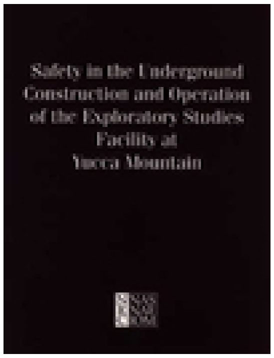

Safety in the Underground Construction and Operation of the Exploratory Studies Facility at Yucca Mountain

U.S. National Committee on Tunneling Technology, National Research Council

ISBN: 0-309-57347-5, 176 pages, 8.5 x 11, (1995)

Safety in the Underground Construction and Operation of the Exploratory Studies Facility at Yucca Mountain

Proceedings of a Symposium held at
Yucca Mountain and Las Vegas, Nevada
November 30-December 1, 1993

U.S. National Committee on Tunneling Technology
Geotechnical Board
Board on Energy and Environmental Systems
Commission on Engineering and Technical Systems
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1995

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This project was supported primarily by the Department of Energy, Yucca Mountain Project Office. Other agencies provided core support for the activities of the Geotechnical Board under the auspices of which this project was initiated. These agencies include the Department of the Army (Defense Nuclear Agency), Department of the Air Force (Air Force Office of Scientific Research), Department of the Interior (Bureau of Mines and Burreau of Reclamation), Department of Transportation (Federal Transit Administration), Department of Energy (Office of the Superconducting Super Collider), Department of the Army (Defense Nuclear Agency, Nuclear Regulatory Commission, and National Science Foundation—MSS-9203139.

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Library of Congress Catalog Card Number 95-68330
International Standard Book Number 0-309-05243-2

Printed in the United States of America

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Preface

In 1987, Congress instructed the U.S. Department of Energy (DOE) to study Yucca Mountain, located on the Nevada Test Site, as a potential repository site for spent nuclear fuel and high-level radioactive waste. To determine the suitability of the site for that purpose, the Exploratory Studies Facility (ESF) will be constructed at Yucca Mountain. There scientists and engineers will perform tests and experiments to evaluate Yucca Mountain as a potential repository. In addition, ESF construction and excavation data will be used to guide potential repository design and construction.

Underground construction safety management is challenging on any project, but it will be particularly so at the ESF. Many tests and experiments will be conducted even as the ESF is being constructed. Construction workers, scientists, and engineers will be working in close proximity. ESF construction and operation will be concurrent.

To increase DOE project personnel's level of understanding regarding underground construction safety management, the U.S. National Committee on Tunneling Technology held a symposium on underground safety November 30 through December 1, 1993, in Las Vegas, Nevada. Experts from the United States and abroad presented their experiences with safety management and practice, as well as lessons learned on their respective projects.

Within these proceedings, papers and presentations from the symposium have been organized into two sections. The first of these addresses the broad topic of underground safety management. Papers and presentations within this section discuss the process of planning for safety, the value of approaching underground construction with a mindset conducive to safety, safety regulations and the regulatory environment, interpretation of safety regulations, and the enforcement process.

Papers in the second section present several underground safety management experiences in the United States and around the world. Each of them illustrates organization for safety management and gives examples of successful approaches to creating a safe underground work place. To some degree, each of them addresses the particular issue of safely integrating different tasks and different safety cultures underground, a situation certain to be encountered at the ESF.

Each of the authors has some insight to offer those who are planning and carrying out the construction and operation of the ESF. These proceedings are being published to make their insights available to those who were not able to attend the symposium, as well as to those who did attend.

Acknowledgements

The U.S. National Committee on Tunneling Technology acknowledges the assistance of the Yucca Mountain Project Office of the U.S. Department of Energy in the conduct of the symposium and for arranging a site visit for the participants to the Exploratory Studies Facility. The committee thanks all of the speakers for their contributions at the symposium and for their help in preparing the proceedings.

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List of Acronyms

ANSI	American National Standards Institute
CFR	Code of Federal Regulations
DOE	Department of Energy
ESF	Exploratory Studies Facility
ET	Eurotunnel
FAR	Federal Acquisition Regulation
FMECA	failure mode, effects, and criticality analysis
FTA	fault-tree analysis
KY	Kiken Yochi
LEL	lower explosive limit
MMSD	Milwaukee Metropolitan Sewerage District
MSHA	Mine Safety and Health Administration
MWPAP	Milwaukee Water Pollution Abatement Program
NLRB	National Labor Relations Board
OSHA	Occupational Safety and Health Administration
REECo	Reynolds Electrical & Engineering Company
SKB	Svensk Kärnbränslehantering AB
SNL	Sandia National Laboratories
TBM	tunnel boring machine
TML	Transmanche Link
WID	Waste Isolation Division
WIPP	Waste Isolation Pilot Plant
YMP	Yucca Mountain Project

Underground Construction Safety: Be Sure You're on the Right Track

Joseph E. Fitzgerald, Jr.

ABSTRACT

Taking care of safety means accepting responsibility for safety at every level, identifying hazards, training and equipping workers properly, and ensuring that they will be taken care of in emergencies. The Department of Energy (DOE) is striving to demonstrate the leadership necessary to make excellence in safety and health the rule rather than the exception.

Of DOE initiatives underway, contract reform and external regulation have particular relevance to the Yucca Mountain Project (YMP). DOE is changing its contracting process to better define expectations, measure performance, improve incentives, and strengthen departmental management of contracts. While a regulatory regime demands more in the way of demonstrable or verifiable compliance with specified regulations, it will not, of itself, foster a safe work place; DOE and industry must work to create a safe operating environment.

Two challenges stand out as areas for improvement in safety and health at the operating level: (1) the need for better safety accountability and (2) the need to better instill safe practices and behavior. Given the hazards inherent in underground construction, the industry has made commendable strides in accident prevention. However, more can and should be done to increase margins of safety in what remains a dangerous enterprise.

INTRODUCTION

The subtitle of this paper, Be Sure You're on the Right Track, means as always, that we have a distinct choice in managing safety: either let safety take care of itself or take care of safety.

The first course—one that, unfortunately, all of us are familiar with—assumes that workers will always understand and follow procedures. It assumes that if procedures do not exist, the workers' experience will keep them out of harm's way and that good judgment will prevail in those hazardous situations that might be encountered. It has meant, for some managers, letting the subcontractors take care of themselves.

Taking care of safety, on the other hand, means accepting responsibility at every level for the workers on the ground and in the tunnel. It means identifying the hazards workers will face, training them for effectiveness, equipping them properly, and ensuring that they will be taken care of in emergencies.

What is both right and wrong with safety practices must be confronted to assure that past mistakes and past accidents will not be repeated. To accomplish this, the status quo (the convention that has us believe that "it must be right, it's the way we've always done it") must be challenged. Lessons from accidents and near-misses must be extracted and defensiveness or embarrassment must not preclude an honest and open exchange on future prevention. As safety professionals are apt to say, it is the only good thing that comes from an accident.

WORKER SAFETY AND HEALTH

Worker safety and health has been given a very prominent place by Energy Secretary Hazel O'Leary. She has challenged DOE to demonstrate the leadership necessary to make excellence in safety and health the rule rather than the exception. Tangible actions have been taken to aggressively move the department from a largely reactive posture to one that establishes accident prevention as its goal and employee involvement as its mode of operation. A number of initiatives have been announced and are underway; two are discussed below.

Contract Reform

The first initiative is contract reform. DOE is developing changes to its contracting process that will better define expectations, measure performance, improve incentives, and strengthen departmental management of contracts. This reform effort addresses significant issues, such as explicit consideration of the safety record of contractors, including subcontractors, who bid on DOE work. Also considered are performance criteria for safety and health built into contracts, providing both incentives and penalties for on-the-job performance. Yet another issue is the extent to which DOE will indemnify contractors for civil fines and penalties, as well as liability for third-party claims. In addition, to what extent will DOE reimburse contractors for litigation, judgments, and compliance costs? DOE is assessing risk-sharing, to ensure that contractors appropriately shoulder the burden of poor performance while sharing in the rewards of good performance. The task group reviewing these questions delivered its recommendations to the Secretary, and publicly released them, in February 1994.

External Regulation

Another DOE initiative addresses external regulation. In May 1993, Secretary O'Leary announced her endorsement of work-place regulatory enforcement at DOE facilities by the Occupational Safety and Health Administration (OSHA). O'Leary recognized the need for a transition period of three to five years to assess resource issues and determine how future regulatory enforcement actions will be handled. She also expressed a willingness to consider the issue of regulatory oversight by the Nuclear Regulatory Commission. Whereas until now the YMP, along with the Waste Isolation Project Plant, has occupied a rather unique niche within DOE because of its legislated external oversight, it is unlikely this singularity will persist much longer.

The issue of regulatory oversight of big runnel projects is a top-priority topic that should be kept in perspective. Despite some views to the contrary, regulatory oversight will not, in any way, relieve DOE of the responsibility to enforce the safety and health provisions of contracts, nor in any way relieve DOE or its contractors from liability for accidents for which culpability can be shown. More importantly, while a regulatory regime does demand more in the way of demonstrable or verifiable compliance with specified regulations, it will not, of itself, foster a safe work place.

SAFETY EXPERIENCE IN UNDERGROUND CONSTRUCTION SAFETY

A recent review of OSHA's data base bears out that safety in U.S. underground construction has increased over the years. We are now far removed from the exceedingly dangerous times of yesteryear, when tunneling was performed using dynamite and black powder and canaries were used for methane detection. For example, in 1890, 68 workers died as they bored a gas runnel under what is now Roosevelt Island in New York City. At least 50 tunnel workers died from January to May 1906 in the construction of Pennsylvania Railroad tunnels. Thirteen runnel workers died while building the Holland Tunnel in the 1920s.

There are still, however, holdovers from those tragic times in underground construction. For example, to this day, the notion persists in many circles that one fatality per mile is a statistical norm for tunnel construction and should be the expected price to pay for the hazards involved. However, a review of 3,496 fatalities investigated by OSHA for the five-year period of 1985 through 1989 shows that 7 were attributable to tunnel construction projects. Of those 7 fatalities, 3 resulted from 1 incident, the methane explosion at the Milwaukee runnel project. However, these projects involved many miles of construction. It is also easy to lose sight of how much ancillary surface construction is performed in support of tunnel excavation and the risk associated with it. In 1992, surface construction accidental fatalities numbered 18, as compared with 5 underground, according to Mine Safety and Health Administration data.

While the overall safety record of underground construction has improved considerably, there are obviously some big qualifiers. As with other heavy construction activities, safety lapses have been, and remain, unforgiving for the workers involved. The following account is *not* from yesteryear, but in fact is from a recent issue of the New York Times.

> Many of the men in shaft No. 23 knew Anthony Oddo, 33, who was killed last Wednesday in a water shaft... in Queens as a 16-ton construction winch plunged into the hole. He was the 20th man to die building ... the water tunnel project [under New York City], begun in 1970.... A coworker, John Moon, 53, survived an accident in 1977 in a shaft in the Bronx, an example of how even the smallest of dangers can turn deadly in runnel work. He was struck on the left side of his face by a falling clump of ice the size of a basketball, formed by tiny droplets of water that froze and accumulated on the shaft's wall .... Ice is perhaps the least obvious hazard: every day, cranes and winches lower into the holes enormous drills, bulldozers, [and] buckets that weigh 32,000 pounds when filled with rock. Rocks fall and tunnels flood, sometimes fatally.
> (The New York Times, 1993)

Given the potential for a catastrophic accident under these everyday dangers, not only must we stay vigilant, but we must continue to challenge the status quo, particularly the attitude held by some that an occasional accident is to be expected in underground work.

Reliance on an Experienced Contractor

Several DOE construction accidents over the past few years bear out these concerns. In Hanford, Washington, two separate fatal accidents occurred where experienced workers were operating in unfamiliar work environments without suitable pre-job planning and hazard analysis. In Oak Ridge, Tennessee, in November 1993, an experienced construction subcontractor was killed while inadequately performing a hoisting operation with inadequate equipment. Finally, at the Superconducting Supercollider construction site in Texas in January 1993, a tunnel worker was fatally injured when a segment of tunnel liner fell on him.

In this last case, the subsequent investigation found that DOE and its construction manager relied unduly on the construction contractor's previous experience and positive safety record on another project for assurance that safety would be properly addressed. However, as the investigation determined, at the time of the accident the contractor was using a different tunnel boring machine than at the previous job, with differing controls, in a different size tunnel, within a different geological formation, and with a crew that had, in part, changed job assignments since their last tunnel project.

These issues show that while previous experience is a valuable asset, it cannot be used as a crutch to ensure effective safety and health performance. We have learned the hard lesson that both DOE and its operating contractors must manage, oversee, and be accountable for safety and health for subcontractors and prime contractors alike at all phases of construction.

WORKER SAFETY AND HEALTH ISSUES AT YUCCA MOUNTAIN

Following are several important construction management issues and concerns bearing on safety programs at the Exploratory Studies Facility. These include considerations of cost, liability, and contract management.

Cost Considerations for Safety

An obvious issue in construction at the YMP, in terms of both safety and cost, is the remote location of the project site. In addition to cost considerations such as personnel and material transport during construction, extensive planning and preparation will be essential to provide the necessary emergency response capability. The standard applicable to emergency response in underground construction is quite prescriptive in terms of rescue team make-up and its proximity to the project site. It will present a challenge to fulfill this responsibility in the most cost-effective manner without compromising project safety.

Subcontractor Management—Responsibility and Liability

In parts of the DOE complex, as in private industry, many construction managers and owners are reluctant to dictate or become involved in subcontractor safety and health programs, due to concerns about increased liability exposure, whether real or perceived. In the federal sector, these liability concerns have been heightened due to the much-publicized case of the Aberdeen Three in which three civilian federal employees of the Army Aberdeen Proving Ground were convicted of environmental crimes. This unfortunate and unintended interpretation by some in the industry has led to an increasingly defensive posture, one in which federal and private sector managers distance themselves from hazardous or risky activities for which they are responsible.

Yet too often missed is the perspective that most liability cases center around malfeasance or intentional and illegal acts, not good-faith efforts to comply with applicable regulations. Experience tells us that legal precedent leans against those who have the responsibility and authority to enforce job site safety and health but fail to use it. This notion is borne out by a March 1990, Washington State Supreme Court ruling that upheld the liability of both general contractors and owner/developers for safety and health on construction work sites, even where the contractor manager or owner chose not to assume control over project subcontractors. The bottom line here is that avoiding management responsibilities may actually increase liability.

Worker's Compensation—Avoiding Injuries and Saving Money

There are also economic reasons for DOE and its construction managers to proactively enforce contract safety and health provisions. In DOE, most contractors are indemnified and reimbursed for worker's compensation and other losses, or wrap-up policy premiums themselves are reimbursed, as with the Superconducting Supercollider. In both instances, successful management of safety and health can save considerable sums of money that would otherwise be used to pay compensation claims.

Over the past ten years, accidents have cost DOE over one half of a billion dollars in injury costs that are typically insured under worker's compensation. And this is a minimum, since DOE incurs more than medical costs when workers are injured. Termed indirect costs, these include a loss of productivity of the injured workers and their coworkers, transportation costs to medical facilities, damaged property, and significant project delays. There are also the costs of third-party claims filed on behalf of the injured. These hidden costs of accidents can exceed direct, insurable costs by factors ranging from two to four, depending on the severity of the injury. For example, the total estimated cost for a lost workday injury or illness in construction work today is about $24,000, including claims. DOE had 3,000 such cases last year.

UNDERGROUND CONSTRUCTION SAFETY: WHAT IS IMPORTANT?

Experience has shown a weakness at DOE construction sites in the way potential hazards are identified, analyzed, and mitigated before work begins. The tendency is to rely on the expertise and experience of the contractor to keep out of trouble, rather than ensuring that the project team carefully walks through planned activities with an eye toward "what ifs." It is illustrative that four of the five construction fatalities at DOE sites over the past two years had inadequate planning as a major cause. This is a particular irony in that safety planning is a well-established, obligatory part of doing work on the nuclear side of DOE' s responsibilities, where the risks to life and limb are arguably much lower than in conventional construction.

DOE is meeting the need for more explicit departmental direction on construction job hazard analyses through the issuance of the upcoming DOE Order 5480.9A, "Construction Project Safety and Health Management." Within this Order, hazard analyses are addressed through a required preliminary hazard analysis prior to the commencement of a construction project and an activity hazard analysis prior to the commencement of work on any phase of the project.

About 20 percent of all construction injuries occur within the first month a worker reports to a new work site; about 90 percent fall within the first 12 months. From past program assessments and accident investigations, it appears that inadequate training is probably the most common root cause of construction injuries. For underground construction, an assessment at one site found that no procedures existed for training workers on tunnel construction equipment. Many sites emphasize classroom-style general safety training, with too few hands-on exercises. In many instances, there is not much in the way of defined training performance objectives coupled with testing or observation to validate training effectiveness.

A construction contractor needs to ensure that each employee entering a work site has—through experience, training, and where required, certification—the skill and knowledge necessary to safely perform the assigned tasks. A comprehensive training program at a construction site should include the following: (1) work-site safety and health orientation; (2) training prior to each phase of construction; and (3) regular "toolbox" safety and health training at the job site.

However, this issue goes beyond a more explicit set of requirements. In a major project such as the YMP, a large influx of both new and experienced workers is likely. A number of skills are unique to underground tunnel construction, and it is well-known that procedures tend to change from job to job. In the past, employees usually learned these skills and procedures while training on the job under the guidance of an experienced worker. The adequacy of the training, as with much on-the-job training, varied with the trainer involved and the amount of time available to learn necessary skills. Without clear performance criteria and skills testing—not just for machinery operation, but also for hazard recognition, emergency response, and personal protective equipment—there is little assurance that new workers will be adequately prepared and experienced workers will not bring bad habits to the new job.

Given the unique challenge of safely evacuating workers from a tunnel in the event of a fire, a cave-in, or an injury, a comprehensive emergency preparedness program is not merely a facet of a complete safety program, it is an absolute necessity. Such a program must provide for clear procedures, thorough training, and the availability and use of protective equipment.

A number of valuable lessons derive from the N-Tunnel flammable gas flashover accident that occurred at the Nevada Test Site on October 30, 1992. Although the contractor had good operational procedures in place, that accident, involving three workers at a tunnel face several hundred feet underground, exposed weaknesses in emergency planning. DOE's Nevada Operations Office investigation found, for example, that the placement of equipment in the runnel impeded egress. Similarly, air hoses were tied off by the workers to the tunnel walls, slowing escape with protective equipment intact. No provision was made for the positioning of rescue workers and equipment. A coworker rushed into the runnel to assist the injured workers without benefit of protective equipment, thereby potentially risking his life.

To its credit, the Nevada Operations Office staff, in conjunction with the Reynolds Electrical and Engineering Company, has reflected on the importance of worker training and expanded procedures to correct these problems. This is obviously an area where we can all help each other in terms of approaches proven effective in planning and training for emergencies.

INVESTMENTS IN PREVENTION

We, in the Department, face a dual challenge in terms of meaningful improvements in safety and health at the operating level. The first challenge is the need for better accountability for safety, accountability that does not stop with the operating contractor, but instead flows between DOE, the prime contractor, and the various subcontractors. The second challenge is to strengthen how we instill safe practices and behavior in doing construction. The first challenge is already one of the central topics of this symposium; following are some thoughts on the latter challenge, improving how the construction operations are conducted from a safety standpoint.

First, significant improvements can be made in the conduct of operations in construction from a safety standpoint. Conduct of operations consists of the philosophy and systematic process that guide safety in everyday operations and provide the necessary margins of protection against the inevitable human errors that take place. It encompasses hazard analysis, procedures, training, pre-job planning, and emergency planning, to name a few key components. If approached adequately, these safety provisions are formally defined, trained against, and made an integral part of routine operations.

Coupled with safety-based engineering design and review, good conduct of operations provides what could be called defense in depth. That is, the approach to safety is one that provides sufficient design and operational provisions such that if one or even two safety features fail (for example, a hazard analysis fails to predict flammable gases or a piece of personal protective equipment fails to function) the situation remains recoverable, with other options and backups to prevent worker injury or death.

All of the construction fatalities within DOE over the past two years, with one possible exception, could have been readily avoided with management attention to identifying and analyzing work-place hazards, planning work, developing appropriate procedures, and training workers in safe practices.

Specific to tunnel projects, change control is a vulnerability that deserves attention. Any time change is introduced, whether between two work shifts, between two different phases of construction, between different construction jobs, or even with the entry of new workers, the likelihood of mishaps increases dramatically. Change control is a critical and often overlooked part of conduct of operations. It is also an aspect of work practice that is amenable to improvement through a behavior-based safety approach.

The concept of approaching hazardous construction work—particularly, the often unconventional work required in tunneling—from a systems safety standpoint, making sure all the right bases are touched, is overdue in what is one of the most dangerous occupations in the world. While human error will always be with us, more can be done to make such errors less frequent and more forgiving in terms of consequences. Desired improvements must be balanced against any associated loss of efficiency and cost, but the best companies have proven that such accident prevention is invariably cost-effective.

CONCLUSION

In conclusion, given the risk inherent in underground construction, the industry has made commendable strides in accident prevention. However, more can and should be done to increase margins of safety in what remains a hazardous enterprise. DOE looks forward to working to accomplish this goal.

REFERENCE

The New York Times. November 28, 1993. Section 1, p. 45. The Hazards of Tunneling.

Department of Energy's Construction Safety Program

Patrick F. Finn

ABSTRACT

This paper presents the program requirements of the recently developed policy for the management of safety and health on Department of Energy (DOE) construction projects. In a review of the program's elements, the paper discusses the shortcomings addressed and the options evaluated and chosen with supporting rationale. The paper provides insight to those responsible for developing or implementing policies for the management of construction safety and health within the contracting constraints of publicly funded construction projects.

INTRODUCTION

In early 1992, DOE's Office of Safety and Quality Assurance began revising the existing policy for the management of safety and health on the department' s construction projects, which is described within DOE Order 5480.9, "Construction Safety and Health Program," which was originally published in December 1980. This policy was developed well before DOE's primary mission changed from defense production to environmental restoration and waste management. At that time, DOE weighted production goals over employee safety and health. This philosophy led to a management system in which there was minimal oversight of contractor compliance with applicable environmental, safety, and health requirements.

With the change in DOE's primary mission came considerable public interest in and congressional scrutiny of the department's ability to effectively and safely manage the task of cleaning up the vast defense complex. Internal assessments and reviews by other government agencies, as well as several widely publicized events with significant safety and health ramifications, all pointed to a need to review and revise the policies that dealt with the safety and health of DOE-contractor employees.

With its wide range of nuclear facilities, DOE expends considerable resources in managing the safety of its nuclear operations. Yet in terms of lost-time injuries, fatalities, and associated costs, the department's historical losses have been skewed heavily toward those attributable to exposure to conventional hazards, with construction a primary contributor. Beyond the moral imperative to improve safety in its operations, DOE has a significant economic interest beyond that of most public sector owners or contracting agencies, because, in most cases, it fully reimburses its contractors for worker's compensation costs and other casualty losses.

With its environmental restoration and waste management mission and significant projects in program areas such as energy research and civilian radioactive waste management, DOE has become the largest construction owner in the nation. Thus, the obligation to review the construction safety management practices of the past and develop more effective policies for the future is created.

The discussion that follows reviews the primary features of DOE's recently developed construction safety and health management policy, the issues and considerations involved in the development of this policy, and how the program deals with these issues. This discussion may help in the development or revision of agency or corporate policies dealing with the management of safety and health during construction activities.

DEPARTMENT OF ENERGY POLICY

The departmental directive in place since 1980, DOE Order 5480.9, prescribed little more than that "contractors bidding on or selected for DOE construction contracts" shall submit a "descriptive outline" of an appropriate program with "adequate provisions for emergency aid, ... training, inspections, reporting, and certifying the safe operating condition of ... equipment" acceptable to the contracting officer. It provided little detail on what constituted an acceptable program and it did not establish a management framework for DOE or its construction manager to ensure the effectiveness of the program at the project work site. Further, its objective was weighted strongly toward compliance with applicable standards and not toward the identification and control of project hazards, whether or not they were adequately addressed within the standards.

This policy, along with DOE's legacy of limited oversight of its contractors, led to construction safety programs with widely ranging degrees of effectiveness across the DOE complex. DOE's greater emphasis on environment, safety, and health in recent years, however, has caused many of its contractors to develop construction safety programs that go far beyond the requirements of existing departmental policy and has led to outstanding safety records in many locations. Yet there are also a number of locations with less-thanexemplary performance records. Accordingly, a primary objective was to develop a policy that was flexible enough to allow (and encourage) those performing well to continue what they were doing, yet prescriptive enough to provide an effective framework for improvement for those that were not performing as well.

It was necessary to recognize the elements present in nearly all successful programs and to establish a working group—the DOE Construction Safety Committee, composed of representatives from affected field and headquarters organizations—to present how these elements were addressed within their respective organizations. This process helped not only to achieve the acceptance of departmental organizations and their contractors, but also to ensure that the resulting program represented a minimum set of requirements for an effective program.

Developing a minimum set of requirements was necessary for several reasons. Much existing DOE policy is a mix of requirements, philosophy, and opinion that does not lend itself well to the fixed-price, low-bid contracting method mandated for most federally funded construction work. In this firm fixed-price environment, there is ample legal precedent stating that the least reasonable interpretation of a contract requirement fully meets the contract terms. With the current emphasis on safety in DOE, it is DOE's obligation to clearly state its requirements to avoid the lengthy and often expensive disputes regarding minimum levels of acceptable safety and health performance.

In addition, with efforts in the federal government to reduce internal departmental regulations, directives, and their derivative paperwork, there is a great deal of scrutiny of new or revised policy documents in terms of length, form, and content. Reviews of draft directives such as DOE Order 5480.9, therefore, result in comments such as: "What do we gain by imposing such requirements on our contractors?" "What's the added value of such a policy?" Or more to the point, "What do you folks in Washington know about what's needed out here?" These questions are as valid as they are predictable. Accordingly, the final product must be defensible to all affected parties, not only in terms of its technical content but also in terms of its cost-effectiveness. This constraint inherently limits how far one can go in prescribing program requirements beyond the accepted industry norm.

The committee members' past experience in both the private and public sector, input from DOE contractors, and a review of several widely known construction safety program documents[1] formed the basis of discussion for what should be required within the revised

1 These include American National Standards Institute (ANSI) Standard A10.33, "Construction and Demolition Operations Safety and Health Program Requirements," and the U.S. Army Corps of Engineers, "Safety and Health Requirements Manual," EM 385-1-1.

DOE Order. The following were universally accepted as elements that needed to be addressed within the policy:

- contractor qualifications;
- a written plan that clearly delineates respective responsibilities and ensures proper coordination of safety and health programs of project subcontractors;
- a formal, written analysis of project hazards;
- employee training that is related to the anticipated hazards; and
- a minimum acceptable level of on-site verification by the construction manager and the DOE project manager.

Nonetheless, some comments received during the review process maintained that the Occupational Safety and Health Administration (OSHA) Safety and Health Regulations for Construction, Title 29, Section 1926, Subpart C, of the Code of Federal Regulations (CFR) provided sufficient means to ensure an adequate level of safety in DOE construction operations. But Subpart C lacks requirements for written safety and health programs or a formal analysis of project hazards.

The fundamental basis for these comments was twofold—it included cost and liability. There was a belief that anything beyond the requirements of Subpart C would cause project costs to increase far beyond any direct benefits received and that prescribing (and enforcing compliance with) essential elements of a contractor's safety and health plan would increase DOE liability in the event of a job-related injury or illness. There are, however, compelling arguments against these positions.

The tremendous costs associated with injury and illness in the construction industry, or more specifically, the cost of insuring against these losses, has recently been the subject of considerable discussion. The escalation of worker's compensation costs has resulted in premiums that are now nearly 100 percent of direct-labor costs for particular trades in certain states. Yet this remains a fraction of the total costs of a disabling injury, in that indirect costs are generally estimated to be approximately four times direct, or insured, costs. This is particularly pertinent to DOE, because, by and large, the agency reimburses contractors directly for such costs. According to a report entitled "Improving Construction Safety Performance" (The Business Roundtable, 1982), which used extremely conservative data, the ratio of benefits to costs for administering effective safety and health programs was 3.2 to 1.

With regard to liability, there are two prevailing bodies of opinion as to the advantages and disadvantages of prescribing and overseeing contractor safety and health programs. The first is that such involvement increases owner and construction manager liability exposure and should therefore be avoided. The second is that, by virtue of having the responsibility (and the financial ability) to exert control over a contractor's safety and health performance, the owner's, construction manager' s, and general contractor's liability is inherent, and positive steps need to be taken to limit this liability exposure. There is a considerable body of case law supporting the latter argument, as was emphatically underscored in a recent Washington State Supreme Court ruling (*State v. PBMC*, 1990) and subsequent Washington State Appeals Court rulings (*Husfloen* v. *MTA Construction*, 1990; *Weinert v. Bronco National Co*., 1990; and *Doss* v. *ITT Rayonier*, 1991).

Interestingly, one of the more contentious issues during the development of this policy was the definition of construction. There were two primary reasons for this seemingly mundane point being discussed so thoroughly. First, unlike some other government agencies or private sector companies whose primary mission is construction management, DOE's mission involves a wide range of activities, from building, maintaining, and operating complex industrial facilities to scientific research and electrical power distribution. Accordingly, a definition that clearly distinguished between construction and maintenance was needed, because many questioned the benefit and cost effectiveness of applying the policy to daily maintenance activities.

Second, the diverse organized labor representation on DOE facilities had an interest in whether future DOE environmental restoration and waste management work would be considered construction or the continued operation of a facility, albeit with a different product. This distinction could play a major role in determining which unions perform the bulk of future environmental restoration work. There was accordingly an expressed desire of the affected parties to use the revised policy as the arbiter of this issue.

A policy document for the management of construction safety, however, is not the proper vehicle with which to resolve such an issue. Any effort to do so not only would have been inappropriate but also would have politicized and overburdened the process unnecessarily, resulting in many unneeded fights and delays as well as the risk of continued dissension by those adversely affected. It was, therefore, decided to defer to the definition of construction provided within the Davis-Bacon Act (used for wage-rate determination on federally funded construction projects). This definition is consistent with that provided within both the OSHA standards for construction safety, 29CFR1926, and the Federal Acquisition Regulation (FAR). Moreover, there exists at each DOE site a committee whose responsibility it is to review proposed construction-like activities above a threshold of $2,000 to determine the applicability of wage rates prescribed by the Davis-Bacon Act.

The requirement for the construction contractor to perform a written analysis of projected hazards for each project phase elicited a significant number of comments. Many expressed concern that the level of effort demanded by this requirement would parallel that required by another DOE directive, which requires safety analysis reports to evaluate, in a rigorous and exhaustive fashion, the safe operating parameters of DOE nuclear facilities. It is important to note that the job safety analysis or activity hazard analysis that is common to most successful construction safety programs is considerably less rigorous and resource-intensive.

A shortcoming of some construction safety programs that require a hazard analysis for each project phase is that a definition for the term project phase is not provided in the program, nor is there a requirement for a determination in advance of the construction activities that comprise a project phase and require such an analysis. In these cases, it is often difficult to assess a contractor's implementation of the contract's safety program requirements. Proactive, pre-job safety and health planning, the objective of such hazard analyses, is not always achievable when it is unclear which elements of the project require it and no clear tie can be made back to the project schedule.

The DOE Order 5480.9 deals with this issue through the requirement for a preliminary hazard analysis in which the anticipated project phases are identified, typical associated hazards and control measures are listed, and specific contract requirements for the design or inspection of control measures by a professional engineer or other competent person are emphasized. (OSHA standards define a competent person as "one who is capable of identifying existing and predictable hazards... and has the authorization to take prompt, corrective measures to eliminate them.") This prescribed level of planning allows for a timely completion of a second step, the activity hazard analysis, in which the specific hazards and their control measures are identified. All engineering requirements are then completed prior to commencement of work on the affected project phase. For the sake of flexibility and economy, the Order allows for the preliminary hazard analysis to be completed in advance and provided within the bid documents or to be completed concurrently with the activity hazard analysis by the construction contractor, provided that all requirements are fulfilled.

In addition to containing customary employee safety orientation and weekly toolbox training, the DOE Order uses the completed activity hazard analysis to ensure that employees are trained specifically regarding identified project hazards and the appropriate control measures. This method was chosen to address what all too frequently occurs in the construction industry: employees are given an 8- or 10-hour block of construction safety and health training by vendor or videocassette that may not reflect the hazards found on the job site and may not be consistent with the company's safety and health policy or practices.

Another fundamental element of a program that effectively manages construction 'safety and health is a means to evaluate prospective bidders' safety and health records to ascertain whether they meet a minimum level of performance. In this element, the methods used in the private sector may not fit the constraints of the federal procurement process. For example, in the private sector, prospective bidders are frequently prequalified on the basis of several indicators of past safety and health performance. These may include a review of each contractor's safety and health plan, the worker's compensation experience modifier rate, the OSHA 200 Log (a required listing of recordable injuries and illnesses), or the incidence rate derived from the OSHA Log.

As meaningful as these indicators might be, for several reasons their use is problematic in the federal sector. First, the use of a prequalification process for prospective bidders on federal work is restricted to specific and compelling technical competencies essential to perform the work; a written justification for the resulting limited competition is mandatory. It would be difficult to argue that safety and health performance indicators that are less than absolute constitute a compelling reason for restricted competition on federally funded construction projects.

Furthermore, the fundamental tenet of federal procurement policy, fair and open competition, would be compromised by the indiscriminate use of indicators such as the experience modifier rate or incidence rate. The experience modifier rate is deliberately and inherently biased against companies with small payrolls (i.e., small businesses) in that a single catastrophic loss constitutes a larger percentage of annual payroll (upon which premiums are based) than it would for a large corporation. Moreover, it is based on performance from two to four years ago as opposed to current performance and therefore may not reflect significant safety and health program improvements. With respect to the use of incidence rates as a prequalification criterion, history has shown clearly that the mere use of these rates for such purposes has led, in and of itself, to their marked improvement, without necessarily a corresponding improvement in true safety performance. The fairness of either of these indicators can easily be questioned.

What is allowed—and in fact required—under applicable federal procurement policies is that the responsibility of a bidder, based on past performance, be determined prior to contract award. On fixed-price construction contracts, this performance record is to be based, in part, on past evaluations of performance in five elements: (1) quality of work, (2) timely performance, (3) effectiveness of management, (4) compliance with labor standards, and (5) compliance with safety standards. Therefore, in the interest of fair and open competition, any contractor with appropriate bonding can bid on and be awarded a federally funded, fixed-price construction contract. The contractor's ability to continue doing so, however, is based largely on satisfactory performance. Although this system is more fair than a prequalification process based on sometimes faulty safety performance indicators, it is by no means foolproof. It is essential to maintain accurate and thorough records to support the issuance or use of such ratings. To do otherwise is to invite contract disputes and bid protests with their accompanying impact on project cost and schedule.

These principles were considered in several areas in the development of the Order. When DOE contracts directly for fixed-price construction (which it seldom does), the policy defers paragraph 36.201 of the FAR provision. Similarly, when the department procures construction services through fixed-price subcontracts to its maintenance and operation contractors, environmental restoration management contractors, or construction management contractors, the policy requires that these contractors develop and implement a system to measure contractor safety and health performance on their projects and use the results during bid evaluations for future work. Their systems should be similar to that prescribed in the FAR in that they are obligated to subcontract consistent with the federal acquisition policy.

The FAR prescribes application of such an evaluation system to fixed-price contracts exceeding $500,000, or less in exceptional cases. This amount was used in the Order to establish the threshold above which an enhanced level of DOE project manager involvement was required in subcontracted projects. This threshold was needed for two reasons. First, DOE does not have the personnel at its sites to allow the active participation of its project managers on construction projects down to the threshold of $2,000 provided within the Davis-Bacon Act. Second, enhanced participation above this $500,000 threshold helps ensure that the department is involved in decisions on those projects for which such an evaluation is required. This involvement will include reviewing project documentation that may form the basis of future unsatisfactory evaluations and even become the subject of future contract disputes or bid protests.

There were a number of comments concerning the perceived inability of small or minority-owned businesses to comply with the construction safety and health program requirements of the order. Of primary concern was that these requirements would work against programs meant to encourage small and minority-owned business participation on DOE sites. Interestingly, there were at least as many comments (some from the same sources) stating that a rigid prequalification process based on experience modifier rates and incidence rates was superior to the contractor evaluation system prescribed by the FAR and referred to in the Order, despite the fact that the experience modifier rate is inherently biased against small businesses.

In reviewing these contradictory positions, it was believed that it was more desirable to allow contractors the opportunity to demonstrate their ability to comply with DOE's construction safety program requirements than it was to preclude contractors on the basis of safety performance indicators that were neither fair nor completely reliable. Not only does this win the "fairness" argument, but also it will probably result in a larger pool of prospective bidders capable of performing in accordance with DOE's program requirements. In addition to the desired positive effect on safety and health, this larger bidder pool should exert downward pressure on bid prices, thereby enabling DOE to perform its construction more safely and more economically.

SUMMARY

Within a short paper, it is impossible to review all the elements of DOE's recently developed policy for the management of safety and health on its construction projects, or the issues confronted in its development. However, it is hoped that some of the approaches taken and the supporting rationale provided will prove helpful to those who may have a hand in implementing it or developing similar policies.

REFERENCES

The Business Roundtable. 1982. Improving construction safety performance: A construction industry cost effectiveness project report. Report A-3. January. Reprinted August 1991. New York: The Business Roundtable.

Doss v. *ITT Rayonier, 60* Wn. App. 125. 803 P.2d 4 (1991).

Husfloen v. *MTA Construction*, 58 Wn. App. 686. 794 P.2d 859 (1990).

State v. *PBMC*, 114 Wn.2d 454. 788 P.2d 545 (1990).

Weinert v. *Bronco National Co.*, 58 Wn. App. 692. 795 P.2d 1167 (1990).

OSHA Regulations and Their Implications

Fred A. Anderson

ABSTRACT

This paper describes the pertinent Occupational Safety and Health Administration (OSHA) regulation that will govern much of the underground construction of the Exploratory Studies Facility (ESF) for the Yucca Mountain Project (YMP). The provisions of the regulation are outlined, and their cost and contractual implications are discussed based on recent experience on other underground projects. Recommendations are provided for the drafting of contract documents to establish responsibility and compensation for ensuring compliance with the regulation.

INTRODUCTION

The scope of this paper is limited to the discussion of the cost and contractual implications of compliance with the provisions of the OSHA regulation related to underground construction as found in Title 29, Section 1926.800, of the Code of Federal Regulations (29CFR1926.800). Only the construction of underground openings is discussed.

This particular regulation will be the one most pertinent to the tunnels to be constructed for the ESF at the YMP. Agency jurisdictional issues are not addressed, since 29CFR1926.800 will be the basis for regulatory activity by federal OSHA, Nevada OSHA, or the Department of Energy (DOE), depending on the outcome of various legislative or policy decisions currently under consideration.

The purpose of this paper is to encourage project personnel involved in the planning, design, and construction of the ESF at Yucca Mountain to consider and discuss the facilitation of ESF contractor compliance with OSHA regulations.

The Occupational Safety and Health Act of 1970 requires employers to provide a safe and healthful work place for employees. Therefore, the employer is the organizational entity or individual cited and fined for failure to comply with OSHA regulations. In the context of this paper, the entity cited will be a construction contractor or subcontractor or another contractor or agency having employees exposed to a particular hazard, whether caused by an employee's employer or another employer working at the same site. In the latter case, citations are issued in compliance with OSHA's multiemployer work-site policy outlined in the OSHA Field Operations Manual.

PROVISIONS

Various provisions of the OSHA regulation follow.

1. *Access and egress* is generally interpreted to require a safe walking surface in the runnel, which personnel may traverse without being exposed to water, debris, or tripping hazards. To date, the European practice of providing a safety railing between a walkway and a haulage way has not been a U.S. requirement, but this possibility should be considered in the United States and a decision obtained from the agency ultimately determined to have jurisdiction before cost estimates are finalized. Contracts should clearly establish who will construct and maintain the walking surface, since it will be traversed by employees of numerous employers, including technicians, rescue personnel, and official visitors. For obvious reasons, the walkway should be out of the path of moving equipment, but in a tunnel boring machine (TBM)-driven tunnel this can mean additional blocking or shoring to provide a level surface above the invert. Providing a safe walking surface in the area of sumps, track switches, or passing zones will carry additional costs. Other hazards to walking personnel, such as conveyor belts, electrical conductors, and load lines, should be kept a safe distance from the walkway or otherwise guarded.

   Personnel haulage requirements generally follow Mine Safety and Health Administration (MSHA) requirements for man-cars or tracks transporting personnel. Arms or heads protruding from the conveyance are the chief hazard requiring attention.
2. *Check-in/check-out* is a common requirement for underground construction and is easily met. Maintaining a single check-in/check-out board facilitates a rapid determination of how many people are underground in the event of an emergency.

3. *Safety instruction* is a requirement that each employer will generally be responsible for meeting. The proper maintenance of records facilitates proof of compliance. Such records include class rosters and entries in employees' personnel records indicating the content and times of training. Note that training in the use of self-rescuers is required in 29CFR1926.103.
4. *Notification* requires that employees be informed of hazardous occurrences or conditions when they come on shift and that employers communicate with one another to ensure coordination of activities and notification of employees.
5. *Communications* requirements are not unusual. Project management chooses one contractor to provide and maintain the communications system, avoiding the cost and confusion of having multiple systems installed by the several employers. The system must be capable of functioning during emergencies.

The next five items are addressed in the OSHA regulations under the heading Emergency Provisions.

6. *Hoisting capability* only applies when shafts are used as a means of egress. Again, to best address this requirement, project management identifies the contractor responsible for providing and maintaining the equipment and operators.
7. *Self-rescuers* are a long-standing requirement. Generally, each employer provides self-rescuers and training in their use to each employee. Thought should be given to identifying a supplier of self-rescuers to official visitors or others who may have occasional need to go underground. There is an obvious advantage to having only one type of self-rescuer in use on the project—to minimize the risk of employees mixing up self-rescuers stored at the heading or at other locations underground.
8. At least one *designated person* shall be on duty aboveground whenever any employee is working underground. This person keeps an accurate account of employees underground and shall secure aid, if necessary. It may be most efficient for one contractor to provide the designated person.
9. *Emergency lighting* responsibilities to provide hand lamps or cap lamps traditionally rest with the individual employer. Compliance with this provision is generally not a problem.
10. The costs and contractual implications of compliance with the provision of *rescue teams* are significant. Salary and equipment costs alone ensure that this will be a million-dollar item in a year's time, especially at a site as remote as Yucca Mountain.

The regulation states, in part, that on job sites where 25 or more employees work underground at one time, the employer shall provide at least two 5-person rescue teams. Where fewer than 25 employees work underground at one time, the employer shall provide at least one 5-person rescue team. In either case, one rescue team is to be either at the job site or within one-half-hour travel time from the entry point. The second rescue team, if required, can be up to two hours' travel time from the site.

The question of whether one or two rescue teams are required is subject to interpretation. In modem tunnel construction, the tunneling contractor will often have fewer than 25 people underground, but all the employers at the site may well have a total of more than 25 people underground. This will likely be the case at the ESF, with all the visitors, technicians, engineers, geologists, and others who will flock to the site. On the other hand, given the long history of excavation in geologic formation, its generally stable nature, the lack of detectable methane, and the absence of ground water sources, it is reasonable to question the likelihood of any emergency involving more than a few of the employees who are underground. There remains only the remote possibility of smoke being generated by a fire coincident with a failure of the ventilation system.

The primary five-person rescue team will have to be available from a point not more than 30 minutes from the entry point. This probably means that a team located at the Nevada Test Site could also be available to respond to emergencies at the ESF. The overall resources of the two facilities should be reviewed to judge response capability. Whatever arrangements are feasible will have to be incorporated into the various contracts involved.

In these deliberations, it is important to note that firefighters equipped with normal turnout gear and Scott air packs are generally very much out of their element underground, if for no other reason than the limited air supply provided by these units, but also because it cannot be assumed that they have training in underground emergencies.

Familiarity with the tunneling activities underway is essential to the rescue team members. The fact that transportation, haulage, ventilation, and other services change as the heading is advanced is often overlooked in the planning of rescue operations. Rescue team members may lack the familiarity needed to perform various tasks (e.g., reach the heading, restore ventilation, etc.), unless they receive continuing training.

Labor issues may require resolution, or the appropriate trades may need to be represented on the rescue team. Problems arising from labor issues may include the following: rescue team members being unable to operate haulage or transportation equipment, either through lack of training or jurisdictional rules; rescue teams lacking personnel able to recognize or mitigate electrical hazards; and rescue team members having no knowledge of and sometimes not even the ability to recognize construction explosives.

This provision only states, "The employer shall ensure that rescue teams are familiar with conditions at the job site." There is a real concern that improperly trained or equipped rescue team members may themselves become victims or that runnel workers who have the necessary knowledge and a strong desire to aid their coworkers may be injured while operating a critical piece of equipment, for example, without breathing apparatus.

In any case, planning is required, and contracts may have to be written or modified to ensure the provision of a rescue team or teams available at all times that personnel are underground at Yucca Mountain.

11. The provision regarding *hazardous classifications* (potentially gassy operations) states, "The atmosphere in all underground work areas shall be tested quantitatively for carbon monoxide, nitrogen dioxide, hydrogen sulfide, and toxic gases, dusts, vapors, mists, and fumes as often as necessary to ensure that the permissible exposure limits prescribed in [29CFR]1926.55 are not exceeded." This section of the regulation goes on to outline requirements for monitoring, for example, flammable gases and engine exhausts and for maintaining records of the test results. Given the long history of tunneling at the Nevada Test Site, it is reasonable to assume that there will be no exposure to methane, other flammable gases, or hydrogen sulfide. However, this does not eliminate the need for air quality monitoring.

    Project planning should therefore include provision for air quality monitoring (including the designation of a responsible contractor), coordination among contractors, and maintenance of records readily available to OSHA inspectors.
12. *Ventilation* requirements for underground areas outlined in the regulation are not unusual, but again, project planners should determine who will be responsible for providing ventilation, during what periods of time, and in what amounts to accommodate all activities anticipated in the ESF during construction. The provision of ventilation should then be made a contract requirement with a corresponding pay item.
13. *Illumination* can be handled in much the same way as ventilation.
14. *Fire prevention and control* is aligned with normal tunneling practice, but note specifically the requirements that flammable materials may not be stored within 100 ft of any access opening, surface structures may not be located within 100 ft of any opening, and any underground structures shall be constructed of materials having a 1-hour fire rating. There is also a requirement that fire-resistant hydraulic fluids be used underground.

15. The provisions on *ground support* contain no requirements different from those dictated by good tunneling practice. However, there is a provision that a competent person must inspect the work area at the start of each shift to assess ground stability. That same or another competent person shall determine that rock bolts are correctly torqued. The tasks given these people are reminiscent of those assigned to the safety miner in years past.
16. If there are *shafts* at this project, the provisions of this section of 29CFR1926.800 will need to be met. However, the requirements for shafts should not have significant cost or schedule impacts.
17. Provisions related to *blasting* in the underground construction regulation (29CFR1926.800) generally refer to 29CFR1926.900, entitled "Blasting and the Use of Explosives," to provide requirements. 29CFR1926.900 is derived from common and generally accepted blasting standards used by MSHA, the U.S. Army Corps of Engineers, and other agencies and organizations. In addition to those included by reference to the Blasting Standard, there are only two provisions added to the Underground Standard. One of these prohibits the common practice of miners returning to the heading before ventilation is restored and the powder smoke is cleared. The other requires that blasting wire be kept clear of other conductive material.
18. The 11 subparagraphs under the heading *drilling* contain no surprises and generally apply only to the contractor who is actually advancing the heading.
19. *Haulage* procedures also follow accepted practice and provisions generally found in mining regulations.
20. *Electrical safety* essentially references 29CFR1926.400, "Electrical," of the construction standards. Compliance with this regulation has proven difficult on at least one occasion related to the general requirements found in 29CFR1926.403, which discuss approval; examination; and listing, labeling, or certifying equipment. The issue in that case involved a TBM; its power supply cable; and the requirements for listing, labeling, or certifying the individual electrical components on the TBM. In addition, the case involved the potential requirements for listing, labeling, or certifying the total system, meaning the TBM, its power supply, and auxiliary equipment, such as the conveyor system.

    The TBM manufacturer, the contractor, and the electrical subcontractors must ensure that conditions likely to be found underground, such as ground water, cannot infiltrate the electrical system at any point to cause fires or explosions. Costs and delays associated with these issues can be significant.

Electrical fires and explosions, aside from being potentially life-threatening, are also noisy, smoky attention-getters with both the press and OSHA.

There is at least one way to reduce the possibility of electrical hazards. The authority issuing plans and specifications can seek interpretations beforehand and can require a careful inspection of the TBM before startup. Inspection should ensure that none of the conditions expected underground can possibly cause electrical problems and that all electrical components are properly listed and labeled for their intended use and exposure.

The contractor operating the TBM should ensure that only a few trained electricians are allowed to work on, alter, or maintain the electrical system and that all others clearly understand that the components of the electrical system are off limits to welding, cutting, drilling, storing of lunch buckets, drying of gloves, and all other forms of tampering that seem to be the assumed right of underground workers everywhere.

21. The section on *hoisting unique to underground construction* regulates cranes and hoists used in underground construction and principally applies in underground work involving shafts. While cranes are generally not allowed to be used for hoisting personnel in surface construction, the standard specifically excludes this prohibition for underground construction.
22. The remaining sections address *underground work in a pressurized environment*. The standard continues with sections on caissons and other underground work in which compressed air is used to provide a pressurized environment. Since such work will not be conducted at Yucca Mountain, this paper will not address these issues.

Of necessity, this paper does not discuss each provision in great detail. However, there are detailed requirements in the standard that must be met. For example, a large and good construction company recently retained a reputable firm to design a hoisting cage for a shaft. Somehow the cage was enclosed with three-quarter-inch wire mesh instead of the one-half-inch wire mesh plainly required by the regulation. As luck would have it, an OSHA inspector noted this failure to comply and issued a citation.

CONCLUSIONS

The total number of safety regulations covering the work at Yucca Mountain spans several volumes and includes more standards than those previously discussed. Additional standards that will apply at Yucca Mountain include the hazard communications standard, posting requirements, requirements for personal protective equipment, and lock-out/tag-out requirements for equipment and may include confined space entry requirements, as well. Employers will need to be aware of those standards pertinent to their respective operations.

One way to ensure compliance and lessen the potential for cost and schedule impacts is to include specific contract requirements and corresponding pay items for those safety requirements involving multiple employers. This approach also promotes a safe work place.

In the case of the ESF at Yucca Mountain, for example, the provision and maintenance of a walkway in the tunnels for access and egress, of lighting and ventilation, of a tunnel rescue team or teams, and of underground transportation are items that should be made contract requirements with specifications and specific pay items. Other items that should be considered as specific contract requirements include check-in/check-out, communications, and air-quality monitoring.

Taking these steps assigns both responsibility and compensation, reducing the likelihood of duplication or gaps in compliance.

DISCUSSION

Several conference participants agreed that standards with which a project must comply should be specified before the commencement of the project. DOE has done so for the YMP, telling the underground contractors that they must comply with the California OSHA runnel safety orders, MSHA standards, and OSHA standards. DOE and its contractors have agreed on the particular requirements from the respective standards that must be met at Yucca Mountain. Nevertheless, at least one conference participant was concerned that problems may arise when safety jurisdiction is returned to the federal OSHA.

Mr. Anderson anticipated no problems with OSHA for the ESF at Yucca Mountain. He suggested that throughout the project, contracts should include explicit requirement language to keep the contractors continually aware of the requirements they are responsible for meeting. Also, to forestall any problems with the federal OSHA, project planners at DOE should contact OSHA and force them to take a stand on any questionable issues and thus to share responsibility for safety management at Yucca Mountain. This will prevent OSHA from later citing project contractors for noncompliance in cases where DOE was compelled to make safety management choices without explicit OSHA guidance. However, one participant cautioned that in his experience, the best a company can expect from the governing organization is non-objection to documented procedures. He expressed hope that DOE will achieve better cooperation with OSHA.

Underground Regulatory Safety Today

Byron M. Ishkanian

ABSTRACT

The Yucca Mountain Project (YMP) safety effort benefits not only from the experience of other major projects but also from recent innovative safety ideas. The project has access to an excellent reservoir of knowledgeable personnel. If a cooperative team spirit is built among all participants—agencies, contractors, subcontractors, and subsidiary personnel—many problems can be solved before they become obstacles. The YMP will benefit from an environment promoting common sense in safety through prudent use of safety codes, inspections, job hazard analyses, communication, and a climate of safety.

INTRODUCTION

Of primary importance during the planning phase of a safety effort for a massive program, such as the YMP, is the imposition of a practical base that addresses the outstanding needs of all who will work on the premises. The building blocks of this foundation include:

- the agency that has employee-safety jurisdiction over the project;
- the safety codes that apply at the site;
- a cooperative safety effort among all participants;
- development and maintenance of good channels of communication;
- meaningful safety monitoring of all operations;
- job hazard analysis of planned operations;
- analysis of accidents to correct conditions;
- initiation of changes in safety and health requirements, when necessary;

- safety training for all levels of personnel;
- increased awareness of expected exposures and risks associated with the use of different types of excavation equipment;
- management of safety liability on a multicontract work site; and
- handling of emergency response in case of accidents, fires, or a disaster.

Each of these items is discussed below and, where appropriate, accompanied by examples. The examples are the result of distillation of ideas from a number of projects and may be freely adapted for a given project after revision for local conditions.

EMPLOYEE-SAFETY JURISDICTION

The YMP is situated on a federal reservation in the state of Nevada and is being constructed under the auspices of the Department of Energy (DOE). Nevada has state-plan status within the federal Occupational Safety and Health Administration (OSHA) framework, and as such the Nevada OSHA may be designated as the YMP enforcement agency. States with state-plan status obtain funds from the federal government, add their own funds, and run their own job safety programs. There are about 28 states in this category. These states operate within a tight framework that is designed by the federal OSHA and receive approximately one-half of their program funds from the federal government.

Experience dictates, however, that should the Nevada OSHA be given the job safety responsibility, there will be very close scrutiny of the project by the federal OSHA's area and regional offices. Another scenario might have the Nevada OSHA watching private entities at the YMP, while the federal OSHA watches the federal agencies; this approach could be a bureaucratic nightmare.

WHICH SAFETY CODE WILL APPLY AT THE YUCCA MOUNTAIN SITE?

Operating a safety program in the state-plan mode, a state may choose to use its own safety orders or adopt the federal OSHA orders. California maintains its own safety orders, which is possible as long as the orders are at least as stringent as parallel federal regulations.

States that maintain their own safety orders are constantly at loggerheads with the federal OSHA over regulations that the federal agency determines are not as good as its own—not as stringent; not timely; and basically, not the same as the federal OSHA's.

A state with state-plan status has the choice (1) to go its own way, not accepting federal monies and the accompanying dual safety jurisdiction within the state or (2) to accept the federal safety orders, receive the federal monies, and tolerate federal micromanagement. Nevada retains a measure of its identity by holding state-plan status while adopting the federal safety regulations. As a result, regardless of who has safety jurisdiction, the federal regulations will be in effect at the YMP.

Passage of the Federal Occupational Safety and Health Act in 1970 caused a flurry of activity regarding regulations for the new agency. For the most part, American National Standards Institute standards were quickly adopted, though they were not written with compliance enforcement in mind. In the underground construction arena, a set of standards was adopted as a stopgap measure. The revision of the stopgap orders in Title 29, Section 1926.800 of the Code of Federal Regulations (29CFR1926.800) for underground construction began in 1973. California tunnel safety orders, which were being rewritten, were held up, since they would have to be as stringent in the new orders as the proposed federal orders. As time passed, however, state regulators went ahead, since the federal process appeared to be moving slowly.

The federal rewriting of 29CFR1926.800 took almost 17 years. Were it not for the Milwaukee Tunnel accident, where three people were killed in a methane explosion during construction, the old regulations might still be on the books. Although many involved in the underground industry contributed to the new regulations through hearings, verbal communications, and letters to the authors, the final role issued on Friday, June 2, 1989, was far from what was expected. This role was a set of underground construction regulations that appeared to have been thrown together quickly in the wake of the Milwaukee accident. The orders have many shortcomings that leave those who wish to comply in a quandary. Some of the most obvious of these shortcomings are described below.

Ventilation

Subsection k (1)ii of 29CFR1926.800 seems to allow the use of natural ventilation in some instances. This regulation opens the door to other-than-mechanical ventilation, a dangerous loophole. Section (4) states that mechanical air flow shall be reversible. This would appear to preclude the use of a flexible vent line, since reversal of the air flow would collapse the vent line. Has this eliminated the use of a flexible vent line? Absolutely not. In fact, flexible, nonmetallic vent lines are finding greater use than ever before. The federal OSHA regulation confounds itself further by stating in Section (11)(i) that vent lines should "be constructed of fire-resistant materials."

How are these regulations being implemented in the real world? Operators are selling OSHA on the idea that the reversal fan is placed within the tunnel atmosphere, usually on the excavation equipment. When reversal is needed in the ventilation system, one fan in the blowing mode is shut down, and the other, at the distant end of the main ventilation line, is started up. The primary purpose of any reversal of ventilation requirement is to retain some semblance of control of the underground atmosphere from the surface, in case of an underground emergency, fire, or ground collapse. When the reversal fan is at or near the heading, any occurrence that cuts off the vent line between the fan and the portal, destroys the fan, or closes the tunnel cross section negates the reversal capability. Furthermore, inferring that the use of fire-resistant materials are required in potentially gassy and gassy classified operations, by exclusion, appears to allow the use of other than fire-resistant vent-line materials in all other operations.

Of great importance to the YMP is the rule requiring that, because of the possible contamination of formations for the characterization study, much of the excavation, whether by road header, tunnel boring machine (TBM), or drilling, be done with as little water or other lubricants as possible. This requirement automatically dictates an exhausting ventilation configuration, wherein the generated dust is collected in the ventilation line as quickly as possible and discharged at the surface. This will lead to the placement of the main fan in the tunnel, at or near the advancing face, blowing down the vent line to the surface. The fan at the surface will be idle, used only to provide the reversal capability required in the underground construction orders.

In many underground operations, federal, state, and local laws prohibit dry drilling of rock. It will be interesting to see how these contrasting philosophies affect the YMP. Serious consideration should be given to requiring metallic vent lines only in the main ventilation systems. All controls would be at the surface. This would allow the emplacement of one reversible fan in fresh air at the surface and a line that is not fire-resistant but fire-proof.

Hazardous Classifications

This Subsection h of 29CFR1926.800 pertains to the actions that must be taken in an underground construction atmosphere to protect employees from explosive gases. It is unlikely that explosive gases, which are natural in origin, will be encountered during excavation at the YMP site.

Section (1)(i) states that if explosive gases are encountered at 10 percent or more of the lower explosive limit (LEL) for a period exceeding 24 hours, then the operation is classified as potentially gassy. Section (2)(i) goes a step further and states that if explosive gases are encountered or intrusion continues for three consecutive days, then the operation is classified as gassy at 10 percent LEL. No sane operator, agency, or contractor would allow explosive gas intrusions at 10 percent of the LEL for 1 hour, much less 24 hours or three days, before taking corrective action. Intrusions of that magnitude demand immediate, instantaneous action. What is now intrusion at 10 percent LEL, in the next bedding plane, fracture, or push could be 100 percent of the LEL and in the explosive range. Adjustments of the ventilation system, excavation rate, and any other valid control must be made immediately. Disaster is just around the next comer. Another unanswered question is who makes this classification change determination.

Section (2)(ii) makes matters even more difficult to discern, stating that if there has been an ignition of methane or flammable gases emanating from the strata, then the classification is automatically gassy. This does not provide much guidance to an operator who encounters explosive gas in small amounts within a period of less than 24 hours or experiences a gas ignition underground. The operator wants and needs a classification change, but from whom? The operator must write the change order while trying to protect the tunnel atmosphere. This has occurred on several projects.

Illumination

Illumination requirements for underground work areas and other construction locations are noted in Table 1, which is taken from Table D-3 of 29CFR1926.56(a). This table requires, albeit not clearly, 5 foot-candles (ft-c) of illumination in tunnels, assumed to be along the lengths of all tunnels, and 10 ft-c (see exception) at the "tunnel and shaft heading during drilling, mucking, and scaling." In addition, it indicates that "Bureau of Mines approved cap lamps shall be acceptable for use in the tunnel heading." Loosely interpreting this regulation, one might say that 5 ft-c of illumination is required along the length of all tunnels under construction and 10 ft-c is required at the heading. In reality, this can be and has been interpreted in many ways. Some tunnel projects have provided 10 ft-c at the heading; required all personnel to wear a cap lamp; and required no lighting along the length of the balance of the runnel, except at emergency phone, first aid, and pump and valve control stations. The author has seen few tunnels having 5 ft-c of illumination along the entire length. In those where cap lamps are required to be worn, one soon finds few actually being worn but rather the majority being hung on equipment near the individual.

TABLE 1 Minimum Illumination Intensities in Foot-Candles

Foot-Candles	Area or Operation
5	General construction area lighting.
3	General construction areas, concrete placement, excavation and waste areas, accessways, active storage areas, loading platforms, refueling, and field maintenance areas.
5	Indoors: warehouses, corridors, hallways, and exitways.
5	Tunnels, shafts, and general underground work areas. (Exception: minimum of 10 foot-candles is required at tunnel and shaft heading during drilling, mucking, and scaling. Bureau of Mines-approved cap lights shall be acceptable for use in the runnel heading.)
10	General construction plant and shops (e.g., batch plants, screening plants, mechanical and electrical equipment rooms, carpenter shops, rigging lofts and active storerooms, barracks or living quarters, locker or dressing rooms, mess halls, and indoor toilets and workrooms).
30	First-aid stations, infirmaries, and offices.

Ventilation, hazardous classifications, and illumination are but three of many regulations in 29CFR1926.800 that lack clarity and guidance and are instead ambiguous and impractical. The YMP must eliminate as many of these critical regulatory conflicts as possible, before they become obstructions to the work process.

ENCOURAGING A COOPERATIVE SAFETY EFFORT

Since a number of federal agencies will be participating in the work at the YMP, a cooperative effort early on is important. This effort can take many forms. Continuous communication by DOE on successive phases of project development would make other agencies feel they are an integral part of the action, enabling these agencies to contribute meaningfully.

One of the primary efforts in this area is the writing of a safety manual for the entire project. Those who take part in the writing of such a manual, or comment on or contribute to the document, often feel that it is their own. Through this and other means, continuous contact of the prime management parties can diffuse problems before they develop into major obstacles. In addition, contact among top safety individuals in these agencies and companies tends to lessen personality conflicts and build a team effort and atmosphere.

DEVELOPING AND MAINTAINING GOOD CHANNELS OF COMMUNICATION

Communications start to slip as a project matures and nears the completion stage. The birth of a large project sees various meetings, conferences, and exchanges of information of all types, but gradually a degree of complacency sets in, and communication channels start to weaken. A constant communication effort is required to maintain life in these channels during the construction phase. The operational phase is another subject. Sometimes attending a multitude of meetings is self-defeating, leaving little time to do meaningful work. Concentrating on a few safety meetings, maintaining meaningful content, and discussing current problems and solutions are far more effective than meeting just to be meeting.

Most major projects settle down to the following schedule:

1. tailgate safety meetings of foremen and personnel (weekly);
2. progress meetings, with a safety section (usually biweekly); and
3. supervisors' safety meetings, for overall project safety direction (monthly).

There will be other meetings prior to major occurrences or hazard analyses, but the three types listed above usually suffice. The information that is generated is then distributed throughout the project work force.

Continuing efforts should be made to apprise contractors, subcontractors, and others of information vital to their work. For example, many times the contractor's hands-on personnel are the last to know what is contained in geotechnical and similar reports. These reports should be available to all who are involved in the work, especially to those involved in underground operations. Figure 1 is a sample form for a safety meeting report.

REPORT OF SAFETY MEETING
DATE:
CONTRACT NUMBER:
PROJECT:
CONTRACTOR:
CRAFT:
NUMBER ATTENDING:
TOPICS DISCUSSED:
SUGGESTIONS FOR IMPROVEMENT:
FOREMAN'S SIGNATURE:
SAFETY REPRESENTATIVE'S SIGNATURE:
FORM NUMBER:

FIGURE 1 Sample safety meeting report form.

MEANINGFUL SAFETY MONITORING OF ALL OPERATIONS

Safety monitoring or inspections are an integral part of any construction project. Questions for which specific answers are dependent on specific projects include: Who does this monitoring? What is the frequency of monitoring? What are the results of the inspection? And what actions do safety violations trigger?

If each agency chooses to have its own safety officer, then the cooperation among entities must be spelled out in the project safety manual. If all agencies work solely from checklists, then the lists must be uniform throughout the project. Figure 2 shows the first page of a construction safety inspection checklist. Although some feel that safety checklists blur the safety instincts of those with responsibility, a combination of the two philosophies is an excellent blending. Competent people who do not operate by rote can use a checklist as a back up, so as not to miss the smaller items. The individual's competency, knowledge, and safety instinct will ferret out the major exposures.

If a safety officer is assigned on a given project, then the frequency of inspections is constant. However, there is some question as to whether this is a valid method of operation. In some instances, a mine safety inspector, permanently assigned to a mine location from an oversight agency, loses his effectiveness in a very short period of time. Therefore, when he attempts to take corrective actions, his efforts are taken lightly. However, company—or contractor—assigned safety officers tend to maintain their effectiveness. A balance is necessary, so that inspections are meaningful and not done continuously but accomplish the task with strategic time lapses.

JOB HAZARD ANALYSIS OF PLANNED OPERATIONS

A job hazard analysis is a necessity before any phase of construction that is known to be dangerous. Development of a hazard analysis plan for such a phase is in the hands of the safety officer and the manager directly responsible for the work. This plan then serves as a training vehicle for all those who will take part in the operation. The primary consideration in the development and implementation of any hazard analysis plan is the safety of the personnel who will actually do the work. Such plan development is a giant step forward in assessing all of the effects and exposures in dangerous operations. However, adequate time must be allowed for these deliberations, so that individuals can judge the adequacy of the analysis and submit comments. For an example of a generic job hazard analysis form that might be adapted for the YMP, see Figure 3.

CONSTRUCTION SAFETY INSPECTION CHECKLIST

Contractor:	Contract Number:
Job Site Location:	
Person in Charge:	
Date: Time:	
Person(s) making inspection:	A=Adequate B=Inadequate

(1) PROGRAM ADMINISTRATION:	A	B	REMARKS
(a) Posting OSHA and other job site warning posters.			
(b) Do you have safety meetings?			
(c) Do you have job-safety training, including first-aid training?			
(d) Are there medical service and first-aid equipment, stretchers, and emergency vehicles available?			
(e) Are job-site injury records being kept?			
(f) Are emergency telephone numbers posted?			
(2) HOUSEKEEPING AND SANITATION:	A	B	REMARKS
(a) General neatness of working areas.			
(b) Regular disposal of waste and trash.			
(c) Passageways and walkways clear.			
(d) Adequate lighting.			
(e) Projecting nails removed.			
(f) Oil and grease removed.			
(g) Waste containers provided and used.			
(h) Sanitary facilities adequate and clean.			
(i) Drinking water tested and approved.			
(3) FIRE PREVENTION:	A	B	REMARKS
(a) Fire instructions to personnel.			

FIGURE 2 Sample construction safety inspection checklist.

JOB HAZARD ANALYSIS

1. Job operation title:

2. Position title of employee(s) who does (do) the job:

3. Required/recommended personal protective equipment:

4. Accurate analysis of job in terms of tools, methods, and expected working conditions:

5. Job operation hazard:
    A. Description of hazardous condition:

    B. Worst likely accident (death, service injury, etc.):

    C. Procedure to be followed to ensure job safety:

Prepared by: Date:
Approved by: Date:
Distribution:
    Resident Engineers
    Managers (Safety and Security)
    Area Managers

FIGURE 3 Sample job hazard analysis form.

ANALYSIS OF ACCIDENTS AFTER INVESTIGATION FOR CORRECTION OF CONDITIONS

Industrial accidents occur daily and are investigated, sometimes in great detail. This information is forwarded to management or the heads of companies or agencies, but what happens next is critical to the whole process. Is the information used to prevent a recurrence? Is it used to fortify a legal position? Or, is it simply buried in the files? It is important for these reports to be used and for corrective action to be taken immediately.

Figures 4 and 5 show a supervisor's accident investigation report form and a monthly accident experience summary form.

INITIATION OF CHANGES IN SAFETY AND HEALTH REQUIREMENTS

When the project's safety manual has been written and put in place, all portions of the manual must be at least as stringent as applicable federal OSHA regulations. The manual may include requirements that are more stringent. However, as operations proceed, changes may be necessary in certain portions of the manual. What is the most suitable way to make these changes?

Bureaucracies that write and enforce regulations must go through the following procedures during promulgation of the safety orders:

1. A demonstrated need for new regulations must be shown.
2. An advisory committee is convened to study the problem and to write the regulations.
3. The written changes are then massaged for clarity, conciseness, consistency, and appropriateness.
4. Public hearings are held for comments.
5. Revisions are made and comments are solicited from the public, the advisory committee, and other regulatory and oversight administrative agencies.
6. The regulations are rewritten and issued.

This system works quite well but takes an inordinate amount of time. Projects like the YMP can use the basic framework of this system for proposed changes in safety and health requirements. Using a committee format, the public procedures can be adapted to specific projects. Solicitations of comments defuse complaints that one or another party was not informed of the changes.

SUPERVISOR'S ACCIDENT INVESTIGATION REPORT			
Contractor:			
Accident date:	Time:	Contract number:	
Accident location (specific):			
What happened? (Describe operation, activity, condition, and how accident or loss occurred. Use separate sheet and diagram if necessary.)			
Condition or act that caused the accident:			
Recommended corrective action:			
Equipment involved number:	Employee involved:		
Employee injury (describe): Medical referral?			
Company property damage or loss (describe):			
Property damage or injury to others (describe):			
Owner/injured (name, address, phone number):			
Witnesses (name, address, phone number):			
Police Report?	Agency:	Photos?	Taken by:
Foreman/Supervisor:	Date:		
Contractor Project Manager/Superintendent Approval:	Date:		

FIGURE 4 Sample supervisor's accident investigation report form.

MONTHLY ACCIDENT EXPERIENCE SUMMARY	Contract Number: Contractor's/Subcontractor's Name: Month: Year: Reporting Period: Through:

	This Month	Year to Date	Project to Date
Hours Worked			
First-Aid Cases			
Doctor Cases			
Recordable Cases			
Lost Time Cases (List each under comments)			
Days Lost			
Recordable Incidence Rate *			
Lost Time Incidence Rate *			
Days Lost Incidence Rate *			

$$^{*}\text{ INCIDENCE RATE} = \frac{\text{Number of Cases (Days)} \times 200{,}000}{\text{Hours Worked}}$$

AVERAGE MONTHLY EMPLOYEES:	DAYS LOST
COMMENTS:	

Prepared By: Date:	Project Manager/Superintendent: Date:

FIGURE 5 Sample monthly accident experience summary form.

SAFETY TRAINING, SAFETY OVERSIGHT, AND INSTRUCTION

Safety philosophy incorporates the constant need for training all levels of personnel on a given project. However, with a project such as the YMP, how is this training effort organized? There are three groupings of persons on this and similar projects: full-time underground personnel, personnel who periodically go into the underground environment, and visitors.

Full-time underground personnel and those who go underground periodically should receive an initial eight hours of training and follow-up or specialized training, according to the subject and the demand. It is imperative that accurate records be kept of the participants in these training sessions. This record is crucial when dealing with exposures of employees to hazardous materials, radon daughters,[1] and various contaminants. Visitors must be given an orientation that discusses exposure to hazards on the premises. If visitors must wear protective equipment during tours, that instruction should be included during their orientation. Experience from other projects dictates that visitors must be kept in a tight group and escorted throughout the tour.

EXPECTED EXPOSURES AND RISKS ASSOCIATED WITH DIFFERENT TYPES OF EXCAVATION EQUIPMENT

Three different methods of excavation are to be used in the YMP: conventional drill-and-blast, TBMs, and road headers. The following exposures are common to all methods of excavation:

- haulage equipment accidents;
- collapse of ground support;
- hoisting of personnel and equipment;
- radon-daughter encounters in the welded tuffs;
- high dust concentrations, if the characterization studies preclude the use of water for drilling and excavation lubrication and dust control; and
- contaminants from diesel exhaust in the underground atmosphere.

[1] Radon daughters are the radioactive decay products of radon gas. These airborne particles are present in many rock bodies of sedimentary, igneous, and metamorphic origin. If the concentration of these particles is not controlled, the lungs of exposed individuals may be affected, causing lung cancer.

Exposures that are common to TBM and road-header operations include:

- personnel being caught in or between moving parts of machinery;
- falling ribs and lagging segments;
- high-voltage exposures underground, trailing cables, and transformers;
- and ignition of atomized lubricants and hydraulic fluids.

Exposures that are common to drill-and-blast methods include:

- explosives handling and usage;
- static electricity;
- storage and transportation of explosives; and
- propagation of energy release along fractures and fault planes.

Each of the three methods of excavation has its strengths and weaknesses. Injury and accident statistics in the mining industry, with category breakdown, can be obtained from the Mining Safety and Health Administration (MSHA). However, federal OSHA statistics for the construction industry lump TBM and road-header accidents with others and are almost impossible to break out.

One can imagine, then, that expected exposures will be high for dust, heat, noise, and vibration in the mechanical excavation modes (i.e., TBM and road-header methods), and for dust and noise in the drill-and-blast work.

MANAGING SAFETY LIABILITY ON A MULTICONTRACT WORK SITE

Organization, communication, shared responsibility, one safety manual to which all involved contractors and managers contributed, and the development of a favorable safety climate will have a beneficial effect on liability experience. A team effort will prevent or greatly lessen conflict on the site.

Many projects are built in the center of urban areas (e.g., The Metro Rail Project in Los Angeles) where the general public is exposed to all of the surface manifestations of underground work (e.g., noise, traffic congestion, dust, dirt, mud, ground settlement, exhausting of gases and vapors, and general disturbance of life around the project site). On the other hand, at remotely located project sites (e.g., the YMP) the actions of one contractor and its employees have an impact on another contractor and its employees working at that same site. It is necessary that safety engineers and management, with the guidance of the construction manager, coordinate efforts to solve many safety problems in their infancy or before work progresses. At the same time, the public must be protected from the cumulative exposures that are created by the contractors' efforts.

A construction safety report may help lessen confusion and clarify expectations from contractors and their supervisory personnel. Figure 6 shows a summary of construction safety reports. It is in the submission, writing, and research for these reports that team effort and cooperation starts.

HANDLING OF EMERGENCY RESPONSE IN CASE OF ACCIDENTS, FIRES, OR A DISASTER

An incident command organization chart (Figure 7) is essential to handle the response in case of an accident, fire, or disaster. This chart should not be so cumbersome and complicated that personnel decline to study it. The task of responding to accidents, fires, or disasters should be less complicated in a remote area, where urban fire departments are not involved. Ascending levels of emergency are the following:

1. a primary level for accidents, treatment, transportation of the injured, and so on;
2. the next level for fires, explosions, underground adjustments, command posts, and responses by select personnel; and
3. the highest level of response to a disaster, including the first two levels above.

Incident commanders should organize their forces by calling for drills; organizing the various components; and selecting key personnel, rescue crews, and surface back-up personnel.

CONCLUSION

Safety jurisdiction of the YMP may be in the hands of federal OSHA, of Nevada OSHA in the private sector and federal OSHA in the governmental sector, or of DOE. Regardless of jurisdiction, federal OSHA regulations will be in effect, with reference to MSHA regulations in specific areas and instances.

Site stratigraphic characterization studies may preclude the use of water or other lubricants during drilling and excavation to prevent native rock contamination. This will increase the hazard from dusts and possibly force the main ventilation systems to be in

SUMMARY OF CONSTRUCTION SAFETY REPORTS

FORM	TITLE	EVENT(S) GENERATING REQUIRED REPORT	PREPARED BY	DIST*	REMARKS
	Report of Safety Meeting	Recording of weekly tool box meeting	Supervisor/ Foreman holding meeting	(3)	
	Construction Safety Inspection Checklist	Monthly report	Contractor	(3)	
	Job Hazard Analysis	Known safety hazards and all major construction operations	Contractor	(1)	Filled out and submitted as requested
	Construction Safety Survey	Recording of safety hazards	Contractor	(2)	Filled out and submitted daily by the Contractor's Safety Representative
	Supervisor's Accident Investigation Report	Bodily injury to contractor, subcontractor, employee, or the general public	Contractor	(4)	Report must be submitted within 24 hours of the event
	Monthly Accident Summary	Monthly report	Contractor	(2)	
	Crane Inspection Record and Wire Rope Inspection Record	Monthly report(s)	Contractor	(1)	
	Weekly Safety Update	Weekly	Contractor	(1)	Submitted each Monday, covering previous week
	Confined Space Entry Permit	Confined space work	Contractor	(3)	Posted at job site during confined space work
Federal OSHA and California OSHA Form 200	Log and Summary of Occupational Injuries and Illnesses	Employee occupational injury or illness	Contractor	(3)	Contractor required to retain Form 200 and related records for 5 years subject to California OSHA or Federal OSHA inspection

*Distribution: (1) Contractor, Resident Engineer, Safety Manager; (2) Contractor, Safety Manager, Resident Engineer; (3) Contractor; (4) Insurer, Contractor, Safety Manager, Owner Controlled Insurance Program Administration, Resident Engineer

FIGURE 6 Sample summary of construction safety reports.

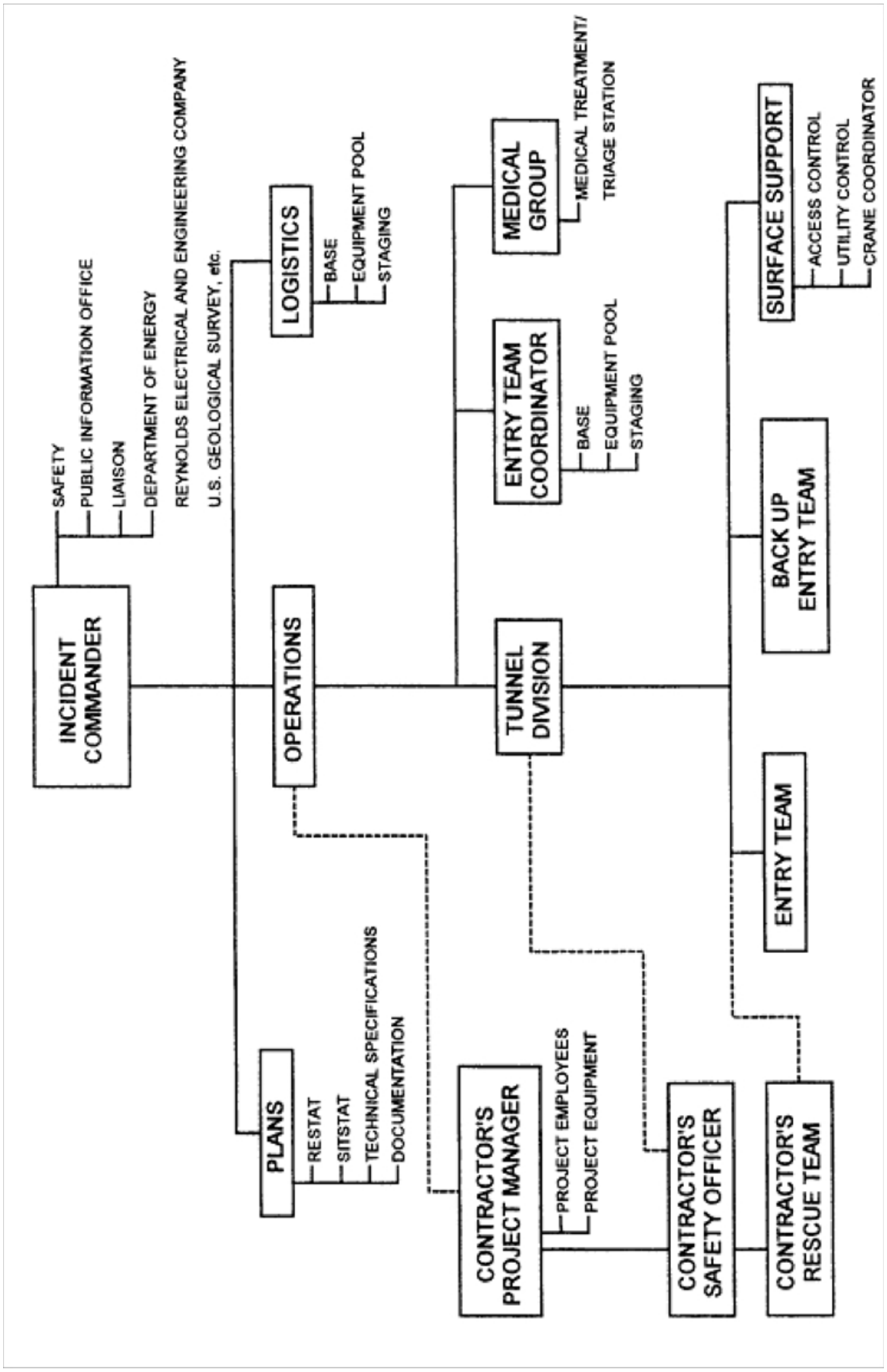

Figure 7
Tunnel incident command organization chart.

the exhausting mode, whether excavation is done by drill-and-blast, TBM, or road-header equipment.

To build an atmosphere of team safety on the project, there must be an all-encompassing safety manual, good communication among all agencies and contractors, and continuous contact among prime participants. Safety monitoring must be meaningful, coupled with job hazard analyses of proposed operations and a gleaning of every bit of useful information from accident investigations in order to prevent recurrence.

Clear lines of responsibility must be drawn to designate those who are authorized, designated, qualified, and competent to complete assigned tasks. Changes in the safety and health regulations must have input from all those with legitimate interest. Safety training is a continuing process. Expected exposures during various work operations pose a challenge in that one must ensure that the personnel actually doing the work are knowledgeable of the hazards to which they are to be exposed and the methods of mitigation of these hazards.

Emergency response plans must be rehearsed to ensure preparation and no last-minute surprises. Safety liability on adjoining contracts must be clear, but a cooperative effort at the management level is necessary to prevent the actions of one phase of the work unfavorably impacting another.

There is no excuse for the YMP not to have the highest level of safety effort and Success.

DISCUSSION

After the presentation, Russ Baumeister, occupational safety and health specialist at DOE, said that the YMP received notification from the state of Nevada recognizing that the state OSHA has the authority to enforce project compliance with federal OSHA regulations. However, DOE also has rights in a crisis situation and, as in the Superconducting Supercollider Project, is likely to negotiate with the state authority.[2]

Regarding the need for DOE and other agencies to work together, it was noted that the Army Corps of Engineers has suggested that federal agencies involved in construction put together a construction safety manual. This document might then supplant 29CFR1926 for federal construction projects. Although DOE could have conflicting

[2] Russ Baumeister recently said that the YMP is recognized as a DOE project exempt from the regulatory oversight authority of OSHA or the state of Nevada. DOE retains the authority to enforce compliance with safety and health regulations.

issues that preclude total participation, its best interest would be served in reaching a meeting of the minds with other agencies.

Bibliography

U.S. Department of Labor. Code of Federal Regulations 29, Part 1926: Safety and health regulations for construction.
World Tunneling Magazine, November 1991.
Rail Construction Corporation. 1993. Safety and Security Manual, Revision 6. February 22. Los Angeles, California.
California Administrative Code. 1973. Title 8, Chapter 4, Subchapter 20: Division of Occupational Safety and Health. Tunnel Safety Orders.
Los Angeles Fire Department. 1990. Tunnel Incident Command Organization. California.
California Administrative Code. 1966. Title 8, Chapter 4, Subchapter 17: Division of Occupational Safety and Health. Mine Safety Orders.

Safety Engineering Design Analysis For Tunneling Equipment

Bruce L. Blackford

ABSTRACT

This paper describes the two predominant design analysis techniques that are currently employed to perform safety engineering analysis on modern-day, sophisticated equipment and systems. These analysis techniques provide a cost-effective means of uncovering design flaws that otherwise would go undetected until after the equipment has been delivered to the user.

Unfortunately, tunnel equipment designers and manufacturers do not routinely perform these analyses in their design process, thereby leaving potentially catastrophic design flaws that can result in fatal accidents. Pieces of tunneling equipment in general, and tunnel boring machines (TBMs) in particular, are not mass-produced items, but rather are one-of-a-kind prototypes. As such, TBM designs are not field-proven to be fail-safe.

Failure mode, effects, and criticality analysis (FMECA) and fault-tree analysis (FTA) provide invaluable insight into a design and its potential failure mechanisms during the design process. These analyses can identify potential equipment-failure modes that can be catastrophic, while the design is still on the drawing board. It is at this point in the design process that action to correct potential safety hazards is most cost-effective. For this reason it is imperative that government agencies and management and operations contractors fully understand the benefit of these two types of safety design analysis when procuring tunneling equipment. These analyses should be a contractual requirement during the design of all tunneling equipment delivered as part of the Yucca Mountain Project (YMP).

INTRODUCTION

Safety is of prime importance in today's society. In fact, we all want to know how safe our streets are after dark, or whether it is safe to swim in the ocean when we know we share it with sharks. However, when it comes to the safety of those using sophisticated, modern-day equipment, we rely on a false security, believing that the equipment designer has considered all safety issues and has resolved all critical design flaws before the equipment is delivered to the user. If this were true, we would not have manufacturer safety recalls, which occur on a regular basis. In fact, most designers in America are only concerned with equipment performance, producibility, and cost to manufacture, *not* safety. Safety considerations at the design level are usually limited to issues mandated by law or government regulations (e.g., federal seat-belt laws, Occupational Safety and Health Administration regulations).

Pieces of tunneling equipment in general, and TBMs in particular, are not mass-produced items, but rather are one-of-a-kind prototypes, designed for a specific user with a specific application. As such, these designs are not field-proven to be raft-safe. While TBM manufacturers have been around for decades, the engineering design effort still remains largely void of engineering analysis techniques that would provide safety insight into the design on *an a priori* basis.

Some government agencies (e.g., the National Aeronautics and Space Administration, the Department of Defense, and the Federal Aviation Agency) have been instrumental in developing engineering analysis techniques due to the catastrophic nature of equipment failure in their environments. Techniques such as FMECA and FTA provide great insight into the design before the item is even built. Failure of the design team to perform such analyses leaves the eventual user or operator with equipment for which safety is by chance, not by design. Failure of government agencies and their management and operations contractors to understand fully the benefit of and to require contractually these types of analyses during the design of sophisticated electrical and mechanical systems and equipment can result in preventable, fatal accidents.

This paper will describe two types of analysis, FMECA and FTA, as they apply to typical tunneling equipment and TBMs. Most designers are not even aware that these safety engineering design analyses have been developed to proactively understand equipment modes of failure while the design is still on the drawing board. This stage is the most cost-effective timeframe in which to understand basic failure modes so they can be designed out, rather than being discovered later after a catastrophic event, such as a major injury or loss of life, during in-service use.

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS

FMECA basically consists of identifying and tabulating each of the modes by which a system, component, or part may fail, along with the resulting effect on the system or equipment. It is normally performed by considering one failure at a time (i.e., a single contingency).

The primary objective of FMECA used as a safety design analysis is to iteratively examine all potential failure modes, their causes, and their effects to give the designer information on areas where design failures may cause hazardous effects. Figure 1 shows an example of an FMECA worksheet. FMECAs should be started as soon as preliminary design information is available at the system level for early identification of all critical and catastrophic failure possibilities. This allows such potential failures to be eliminated or minimized through design correction at the earliest possible time. The FMECA is an iterative process as the design continues, evaluating not only these design changes but also any changes that were incorporated to reduce potential safety hazards.

A properly performed FMECA is invaluable to those responsible for making program decisions regarding the feasibility and adequacy of a design approach. The extent of the effort and the sophistication of the approach used in FMECA will depend on the nature of the equipment and its intended application. This makes it necessary to tailor the requirements for FMECA to each individual program.

Severity Classification

Once the failure modes and their effects have been identified, severity classifications are assigned to provide a qualitative measure of the worst potential consequences of each failure. Severity classifications are assigned to each identified failure mode and each item is analyzed in accordance with the following loss statements, defined specifically for human safety hazards.

- category I—catastrophic—a failure mode resulting in death;
- category II—critical—a failure mode resulting in severe injury;
- category III—marginal—a failure mode resulting in minor injury; and
- category IV—minor—a failure mode that is not serious enough to cause injury.

EQUIPMENT NAME: Tunnel Boring Machine
SUBASSEMBLY: Hydraulics
DRAWING NUMBER: 123-4567

DATE: 11/30/1993
ANALYST: A.B. Normal
SHEET: 1 of 20

FAILURE MODE	FAILURE CAUSE	FAILURE EFFECT: LOCAL	FAILURE EFFECT: NEXT HIGHER	FAILURE EFFECT: SYSTEM	SEVERITY	PROBABILITY OF OCCURRENCE
Loss of hydraulic pressure	Leak in internal cylinder check valve Ruptured high-pressure hose Failure of the directional control valve (DCV)	Cylinder retracts under load	Load falls against TBM structure	Load damages TBM and pins miner under erector carriage	I	C
Erroneous signal sent to DCV to retract	Failure of the programmable logic controller I/O circuit card Control box switch shorts	Cylinder retracts under load	Load falls against TBM structure	Load damages TBM and pins miner under erector carriage	I	C

FIGURE 1 FMECA worksheet example.

Probability Of Occurrence

Once a severity classification is assigned, a probability of occurrence is then assigned so that the criticality portion of the FMECA can be accomplished. The purpose of the criticality analysis is to rank each potential failure mode according to the combined influence of its severity classification and its probability of occurrence. Individual-failure-mode probabilities of occurrence should be grouped into distinct, logically defined levels establishing the qualitative failure probability level. Probability of occurrence levels are defined as follows:

- level A—frequent—a failure mode occurring more than 20 percent of the time;
- level B—probable—a failure mode occurring more than 10 percent of the time, but less than 20 percent of the time;
- level C—occasional—a failure mode occurring more than 1 percent of the time, but less than 10 percent of the time;
- level D—remote—a failure mode occurring more than 0.1 percent of the time, but less than 1 percent of the time; and
- level E extremely remote—a failure mode occurring less than 0.1 percent of the time.

Criticality Matrix

The results of an FMECA can best be presented using a criticality matrix (see Figure 2). The criticality matrix provides a means of identifying each failure mode and comparing it to all other failure modes with respect to severity and probability of occurrence. The matrix is constructed by inserting item or failure-mode-identification numbers in matrix locations representing the severity-classification category and the probability of occurrence of each of the item's failure modes.

The resulting matrix display shows the distribution of the criticality of item-failure modes and provides a tool for assigning corrective action priorities. As shown in Figure 2, the further along the diagonal line from the origin the failure mode is recorded, the greater the criticality and the more urgent the need to implement corrective action.

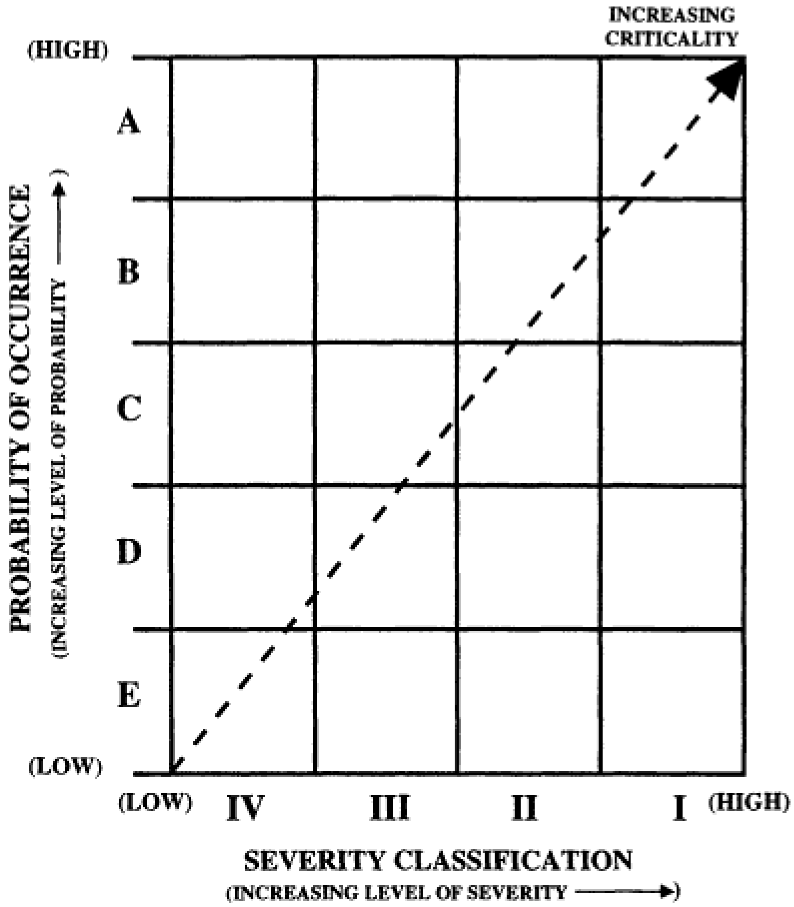

Figure 2
Example of a criticality matrix.

FAULT-TREE ANALYSIS

FTA is also a valuable design and diagnostic tool and is one of the principle methods of system safety analysis. It is a detailed analysis that can predict the combinations of multiple failure events (i.e., multiple contingencies) inherent in a system design that are most likely to cause system failures resulting in potential accidents. In this way, FTA can identify critical and catastrophic events on a proactive basis.

FTA evaluates an undesired event by working backwards from the undesired event through an enumeration of its causes. This approach identifies all influences contributing to the undesired event, including not only hardware failures but also nonhardware causes such as human error, rare operational or maintenance events, and unusual environmental conditions. Once these influences are identified, the relative impact of each is assessed.

The FTA process includes two major steps: (1) fault-tree construction and (2) fault-tree evaluation. The following paragraphs describe these steps.

Fault-Tree Construction

The goal of fault-tree construction is to identify all event conditions that can result in the top-level undesired event. Before construction of the fault tree can proceed, a thorough understanding of the system is required.

A fault tree is a deductive process that graphically and logically represents the various combinations of possible fault and normal events occurring in a system that lead to the top event. An event is a dynamic change of state to a system element. System elements include hardware, software, and human and environmental factors.

Various symbols represent specific types of fault and normal events in FTA. In constructing the fault tree, these symbols are used to describe a variety of events and are common to all types of fault-tree construction. They are not repeated in this paper but are readily available from a number of FTA sources.

The fundamental logic gates for fault-tree construction are the "OR" and the "AND" gates. The "OR" gate describes a situation where the output event will exist if one or more of the input events exist. The "AND" gate describes the logical operation requiring the coexistence of all input events to produce the output event. The symbols for these two logic gates and some of the event symbols are shown in a simplified example of a fault tree in Figure 3.

Once constructed, the fault tree serves as an aid in determining the possible causes of an undesired event. When properly used, the fault tree often leads to the discovery of failure combinations that otherwise might not have been recognized as causes of the event being analyzed. The fault tree can also serve as a visual tool in communicating and supporting decisions based on the analysis, specifically when determining the adequacy of a system design. The fault tree provides an efficient format helpful in evaluating the safety of the design for the intended application.

Fault-Tree Evaluation

The evaluation of the fault tree can be either qualitative, quantitative, or both, depending on the scope of the analysis. The primary objective of fault-tree evaluation is

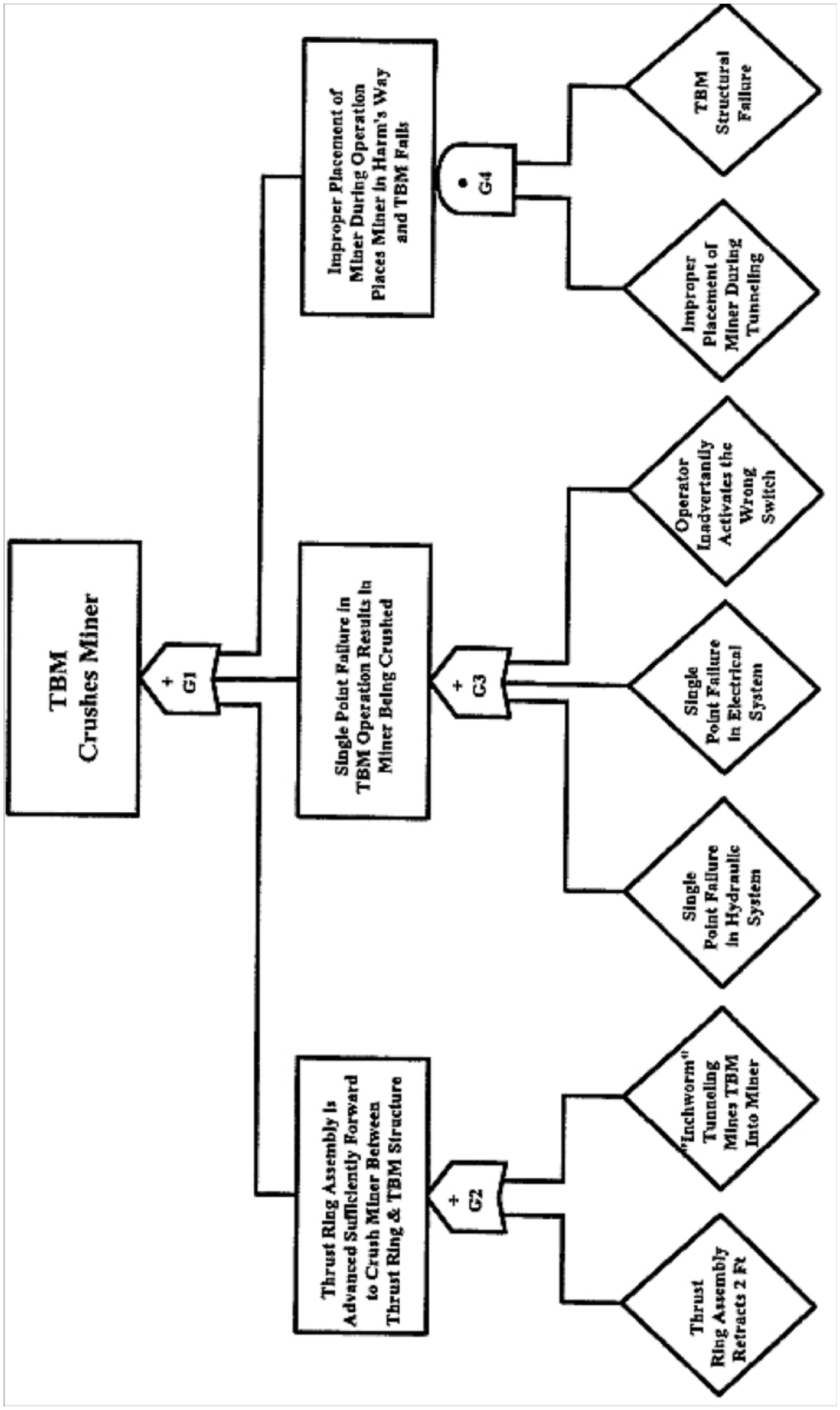

Figure 3
Example of a simplified fault-tree diagram.

to determine if there is an acceptable level of safety in the proposed system design (i.e., will the proposed design suitably minimize the probability of occurrence of the top event). If the system design is found inadequate, then it is upgraded by first identifying critical events that significantly contribute to the top event and then by changing the design to reduce the effect of the critical events. Cost constraints, contractual requirements, and other factors limit the design changes that can be made. Therefore, trade-off studies are necessary to determine what changes will be incorporated. When all design changes have been made, the fault tree is re-evaluated to determine whether the revised design provides an acceptable level of safety.

SUMMARY

Well-proven analysis techniques exist to uncover safety-critical design flaws during the design process, rather than after the equipment has been delivered and is operating in the tunnel. The two most effective techniques are the FMECA and the FTA. In essence, these analysis techniques can be used either as a tool to uncover safety flaws during the design process, when design change is the most cost effective and can prevent potential accidents, or after an accident to assist investigators in determining the cause of the accident. The first of these is clearly preferable. Therefore, government agencies and management and operations contractors should require these two safety engineering design analyses as part of the design process for all tunneling equipment. More specifically, the Department of Energy should require FMECA and FTA of the tunneling equipment to be delivered as part of the YMP.

Milwaukee Water Pollution Abatement Program: Underground Safety—Dealing With Osha

John Ramage

ABSTRACT

Underground construction is fraught with hazards. Although many of these can be anticipated, sometimes workers' own choices put them beyond the protection of countermeasures. The Milwaukee Water Pollution Abatement Program (MWPAP) can attribute three of its six fatalities to such a choice.

Guidance in structuring a safe underground work place can be found in regulations published by the Occupational Safety and Health Administration (OSHA), the Mine Safety and Health Administration (MSHA), and other agencies with a similar mission. OSHA regulations have improved recently, but the industry still requires better understanding and definition of responsibilities for such issues as tunnel classification and control of a multiemployer work site. Those involved in tunnel construction should work with OSHA to establish clearer direction on these issues.

BACKGROUND

MWPAP began in 1977 as a program imposed by the federal and state regulators that encompasses the 450 square mile Milwaukee metropolitan area. The work consists of upgrading two waste water treatment plants, as well as establishing a large-diameter, in-line storage interceptor system and a program to relieve combined sewer overflows in the Milwaukee metropolitan area. MWPAP is now 97 percent complete, with completion expected in the fall of 1995, a year ahead of schedule.

The total cost of MWPAP is $2.29 billion. The program comprises 324 separate construction contracts,[1] and construction costs represent $1.6 billion of the total cost. The underground component, with construction costs of approximately $900 million, consists of 20 miles of 17-to 32-ft-diameter rock tunnels lying 300 ft below the ground surface, 24 drop shafts and approach channels connecting to that deep system, and 62 miles of small-diameter (i.e., 60 to 144 inches) near-surface collector runnels at depths of 30 to 100 ft below the surface.

ORGANIZATION OF MWPAP

The owner of MWPAP is the Milwaukee Metropolitan Sewerage District (MMSD), which was the first special service agency in the United States. CH2M Hill is the program manager and as such is responsible for planning, design, construction management, cost and schedule control, and claims management or mitigation. All construction contracts were procured using the normal public works bidding process. Construction contracts are between MMSD and the construction contractor. Eighty-eight engineering firms work under direct contract to CH2M Hill, with a maximum of 650 personnel. At the height of construction in the late 1980s there were 75 active construction contracts, employing 1,200 construction personnel.

The controlling regulatory code for safety is the federal OSHA code. Underground construction is governed by Subpart S, "Tunnels and Shafts, Caissons, Cofferdams, and Compressed Air," which was revised in 1989. Subpart K of the OSHA regulations, "Electrical Code," was another critical regulatory component for the program. Safety on MWPAP was also under the review of the Wisconsin Department of Industrial Health and Labor Relations.

The roles and responsibilities of team members are well defined and have been throughout the program. The owner, MMSD, alone has the authority to shut down work for any reason. MMSD also committed to fund, train, and have available the rescue team for all underground contractors. To meet this commitment, the Milwaukee Fire Department assembled three full rescue teams staffed through the Milwaukee metropolitan area that meet the OSHA 30-minute response criterion, with more than adequate backup for the second team. Finally, and most importantly, the prime construction contractor (i.e., the organization responsible for the work on site) carries the overall responsibility for work-site safety.

[1] MWPAP's 324 separate construction contracts have been distributed across the years of the program's existence.

The program manager, as one employer on a multiemployer work site, has the responsibility to train its own staff for their work activities underground. This also requires an understanding of the prime contractor's safety program and an implementation of appropriate components of the program by the program manager's staff. All personnel are to report their safety concerns to the contractor and the program's on-site representative (usually the resident engineer). Finally, each individual has the responsibility to take action as a prudent professional if danger appears imminent.

PROGRAM SAFETY

The subsurface environment in the Milwaukee metropolitan area has had a significant impact on underground construction and associated safety requirements and programs. The metropolitan area lies at the confluence of three rivers as shown in Figure 1. These rivers are surface expressions of deeply carved glacial valleys. Since the last glacial period, these valleys have been filled with a wide range of deposits ranging from dense glacial till to sand and gravel alluvial deposits and highly organic marsh deposits. While construction challenges occurred on the deep rock tunnel component of MWPAP, the major challenges occurred in work conducted in materials deposited since the last glacial period.

Three major elements challenged the construction team. First, since most of the near-surface tunnels constructed on MWPAP followed the paths of the three rivers in the area, ground water levels were close to the surface. This required soft-ground tunneling methods, as shown in Figure 2, that control the inflow of water to minimal levels.

Second, the variable nature of these subsurface deposits required ground support systems that were robust, with the flexibility to support widely varying loading conditions. This was particularly crucial in the soft organic marsh deposits.

Finally, the most significant challenge of all was dealing with the potential of methane produced from the natural decay of organic materials in the marsh deposits. These deposits were the source of the methane that fueled a 1988 explosion.

SAFETY RECORD

MWPAP has had six fatalities in over 20 million hours of underground work. One worker fell in a shaft, another was hit on the head by falling debris, and a third was caught in a conveyor. The last three fatalities resulted from the 1988 methane explosion. There were no citations for the first three, but litigation and federal action continue in the case of the explosion.

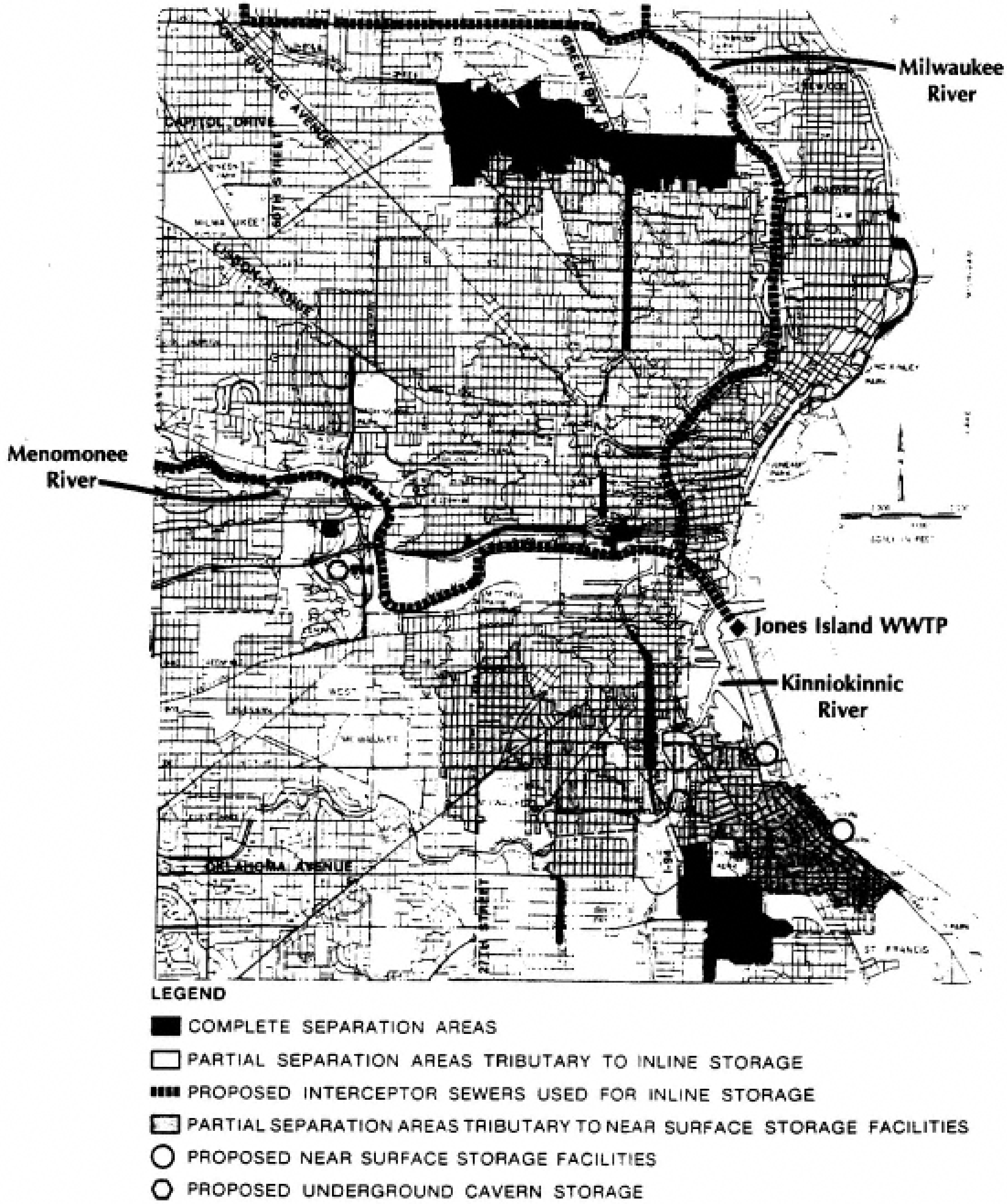

Figure 1
Metropolitan Milwaukee area map showing the confluence of the Menomonee, Milwaukee, and Kinniokinnic rivers.

Figure 2
Soft-ground tunneling method used to control the inflow of water.

THE REGULATORY ENVIRONMENT AND THE TEAM'S RESPONSE

The OSHA Code, Subpart S, in force through most of the program's underground construction, did not include the current classification system, that provides definitions classifying tunnels as nongassy, potentially gassy, or gassy. In addition, before 1989, Subpart S contained only minimal language on air quality and ventilation. It required mechanical ventilation, a reversible ventilation system, 30 ft/min of airflow in the tunnel, 200 ft^3/min per worker, and mandatory shutdown and evacuation of workers at 1.5 percent (i.e., 30 percent of the lower explosive limit [LEL]) or higher concentrations of flammable gas, with no return to work until concentrations diminished to less than 1 percent (i.e., 20 percent of the LEL). The OSHA regulations also required that evacuation plans be developed and made known to the employees and that electrical equipment conform to the requirements of Subpart K. These requirements set the minimum standards for underground safety.

In December 1987, a contractor ran into methane while mining through a highly organic soft clay. Several shutdowns occurred. Responding to the contractor's concern, CH2M Hill conducted a major investigation to determine the potential occurrence of methane in this environment. The findings, shared with all underground contractors, led the program manager to take a proactive approach to the potential methane hazard by modifying all of the contracts to establish stringent, specific safety requirements.

They took the best, most stringent requirements from several sources, including California OSHA, MSHA, and the federal OSHA. From these requirements they crafted precise language for the seven tunnel contracts in the soft organic clay environment. The contract modification required the following:

- ventilation 24 hours a day, using Class I, Division 1 fans for the main ventilation system (Subpart K, Section 1926.449, "Electrical Code, Classification of Hazardous Work Space");
- an airflow increase from 30 to 60 ft/min;
- continuous monitoring at the heading with warning broadcast at 10 percent of the LEL and shutdown and evacuation at 20 percent (recall that Subpart S at the time required shutdown and evacuation at 30 percent of the LEL); and
- the conformance of all electrical components on the TBMs to Class I, Division 2 requirements (also from Subpart K).

Contractors were required to develop a detailed, formal training program and a detailed evacuation and recovery plan should a shutdown occur.

CH2M Hill performed a detailed fault-tree analysis of failure mechanisms in the underground construction environment to establish redundancy priorities. (A fault tree is a logic diagram that allowed CH2M Hill to reason through the chains of circumstances and events that lead to the failure mechanisms.) Ventilation proved most critical in providing a safe working environment. The team required 24-hour ventilation; fully reversible, explosion-proof fans; and air velocities greater than those required by OSHA (see Figure 3). The next redundancy priority was early detection. The team required continuous monitoring and early detection and warning. Shutdown and evacuation were the third redundancy priority, and comprehensive training was the fourth. Class I, Division 2 electrical components were considered the fifth level of redundancy. Preventing the environment from becoming hazardous was the first objective of the contract safety program. If prevention proved impossible, getting the workers out and the power off before it became hazardous was the backup.

THE EVENT

On November 10, 1988, the contractor started the morning shift and quickly encountered a concentration of methane in excess of 20 percent of the LEL that shut down the TBM. The 11 people in the tunnel at that time evacuated safely. The contractor's evacuation and recovery plan required that the superintendent account for all workers who had been in the tunnel and then de-energize the tunnel, reverse the fan on the main vent line, and monitor the return air, waiting a minimum of one hour or until he or she could no longer detect a flammable mixture in the return air, whichever period of time was longer, before reentering the tunnel.

Instead of following the evacuation and recovery plan, the superintendent, the safety engineer, and the shift foreman—the three most experienced people on the contractor's team—reentered the tunnel after 45 minutes. They neither reversed the ventilation system's air flow nor monitored the methane levels in the return air, they never shut off the power, and they did not wait the minimum hour. Five minutes after they reentered the tunnel, an explosion killed them.

THE FALLOUT

Despite the belief of the MWPAP team that program roles and responsibilities are well established, legal determination of responsibility for the explosion remains unresolved. OSHA continues to pursue action against CH2M Hill.

Figure 3
Tunnel ventilation system using fully reversible, explosion-proof fans.

The consequences for the contractor included convictions for negligent homicide at the state level and for criminal violation of OSHA regulations at the federal level. The contractor's total expenses for litigation, recovery of the tunnel, and returning to work ran over $7 million. The contractor also was disqualified from a bid that he had essentially won for work on the Los Angeles subway system.

CH2M Hill was charged with 47 willful violations of OSHA regulations, with a fine of $10,000 per violation. Twenty-seven of those violations were for the lack of explosion-proof light bulbs, as required in Subpart K, in the string leading from the shaft to the heading. OSHA has taken the position that the hazardous classifications under Subpart K, which were intended for work spaces such as paint shops and manufacturing facilities, apply to underground construction. CH2M Hill was also charged as having control over the construction work site. Their cost thus far has exceeded $2 million.

Personally, the author has spent much time giving depositions to federal lawyers, state lawyers, and insurance company lawyers. He has been a witness in the criminal proceedings. And the U.S. Attorney from the southeastern district of Wisconsin believed that the author sat down with the contractor's project manager after the explosion and drafted the evacuation plan. The author testified before a federal grand jury, as the Department of Labor and U.S. Attorney explored a possible corporate and personal indictment for criminal violation of OSHA regulations. Fortunately there were two engineers on the grand jury. One of these, who had worked in a manufacturing facility, observed that using Subpart K hazardous classifications in the underground environment was inappropriate. Criminal indictment of CH2M Hill and the author was not pursued.

Subpart K's hazardous classifications assume that work must be conducted in a hazardous environment. However, the MWPAP team's approach to the underground environment, demonstrated by their contract modifications in the face of a high probability of methane being encountered, was to detect hazards early, shut down work, and evacuate the tunnel before the environment became hazardous. From that perspective, Subpart S and the MWPAP team's contract modifications were far more stringent than Subpart K.

Five years later, CH2M Hill is still embroiled in legal repercussions. On August 25, 1993, upon CH2M Hill's formal appeal, a Department of Labor administrative judge dismissed all charges, saying in his decision that it was unequivocally clear that the program manager did not control the work site. The contractor even asserted under oath that he controlled the work site and assumed all responsibility for safety. However, OSHA filed an eleventh-hour appeal and continues to insist that CH2M Hill controlled the work site, despite the contractor's insistence to the contrary. The case will go before the OSHA Review Commission and quite possibly to the U.S. Appeals Court and the Supreme Court. CH2M Hill expects that a resolution of the case is three or more years away.

LESSONS LEARNED

The following lessons can be drawn from the CH2M Hill experience with the methane explosion on the MWPAP. First, in underground construction, all responsibility for and direction of safety must be centered in a single entity or organization. That entity must have a well-documented safety plan and must ensure that all involved are properly trained in safe practices and responses to contingencies. All employees on the project must follow the safety program. The responsible entity must exhaustively document all its efforts to ensure safe practices.

Second, those involved in underground construction have a number of issues to resolve with OSHA. Subpart S was revised in 1989, after the MWPAP methane explosion, to provide definitions for tunnel classification as nongassy, potentially gassy, or gassy. The revisions also require a warning when explosive gases reach a level of 10 percent of the LEL and evacuation at 20 percent, as was required by the revised contracts on MWPAP. Finally, the revisions add details concerning ventilation requirements and training and evacuation plans.

However, despite the revisions providing the definitions, OSHA has shown no willingness to classify tunnels. Those involved in tunnel construction must work with OSHA to determine who is responsible for doing so. Also, the question of whether the hazard classifications of the Electrical Code apply underground must be resolved. Finally, in a multiemployer work site, what does control of the work site mean? Roles and responsibilities of the various parties to a project must be better defined.

In the end, safety is an attitude that must be maintained continuously. Those involved in an underground construction project must work together as an integrated, coordinated, and committed team with safety as a primary focus; otherwise, accidents will happen.

DISCUSSION

In response to participant questions, John Ramage added the following points of clarification. Before the methane explosion, there had been one other shutdown because of a high methane concentration. Interpreting the question further, he added that there is not really any way to prevent workers from making bad decisions, such as the one to go back into the tunnel, either with regulations, program plans, or training.

The decision to go back into the tunnel was made by the safety engineer, who had returned two days before the incident from a week-long training course given by MSHA.

He was an employee of the contractor and had the authority to make that decision. The safety engineer was one of the three who reentered the tunnel.

Following the question period, Ted Petrie, who is a division manager for the Department of Engineering at the Department of Energy (DOE), described the process by which DOE selects the regulations to be imposed contractually at the Exploratory Studies Facility (ESF) at Yucca Mountain and named the agencies involved in the safety oversight of the program.

The following are the regulations from which DOE has selected the health and safety requirements to be met at the ESF: the State of California Tunnel Safety Orders, the OSHA Orders, the MSHA Orders, the State of Nevada Health and Safety Standards, and the State of Nevada OSHA regulations. From these various sources, DOE selects the most stringent requirements (i.e., the ones providing the most protection) in each category and imposes them contractually upon the prime contractor and, through the contractor, upon all parties working on the ESF.

The enforcement agency with jurisdiction over the ESF is the State of Nevada OSHA. That agency has formal inspection authority at Yucca Mountain. DOE also has a memorandum of understanding with MSHA, through which MSHA will provide, upon request, less formal design review and inspections to assist DOE in ensuring safety at the Yucca Mountain ESF.

Bibliography

Goodman, G.V.R. 1988. An assessment of coal mine escapeway reliability using fault tree analysis. Mining Science and Technology. 7:205-215.

MSHA. 1986. Fault Tree Analysis. Safety Manual Number 8. U.S. Department of Labor, Mine Safety and Health Administration.

Osha Today And Tomorrow

Patrick Tyson

Patrick Tyson gave the keynote address to open the discussion session, held on the second day of the conference. His stated goal was to respond to some of the issues and questions raised during the conference and to give participants some sense of Occupational Safety and Health Administration's current and future operations.

ABSTRACT

The Occupational Safety and Health Administration (OSHA) is a small agency with a big mission. Its limited budget makes it difficult for OSHA to protect the safety and health of American workers in the work place. However, OSHA does have solid enforcement authority, including the ability to issue first-instance sanctions and to levy substantial fines.

Congress and Department of Energy (DOE) Secretary Hazel O'Leary have indicated a desire to turn safety and health jurisdiction on DOE projects over to OSHA. Federal or Nevada OSHA inspectors will evaluate compliance of the Exploratory Studies Facility (ESF) project with OSHA regulations. Particular areas that are likely to receive OSHA attention include record keeping, especially regarding training and material safety; lock-out/tag-out requirements; and electrical standards.

DOE should establish a sound safety and health program that emphasizes employee involvement. Making a good-faith effort to protect workers' safety and health and demonstrating a willingness to work with OSHA to address safety concerns can ensure a productive relationship between DOE and OSHA concerning safety at the Yucca Mountain Project.

OSHA: THE AGENCY AND ITS MISSION

OSHA is a small entity among federal agencies. It claims to have 1200 inspectors for federal enforcement purposes, but the actual number is probably closer to 900. In addition, there are 23 states that also enforce occupational safety and health, with OSHA oversight, adding another 1,000 to 1,200 inspectors to the field.

With such numbers, it would take OSHA perhaps 40 to 50 years to inspect every work place under its jurisdiction. In fact, OSHA tends to focus on certain areas and certain companies. There are many companies and many work sites that will never see an OSHA inspector.

By contrast, the Environmental Protection Agency (EPA) is huge. OSHA has a lot of authority but little money and few people to enforce its standards. EPA, on the other hand, has limited authority with a large budget; this year's EPA budget is larger than the total of all OSHA budgets over the years of its existence.

To protect the safety and health of every American worker in the work place, OSHA needs a presence larger than its budget alone would allow. Recognizing that OSHA has an impossibly large area of jurisdiction, Congress wrote the law to allow first-instance sanctions; that is, the first time that OSHA determines that a violation exists, a penalty is assessed. With the threat of immediate penalty upon discovery or determination of a violation, Congress hoped to ensure work-place compliance with OSHA regulations.

OSHA PENALTIES

Before 1990, the maximum penalty for a willful violation was $10,000. In 1990, legislation was introduced in Congress that would raise it sevenfold; the maximum was raised to $70,000. Congress passed it, and President Bush signed it—not to encourage better compliance, but to bring in more money for the federal government. The then Assistant Secretary Jerry Scannell decided that raising all fines by a factor of seven was not wise, but that some increase was a good idea. Since $70,000 was a maximum and because OSHA has wide latitude in the imposition of penalties, he led OSHA in raising fines to two or three times what they had been. However, the Clinton administration can be expected to double the penalties again, nearly realizing the sevenfold increase originally intended by Congress.

In addition to higher penalties for violations, OSHA is known to use what is called the egregious multiplier. Ordinarily, if OSHA finds multiple, identical instances of a violation at a work site, the multiple instances will be classified as a single violation. However, if OSHA chooses to apply the egregious multiplier, each instance will be counted as a separate violation. This multiplier was first used in a case in which a company had failed to record properly the names of 130 injured workers in their OSHA log; OSHA assessed a penalty for each missing name.

The penalties discussed above are civil penalties; OSHA also has a criminal penalty for a willful violation that results in the death of an employee. That penalty is 6 months in jail or a $10,000 fine, which if assessed, would probably be increased to $250,000 by the applicability of another federal law.

However, criminal prosecution has rarely been used by the federal OSHA. They have referred fewer than 100 cases to the Justice Department for prosecution; of these, perhaps 2 or 3 have been successfully concluded. This relative lack of action on the part of the Justice Department and the U.S. Attorney's Office may be related to the small size of OSHA's criminal penalties. However, those penalties may undergo changes.

The OSHA Reform Bill includes a provision that would increase the criminal penalty from 6 months in jail for a willful violation resulting in the death of an employee to 10 years in jail. The Bill would also increase the monetary penalty to $500,000 and require that, if the monetary penalty is applied against an individual, that individual will be held personally liable; the amount cannot be paid from corporate funds. Also in the OSHA Reform Bill is a provision to make a willful violation resulting in the serious injury (as defined by the bill) of an employee a criminal offense, punishable by 5 years in jail.

As noted earlier, the federal OSHA has not often pursued criminal enforcement, but many states have. For example, several criminal actions have been brought by the state of California, where a particular department within that state's attorney general's office investigates all work-related deaths as potential criminal violations. Illinois also recently convicted two corporate officers of murder as the result of the death of an employee at their work site.

These states are not applying their OSHA laws but rather are trying these incidents as common-law crimes, such as murder, manslaughter, or reckless endangerment. An example of this approach can be found in the case of the fire in an Imperial Foods plant in Hamlet, North Carolina, where 25 people died as a result of locked exit doors. After plea bargaining, the president of that company was sentenced to jail for 20 years but the potential penalty was even higher. That conviction was rendered under North Carolina's murder law rather than under its OSHA law.

HOW OSHA CONDUCTS AN INSPECTION

Typically an OSHA inspection follows a complaint filed by an employee or else results from the OSHA targeting system or a special-emphasis program. In every OSHA inspection there is a mental evaluation; the inspector tries to determine whether the object of the investigation is a good guy or a bad guy. The inspector makes that assessment early in the process, and that determination has a great impact on the direction of the rest of the inspection. OSHA inspectors will not *be hard on a good guy*, but they will charge a *bad guy* with any infraction they can find.

If an employer does not have a safety program, he or she starts out being a bad guy, because that indicates a lack of concern for safety. The better the program the employer has in place, the better the inspectors' perception will be of that employer.

If an employer is not keeping injury records properly, then he or she is a bad guy. Without knowing where the injuries are taking place, a company cannot creme a safety program that addresses those problems effectively.

Inspectors will look at specific programs that are required by law, such as the hazard communication program and the management of lock-out/tag-out and confined space, to assess the organization's approach to the issue of safety.

In addition, the company should assign the highest-ranking official it possibly can to interface with the OSHA inspectors, because this demonstrates that the company cares about the safety and health of its employees. That kind of attitude will affect the evaluation of the OSHA inspectors.

A tunneling work site presents special problems. There will be several contractors on site, but typically OSHA will go in or be called in to inspect only one of these. Looking at one contractor's logs will not tell the OSHA inspectors what is happening elsewhere at the site.

OSHA is concerned about multicontract work sites, because there have been cases in which companies used contractors or subcontractors to perform hazardous work, often at a lower cost than a company's own employees would require. If accidents occurred in such a situation, they did not appear on the lead company's OSHA records. To respond to such multicontract work sites, OSHA has a multiemployer work-site policy that holds all contractors on a site responsible for hazardous conditions, regardless of who causes or fails to address the hazard.

This policy clearly encourages each member of an underground contractor team to do as much as possible to ensure the safety of its own employees and the employees of other team members. However, every action that affects or impinges upon another company's safety and health program may increase the acting organization's liability should an employee of the other company be injured, which raises the issue of third-party liability. One way to avoid this situation is to select contractors and subcontractors only after rigorous evaluation of each organization's safety record.

THE ISSUE OF JURISDICTION

In the forefront of the minds of many DOE contractors is the jurisdictional change that is likely to occur in the near future. The OSHA Act of 1970 gives OSHA jurisdiction in all cases except those in which another federal agency has asserted responsibility for the working conditions of employees. For many years DOE, like the Department of Defense, the Department of Transportation, and several other federal agencies, has claimed jurisdiction over the safety of DOE contractors, based on the contract between DOE and each of its contractors. Each contract requires the contractor to comply with DOE safety and health regulations. When DOE claims authority for safety, OSHA will not challenge it, regardless of how effective the department' s authority is or how effective the standards and regulations are.

However, the current Secretary of Energy, Hazel O'Leary, has indicated a desire to give jurisdiction back to OSHA. Additionally, the OSHA Reform Bill singles out DOE as the sole agency not to be allowed jurisdiction over its own safety program. This combination of congressional sentiment and Secretary O'Leary's stated desire all but guarantees that jurisdiction over DOE safety will be returned to OSHA.

OSHA UNDER THE NEW ADMINISTRATION

The new leader of OSHA, Joe Dear, was only recently confirmed, on November 8, 1993, but he has been working as a consultant to OSHA since April 1993. He can be expected to move quickly to address a number of issues. One likely outcome is an increase in the OSHA enforcement effort with higher penalties for noncompliance, probably double what they are now. Mr. Dear also plans to find a better way to target inspections and issue standards. He has identified a number of health and safety issues he wants to address.

OSHA under the Clinton administration will not be a throwback to OSHA under the Carter administration. At that time, all employers were seen as bad guys, and OSHA sought to find and punish all their offenses. The current OSHA attitude is that there are some employers who willfully fall to comply with standards, and OSHA will try to find them, but the agency intends to work cooperatively with those employers who are making a good-faith effort to secure the health and safety of their employees.

WHAT OSHA WILL REQUIRE OF THE EXPLORATORY STUDIES FACILITY

Record keeping is probably the area of compliance that will receive the most scrutiny by OSHA on the ESF at Yucca Mountain. The application of the egregious multiplier described earlier illustrates how seriously OSHA takes the issue of record keeping. OSHA inspects records at every site and recognizes that DOE record-keeping practices are different from those of OSHA. OSHA record keeping is more complex than most people think it is, and it is easy to do it incorrectly.

DOE must pay attention to OSHA' s mandatory written programs. First, DOE must ensure that the ESF hazard communication program must meet all OSHA requirements. Employees must be thoroughly trained and all training must be documented, because frequently employees do not remember that they have been trained in hazard communication and may tell OSHA inspectors that they have not been trained.

Second, DOE must ensure that all material safety data sheets are available. Each team member should give copies of the appropriate material safety data sheets to every contractor whose employees are being exposed to materials that team member brings into the operation and should obtain copies of the sheets for materials introduced by other contractors to which its employees will be exposed.

Lock-out/tag-out is a relatively new and complex standard that will probably receive emphasis by OSHA. All team members should ensure that training for that standard and the appropriate audits are well documented. They should also maintain written procedures for the lock-out of every machine being used.

The ESF team should also comply with the electrical standard. This standard receives different emphasis from different compliance officers, so thorough compliance is the best approach.

The ESF should not only comply with specific standards, but should also establish programs to meet employee health and safety objectives and to ensure continuing compliance with OSHA regulations. These programs should emphasize employee involvement.

Determining the effectiveness of such programs requires more judgment of the inspector than simply evaluating compliance. Nevertheless, such programs will be required. Title I of the OSHA Reform Bill requires every work place in the nation to have a safety and health program that includes certain minimum elements. Title II requires each organization to establish an employee/management committee or labor/management committee that includes equal representation of employees and management.[1] This committee will be responsible for operating the safety and health program: conducting accident investigations, performing regular inspections, and recommending corrective action to the employer. The employer will retain responsibility for ensuring that the program works.

CONCLUSION

Work-place safety and health at the ESF at Yucca Mountain will fall under the jurisdiction of the federal or Nevada OSHA. Violations of OSHA regulations can draw civil and criminal penalties; additionally, the state may charge an employer with a common-law criminal violation in the case of injury to or death of an employee.

DOE can take steps to ensure work-place safety and to build an effective working relationship with OSHA. Keeping adequate safety records, particularly of employee training and material safety, establishing a hazard communication program that meets OSHA standards, meeting lock-out/tag-out requirements, and complying with electrical standards are all important actions DOE should take to ensure a safe work place that satisfies OSHA requirements. Perhaps even more importantly, DOE should establish programs that actively involve employees in safety and health in the ESF work place. By making an honest effort to establish a safe work place at the ESF, DOE can facilitate a productive and cooperative relationship with OSHA.

DISCUSSION

A participant asked whether OSHA will try to field an expert in runnel construction as an inspector at the ESF at Yucca Mountain, to ensure an appropriate evaluation. Mr. Tyson responded that both political parties' versions of the OSHA Reform Bill include provisions for construction safety, and the Republican version would require inspectors to be experienced in the industries they are inspecting. More likely than the passage of

[1] Employee representatives are to be selected by the union if the site is organized and elected by the employees if it is not. Many in the business community oppose the Title II requirement, because it mandates a fixed formula for the composition of the committee based on the number of employees in the organization.

the Reform Bill, however, is that OSHA will borrow the expertise from other agencies when it is required, perhaps in the form of detailed personnel.

Answering another query, Mr. Tyson observed that it is a stated goal of this administration to prune OSHA standards and focus enforcement efforts on real hazards, but his evaluation is that the focus will continue to be on compliance, and if the inspectors determine that an employer is deliberately failing to comply, then they will cite that employer on anything they can.

The fate of the Construction Safety, Health, Education and Improvement Bill is unclear, he said. It has been attached to the OSHA Reform Bill but does not fit well with it. The speaker explained that the construction bill was written by members of the construction trades and circulated on Capitol Hill long before the OSHA Reform Bill, which was written by the AFL-CIO. He expects that the differences between those bills will be worked out in committee, if both bills have strong congressional support.

A final question concerned the conflict between the OSHA Reform Bill and a law that formed the basis of National Labor Relations Board (NLRB) actions against two companies, DuPont and Electromation, that had set up safety committees including employee representatives. Late in 1993, NLRB issued decisions against these two companies saying that such employee committees are illegal.

The law applied in these cases was written in the 1930s to prevent companies from establishing sham, company-controlled unions with the goal of stopping their employees from organizing their own unions. The law states that a labor organization cannot receive any support from an employer and defines a labor organization as a group of employees that deals with the employer over any working conditions. A safety committee is a group of employees (even when it also includes management) that deals with the employer over working conditions. Since the companies in question were supporting the committees by paying employees for time spent on committee meetings and by providing space for meetings to be held, Tyson said the groups were clearly illegal according to the 1930s law.

When the OSHA Reform Bill is passed, it will include a statement that the committees mandated by the Reform Act shall not be considered labor organizations for the purposes of the law already on the books and used by NLRB in its findings against Electromation and DuPont. In the meantime, said Tyson, employers are advised to go ahead and establish such committees if they wish and allow them to function until someone files a complaint with NLRB, at which time they should disband the committees and post notices stating their intent not to establish any other such committees. If there is a union involved, an alternative is to negotiate the establishment of such committees as a part of the contract.

Underground Operations At The Waste Isolation Pilot Plant: A True Safety Culture

Fred G. Ashford and Linda M. Calderon

ABSTRACT

The following two papers discuss safety management at the Department of Energy' s (DOE) Waste Isolation Pilot Plant (WIPP). The first paper, written by Fred Ashford, describes the Westinghouse Waste Isolation Division's (WID) Underground Operations organization at WIPP, its achievements, and its safety culture philosophy. By successfully coordinating a variety of technical activities in compliance with requirements and regulations, the author concludes that Underground Operations has contributed significantly to the positive perception of the WIPP Project held by oversight agencies and the public. Underground Operations has been able to strengthen WIPP's image as a safe, technically sound facility by focusing on the safety, well-being, and development of its workers. According to Ashford, this management philosophy has resulted in the formation of a true safety culture, which benefits not only the employees but also the project.

In the second paper, Linda Calderon describes many of the steps taken by Westinghouse to turn the management philosophy into a comprehensive safety culture that reduced WIPP accident and incident rates dramatically in the early 1990s. Change in the corporate culture was one key to establishing new safety records. Management initiated the safety ownership initiatives by identifying problems and closing down facility operations to address them. Employees became engaged in the efforts to correct problems. Westinghouse then strived to keep employees informed, using programs including poster campaigns, special training programs, and focused employee working groups. Safety became a value rather than an obligation. Ultimately, Westinghouse encouraged 24-hour safety, which included sending workers home with information packs on household safety and rewarding them for safe behavior, such as wearing seat belts when leaving the job site.

Management changed, as well. Supervisors were urged to "manage by walking around" to see the conditions and situations their workers faced. Multidisciplinary groups tackled the problems of various work crews to familiarize managers with work areas across the project. Open-door and communication policies became standard. Westinghouse is now continuing these endeavors with its contractors and subcontractors.

FOUNDATION OF A TRUE SAFETY CULTURE

Introduction

The WIPP Project, in southeastern New Mexico, is a DOE research and development project designed to demonstrate the permanent, safe, geologic disposal of transuranic waste resulting from U.S. defense activities and programs. As the first facility designed for the permanent disposal of transuranic waste, WIPP has a responsibility to establish an environment of public trust and acceptance. To achieve this goal, DOE has made the safety, protection, and well-being of its personnel, the public, and the environment its number one priority. Consequently, WIPP's success depends largely on the evolution of a new organizational culture founded on its commitment to safety.

As DOE's management and operating contractor at WIPP, the Westinghouse WID has aspired to meet the challenge of developing a true safety culture. The Underground Operations section at WIPP exemplifies a culture that promotes excellence in safe operations by focusing on employee well-being and development. This paper describes the Underground Operations organization, its achievements, and its safety culture philosophy.

UNDERGROUND FACILITIES

WIPP's waste repository level has been excavated approximately 2,150 ft (655 m) underground in the midst of an approximately 3,100-ft-thick, bedded salt deposit. The layout of the WIPP facility is shown in Figure 1. WIPP has four shafts to the underground: the salt handling shaft, the waste shaft, the exhaust shaft, and the air intake shaft. A map of the storage horizon is shown in Figure 2. The shafts are located in a shaft pillar area, within which mining is limited to ensure safety of the shafts and surface facilities. The shaft pillar area contains the shaft stations, salt storage and loading bins,

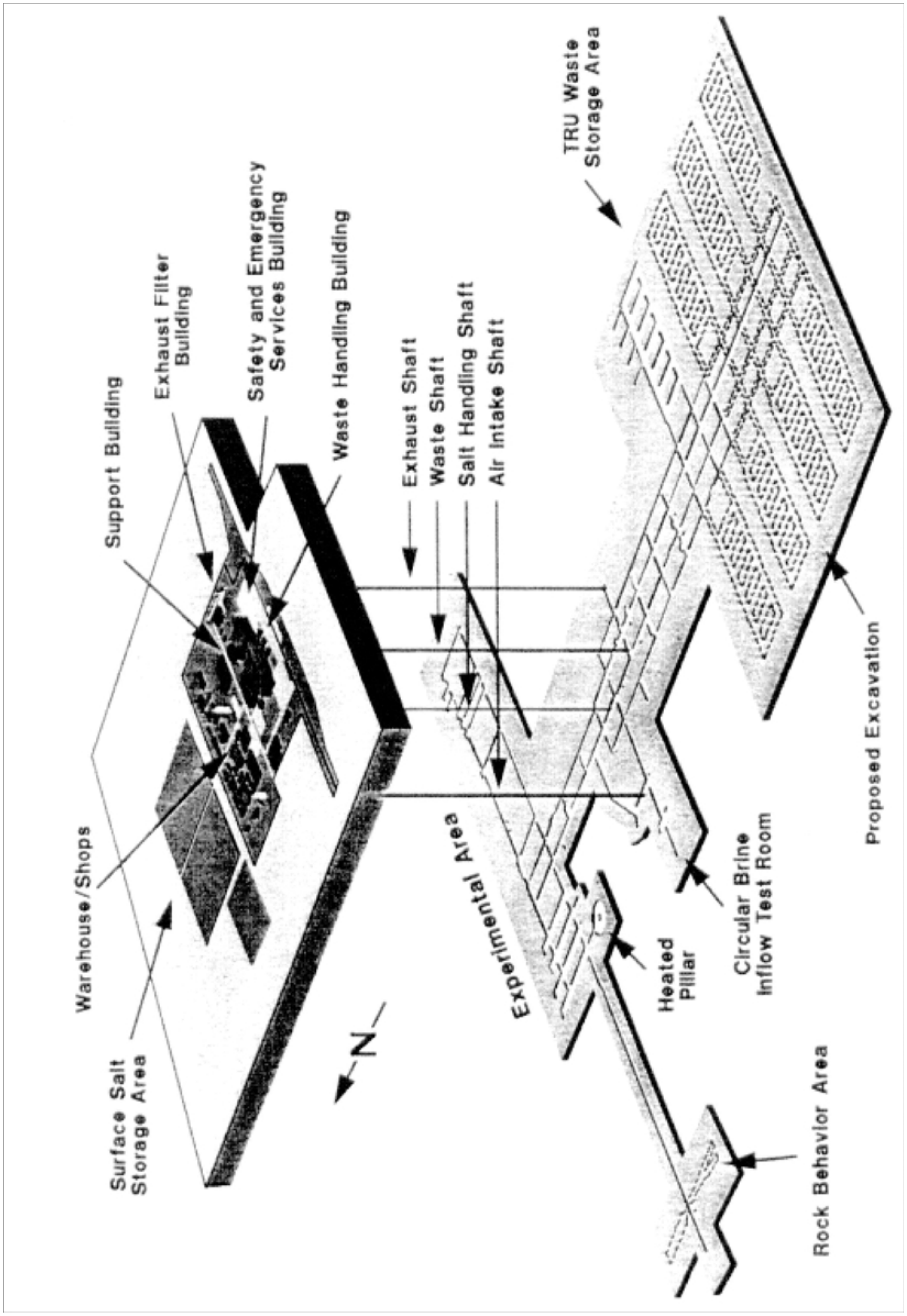

Figure 1
Diagram of the WIPP facility layout.

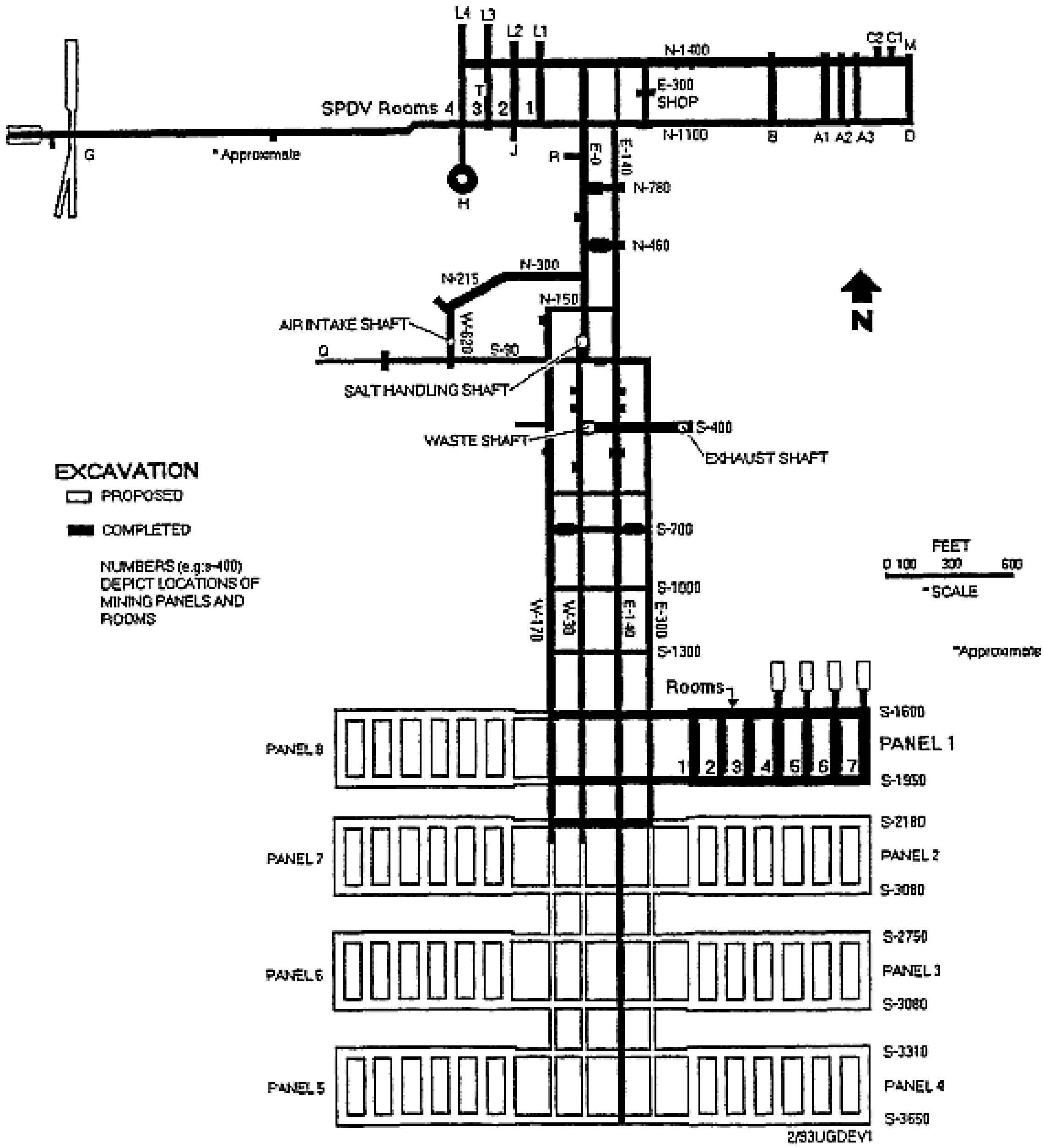

Figure 2
Underground test rooms and waste storage panels.

maintenance shops, decontamination stations, vehicle fueling stations, electrical substations, and vehicle parking areas.

The waste storage area lies south of the shaft pillar area. Waste storage panels are excavated as needed. While waste is being stored in one panel, mining takes place in the next panel. A waste storage panel consists of seven waste storage rooms, each 13 ft high by 33 ft wide by 300 ft long.

The experimental area lies north of the shaft pillar area. This area is used primarily by Sandia National Laboratories (SNL) to monitor the geologic, hydrologic, geochemical, and structural behavior of the WIPP facility.

UNDERGROUND OPERATIONS

The primary purpose of Underground Operations is to excavate and maintain the underground repository and to ensure safe access by personnel and safe storage of waste in support of the WID's efforts to achieve its mission. Following are descriptions of the primary functions of Underground Operations.

Access Control

Underground Operations has established a controlled-access process that incorporates guidance from Title 30 of the Code of Federal Regulations (30CFR) and DOE Order 5480.19, Conduct of Operations. This process controls access into the underground facility prior to the point of entry. An underground controller issues access permits based on required travel underground. The underground controller has two rovers in the underground facility who are responsible for placing barriers, ensuring the competency of barricades, and ensuring that the flow of underground travel is conducted safely. This process is the primary system by which WID Underground Operations managers ensure that all personnel underground are conducting work in a safe manner.

Ground Control

The excavation of underground openings in salt beds causes the salt to deform and gradually creep into and fill any temporary opening. Because of this dynamic environment, a dedicated mine-openings crew maintains 7.1 linear miles of tunnel. These individuals work directly with a cognizant mine engineer and a geotechnical monitoring crew to ensure ground safety in the underground facility.

Ground control includes milling the floor and scaling the ribs to counteract the slow but constant salt deformation. Primary overhead ground support consists of mechanical point anchor bolts, yieldable bolt systems, and cable span systems for areas of fractured ground. The ground is monitored using radial convergence points throughout the openings, extensometers that penetrate the overhead strata, video observations of vertical boreholes, and weekly visual observations of the openings. All these monitoring processes are integrated through the cognizant engineer and are reported to the customer, DOE, in a monthly interface meeting with Underground Operations.

Emergency Response And Utilities Distribution

Underground Operations uses a facilities engineer and two technicians who are removed from the work process in order to maintain centralized control over utilities distribution and emergency response. Because they have no vested interest in completing work projects, they provide independent coordination of resources. This crew releases all work underground, configures all utilities, and aligns the underground ventilation. In addition, the crew controls initial emergency response underground.

Any incidents occurring in the field require operators and technicians to contact and report to a centralized location. This ensures management timely categorization of the incident according to DOE requirements set forth in DOE Order 5000.3B, Occurrence Reporting and Processing of Operations Information. Incidents meeting the reporting requirements are investigated by a Root Cause Analysis Team. Incidents that do not meet the reporting requirements are investigated under the direction of Underground Operations management.

Work Authorization

WID Underground Operations conducts work in the facility in a controlled manner, in accordance with site-wide work authorization guidance. This work is coordinated among representatives from the entire site through plan-of-the-day meetings. All activities *and system line-ups are* coordinated prior to the commencement of work in the field. Work is scheduled through a central planner on a weekly basis. Emergent work is discussed daily prior to approval.

All work instructions are approved by a maintenance engineer. Any modifications or design implications require the technical guidance of a cognizant engineer. The cognizant engineer operates independently of the operating group and provides the operator with an engineering analysis of proposed changes to systems.

IN COMPLIANCE: EVIDENCE OF SUCCESS

Underground Operations is responsible for performing all operations in compliance with DOE Orders; the WIPP Final Safety Analysis Report and Operational Safety Requirements; Mine Safety and Health Administration (MSHA) requirements; all other federal, state, and local statutes and directives; and internal site procedures.

WID Underground Operations complies with guidance from the Land Withdrawal Act of 1992. A 1987 memorandum of understanding between DOE and MSHA ensures that MSHA visits and inspects the facility a minimum of four times per year. These inspections are on-site field validations of compliance with specific parts of 30CFR cited within the memorandum of understanding. MSHA inspections in the first quarter of 1990 netted 52 violations. In 1992 and 1993, WID Underground Operations experienced six quarterly inspections with only one violation noted by the inspector (see Figure 3).

The Land Withdrawal Act also requires the U.S. Bureau of Mines to perform a comprehensive annual evaluation of the stability of the salt structures in the underground facility. This evaluation enables WID to make specific recommendations on mine design to DOE.

WID adheres to regulatory mining requirements set forth by the state of New Mexico via the New Mexico Mine Safety Code. Adherence to these standards is evaluated during biannual visits of the State Mine Inspector. Since the first quarter of 1990, the State Mine Inspector has not cited the underground facility for any violations of state mining standards.

WID Underground Operations implements industry guidance through DOE Order 5480.19, Conduct of Operations, which provides the management and operating contractors at DOE facilities with guidance on rigorous and disciplined operations in the field. Examples include specific guidance on shift routines and operating practices, lock-out/tag-out requirements, and operator responsibilities.

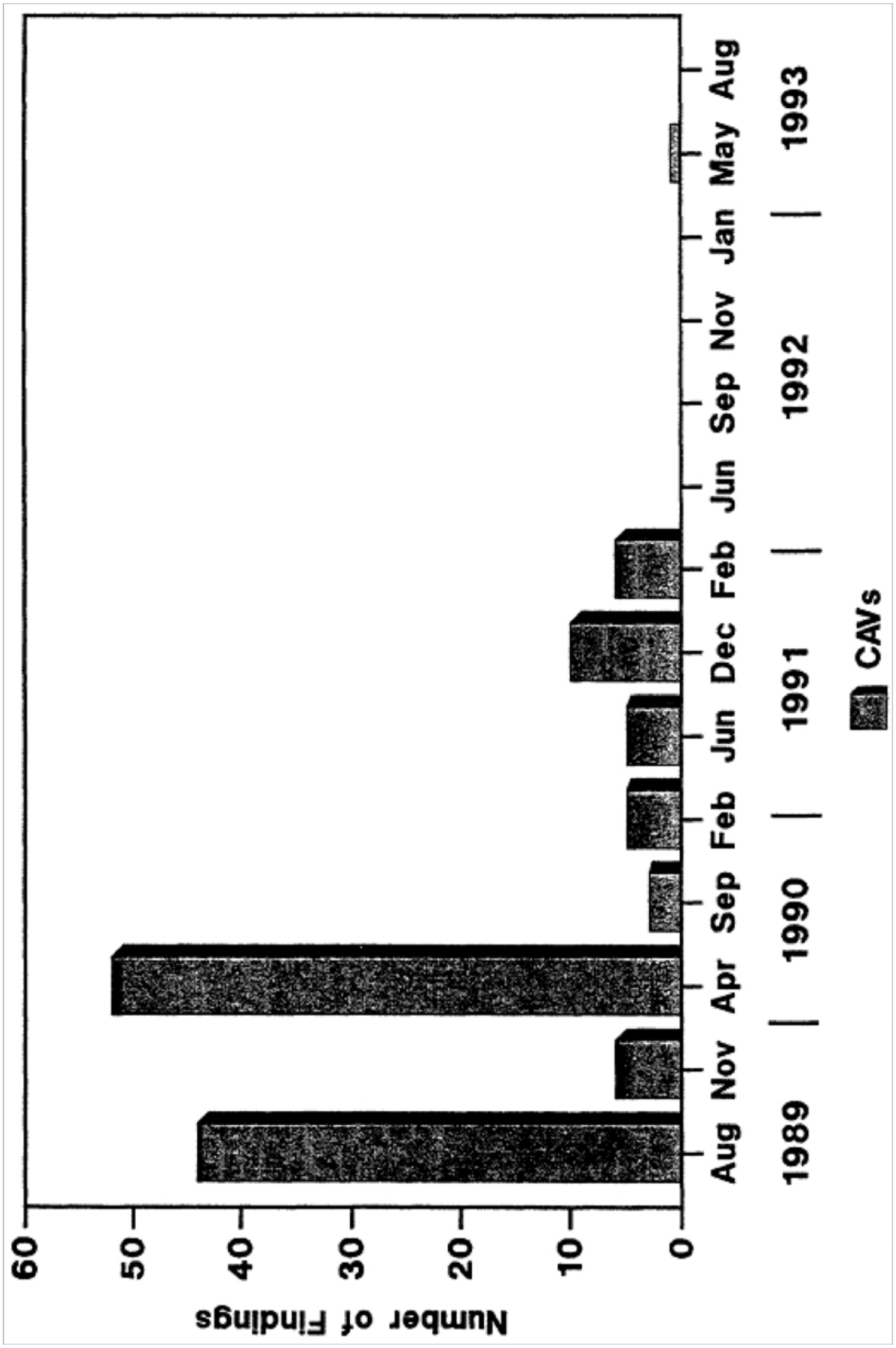

Figure 3
WID underground operations voilations from 1989 to 1993.

ORGANIZATIONAL RELATIONSHIPS

To effectively support the WIPP mission, Underground Operations has established relationships with many organizations outside WID. Some of these organizations are customers, others provide technical support, and still others provide guidance and oversight. In its daily operations, Underground Operations strives to demonstrate to each of these organizations an attitude of cooperation, dedication to quality work, enthusiasm for the project, and a true safety culture.

Department of Energy

DOE's WIPP Project Site Office provides a direct counterpart for WID Underground Operations management to ensure adequate communication of customer needs and expectations, as well as to ensure that both WID and DOE are committed to the same priorities.

Sandia National Laboratories

SNL is WIPP's scientific advisor to DOE. To achieve its objectives, SNL requires the support of Underground Operations. Underground Operations excavates and maintains SNL openings and ensures that SNL activities in the underground facility adhere to regulatory drivers. WID also provides regulatory-driven training to SNL personnel.

Subcontractors

WID has many definitive needs satisfied through subcontractual arrangements with various contractors. WID Underground Operations provides operational and safety oversight of subcontractor performance in the underground facility and ensures subcontractor compliance with WID's regulatory drivers.

Oversight Agencies

Underground Operations has interacted with various WIPP oversight groups, including the Defense Nuclear Facility Safety Board, the Environmental Evaluation Group, and the New Mexico Environment Department. WID's relationships with these groups have proven successful primarily because of WID's emphasis on open communication. Underground technicians, rather than just managers and supervisors, frequently talk directly with representatives from oversight groups. The technicians not only answer technical questions, but also convey their sense of pride in the project.

Community

Underground Operations understands that the success of the WIPP Project depends on the public's perception of the facility as safe and technically sound. Underground Operations personnel provide excellent guides for community outreach tours that are designed to introduce the community to the WIPP Project. WID Underground Operations has provided outreach to local and nonlocal community leaders primarily in the form of educational tours. Leaders taking these tours have included the mayor of Carlsbad; the director of the Department of Development; the governors of the states of New Mexico, Utah, and Idaho; and business leaders throughout the southwest.

Industry

WID Underground Operations has developed close ties to industry. Both nuclear and nonnuclear DOE facilities throughout the country, and the mining industry in particular, have provided Underground Operations personnel with insight and experience. For example, 22 experts from deep evaporite mines assisted WID in the development and validation of the yieldable support system.

EVOLUTION OF A TRUE SAFETY CULTURE

Like many other companies, WID is striving to develop a tree safety culture. In the case of Underground Operations at WIPP, WID has certainly succeeded.

It is not easy to define what a safety culture is; it is easier first to define what it is not. A safety culture is not just the result of establishing safety rules, procedures, regulations, and guidelines; it is not just management commitment to safety or enforcement of rules; and it is not just a result of ensuring compliance with requirements and directives from the customer or oversight agencies.

A true safety culture is evident in each employee's knowledge, belief, perception, and behavior. Each employee's dedication to safety ultimately becomes customary or habitual; it comes naturally and not spuriously. The culture originates among the employees. WID's safety culture is evidenced by its safety record. Table 1 shows a summary of WIPP's 1993 injuries and illnesses.

Initially, management's enforcement of safety rules may help to start the evolution towards a safety culture, but management must also do much more to cultivate the organizational behavior so that the culture may grow and mature. In Underground Operations, the managers and supervisors focus on three particular areas: safety, well-being, and development.

Safety

As stated previously, safety must become the foundation of each employee's behavior and attitude in the work place. To achieve this, management must challenge and train the workers to be personally concerned about safety.

Holding supervisors accountable for the safety of their workers begins the evolution toward a safety culture. This integral part of Underground Operation's management philosophy emphasizes management's responsibility and offers a strong incentive to enforce safe work practices and, in effect, to protect workers from themselves.

If management displays an ongoing, sincere commitment to employee safety, the workers begin to perceive that their managers and immediate supervisors care about their safety above everything else. One of the primary reasons for Underground Operations' successful handling of incidents is that all personnel have complete stop-work authority underground. As a result, all workers can feel comfortable in the work place knowing that everyone else is looking out for their safety. Just as importantly, all workers learn that their concerns will not be ignored by their managers and supervisors; management will make safety concerns their highest priorities.

Once the workers have incorporated their commitment to safety into their behavior and attitude, they unintentionally sell the safety image to everyone who visits the underground area. During community outreach tours, visitors automatically perceive the safety culture and enthusiasm of the Underground Operations workers, and this perception helps WIPP's overall image. By performing underground operations safely day in and day out, WID demonstrates to the public, including oversight agencies, that transuranic waste

TABLE 1 Waste Isolation Pilot Plant 1993 Injury/Illness Summary

Month	**First-Aid Cases**	**Recordable Cases**	**Lost-time Cases**	**Recordable Rate***
Waste Isolation Division, Westinghouse				
January	2	0	0	0
February	3	0	0	0
March	3	0	0	.0
April	3	1	1	.37
May	3	1	0	.59
June	5	0	0	.48
July	2	0	0	.31
August	6	0	0	.36
September	5	1	0	.48
Subcontractors				
January	2	0	0	0
February	1	0	0	0
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	1	0	0	0
September	1	1	1	.73
Waste Isolation Pilot Plant Site				
January	4	0	0	0
February	4	0	0	0
March	3	0	0	0
April	3	1	1	.29
May	3	1	0	.48
June	5	0	0	.40
July	2	0	0	.34
August	7	0	0	.29
September	6	2	1	.52

* Rate = (Number of injuries × 200,000) / work hours

can be handled and emplaced safely, as well. The public knows that the workers feel safe and are confident in their management, proud of their work, and committed to the project.

Well-Being

Supervisors must not only care about the physical safety of their employees, but they must also care about their overall well-being. Like safety, well-being is measured by the perception of the workers. To enable management to ensure the well-being of its workers, supervisors must take on the responsibility of learning what perceptions their workers have. Supervisors therefore try to get to know their employees on a personal level. Since the personal concerns of a worker ultimately will affect his or her performance on the job, each supervisor maintains an open-door policy to encourage employees to discuss any issue, whether job-related or not. By building a personal relationship with each employee, the supervisors can establish more comfortable communication, become more receptive to employee needs and concerns, and keep in touch with the opinions and perceptions of every employee.

To establish a good relationship with each employee and credibility as knowledgeable and supportive supervisors, each supervisor must be knowledgeable about each worker's craft, the technology, and the entire facility. This knowledge enables supervisors to ensure that all work assignments are managed with the employees' best interests in mind. Supervisors are positioned in the field so they can establish good relationships with their teams. They walk the field constantly and spend a minimum of 40 percent of their time talking with their workers. Supervisors continually try to obtain feedback from their workers to be better able to assess workers' needs.

WID management has been successful in developing beneficial supervisor/employee relationships by carefully selecting supervisors and managers who have the capacity to encourage and enrich the safety culture. Although each Underground Operations supervisor has his or her own style of management, they all have one thing in common: they care about people.

Development

If employees came to work each day only to make a living, their devotion to the job and the company would be based solely on the potential of making more money through the WID's performance-based salary increases. Even though this would provide an incentive to improve performance, benefits to WID and the project would be greater if each employee were motivated by more than just salary. Because of this, WID supports the personal and professional development of its employees and offers many opportunities and resources for their continuing improvement. Therefore, perhaps the most important element of Underground Operations' management philosophy is employee development which drives commitment to safety and well-being.

To support employee development, supervisors first assist their workers in defining career goals. Each supervisor then takes a personal interest in helping the workers start to reach their goals. He or she provides counseling and tries to assist each employee in finding the right development tools. There are many development tools, both inside and outside WID. The Training Department offers many classes and self-paced training modules in a multitude of disciplines; WID may also sponsor off-site training. Underground Operations supervisors also keep files of information about various continuing education programs at universities and technical schools throughout the country.

Along with providing these development opportunities, supervisors also try to provide on-the-job challenges for their employees. Employees are often given more responsibility; for example, they are regularly asked to serve as guides for important visitors or given assignments traditionally belonging to supervisors. With this added responsibility, employees can see themselves progressing, mastering a new skill, and meeting a new challenge. They can envision a prosperous future as they work toward their goals, and along the way they gain more experience in a variety of areas that will help them in their overall development. The added responsibilities are not perceived as a burden because they promote self-worth and allow each worker to be a success immediately while he or she strives to reach his or her ultimate goal.

In effect, supervisors *sell the future* to their employees. When workers begin to achieve their aspirations with the help of the company and their supervisors and managers, they develop a stronger commitment to their jobs. Within the Underground Operations culture, workers get *excited* about coming to work. As they begin to benefit from knowledge and training that is not necessarily related to mining, their *loyalty becomes an addiction.* They cannot wait to get to work to further their development. Their job becomes more than just a job, it becomes their path to the future.

Not only do managers and supervisors support their employees' development, but they also practice what they preach. They develop themselves and work toward their own goals. In fact, by fostering the combination of loyalty and development, Underground Operations has matured into an organization with built-in replacements among the crew. Commitment to development is evident in the fact that miners have been promoted to professional-level or supervisory-level positions. In fact, everyone in Underground

Operations has worked up through the ranks. Everyone at WIPP, including all supervisors and managers, started as miners.

CONCLUSION

In 1990, Underground Operations' managers began to cultivate the elements of safety in their organization. As a result, what started as a management philosophy and enforcement of safe work practices has become part of the culture. As the culture has matured, supervisors have been able to move away from the more technical aspects of their jobs and focus on the safety, well-being, and development of their workers.

BUILDING A TRUE SAFETY CULTURE

The Safety Record

The advent of a safety culture is indicated by its success in improving the organization's safety record. At WIPP, Westinghouse has made great progress in industrial safety, and the record warrants review. First, 1992 was a very successful year, for it was then that the company reached 3.2 million employee hours without an injury resulting in a day away from work. That was 2.5 years without somebody being injured in the work place. Although the company experienced an injury in March 1992, its workers once again exceeded 1 million "perfect employee hours," as defined by the National Safety Council Award Program, in November 1993. The current incident rate is just over one-third what it was in 1992, and the current lost work day rate is less than one-half.

With its own record so improved, Westinghouse turned its attention to its contractor program. The initial total recordable incident rate for all company contractors and subcontractors was 1.57; it has since declined to a total recordable rate of .18, or 11 percent of what it was before this recent safety effort.

Clearly, Westinghouse's safety management efforts at WIPP have been successful. The management philosophy described in Fred Ashford's paper deserves credit for providing a firm foundation for the WIPP safety culture. However, a true safety culture must be fully integrated into an organization's operations. Safety must become a way of life and a value for each and every employee.

Westinghouse has taken many steps to engage WIPP employees in the safety effort and to keep them empowered. The following paragraphs describe in some detail the building of the safety culture that has produced such dramatic improvements in WIPP safety statistics.

INITIATING CULTURE CHANGE

Westinghouse began working in the early 1990s to establish a corporate safety culture at WIPP. Although accident and incident rates compared favorably against industry averages, the company wanted to see if the rates could be reduced through a defined process.

Westinghouse's first step in 1990 was to do a comprehensive baseline survey of facilities and programs. Former Occupational Safety and Health Administration (OSHA) employees, working as consultants, examined Westinghouse surface facilities critically and came up with over 360 findings. These findings were trended to look for commonality of hazards and violations throughout the site. To address these findings and the results of MSHA inspections, Westinghouse presented a hazard recognition program to all of its supervisors and managers, then shut down the site for a day, not only to correct these deficiencies, but also to review all areas for items noted in the trending of the inspection findings. At the same time, Westinghouse established a formal training program and checklist for managers and landlords to use in surveying their own areas.

Repeating this exercise with the same consultants in 1991, the company had only 270 findings. Following another stand-down, all supervisors and managers were mandated to take eight hours of OSHA training. A management-by-walking-around approach, as mentioned in Fred Ashford's paper, was initiated to get supervisors to go out in the field and to inspect their areas.

Because nonsupervisory employees were involved in the corrective process, they began developing the desired work habits and attitudes, if for no other initial reason than to protect themselves from being overloaded with corrective work again. The company responded by developing systems that emphasized employee ownership and accountability. An example was the Landlord Program, which held an individual accountable for an area or a building and his or her equipment. These systems were integrated into the overall safety program.

The Westinghouse safety program is modeled on the OSHA Safety and Health Management Guidelines. In addition, the company has added a unique element to encourage and foster safety; the overall concept is that safety should be seen as positive, not negative or boring. To accomplish this, Westinghouse emphasizes continuous improvement and active awareness and recognition programs to keep safety up front and current in the minds of its employees. Examples of various programs follow.

EMPLOYEE PARTICIPATION AND MANAGEMENT COMMITMENT

Employee participation and visible demonstration of management commitment are key elements of the Westinghouse WID program. Draft DOE Order 5483.XX and the OSHA Safety Management Guidelines served as the model for the Worker Protection Policy, the primary document for all of the WIPP safety programs. Its elements include management commitment, employee involvement, hazard reviews, hazard prevention and control, and safety training.

The emphasis is on integrating safety into every part of the project. Safety does not stand alone as an entity and department separate from the rest of the facility. Safety is a part of every operation and every department (e.g., construction, materials control, engineering, purchasing, training, operations, etc.). That emphasis is reiterated for WIPP employees by the general manager, who holds round-table discussions with a cross section of the employee population and routine, all-employees meetings.

This safety commitment is written on a plaque that is in every building and in every supervisor's and manager's office. The commitment states, "Safety is woven into every operation; it cannot be separated. Success cannot be achieved any other way."

Westinghouse wants as many people as possible involved in safety at WIPP. The company uses many methods to involve its employees. For example, it has established task teams and safety committees that develop safety awareness programs. The latter group reviews accident and incident reports, looking for trends and lessons learned that they can take back into the work force and apply there to minimize risk in the work place.

Accountability for safety is written as a key element into every job-level performance appraisal. Work-site analyses and job hazard analyses are a way of life. Pre-job briefings are required for everyone on a project or a task to provide an opportunity for people to talk about and understand the task and the hazards of a project before it begins. Contractors and scientific entities must present a job hazard analysis of any work they are going to do. This is sent to the Industrial Safety Section for review and approval. Westinghouse works with the appropriate parties to resolve any problems but keeps final review and approval authority over all job hazard analyses and safety plans.

A hazard prevention and control document states a management policy of support for the WIPP worker protection program. The integration of this program into all facets of WIPP operations cremes set responsibilities for all elements of the project. Safety and health training educates employees, managers, and supervisors in their roles within the safety program.

To establish the WIPP safety effort in 1988, Westinghouse started with a DuPont Stop Program. It was a good program to bring safety into the work place. It was an observation program based on compliance and emphasized examining conditions.

When Westinghouse first started counting hours to encourage a reduction in injuries and pride in achievement, it seemed the company would make a million hours without an injury and then lose it. It was as though everybody took a deep breath and said, "Ah, that's over. I can relax now." To span the gap after the third occurrence, a program called "Working in Proper Perspective" was initiated. It was a culture program that promoted safety as a condition of employment and stressed that caring for each other in the work place is essential. Everybody in the high or moderate risk group was required to participate, and it helped keep the momentum going past the one-million and two-million accident-free-hour marks.

Another DuPont program, the "Take Two" program, aims to set a positive attitude among employees. This has been widely used in WIPP work-place or safety meetings. The program that is currently in use is the "Start Program," which the general manager gave to all his staff at their meetings. This program follows the philosophy that safety is a condition of employment. Training, accountability, responsibility, and accident investigations for near misses form the essence of the program. The staff managers have in turn given the Start Program to all of their managers. Some departments have taken the initiative to train their staff in this program.

Other awareness programs abound. A poster program that enhances safety awareness uses pictures of employees' children. An employee recognition award program that is run by the safety and security committee allows anybody to nominate another employee for a safety award. The "Million-Hour Campaign" is also a recognized safety program at WIPP.

A "Six Weeks of Safety" program began after it was realized that in the beginning of the summer there was an increase in accidents. Kids are out of school and lifestyles change during that time of the year. Through health and safety fairs organized around specific themes, Westinghouse increased employees' focus on safety and enabled them to avoid the influx of summer injuries.

For driver safety, employees dressed as the "Vince and Larry" crash dummies and visited people in the work place to hand out safe-driving materials. Another driver safety initiative involved safety personnel standing at the exit of the parking lot, and if an employee were wearing a seat belt, they would give that person something such as a pressure gauge or spare key. These initiatives were aimed at keeping awareness high.

The awareness programs begin at site orientation. All new employees, vendors, and visitors working on site go through a three-day orientation program.

A 24-hour safety campaign extends the focus to include safety in the home. Employees receive the National Safety Council Family Safety and Health Magazine. For fire prevention week, safety management sent home a mailer that looked like a firecracker. It contained materials to assist the family in planning escape routes and decals that they could put on their lawn power or other potentially hazardous equipment at home.

In the management overview program, two managers from diverse groups, for example purchasing and engineering, will go out and look at a part of the operations program (e.g., work control or the shaft crew). They will look at the documentation and at the program. They will also talk to the people and will get involved and learn about other areas of the facility and exchange ideas. This gives employees an opportunity to discuss their roles and to explain their work; it gives a different perspective back to the managers. This overview program makes it possible for team members to learn from each other and not have such diverse, isolated functions on site.

Management by walking around is extraordinarily effective, putting supervisors, managers, and staff functions out in the work force. Complementary efforts include an open-door policy, a hotline, and a formal written employee program. There are forms that enable any employee to write to the general manager and find an answer to any question.

CONCLUSION

It is said that safety is like water torture. One or two drops will not bother you, but sooner or later it is going to get to you. Through its multiple safety programs, training, and universal accountability for safety, Westinghouse is integrating safety and spreading the word that safety is more than a priority; it is a value at WIPP, with measurable evidence of success.

DISCUSSION

Participants discussed the relationship between Westinghouse in its role as the management and operating contractor at WIPP and the scientific users of the facility. Fred Ashford observed that for the WIPP science community, "data drives data drives data," and the collection of information raises more questions and never seems to provide definitive conclusions. Ultimately, the management and operating contractor has responsibility for the safety of all who are working underground, and the scientific studies being conducted by the SNL and Ohio State University are secondary in importance to ensuring that safety. Despite the initial complaints of WIPP's science community when confronted with new safety processes, in the end they fit into the processes very well.

Mr. Ashford also noted that Westinghouse WID receives invaluable information about the stability of the openings at WIPP from SNL scientists. In particular, SNL heat induction experiments have provided much data on how the ground fails. WID has developed support systems and yieldable-support systems based primarily on data provided by Sandia researchers.

Safety In Construction And Operation Of Underground Facilities

Joseph W. LaComb

ABSTRACT

This paper discusses the need for safety as a team effort, with all personnel involved in a facilities construction project or subsequent operation having incentive to play.

Defense Nuclear Agency (DNA) experiences in construction and operation of underground facilities and the planned construction and eventual operation of the Yucca Mountain Project's (YMP) Exploratory Studies Facility (ESF) have in common the magnitude of the construction efforts and the scope of activities. Considerations include the codes to be followed and their impact, facility design, mass casualty exercises, tunnel boring machine (TBM) experience, and the intent of the codes.

DNA and its contractor team gleaned extensive experience in the development of safety plans and programs for a facility, not simply an excavation. Overemphasis on excavation and mining can lead to a safety program and plan that is not adaptable to a facility. Therefore, at an early stage, construction activities and subsequent facility operations planning must be integrated.

BACKGROUND

The DNA Weapons Reliability Test Program supports validation of the nuclear survivability, hardness, and effectiveness of U.S. weapon systems. The program includes studies of nuclear effects on strategic and tactical defense systems. It also includes studies of the effects of nuclear airblasts and resulting groundshock on hardened underground targets (modeled at scale) in the underground testbed.

DNA has constructed massive underground facilities in which such tests are conducted. Recording stations underground and at the portal retrieve data from tests. For example, the horizontal line-of-sight pipe system, used to transmit a radiation pulse from a nuclear device detonation up to 1,350 ft from a ground-zero point, requires an immense underground facilities support plant. This plant must support the containment features in the tunnel complex and those installed in the pipe, the pipe's complex vacuum system, and a massive array of experiments. From this limited description, one may grasp the scale and complexity of the facilities required for the DNA Weapons Reliability Test Program.

A typical event or test has several phases, all of which can be in progress simultaneously within a given tunnel facility. These phases are planning, design, exploration, construction, operation, and execution.

YUCCA MOUNTAIN REQUIREMENTS AND DESIGN

It has been proposed that the Yucca Mountain ESF be developed similar to DNA underground scenarios for facility development. The implications of this type of facility development are addressed below. However, two additional issues merit attention. First are concerns that the emphasis at Yucca Mountain is on tunnel excavation, while other areas related to facility development may not receive appropriate attention earlier in the project and during construction and operating phases. Second, the various legal codes regulating both construction and facility operations in the underground environment must be addressed. DNA's experience has demonstrated that codes are not necessarily compatible with each other. They do, in fact, present conflicting information at times, resulting in confusion and misinterpretation in the application of requirements for construction versus preparation for beneficial occupancy of underground facilities. In practical application, such misinterpretations proved incompatible with the codes as written.

The need to construct a facility implies special design requirements ensuring the ability to safely conduct sustained operations for an indefinite period. In addition to its structural boundaries and layout, a facility includes essential functional systems and equipment, site development features (e.g., storage areas, traffic ways, receiving points, etc.), utilities supply and distribution systems, central utility plants, lighting and communications systems, and other physical plant features (see DOE Order 4700). The Nevada Test Site Underground Construction Standards as applied to runnel facility construction were developed jointly by the test site community and included DOE, DNA, Reynolds Electrical & Engineering Company (REECo), Raytheon Services of Nevada, EG&G Energy Measurements, and other site participants.

Working groups promulgated underground construction procedures, tunnel ventilation requirements, electrical installation standards, permanent low-maintenance ground support techniques, and other procedures and standards. The Nevada Test Site Underground Construction Standards accomplished the following:

- generally adopted the most applicable (and restrictive) safety standards from the Mine Safety and Health Administration, Occupational Safety and Health Administration, and the California Mine and Tunnel Safety Codes;
- addressed tunnel facility construction at the Nevada Test Site and considered host rock materials and geological forms, and state requirements for environmental safety and health issues; and
- resolved conflicting provisions in the various federal and state codes.

Most significant were precedents established with regard to correcting design inadequacies that affect facility safety either prior to or following the facilities' beneficial use date. This is especially important when considering the dynamic unfolding of legal and technical requirements affecting facility acceptance and use. Acceptable standards today may not meet requirements for safety tomorrow. Prior to commencing facility construction, an appreciation of this state of affairs is essential. DNA-controlled facilities at the Nevada Test Site have experienced this phenomenon in the following areas:

- tunnel fire suppressant systems;
- tunnel ventilation requirements;
- underground electrical code requirements;
- tunnel access control; and
- underground secondary access and egress requirements.

Consideration of underground facility design factors leads to a realization of a human dimension that affects the design and construction of a facility with the scale and magnitude planned for Yucca Mountain. Once the ESF is operating, expectations and requirements for performing analytical research and work underground, as well as the ability to have normal human support functions available, will drive changes and modifications to the facility. A major cost increase is incurred.

Historically, it has proven extremely difficult for facility users to fully articulate their requirements to project and design planners. This is due primarily to the inability of users to completely comprehend the underground environment. There is sometimes a lack of awareness or appreciation of the extensive physical plant support systems necessary for underground activities. It can be difficult to meet user requirements underground even when such support would appear simple in another environment. Therefore, it is essential to put project planners and users together at the earliest opportunity.

Another factor is whether the facility will be temporary or permanent. The codes are often different. If a facility is built under codes for temporary construction and then becomes permanent, it will be very expensive to bring the facility into full compliance. This is particularly true for upgrades or modifications involving electrical systems. DNA's recent experience with such required upgrades has resulted in added costs totaling many millions of dollars.

Among the facility-level operations sponsored by DNA and conducted by REECo, the site prime contractor, was an underground mass casualty exercise at the DNA P-Tunnel complex. The exercise scenario emphasized the nature of the underground complex as a facility having amenities required for sustained operations. The objectives of the June 1993 exercise were to:

- exercise and evaluate emergency responders;
- train a large cadre of multiorganizational workers in emergency procedures;
- evaluate each participating organization's notification and accountability procedures; and
- evaluate the operation and use of emergency equipment during an emergency.

Each participating organization had detailed exercise objectives related to their functions at the tunnel complex. REECo, with the greatest number of exercise objectives and the most extensive evaluation network, coordinated the exercise. Afterwards, a detailed report revealed some problems covering facility emergency response. While emergency elements such as paramedics and fire department crews were on site quickly, there were weaknesses in training and notification procedures. The importance of emergency equipment status was highlighted. The critical role played by teams qualified for mine rescue became evident, as did the logistical effort required to conduct such an emergency operation.

DNA FINDINGS

DNA's experience in the underground test program is highly varied. TBMs, road headers, and drill-and-blast operations have all been used as excavation techniques. DNA used an 18-ft, 6-in TBM to construct the N-Tunnel extension and a parallel drift in Ranier Mesa. Experience gained in maneuvering the TBM for new headings and backing the equipment underground, as well as steps taken to ensure a safe, efficient TBM operation, are available at DNA to share with the Yucca Mountain staff and others.

Further experiences of DNA managers working in construction and operation of underground facilities reveal the need to appreciate the intent of the various legal requirements governing underground activities. Once the management staff understood that such laws are not passed to bring pain into their lives, much could be accomplished. It was necessary for managers to examine and evaluate the various laws and codes to determine what the legal requirements were intended to accomplish. Generally the intent is to benefit the safety of operations. But after a law is written, the effect of the letter of the law often is not directly applicable to the immediate construction or operations in progress at that time.

It has been DNA's experience that managers must work at the onset of a project to determine the intent of the law. This is best accomplished by working closely with the safety staff and allowing them to be a part of the bigger mission/project team. The safety staff can help adapt the organization so that operations may proceed efficiently, effectively, and safely. Meeting the letter of the law without careful thought and planning can result in an ineffective safety program, a charade on paper. Understanding and meeting the intent of the law, however, leads to the development of a safety program that is effective, efficient, and productive. Such a program has credibility with the line staff as a no-nonsense program to be honored at all times by all managers and workers. Safety occurs when everyone is involved in making the program work and the intent of the law is met.

COMMENTS AND SUGGESTIONS

In a facility project such as the ESF, it is likely that there will be numerous requirements for development of site safety procedures supporting various operational construction activities. Development of site procedures may or may not meet the scrutiny of higher organizational echelons. This can be a point of much contention, as under normal conditions safety engineers in the field make final determinations in many safety-related areas. A clearly defined line of safety review, established early, prevents operational managers from becoming frustrated in their construction efforts.

Safety engineers must be integrated into all phases of project execution, with the tempo established during the planning phase. The safety engineer must work closely with planners, other engineers, technicians, estimators, and others to integrate safety features efficiently into facility design. The DNA management team observed the following rules:

- There is no substitute for technical expertise, especially among the management staff.
- Honest communications are essential for an effective team.
- The staff safety engineer is selected based on the following:

  1. a demonstrated level of expertise in both formal education and experience;
  2. a confirmed demeanor in the field to speak forthrightly; and
  3. the ability to articulate safety-related problem areas, understand multiple engineering methodologies, and assess risks across a wide spectrum of potential safety threats.

- The safety engineer joins the project's operational staff at the earliest planning stages.
- Operational managers must understand that they are ultimately responsible for safety in their work areas.
- Communications should flow both up and down.
- Attention to detail is critical.

The overall safety program must be simple and outside bureaucratic incorporation. Over-complication of safety management fundamentals will sacrifice real work-place safety. The safety analysis report and operational safety plan must be in place before construction begins. Sensitivities in the environmental safety and health arena are such that any deviation from accepted and proven safety practices and construction practices and methods could jeopardize the entire project. Even the perception of less-than-solemn management practices is cause for concern. It represents a potential danger in that managers feel compelled to establish ever more elaborate oversight procedures and managerial checks. In mm, this approach taken to extremes perpetuates the syndrome of a bureaucratic safety program that has become a charade. The organization can appear squeaky clean, having provided a program that is perfect on paper, but in practice is only a sham, ineffective in providing real safety in the work place.

DOE should task the lead contractor through a clearly stated mission statement and then allow the work to proceed under the contractor's direction. The lead contractor should weld a team from the support contractors, which should assume full responsibility for safety in facility work areas. DOE should share its experience with contractor staff and keep them informed at all times. DOE's technical representatives must resolve problems as they occur and continue to focus the lead contractor's effort on the task at hand.

DOE's technical representatives must understand the fundamentals of assigned contractor duties and must be capable of understanding the levels of effort and the safety implications involved for a variety of technical tasks. Technical representatives must foster a feeling of mutual trust between government and contractor staffs. Both contracting officers and technical representatives in the field must develop an appreciation of the safety issues and requirements and the extent to which these affect facility construction efforts and operations at federal installations.

SUMMARY

The hallmark of DNA operations has been persistent and continuing attention to detail in all project phases. The small details are often the ones that "bite" regarding safety programs. But the stakes are higher than they have ever been, and management must appreciate this fact.

The DNA experience is available to help develop safety programs that are effective, flexible, and understood by all team players. DOE should develop a real safety team, not a charade. A letter-perfect program does not necessarily ensure real work-place safety; the work force usually suspects such a program of being only a sham. Credible programs are always carefully thought out and include the concept of team development. The YMP should consider the procedures and codes developed by the Nevada Test Site users. Review of these documents will clarify many requirements for facility construction and operations.

Underground Safety At The Äspö Hard Rock Laboratory

Olle Zellman

ABSTRACT

In Sweden, industrial safety is formally governed by the Work Environment Act (WEA) and a number of agreements and directives. Under the WEA, the proprietor of a work site has coordinating responsibility for that site, although this responsibility is often transferred to the contractor.

Safety in underground work begins with the planning and design phase. A layout can be made safe by relatively simple means, for example, the location of turnaround niches or transformers. Underground facilities have very few exits, often only one. A combination of shaft and ramp greatly improves the opportunities for evacuating personnel in the event of an emergency.

Good communication is necessary in all safety work. Knowledge and understanding of each other's activities is perhaps especially important between scientists and rock workers conducting completely different tasks in the same areas. This is accomplished with all employees at regularly scheduled information meetings and before the start of major research activities.

At the Äspö Hard Rock Laboratory (HRL) in Sweden, the greatest risk of underground accidents involves transports. The reason is, of course, that vehicles and people have to share a small space that is usually dark. Nevertheless, it is possible to greatly reduce this risk by simple, inexpensive means, such as, a good safety manual and a high safety awareness.

The greatest resources in safety work should be concentrated on the prevention of accidents. But should an accident occur, it is important that all personnel have the right knowledge and equipment at their disposal. Everyone must know, for example, how to alert the surface facility, where the nearest fire extinguisher is, and how oxygen masks work.

Unfortunately, it is impossible to eliminate all safety risks by means of legislation. By raising each individual's level of safety awareness, however, it is possible to reduce

the risks considerably. The safety manual will not do any good unless everyone is familiar with its contents.

INTRODUCTION

The Swedish Nuclear Fuel and Waste Management Company (Svensk Kärnbränslehantering AB, or SKB) is a wholly owned subsidiary of the four companies that produce nuclear power in Sweden. SKB's main duty is to safely manage and dispose of the radioactive waste that results from the operation of nuclear power plants. The company is also responsible for the nuclear waste from medicine, research, and industry.

To perform this duty, SKB has developed and built a complete waste disposal system. For the operational waste, there is an underground final repository in Forsmark, about 100 km north of Stockholm. The spent fuel is stored in water pools in an underground, interim storage facility outside Oskarshamn in southeastern Sweden. Since all Swedish nuclear power stations are situated on the coast, all transports take place by sea on a specially built ship.

A deep repository is planned to accommodate the long-lived waste. The Äspö HRL is one of several links in the chain leading to this repository. The research and development activities in the Äspö HRL have the following main goals:

- test the quality and appropriateness of different methods for characterizing the bedrock with respect to conditions needed for a deep repository;
- refine and demonstrate methods for adapting a deep repository to the properties of the rock in connection with design, planning, and construction; and
- collect material and data important to the safety of the deep repository.

Seven organizations from the United States, Canada, Japan, the United Kingdom, France, and Finland are also participating in the project.

The Äspö HRL can be likened to a dress rehearsal for the construction of the deep repository. This paper describes the safety work during the construction of the tunnel part of the laboratory.

THE FACILITY

The Äspö HRL is situated in southeastern Sweden, an area dominated by Precambrian granites that are 1.7 billion to 1.8 billion years old. North and south of the laboratory there are younger, diapir-like granite structures that intrude underneath the laboratory. A fine-grained granite found in the area is often fractured and water-bearing.

The underground part of the facility, when finished in early 1995, will consist of a 4-km tunnel down to a depth of 500 m. The tunnel connects with the ground surface through three shafts—one for an elevator and two ventilation shafts. The raise-bored shafts are being excavated in several stages, the first of which is complete.

The tunnel's cross-sectional area is 25 m^2 except on the curves, which have been designed as meeting places and where the area is over 40 m^2. The gradient is 1:7, which approaches the maximum gradient conventional vehicles can negotiate.

Tunneling is being carried out by conventional drill-and-blast methods. But the Tunnel Boring Machine (TBM) method will be tried out during the last 400 m. The diameter will then be 5 m, while the gradient of 1:7 will be retained, which is very unusual for TBMs.

To provide for the eventuality of a pump breakdown, basin capacity for around 10 hours will be provided at the bottom of the facility. A visitors' niche has been built at the beginning of the tunnel. Visitors can walk along a sidewalk that is separated from the roadway by a railing.

REGULATORY AUTHORITIES AND LAWS

The WEA is the foundation of industrial safety in Sweden. A number of other agreements and directions regulate various activities in greater detail. As far as underground work is concerned, a number of regulations apply. The three most important regulations for the activities at the Äspö HRL are those concerning rock work, blasting work, and personal safety equipment. With the exception of certain visitors, all persons who will be working underground must sign off on the text of these three regulations before they begin work. The literature is unfortunately only available in Swedish, and since the project has many international participants, this can sometimes cause problems. SKB provides an oral briefing on the most important provisions before work begins.

The National Labor Inspectorate, a state authority, uses two labor inspectors (each of whom has certain specialties) to enforce compliance with existing acts and ordinances. The two labor inspectors cover all underground work, which is dominated by mining operations in northern Sweden. One labor inspector visits the Äspö HRL about four times a year, at which time client and contractor representatives review activities from a safety viewpoint.

According to the WEA, the client has coordinating responsibility for all risky work on the work site. Normally, however, this responsibility is transferred to the contractor, as is the case with the Äspö HRL.

PLANNING AND DESIGN

Much of the preventive safety work can be done in connection with the planning and design of the facility, but many different requirements have to be met. This is particularly true in the case of underground facilities where a great deal of research will take place and where the layout must primarily satisfy the researchers' needs. Satisfying some needs is relatively easy, for example, ensuring that the distances between turnaround niches are not too great and that the niches are large enough for all types of vehicles.

The choice of rock reinforcement measures can be more complicated. In the case of the Äspö HRL, the researchers wanted wire mesh reinforcement to be given priority over shotcreting. This request proved difficult to satisfy from a safety viewpoint. The wire mesh became filled with breakouts, which were finally such a great safety hazard that shotcreting was necessary. Furthermore, it is difficult to use wire mesh near the working face, since it usually gets shot apart in the impending blasting round.

Normally, underground facilities have very few escape routes. The Äspö HRL has a ramp and shafts. The primary consideration was not safety, but there is no doubt that the purpose of safety is served.

Ventilation is another key factor to be determined before construction work begins. The main purpose of ventilation is to remove unwanted gases and supply fresh air. In the event of fire, however, it is important to be able to control the ventilation; so the combustion gases do not, for example, rise in a shaft with a stationary elevator full of people. This is relatively easy to arrange in a permanent facility but is often difficult during the construction period.

During the construction period at the Äspö HRL, there is a ventilation tube along the ceiling; there is no means for controlling the ventilation aside from starting and stopping the fans that are used for fresh air ventilation. The two ventilation shafts will not be used until the facility is finished. Construction of the Äspö Research Village is going on directly above the shafts, which makes their use difficult.

SITE OFFICE ROUTINES

A working-environment group with representatives from the client, the contractor, and the labor inspector (sometimes also from the trade union and the municipal rescue service) meets every three months. The labor inspector usually issues directions and advice on how activities should be carried out without lowering the level of safety. Inspections of the facility, rock reinforcement, vehicles, etc., are additional duties of the labor inspector.

Safety delegates come from both the client's and the contractor's organizations. Their duty is to prevent accidents. Their work includes making safety inspection rounds every 14 days together with the production manager. On these occasions, they check virtually everything having to do with safety. Any deficiencies they note must be corrected immediately. A safety delegate finding an immediate danger to life or property has the right to stop the work completely or partially. This is rare and has never happened at the Äspö HRL, but the fact that it can occur has a safety-enhancing effect.

It is common for research work underground to be conducted at night and on weekends when the contractor is not present. To give research personnel added safety, there is a check-in system with the nearby nuclear power station's local guard center. Before personnel go underground, they phone the guard center and state when they plan to return to the surface. Once aboveground, they must phone in again. If they do not check in within 30 minutes of when they were supposed to come up, an alarm is sent to the rescue service, which goes into the tunnel and searches. The system is simple but works well.

ROCK WORKS

Tunneling is done in two shifts using a conventional drilling rig equipped with three drills and a charging basket. The rig is also equipped with a Beaver control for recording various drilling parameters. Normally, one 4-m round is shot per shift. Owing to large earth currents in the rock, bulk explosives are inappropriate. For ignition, non-el, pentyl fuses, and powder fuses are used. The client determines the degree of rock reinforcement, but safety delegates can always demand additional reinforcement. Mucking is done with ordinary trucks equipped with catalytic converters and soot-particle filters to improve the environment in the tunnel. The loader is electric, which is a big advantage. During mucking, no research activities may be carried out in the vicinity of the loading area, and other transports in the tunnel must be limited to those that are absolutely necessary. Visitors may, however, go down into the special visitors' niche.

COORDINATION BETWEEN RESEARCH AND TUNNELING WORK

Conducting Äspö HRL's extensive research work while tunneling is in progress makes special demands on safety awareness. Two different organizations, several different occupational categories, and different opinions on what is important make communication both aboveground and underground very important.

After each blasting round, geoscientists document the newly shot rock. No other activities may be conducted at the tunnel face during this work, which normally takes about an hour. The drilling rig serves as a light source after having been moved back about 10 m. Before the geoscientists go underground, they sign a protocol that has been completed by the contractor's shift boss. It describes the appearance of the tunnel face and states whether any special precautions must be taken, for example, whether the rock must be reinforced. By the time the geoscientists go underground, the tunnel face will have to be scaled, washed clean, and completely mucked out. If the rock conditions are such that reinforcement in the form of shotcreting is necessary, the tunnel face is mapped from a safe distance, normally 5 to 10 m.

After every fourth round, 20-m-long probe holes are drilled to investigate the rock in front of the face. The contractor and scientists cooperate on these drillings. The scientists constantly record what happens during the actual drilling procedure. When the hole is finished, it is packered and tests are performed to determine pressure build-up. At a water pressure of around 35 bar, there are some practical problems with packer setting when the holes contain a great deal of water. A method has been developed whereby the rig helps to put each packer in position. The packers are then chained to the rock, so that they will not act as projectiles if they should come loose.

Prior to investigation drilling where large water flows can be expected, a 3-m-long casing pipe is cemented to the rock and anchored with four concrete bolts through a steel plate. A ball valve is fitted at the far end of the casing. Drilling then takes place through this valve. This makes it easy to stop large water inflows that might exceed the capacity of the pumps. Today the total inflow to the tunnel is about 2,000 liters per minute, and the pump capacity is about 3,500 liters per minute.

Because the contractor has coordinating responsibility for the construction site, the shift supervisor must always give verbal permission before anyone may go underground, along with information on any problems with passage, fan or pump troubles, etc., that might affect safety.

SAFETY-RELATED EQUIPMENT

Near the tunnel face, a steel container with an inner wooden cage serves as a rescue chamber. The chamber has a telephone and oxygen for six hours' consumption by six persons. There may only be as many persons between the rescue chamber and the face as can be accommodated in the container. This provides an extra escape route in the event of an emergency.

After discussions with the local rescue service, trials with radio communication have been conducted underground. Due to the layout of the facility, it has been difficult to get this kind of communication to work. Far too much cable would be necessary for the system to have any advantage over an ordinary telephone. Thus, the project participants recently decided to schedule the installation of the permanent internal telephone system earlier than originally planned and to expand it with additional telephones, a solution accepted by the local rescue service.

All vehicles underground are diesel powered, except the drilling rig and the loader, which are electrohydraulic. A fire extinguisher is mounted on every vehicle. In addition, there are oxygen masks on most of the vehicles. Fire extinguishers and first-aid equipment are available in the visitors' niche.

CONCLUSION

In summary, the patchwork of rules and regulations governing underground work in Sweden has evolved gradually, based in part on experience from several hundred years of underground work. In addition to all the laws and rules, common sense and a firmly rooted safety awareness are essential. The latter can always be raised with training and information. It is also very important that the personnel perceive existing rules to be clear and practically applicable. Otherwise these rules will never be more than just words on pages in a dusty binder in an office.

DISCUSSION

After Mr. Zellman's presentation, in an exchange about compliance and enforcement, the safety of scientists working during off-hours was questioned. In Sweden, the equivalent of the Occupational Safety and Health Administration has authority to issue directives, copies of which are distributed to everyone working on the project site. Every scientist must go into the tunnel with at least one other person. Also, to ensure familiarity with the facility, each must first complete a long introductory session. If these criteria are met, scientists may go underground for up to nine hours without mining personnel accompanying them.

Safety Management In PNC's Shaft Excavation Effects Project in Japan

Kozo Sugihara

ABSTRACT

The Power Reactor and Nuclear Fuel Development Corporation (PNC) constructed a shaft with a diameter of 6 m and a depth of 150 m in the Tono Mine, where comprehensive geoscientific studies are underway, and carried out the Shaft Excavation Effects (SEE) Project. The shaft excavation was performed using the drill-and-blast method in the Tertiary sedimentary rocks, which consist mainly of tuffaceous sandstone. In the SEE Project, many kinds of in situ experiments were carried out before, during, and after the shaft excavation in order to measure and estimate the mechanical and hydrological influences induced by the shaft excavation.

The SEE Project has been controlled by PNC in cooperation with contractors. The organization for safety management of the Tono Mine has managed the safety issues of the SEE Project according to the Japanese laws and regulations for metal mines and PNC's own regulations.

Excavation and in situ experiments were performed alternately and sometimes concurrently, so many groups of workers from different companies worked together in the shaft. PNC held weekly and monthly meetings attended by the heads of all groups to discuss the time schedule and safety issues of each task.

The most important goals of safety management are to enhance each worker's sense against dangers and to teach each worker to avoid dangerous actions. For this purpose, safety education was conducted for workers who were newly joined to the project, and a meeting of each group was held every morning informing all workers of the schedule and precautions for the day.

INTRODUCTION: A HISTORY OF THE TONO MINE

The Tono Mine is located on the main island of Japan, Honshu, approximately 300 km west of Tokyo, as shown in Figure 1. In 1964 a uranium deposit was discovered in this area, and 1972 marked the start of the Tono Mine's operation. The goal of the mine

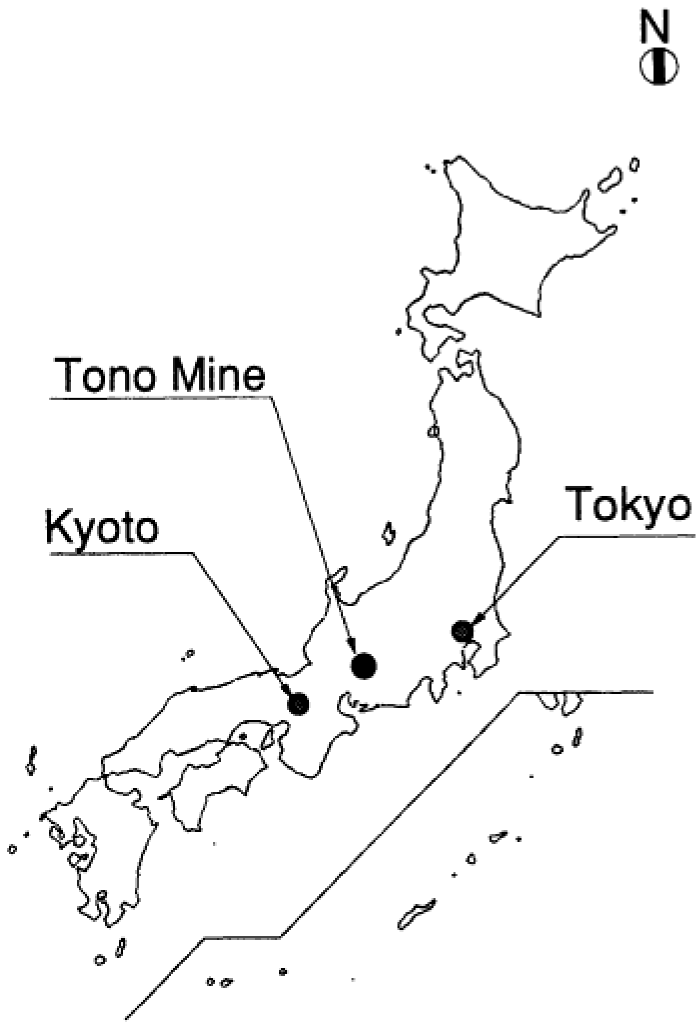

Figure 1
Map showing the location of the Tono Mine in Japan.

was limited to the exploration of the uranium deposit. Exploration revealed that development of the mine for production was economically infeasible.

In 1987, geoscientific studies were begun in the mine and were for the most part aimed at gaining a basic understanding to support a waste disposal project. Scientists conducted in situ experiments observing the corrosion of engineered barrier materials, as well as a hydrochemical investigation of ground water, a geochemical investigation of uranium-series radionuclides using the ore body of uranium, and mine-by experiments (see Figure 2). Planning for the SEE Project began in 1988, and pre-excavation experiments started in 1989. Excavation commenced in 1990 and ended in 1991.

OVERVIEW OF THE SHAFT EXCAVATION EFFECTS PROJECT

The geology of the Tono Mine area can be described as a granitic basement overlaid with Tertiary sedimentary rock that consists primarily of tuffaceous sandstone. Unconsolidated sediment covers the sedimentary rock layer. This sedimentary rock is about 150-200 m thick. The new shaft excavated for the SEE Project has a depth of over 150 m; the sedimentary rock was the main object of study during the project.

The Tsukiyoshi Fault adjoins the Tono Mine. It runs roughly east-west and dips about 65 degrees. The new shaft crosses the Tsukiyoshi Fault approximately 125 m below the surface.

Using the mechanical properties of the sedimentary rock shown in Table 1 as parameters, the standard section of the shaft was designed as shown in Figure 3. The inner diameter is 6 m. The concrete lining has a width of 40 cm except in the first 5 m of the shaft, where the lining has a width of 1.5 m.

A cross section of the shaft is shown in Figure 4. The shaft has a depth of 150 m and 4 horizontal drifts. The upper connecting drift is connected to an old mine drift. These drifts were designed to accommodate many kinds of in situ experiments. The lower measurement drift was excavated to study excavation effects around the Tsukiyoshi Fault.

The upper part of the shaft, to a depth of approximately 31 m, was excavated with a small backhoe. A crawler crane and a kibble removed the excavated rock from the shaft.

After excavating down to 31 m, the team constructed a shaft tower with a height of about 24 m. A double-deck scaffold and the shaft loader were lowered into the shaft using a winch. The drill-and-blast method was used to excavate the rock, and a kibble raised by a second winch removed the excavated rock from the shaft. A third winch raised and lowered a cage used to transport the workers.

Segment work made use of a mobile hopper, a concrete kibble, and a round steel frame. Concrete was poured between the frame and the excavated wall. The SEE Project

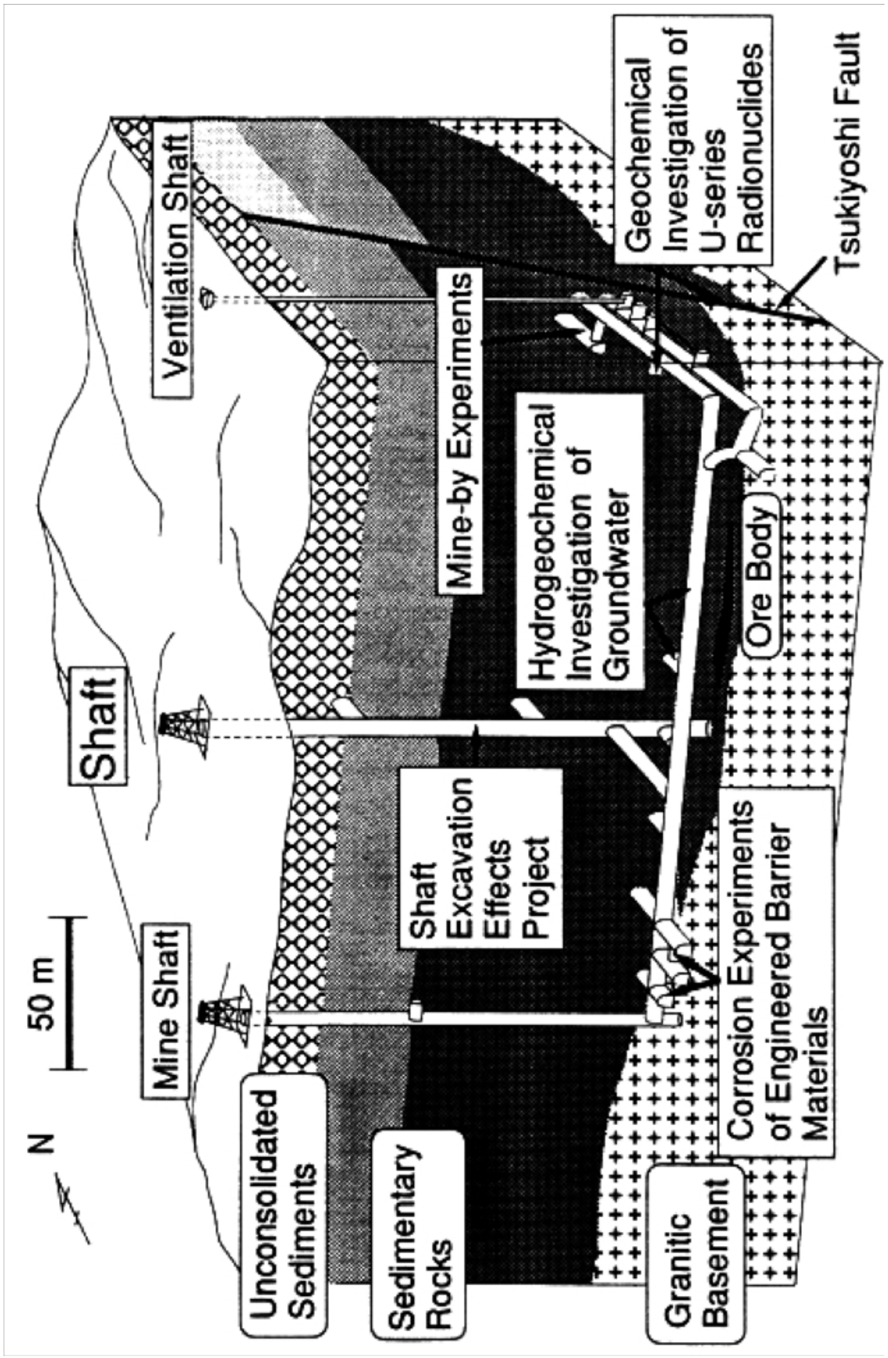

Figure 2
Geoscientific studies in the Tono Mine.

TABLE1 RockMechanicalPropertiesoftheSedimentaryRocks

Depth (m)	γ (kN/m³)	C (MPa)	ϕ (°)	υ	E (MPa)
	18	0.5	15	0.35	100
50	17	1.0	15	0.30	1000
	18	0.5	25	0.35	200
100	20	0.5	20	0.30	1000
150	19	2.0	10	0.30	700

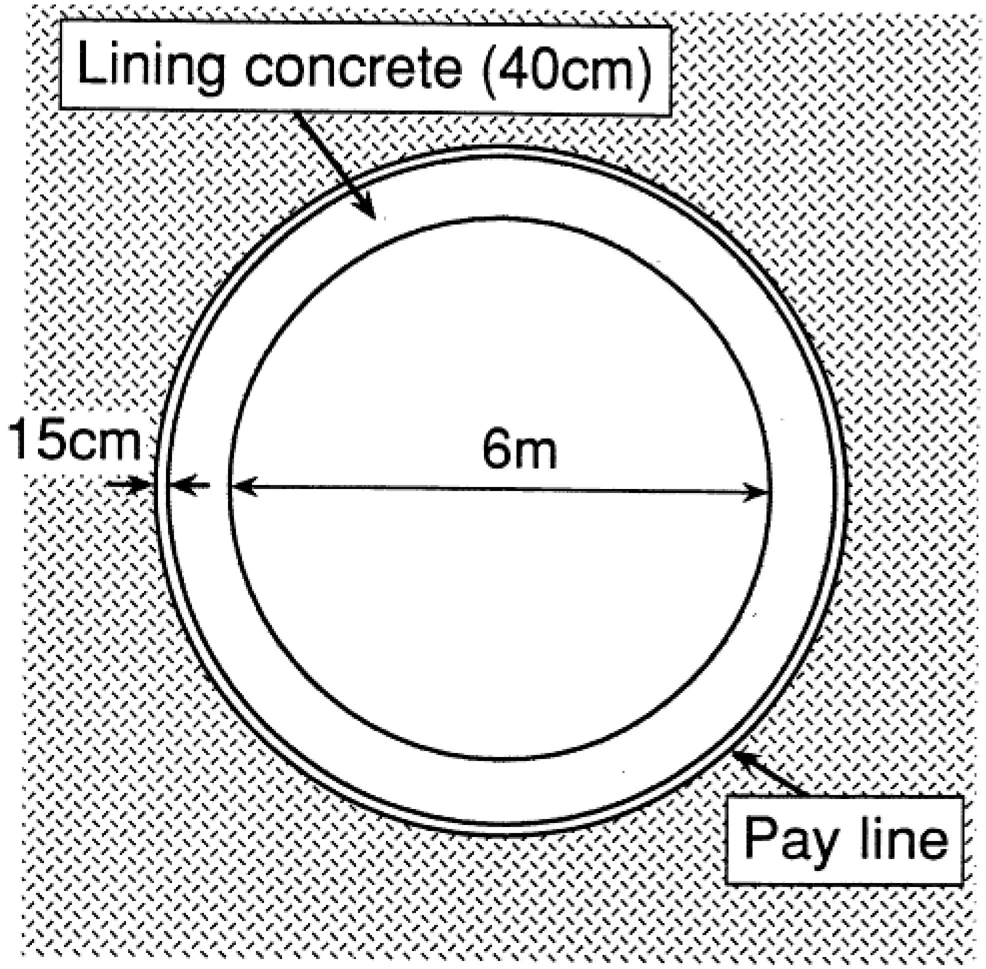

Figure 3
Standard section of the shaft.

team excavated 1.2 m at a time and then installed the concrete lining, an approach they call the Short Step Mining Method.

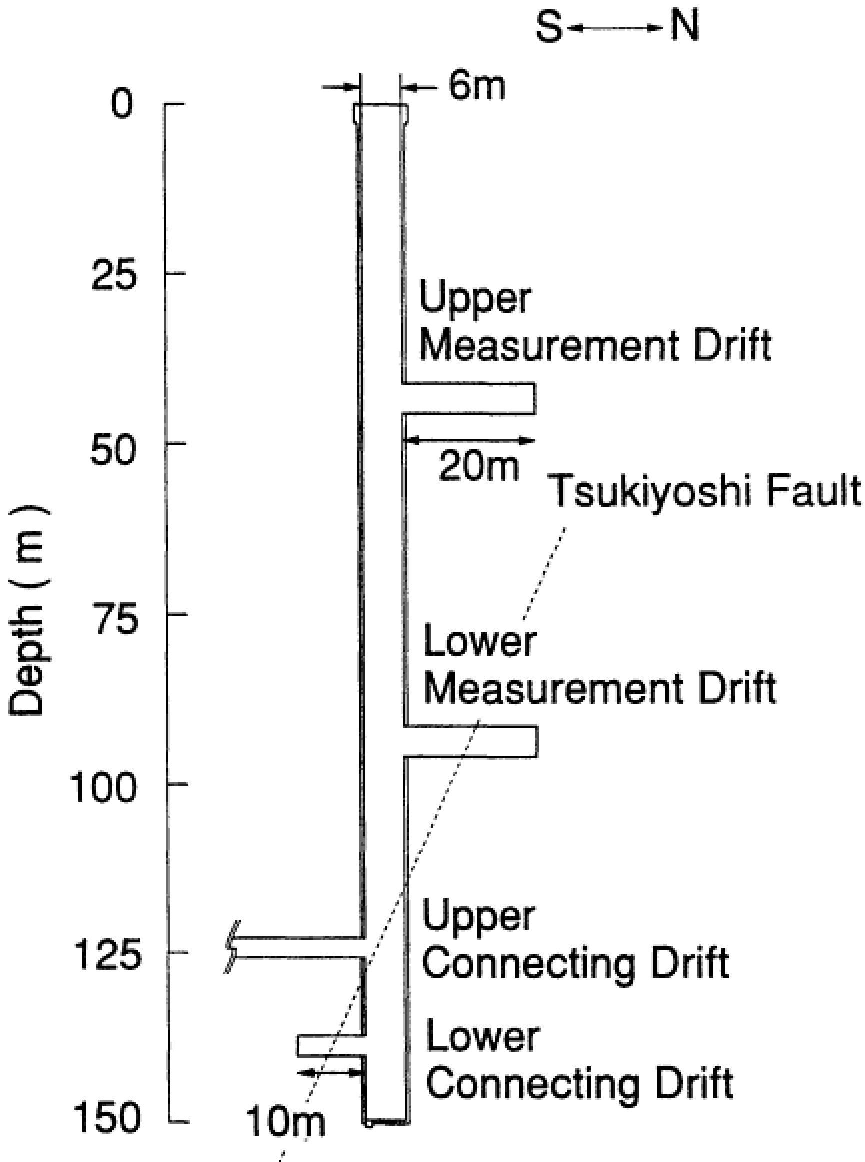

Figure 4
Cross section of the shaft.

OBJECTIVE AND APPROACH

The objective of the SEE Project was to develop methodologies to measure and simulate the mechanical and hydrological effects induced by shaft excavation. To accomplish this, the SEE Project team designed many sections and boreholes for measurements. These are illustrated in Figure 5. For example, in sections A, B, and C, rock properties such as permeability and deformability were measured. In other sections the project team measured displacement, support stress, and inclination and applied seismic tomography. These in situ experiments were performed in very confined settings.

The team sometimes interrupted excavation to conduct experiments in the shaft. At other times, excavation and experiments were carried out concurrently. This combination of activities required people from several different organizations to work together.

PROJECT MANAGEMENT AND ORGANIZATION

The PNC project management and organization is illustrated in Figure 6, which shows relevant portions of the overall PNC organization, and Figure 7, which shows the organization of PNC's Chubu Works. A Board of Executive Directors heads the PNC organization. The Public Relations Office conducts public affairs; they also compiled the visual record of the SEE Project, which includes photographs and video recordings. The Finance Division and the Contract Division controlled the finances and contracts of the project for both excavation work and in situ experiments. The Radioactive Waste Management Project was the group responsible for the SEE Project in PNC's head office.

Three sections managed the shaft construction. The Construction and Maintenance Management Office (see Figure 6) assisted in managing the excavation work and gave advice to the other two sections, the Mine Group of the Exploration and Mining Technology Development section and the Shaft Group of the Waste Isolation Research section; both of these fall within the PNC Chubu Works (see Figure 7). The Mine Group, under the Exploration and Mining Technology Development section, is responsible for the management of the Tono Mine. Since the new shaft was constructed in the Tono Mine area, the Mine Group managed the shaft's construction and was responsible for safety management. The Shaft Group, under the Waste Isolation Research Section, planned and conducted the entire SEE Project, including the research activities as well as the construction. The Hydrogeology, Geochemistry, and Natural Phenomena Groups also joined the Project to conduct their respective experiments, and the Drill and Survey Group drilled the boreholes and carried out borehole surveys.

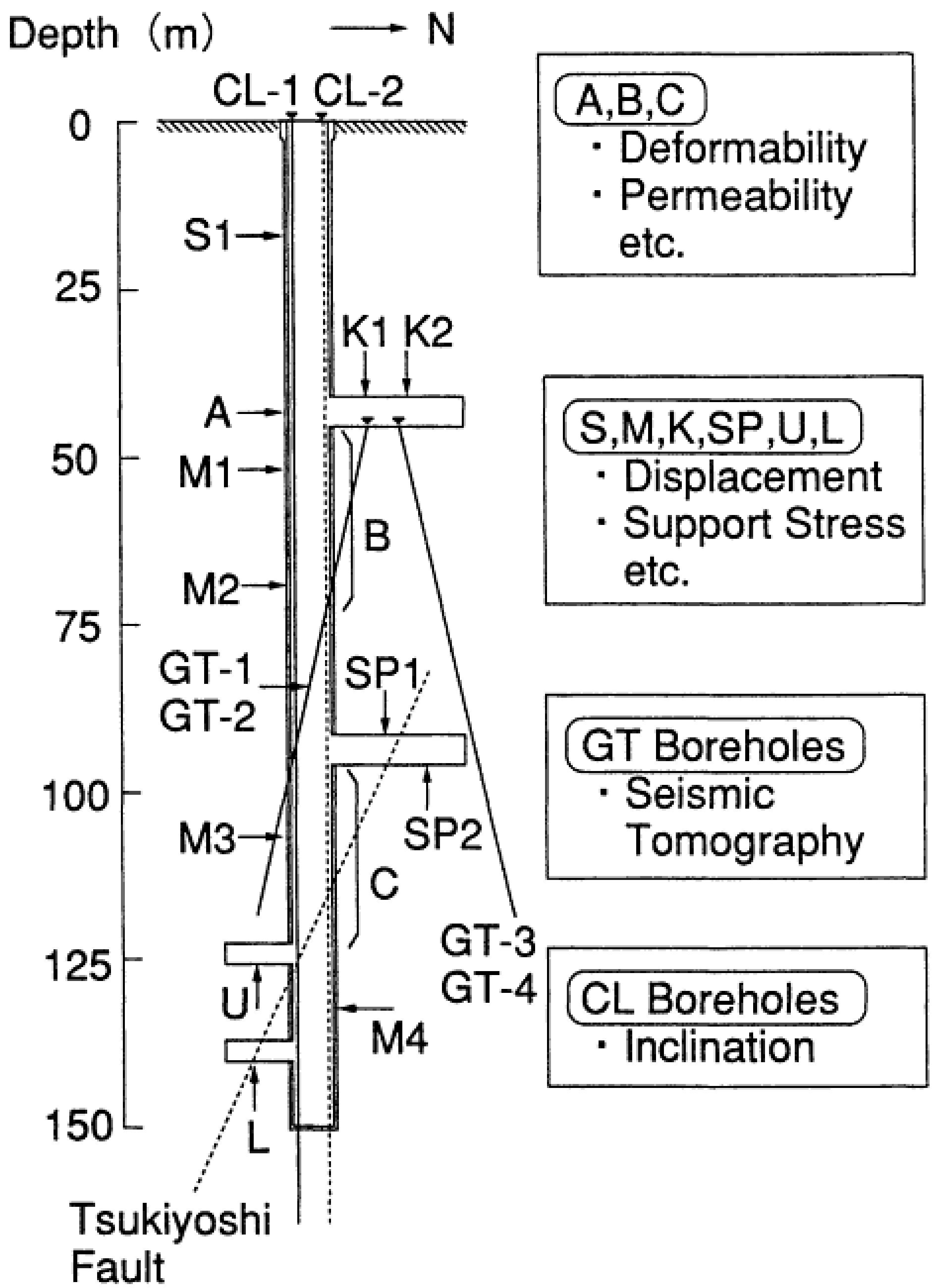

Figure 5
Location of sections and boreholes for measurements in the SEE project.

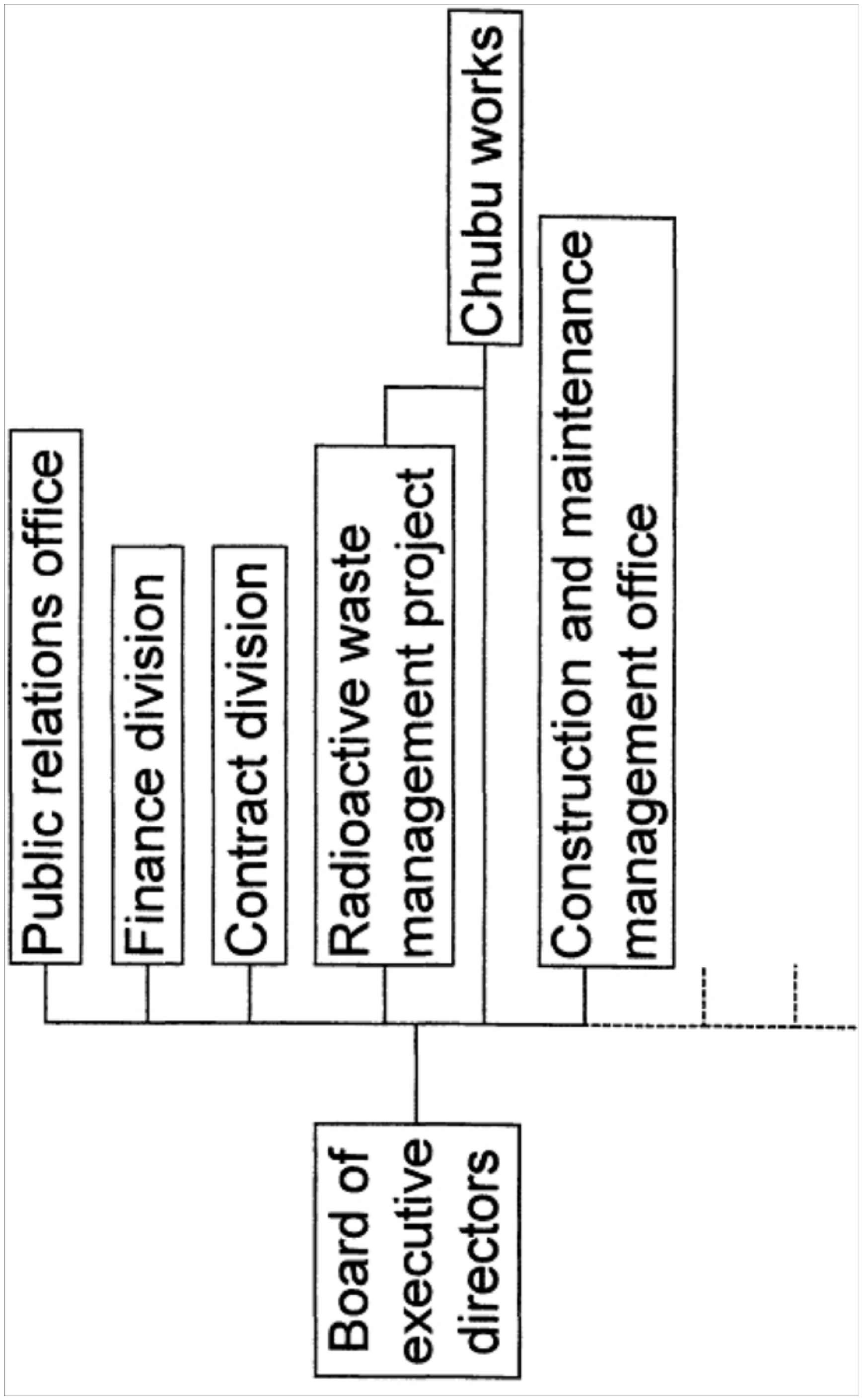

Figure 6
Relevant organization chart of PNC.

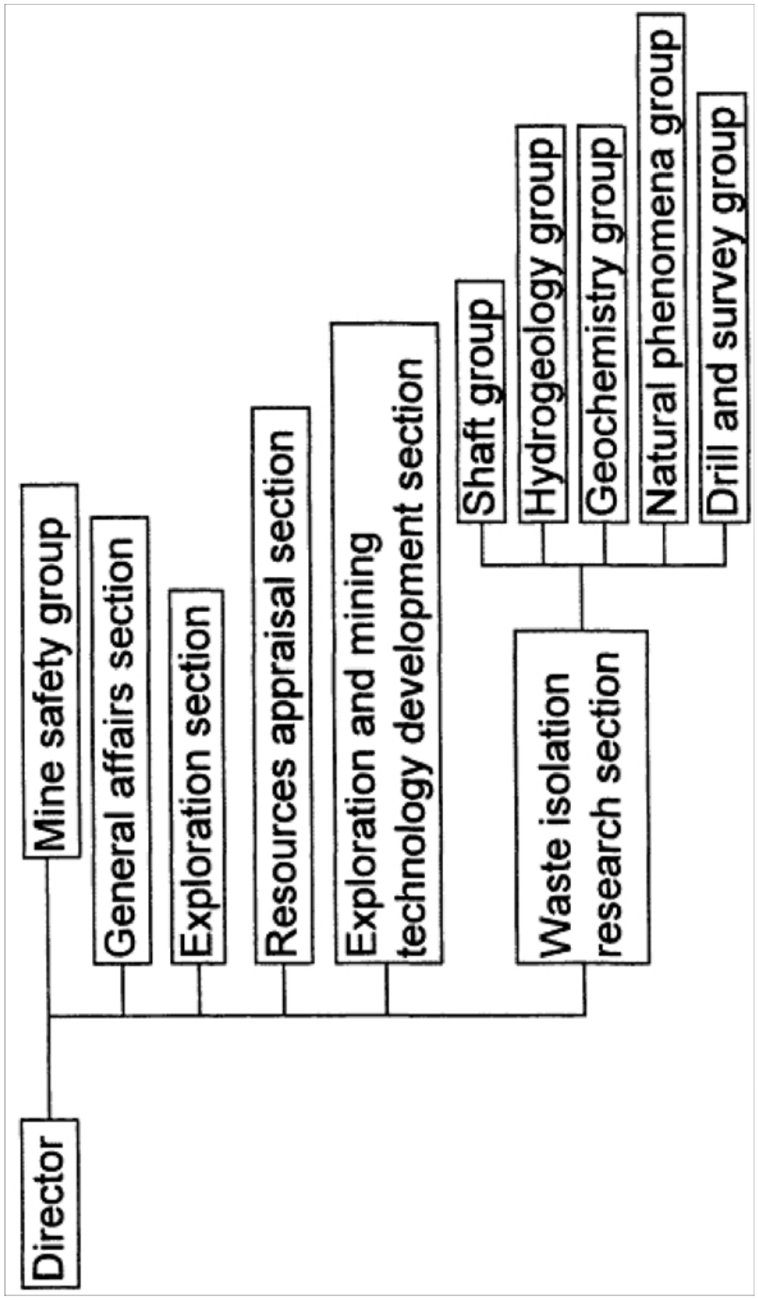

Figure 7
Organization chart of PNC's Chubu Works.

Because there were many experiments carried out in the SEE Project, there were many kinds of contracts and several contractors, and some of these had subcontractors. For the excavation of the shaft, however, there was a single contractor, which had several subcontractors. PNC controlled all of the contractors but had no direct relationship with the subcontractors.

The Science and Technology Agency of Japan ultimately controlled the plan and budget of the project. Under the laws and regulations for rock labor safety and health, the Local Labor Standards Inspection Office controlled PNC, and under the laws and regulations for mine safety, the Regional Mine Safety Inspection Bureau controlled the SEE Project. These two organizations can be compared to the Occupational Safety and Health Administration and the Mine Safety and Health Administration, respectively.

SHAFT EXCAVATION EFFECTS PROJECT SAFETY MANAGEMENT

Safety activities on the SEE Project can be broken down into six parts: (1) a safety plan and rules of safety management, (2) safety documentation, (3) the safety and health management structure, (4) safety inspections, (5) safety meetings, and (6) safety education.

Safety Plan and Rules of Safety Management

Japan's laws and regulations governing mine safety required the development of an implementation program, annual safety programs, and rules of safety management in the Tono Mine. The plan and rules formed the foundation of safety management at Tono Mine during the SEE Project's tenure.

Safety Documentation

Documentation of project safety activities consisted of a monthly report to the Mine Safety Committee of the Chubu Works. The Mine Safety Committee then submitted an activity report to the Regional Mine Safety Inspection Bureau.

Safety and Health Management Structure

To clarify and assign safety responsibilities, PNC established several organizations or systems, such as the Safety and Health Management Organization, the Emergency Countermeasure System, the Explosives Management Organization, and the Fire Safety Management and Fire Fighting System. PNC also kept a list of subcontractors and charts of these organizations; the list and organization charts were posted in each office of PNC and the contractor in charge of excavation work. The Safety Manager and Health Manager of the contractor in charge of excavation work were appointed to their positions and notified.

The Safety Manager at Tono Mine is the director of PNC's Chubu Works. During the SEE Project, the Mine Safety Committee and the Safety Superintendent reported to him, as did the senior safety staff. Senior safety staff were assigned for each area of safety, including general safety, machinery safety, electrical equipment safety, and environmental pollution safety. Figure 8 illustrates this safety management structure.

The safety staff of the contractor in charge of excavation work was considered part of the safety staff of PNC. Safety in Tono Mine has always been the responsibility of PNC, not of any contractor.

The accident reporting system, an important part of the safety management structure, is illustrated in Figure 9. When an accident occurred, it was reported up the chain to the head office of PNC and related governmental authorities.

Safety Inspections

SEE Project safety inspections can be sorted into three categories by frequency of occurrence: monthly, annually, and occasionally. The Mine Safety Committee of the Chubu Works, the Safety and Health Committee of the Chubu Works, and the Safety and Health Committee of Contractors all conducted monthly safety inspections of the project site. The central Safety Committee of PNC inspected the site annually. Finally, the Regional Mine Safety Inspection Bureau conducted occasional safety inspections of the Tono Mine.

Safety Meetings

Safety meetings were a way of life at the Tono Mine. Each group or section held daily safety meetings attended by all of its members. PNC and its contractors, including

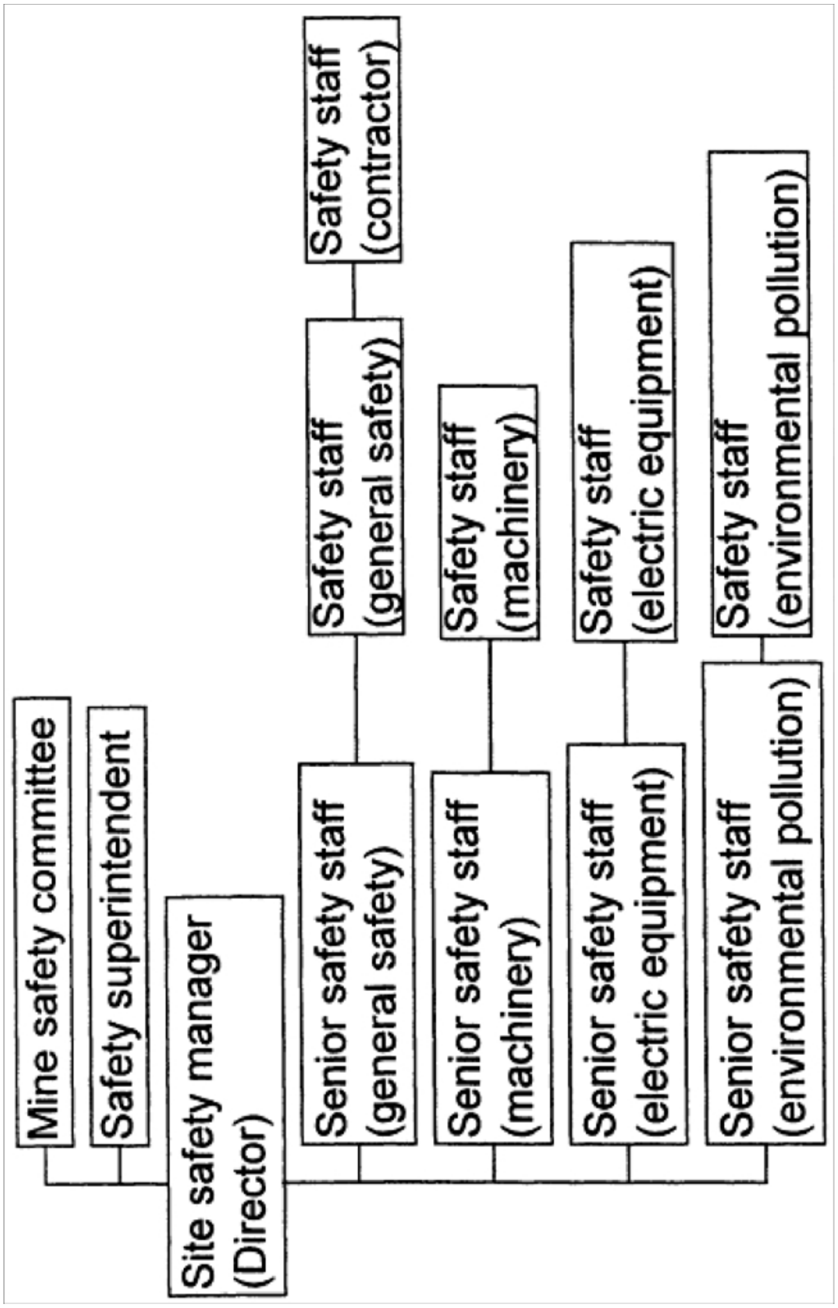

Figure 8
Organization chart of safety management in the Tono Mine.

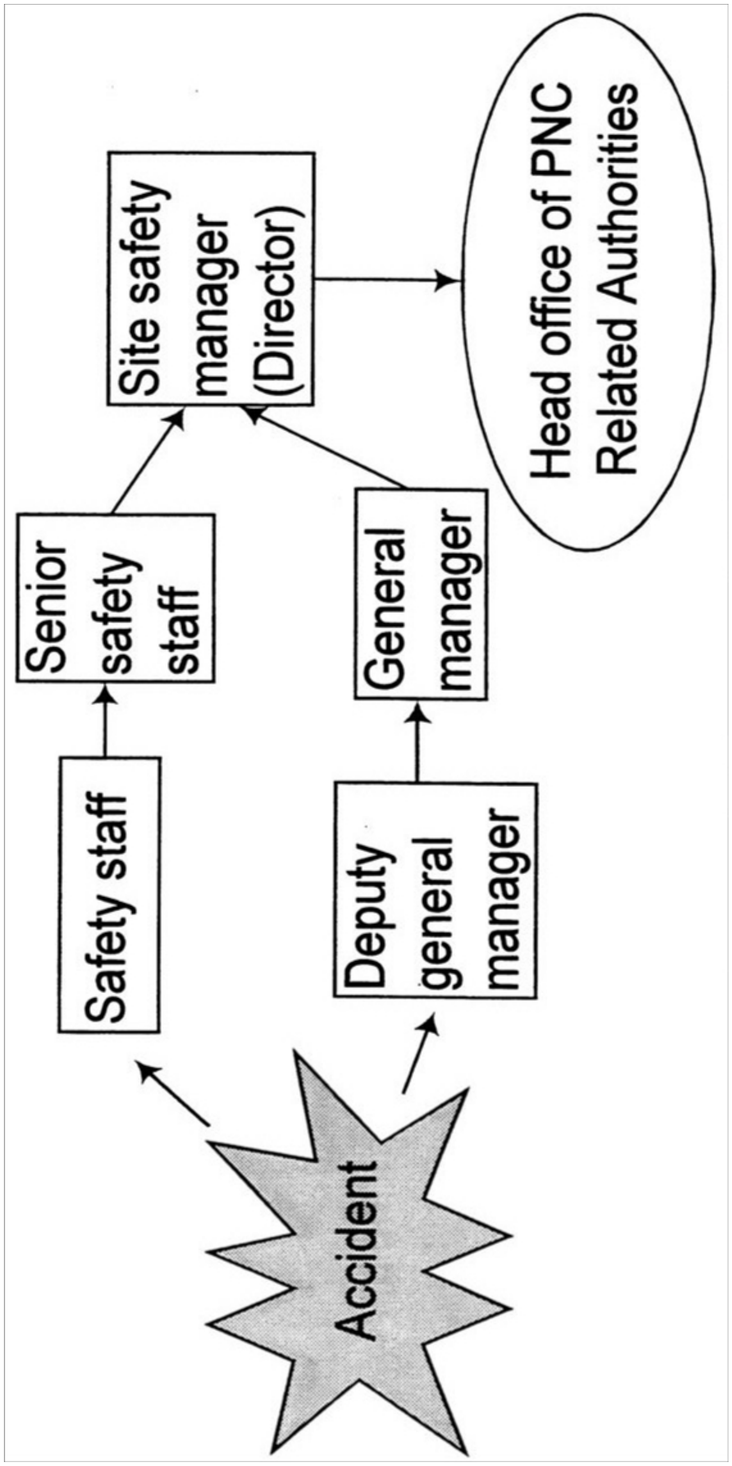

Figure 9
Accident report system of PNC's Chubu Works.

the contractor in charge of excavation work and the contractors running in situ experiments, held safety meetings on a weekly basis. The Mine Safety Committee of Chubu Works, the Safety and Health Committee of Chubu Works, and the Safety and Health Committee of Contractors met once a month.

Weekly safety meeting subjects included particular issues of concern at the time of the meeting, operations progress and planning, a review and reconfirmation of safety issues, and any findings of recent safety inspections. In the weekly meetings, team members informed the group of any upcoming excavation work or research activities. Based on these reports, the group coordinated the impending activities, and the safety staff delivered a safety report and appropriate safety instructions. The weekly safety meeting effectively kept safety uppermost in the minds of team members.

Education

Safety laws and regulations required safety education for both the new worker and the licensed worker. In addition to this required safety education, the SEE Project also conducted KY activities, which were exercises to identify potential risks and to propose countermeasures to address the risks. The KY stands for Kiken Yochi; in Japanese Kiken means potential risk and Yochi means to find them.

Figure 10 shows an example of a picture used in KY activities. A sheet such as this one, designed by project workers, was distributed to all those attending the meeting. Attendees identified potential risks in the scene depicted and then proposed and discussed possible countermeasures to reduce or, better yet, eliminate the risks.

THE RESULT

Only one serious accident occurred on the SEE Project, during the drilling of a horizontal borehole in the shaft. The injured worker was a member of the drilling team. His right hand became stuck between the water delivery hose and the rotating rod, and the injury kept him out of work for two months. After this accident the project team covered the gap with wire mesh. Excavation and research work were stopped by the Regional Mine Safety Bureau for one week following the accident.

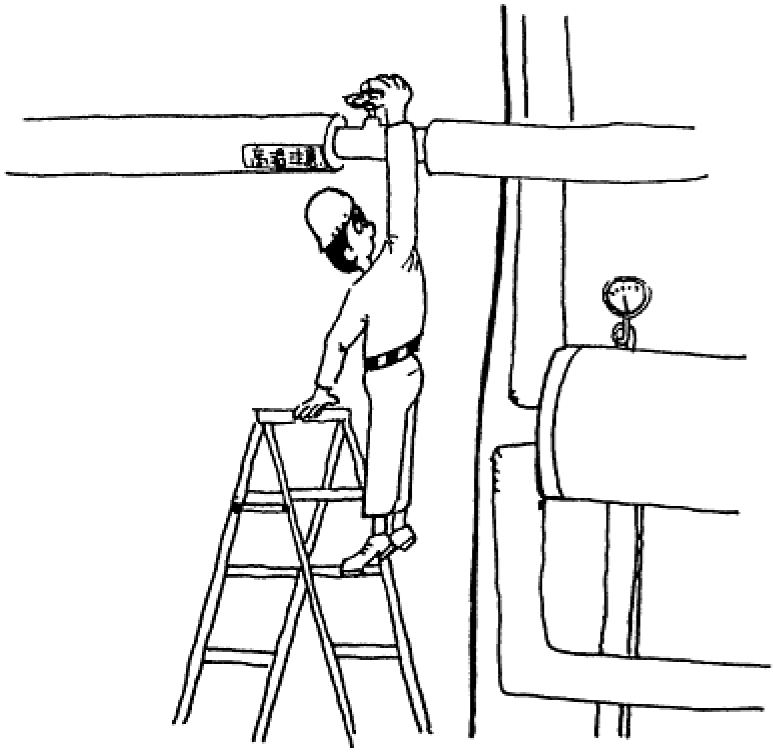

Figure 10
A sample KY sheet.

CONCLUSION

As will the Exploratory Studies Facility at Yucca Mountain, the SEE Project combined excavation and experiments, sometimes alternating between these and sometimes conducting them concurrently. This approach combined workers from several different organizations in a confined, risky work environment.

Two aspects of the safety management approach at Tono Mine during the SEE Project stand out as exceptional contributors to effective safety management: frequent safety meetings, including the weekly meetings of group leaders and the daily meetings of work groups, and safety education, in particular the KY activities.

The KY activities involved all the workers directly with the issue of safety. Identifying risks in hypothetical situations and proposing countermeasures to reduce or eliminate those risks developed the habit of constantly looking for risks and thinking of ways to address them. This habitual heightened awareness undoubtedly protected SEE Project workers on the job.

Safety meetings also heightened the awareness of safety issues. The weekly meetings enabled group leaders to coordinate and schedule project activities and to anticipate and work to prevent any hazards resulting from the week's planned tasks. Daily safety meetings prepared each group for the day's work, made them aware of expected hazards, and reminded them of appropriate safety practices.

The most important goals of safety management are to enhance each worker's sense against dangers and teach each worker to avoid dangerous actions. An effective safety management program will focus on these goals.

The Channel Tunnel

Timothy Green

ABSTRACT

The paper begins with a brief outline of the scope and size of the Channel Tunnel project and the author's particular role of control of four types of underground logistic service: a 900-mm construction railway, a standard-gauge railway, a rubber-tired vehicle service, and recently a fleet of 125 mountain bikes.

The Exploratory Studies Facility (ESF) at the Yucca Mountain Project (YMP) may need to embrace the concept that only line management can be responsible for the management of safety, with a number of safety professionals as advisors. If chosen, to be used at the YMP this approach will have organizational implications.

The author draws on his Channel Tunnel experience to show how a safety culture that started out being safety-department-led developed to the point where line managers accepted the ownership of safety. He suggests a series of practical steps by which this can be accomplished on other projects.

The control of major incidents on the Channel Tunnel sites is described briefly. Control involves the use of dedicated duty controllers, but when things go wrong, they are directed by line management. Thus, the crucial role managers must perform if work is to be carried out safely is critical.

OUTLINE OF THE CHANNEL TUNNEL PROJECT

The Channel Tunnel, now nearing completion, provides a fixed link between southeast England and northern France under the English Channel. The three parallel tunnels are 50 km long portal to portal. On the English side, approximately 8.5 km are underland; on the French side, 2.5 km are underland. Each of the two larger tunnels (7.8 m in diameter) will house a single-track, standard-gauge railway. At the two points where each tunnel is divided into thirds, the running tunnels come together in single, large caverns housing scissor crossovers. These two crossovers and the switch-and-crossing work near each portal divide the runnels into six sectors, three in the North Tunnel and three in the South Tunnel. By working single-line traffic on one of these sections, the client (Eurotunnel [ET]) will be able to take possession of one-sixth of the runnel for maintenance. The maintenance is planned for short periods each night, with slightly longer possessions on weekends.

A third, smaller tunnel (4.8 m in diameter) lies between the running tunnels. This service tunnel carries much of the linear, fixed equipment and is a crucial element of the ventilation system. It will also serve as an access spine for rubber-tired vehicles to cover maintenance and emergencies. At the portals and both the United Kingdom and French crossovers, the service tunnel extends under a running runnel and then back again to permit the larger tunnels to come together.

There are cross passages between each of the running tunnels and the service tunnel at every 375 m. These can be used in emergencies and are also the route taken by many of the linear, fixed-equipment services. At 250-m intervals there are 2-m-diameter, piston-relief ducts between the running runnels that pass over the top of the service tunnel but are not connected to it.

After ET starts commercial service, ventilation of the tunnel complex will normally be accomplished by pressurizing the service runnel with cross-passage doors closed and with doors at the crossovers also closed. The two remaining runnels will thus be separated from the service tunnel, which should be a safe haven in the case of fire. Should it be necessary to ventilate the running runnels, a supplementary ventilation system can be used that can operate bidirectionally, with United Kingdom fans blowing and French fans sucking and vice versa.

At each portal, major terminals have been built. The United Kingdom terminal is the smaller of the two due to the geographical restraints of the North Downs to the north of the terminal and a motorway to the south. The French terminal is not as constrained and is many times larger. ET will develop an industrial estate on the French terminal.

The commercial services will be of a number of different types. Principally, there will be shuttle services for heavy goods vehicles and for private cars and coaches. The shuttle vehicles are large in cross section and are, therefore, captive to the project. On each terminal there are toll booths, customs, and immigration facilities for both countries. Tunnel users will clear all these formalities in the country from which they are leaving. Upon arrival across the channel, vehicles will be free to drive from the terminal straight onto the motorway network. Car passengers will drive themselves onto the trains and then ride in their own cars. Lorry drivers, having driven onto their shuttle trains, will ride in an amenity coach on the same train. In addition to the shuttle trains, there will also be through passenger and freight trains of normal proportions, which will join together the United Kingdom and European railway networks.

The project is a design-and-construct package. This includes the entire infrastructure and all the systems needed to make this major transportation project work. Ten major civil engineering contractors, five French and five British, form the joint venture Transmanche Link (TML).

The author's personal involvement has been to provide, maintain, and run the temporary logistic services used during construction. They have included a two-track, 900-mm-gauge railway in each of the United Kingdom side runnels for shifting muck, taking men and materials into the tunnels, and providing work rigs from which the fixed equipment was erected. The following statistics should be considered as a scale indicator: 160 prime movers; 1,000 items of rolling stock, one-third of which were muck skips used to bring out 17 million tons of chalk marl; and half a million concrete segments carried in, which, together with 123,000 cast-iron segments, hundreds of kilometers of pipework, and thousands of kilometers of cabling, amounted to a further 10 million tons of traffic carried. In its five-year life, the construction railway traveled enough train-miles to have gone to the moon and back more than four times. At peak traffic, the train-miles added up each month to four circumnavigations around the world.

The standard-gauge track, once laid, was also used for construction logistic purposes. This substantial fleet comprised 25 locomotives, 100 flatbeds, and 4 passenger-carrying, multiple-unit sets.

Once the construction railway was removed and replaced by a concrete surface, a fleet of articulated, man-riding, robber-tired vehicles; 40 tractors; and 70 trailers formed the basis of the logistic services in the service runnel. Recently this service has been enhanced by 125 self-drive mountain bicycles. When exiting the tunnel, 15 km of pedaling against the 1.1 percent grade proved challenging.

The tunneling works were carried out by runnel boring machines; by road headers in the crossover cavern, for which New Austrian Tunneling Method techniques were adopted; and by hand. The majority of the tunneling was through chalk marl.

THE CHANNEL TUNNEL AND YUCCA MOUNTAIN

One of the more pertinent similarities between the Channel Tunnel Project and the Yucca Mountain Project (YMP) is the mixture of people, each group with its own safety customs, practices, and cultures, in close proximity underground to those engaged in tunneling. In the Channel Tunnel, this was the mix of those installing and testing fixed equipment while tunneling was still taking place. At the YMP, tunneling and the investigation of what is exposed by the tunneling will bring together diverse cultures.

ORGANIZATION FOR SAFETY

TML's experience is that, for a project as large and diverse as the Channel Tunnel, line management must be responsible for ensuring safety. Furthermore, that the line management of the project must be under single, unified control. Thus the chief executive is also, ex officio, the chief safety officer. This philosophy does not decry the crucial role that safety professionals must perform. Their role is one of support, however, not of direction. TML's safety professionals were overjoyed as line management's commitment to safety grew.

The following are some additional points on organization, gathered from TML's experience.

- As the need arose for organizational change to suit the development of the work, TML used the tracing of safety responsibility from the bottom up to the chief executive as one of a number of checks to prove the organization proposed.
- Having taken on a subcontractor destined later to be at the very heart of the project, suspicions about its safety culture were aroused when a front-line supervisor remarked that he could not take a proposed safety measure until he had his company safety officer's approval.
- The most complex change in organization, and therefore in responsibility for safety, that TML is facing is for the phased hand-over of the project to the client, ET. The principal cause for rejecting the proposed organization has been the failure to identify satisfactorily the safety chain from the operative to the chief executive.
- By its nature, the Channel Tunnel project started simple and became complex as further types of work were added before earlier phases were complete. The tunneling was naturally dominant, especially as the logistic support of the team at the runnel work face clearly affected all work in the runnel complex.

In TML's experience, procedures and safety systems developed for the tunneling phase were surprisingly easily adapted to suit the advent of different types of work forces. This was true on two planes: (1) on matters physical and (2) on attitudes about safety.

The author feels qualified to offer the last few paragraphs not because TML did everything right, but rather because TML got it wrong a good few times and worked mighty hard to try to get it right. There follow a number of things TML did; most, but not all, worked.

EARLY STEPS, EASILY TAKEN

TML management realized fairly early that they, like the construction industry generally, had a wrong safety culture. But safety cultures do not respond to "one, two, three, change" instructions. Substantial procedures must be followed. Both of the following suggestions are excellent first steps.

First, having established an organization through which safety responsibility can be traced from any person on the project up to the chief executive, project managers should set up a series of tiered management meetings dedicated to safety only. These meetings should occur on a monthly basis and last about two hours. The most senior of the meetings is to be chaired by the chief executive and the most junior chaired by a line manager in each group, with front-line supervisors as attendees. The meetings will all have the same agenda:

- feedback from the tier above;
- information to the tier above;
- review the previous month's accidents in detail, seeking patterns for each attendee's group of people;
- review the progress of each attendee's safety initiatives from the previous month; and
- approve of each attendee's proposed safety initiatives for the following month.

Each tiered safety meeting should have a safety professional to act as an advisor and minute-taker, but the meeting must be chaired by a line manager. Peer pressure works wonders. Safety is soon seen to be the sum of a series of apparently minor initiatives.

The second but contemporary step that can be taken is to have all accidents investigated by the injured parties' leader on site. The lead hand will examine what happened and how and why it happened and come up with a solution. The lead hand's supervisor will need to evaluate whether the lead hand is correct and whether his solution will work. The supervisor's manager should evaluate whether the supervisor is right. In all cases, they should ask what they can do to help and to prevent the accident from happening again. TML has found that this works well whether the lead hand is a miner or a doctor of philosophy. The benefits of this technique are threefold:

- The lead hand accepts ownership of the safety of the people for whom he is responsible.
- Detailed knowledge of what happened can enhance future accident prevention efforts.
- The same detailed knowledge can be used by the line manager to categorize the accidents his people have suffered. This categorization and seeking patterns where, *prima facie*, no patterns exist is the basis upon which scientific management can prosper. That is to say, "what can be measured can be managed."

ANALYSIS OF ACCIDENTS

Project management should not seek to impose categories of accidents from the top down. Let each line manager produce his own. Where appropriate, those gathering the accident figures can amalgamate these categories at the monthly safety meetings, tier by tier, feeding the results upwards. Wherever possible, the categories should be specific and tailor-made to suit the job; also, the categories should be such that prevention of a category of accidents can be one line manager's task.

As an example, back strains were a commonplace accident at TML. By establishing detail the author found that back strains of his people generally occurred when operatives were pulling point levers to switch trains between tracks. A short study established a good, kinetic method of pulling points. This was taught to the existing work force by the toolbox talk method and was included in the training of new starters. That accident category disappeared almost overnight. TML measured its overall progress by reportable accidents (i.e., the more serious accidents) per 100,000 man-hours and by a frequency rate of all work-related attendances at an on-site medical center, as shown in Figures 1 and 2. In Figure 3, the dramatic drop in eye injuries occurred when the chief executive decided enough was enough and made the wearing of safety spectacles mandatory.

By analysis of the accidents of the author's own group and at more senior levels (with access to other groups) it became clear that,. despite the apparently hazardous nature of the underground tasks, only a very small proportion of accidents were due to bad ground or faulty materials, plant, or equipment. Human behavior was responsible for about 95 percent of all of TML's accidents. Thus, not only had the hard-pressed line manager become a safety man, he also now needed to become a behavioral scientist.

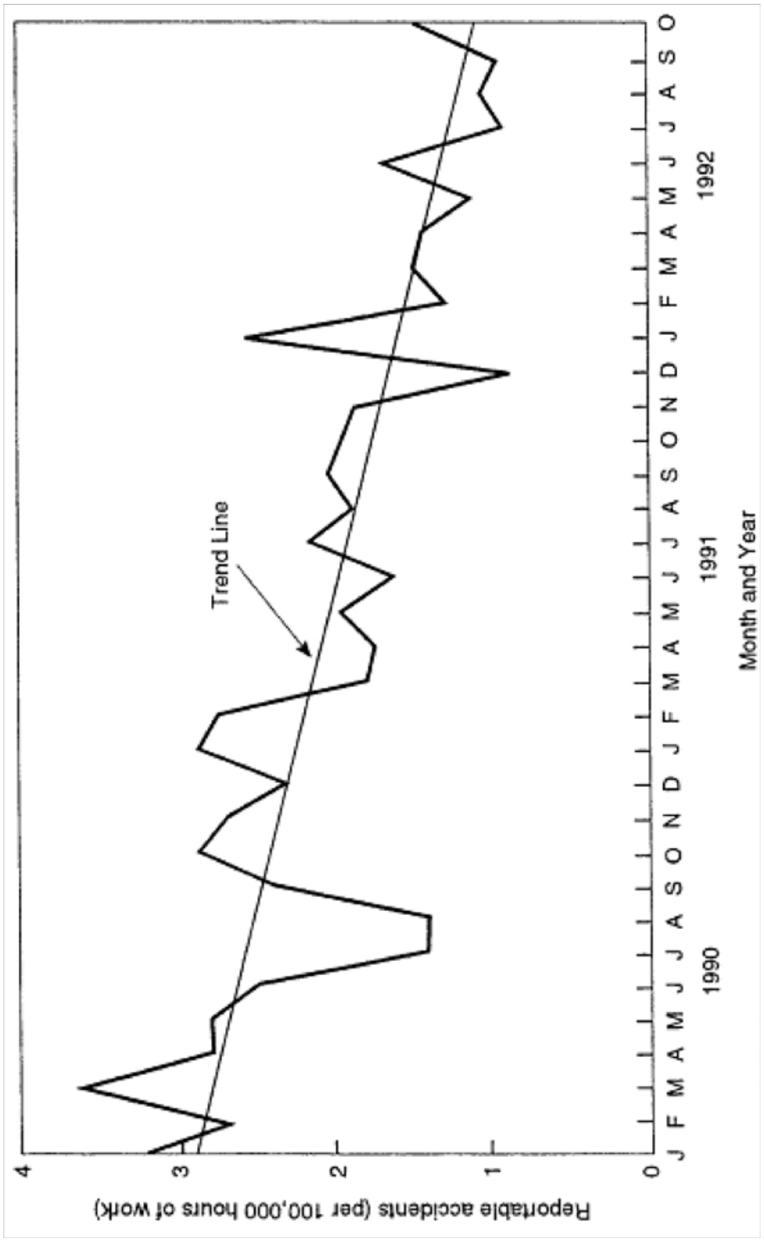

Figure 1
Accident frequency rate per 100,000 hours of work.

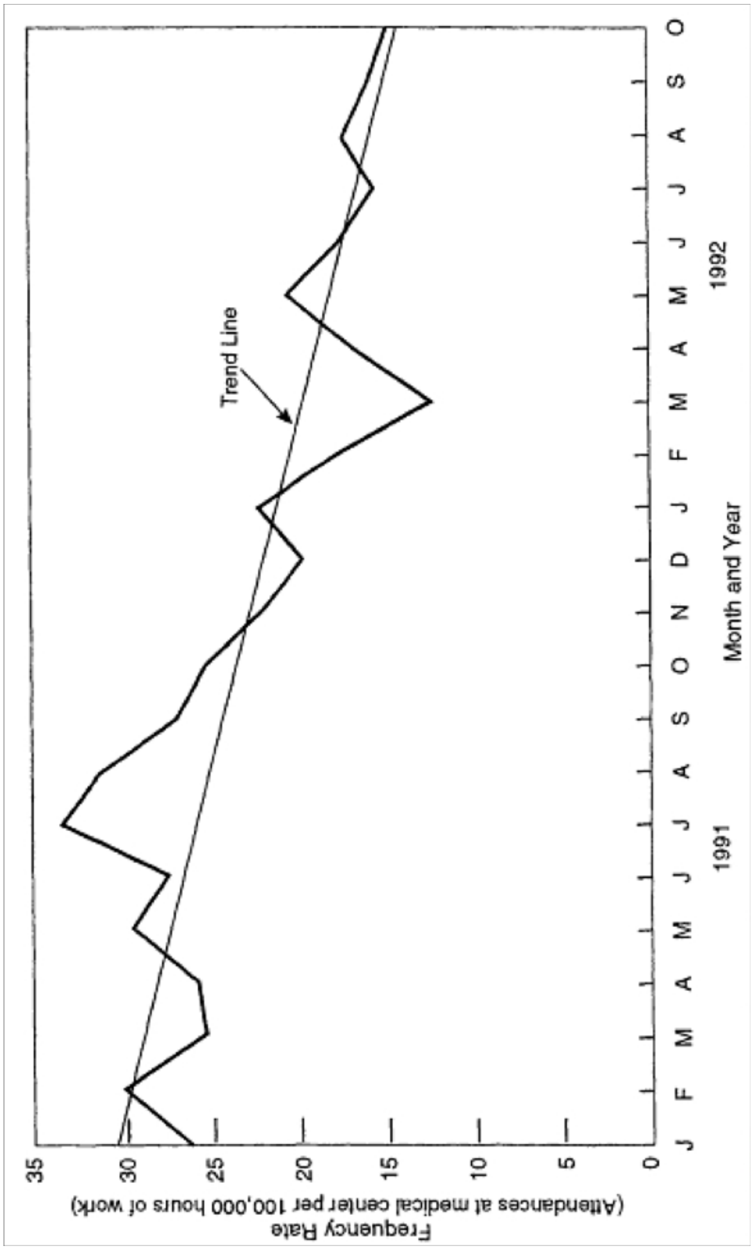

Figure 2
Work-related medical center attendances at the tunnel subproject.

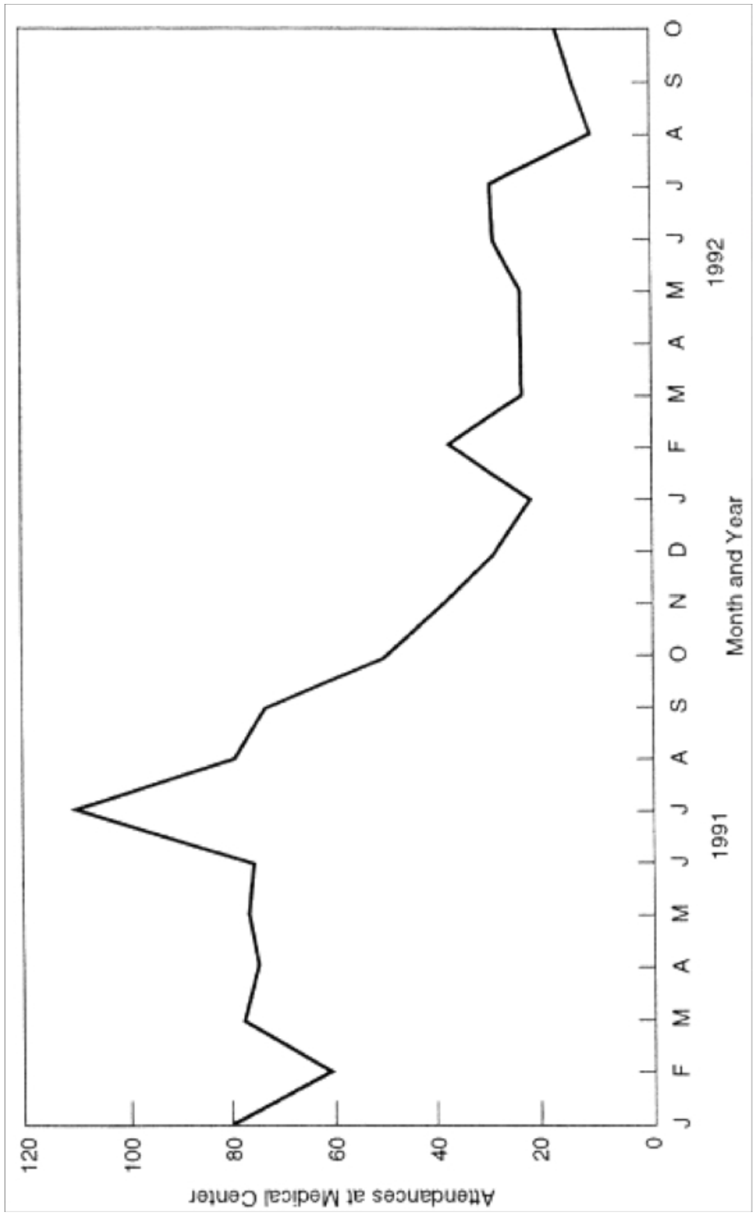

Figure 3
Number of eye injuries of attendances at the runnel subproject medical center.

The cultural change TML sought to achieve and the need to address behavioral issues led to a whole series of safety initiatives. They were not all done at once. The choice of what to do when is very much a matter of judgment. It depends on how far the cultural pendulum has swung and what is practical at the time.

A SERIES OF INITIATIVES

The following are two success stories related to safety initiatives taken by TML.

TML required members of the line-management team to go on well-publicized "safety walkabouts" every two weeks. This initiative had two effects:

- The line manager who was not as committed to safety as was desirable was nudged in the right direction.
- Those on-site underground, or wherever, seeing management devoting time and energy to safety, became more convinced that safety was on the list of things, such as productivity, quality, materials control, and cost control, that managers traditionally cared about.

TML realized that its work force, properly directed, was highly talented and that this talent could be used for bottom-up safety problem-solving. One of the safety-management, tiered committees would sponsor problem-solving by groups established ad hoc. The committee, usually consisting of between four and six people from different groups (and even including subcontractor input), would meet two or three times. The ad hoc groups have a universal membership—again an opportunity to mix doctors of philosophy with plant fitters.

TML had many success stories. Locomotive drivers recommended a change of style and some change of content in the procedures that described how things should be done. The procedures were revised, and the reasons for their revision were explained. Adherence to procedures improved because the drivers and others working on the construction railway accepted ownership of the procedures as they recognized their own bottom-up input.

While the waste of industrial gloves was reduced and their usage was increased, based on the findings of an ad hoc group given total freedom to choose the types of gloves used, TML had a slight problem. Bricklayers found that their brick hand and their trowel hand needed different gloves. TML is seeking a group of predominantly left-handed bricklayers and would do a deal!

Toolbox talks, which TML calls field safety talks, were targeted at one per employee per week. Two benefits resulted: (1) it proved to be a valuable means of conveying information top-down and (2) it had a considerable impact on front-line supervision forced, perhaps for the first time, into a teaching rather than driving mode.

Recognizing the behavioral nature of the majority of the safety problems led TML unashamedly to market safety as a commodity. The organization produced site videos using their own recognizable people; placed notes in the pay packet (a document always studied); conducted field safety talks on particular issues; prepared in-house posters, frequently rude and often with caricatures of the well-known (Figures 4 and 5); and created encapsulated cards as an *aide mémoire*.

TML's site was unionized, and somewhat atypically, the project team enjoyed excellent industrial relations. The trades' unions participated with vigor in the safety program and never once used safety as a bargaining tool. A shop steward on one occasion chaired an ad hoc group, and among his team there were an engineer and a tunnel agent, as well as two or three operatives. The group was very successful.

TML management thought that the pendulum of change had swung enough and that there was sufficient evidence of operative involvement in safety to try a "safety suggestions scheme." Wrong! almost no response! This raised an important point: if it, or any safety initiative, clearly does not work, drop it quickly.

TML embraced the DuPont-style, one-to-one audit system. Supervisors were trained to do these audits, which was again a benefit to TML, as it encouraged leadership and teaching rather than the traditional construction-industry, physically robust style of the big stick. Supervisors acted as auditors and watched an operative or a small group of operatives, preferably while remaining unseen, and then had a chat with them. The chat was a no-risk discussion, as the auditee would not be named. The auditee was encouraged to tell the auditor how he was "out of line" in safety terms. He was also encouraged to make no-risk suggestions. After the auditor left the auditee, the auditor completed a record of the audit. The auditor recorded good and bad actions observed against a simple checklist that monitored protective equipment, housekeeping, orientation, tools, and operating procedures.

For his group of departments, the author received the audit reports directly from the supervisors. Each month, for each group, he summarized the particular findings, stressing the positive rather than the negative. For example, a group would present typically 60 or 70 audits covering 80 or 90 auditees. If in the protective equipment section there were sightings of 2 workers without their hard hats and 4 without safety glasses, this was put into perspective by reporting this as 6 transgressions out of 450 possible (90 people × 5 pieces of protective equipment: each person wears hat, overalls, boots, gloves, and glasses).

Figure 4
Example of an in-house poster used to market a safety spectacles campaign at TML.

Figure 5
Example of an in-house poster used to market the TML track safety campaign.

Each month the author would pick out 4 or 5 key issues for each group (usually out of 50 or 60 suggestions from the auditors/auditees on the lower half of the form). Sometimes the same concerns would be raised by many auditees. These monthly reports would become part of his own line manager's list of safety initiatives for the next month.

TML offered groups of any predetermined size an 18-inch color TV or a voucher with an equivalent value if they worked collectively 25,000 hours without any form of accident. One group of plant fitters managed four such consecutive prizes. For a single 9-to-5 guy, 100,000 hours equates to 50 man-years. The prizes were raffled among the group who had been accident-free. They were not prizes for being safe. Publicity was the aim.

Figure 6 shows a number of bricks TML used to build a wall of safety. This paper has described some of them. Many are self-evident, but the Safety Performance Management System will not be one of these. This system was TML's attempt to measure the effort put into and tangible evidence of safety management. There are complex measurement methods, but they take an army of specialists to drive them. TML simplified a complex method but it, along with most such systems, begs more questions than it solves. Any project should therefore devise its own method of measurement. Of course, the only true method is to be able to say that no one was hurt.

ENVIRONMENTAL MONITORING AND CONTROL OF INCIDENTS

TML has sensors in the tunnel to measure temperature, oxygen, carbon monoxide and dioxide, nitrogen oxide and dioxide, flammable gases, water flows, etc. All measurements by these sensors are permanently recorded on a time base and are monitored in real time by full-time duty controllers. The control center is also the hub of all the radio and telephone communications networks. The duty controllers work to a set of procedures to control incidents. They call for emergency help from off site if needed and can command help from on site as required. There is also a roster of main controllers. Main controllers, one at a time, give continuous, on-call cover. Needless to say, main controllers are again line managers in disguise.

This takes the paper nicely back to the original theme: it is the line managers who must manage safety and control incidents and emergencies, just as they manage such things as costs, productivity, quality, and industrial relations.

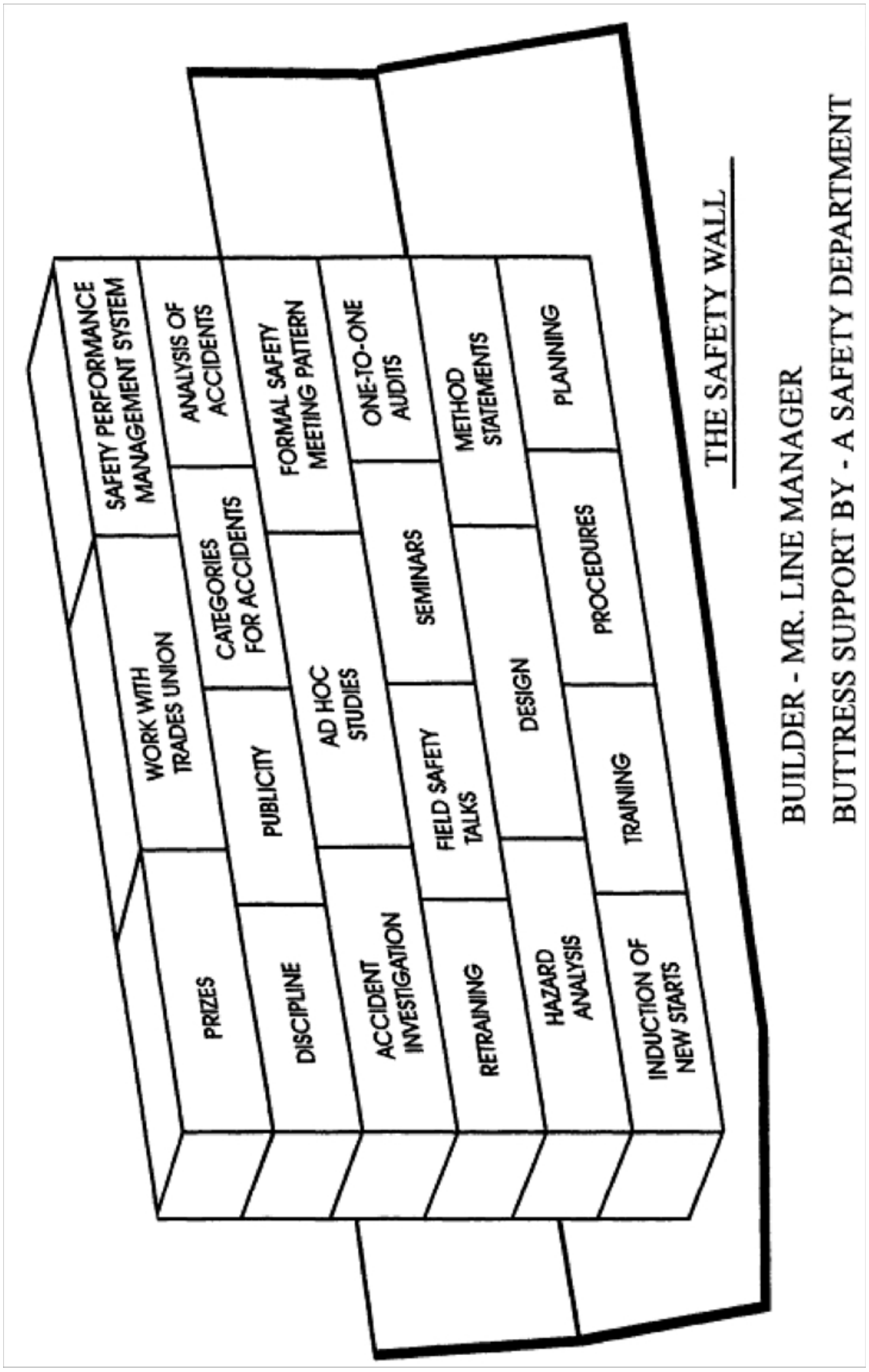

Figure 6
TML's safety wall.

DISCUSSION

Responding to a question, Tim Green said that the figures shown in his presentation did not reflect the combined English and French work forces. At peak, the total number of workers from both England and France was approximately 15,000. The Channel Tunnel will finally have required about 74,000 man-years of construction work.

Participants were also curious about the differences in English and French safety regulations. The English and French have very different safety cultures and regulatory styles. In particular, the electrical requirements of the two nations are entirely different. However, the Channel Tunnel project permanently links the two together. Mr. Green anticipates that the project will have to maintain its own set of electrical regulations, representing a compromise negotiated between the two countries.

Another, more common example of the difference in cultures and national regulatory styles is the issue of smoking and drinking alcohol in the work place. English health and safety laws do not allow either activity, but French workers do both; they sometimes share cigarettes with their English colleagues at the midpoint, and bottles of champagne have also been available on special occasions.

Appendix A:

Symposium Agenda

SYMPOSIUM ON SAFETY IN THE UNDERGROUND CONSTRUCTION AND OPERATION OF THE EXPLORATORY STUDIES FACILITY AT THE YUCCA MOUNTAIN PROJECT

November 29-December 1, 1993

Monday, November 29—Tour of Yucca Mountain Site

Tuesday, November 30

8:45 a.m.	Welcome and Introduction to the Symposium
	• *Ray Sterling, Chairman, U.S. National Committee on Tunneling Technology*

Session 1 - Introduction to the Yucca MountainProject(YMP)

8:55 a.m.	• *William B. Simecka, Director, Engineering and Development Division, USDOE*
10:00	• *Dennis R. Williams, Chief, Site Investigation Branch, USDOE*
10:20	Questions

11:00	**Keynote Address**: Underground Construction Safety: "Be Sure You're on the Right Track" *Joseph Fitzgerald, Deputy Assistant Secretary for Safety and Quality Assurance, USDOE*
11: 45	Lunch

Session 2 - Invited Presentations on Issues in Underground Safety Management

1:00 p.m.	Introduction *Priscilla Nelson, Member, U.S. National Committee on Tunneling Technology*
1:10	Considerations in the Development of the DOE's Construction Safety Program *Patrick Finn, Safety Engineer, Office of Occupational Safety, USDOE*
1:45	OSHA Regulations and Their Implications in the Construction of the ESF at Yucca Mountain *Fred A. Anderson, P.E., Consulting Engineer*
3:00	Underground Regulatory Safety Today *Byron Ishkanian, Principal Safety Engineer and Corporate Safety Director, Cordoba Corp.*
3:40	Safety Engineering Design Analyses *Bruce Blackford, P.E., Research Analysis Corporation*
4:20	Milwaukee Water Pollution and Abatement Program: Underground Safety—Dealing with OSHA *John Ramage, Vice President, CH2M Hill*
5:00	Adjourn/Informal Discussion

Wednesday, December 1

Session 3 - Experience in the United States and Abroad

8:00 a.m.	Introduction *Priscilla Nelson*
8:10	Waste Isolation Pilot Plant (WIPP): The Underground Safety Culture *Fred Ashford, Mining Operations Manager, Westinghouse* *Linda Calderon, Manager of Industrial Safety*
9:00	Defence Nuclear Agency *Joseph W. LaComb, Chief, Nevada Operations Office, DNA*
10:20	Underground Safety of the Äspö Hard Rock Laboratory (Sweden) *Olle Zellman, Swedish Nuclear Fuel and Waste Management Co.*
11:10	Safety Management in PNC's Shaft Excavation Effects Project in Japan *Kozo Sugihara, Senior Research Engineer, PNC Chuba Works*
12:00	The Channel Tunnel *Timothy J. Green, U.K. Operations Project Office, Transmanche-Link*
12:50 p.m.	Lunch

Session 4 - Discussion Session

2:00 p.m.	**Keynote Address**: OSHA and Construction Safety *Patrick Tyson, Consulting, Brooks and Smith*
2:30	Open Discussion

Session 5 - Safety Programs At the YMP

3:05	Safety Review/Coordination

Russell B. Baumeister, Occupational Safety and Health Specialist, USDOE

Systems Safety

H. Kenneth Elder, General Engineer, Engineering and Development Division, USDOE

Management and Operations Contractor

Carl Pierce, Manager of Safety and Health, TRW Environmental Safety Systems, Inc.

Construction Safety (Reynolds Engineering and Electrical Co.)

Panel:

H. Steve Jones, Manager, Occupational Safety and Fire Protection
Randy H. Leske, Safety Professional
Ronald Costin, Medical Director
Harrison F. Kerschner, Manager, Health Protection Department
Tunnel Constructor

Lance de Stwolinski, Project Manager, Kiewit/PB

5:00 Closing Remarks

Ray Sterling

5:15 Adjourn