Occupational Hazards

Hawk's Nest Tunnel

A forgotten tragedy in safety's history

By C. Keith Stalnaker

WEST VIRGINIA'S New River is the largest whitewater rafting river in the eastern U.S., with more than 25 Class II to IV rapids. Starting in the Blue Ridge Mountains of North Carolina, the New River flows north, entering West Virginia and the New River Gorge where the New River Gorge National River becomes part of the national park system. One of the most spectacular canyons in the eastern U.S., the depth of the New River Gorge ranges from 700 to 1,300 ft. Setting atop the summit of the New River Gorge near Ansted, WV, the beautiful Hawk's Nest State Park borders the national park's northern edge.

Each year more than 150,000 people take whitewater rafting trips down the New River and some 1.1 million visitors enter the National River Park. Few of them realize that a trip to the park's northernmost tip would bring them to the now invisible site of America's worst industrial tragedy—the Hawk's Nest Tunnel.

The rapidly flowing New River that enchants rafters and kayakers today was also of interest to industrialists during the Depression. Union Carbide and Carbon Corp. (renamed Union Carbide Corp. in 1957) needed electrical power for an electrometallurgical complex to be built in Boncar, WV (renamed Alloy, WV, in 1931). West Virginia needed jobs and the prospect of a new metals plant was welcome news to the state's impoverished residents.

However, a 100,000 kW power station near the town of Gauley Bridge, WV, would first need to be constructed to generate the hydropower required by the Boncar operations (Jordan, 1998). In addition, a 3-mile (15,368 ft) tunnel would have to be constructed through Gauley Mountain to intercept the waters of the New River near Hawk's Nest and deliver the energy source to the power station. The resulting "Hawk's Nest Tunnel" dropped 162 ft from the New River, developing more than enough energy to rotate the power station's turbines and produce the needed electricity.

Construction groundbreaking took place on March 31, 1930—only 18 days after the tunnel contract was awarded to the Rinehart and Dennis Co. of Charlottesville, VA. Working in both directions, tunneling began on one end in June and the other in September ("Governor Conley," 1931). When the borings met in the middle, the joining grade and center lines were off by less than 1 in. ("Big Project," 1931).

Amazingly, the tunnel was completed in only 18 months in December 1931 (Cherniak, 1986). During an August 1931 celebration ceremony marking the joining of the two sections of the tunnel, West Virginia Governor William G. Conley aptly described the project as a great engineering accomplishment. Company officials commended tunnel management "who drove the work through in record time," while workers who had pushed a shaft heading 120 ft in 6 days were recognized as "the real men who have help put this job through" ("Highly Commended," 1931). The Hawk's Nest Tunnel proved to be a valuable asset, repaying the initial $9 million investment in 9 years and continuing to this day to be a significant source of hydroelectric power (Cherniak, 1986).

West Virginia during the Depression

According to Shepherd College historian Jerry Thomas, "West Virginia was already in bad shape by the time the Depression came around" and "was probably more severely victimized than other places as the Depression came because [the state was]

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This year marks the 75th anniversary of the completion of Hawk's Nest Tunnel in West Virginia. The 3-mile-long tunnel was an engineering marvel in Depression America and has performed flawlessly in the years since its construction. While it has enjoyed a long life, the same is not true of many of the tunnel's constructors. The exact number of Hawk's Nest victims is unknown, but more than 700 deaths seems a conservative estimate. Hawk's Nest served as the catalyst for the designation of silicosis as an occupational disease, opening the door to compensation of affected workers. Although largely forgotten by the nation and many in the safety profession, the incident was a major milestone in the development of America's safety culture. Its lessons learned continue to merit periodic review by both experienced and new safety professionals. This article provides details of the tunnel's construction, reviews the characteristics of silica, describes the hazards of crystalline silica exposure and cites current issues with occupational exposures to silica.

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so dependent on coal mining and subsistence agriculture. Both of those were severely hit early on" (McElhinny, 1999). As mines shut down, the depressed coal industry devastated the lives of miners. Unemployment in some counties rose as high as 80%. In others, unemployment rates were consistently between 30 and 40%, well above national averages (McElhinny, 1999). Desperate people were willing to work in almost any condition for nearly any wage. An Ohio missionary to a West Virginia coalfield town wrote, "I wonder whom God will hold responsible" for the conditions in and around the mines (Kreiser, 1994). Not surprisingly, residents working in such conditions welcomed the new Union Carbide complex that would provide many good paying jobs.

Although the completed electrometallurgical complex has employed generations of West Virginians, relatively few local residents worked on the Hawk's Nest Tunnel. Uneducated and unskilled African-Americans from southern states made up approximately 75% of the tunnel's workforce, while the relatively few skilled workers needed for the project came to the area with Rinehart and Dennis (Jordan, 1998). While it cannot be stated with certainty that the tunnel's owner and construction contractor took advantage of the desperation that existed during the Depression, conditions were undoubtedly conducive to occupational safety and health abuses.

Rinehart and Dennis had many more people applying for work on the tunnel than could be used. Poor men looking for work hoboed into the remote rural area by train in numbers so great that the contractor "could not handle them all" (Orr & Dragan, 1981). One worker who described the tunnel work as a "bad job" went on to explain that he stayed because "when you got some babies looking at you for something to eat, you're going to work" (Orr & Dragan, 1981). Historians have suggested that had the impoverished workers known of the danger it probably would not have caused them to leave, reasoning that silicosis "surely killed more slowly than starvation" (Bragg).

The stage was set: The sooner the tunnel was completed, the sooner the Boncar electrometallurgical complex could begin operations and hire workers. West Virginia needed employers and revenue. West Virginians needed the jobs that the complex would provide. Union Carbide stockholders stood to make a profit from electrometallurgical operations. The project was a win/win for everyone involved. Everyone, it turned out, except the workers who built the tunnel.

Mineralogy

The New River formation where the Hawk's Nest Tunnel was constructed consists of sandstones, siltstones and shale (West Virginia Geological and Economic Survey [WVGES], 2004). Part of the tunnel was drilled through nearly pure quartz arenite of Lower Pennsylvanian Nuttall sandstone. The mineralogy represented optimum potential for the creation of hazardous exposures to airborne quartz, a form of crystalline silica (Krizan, 2000).

The Hawk's Nest Tunnel was originally designed to be 32 ft in diameter. When silica-rich deposits—some approaching 100% quartz—were found, the diameter was increased to 46 ft (Bragg) for approximately one-third of its length (Cherniak, 1986). In many respects, the tunneling also served as quartz mining. The silica-rich debris from these deposits was removed and transported to Boncar, where it was stored for future use in the electrometallurgical complex. Silica was and is still used to produce ferrosilicon, a key fabrication component of stainless, alloyed and carbon steels. The revenue from the removed silica helped offset the cost of tunnel construction (Bragg).

Work Practices

Almost 5,000 men constructed the tunnel and approximately 2,500 of this number worked underground at least part-time. The largest number of tunnel workers at one time was 600 (Cherniak, 1986). The tunnel work schedule was 6 days a week with two 10-hour shifts per day (Lucas & Paxton).

Work in the tunnel used the heading-and-bench method of drilling. Ten "heading" drills bored horizontally while six "jackhammer" drills simultaneously penetrated the unexcavated bench. Hole depth ranged from 10 to 12 ft. Each hole was packed with dynamite, the shaft vacated and the dynamite detonated. Following detonation, the contractor reported that workers were not allowed to re-enter the area for 2 hours to allow the dust to settle. Workers gave differing accounts, claiming that the air was full of dust when they were directed to initiate mucking, the process of hauling away blast debris in cars pulled by small locomotives called "dinkeys."

Wet drilling is one method used to control dust exposure during drilling. Although varying accounts exist, it appears that the horizontal drills were largely the "wet drifter" type and that water was used on them most of the time. One reason may be that the water facilitated dust removal from the hole, improving drilling progress. Despite having water connections for dust control, the jackhammer drills were run dry because they could cut twice as fast as when wet. Eyewitnesses reported that water was used on the jackhammer drills only when inspectors arrived (Orr & Dragan, 1981). Despite conflicting reports following the disaster, it seems apparent that a significant amount of drilling was performed with little or no dust control. Tunnel progress was 250 to 300 ft per week at its peak. After the tunnel was constructed, mining experts suggested that such progress would have precluded the use of water to suppress construction dust from the jackhammer drills.

As the photo on page 28 (left) shows, dust was a problem even at the mouth of the tunnel; it was also not limited to the worksite. Typical of that era, there were no change rooms and no end-of-shift shower facilities. Workers went home in the same clothes they wore in the tunnel. Wives reported that the "powdery tunnel dust" collected in the hair, eyebrows and on the clothes of their tunnel-worker husbands. When they came home and changed clothes, the quartz dust reportedly scattered on the floor (Jordan, 1998). Although largely unstudied, family members likely experienced exposures and health effects due to secondary silica dust carried home by their husbands and fathers.

Dust may have been the most obvious and the most severe exposure experienced by tunnel workers, but it was not the only hazard. Carbon monoxide from mining equipment also posed serious hazards. In 1981, a surviving worker recalled having loaded up to 15 workers at a time on muck cars to be

> ***"I remember it as a bad job. But at the time, a job was a job. That was the only thing there was in this whole country. When you got some babies looking at you for something to eat you're going to work."***
>
> ***—B.H. Metheney, Hawk's Nest Tunnel worker March to October 1930 (Orr & Dragan, 1981)***

Hawk's Nest Tunnel Timeline

Facts about the 1930s

U.S. population
123,188,000
in 48 states

Life expectancy
Male: 58.1
Female: 61.6

Average salary
$1,368

Unemployment
25%

Food prices
•Quart of milk: 14 cents
•Loaf of bread: 9 cents
•Pound of round steak: 42 cents

Note. *Kingwood College Library, 2001.*

hauled outside to get fresh air so they could resume work (Cherniak, 1986).

Considering the tough economic times, the tunnel project had an amazingly high turnover rate. The average length of employment was approximately 15 weeks; 60% of workers stayed less than 2 months. Although both terminations and resignations were frequent, the large number of available and willing replacement workers allowed the project to make steady progress.

Silica

Silicosis can exist in three forms: chronic, accelerated and acute. Chronic silicosis, the most common form today, occurs after years of exposure to typically low levels of silica dust. Accelerated silicosis results from higher exposures to silica dust and develops over 5 to 10 years. Acute silicosis typically occurs following exposures to high concentrations of silica dust and symptoms develop over a short period following exposure. Most of the known deaths at Hawk's Nest were from acute silicosis. Undoubtedly, many other workers' life spans were reduced from the effects of accelerated silicosis.

Silica terminology can be confusing. Silica is a term for silicon dioxide (SiO_2) and exists in crystalline and amorphous forms. Amorphous silica (CAS number 7631-86-9) is the noncrystalline form of SiO_2 and is much less toxic than crystalline silica. Crystalline silica (CAS 14808-60-7) forms in the earth under conditions of high heat and pressure. Synonyms for crystalline silica include agate, amethyst, chalcedony, cherts, cristobalite, flint, onyx, pure quartz, rose quartz, sand, silica flour, tridymite and Tripoli (Lewis, 2004). Crystalline silica comes in seven forms, quartz being the most common (Staff, Branch of Industrial Minerals, 1992).

One of earth's hardest minerals, quartz resists erosion and is soluble in very few chemicals. It is also the cause of most cases of silicosis (U.S. National Library of Medicine, 2006). Epidemiological studies have shown an increased risk of lung cancer for workers exposed to silica.

Crystalline silica is a common component of soil and rocks, and workers involved in mining, tunneling and other earthmoving occupations are typically at risk. Quartz is common in sandstone, a sedimentary rock typical of the Hawk's Nest area mineralogy. While sandstone quartz can range from trace to major amounts, the rock drilled for the Hawk's Nest Tunnel was nearly pure quartz in places.

Silicosis

Silicosis is typically caused by exposure to respirable crystalline silica particles less than 10 µm in diameter. According to NIOSH (2002a), the most important factor in the development of silicosis is "the product of the concentration of dust containing respirable silica in workplace air and the percentage of respirable silica in the total dust." Respirable versus nonrespirable silica is largely a factor of particle size. Quartz particle sizes smaller than 1 µm are believed to be the most harmful. Larger silica particles impact and lodge in the major airways and do not reach the lungs. As is the case with most toxic substances, the length of exposure is also an important consideration in the development of silicosis. Silicosis has a latency period that varies from several months to more than 30 years (NIOSH, 2002a).

Silicosis is characterized by the development of scar tissue—or nodules—in the lungs. Recovery from advanced silicosis is unlikely; there is no known cure even today. Shortness of breath on exertion is usually the first and most common symptom. A limited ability to expand the chest is the most common physical sign of silicosis. There may be a dry cough, sometimes severe. Breathing difficulties may incapacitate the worker for even light physical exertion, and in extreme cases there may be shortness of breath even while at rest. Loss of appetite and weight are common (NIOSH). Over time, the lungs' ability to extract oxygen from breathed air is progressively reduced and may ultimately result in respiratory failure (Lewis, 2004).

In addition to silicosis, workers exposed to respirable crystalline silica have an increased risk of developing lung cancer, pulmonary tuberculosis, airway diseases and various other adverse health effects (NIOSH, 2002a). Individuals that work in mining, sandblasting, construction, masonry, glass manufacturing and railroad construction have the greatest risk of developing silicosis (Egan, 2004).

Exposure Standards

In the early 1930s, there were no silica exposure standards in the U.S. Today, OSHA and other agencies have standards, but with significant variation. The OSHA general industry permissible exposure limit (PEL) and MSHA standard (metal mines) for respirable quartz is $(10\ mg/m^3)/(\%SiO_2 + 2)$. The OSHA and MSHA standards vary depending on the percentage of free silica in the sampled dust. In most cases, the TLV ranges from 0.1 to 3.3 mg/m^3. The higher the percentage of free silica in the sample, the lower the TLV will be (MSHA, 2006). NIOSH recommends a crystalline silica exposure limit of 0.05 mg/m^3. The ACGIH threshold limit value (TLV) has been reduced twice since 2000 and is currently 0.025 mg/m^3. Despite regulatory controls, silica remains the chief cause of pulmonary dust disease. According to OSHA, 2 million workers are exposed to silica each year.

The duration of exposure which is associated with the development of silicosis varies widely for different occupations. The average duration of exposure required for the development of silicosis in sandblasters is 2 to 10 years; in molders and granite cutters, about 30 years; and in hard rock miners, 10 to 15 years. Variation in individual susceptibility exists, with certain workers showing radiological evidence of the disease years before fellow workers who are similarly exposed.

The International Agency for Research on Cancer (IARC) upgraded crystalline silica to a "Group (1) human lung carcinogen" in 1997. The U.S. National Toxicology Program moved silica into the "known to be a human carcinogen" category in 2000. In 2003, a study by OSHA and NIOSH "corroborated the reported association between crystalline silica and several respiratory and autoimmune diseases" (Egan, 2004).

What Was Known about Silica in the 1930s

Were the companies involved with the Hawk's Nest Tunnel aware of the dangers presented by human exposure to crystalline silica? While the answer is uncertain, clearly the contractor and owner of the tunnel had the responsibility to have been familiar with the health and hazard information then available.

The dangers of silica exposure have been recognized since the days of ancient Greeks and Romans. In Peru from 1545 until the mid-1800s, 8 million slaves died in the Spanish mines of Cerro Rico, many from silicosis. Life expectancy in the Spanish mines, which had no dust controls, ranged from 6 to 18 months.

Having documented disease problems dating to the 1790s, Europe appears to have had a greater awareness of the health dangers of silica dust than existed in the U.S. in the early 1900s (Silicosis and Silicate Disease Committee, 1998). Wet drilling had been introduced in England in 1897 and South Africa had banned dry drilling in 1911. By 1914, the federal Bureau of Mines recommended annual physical examinations for workers exposed to silica dust, and in 1917 the U.S. Public Health Service widely distributed a bulletin about silicosis (Cherniak, 1986).

Several tunnel work practices contributed to increased silica exposure. According to a NIOSH case study, Hawk's Nest employers took "almost no precautions against inhalation of silica." No silica air sampling was performed, dust levels in the tunnel were not measured, respirators were not made available to tunnel workers except those directly employed by Union Carbide, and the tunnel ventilation system was inadequate and often out of service (Lang).

Death from "Tunnelitis"

Like much of the information about Hawk's Nest, the number of workers who died from acute silicosis is uncertain. Estimates range from as low as 400 (Hawks Nest Tunnel, 1936) to 1,000 (NIOSH, 2002b) to 1,500 (Nash, 2004). Official estimates place the number at 432, but a more realistic estimate of the deaths caused by acute silicosis is 764 (Cherniak, 1986). More than three-quarters of the workers who died were African-American (Douglass, 2004). Approximately 1,500 additional workers are estimated to have suffered from the disease (Bragg).

Although tunnel worker deaths started before construction was complete, work on the tunnel did not slow. To dispose of the bodies, a local undertaker was paid $50 for each burial. A company physician reportedly told families of the dead and dying workers that they suffered from the nonexistent disease "tunnelitis." Others were diagnosed with pneumonia while deaths of African-Americans were attributed by employer representatives to the race's claimed susceptibility to lung disease (Bragg), the general inability to resist disease and poor nutritional habits (Cherniak, 1986).

> ***"The tunnel is not a pretty picture of our culture during the Depression. But if we reflect on it and learn from the mistakes that were made, then we can hope that the workers' deaths will not be in vain."***
>
> *—William "Rick" Crandall, associate professor, Concord University, WV ("Concord associate professor," 2001)*

Reactions to Hawk's Nest

In 1936, a congressional subcommittee investigated Hawk's Nest and found that "there was an utter disregard for all" approved methods of dust prevention during tunnel construction. The subcommittee went on to report that the tunnel was completed "with grave and inhuman disregard of all considerations for the health, lives and future of the employees" (Hawk's Nest Tunnel, 1936). Although highly critical of working conditions in the tunnel, the subcommittee failed to take further action.

Despite inaction by Congress, attention to silicosis brought about by the Hawk's Nest Tunnel did help to reduce silica exposures as employers improved ventilation, increased use of wet dust control methods and expanded use of respiratory protection. Increasing financial liability from worker lawsuits occurred as U.S. courts became more willing to hold employers liable for actual and punitive damages. Many leading national news publications including *Time* and *Newsweek* ran stories about Hawk's Nest.

The press exposure and increasing financial penalties greatly heightened the awareness of silica hazards. Hawk's Nest even spawned a popular blues song, "Silicosis Is Killing Me." By 1937, a total of 46 states passed laws relevant to workers with silicosis and many incorporated silicosis into state workers' compensation schedules. By the end of the decade, silicosis had become a recognized occupational disease.

Hawk's Nest contributed to passage of the Walsh-Healy Act of 1936, which made it unlawful for companies supplying the federal government to carry

Lessons Learned

What the SH&E profession can learn from revisiting the Hawk's Nest Tunnel disaster

1) The SH&E professional has a responsibility to stay abreast of current information about occupational hazards and their controls.

2) It is unacceptable for an employer to take advantage of poor and/or uneducated people who are willing to compromise their own safety and health for a paycheck.

3) The SH&E professional has an obligation to advise management and workers when the protection of people is unacceptably at risk.

4) Crystalline silica is an occupational hazard, although a less-frequently occurring hazard than in the early to mid-20th century.

5) Effective dust control measures and other controls must be implemented when there is a chance of worker exposure to airborne crystalline silica.

out contract work under working conditions that were unsanitary, hazardous or dangerous to the safety and health of employees. The act remains in effect today.

Hawk's Nest also led to the formation of the Air Hygiene Foundation (AHF) in 1936, with 200 corporations and trade associations as members. One of AHF's goals was to establish standards for the control of industrial dusts. Formation of AHF led to the establishment of the American Conference of Governmental Industrial Hygienists (1938), the American Industrial Hygiene Association (1939) and the initial development of TLVs.

Silica Exposures Today

With an event the magnitude of Hawk's Nest, silica-related problems might not be expected to exist 75 years later. Indeed, silicosis disease is becoming less of a problem in the U.S. From 1968 to 2002, silicosis was recorded as the underlying or contributing cause of 16,035 deaths. During the same period, the silicosis death rate decreased from 8.91 to 0.66 per million persons age 15 and older, translating to a 93% decline in the overall silicosis mortality rate (CDC, 2005).

CDC cites two primary reasons for the declining rates of silicosis in the U.S. First, deaths in the 1960s and 1970s occurred before introduction of national compliance standards for silica dust exposure. MSHA and OSHA PELs were applied starting in the early 1970s. MSHA regulations included control of mine dust in underground coal mines. These regulatory limits, coupled with other recommendations such as those by NIOSH in 1974, led to reduced silica dust exposures. Increased use of respiratory protection, warnings and illness documentation has also helped. Second, a declining employment in heavy industries such as mining has reduced the number of workers involved in dust-producing work activities.

Despite continuous reductions in mortality associated with silicosis, silica overexposure remains widespread, indicating a need for hazard surveillance and development of workplace-specific interventions. The U.S. Department of Energy's (DOE) radioactive waste storage project at Yucca Mountain has received considerable attention due to worker claims of silica overexposure. The project involved drilling a 25-ft-diameter tunnel approximately 5 miles into volcanic tuff containing silica. Drilling was performed by a massive tunnel-boring machine nicknamed "the Yucca mucker." At the beginning of tunneling in 1992, dust masks were issued to protect against silica exposure. DOE acknowledges that respiratory protection was not consistently applied in the project's early years and that regulatory limits for airborne silica were exceeded at times during tunneling (DOE, 2004). Eerily similar to Hawk's Nest, early Yucca Mountain workers were not informed of the potential presence of silica. They also described dusty work conditions in the tunnel and expressed the willingness to put up with adverse conditions for fear of losing their paychecks (Young, 2004).

In January 2004, DOE established the Yucca Mountain Silicosis Screening Program for approximately 1,200 to 1,500 former Yucca Mountain workers involved in tunnel mining activities.

Conclusion

George Santayana said, "Those who refuse to learn from history are condemned to repeat it." Has the safety profession learned all that needs to be learned from Hawk's Nest? Is that why the event has been largely forgotten? Or are we, like generations that have lived before us, declining to learn from mistakes and therefore dooming ourselves to repeat them? The author does not believe that another large-scale event of acute silicosis like that at Hawk's Nest is likely to occur during the 21st century in the U.S. Workplace monitoring by employers and regulators, public scrutiny, organized labor oversight and vastly improved communication all serve to reduce that likelihood. Yet, 75 years after completing the Hawk's Nest Tunnel, silicosis is still a significant occupational health issue.

The Hawk's Nest Tunnel history pages serve to remind us of the conditions from which the safety profession was born, and why there continues to be a need for safety and health vigilance against workplace hazards. Employers usually hire SH&E professionals and establish safety programs to protect the safety and health of workers. One of the deficiencies at Hawk's Nest in 1930-31 was either the lack of awareness of silica hazard information then available, or ignoring that information. Today, the effective SH&E professional must make every effort to stay informed about safety and health hazards and all available information about those hazards, avoiding technical obsolescence by keeping abreast of emerging safety knowledge. While employers and line managers retain the responsibility for safety and health performance, it is essential that the SH&E professional help management fulfill that responsibility. It is hard to imagine a scenario worse than one in which a serious illness or death results from an SH&E professional's failure to stay informed and be knowledgeable of the hazards that s/he is supposed to help control. The Internet makes staying abreast of the latest information easier than ever.

Hawk's Nest is also a reminder that desperate people can be victimized in the workplace. Reports are common today of Latino workers suffering silently amidst poor safety and health practices and illegal work conditions in construction and other industries. Like the 1930s workers at Hawk's Nest, disadvantaged Latinos are often unwilling to raise questions about safety and health practices for fear that doing so could result in job and income loss. In China, reports are emerging of primitive conditions in which workers have no respiratory protection. In one case, 47% of the workers at an agate mill were reported to have contracted acute silicosis (Wang & Christiani, 2003).

Loyalty to an employer is important and expected, but as stated by Dr. Peter Strahlendorf (2004) of the Ryerson University School of Occupational and Public Health, "Loyalty should not be blind, however, and so other values may be in conflict with loyalty if the employer's goals are not in themselves worthy in the circumstances." Hawk's Nest is an example of a time when economic circumstances resulted in poor people being willing to work in unhealthy conditions. That desperation combined with poor worker safety knowledge made the Hawk's Nest Tunnel workers of the 1930s—and continues to make some workers today—vulnerable to safety and health abuses. It is a professional and ethical obligation of SH&E professionals to work to prevent such abuses. Two of the fundamental canons of the ASSE Code of Professional Conduct are that SH&E professionals shall:

1) hold paramount the protection of people, property and the environment;

2) advise employers, clients, employees or appropriate authorities when our professional judgment indicates that the protection of people, property or the environment is unacceptably at risk.

The story of the Hawk's Nest Tunnel is a stark reminder of just how serious that responsibility is. Hopefully, the increased awareness of respirable hazards and the vigilance of SH&E professionals will prevent a repeat of America's worst industrial disaster. ■

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