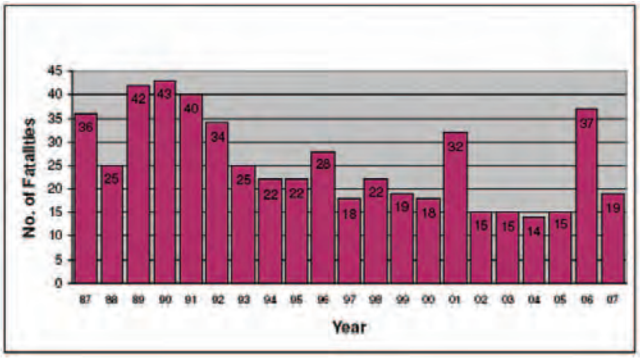
NIOSH's recent research on refuge alternatives was limited to underground coal mine applications. Historically, the use of refuge alternatives has been more prevalent in underground metal/nonmetal mines. The underlying

Abstract

In response to the mandates in the MINER Act of 2006, the National Institute for Occupational Safety and Health (NIOSH) conducted refuge alternatives research that included characterizing the utility, practicality and survivability of refuge chambers and outby safe havens. NIOSH also prepared and delivered a report to Congress in late December 2007 that summarized the findings of the research, included recommendations concerning the design and performance specifications for refuge alternatives, and focused on specific information that could inform the regulatory process on refuge alternatives. This paper highlights NIOSH's research and recommendations concerning refuge alternatives, survivability evaluations of refuge chambers and presents a brief review of the current deployment of refuge chambers in underground coal mines in the U.S. The research has lead to the conclusion that refuge alternatives have the potential for saving the lives of mine workers if they are part of a comprehensive escape and rescue plan and if appropriate training is provided.

FIGURE 1

Underground coal mine fatalities 1987-2007 (Bauer Kohler, 2009.



differences between mining sectors are significant and practices in one sector cannot be generalized to the other. Even so, the findings from this research may be useful for metal/nonmetal application.

The research efforts summarized in this document involved a number of activities. First, a literature search was performed to identify the findings from any past research on refuge alternatives and topics related to mine refuge and mine disasters, escape and mine rescue. Visits were made to mines, nationally and internationally, and meetings were held with mining experts from labor, industry and government in the U.S., Australia and South Africa to collect information on refuge alternatives, specific refuge regulations and to discuss contemporary issues associated with refuge alternatives. Several contract efforts were completed that examined existing U.S. and international practices, regulations and refuge products. However, these efforts revealed very little information related to coal mining refuge applications, while identifying several knowledge and technology gap areas. In response, a major research contract was awarded to address the gap areas, including guidance for locating and positioning refuge alternatives and establishing specifications for chambers and in-place shelters[1].

Concurrently, NIOSH researchers examined nonmining applications where survival in confined spaces is critical – notably civil defense shelters, submarines and space capsules – in search of guidance for application to coal mining. Overall, NIOSH researchers studied a range of practical issues associated with refuge such as movement of chambers from place to place, collected cost data and performed cost analyses of refuge alternatives. NIOSH researchers also conducted survivability evaluations of refuge chamber performance at the Lake Lynn Experimental Mine.

Finally, separate research projects were initiated as gap areas were uncovered and several research efforts remain ongoing. These research areas include the development of communications technology specifically for use in refuge alternatives and the development of training modules for using refuge alternatives during escape and rescue. These projects are expected to continue through 2009 and will be reported on in future publications.

Table 1

Underground coal mine fatalities for 2005-2007 (MSHA 2008).

Cause of fatality	2005	2006	2007
Electrical	0	0	0
Exploding vessels under pressure	0	0	0
Explosives and breaking agents	0	0	0
Falling, rolling, sliding rock/material	0	0	1
Fall of face, rib, pillar or highwall	0	3	9
Fall of roof or back	9	7	3
Fire	0	2	0
Handling material	0	0	1
Powered haulage	5	6	2
Ignition/explosion of gas/dust	0	18	0
Machinery	0	1	2
Slip or fall of person	1	0	0
Stepping or kneeling on object	0	0	1
Mine Type Total	**15**	**37**	**19**

NIOSH refuge alternatives research

Utility. The utility, or usefulness, of refuge chambers has been debated in the U.S. at least since the passage of the Coal Mine Health and Safety Act of 1969, PL 91-173, which authorized the Secretary of Labor to prescribe in any coal mine that rescue chambers, properly sealed and ventilated, be erected at suitable locations in the mine to which persons may go in case of an emergency for protection from hazards. Despite this and the significant research conducted by the U.S. Bureau of Mines nearly 30 years ago, refuge chambers have not been embraced by industry, labor or government. The focus, understandably, has been on escape rather than refuge.

NIOSH investigated the utility of refuge alternatives to aid in the survival of miners following a mine disaster. Past mine disasters were reviewed to determine if the presence of refuge alternatives might have altered the outcome of these disasters. The results are mixed given the small number of disasters and the mine-specific circumstances under which they occurred. Thus, it is difficult to make a strong case for or against a specific refuge alternative, or even for or against the efficacy of coal miners taking refuge. Nevertheless, the recent mine disasters have refocused attention on the utility of refuge alternatives. And it has been argued that the availability of refuge alternatives may have been useful in these disasters.

An extensive study of the mining disasters in underground coal mines in the U.S. from 1970-2006 involving fires, explosions and inundations in which fatalities occurred revealed the potential affect of refuge alternatives on both survivors and fatalities (Ounanian, 2007a, 2007b). This included 17 major disasters in which five or more miners perished; 20 disasters in which one to four miners were killed; one disaster in which no miners were killed, the July 2002 inundation at BlackWolf Coal Co.'s Quecreek No. 1 Mine in which all nine miners trapped in a flooded mine were rescued as well as four other disas-

[1]The gap areas were identified at the end of the international survey effort, which was performed during July through October 2006. The technical part of the contract to address these areas was completed at the end of October. The actual contract award, conducted in compliance with the Federal Acquisition Rules, was made in March 2007. Work on this contract will continue through 2009. The contractor was able to provide key inputs for the preparation of the report to Congress.

ters involving fatalities that were not deemed applicable. In all, 38 disasters were investigated for inclusion in the analysis.

From the disaster analysis, a number of positive impacts were identified. The term "positive impact" described when the presence of a refuge alternative might have changed the final outcome of a disaster in a positive manner such as miners surviving instead of perishing. First, it was estimated that the presence of a refuge alternative (chamber or safe haven) might have positively impacted the outcomes in 12 of the 38 disasters studied. Second, of the 429 miners who were underground and impacted (forced to escape, injured, barricaded or perished) by the 38 disasters, 83 might have been positively impacted by the presence of a refuge alternative. Finally, if a refuge alternative had been present, 74 of the 252 fatalities might have been positively impacted, resulting in the potential survival of the miners.

The group of miners that might have been most impacted were those who perished during their escape attempts. The analysis indicated that 57 of the 67 miners who expired while escaping might have been positively impacted if an outby refuge station had been present, the escaping miners found it and they successfully activated the breathable air systems. A second group most likely to benefit were the miners who barricaded. While barricades were used in only two relevant incidents, these

FIGURE 2

Refuge chamber located in Bruceton Safety Research Mine.

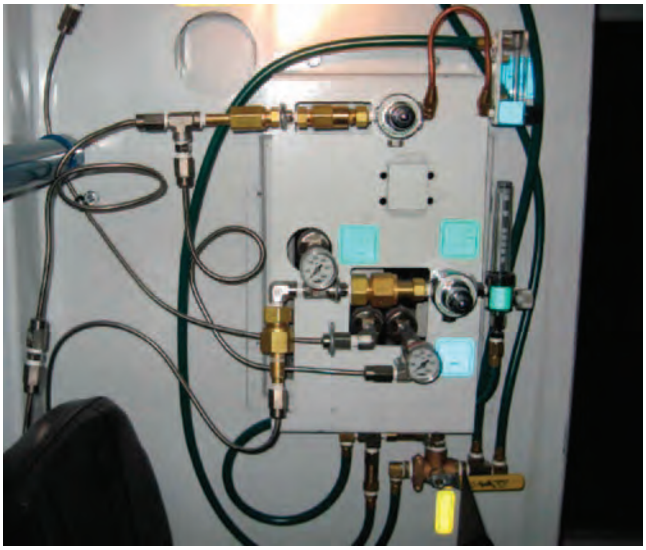
Table 2

Design and performance specifications for refuge alternatives (NIOSH 2007).

Parameter	Recommended value or practice
Minimum rated duration	48 hours.
Strength	15 psi overpressure for 0.2 seconds.
Anchor system	Not recommended at this time.
Fire resistance	148° C (300° F) for 3 seconds.
Deployment time	Minimize this time when establishing the location of the refuge alternative and consider as part of the travel time.
Min. concentration O_2	18.5%.
Max. concentration O_2	23%.
Max. concentration CO	25 ppm.
Gases to be monitored inside chamber	O_2, CO, CO_2.
External gases to be monitored	O_2, CO.
Max. concentration CO_2	1.0%, not to exceed 2.5% for any 24-hour period.
Apparent temperature	35° C (95° F).
Entry and Exit	Provide a means of egress without contaminating the internal environment and/or a means to maintain a safe environment during and after ingress/egress.
Potable water per person	2 to 2.25 qt per 24 hour.
Durability	Structurally reinforced and of sufficient physical integrity to withstand routine handling.
Purge air volume	No specific recommendation (see entry and exit parameter).
Food, per person	2000 cal per 24 hour.
Human waste disposal system	Required.
First aid kit	Required.
Occupant-activated annunciation	Battery-powered strobe light or radio homing signal.
Communication with surface	Survivable post-disaster system.
Minimum distance to working face	305 m (1,000 ft).
Maximum distance from working face	Distance that a miner could reasonably travel in 30–60 minutes, under the expected travel conditions
Security	Visual indication that a refuge alternative has been entered; inspection and maintenance actions required subsequent to discovery.
Repair materials	Materials and instructions supplied by manufacturer.
Testing and approval	Required.
Unrestricted floor space	> 1.4 m^2 (15 sq ft) per person.
Unrestricted volume	> 2.4 m^3 (85 cu ft) per person.
Capacity	Sufficient to accommodate the maximum number of miners in the area to be served by the refuge alternative.

FIGURE 3

Example of oxygen supply system in a refuge chamber.



incidents resulted in at least 17 and possibly 19 fatalities. All of these miners might have been positively impacted (survived) by the presence of a refuge chamber on the working section.

Based on the disaster analysis and numerous other NIOSH research efforts associated with the utility of refuge alternatives, the significant opportunity today is to recognize that refuge alternatives can be useful to facilitate escape from the mine as well as to serve as a safe haven of last resort. The potential of refuge alternatives to save lives will only be realized if mine operators develop comprehensive escape and rescue plans that incorporate refuge alternatives. Such an approach would be far superior to one in which refuge chambers are simply placed into the mine to comply with a regulation. Thus, it does make sense to use refuge alternatives because it is likely that miners' lives could be saved.

Practicality. The practicality of refuge alternatives encompasses whether or not they can be implemented, moved and maintained in underground coal mines. Refuge chambers are commercially available and have been successfully installed in underground coal mines abroad and, to a limited extent, in the U.S. Although there are no documented cases of successful use of a refuge chamber in an underground coal mine in an emergency, there is no evidence to suggest that refuge chambers or alternatives are impractical, but their use will be challenging. The installation of refuge alternatives and the moving and maintenance of such chambers will require an ongoing effort on the part of mine operators. There was a concern that the moving of refuge alternatives to advance or retreat with mining could be difficult and possibly impractical. After a thorough investigation of this issue including numerous site visits, it was found that the moving of refuge alternatives can be done safely and feasibly (NIOSH, 2006a). Also, it is thought that it may be impractical to implement viable refuge alternatives in the few mines that operate in very low coal, e.g. less than 914 mm (36 in.). The finding of the NIOSH research is that refuge alternatives, to facilitate escape and to serve as a refuge of last resort, are practical for use in most underground coal mines.

Survivability. Survivability focuses on the ability of refuge alternatives to ensure that the workers who use the alternatives will survive for a specific duration. The most crucial specifications for the survivability of miners who seek refuge in a chamber or safe haven are: maintaining the structural integrity of the unit through an initial explosion; initiating and maintaining an atmosphere that will support life; and providing for basic human needs. These parameters need only address the support of life for a limited time under emergency conditions since refuge alternatives are not intended to serve as routine workplaces. Ultimately, the desired result is a survivable event and not necessarily the most comfortable experience.

The likelihood of a refuge alternative to survive an explosion is enhanced by the integrity of structural design, the positioning of the alternative out of the expected direct explosion force path, by minimizing the probability of being struck by flying debris, and by not locating the alternative near likely explosion/fire sources such as seals, belt drives, etc.

Providing and maintaining a survivable atmosphere has generally been solved by chamber manufacturers. Oxygen is supplied from breathable grade (99% pure with no harmful contaminants) oxygen bottles, flowing through manifolds and ball float meters (Fig. 3). Carbon dioxide scrubbing has been accomplished in a number of ways including passive lithium or soda lime curtains (Fig. 4), and air, or battery-powered fans pulling contaminated air through soda lime cartridges (Fig. 5). The control of heat and humidity was not an issue for the inflatable chambers since there is considerably more surface area for the heat to dissipate. Initially, this was a problem in the rigid steel chambers, but recent simulation testing and short duration human occupancy testing has indicated that the steel chambers can also be operated at apparent temperatures below 35° C (95° F), the WV standard for the combination of heat and humidity.

Basic human needs such as water, food and toilet facilities can and have been successfully addressed by all chamber manufacturers. All in all, there is no reason to believe that miners using a refuge alternative can not survive for the NIOSH recommended minimum duration of 48 hours.

Simulation testing

NIOSH, as part of its research and as required in the MINER Act, evaluated the performance of the West Virginia approved refuge chambers. NIOSH developed a protocol to simulate human occupancy based on a specific set of performance standards. The protocol was subsequently peer-reviewed and implemented.

The goals of the evaluations were limited to investigating the CO_2 scrubbing, oxygen flow rates and the heat index (i.e., apparent temperature during chamber operation). In addition, the overall deployment and operation of the chambers were observed and evaluated. Of critical importance was a chamber's ability to maintain a breathable atmosphere. This included maintaining O_2 above 19.5%, CO_2 below 0.5%, and a maximum 'apparent-temperature' of 35° C (95° F). The protocol defined the means of simulating human occupancy to facilitate the evaluation of the chambers as follows: the oxygen flow rate was measured and removed from the chamber

Table 3

Number of operating underground coal mines.

State	No. of Operating underground coal mines	Year	Source
Alabama	8	2007	http://dir.alabama.gov/mr/2007_ANNUAL.pdf
Arkansas	1	2006	http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html
Colorado	11	2007	http://mining.state.co.us/Reports/12-07CoalSummary.pdf
Illinois	15	2006	http://dnr.state.il.us/mines/public/asr2006.pdf
Indiana	8	2006	http://www.in.gov/dol/files/CoalMineStatistics91307.pdf
Kentucky	302	2006	http://www.omsl.ky.gov/NR/rdonlyres/6BAD4878-7779-4BEE-873F-0960535D2685/0/2006ARbook.pdf
Maryland	3	2006	http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html
Montana	1	2006	http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html
New Mexico	1	2006	http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html
Ohio	11	2006	http://www.dnr.state.oh.us/Portals/10/pdf/min_ind_report/06minind.pdf
Oklahoma	1	2005	http://www.mines.state.ok.us/id20.htm
Pennsylvania	38	2006	http://www.dep.state.pa.us/dep/deputate/minres/bmr/annualreport/2006/table09_bituminous_operators_and_sites_summary.htm
Tennessee	10	2006	http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html
Utah	11	2006	http://168.179.220.114/idev/coalmines/coalsiteinfo.php
Virginia	76	2006	http://www.energy.vt.edu/vept/coal/coal_prod_eia.asp
West Virginia	330	2007	http://www.wvcoal.com/index.php?option=com_content&task=view&id=34&Itemid=41
Wyoming	1	2006	http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html
Total	**828**		

(a rate of 0.62 L/min (0.022 cuft/m) per occupant was desired); CO_2 was injected into the chamber based on the respiratory quotient of 0.8 or 0.51 L/min (0.018 cuft/m) per occupant; the heat from light bulbs was used to mimic the metabolic heat load of 117.24 W/hour (400 Btu/hr) per occupant; and humidified air was injected into the chamber at a rate of 1.5 L/day (0.4 gpd) per man to simulate moisture from human respiration and perspiration. The evaluations were conducted continuously over a 96-hour period unless developing problems necessitated shortening the evaluations. Four manufacturers provided chambers for testing, two inflatable and two rigid steel.

The testing revealed unanticipated shortcomings in some of the chambers. For instance, heat dissipation was more of a problem in the rigid steel than the inflatable chambers, and the heat stress index[2] in both steel chambers exceeded the levels established as acceptable by the state of West Virginia. It should be noted that the ambient mine air temperature for the tests was in the range of 13-16° C (55-60° F) with little if any airflow over the chambers. If the steel chambers were used in mines with ambient temperatures closer to 21° C (70° F), as is found in some deep mines, the problem would be exacerbated. Three of the four chambers were unable to maintain CO_2 concentrations below the level specified by West Virginia OMHST, while two of the four chambers were unable to deliver oxygen for the duration of the test. Finally, the time to activate[3] each chamber varied from a few minutes to more than 30 minutes in two cases. There is no consensus on what constitutes a reasonable activation time, but the time to activate a specific chamber should be considered when establishing the maximum distance that a chamber can be located from the face. These shortcomings are sufficiently serious in three of the chambers to require correction before deployment. In most cases, but not all, these shortcomings should be correctable, or have already been corrected, with minor technical changes, the addition of clear instructions, and/or improved design/engineering.

Testing also revealed deficiencies with the documentation provided for each chamber, and this information has been discussed with the manufacturers. As a result, NIOSH initiated research to define and develop improved documentation. Additional opportunities for improving the usability and performance of chambers were noted. Finally, the results of the simulated evaluations indicate the need for independent evaluations and testing beyond the chamber manufacturers. Computational modeling and other engineering and mathematical analyses proved to be inadequate.

Re-evaluations

To address some of the deficiences found during the simulated occupancy evaluations, some additonal evaluations were conducted, modifications observed and chamber manufacturer test results analyzed. One manufacturer's redesigned curtain stands were viewed and found to be sufficiently strong to prevent tipping. Their oxygen flow meter problems were also addressed and a 96-hour test was observed that indicated the fluctuating flow was corrected. Another manufacturer's all-steel chamber was subjected to a repeat evaluation at Lake Lynn. This evaluation lasted 14 hours until a steady state condition was reached and demonstrated the chamber's ability to remain below 35° C (95° F) apparent tempera-

[2] West Virginia specified "apparent temperature" as a measure of heatstress and established an upper limit of 35° C (95° F), which is reasonable and is conservative.

[3] This is the elapsed time from arriving at the chamber until the environmental systems inside the chamber have begun to function. This time would include the setup and inflation time for an inflatable chamber in addition to the time required to start the oxygen flow and CO_2 scrubbing inside of the chamber.

FIGURE 4

Passive lithium curtains for scrubbing carbon dioxide.

ture. Finally, one manufacturer, without NIOSH participation, completed a short-term human subject evaluation. The results of the human occupation test were sent to and reviewed by NIOSH for verification that the scrubber containers were redesigned to prevent spillage and that the apparent temperature met the West Virginia standard.

Recommendations

NIOSH's Report to Congress on refuge alternatives contained many recommendations concerning the characteristics of refuge alternatives for use in underground coal mines (Table 2) (NIOSH 2007). A more complete explanation of the recommendations can be found in the original report at: http://www.cdc.gov/niosh/mining/mineract/pdfs/Report_on_Refuge_Alternatives_Research_12-07.pdf.

Chamber deployment in U.S. underground coal mines

Deployment possibilities. The number of underground coal mines in the U.S. in 2005 and 2006 was estimated to be between 600 and 670 (EIA 2006 and NIOSH 2006b).

FIGURE 5

Air powered soda lime carbon dioxide scrubber system.

MSHA data from August 2007 on mechanized mining units (MMU's) places the number of MMU's at 873 and the total underground mines at approximately 464. According to the individual states, the number of operating underground coal mines exceeds 800 as seen in Table 3. Despite this variation, if all underground coal mines in the U.S. were required to have a refuge chamber on each working face, it is estimated that from 450 to more than 1,000 chambers might be required.

Number and type of chambers ordered. Although the exact numbers and types of chambers ordered, sold and delivered is not readily identifiable because information from all chamber manufacturers was not obtained, some preliminary numbers are available.

First, according to Bruce Watzman, vice president for Safety and Health with the National Mining Association, in testimony before the Senate Subcommittee on Employment and Workplace Safety, the underground coal mining industry has spent $53 million for 752 total facilities to maintain trapped miners (Watzman, 2008). Also, from information provided by chamber manufacturers, as of August 2008, approximately 980 orders have been placed for rigid and inflatable refuge chambers, or bulkhead type systems. More than 90% of the chambers ordered were soft-side deployable (inflatable). It was also reported that more than 540 units have been delivered to underground coal mines in Alabama, Colorado, Illinois, Indiana, Kentucky, New Mexico, Ohio, Oklahoma, Pennsylvania, Utah, Virginia and West Virginia. The greatest number of units were delivered to West Virginia (approximately 36%).

Secondly, the capacity has been selected to cover the maximum number of expected users, based on between-shift and hot-seat change outs of personnel. The result is inflatable chambers of up to 36 person capacity being ordered. Finally, orders by the larger coal companies have been placed on a company-wide basis, resulting in chambers being placed not only in West Virginia mines but also in the company owned mines in other states as well.

Problems and concerns with underground deployment. NIOSH has heard minimal negative feedback about the deployment of the chambers, which is interpreted as little if any problems have been encountered. Issues have been mentioned concerning training, ie, availability of training models, in-mine or outside training, etc. In addition, at least two mines found that the rubber door seals had deteriorated after the chambers sat outside for the winter. These were replaced prior to deploying the chambers underground. It does raise questions as to the environmetal conditions that could lead to sealing problems. Recently, a problem has surfaced concerning the apparent temperature in refuge chambers employed in mines where the ambient temperature is greater than 13-16° C (55-60° F). This could force a reduced occupancy requirement in somes cases due to expected apparent temperatures above 35° C (95° F). These might need further investigation.

MSHA proposed refuse alternatives rules

The MINER Act required the Secretary of Labor to report on proposed regulatory changes within 180 days of receipt of NIOSH's refuge alternatives report. In response, MSHA published a Notice of Proposed Rule Making on Refuge Alternatives for Underground Coal Mines on June 16, 2008 (MSHA, 2008). At the time of the preparation of this manuscript, the comment period was closed, public hearings completed and MSHA was in the process of developing the final rule. The proposed rule contains many of NIOSH's recommendations found in the report to Congress, as well as solutions to other critical issues, a result of ongoing communications as part of the MSHA/NIOSH Refuge Alternatives Working Group and MSHA's diligent investigative efforts since passage of the MINER Act.

Summary and conclusions

The 2006 mine disasters and subsequent passage of the MINER Act has led to the development, testing and deployment of refuge alternatives in underground coal mines in the U.S. Specifically, a number of manufacturers have researched, developed, built and supplied refuge chambers to the coal industry.

The state of West Virginia has passed legislation requiring the use of refuge chambers in all the underground mines of that state and has approved a number of refuge chambers. MSHA has proposed rules for the use of refuge alternatives in all U.S. underground coal mines. NIOSH has conducted numerous research efforts to investigate the utility, practicality and survivability of refuge alternatives in underground coal mines, performed survivability analyses of a number of chambers and provided recommendations for use in the rule making process. Finally, all research has led to the conclusion that refuge alternatives have the potential for saving the lives of mine workers if they are part of a comprehensive escape and rescue plan and if appropriate training is provided.

Disclaimer

The findings and conclusions in this report have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

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