Proceedings

TWENTY-SECOND ANNUAL INSTITUTE ON COAL MINING HEALTH, SAFETY AND RESEARCH

Edited by
EDWARD HUGLER ALEX BACHO
MICHAEL KARMIS

PROCEEDINGS
OF THE
TWENTY-SECOND ANNUAL INSTITUTE ON COAL MINING HEALTH, SAFETY AND RESEARCH

BLACKSBURG, VIRGINIA
AUGUST 26-28, 1991

SPONSORING ORGANIZATIONS:

DEPARTMENT OF MINING & MINERALS ENGINEERING
VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY

MINE SAFETY AND HEALTH ADMINISTRATION
U.S. DEPARTMENT OF LABOR

BUREAU OF MINES
U.S. DEPARTMENT OF THE INTERIOR

EDITED BY:

Edward Hugler
Mine Safety and Health Administration
U.S. Department of Labor

Alex Bacho
Bureau of Mines
U.S. Department of The Interior

Michael Karmis
Department of Mining and
Minerals Engineering
Virginia Polytechnic Institute
and State University

Published by the Department of Mining and Minerals Engineering
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061-0239

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

Grateful acknowledgement is made to the speakers of the Twenty-Second Annual Institute for their outstanding program contributions in the field of coal mining health, safety and research. Appreciation is also expressed to the program session chairmen and co-chairmen.

Thanks and appreciation go to the Planning and Advisory Committee for its effort and support throughout the development of the conference program. In addition, specific acknowledgement is made to Mr. Alex Bacho and Mr. Edward Hugler, my conference co-chairmen, for their special assistance and advice during the planning of the conference and for their contributions in editing the *Proceedings*. Finally, the assistance received from Margaret Radcliffe in the editing of this volume, and from Mary Behnke, Lisa Blankenship, and Peggy Douthat in its preparation, is greatly apppreciated.

Michael Karmis
Conference Co-Chairman
Blacksburg, Virginia
August 26, 27 & 28, 1991

INTRODUCTION

This *Proceedings* contains the presentations made during the program of the Twenty-Second Annual Institute on Coal Mining Health, Safety and Research held at the Donaldson Brown Center for Continuing Education, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, on August 26, 27 and 28, 1991.

The Twenty-Second Annual Institute on Coal Mining Health, Safety and Research was the latest in a series of conferences held at Virginia Polytechnic Institute and State University and cosponsored by the Mine Safety and Health Administration, United States Department of Labor and the Bureau of Mines, United States Department of the Interior.

The Institute provides an information forum for coal operators, mine managers, superintendents, safety directors, engineers, inspectors, researchers, teachers, and state agency officials, and others with a responsible interest in the important field of coal mining health, safety and research.

In particular, the Institute is designed to help mining operating personnel gain a broader knowledge and understanding of the various aspects of coal mining health and safety, and to present them with methods of control and solutions developed through research.

1991 CONFERENCE ORGANIZATION

ADVISORY AND PLANNING COMMITTEE

James Adkins
General Manager - Safety
Cannelton Holding Company
Cannelton, WV

John Baugues
President
Mountain, Inc.
Knoxville, TN

Mack J. Blackwell
V. P. Engineering &
Communications
Simmons-Rand Company
Bristol, VA

George Bockosh
Research Supervisor - MSHE
Bureau of Mines
Pittsburgh, PA

John Caylor
Director - Corporate Safety &
Industrial Health
Freeport-McMoRan
New Orleans, LA

Harry Childress
Chief, Division of Mines
Virginia Department of Mines,
Minerals & Energy
Big Stone Gap, VA

John W. Crawford
Vice President, Health & Safety
The Pittston Coal Group
Lebanon, VA

Harry M. Dushac
Manager OEM Sales and
Product Services
National Mine Service Company
Carnegie, PA

Mark G. Ellis
Senior Counsel
American Mining Congress
Washington, DC

Richard B. French
Regional Inspector
Consolidation Coal Company
Bluefield, VA

James L. Gallimore
Mining Consulting Services, Inc.
Tri-State Engineering Division
Lexington, KY

McDonald Hagy
Manager of Safety
Island Creek Coal Company
Oakwood, VA

Chris R. Hamilton
V. P. of Health & Safety
West Virginia Coal Association
Charleston, WV

Robert E. Havener
Consultant
Mine Safety Appliances Co.
Pittsburgh, PA

Barton B. Lay
Dir. Health, Safety & Training
West Virginia Division of Mines
& Minerals
Charleston, WV

Frank Linkous
Vice President, Health & Safety
Westmoreland Coal Company
Big Stone Gap, VA

John W. McEwen
District Manager
Mine Safety Appliances Co.
Dunbar, WV

P. L. "Judge" McWhorter
General Sales Manager
Phillips Machine Service, Inc.
Beckley, WV

Robert C. Milici
State Geologist
Va. Div. of Mineral Resources
Charlottesville, VA

Ronald Mullins
Director of Safety & Training
United Coal Company
Grundy, VA

Joseph Turley III
President & CEO
Leckie Smokeless Coal Co.
Rupert, WV

Williard C. Walker
Branch Manager - Distributor
Products & Warehousing
National Mine Service Company
Beckley, WV

James L. Weeks
Director of Research
Laborers' Health & Safety Fund
of North America
Washington, DC

EXECUTIVE COMMITTEE

Alex Bacho
Chief
Branch of Health & Safety Technology
U.S. Bureau of Mines
Washington, DC

Joseph Cook
Manager of Mines
Pennsylvania Mines Corporation
Ebensburg, PA

David Forshey
Associate Director - Research
Bureau of Mines
U.S. Department of the Interior
Washington, DC

Edward Hugler
Deputy Assistant Secretary
U.S. Department of Labor
Mine Safety and Health Administration
Arlington, VA

Michael Karmis
Professor and Head
Dept. of Mining & Minerals Engineering
VPI & SU
Blacksburg, VA

Jerry Spicer
Administrator, Coal Mine Safety
Mine Safety and Health Administration
Arlington, VA

KEYNOTE ADDRESS

Richard Lawson
President
National Coal Association
Washington, D.C.

"Coal and American Energy Policy: The Warthog of Energy Security"

COAL AND AMERICAN ENERGY POLICY: THE WARTHOG OF ENERGY SECURITY

Richard L. Lawson
President

National Coal Association

Thank you, Ed Hugler; hearty congratulations are in order on your recent promotion to deputy assistant secretary of the Mine Safety and Health Administration, and I want to offer them here and now in behalf of the coal industry.

Dean Clough, congratulations also are due the university and the College of Engineering for the continuing sponsorship of these most necessary and effective institutes on coal-mine health and safety.

This is the 22nd Annual Institute and a history of that duration says many things. For one, the coal industry's continuing support and participation demonstrates a commitment to build on the dramatic advances made in miner safety and health since the first institute in 1969.

Commendations are due as well to the co-chairs--to Michael Karmis of the Department of Mining and Minerals Engineering; to Alex Bacho, the Chief of Health and Safety Technology for the U.S. Bureau of Mines; and to Secretary Hugler of MSHA.

And finally, I want to especially acknowledge those in attendance: the scientists and engineers whose work moves improvement forward; the federal and state officials who oversee production; the representatives of the United Mine Workers of America; and the participating coal executives. It is good that we have forums such as these institutes to draw us together on a regular basis. The skills you use here--the ability to study and reason cooperatively on mutual problems--will become increasingly critical to the future; and not just to the future of coal.

Ladies and gentlemen, your subject during these two days will be some of the most recent developments and concerns in coal-mining health, safety and research. My topic is the role of coal in establishing America's energy security. There is no mismatch of subject and keynote, for in the truest sense my topic is nothing less than the health and safety of the United States. Both will begin with the way we handle things in the coal mines at the working face.

Perhaps the best place to begin is with the administration's National Energy Strategy and the implementing Senate legislation--the National Energy Security Act of 1991. Then I'll come back to the beginning--to the demands the act and the Nation's needs will make on us as the collective group known as the coal industry.

If energy policy were a piece of new equipment, the National Energy Strategy would be the equivalent of specifications--what the new hardware should be capable of doing. The National Energy Security Act of 1991 is the blueprint for the equipment. The hardware still must be assembled, tested and perfected.

Undertaken between oil-related U.S. military deployments to stabilize the oil-exporting regions of the Persian Gulf that dominate world markets, the strategy has two objectives. There are multiple threats to America's energy security.

The first objective is to reduce dependence on imported oil for economic activity and future growth. Imported oil dominates the U.S. and world economies. The dominant oil-exporting nations are susceptible to turmoil and disruptions. The need for oil imports to survive is almost universal. The world oil market is dominated by only a few. All nations are hooked together where the world market is concerned. These things distort and deform America's economic policy, foreign policy and National Security Policy. The American economy is the engine that pulls the world economy. And today the world looks to the United States to keep it stable.

Since 1969, we've had two severe and global economic dislocations due to the poor geographic and political distribution of the market-dominant world oil reserves--in 1973 with the Oil Embargo and in 1979-80 with the fall of the Shah. Just four years ago we sent into harm's way a force of 25,000 young American men and women to stabilize the oil producing Mid-East during the Iran-Iraq War. And last year 500,000 went for what became the 100-Day War to turn back an act of old-style aggression. When Saddam Hussein reached to control two-thirds of the world's oil reserves he also was reaching for the throat of the industrialized world to attempt future political extortion.

At present neither Kuwait nor Iraq are contributing to the world oil market. The producers' ability to deliver oil and the demand for oil are not far out of balance. The Soviet Union produces about 20 percent of the world's petroleum; some is sold on the world market for hard currency and Eastern Europe is heavily dependent. Western Europe is dependent and becoming more so on Soviet natural gas. A civil war would have called all of those supplies into question. It would have put all of that additional demand on the more-or-less-free oil market. And the market would have reacted as it usually does. Thus, if recent events in the Soviet Union had gone another way, we could today be in the middle of a fifth oil dislocation in little more than 20 years.

There is a second danger with the Soviet Union. Its oil industry is backward, its reserves uncertain, its society still critically unstable. A future failure of the industry or accelerating decline could certainly produce new and serious pressures on international stability.

The dominant oil-producing regions are too volatile, the oil market too unstable to uphold the hopes and aspirations of the era emerging from what we used to call the Cold War. Around the world only two things went up the day of the Soviet coup attempt--the value of the U.S. dollar, and the price of oil as the traders hedged their bets. As other reserves are pumped and discoveries decline, the power to dominate the market concentrates in the oil-exporting nations of the Mid-East. They are not yet politically stable and may not be for years. Future actions and reactions in the Soviet Union are unknowns.

One economic dislocation is one too many--especially if economic alternatives to imported oil are available or can be made available through technology. One Desert Storm is one too many--especially if alternatives to imported oil are available or can be made available. Thus the National Energy Strategy was an effort to catalogue need and identify alternatives to the inflexible, live-or-die dependence on imported oil that brings on crises. We've had four in less time than you've been holding these meetings.

No less important, the strategy's second objective is to deal reasonably and effectively with reasonable environmental concerns; and to do it before economic no-growth philosophies--domestic and foreign--can take command of the politics to engineer artificial constraints on all fossil energy.

The Bush Administration is putting forward elements of the energy strategy as answers to concerns driving the worldwide movement to establish an international treaty on global climate change. A key demand of the most-vocal anti-growth partisans in the treaty movement is for immediate and dramatic reduction in fossil energy use and, thus, in economic activity. The mechanism is a pledge to reduce carbon dioxide emissions that may, or may not, be driving climate change that may, or may not, be in prospect.

But three-quarters of the world is in ferment to obtain the standard of living that can only be delivered by adequate energy and economic development. The ferment covers whole continents and hemispheres. Count them: the Soviet Union; Eastern Europe; the developing nations of Asia and Latin America; the long-suffering nations of Africa.

Add to the ferment the problems of population and the pressures raised by the aspirations of an additional 3.2 billion persons that demographers expect to be born in the next 35 years. Most of the growth will come in the energy-poor nations of Latin America, Asia and Africa: in the geographic dooryards of America, Japan and Europe.

The sum of history suggests that if these billions are denied the opportunity to earn their bread and shelter--plus a little comfort--at home, then they will try to take them from their neighbors. The experience of this century says that rising standards of living lead to lower and, eventually, stable birth rates.

But a higher standard of living rests on energy, on economic activity and on trade between the advanced and developing nations. If, by treaty, the advanced nations cause their economies to stagnate or decline, there will be no markets for trade. The advanced nations could themselves destabilize, the others left to fester.

Thus the administration's "no-regrets" policy on climate change is being advanced for inclusion in the treaty being prepared for next year. It stresses technology; and increased efficiency; and a balancing and treatment of all suspected driving forces; and a short period of intense study to determine if economic activity might cause climate change.

The National Energy Security Act of 1991 embodies the domestic version of the "no-regrets" international policy. It takes the actions the United States feels are warranted by the evidence at present. In the strategy recommendations the administration sought to increase America's domestic energy supplies while balancing and treating the causes of concerns about three environments--the natural, the economic and the geo-political.

As for coal specifically, I'd like to quote Deputy Secretary of Energy Henson Moore's remarks at this year's annual meeting of the National Coal Association. Secretary Moore said, "Coal is a centerpiece (of the strategy)...coal is here to stay!" The Department of Energy projects U.S. domestic coal demand of 1.2-billion tons by the year 2000 and 1.6-billion tons by 2010. From the present this would be 20 percent growth in nine years and 60 percent growth in less than 20. We will be put on our mettle to do this, just as we have been to accommodate the 80 percent growth that took place between 1969 and the present.

Globally, the strategy cites an estimate that world energy demand will increase by 35 percent between now and the year 2000; by 157 percent between now and 2025; and by 358 percent between now and 2050. In coal, the projections are that world demand will rise to almost equal world oil demand by the year 2000; that it will exceed oil by a factor of two by 2025; and that it will surpass oil demand by a factor of almost two-and-a-half by 2050.

The department estimates that U.S. coal exports will reach 137-million tons by the year 2000 and 250-million tons by 2010. From the present, this would constitute 37 percent growth in nine years and 150 percent in less than 20.

None of this is guaranteed, especially the high end of the export estimates.

The strategy is only an accounting of assets and requirements. It deals with what we can do about our energy vulnerabilities. The National Energy Security Act of 1991 is the best and bipartisan judgment of the Senate energy committee leadership on how we can do it. Similar legislation is being prepared in the House. The bill contains a strong coal section that matches 90 percent of America's fossil fuel reserves--coal--with important national requirements.

The first match is in electric-power generation. Estimates are that the United States will increasingly turn to electric power as the economy grows and becomes more modern. The converse is that without electric power, the economy will be pressed to grow. The strategy projects a need for as much as 100,000 megawatts of new electric-generating capacity by the year 2000, as much as 322,000 additional megawatts by 2010.

Coal is well-suited for generation of electric power. It is the only fuel that is unconditionally available for large scale use in new capacity. It requires neither additional infrastructure to be shepherded through lengthy due process nor government action to remove some legal, regulatory or political impediment.

Against this need we have first- and second-generation clean-coal technologies of exceptional promise in both thermal efficiency gains and pollution reduction. Now in market-readiness testing, the first generation for retrofit and new capacity is comprised of atmospheric- and pressurized-fluidized-bed combustion and integrated-gasification-combined-cycle generation. They offer gains that range from 10 percent to 30 percent of the thermal efficiency of present technology. Compared with present technology, they can produce a given amount of power at carbon dioxide emission rates that are 10-to-20 percent lower. Deployment of these technologies would be good for the economic and natural environments.

The Senate bill offers strong incentives for the deployment of clean-coal technology in power generation. They include federal rate incentives; and a means of predetermining that clean-coal investment is prudent to eliminate possible regulatory difficulties; and a finding that deployment is in the national interest.

But the bill does not direct deployment and it does not demand that utilities use coal rather than oil or natural gas. It leaves those choices to the market. Therefore, if the resource and the need are to be matched, those involved in coal production must see to it that coal maintains its advantages, that coal remains the low-cost fuel.

The bill also provides for the development of the second-generation technologies that include fuel cells and magnetohydrodynamics. Their respective thermal efficiencies are of 50 and 55 percent--gains over the present of more than 50 percent for one and 67 percent for the other.

There are strong provisions for coal-technology research, development and deployment; and the bill continues the Clean-Coal Technology Program.

In addition, the legislation would foster exploration of other uses for coal. Much of America's imported-oil demand is for transportation and petrochemical feedstock. The bill directs research into the concept of "coal refineries" to produce transportation fuel and other value-added products. It would foster research into other coal-energy technologies of promise in the direct displacement of imported oil.

Equally important from the standpoint of America's world leadership, the bill would encourage the export of both U.S. coal and clean-coal technology. Export would make reliable, low-cost energy available to the population-rich but energy-poor developing countries in the geographic dooryards of the advanced nations. It would allow China and India to use their coal in ways to benefit their development and the world environment. And it would provide the economic means of cleaning up the polluting economies of struggling nations such as the Soviet Union and those of Eastern Europe. Competition in world coal trade is--and will remain--fierce.

From all of this one can see both great opportunities and great need for coal. But there also is a very vocal and well-organized opposition to coal. When the press at least once a week quotes some large pressure groups and politicians as saying they are out to ban coal use, one is not necessarily paranoid to begin to suspect some folks simply don't like coal.

The critics' present weapon of choice is the economists' concept of externalities--the unaccounted-for costs. By the artful manufacture and manipulation of new externalities it is possible to raise the price of coal--or any energy--beyond what is competitive. A high carbon tax would be one way of prohibiting the use of coal without saying the use of coal is hereby prohibited.

So nothing is guaranteed by the National Energy Security Act. When all the talking is done and all the laws passed, the role of coal in national energy policy will be no more and no less than those involved in and with the coal industry are willing to make it.

On our part, increased competitiveness will be necessary. Necessary to meet the competition from other fuels. Necessary to meet the international competition. And most necessary to offset any new "environmental externalities" that might attach, major or minor.

We must establish right away four goals of our own:

First, for the most efficient, well-trained labor force we have ever developed;

Next, for the best-ever equipment and production base and practices;

Then, for the most efficient handling and transportation operations ever;

And fourth--but most important--to make the coal industry the safest and healthiest place to work that it can possibly be.

Twenty-two years is time enough to distinguish trends from current events, capabilities from flukes. Since 1969 coal production has increased 80 percent--from 560.5-million tons to more than 1-billion tons. The share of domestic electric power generated with coal rose to 57 percent from about 45 percent. Increased electric-utility coal use since 1973 is the equivalent at least 3.2-million barrels of oil a day that don't have to be imported.

Through these years coal won and held market share because productivity gains of 100 percent in the last 12 years made and kept it the low cost fuel. A ton of coal today costs $16.73 as compared to the 1970s peak of $32.43 in real terms of 1982 dollars. Coal picked up the slack when other forms of power generation faltered and fell away. It fueled the economic growth of the 1980s.

These things are no small accomplishment, and they are due to the efforts of those here and their counterparts elsewhere. This growth was won--not granted--by miners and managers despite many who were eager to write them off on almost any excuse.

In the same time, a revolution was being worked in coal-mine safety and health. In the year this institute first met there were 203 coal-mining fatalities, and in all the years since 1930 there had never been fewer. Last year there were 66. In 1969 the fatality incidence rate was .17 per 200,000 hours. Last year it was .04.

Production is up 80 percent, fatalities down 67.5 percent and the incidence rate down 76.5 percent.

I am confident we in the industry can achieve the four goals necessary to make coal a force in national energy security. In safety and health our goal is--must be--the routine achievement of zero fatalities. It must be greater improvement in the days-lost injury category. And it must be to improve all health and safety practices. Either we'll become a team and look together to the common good, rather than temporary advantage, or we'll all be looking around separately for another industry to support us. This applies to management and labor, regulator and lawyer, professor and student.

Secretary Moore's declaration--"coal is here to stay!"--is not unconditional. It will not be written into the law.

It's time to begin thinking! Everything is hooked together. And coal is critical to America's health and safety. Let's not take ourselves out of the game. Our country needs us. America's recoverable coal reserves are the energy equivalent of 1-trillion barrels of imported oil, more than all the world's known oil reserves.

If we fail in meeting the tests of today, our sons and daughters and their sons and daughters unto the third and fourth generations will pay the largest externality of all--the imported-oil security fee. The first installment was called Desert Storm. It cost $68 billion and 148 American lives. It took 500,000 young American men and women into harm's way for the better part of a year. In Desert Storm the brunt of the military task fell to the Stealth fighters and to the less-glamorous but extraordinarily capable A-10 Warthog aircraft. The next installment on imported-oil security may well be higher.

But in the National Energy Strategy we have the specifications for a strong counter-measure. The Senate is expected to vote on the National Energy Security Act this fall, thus providing the blueprint. With the strategy and the blueprint in hand for our country's energy security, it will be up to the energy industries to build and man the energy security apparatus. And when that happens, the coal industry--as represented by the labor, the management, the regulators and the academics in this room--may well prove more valuable to a future president than all of our A-10 Warthogs or Stealth fighters. For only the deterrent of an adequate and flexible energy supply can make the need to use these other things less likely. In a way, coal is the Warthog of energy: we are a gritty, tough, efficient and very productive industry.

Let's all pledge our mutual efforts to make coal a strong cornerstone of America's energy security. May God grant success to all your efforts.

TECHNICAL SESSION I: HEALTH ISSUES

Chairmen:

P. L. McWhorter
General Sales Manager
Phillips Machine Service, Inc.
Beckley, West Virginia

John Baugues
President
Mountain, Inc.
Knoxville, Tennessee

Air Quality In Coal Mines

Robert A. Thaxton

U.S. Department of Labor
Mine Safety and Health Administration
Arlington, Virginia

"Air quality" . . . what is air quality? According to today's thinking in the U.S., it is the security of safe air in which to breathe and work. Air quality in coal mines means a healthy and safe atmosphere for miners to breathe both on the surface and in the underground workings.

In many people's eyes, "air quality" concerns of the Mine Safety and Health Administration (MSHA) are limited to respirable coal mine dust levels. In this area, MSHA Coal Mine Safety and Health has extensive regulations and experience in both enforcement and control methodologies. Indeed, when the Federal Mine Health and Safety Act was passed into law, respirable dust levels were seen as the most severe health problem affecting coal miners.

The Congress of the United States established its intent to protect the health of the mining industry's most precious resource - the miner - with the passage of the 1969 Federal Coal Mine Health and Safety Act and the subsequent amendments in 1977. The 1977 Act states under Section 101(a)(6)(A): "The Secretary (of Labor), in promulgating mandatory standards dealing with toxic materials or harmful physical agents under this subsection, shall set standards which most adequately assure on the basis of the best available evidence that no miner will suffer material impairment of health or functional capacity even if such miner has regular exposure to the hazards dealt with by such standard for the period of his working life. Development of mandatory standards under this subsection shall be based upon research, demonstrations, experiments, and such other information as may be appropriate. In addition to the attainment of the highest degree of health and safety protection for the miner, other considerations shall be the latest available scientific data in the field, the feasibility of the standards and experience gained under this and other health and safety laws. Whenever practicable, the mandatory health and safety standard promulgated shall be expressed in terms of objective criteria and of the performance desired."

MSHA, and its predecessor agency the Mining Enforcement and Safety Administration (MESA), have instituted regulations in relation to chemical substances since 1971 to endeavor to provide controls on the quality of the air in which coal miners are required to work. The initial regulations under MESA provided regulatory controls of airborne contaminants at surface mines, surface areas of underground mines and surface facilities. Areas of underground mines were provided protection for gaseous contaminants only.

The underground regulations implemented in 1971 remain in effect today. This regulation states: "Concentrations of noxious or poisonous gases, other than carbon dioxide, shall not exceed the current threshold limit values (TLV) as specified and applied by the American Conference of Governmental Industrial Hygienists. Detectors or laboratory analysis of mine air samples shall be used to determine the concentrations of harmful, noxious or poisonous gases."

The regulations applicable to the surface areas of coal mines were implemented in 1972. These same regulations remain in effect today. The surface regulations provide a more comprehensive approach toward air quality than the regulations under 75.301-2. Provisions under 30 CFR Part 71.700 provide for sampling by the operator, institution of control measures, a specific standard for exposure to asbestos fibers and standards for approximately 450 airborne contaminants. These standards were those listed in the 1972 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV) Handbook.

Over the past 20 years, MSHA or MESA have taken several steps toward enforcement of the current air quality standards. In 1983, MSHA, Coal Mine Safety and Health, began training selected inspectors in the area of industrial hygiene. The intent was to have inspection personnel located in all 10 coal districts who were familiar with basic industrial hygiene practices so inspections could be conducted at selected mine sites. This program of training was conducted in conjunction with Coal Mine Safety and Health's industrial hygiene enforcement program.

The industrial hygiene enforcement program provided for Coal Mine Safety and Health inspections of 5 percent of the active mines annually. These inspections consisted of walkthrough inspections for chemical and physical agent problems, review of accident/injury reports relating to chemical exposure, sampling of chemical exposure, inventory of chemical solutions, review of protective devices being utilized to control exposures, and review of education and training being provided by coal operators. This program worked well the first year or so and then, with reduced manpower available to the agency, the emphasis was dropped in most districts.

The Coal Mine Safety and Health industrial hygiene program provided data on the existence of chemicals on coal mine sites. The inventory listing obtained during industrial hygiene inspection activities shows that 692 chemical substances, as listed in the 1989-1990 ACGIH TLV Handbook, have been found in some form on coal mine property. MSHA coal mine inspectors have conducted sampling on approximately 50 of these substances to determine exposure concentrations (Table I). These inspections, as well as review of data submitted by coal mine operators, indicate that approximately 100 injuries have been reported relating to chemical exposures over the past 5 years. All of this data has been obtained while MSHA has operated at the 5 percent of active mines level of the Industrial Hygiene Program.

Controls utilized by mine operators were reviewed for adequacy in assuring compliance with the established standards. The majority of sites do not utilize formal engineering controls such as process enclosure, exhaust ventilation systems, chemical scrubbers, etc. There are essentially no established respiratory protection programs in use to limit exposures to airborne chemical substances. The predominant means of maintaining compliance in coal mines, is accomplished by limiting employee exposure time.

As most of you are aware, MSHA has proposed new air quality regulations for the mining community, that is both coal and metal/nonmetal mines. The proposed rule was published in the Federal Register as applicable to coal mines in 1989. These proposed regulations are comprehensive in their coverage, mirroring protections afforded general industry workers by MSHA's sister organization in the Department of Labor, the Occupational Safety and Health Administration (OSHA). These proposed regulations would provide protections in such areas as:

* Permissible Exposure Limits (PELs)
* Means of Control
* Exposure Monitoring
* Carcinogens
* Medical Surveillance
* Respiratory Protection
* Nonmandatory Asbestos Control Procedures
* Nonmandatory Medical Evaluation Procedures
* Nonmandatory Fit Testing Protocols

While these proposed regulations are still undergoing review and modification, they have

TABLE I

COMPOUNDS SURVEYED BY MSHA INSPECTORS

Acetic Acid
Acrylamide
Ammonia
Benezene
Benzo (a) Pyrene
Bromine
Butanol
Carbon Tetrachloride
Carbon Monoxide
Carbon Dioxide
Chlorobromomethane
Chloroform
Chrysene
Coal Tar Pitch Volatiles (Naptha)
Cynaides
Decane
Dichloroethane
Dicyclopentadiene
Dioxane
Epichlorohydrin
Ethylene Glycol
Ethyl Ether
Formaldehyde
Furfural
Gasoline
HDI (Hexamethylene Diisocyanate)
Hydrogen Chloride
MDI (Methylene Bisphenyl Isocyanate)
MEK (Methyl Ethyl Ketone)
Methanol
Methyl Mercaptan
Methylene Bromide
MIBC (Methylisobutyl Carbinol)
MIBK (Methyl Isobutyl Ketone)
Nitrobenzene
Nitrogen Dioxide
Nitrosodimethylamine
Nonane
Octane
PAH (Polynuclear Aromatic Hydrocarbons)
PCB's
Perchloroethylene
Phenol
Phosgene
Pyridine
Stoddard Solvent
Sulfur Dioxise
Toluene
VM & P Naphtha
Xylene
Xylidene

brought to light the need to prepare for dealing with air quality concerns in coal mines. How is this need for information in relation to industrial hygiene practices to be met? Some companies may obtain industrial hygienists of their own, others will share the expertise available through a parent corporation structure, and still others may need educational help from MSHA to educate capable personnel already on staff in industrial hygiene practices. MSHA will need to be prepared for the requests of industry to provide training programs to prepare personnel for the basic requirements of any air quality rule.

The future adoption of improved air quality protection in coal mining will be a major undertaking from both MSHA's and industry's point of view. There will be a great need for cooperation, communication, and education. The aspect of providing a healthy work environment for coal miners could be one of the most important activities for the coal industry and MSHA since the passage of the Federal Mine Safety and Health Act.

MSHA AIR QUALITY PROPOSAL
AN INDUSTRY VIEWPOINT

B. R. Roy, CEO

B. Roy & Associates
Trumbull, CT

INTRODUCTION

Your Advisory and Planning Committee in its wisdom gave me a very broad assignment. The assigned topic in a generic sense was to talk about the Mine Safety & Health Administration (MSHA) Air Quality proposal and offer an industry perspective on its complexity and potential impact. Specifically, I believe that I was given the latitude to address any issues outlined on the 92 page Federal Register of August 1989 and/or the product of the six rule making hearings.

Needless to say, this could have been an "impossible task." But in my new role as the CEO of a consulting firm specializing in Occupational Health, nothing is impossible--difficult maybe, but not impossible. Thus for today's assignment I've chosen to focus my comments in three generic areas, namely:

(1) General observations about the rule making process

(2) Some of the more controversial proposals and

(3) The potential impact of this rule making on the industry.

I've also allowed several minutes for questions to clarify my views on these issues and/or others that may trouble you.

OBSERVATIONS

My thoughts on the Air Quality proposal and the rule making process can be summed up simply by stating that the proposal was extremely complex and that MSHA has been fair and acted very professionally during the entire hearing process. Having said that, I'd like to share a few observations which I believe reflect the views of my industry colleagues.

First, this proposal of a health standard for miners has been ongoing for several years. It started out as an Advance Notice of Proposed Rule Making, I believe in 1982. This was followed by a lengthy period for analysis of comments and the drafting of the August 29, 1989 proposal. During all of this time and continuing to this date, there were and are standards in place that can protect miners from material impairment of health.

Second, this proposal has been found to be an extremely complex and detailed rule making attempt to include new concepts, i.e. carcinogens and practically all aspects of an occupational health program. At first glance we should compliment MSHA for attempting to update the state of the art in miner health protection and for allowing us the flexibility through three segments of rule making to make this happen. At second glance we, the respondents, found ourselves in a regulatory web which lacked the cohesiveness and thoroughness to accomplish these noble goals. Let me give you a few examples.

(1) Risk Management for carcinogens without benefit of a thorough risk assessment for each carcinogen the agency proposed to regulate.

(2) An ongoing American National Standards Institute (ANSI 88.2) approval process for respiratory protection. Other agencies such as OSHA & NIOSH are concurrently working on this issue, particularly as it relates to protection factors.

(3) Overlapping rule making on air quality & diesel gaseous emissions; where does one focus one's interest and energies, etc.?

Please don't get me wrong. Having attended and testified at all six hearings of this rule making, plus a few on diesels, I can assure you that the MSHA panel conducted itself in a very professional manner. They have been forthright in their questions to us and all those that testified. They have also given us the flexibility to respond to their inquiries and have corrected some of the procedural problems we have identified. Maybe the task at hand was too big for all of us.

SPECIFIC ISSUES

The specific issues I chose to address today are:

(1) Permissible Exposure Limits
(2) Carcinogens
(3) Exposure Monitoring
(4) Medical Surveillance and
(5) Respiratory Protection.

Permissible Exposure Limits

The proposal lists some 600 changes in the current MSHA Permissible Exposure Limits (PEL's), which they define in terms of eight hour Time Weighted Average Exposure (TWA), Short Term Exposure Limits (STEL's), Ceiling Limits (C's), and Mixed Exposure Limits (MEL's). The basis for these changes includes recommendations of the American Conference of Governmental Industrial Hygienists (ACGIH), the current OSHA PEL's, as well as the Recommended Exposure Limits (REL's) of NIOSH.

The mining industry, through their PEL air quality task groups, had identified some 25 of these changes which could have significant impacts on mining. The most troubling to us was nitrogen dioxide (NO_2) which is generated by blasting operations and/or the use of diesels. The applications of the MEL concept was also a point of contention. Permit me to reiterate our concerns on this matter.

MSHA's proposed air quality standards would regulate miners' exposures to certain combinations of chemical substances through the employment of a mixed exposure limit (MEL). By adding the ratio of Exposure/PEL of one substance to the ratios of other substances affecting the same target organ, the worker's exposure would be controlled below aggregate unity.

This concept has generally been utilized by professional industrial hygienists who truly understood the concept to be another guideline or tool to be used in worker exposure evaluations. In that context we certainly have no qualms with the concept. The problem we have is with the potential indiscriminate use of the MEL formula. In our opinion, this concept should not be made part of the Air Quality regulations. Having said that, we would not be adverse to the use of MEL's as a guideline for a miner's exposures to two or more airborne substances that act upon the same target organ system to produce the same toxicological effect.

Two points need to be made about this specific issue.

(1) Application of the MEL formulae as proposed by MSHA assumes, with a lack of scientific evidence, that the combined effect of mixed chemical substances is always additive. We submit that application of the MEL under this premise is totally inappropriate. It should be noted that even in the same organ system, different chemical substances assault that system with great physiological and site differences, thereby producing vastly different physiological responses.

(2) The measurement of exposure levels to determine compliance with the proposed MEL concept may not be technically feasible, given the potentially low ambient levels for individual substances that may exist in a mixture environment. Taken together with sampling variability at these low levels, it may be impossible to statistically demonstrate compliance.

Carcinogens

MSHA proposed four different classes of carcinogens and listed several chemicals in each. Very few of these are expected to be found in the mining environment. Those listed are apt to be found in the processing laboratories, and hence should be easier to control. Nonetheless, another process of classification has been proposed which could affect future perceived or real occupational carcinogens such as crystalline silica, diesel particulates, etc. The requirements to handle these carcinogens include restricted areas, engineering controls, use of personal protective equipment, decontamination procedures, monitoring, training, approved plans, etc. This in essence is a risk management program without the benefit of risk assessment.

Exposure Monitoring

As most of you already know, the 1969 Coal Mine Health and Safety Act and the 1977 Mine Safety & Health Act require operators of underground coal mines to sample every section of their mines on a bimonthly basis. Five consecutive samples of each designated occupation or mechanized unit as well as general area samples--as specified by MSHA--must be taken by certified technicians and submitted to MSHA for analysis. In metal and nonmetal, MSHA to date has basically left it to the discretion of the mine operators when to sample. The key is when the operator has "reason to believe." This proposal would require sampling anytime the PEL's are being exceeded, when respirators are being used and whenever a change occurs in the process or controls. The specific number of samples and frequency of sampling has not been specified except to say that they must meet the 95% confidence level, which, translated into statistical jargon, could require upwards of 20 samples per occupation.

Medical Surveillance

The proposal calls for initial medical exams and periodic follow-ups to employees exposed to carcinogens, exposures above any PEL, and whenever respirator protection is required. In addition to a written program, the provisions are somewhat onerous in that the exam must be given by a licensed physician, on at least a yearly basis, and reports must be given to the employees. These reports are to serve as a basis for the transfer of employees to lower exposure areas.

Respiratory Protection

The proposal on respiratory protection addresses several issues. First, in the medical areas one must determine who has the functional capacity to wear a respirator and what type of respirator. Second, the selection of the respirator is based on the basic PEL. In other words, if the PEL is reduced the respiratory protection becomes more stringent and third, respirators may play a key role in the hierarchy of controls. This of course is in addition to fit testing, cleaning and maintenance of respirators, record keeping, notification of employees, etc. The final standard on this issue will most probably be a cross between requirements spelled out in the ANSI consensus standard, the NIOSH guidelines, and existing OSHA requirements.

IMPACT ON INDUSTRY

The impact of this Air Quality proposal on industry falls basically into two general categories, namely: 1) the actual standard requirements and costs and 2) the additional responsibilities this proposal would impose on our supervisors.

The first of these had been debated quite extensively during the rule making process and focuses on feasibility, which I do not plan to address at this time. The second, namely the impact on supervision, seems to me to be where the action is going to be.

With all the demands and requirements I've mentioned, the poor line supervisor will undoubtedly be the person responsible for compliance. Industry's biggest problem may well be to maintain a supervisory staff! Why? Simply because these standards will require more of what could be referred to as "unproductive time."

First, the supervisor will have to take some additional time to develop better rapport with the management team. Obviously, any citations for health standard violations which occurred in his/her department will require some explanation to his/her superior. The supervisor will also have to spend some more time developing a better rapport with the safety director and the industrial hygienist, because these are the two professionals who will be able to advise him/her as to the validity of the citations, the interpretation of the standard, the initiation of control measures, etc.

The supervisor will also have to develop a better working relationship with the engineers, the chemists, the medical personnel, etc. For example, the engineer who has been assigned the responsibility of designing control measures for an operation may want to design practical ones--this will be the supervisor's opportunity for input. Likewise, the chemist will have to be advised of the various chemicals or materials that are used in the department, because analysis of the air samples will be quite dependent on the presence of other contaminants, which may interfere with the analytical methods. Since there will be a need for replacements during the time that workers are sent out for medical examinations or transferred to areas of lower exposures, the supervisor may have to assist personnel on scheduling.

A second significant impact on supervisors will be in the area of **training and education**. Needless to say, the supervisor will have to become very familiar with and understand the various requirements of the standards. Thus, supervisors will need additional time for self-training, in order to in turn train their workers. Believe it or not, the supervisor will also have to educate his/her superiors, particularly in those little subtle things that are happening in his/her department. For example, the supervisor may have brought in a can of a new type of solvent to clean the machine, or whatever the case may be. His/her superior should be so apprised. Finally, the bulk of the responsibility for training the worker may rest on the supervisor's shoulders. Although the operator may have a formal training section which will give the initial part of the training to the worker, the on-the-job safety training and training in health matters will always be the ultimate responsibility of the supervisor.

A third impact will be the administrative requirements. Consider, for example, a maintenance problem that may take two workers eight hours to correct. In addition to the problem of locating workers who are qualified for the assignment, there may be detailed requirements in the standards for monitoring of the air in the breathing zone of these workers. It will be the supervisor's responsibility to assist the investigators, and to get the cooperation of the worker in wearing the necessary sampling equipment. In terms of the medical monitoring, it will be necessary to allow time for the surveillance tests.

CONCLUSION

This proposal in my opinion addresses most aspects of an occupational health program, namely Permissible Exposure Limits (PEL's), environmental monitoring, medical surveillance, respiratory protection, hierarchy of controls, and a number of controversial issues such as a new carcinogens policy, a mixed exposure limit formula, etc. It was a gigantic effort on the part of the agency to update the state of the art in miner health conservation. It required that the regulated community make a gargantuan effort to analyze and to present its case to the agency. Let us hope that the final product will accomplish our common goal of human resource conservation.

RESEARCH NEEDS FOR CONTROLLING HAZARDOUS SUBSTANCES AND TOXIC MATERIALS IN THE MINING INDUSTRY

Robert A. Jankowski, Steven J. Page and J. Drew Potts

U.S. Bureau of Mines, Pittsburgh Research Center, Pittsburgh, PA 15236

There has been a long and steady evolution of awareness regarding hazardous substances in our society. In the 1950's, attention was given to air pollution and the potential respiratory issues resulting from airborne contaminants. In the 1960's, attention was focused on water quality with the concern arising from unrestricted dumping of chemical substances into water resources. In the 1970's and 1980's, the interest became more focused. The issues of soil pollution, particularly from landfills, became prominent so that today there is scarcely an individual who has not heard the names PCB's and dioxin.

Along with this increasing concern of toxic substances and the environment, there has evolved the concern of contamination in the workplace. The U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) was created in response to these concerns. The jurisdiction of OSHA essentially covers all nonmining-related occupations. The mining-related occupations are regulated by the U.S. Department of Labor, Mine Safety and Health Administration (MSHA). The American Conference of Governmental Industrial Hygienists (ACGIH) Handbook of Threshold Limit Values and Biological Exposure Indices is currently the recognized document used by MSHA for enforcement of personal exposure to harmful chemical agents.

Many physical and chemical substances are introduced into the mine environment to facilitate ore winning and processing. These substances are in addition to the dusts and gases generated from the extraction of ore that can also be hazardous if exposures are not controlled. Exposure to these substances can occur through inhalation, ingestion, and absorption. MSHA reports that complaints and inquiries concerning exposure to toxic substances have been increasing in recent years (1). It is speculated that this trend has resulted from an increase in chemical usage in the mining industry, and a greater public awareness of the health hazards associated with exposure to toxic materials.

While the awareness of airborne contaminants continues to increase, there is also proposed Federal rulemaking regarding exposure standards and right-to-know legislation. Of the over 600 toxic materials identified by the ACGIH, little is known about the actual exposure levels of many of these substances in the mining environment. Only a few mining related Health Hazard Evaluations (HHE) have been performed by the National Institute of Occupational Safety and Health (NIOSH). The limited information obtained from these indicates several potential health risks in the mining environment. These HHE's include:

- o Potential Health Effects of Exposure to Coal Antifreeze Agents.
- o Worker Exposure to Organic Hydrocarbon Cleaners.
- o Adverse Health Effects Caused by Employee Exposure to Welding Fumes and Solvents.

A more detailed study of the sources of toxic materials and possible exposure levels in the mining industry is needed to identify what potential problems may exist. Control of the exposure to these substances remains the strategy for worker protection.

MSHA has recently published proposed changes to 30 CFR, Parts 56, 57, 58, 70, 71, 72, 75, and 90. These rule changes will establish new Air Quality, Chemical Substance, and Respiratory Protection Standards for the U.S. Mining Industry. These changes contain standards for over 140 substances that would be regulated for the first time in the mine environment.

The potential for exposure to these substances is unknown in many cases. The substances either exist in the mining and mineral processing environments or are introduced into these environments to aid in ore extraction or processing. They may be brought into the mine environment via supplies and materials, and into the ore processing environment as chemical reagents for use in flotation and other ore beneficiation processes. Many of the chemical reagents may have teratogenic and mutagenic effects which could persist for generations. Toxic substances such as amines, cyanides, and carbonyls are used to control mineral flotation processes. Smelting operations can generate toxic metal fumes including lead, mercury, beryllium, chromium, cadmium, and manganese. Toxic organic liquids such as gasoline, benzene, perchlorethylene, carbon tetrachloride, bromoform, acetylene tetrabromide, and pentachlorethane are used extensively for laboratory float-sink testing of mineral processing techniques. Toxic substances encountered in the underground mine environment include some ore dusts and gases, oil mists, epoxy resins, chemicals used to treat cribbing wood, surfactants, solvents, metal fumes, and blasting and diesel fumes.

A sample listing of possible toxic substances released into the mine environment includes:

- o Water sprays with surfactants for dust control.
- o Substances resulting from outgassing of cribbing treatment for fire retardation or prevention of decay.
- o Hydrocarbons in the diesel exhaust gases.
- o Welding fumes.
- o Blasting fumes, primary or residual, from conventional mining methods.
- o Sulphur compounds present in coal deposits.
- o Products of combustion from fire-fighting foams and roof bolt resins stored in the underground environment.
- o Hydraulic fluids and oils.
- o Solvents used in shop areas.

As a rule, mineral processing operations are not as confining as the underground mine environment and are more accessible, but do involve workers in closed areas. There are approximately 32,780 direct workers at 155 noncoal processing plants, refineries, and smelters operating in the United States. Many of these fall under the jurisdiction of MSHA by virtue of the fact that the operation resides on mine property or is owned by the mining company. The processing of these noncoal minerals usually involves a large number of chemicals, and in some cases, the mined material is hazardous.

With the changing economics of the mining industry, a continuing effort is being made to recover greater percentages of valuable minerals from ores of lower assay. This has resulted in the tailings of many mining facilities, previously considered uneconomical, being re-examined and reprocessed for the further extraction of mineral value. The introduction of solvent extraction allowed a copper company to treat 9.9 million tons per year of flotation tailings to produce 88,000 tons of finished copper from what was previously regarded as waste. There are many other plants where minerals are recovered in secondary circuits (treating tailings) and the feed grades are much lower than would be economic on a mined basis. For example, typical ore grades for tungsten ores are in the range 0.5 - 1.5% WO_3, but the Climax Molybdenum plant treated 49,500 tons per day of tailings, containing less than 0.1% WO_3.

The consistency of an ore may vary significantly throughout the life of the mine. The mineral processing techniques must keep pace with these changes, thus, many mine facilities are equipped with material testing and mineral processing control laboratories that fall under the jurisdiction of MSHA. These laboratories often use substances that MSHA does not allow in other mine facilities.

An initial thrust under the Occupational Health program of the Bureau of Mines to determine the hazards of physical and chemical agents in the mining industry and to reduce potentially harmful exposures of workers to these agents would include the following objectives:

- o Identify potential exposure hazards of physical and chemical agents.
- o Rank exposure hazards based on degree of usage, toxicity, and expected worker dose.
- o Perform field evaluations to verify exposure levels of agents where suitable measurement and monitoring techniques exist.
- o Investigate design of measurement and monitoring techniques where no suitable technology exists.
- o Design and develop appropriate control technology.

The current emphasis of the Occupational Health program is in reducing worker exposure to the identified, long-term health hazards of exposure to respirable dust, diesel engine exhaust emissions, and noise levels. The control of respirable dust focuses on reducing the silica component of the dust by designing ventilation techniques to more effectively distribute ventilation air; investigating more effective dust suppression techniques; and developing more efficient coal extraction methods. Diesel exhaust emission research concentrates on the control of the most hazardous product of combustion--the particulate or soot--as well as on particulate sampling and monitoring techniques. The noise control program concentrates on the application of active noise cancellation techniques to reduce noise levels from fans, and the noise attenuation provided by hearing protectors in the mine environment.

As the current health research projects are successfully completed and research thrusts in the health and safety program change, the increasing concerns of airborne toxic substances will be more actively pursued.

REFERENCES

1. Robert A. Thaxton, Supervisory Industrial Hygienist, U.S. Department of Labor, Coal Mine Safety and Health, Arlington, Virginia, Enhanced Industrial Hygiene Program, International Conference on the Health of Miners, Cincinnati, Ohio, 1986, Vol. 14, pp. 367.

WHAT IS THE STANDARD FOR AIR QUALITY STANDARDS?

James L. Weeks, ScD, CIH

Consultant
United Mine Workers of America

INTRODUCTION

Throughout the process of rule-making on air quality standards during the past two years, a number of underlying philosophical and legal issues have been raised. I would like to highlight some of these and to discuss them in one place. Put as questions, the issues are (1) what is the mission of MSHA, (2) should air quality standards be "technology forcing," and (3) how does MSHA achieve its mission in a way that is "feasible." But first, some historical introduction is appropriate.

BACKGROUND

The MSHA rule-making for air quality standards is similar to the OSHA rule-making for permissible exposure limits (PEL) and, to some extent, derived from it. Therefore, it would be useful to review the history of OSHA's rule-making.

When the OSHAct was passed in 1970, the agency adopted the 1969 TLV list as temporary exposure limits. This was done largely for expediency's sake. The OSHAct authorized OSHA to set standards. However, substance-by-substance rule making following the statutory procedure resulted in a long, drawn-out and litigious process, that was painfully slow and expensive. Consequently, OSHA changed from adopting whole standards substance-by-substance (including exposure limits, labelling, medical monitoring, exposure monitoring, and other requirements) to adopting generic standards on a topic-by-topic basis: exposure limits, medical monitoring, exposure monitoring, and process control. The OSHA PEL project is the first phase of this generic standards-setting procedure.

The chemicals covered by OSHA's PEL project are the same chemicals found on the TLV list. Thus, the OSHA procedure for setting PEL's is similar to the procedure adopted in 1970 when the 1969 TLV list was adopted. In the current rule-making, OSHA allegedly has met its statutory responsibilities of evaluating the "best available evidence" for its exposure limits. This issue and others are currently before the courts. OSHA has gone from one extreme (adopting the TLV list in 1970 with no changes) to another (substance-by-substance) during the 70s and 80s, and back to a modified version of the first (making a few changes and then adopting the TLVs).

The MSHA process is similar to OSHA's. The agency has proposed exposure limits for chemicals found on the TLV list, conducted a cursory evaluation and changed a few, then proposed its PELs which are essentially the same as those adopted by OSHA with a few exceptions. The procedure that MSHA has used looks more like OSHA's procedure in 1970, i.e., simply adopting the TLV list. This was not sufficient under OSHA's jurisdiction in 1970 and it is not sufficient for miners in 1991.

MSHA's rule-making is also a departure from the way in which the limit to respirable dust was established with the 1969 Federal Coal Mine Health and Safety Act. At that time, the PEL was set by Congress as part of the legislative process and not by rule-making. Aside from Congressional action, there has been no rule-making on the most important MSHA standard, the exposure limit for respirable dust. For exposure limits to all other chemicals, MSHA, like OSHA, adopted the TLV list as an interim measure.

I have implied that the TLV's are inadequate. They are, but why? The TLV's are not intended as legally enforceable standards. They are not intended to protect all workers. The TLV Committee admits that ". . . a small percentage of workers may experience discomfort from some substances at concentrations at or below the TLV."[1] The TLVs have recently been the subject of criticism in the scientific literature. Castleman and Zeim,[2] for instance, document the influence of employers over adopting TLVs. Their conclusion is that the TLVs are not standards intended to protect workers but rather are exposure limits that employers can achieve.

Another criticism is that the TLV list was not the only list either OSHA or MSHA could have used to formulate its exposure limits. Either agency could have used NIOSH, the agency officially designated both in the OSHAct and the Mine Act to recommend standards.[3]

None of this criticism detracts from the pioneering task that the ACGIH undertook in 1946 when it formed the TLV Committee. At the time, there were no standards, no federal regulation, and weak enforcement by state governments. However, the environment now is considerably different and so should be the function of the ACGIH and its TLV Committee.

MSHA'S MISSION

MSHA has a public health mission. Some would say that MSHA's mission is to enforce the Mine Act, which is true, but incomplete and short-sighted. MSHA's functions also include setting standards and conducting injury surveillance. The overall public health mission of MSHA and of other agencies is to prevent occupational diseases and injuries; enforcement is simply one important means among others for reaching this goal. Others are entrusted to other agencies. Thus health surveillance and research on exposure limits is the responsibility of NIOSH, safety and health engineering, the responsibility of the Bureau of Mines.

The standards-setting function for health standards has been neglected. In part, this is a recognition that mining is the most dangerous industrial environment in which to work; it regularly has the highest fatality rates of any industry in the U.S. and, therefore, causes of fatalities have received significant attention. The neglect of health standards-setting is also a response to the leading role Congress has taken in setting the exposure limit for respirable dust. As a consequence, the agency has limited experience (ant thus limited expertise) in setting health standards. The result has been to simply follow in the footsteps taken by others, such as OSHA and the ACGIH.

The problem with this approach is that it does not conform to the legislative mandate. This mandate is very specific. The Act requires the Secretary (of Labor) to

> . . . set standards which most adequately assure on the basis of the best available evidence that no miner will suffer material impairment of health or functional capacity even if such miner has a regular exposure to the hazards dealt with by such standard for the period of his working life. . . In addition to the attainment of the highest degree of health and safety protection for the miner, other considerations shall be the latest available scientific data in the field, the feasibility of the standard, and experience gained under this and other health and safety laws.
>
> Sec. 101 (a)(6)(a)

The legislative history of the Mine Act expands:

> The [Senate] Committee [on Human Resources] believes that the overriding consideration in setting health standards dealing with toxic substances and harmful physical agents must be the protection of the health of miners. . . While feasibility of the standard may be taken into consideration with respect to engineering controls, this factor should have a substantially less significant role. Thus the Secretary may appropriately consider the state of the engineering art in industry at the time the standard is promulgated. However, as the circuit courts of appeals have recognized, occupational safety and health statutes should be viewed as "technology forcing" legislation, and a proposed health standard should not be rejected as infeasible when the necessary technology looms on today's horizon."[4]

Then later,

> [T]he Committee wishes to emphasize that it rejects the view that cost benefit ratios alone may be the basis for depriving miners of the health protection which the law was intended to insure.[4]

Thus in setting standards for exposure limits to toxic chemicals, the agency must be guided by the following:

(1) The PEL must assure that <u>no</u> miner suffer imperial impairment of health or functional capacity even if exposed for his or her entire working life

(2) The PEL must be based on the latest and the best available scientific data

(3) Feasibility

considerations should be given secondary importance.

(4) The PEL should be technology forcing rather than accommodating the status quo.

Based on these four tests, the TLV's recommended by the ACGIH should not be the starting place for standards development. In its opening pages, the ACGIH frankly states that its TLVs allow some workers to experience effects at concentrations at or below the TLV. The TLVs are clearly the concentration that employers could accomplish rather than concentrations intended to prevent disease and injury.

The TLVs are not based on the best and latest scientific data. In its documentation of the TLVs, in many cases, the number of references is typically short and out of date. This is not surprising given the limited resources ACGIH has to complete its mission.

As Robinson et al. point out, the TLV list is not the only list from which either agency could have started. In its twenty year history, NIOSH has recommended standards for over 600 hazards found on the workplace. Their documentation, without exception, is more comprehensive and more up to date than any of the ACGIH's documentation. Moreover, NIOSH has been given the official mandate to recommend exposure limits. It is indeed odd that NIOSH's recommendations are nearly invisible in MSHA's rule-making.

Feasibility in the Mine Act is treated differently than it is under the OSHAct. Under the OSHAct, "feasibility" appears much earlier than under the Mine Act and is given a more prominent role. Under the Mine Act, "feasibility" is clearly relegated to a secondary function, subservient to the need to protect miners' health.

Finally, and consistent with its views on feasibility, the PELs are technology forcing. As standards become set, employers must find a way to comply, even if the technology does not yet exist. This requirement runs against the grain of accommodating what employers can do; it tells them what they have to do.

TECHNOLOGY FORCING

I have used this phrase, "technology forcing," a couple of times, but more importantly, the Senate Committee used it. What does it mean? It means simply that a legal requirement may be created even if there is no technology readily available with which to achieve it. The law forces the development of new technology.

A good example is the historical development of the respirable dust standard. When the 2.0 mg/m^3 standard was first imposed, many said it could not be done. However, creation of that limit forced the development of control technologies that are effective. Today, if aggregate data can be believed, the vast majority of mining sections are operating at or below the statutory limit.

This approach to health and safety standards and technological innovation stands in stark contrast to the view that regulation inhibits innovation, that it locks mine operators into certain methods. Far from inhibiting innovation, technology forcing requires it.

FEASIBILITY

Similarly, feasibility is to be considered, as is proper, but it is important to note <u>when</u> during the standards setting process it should be considered, especially when compared to OSHA's standards setting process. Under the OSHAct, consideration of feasibility occurs in the first sentence of the enacting section. Under the Mine Act, it occurs in the last. Otherwise, the two sections are nearly identical.

These differences are not accidental. The sentence containing "feasibility" was the last sentence in the standards setting portion of the Mine Act in 1969. When the Act was amended in 1977, the first section was taken verbatim from the OSHAct of 1970, excluding the word "feasibility;" the last sentence was left intact. Furthermore, the legislative history of the Act quoted above clearly states that feasibility is to be given a secondary role.

Thus the agency's first concern should be protection of miners' health. Only after that goal has been achieved is the question of feasibility to be raised.

CONCLUSION

The standard for air quality standards is to be found in the Mine Act itself. It requires the Agency to place its first priority on the miner himself and only then to consider the question of feasibility, to base standards on the latest and best scientific data, and to force the development of new technology. These requirements are not intended simply to accommodate existing practices and uncritically to adopt existing conventions for standards.

REFERENCES

[1]Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, 1991-1992. Cincinnati, OH. American Conference of Governmental Industrial Hygienists.

[2]Castleman, B. and G. Ziem. Corporate Influence on Threshold Limit Values. American Journal of Industrial Medicine, 13:531-59, 1988.

[3]Robinson, J.C., D.G. Paxman and S.M. Rappaport. Implications of OSHA's Reliance on TLVs in Developing the Air Contaminants Standard. American Journal of Industrial Medicine, 19:3-13, 1991.

[4]U.S. Congress, Senate, Committee on Human Resources, Subcommittee on Labor, Legislative History of the Federal Mine Safety and Health Act of 1977. 95th Congress, 2nd Session, 1978.

TECHNICAL SESSION II: JOB SAFETY ANALYSIS
A panel discussion

Coordinator:

John DeMichiei
Special Assistant to the Assistant Secretary
for Mine Safety and Health Administration
U.S. Department of Labor
Arlington, Virginia

Panelists:

Harry Childress
Chief
Division of Mines
Virginia Department of Mines, Minerals & Energy
Big Stone Gap, Virginia

Carl Ankrom
Acting Commissioner
Kentucky Department of Mines and Minerals
Lexington, Kentucky

T. J. Ward, Jr.
Director, Bureau of Deep Mine Safety
Pennsylvania Department of Environmental Resources
Harrisburg, Pennsylvania

JSA IN VIRGINIA

Harry D. Childress

Chief, Division of Mines

Department of Mines, Minerals and Energy

Good afternoon. I would like to thank the Executive Committee and the Advisory and Planning Committee for the opportunity to participate in the 22nd Annual Institute on Coal Mining Health, Safety and Research. I first would like to provide you with some background information on the Department of Mines, Minerals and Energy and the Division of Mines.

GENERAL INFORMATION ABOUT DMME

The Department of Mines, Minerals and Energy was created January 1, 1985, to consolidate the mining, energy, and mineral-related functions of four separate divisions of three separate state agencies into one agency. This action was recommended by a blue-ribbon advisory committee on mine safety. The purpose of the recommendation was to consolidate activities that would affect mining and mineral resource activities -- to prevent duplication and to increase efficiency in the processes of obtaining permits and addressing public concerns.

We have done various things directed towards these goals, including efforts to streamline the permitting process and to coordinate activities of the multiple divisions.

Soon after the creation of the Department, managerial staff from each of the divisions met to develop a coordinated strategic plan for the whole agency. A variety of changes were initiated, including:

a. institution of procedures to eliminate redundant and overlapping authorities among various programs;

b. sharing of information, particularly permitting data, among divisions; and

c. coordinated issuance of multiple permits for single operations.

The strategic plan was developed around a single unifying mission: To enhance the development and conservation of energy and mineral resources in a safe and environmentally sound manner in order to support a more productive economy in Virginia. This has been the stated mission of this Department ever since. The strategic plan that grew out of this mission was adopted agency-wide by management to ensure all divisions worked to achieve mutual goals, and to coordinate a variety of related activities such as coal mining and coalbed methane development.

In 1987, the regulatory divisions were reorganized to provide better service to the Department's clients and to strengthen management controls. The Division of Mineral Mining was created from units previously located in two different divisions. This enabled all services to noncoal mining industry to be provided by one unit, and it gave the coal mining divisions more time to concentrate on coal mining.

The Department is organized into an administrative division and six line divisions: Mines, Mined Land Reclamation, Mineral Mining, Mineral Resources, Energy, and Gas and Oil.

GENERAL INFORMATION ABOUT DM

The Division of Mines is responsible for administering and enforcing the Virginia Mine Safety Law of 1966, consisting of Chapters 1 through 14 of Title 45.1 of the Code of Virginia, as amended.

The primary mission of DM is to protect the lives and health of all people employed at the state's surface and underground coal mining operations, and to ensure that mine operators comply with Virginia coal mine health and safety requirements. The Division conducts regular inspections, investigates accidents and fatalities, conducts training classes, tests and certifies persons to perform certain tasks in coal mines, and provides technical assistance to mine operators.

In 1985, the Division became part of the newly created Department of Mines, Minerals and Energy. Programs and activities geared towards assisting the mining industry in providing a safe and healthy working environment were expanded significantly at that time. A mine safety training program was created specifically for small, underground coal mines. The Division also established a team of specialists to provide assistance and expertise to mine operators on technical matters related to mine ventilation, electrical, and roof control.

In 1987, the job of regulating health and safety in mineral mining operations was transferred to the newly created Division of Mineral Mining. This enabled each division to more efficiently administer their respective regulatory programs while better serving the training, certification, and technical assistance needs of the coal and MOTC industries.

Since 1985, the Division has been involved in a variety of new projects designed to focus on improving the mine safety record of the Commonwealth. The first thing we did was to modernize. When the Department was created, the Division of Mines had the most antiquated equipment of any division. Transportation was provided by an aging fleet of pickup trucks. Office equipment was largely composed of manual typewriters, and inspectors complained of inadequate and outdated equipment. Our vehicle fleet now consists of fully enclosed four-wheel drive vehicles equipped with two-way radios. The Division is now automated and tied into a computer network linking DMME offices across the state. Inspectors have been provided with new testing equipment and have available portable computers for use in inspections and operator assistance.

Today, the Division of Mines' 43 employees carry out a variety of programs. Through regular inspections of coal mines, the Division of Mines ensures that mine operators comply with the state's mine health and safety requirements. DM inspectors conduct one complete inspection of each underground mine at least every ninety days and of each surface mine every 180 days, as required by state law (the Mine Safety Board allows a reduced rate of inspection for a mine with exemplary safety records). Division inspectors also investigate complaints and serious and fatal accidents. They issue notices for violations found during their inspections, and recommend ways to correct and prevent unsafe conditions.

The Division also conducts training and tests and certifies people who perform certain tasks in mines. Two full-time instructors are in the process of updating and/or developing course outlines, lesson plans and study guides for all certifications.

Under the supervision of the mine-safety engineer, the Division's six technical specialists provide advice and assistance to coal mine operators in roof control, ventilation and electrical use. Their primary purpose is to help the operators solve problems that could lead to unsafe and unhealthy conditions in their mines. Their duties include review and approval of plans submitted by mine operators.

The technical specialists may close a mine in case of an imminent danger or an accident, but do not normally conduct enforcement inspections. Specialists conduct on-site mine safety talks, assist in the investigation of complaints and accidents, and conduct seminars on mine health and safety technologies.

The Division of Mines also operates a comprehensive and modern system of recordkeeping. This computerized system, operated by a well-trained staff, gathers and maintains data on surface and underground mining licenses, permits and plans, serious injuries and fatalities, training and certification, environmental testing, inspections and enforcement activities.

The Division has hired people with a variety of knowledge and experience in mine health and safety. However, we often turn to people outside the agency, people actually engaged in the business of coal mining, to provide a clearer picture of what is needed to ensure the health and safety of Virginia's miners. The Board of Examiners and the Virginia Mine Safety Board are key examples of this approach. The Mine Safety Board consists of nine members including three representatives each from the coal industry, labor, and the Commonwealth at large. The Board reviews and approves or denies applications for reduced inspections, serves as advisor to DMME on matters relating to the health and safety of persons working in Virginia's coal industry and is designated as the official regulatory work committee on all coal mine health and safety matters not under the jurisdiction of the Board of Examiners. The Board of Examiners consists of seven members, including the Chief of the Division of Mines; a surface coal mine operator; an underground coal mine operator; a mineral mine operator; a non-supervisory underground coal mine employee; a non-supervisory surface coal mine employee; and a non-supervisory mineral mine employee. This board issues certificates of competency to miners involved in certain jobs in underground and surface mining. The Board reviews and approves tests that are administered by the Division to determine whether miners are qualified for certification by the Board.

In a cooperative effort to further improve mine safety in Virginia, DM and MSHA have developed a special initiative focused at small mines. In March 1991, the Division of Mines and MSHA's District 5 signed a memorandum of understanding to implement the Joint Mine Assistance (JMA) Program at selected mines in Virginia. This program is also being implemented in West Virginia, Kentucky, and Pennsylvania.

The JMA program, developed cooperatively with each state, concentrates on underground coal mines with fewer than 50 employees. Such small mines have historically been shown to account for above-average fatality and lost-time injury rates. Mines selected for the JMA program were evaluated by the Division of Mines (DM) and MSHA based on compliance records, accident history, inspector input and other factors. State and federal mine safety personnel will audit injury records, survey training programs, and make "walk and talk" inspections at selected mines to review safe work procedures with the miners.

Mines identified by either the DM or

MSHA as possible problem mines are evaluated for inclusion in the program based on the following criteria:

Operator's compliance history over four quarters; operator's attitude toward compliance; mine's accident history (looking for trends); fine assessment history (DM examined violation history since Virginia mine safety law does not include provisions for fines); operator's training program; operator's attitude toward compliance with training regulations; operator's special investigation history (refers to MSHA special investigations).

Beginning in January 1991, DM inspectors were asked to recommend mines in their inspection areas they believed to be candidates for the JMA program. Inspectors evaluated each mine based on their experience with that mine and the operator's attitude toward mine safety. DM staff then evaluated the recommended mines by reviewing each mine's overall safety record including violation history. The DM then submitted to MSHA a list of approximately 20 mines it felt would benefit from the JMA program.

In April, five mines were selected for the JMA program. Among the five were mines not initially recommended by DM but included based on MSHA's own evaluation that they needed special attention. In May, the five mine operators were notified by a joint DM/MSHA letter that their mine had been selected for the JMA Program and set a meeting with MSHA and DM personnel. The meetings held at the Norton and Claypool Hill offices of MSHA, were attended by all five operators. At the meetings, each operator was briefed on the program and shown how his mine was selected for the program. In late June and early July, the on-site part of the program began at four of the mines. The on-site portion of the program involves additional inspection activity. Special efforts will be made to assist the operator in identifying how and why the violation occurred and how to prevent such violations in the future. DM personnel will be offering and/or recommending additional technical assistance while MSHA personnel will be providing training on Job Safety Analysis (JSA) and Repeat Violation Reduction Program. Both DM and MSHA will provide the operator with information, training materials, and assistance pertaining to training.

Job Safety Analysis (JSA) is a part of day to day operations for many mines and can benefit all operations, not only those selected for special attention. We believe that JSA can play an important role in the overall effort to reduce injuries and fatalities. JSA should not only improve job safety but also enhance the efficiency of the mining process. The cornerstone of JSA is an agreement between the worker and supervisor to identify all the components of the worker's job and then analyze each for potential hazards and practical solutions to those hazards. An advantage of JSA is that it is grounded in what the worker actually does rather than a job description written by someone with little or no experience of actual "on-the-job" conditions. This reality-based approach to job definition has advantages, such as fewer injuries, increased compliance and greater productivity. A third party such as the Virginia Division of Mines, can assist the process through training, encouragement, or providing materials. But to be successful, the real development and implementation must be accomplished by the worker and supervisor.

Virginia endorses and supports the use of JSA to improve mine safety and reduce accidents and fatalities. I am a member of the JSA Steering Committee and DMME has endorsed in writing, the committee's position statement.

On February 14, 1991, DM sponsored three sites for the JSA video teleconference. One hundred forty-two (142) persons attended the three hour satellite broadcast on JSA. Evaluations indicated that the session provided useful information and needed guidance. Some comments indicated that a video demonstrating the development of a JSA Program for an underground mining job would be very helpful for small operators. DMME's Division of Mineral Mining also sponsored two satellite downlink locations in Northern and Central Virginia. Fifty people from Virginia's non-fuel minerals industry attended these two programs. DM has provided JSA training to most of our field staff and encourages them to discuss JSA with operators and miners during inspections, site visits and investigations.

Both coalfield community colleges, MECC and SVCC, have cooperated in the JSA effort by serving as downlink sites for the satellite broadcasts. Their training personnel attended the tele-conference, and served as a resource for the small operators in the development and implementation of JSA.

To help mine operators successfully implement JSA, DM can generate data from its computerized Mine Safety System identifying jobs with the highest accident frequency on a mine, company or state-wide basis. This information is provided on request to both mine operators and workers and used by DM personnel in their on-site safety talks.

Everyone benefits from JSA, from top management to the general inside laborer. JSA provides a blueprint for training that can help effectively enable new people with a detailed, systematic approach to getting the job done right and safely - first time - every time.

In closing, we believe JSA is a very important element in the effort to reduce accidents and fatalities and improve compliance. DM encourages operators and workers to cooperate and implement JSA at every operation. DM stands ready to assist in that effort. Thank you.

JOB SAFETY ANALYSIS IN KENTUCKY

Carl Ankrom
Acting Commissioner

Kentucky Department of Mines and Minerals

The concept of Job Safety Analysis is not a new idea to the coal industry of Kentucky. Following Scotia Coal Company's Scotia Mine Disaster in March of 1976, which claimed twenty-six (26) lives, then Kentucky Governor Julian Carroll created, by Executive Order, the Deep Mine Safety Commission and charged them with the responsibility of making recommendations for the implementation of a program to save lives and prevent accidents. The findings of this Commission were presented to the Governor, and an Extraordinary Session of Kentucky's General Assembly was called in November of 1976. During this Session, the Division of Mine Safety Analysis was created within the Kentucky Department of Mines and Minerals and became law on December 26, 1976.

The purpose of the Mine Safety Analyst Program was to place trained safety specialists in underground coal mines to observe and evaluate the work habits of all persons involved in coal production and to contact, advise, and assist these individuals in correcting unsafe, careless, or potentially hazardous actions.

Any person employed as a Mine Safety Analyst must hold a valid and current Kentucky mine inspector's certificate. Although his authority is the same as a state mine inspector, it is mandated to be a secondary responsibility.

A typical safety analysis begins with a meeting between the analyst and mine management. The analyst first studies the mine's safety program, and every attempt is made to use this program as a guide. If, however, there is no formal safety program, or if it is lacking in certain areas, the analyst will suggest alternative measures.

The analyst then visits every

unit of the mine on every shift in order to acquaint himself with every employee and to explain the nature of his visit.

Thereafter, each visit to the mine begins with a visual examination of the face areas to check the status of roof control, ventilation, rock dusting and clean-up procedures. The analyst then observes individual miners and management personnel as they perform their assigned tasks. Once he has observed the employee at work, the analyst will usually confer with the employee. If the employee is performing the work in a safe manner, the analyst will so inform him. If not, the analyst will suggest alternative methods of performing the task or discuss past accidents associated with the task. These contacts are intended to be exactly what they are, constructive criticism, which will provide the employee with advice on how to perform that particular job in the safest manner.

The next step is to advise management of his findings of the overall mine conditions and if need be, to point out specific persistent problems and discuss possible solutions. Lastly, the analyst will refer management to existing training programs offered by the Department's Division of Miner Training, Education and Certification.

Each final report of the safety analyst is reviewed by his supervisor and passed on to our central office in Lexington where they are again reviewed by the Division Director. Unsafe acts from these reports are compiled and recorded monthly by District. These reports are then channelled back to the District level for informational use by the supervisor and as training aids by our instructors in their training and retraining classes.

Job Safety Analysis is exactly what our Mine Safety Analysis Division is all about. Each of our analyst employees is issued a handbook which is an assemblage of over seven hundred (700) JSA's. Each one details the sequence of basic job steps, the potential accidents or hazards associated with these steps, and the recommended safe job procedures. This handbook was a source of information for developing MSHA's JSA program.

I, for one, am a firm believer in Job Safety Analysis and an ardent supporter in our Department's Mine Safety Analyst Program. Although Kentucky still has too many coal mining fatalities, I shudder to think what the total might have been if this program had not been implemented fifteen years ago.
In reviewing past statistics, Kentucky suffered 631 mining related deaths in the 15 years prior to implementation of the program compared to 359 in the 15 years since. This program is not the sole reason for the decrease, but I think it certainly deserves its share of the credit.

I applaud Assistant Secretary

of Labor William Tattersall's initiative to instill the concept of Job Safety Analysis in each and every coal mine. However, this task will not be an easy one. Those mines, small ones in particular, which do not have safety programs or the needed resources, will take extra time and considerable effort by state regulating agencies and/or additional resources from the Mine Safety and Health Administration to assist them in initiating the program.

Kentucky's coal industry response has thus far been minimal at best; however, we are in the process of initiating a JSA program in conjunction with Kentucky and MSHA's Joint Mine Assistance Program at the request of Arch Minerals-Arch of Kentucky #37 mine in Cumberland, Kentucky.

On July 23rd of this year (1991), Arch of Kentucky management/safety personnel, representatives from the United Mine Workers of America, Mine Safety and Health Administration, and Kentucky Department of Mines and Minerals officials met for the first time to discuss a course for improving a diminishing safety record at the company's number 37 mine.

Their problems were identified as being two-fold. Number one, their noncompliance record with state and federal agencies was quickly getting out of control. This one mine alone had accumulated 10 orders, 253 citations and 4 safeguards covering October 1, 1990, to July 16, 1991, an eight and one half month time period compared to 4 orders, 231 citations and 2 safeguards from October 1, 1989, to September 30, 1990, a twelve month time period. This mine exceeded MSHA's district, subdistrict & field office averages for violations issued in FY90 and FY91. It was also found that for FY90 and 91, they were most frequently cited for Part 75.400, which relates to loose coal and dust; Part 75.202, which is roof face and rib control; and Part 75.316 for ventilation.

Number two, their injury rate was also rising above the limits of acceptability. The mine's total incidence rate was 8.55 and 8.44 for the calendar years 1989 and 1990 respectively, compared to 9.45 for just the first quarter alone in 1991.

At this point in time only computer generated MSHA statistics were available. Further compliance and accident data is being accumulated from the Kentucky Department of Mines and Mineral's inspection, accident, and mine safety analysis reports.

By the end of this first meeting, a committee comprised of those in attendance was formed to accumulate more data through a more in-depth computer analysis, committee mine examinations, and mine employee interviews. The time frame discussed was expected to take from two to four weeks; however, the committee was given the latitude to take whatever time was necessary to do thorough research. When the committee is satisfied with their findings, another conference session will be held to determine the next course of action.

During the course of the meeting, it was the consensus by those in attendance that a Job Safety Analysis program would play a significant role in our efforts. Just exactly how and when it will be used will be discussed in our next session.

I am confident that through the predicted successes of this venture that the Job Safety Analysis concept will develop itself as a more prevalent tool for mine safety in our state.

I also accept the challenge, and will work diligently with Mr. Tattersall on his goal for zero fatalities by the year 2000. My own personal and more immediate goal for Kentucky is to work more specifically towards reducing roof fall fatalities, which is statistically the primary reason our state leads the nation annually in mining fatalities.

In recent years, when Kentucky has a successful year, roof fall fatalities have been held to a minimum. It seems that 1991 will not be an exception to this trend. Of our ten fatalities through this date, six have been from roof falls. With each and every Kentucky miner's pledge to following simple safe job procedures, MSHA's goal can be realized through my own.

The idea of Job Safety Analysis is a pro-active or preventive type program designed to curtail accidents through increased miner awareness before they occur. As I have frequently stated in the past, the Kentucky Department of Mines and Minerals is not the primary deterrent of mining related accidents. Our personnel cannot be with every coal miner every minute of every day, seven days a week, fifty-two weeks a year. The burden of accident prevention rests primarily with mine management and labor. No matter what kind of program is embarked upon, everyone in the entire mining society must play a part to secure its success.

With this renewed vigor for Job Safety Analysis in Kentucky, my optimism for reducing Kentucky's mine fatalities has increased tremendously. To reiterate, in order for MSHA, Kentucky, and any other state agency or mining company to realize a goal or objective of improved safety, a commitment must be made by all the players.

OPENING REMARKS
J.S.A. IN PENNSYLVANIA

T.J. Ward, Jr.

Director, Bureau of Deep Mine Safety
Department of Environmental Resources
Commonwealth of Pennsylvania

I would like to take this opportunity to thank VPI and the Conference Committee for affording me the opportunity to speak to you today on how Pennsylvania is proceeding with J.S.A.

The Department of Environmental Resources, Bureau of Deep Mine Safety, enforces the Pennsylvania Mine Law for all underground mines--Anthracite, Bituminous, and Metal and Non-metal. The Bureau of Deep Mine Safety is made up of two Divisions:

1. Field Operations
2. Program Development and Technical Services

As Director of the Bureau of Deep Mine Safety, it is my responsibility to see that the Bureau operates in a professional and responsive manner to serve the miners and the mining industry. I feel that the success the State of Pennsylvania has had in the past few years is because of the working relationship between mine operators, labor, manufacturers, academic institutions and the enforcement agencies. We have to work together to make our mines safe and productive. We work in a very depressed and competitive industry. Working together is the key to our success.

What we have done in Pennsylvania with the J.S.A. and J.M.A. program is to move very slowly. The first step was to get a commitment from both the federal and state agencies. We then conducted a two-day meeting with all federal and state mine inspectors to outline the program and to build on our commitment. We then picked a selected group of inspectors to be trained on how to prepare a J.S.A. After that was completed, we began promoting J.S.A., which is a voluntary program, to the coal operators, outlining that we would assist any operator that wanted to start a J.S.A. program.

We also started a J.M.A. program which is a Joint Mine Assistance Program. The J.M.A. program is a voluntary program. The criteria for a mine to be placed in the J.M.A. program is poor attitude, high accident frequency, and high violation frequency. We have started seven J.M.A. programs in anthracite and two in bituminous mines. In the anthracite coal field we only had one operation with difficulty in complying with the mining law. The program has been successful in helping operators to reduce accidents and violations. I might add that before we proceeded with the J.S.A. and J.M.A. program, we had informational meetings for all interested coal operators.

We have been successful in Pennsylvania in reducing fatal accidents. We have gone from having 8 to 10 fatals a year down to 2 fatals a year. To date in 1991, we have not had a fatal accident in an anthracite, bituminous, or metal and non-metal underground mine. I base our success on the commitment and relationship between labor, management, manufacturers, academic institutions, and the enforcement agencies. Working together we can make a difference. Again, thank you and God bless you.

TECHNICAL SESSION III: DIESELS

Chairmen:

Kevin Burns
Counsel
American Mining Congress
Washington, D.C.

James L. Weeks
Director of Research
Laborers' Health & Safety Fund of North America
Washington, D.C.

JUST DO IT --- THE DIESEL WAY

William Murray

Vice President, Safety and Health

Kerr-McGee Coal Corporation

When diesel equipment is properly selected and used correctly in underground coal mines, it will enhance safety and improve productivity without exposing individuals to significant health or safety risks. My background and experience with the use of diesel-powered equipment extends over many years and includes establishing the basic mine design for the use of such equipment. Among design considerations are transport of men, materials and product, as well as adapting diesel power to many ancillary functions. In my experience, proper diesel along with prudent operating procedures, resulted in a safe and healthy work environment for the miners.

It is obvious, that when proper safeguards are taken, diesel-powered equipment should be considered by underground mine operators as a viable equipment power choice.

Diesel equipment will not always be the equipment of choice. Its application is limited, and it is not yet readily adaptable to low seam mining equipment.

Ventilation rates that are required for areas where diesel equipment is used may not be necessary for many mines where lower ventilation rates are adequate when considering only the methane and dust hazards. Many people think of diesel equipment in mining only for hauling coal and rock. However, some of its more productive applications are in support functions, such as supply haulage, personnel transportation, lubrication, maintenance equipment, providing power for outbye equipment, rockdusting, welding, construction, maintenance and for emergency applications such as underground ambulances and power from generators.

As mine operators have recognized the demonstrated safe and productive capabilities of diesel-powered equipment over electrical equipment in appropriate circumstances, the coal mining industry has seen dramatic increase in its use. Since 1980, the number of diesel units has more than tripled in underground coal mines. Currently, some 1850 diesel units are operating in more than 130 coal mines across the country. (See Figure 1).

Increasing use is building a history of consistent safety performance. The all-injury rates for a number of large underground coal mines using diesel equipment reflect significantly lower injury and accident rates when compared with national rates. (See Figure 2).

Moreover, the industry has experienced no major incident or accident directly attributable to the diesel power aspect of mobile equipment.

Rather, incidents stem from the traditional disaster causes (See Figure 3). No record of an underground coal mine fire indicates that diesel fuel was the fire source. The prophecies by some, that use of diesel equipment would reduce safety have not been fulfilled.

Instead, diesel-powered equipment has reduced absenteeism at many of the underground coal mines. The reduction of strenuous manual tasks and use of versatile diesel equipment improve working conditions and reduce labor-related problems.

In addition to safety, diesel equipment offers operators productivity and operating advantages. While the use of diesel shuttle cars for hauling coal from the working face to the feeder conveyor has proven to be highly productive, it is in the area of support equipment outbye the coal face that diesel equipment has particularly proven its worth with the introduction of frontend loaders, forklift trucks, maintenance vehicles, generators and personnel vehicles. These utility vehicles reduce the manual workload while performing in a safer manner. As a result, many of the hand, neck, and back injuries common to the mining industry have been eliminated. Diesel vehicles that transport personnel to almost any area of a mine offer freedom of movement for supervision, transportation, evacuation, and immediate response to any safety or production-related incident. In addition, diesel mantrip vehicles for transporting work crews ensure safe and rapid movement throughout a mine.

The tremendous positive impact of longwall mining on safety, productivity and cost has been greatly enhanced by the use of diesel equipment. In the withdrawal and setup of the longwall faces, the use of diesel shield-movers, transporters, roof bolters, scoops and boom trucks has proven invaluable. The ability and flexibility of diesel equipment to withdraw, transport, and erect the modern longwall face with a minimum of manual labor has significantly improved safety and productivity while lowering costs and downtime.

The mining industry is committed to diesel, and the increased use and experience have allowed manufacturers to continually improve the design features and construction of diesel equipment. The present-day generation of vehicle is much better equipped to operate safely over rugged terrain and in hostile environments where conditions are unsuitable for cable reel or battery-operated vehicles.

Many individual mine operators and equipment manufacturers have worked in conjunction with the medical community, MSHA, and the Bureau of Mines to evaluate the health effects of diesel emissions and to improve diesel emission control technology.

Significant progress has been made in the area of diesel emission control technologies. For example, DRESSER Jeffrey Division, a leading diesel manufacturer, has introduced a paper filter that can be retrofitted on its vehicles, with the capability of removing 90% of the diesel particulates from the exhaust. Continued technological developments will further increase the safety and operating advantages of diesel equipment.

The use of diesel equipment cannot be accomplished without a lot of hard work, planning, designing, maintaining, and trained people to do the job.

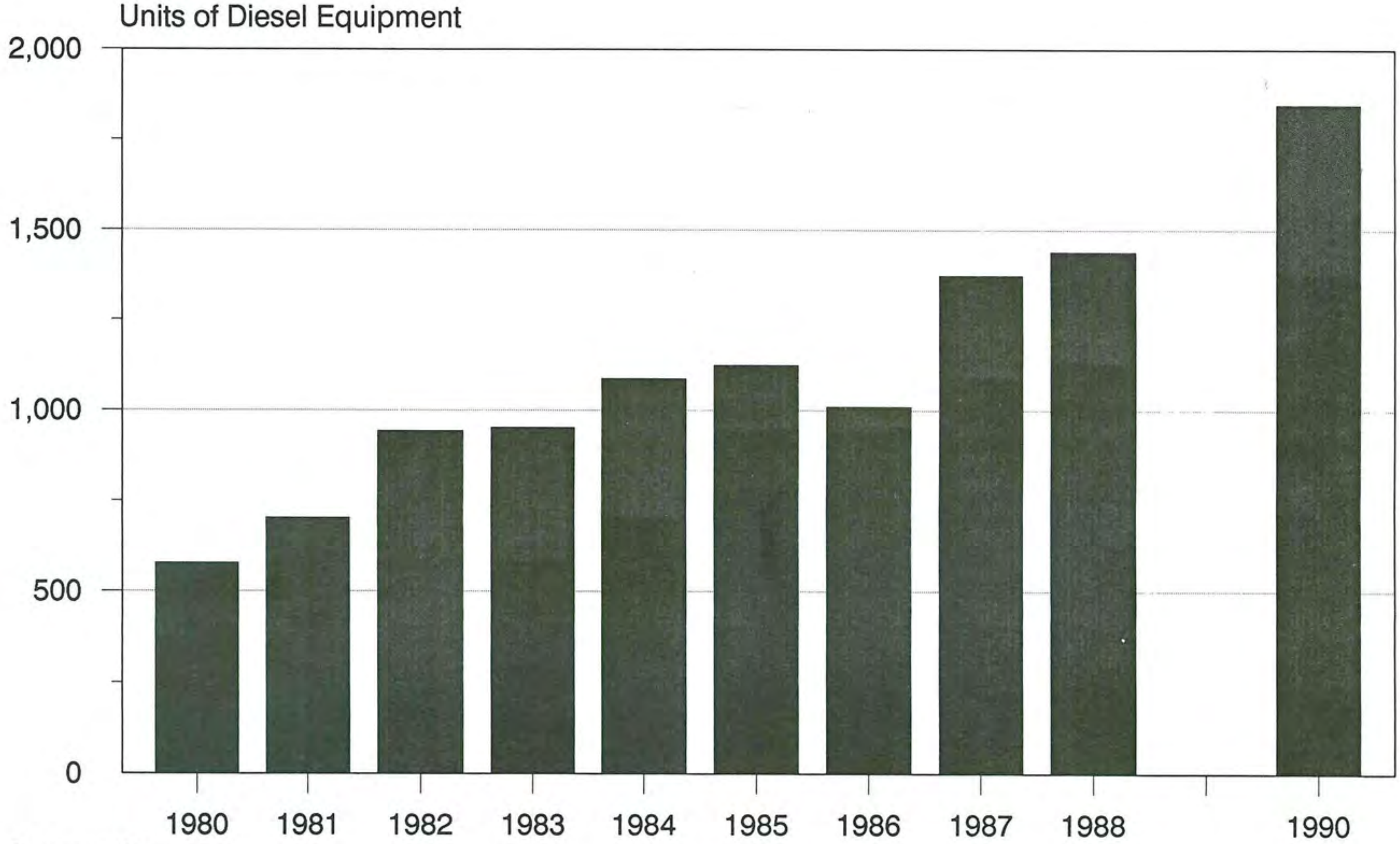
But that is no different from any aspect of our mining profession, be it electrical, shaft-sinking, construction, conveyor installation, preparation, etc. All have their own particular dangers and safety and health aspects. Diesel use is just one more element among the many, that make the skills and experience of our coal miners and our industry second to none.

Diesel equipment has improved the workplace, enhanced safety programs and contributed to the increased productivity that enables the industry to maintain a competitive position and grow in the international market-place.

Smarter and safer has to be the order of the day if our mines are to continue operating. The hundreds of thousands of hours that diesel equipment has been used in coal mines have proven its safe application.

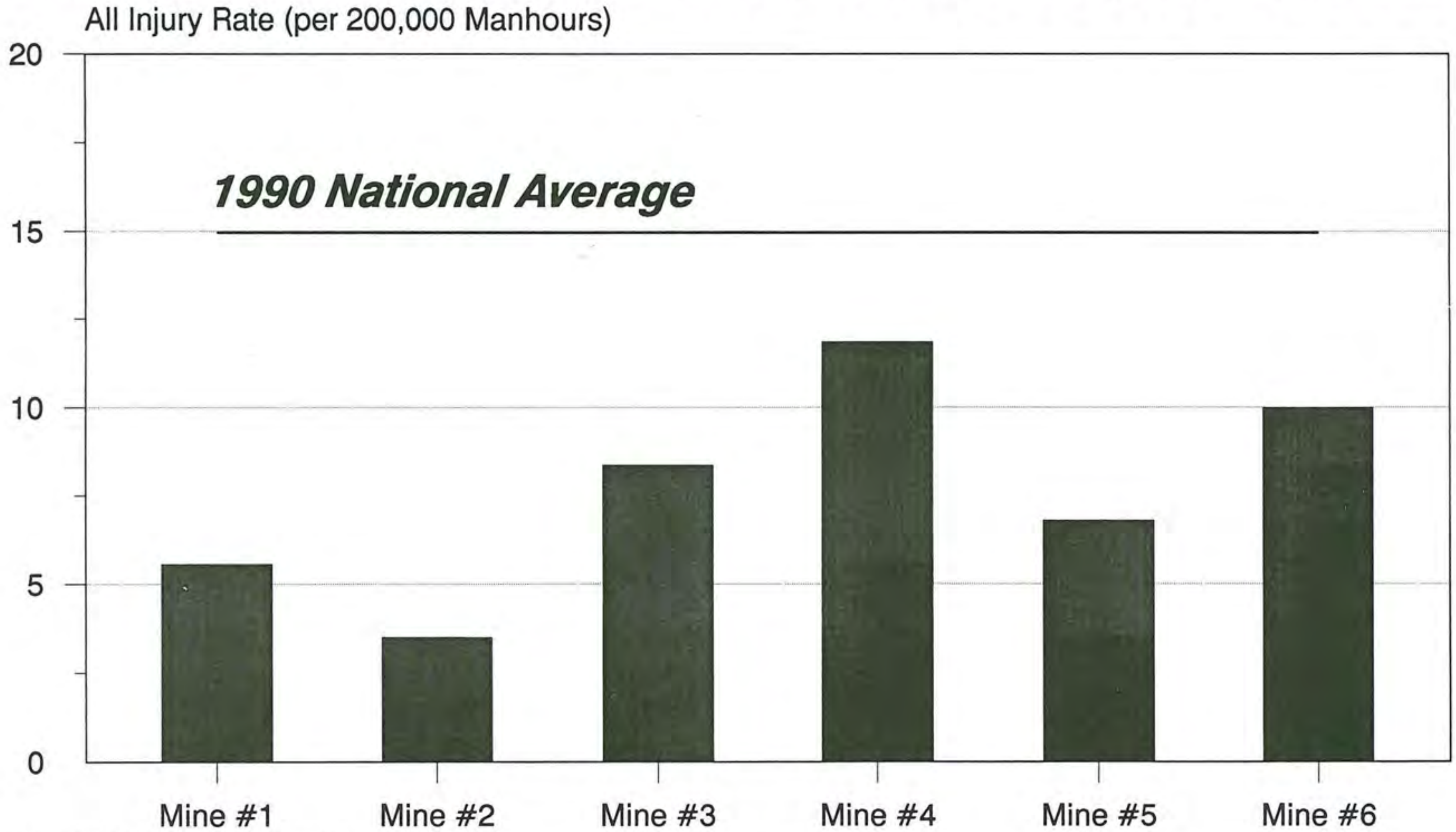
As our nation debates its National Energy Strategy, one of the key "Powerful Ideas for America" for the coal-mining industry is the safe, efficient, and economical production of coal resources through the continued implementation of state-of-the-art technology such as longwall mining and diesel equipment.

FIGURE 1
DIESEL EQUIPMENT IN UNDERGROUND U.S. COAL MINES



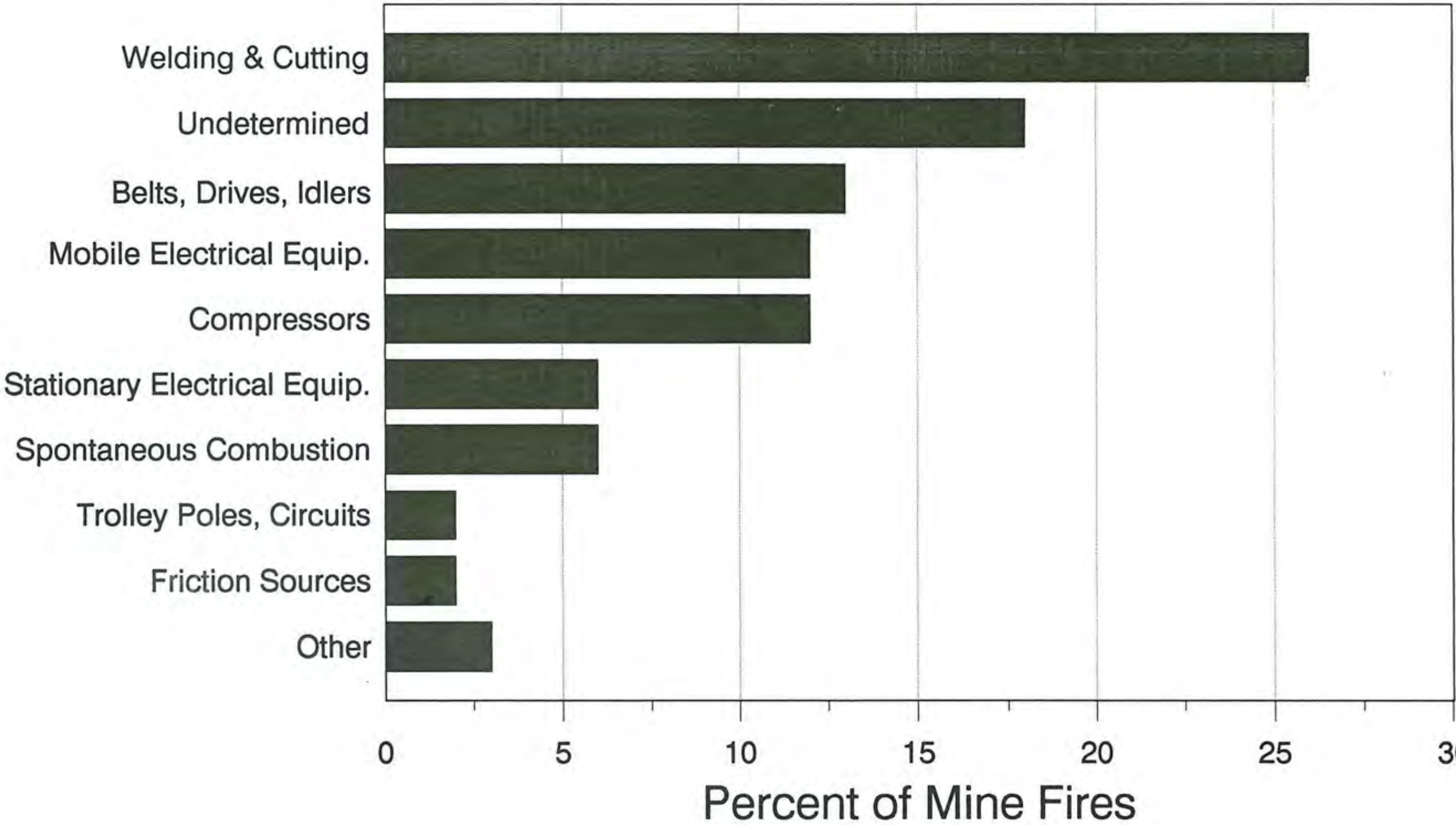
Source: MSHA.

FIGURE 2
1990 ALL INJURY RATES: NATIONAL AVERAGE VS. LARGE UNDERGROUND COAL MINES USING DIESELS



Source: MSHA, N.C.A. Survey.

FIGURE 3
SOURCES OF UNDERGROUND COAL MINE FIRES
January 1980 through July 1990



Source: MSHA Health & Safety Analysis Center.

RISK ASSESSMENT: A KEY STEP IN CANCER PREVENTION

James L. Weeks, ScD, CIH
Consultant

United Mine Workers of America

INTRODUCTION

Risk assessment is one step among many necessary for a strategy for the prevention of cancer. The purpose of this paper is to place risk assessment within the context of a general strategy for cancer prevention. A general strategy for cancer prevention includes (1) identifying the controllable causes of cancer, (2) conducting a risk assessment that allows us to estimate levels of exposure at which the risk is "acceptable," (3) medical and exposure surveillance to identify populations at risk and the occurrence of risk factors, and (4) intervention to prevent disease.

The occasion for this discussion is the existence of a risk assessment conducted by NIOSH intended to estimate the risk of lung cancer among underground coal miners exposed to diesel exhaust. It is my expectation that this risk assessment will be a prominent feature of MSHA's development of a permissible exposure limit (PEL) for exposure to diesel particulate matter. Consequently, my discussion of a general strategy for cancer prevention will be illustrated with the particular example of diesel exhaust.

CANCER PREVENTION

Cancer prevention is inherently preferred to alternative methods of disease control such as treatment and rehabilitation. Not only is this true for disease control in general, it is especially true for cancer control. The alternatives simply are not effective. Except for certain types of cancer--leukemia, lymphoma, cancer of the female reproductive organs, skin cancer--there has been very little progress in successful treatment of cancer. The five year survival rate for lung cancer, for example, has changed little over the past two decades, in spite of extensive investigation of the efficacy of cancer therapy. It is the proportion of persons still alive five years after having been diagnosed with cancer. For lung cancer, the five year survival rate is about 11%.)

CAUSES OF CANCER

Cancer is caused by things to which we are exposed in our environment. This statement is now so much taken for granted that it obscures the important conceptual change that has taken place in our thinking about cancer in the past forty years. The common conception then was that cancer was an inevitable and, some said, natural part of aging. Little could be done to prevent it. The most likely causes were in the individual's genetic inheritance that inevitably resulted in cancer later (or earlier, with some tumors) in that person's life.

That conception changed with the discovery that there were significant differences in the occurrence of cancer within and between nations that could not be explained by this genetic hypothesis. As these differences were investigated further, it became obvious that specific features of the environment were associated with certain tumors. Today, the most obvious of these are cigarette smoking and lung cancer, but there are many others too. One of the first environmental causes of cancer was occupational exposure to chimney soot; it was shown to cause cancer of the scrotum among chimney sweeps. Diets high in fat and low in fiber were associated with cancer of the bowel, exposure to radon daughters in uranium mines was associated with lung cancer among miners, exposure to beta-naphthylamine was associated with cancer of the bladder among rubber workers. With these and other findings, controllable causes of cancer were identified; it was no longer necessary to give in to cancer's presumed inevitability. Instead, if external and typically chemical causes of cancer could be identified, cancer could be prevented by controlling exposure.

This conceptual change then resulted in a search for the environmental of chemical causes of cancer or, in other words, for the first aspect of a strategy for preventing cancer. ("Environmental" and "chemical" are commonly, though strictly speaking, incorrectly treated as interchangeable adjectives, owing to the broad meaning attributed to each term.)

There are four different kinds of methods used to identify the causes of cancer. These are (1) chemical analogy, (2) in vitro experiments, (3) toxicological experiments with laboratory animals, and (4) human epidemiology. None of these methods, by themselves, is sufficient for answering the question whether a particular chemical causes cancer, but taken together, each of them contributes to different aspects of the problem.

The use of chemical analogies is based on the well-established biochemical generalization that chemical structure and function are closely related. Chemicals with similar structures will have similar effects. Therefore, when more than one chemical in a class are identified as carcinogenic (i.e., cancer causing), other members of the class become suspect also. Thus, as classes, tertiary amines (such as beta-naphthylamine, alpha-naphthylamine, and benzidine) and halogenated hydrocarbons (vinyl chloride, vinyl bromide, carbon tetrachloride) are suspect carcinogens because several of their members are carcinogenic. Similarly, products of combustion or, more particularly, pyrenes and nitro-pyrenes, are similarly suspect because chimney soot, cigarette smoke, coke oven emissions, and roofing tar are all carcinogenic. Products of combustion include diesel exhaust.

Biochemical experiments in vitro (literally, "in glass," a carryover from the days when laboratory containers were glass rather than plastic) are used to investigate biochemical functions thought to be central to the initiation of cancer. These functions are primarily concerned with damage to genetic material or DNA. Since cancer is fundamentally a disorder of cellular reproduction and since reproduction, in turn, is controlled by a cell's DNA, it is logical to conclude that damage to DNA is the primary lesion that results in cancer. One purpose of in vitro experiments is to investigate damage to DNA.

There are several types, but I will mention only two. The Ames assay uses bacterial cells to investigate mutagenesis. Specially grown cells are cultivated with the suspect chemical and, if there is damage to the bacterial DNA, the cells grow. One can estimate mutagenic potential by comparing the growth rate of cells when treated with chemicals of unknown v. known mutagenicity.

Experiments with mammalian cells, including human cells, are used also. In these, the biochemist searches for DNA adduct, or the addition of foreign molecules to the cell's DNA. These experiments provide different information than tests with bacteria. Mammalian cells come from multicellular animals that have a nucleus that contains the DNA; bacteria are single-celled organisms and the cells do not have a nucleus.

Extracts of the diesel particulate matter are positive in the Ames assay and the produce DNA adduct when tested with mammalian cells. These experiments have been criticized because it is the extract from the particles that was used to treat the cells. However, experiments with the whole diesel particle have produced positive results also.

Experiments in toxicology have the advantage over in vitro experiments because it is possible to observe effects in a whole organism. They have an advantage over human epidemiology because it is possible to control closely both exposure and effects. Toxicologists often, however, must subject laboratory animals to "high" exposure levels in order to make experiments more cost-effective and, in order to make results relevant to human beings, results must be extrapolated "from mouse to man(kind)," as one author put it.

One factor in extrapolating concerns the route of administration of the chemical or, in other words, whether it is eaten, inhaled, injected, applied to the skin, etc. Thus, if humans are likely to inhale a suspect carcinogen, it is useful for animals to have inhaled it also. This has been an issue in experiments with diesel exhaust. When extracts of diesel exhaust have been painted onto the intact skin of mice, when it has been injected into the lungs or trachea, cancer tumors develop. Until the late 1980s however, inhalation experiments have been negative. It was reported by several laboratories at that time, however, that if rats were exposed to diesel exhaust for sufficiently long time (the lifetime of the animals, in this case), tumors, both malignant and non-malignant, resulted.

Human epidemiology is the final way in which carcinogens are identified. In principle, the methods are fairly straightforward. Cancer incidence or death rates in a population that have been exposed to a suspect carcinogen are compared to rates in populations that have not been exposed. If rates in the exposed population exceed that in the non-exposed population, then an association (not necessarily causation) is demonstrated.

The most common way of comparing rates is to calculate a rate ratio, or relative risk. In cancer studies, this is most often a ratio of death rates expressed as a standardized mortality ratio (SMR). If the SMR is greater than 1.0 (or 100, if multiplied by 100) by a "significant" amount, then an association has been demonstrated. ("Significant" means statistically significant and is a measure of the probability that the SMR arose by chance alone. By convention, $p < 0.05$ is the usual threshold of statistical significance.)

An alternative method is to identify people who have a disease of interest, identify people who do not have the disease, and compare their backgrounds. If there is a cause, it may appear more commonly among those with the disease than without. With this type of study, the relative odds are used as an approximation to the relative risk.

In practice, however, regardless of the type of study, numerous sources of confounding and bias must be accounted for either in the selection of the populations to study or in the analysis of data. Information about populations and what they have been exposed to must be accumulated, verified and analyzed.

Epidemiology has the advantage of studying the occurrence of cancer (or any disease) amongst humans so that extrapolation neither from a biochemical mechanism (such as damage to DNA) nor from a different species is necessary. But proving that an association is causal, that a particular exposure that is associated with a particular outcome actually <u>caused</u> that outcome, is more problematic. As a consequence, there are certain general criteria that can aid our assessment of causality. These are (1) the magnitude of the relative risk, (2) whether a particular study is consistent with other studies, (3) whether there is increasing risk with increasing exposure, (4) whether the finding is biologically plausible, (5) whether the outcome is biologically plausible given the exposure, and (6) whether with control of exposure, the occurrence of the outcome is less likely.

It is rare in practice for any one study to meet all these criteria. When applied to the most recent epidemiologic studies of workers exposed to diesel exhaust, they pass most tests.

These four methods--chemical analogy, <u>in vitro</u> testing, toxicological testing, and human epidemiology--have been applied to diesel exhaust and in <u>each</u> instance, the results are positive. Much more could be said about the particular findings, of course, but the scientific consensus is that diesel exhaust is, or should be treated as if it were, carcinogenic. At this point in time, the first question has been answered, and it is time to move on to the second question, i.e., at what level is the risk of disease acceptable.

RISK ASSESSMENT

The actual practice of risk assessment is not unfamiliar to the coal mining industry; the current scientific rhetoric, theory and applications of risk assessment, however, are unfamiliar. As it has in many other areas of occupational health, the identification and solution of problems in the coal mining industry has set important precedents that others have followed. The practice, but not the theory, of risk assessment is one such precedent.

Current rhetoric surrounding risk assessment is unfamiliar for the simple reason that it has been developed in other agencies, principally OSHA and EPA. Except for promulgation of the standard for radon daughters in underground mines, MSHA has not promulgated PEL's for occupational health hazards in such a way that risk assessment was an integral part of the process. That lack of familiarity must change. Change is easier if it can be linked with the agency's own history and experience, as have said, with the practice but not the theory of risk assessment.

The best illustration of this experience in leadership comes from the publication of data supporting the British coal mine dust standard in 1964, more than a quarter century ago. This data is an exposure-response relationship between exposure to coal mine dust and probability (or risk) of developing coal workers' pneumoconiosis (CWP). Anyone who is familiar with the development and application of the respirable dust standard is familiar with this data and this publication.

There is conceptually no difference between this exposure-response relationship and the NIOSH risk assessment for diesel exhaust. The British data has exposure on the horizontal axis and risk of disease on the vertical axis. The NIOSH risk assessment likewise has exposure on the horizontal axis and risk of disease on the vertical axis. Both show an increase in risk with an increase in exposure. The British data was used to set the PEL for exposure to respirable dust; the NIOSH analysis should be used to set a PEL for exposure to diesel particulate matter and I urge careful study of the NIOSH document.

Thus, the first step and the first half of the second step has been taken and it is now up to the agency to promulgate a PEL for diesel particulate matter.

MEDICAL AND ENVIRONMENTAL SURVEILLANCE

The concluding steps--surveillance and intervention--will be given short shrift but are very important in the overall strategy for disease prevention in general, and prevention of lung cancer caused by inhalation of diesel particulate in particular. Both topics are staples of public health practice.

Amongst public health colleagues, most of whom are either physicians or who place physicians at the top of the public health hierarchy, I would stress the importance of medical surveillance. In both environments, I stress the importance of conducting both kinds of surveillance. The occurrence of disease is a sentinel event, signalling the need to prevent progression and could signal the possible failure of controls. The occurrence of exposure above accepted limits signals the need to improve controls. One type of surveillance acts as a check on the other.

However, the application of medical monitoring for lung cancer is different from medical monitoring for CWP because the two diseases are different. With CWP, it is possible to identify CWP early in its natural history and to take effective action to prevent its progression. This is the purpose of the chest x-ray surveillance program that leads to a job with a low dust level.

With lung cancer there is no screening test currently available that would enable us to prevent the progression of lung cancer. By the time a lung tumor has grown to the point where it can be diagnosed, its eventual outcome, death, is almost certain. Nearly 90% of persons with lung cancer die of lung cancer within five years after it is diagnosed. Neither medical diagnostics nor therapeutics has had much effect on this dismal prognosis. What has had an effect is primary prevention. That is, preventing exposure to its causes.

To discuss medical surveillance thoroughly would require careful consideration of this important difference between lung cancer and CWP. That will not be attempted with this paper.

The purpose of environmental surveillance, or exposure monitoring is both to determine compliance with a PEL and to measure progress in controlling exposure. Monitoring exposure follows setting the PEL.

INTERVENTION

Monitoring systems help to identify problems; intervention is the process of solving problems. For the primary prevention of occupational diseases, solving problems means controlling exposure which is accomplished with the practice of industrial hygiene. Within industrial hygiene, there is a hierarchy of controls from those that are most effective to those that are the least effective.

The most effective controls are a form of positive engineering in which hazards are kept out of the workplace altogether either by changing from more to less hazardous technology or by re-designing hazardous equipment so that hazards are limited or controlled. For example, electrical powered mining equipment does not carry with it the same risks of lung cancer (or other diseases) associated with diesel exhaust. Or diesel engines and diesel fuels could be designed in such a way that environmental pollutants are reduced.

The second most effective control is to remove the hazard from the workplace before anybody is exposed. Thus, ventilation and controls on usage of diesel powered equipment could be used to control exposure.

The least effective form of control is to use personal protective equipment. For every worker wearing personal protective equipment, there is one system of protection. For a work-force, a dozen people results in a dozen separate systems to be designed, installed, and maintained. It is cumbersome and sometimes necessary, but it is not a suitable permanent solution.

These various forms of control are not especially novel but they are effective. What is often lacking for any particular employer is some sort of motivating force to get controls put in place. Often, that force comes in the form of regulations, i.e., setting exposure limits, inspecting mines, and issuing citations for non-compliance.

CONCLUSION

I have attempted to discuss risk assessment within the context of an overall strategy for cancer prevention. This strategy involves four steps: identification of carcinogens, risk assessment, environmental and disease surveillance, and controlling exposure. With respect to controlling diesel powered equipment, we have concluded the first step and are half-way through the second. The best is yet to come.

DIESEL PARTICULATES IN THE UNDERGROUND ENVIRONMENT: ASSESSMENT OF RISK AND CONTROL

Peter M. Turcic

Assistant Director for Health

Office of Technical Support

Mine Safety and Health Administration

ABSTRACT

The Mine Safety and Health Administration (MSHA) is in the early stages of developing a permissible exposure limit (PEL) for diesel particulate to control miners' exposure to diesel exhaust in the mining industry. This follows the recommendations of the Diesel Advisory Committee (DAC) established by the Secretary of Labor in December 1987 to make recommendations for standards and regulations related to the approval and safe and healthful use of diesel-powered equipment in underground coal mines. Considering the information available in 1988, the DAC was concerned that whole diesel exhaust represented a probable risk for causing human lung cancer. The DAC made a number of recommendations related to the use of diesel equipment which served as the basis for regulations proposed by MSHA on October 4, 1989. While the proposed rules did not address a specific PEL for diesel particulate, a number of the provisions do address work practices, equipment designs, and mine system designs to reduce the generation and exposure of miners to diesel particulate. The next step in this regulatory process is to examine the need and appropriate limit for diesel particulate exposures. MSHA is now in the process of assessing both the potential risk associated with diesel particulate exposure and the available technology to evaluate and control diesel particulates in the mine environment. The more significant aspects of the assessment are presented and discussed.

BACKGROUND

The DAC recommended that MSHA regulate the use of diesels in underground coal mines by two means. First, MSHA should implement a system to evaluate the amount of diesel particulate generated by equipment used in coal mines by evaluating particulates during the equipment approval process. They further recommended that based on emission data, the appropriate air quantity be determined for dilution to 1 milligram per cubic meter of air and be reported as a "particulate index." This ventilation rate should then be used by mine operations for mine system design and by MSHA as a basis for evaluating and approving minimum air quantities in mine ventilation plans. Secondly, the DAC recommended that the Secretary of Labor set into motion a mechanism whereby a diesel particulate standard could be set.

MSHA proposed a number of provisions to address the first aspect of the DAC recommendations. These tend to address the control of particulates in the mine environment. The second aspect, the mechanism to set a diesel particulate standard is the assessment of risk. However, setting a particulate standard must also address the feasibility of control and the ability to accurately measure and evaluate exposure levels.

ASSESSMENT OF CONTROL

The assessment of control involves three distinct parts: (1) the ability to detect and measure diesel particulates with a degree of accuracy and precision; (2) determination of current exposure levels in the underground environment; and (3) evaluation of the capability and feasibility of available control technologies to reduce exposures. MSHA has been working closely with the Bureau of Mines (BOM) and the National Institute for Occupational Safety and Health (NIOSH) in these areas. An examination of some of the results provide valuable insight into these three parts of an assessment.

Considerable work has been on-going in the development of analytical procedures to measure diesel particulate in the mine environment. Two approaches have been taken to solve this problem. One is to develop a chemical analysis to separate diesel particulate from other mine particulates. The BOM has sponsored research in this area, as is NIOSH. While these methods appear to offer promise for future application, the use of size selective gravimetric sampling appears to be the near term answer.

It has been shown in both the laboratory and underground that diesel exhaust and mineral dust aerosols can be separated by inertial impaction to estimate the diesel exhaust particulate (DEP) concentration (1, 2, 3 & 4). The BOM in cooperation with the University of Minnesota developed an impactor sampler which has been shown to accurately measure DEP within 10 percent and to have an estimated limit of detection between 0.2 and 0.3 milligrams per cubic meter depending upon the precision of the gravimetric analysis. The device itself is reported to be capable of a precision of 0.015 milligrams per cubic meter (5). MSHA has also developed an impactor sampler having a different design which has been laboratory and field tested. Similar results have been shown with the MSHA sampler (6). Studies have been conducted by MSHA and BOM jointly in mines to evaluate the performance of these samplers. While the detailed results of these evaluations are not the subject of this paper, these studies provide insight into the estimation of current DEP levels in the mining environment.

Since the studies conducted by both MSHA and BOM have been similar in sampling locations and the instruments give similar results, both groups of studies can be used to estimate current DEP levels. For the purpose of this assessment, typical results were considered. These are the average concentrations reported from multiple samples at given locations. Mine averages that were "outliers" were not treated as typical. All the results considered were from production sections. Table 1 shows typical DEP concentrations reported.

The MSHA studies included an analysis to estimate the DEP generation of the diesel equipment used in the production cycle by relating the measured DEP concentration in the intake and return to the quantity of airflow in the return. The typical estimated DEP generation rate (does not include data from equipment utilizing particulate filters) was 1.55 grams DEP per minute based on data from a number of MSHA in-mine studies.

These results can be used to estimate the impact of increased ventilation rates and the installation of other DEP controls. To date, MSHA has evaluated two types of DEP filters. A pleated exhaust filter and a wire mesh filter have been field tested. Using the analysis described above, DEP generation rate reductions were determined. The in-mine test of the pleated exhaust filter showed an average DEP generation rate of 1.91 grams per minute without a filter, compared to 0.10 grams per minute with the filters installed. This is a 95 percent reduction in DEP. The wire mesh filter showed a 53 percent reduction; the DEP generation rate without the filter was 1.50 grams per minute compared to 0.70 grams per minute with the filter.

In order to assess the impact of filters and ventilation, the information presented can be combined for illustrative purposes. Using the formula for estimating the DEP generation rate and assuming the DEP generated in the production cycle is diluted with intake air, the minimum return quantity airflow can be calculated for various section concentrations. This assumes the return concentration is similar but less than other section locations. Table 2 shows the results of these calculations for a range of concentrations from 0.01 to 2.00 milligrams per cubic meter DEP. Figure 1 is a graphic depiction of these results. This table shows the required return airflow (Q_t) for typical generation rates of 1.55 grams per minute; (Q_{wm}) for generation rates using a wire mesh filter; and (Q_{Rf}) for generation rates using a pleated exhaust filter.

The type of information and analyses presented will be useful in assessing the impact of various PELs that may be established for DEP. As seen in the figure, the reliance on dilution alone is limited based on typical DEP generation rates currently encountered. At the limit of detection of available DEP samplers, over 200,000 cfm would be required on a typical mining section without the installation of other controls. However, based on the evaluation of pleated exhaust filter, the technology appears promising and may be able to reduce necessary air quantities by magnitudes.

ASSESSMENT OF RISK

Just as the evaluation and assessment of DEP control has been evolving and advancing over the past several years, so has the assessment of risk associated with whole diesel exhaust. In 1988, the DAC was concerned that whole diesel exhaust represented a probable cause of human lung cancer. At that time the available information addressed the threshold question whether diesel exhaust exposure was carcinogenic. Shortly after the DAC reported to the Secretary of Labor, NIOSH released Current Intelligence Bulletin 50, "Carcinogenic Effects of Exposure to Diesel Exhaust," and concluded that diesel exhaust be regarded as a potential occupational carcinogenic. The International Agency for Research on Cancer (IARC) has also classified diesel exhaust as "probably carcinogenic to humans." These classifications and conclusions are based on animal studies in rats and mice which confirm an association between cancer and exposure to whole diesel exhaust. There is also limited epidemiologic evidence suggesting such an association. After receiving this information and recommendations from the DAC, MSHA sought the assistance of NIOSH in an attempt to quantify the risk associated with exposure to diesel exhaust.

Upon review of existing information, it was determined that the best available data was that reported by Mauderly et al. in 1987. This study was conducted by the Inhalation Toxicology Research Institute of the Lovelace Biomedical and Environmental Research Institute. Briefly, groups of Fisher - 344 rats were exposed to unfiltered diesel exhaust diluted to DEP concentrations of 0.35, 3.47 or 7.08 milligrams per cubic meter of air. Exposures were for up to 30 months.

At the request of MSHA, NIOSH modeled the relationship between exposure to diesel exhaust and the risk to rodents of lung tumors and used these results to produce quantitative estimates of human lung cancer risk. NIOSH submitted this risk assessment to MSHA in comments on MSHA's proposed rules for diesel-powered equipment in underground coal mines.

Based on the analysis, NIOSH concluded that at the upper range of reported in-mine DEP exposure of about 1.5 milligrams per cubic meter of air, the excess risk to miners of lung cancer is approximately 1.5 to 3 in 100. NIOSH emphasized in their report that the risk estimates were based on a series of assumptions and involve considerable uncertainty.

MSHA is developing an advanced notice of proposed rulemaking (ANPRM) to obtain information and public input concerning the NIOSH risk assessment and other aspects of setting a DEP PEL. As with any quantitative risk assessment based on animal studies, significant issues concerning models and assumptions need to be addressed. The choice of model has a significant impact on the resulting risk estimates. For example, a risk of one in a thousand is estimated at about 0.045 milligrams per cubic meter using the Armitage-Doll multistage model used by NIOSH as the preferred model for this data. Based on the NIOSH report, this same risk estimate occurs at about 0.20 milligram per cubic meter for the Multistage Model; at about 1.0 milligrams per cubic meter for the Weibull Model; and at about 1.1 milligram per cubic meter for the Probit Model. Other assumptions that have significant impact on the resulting risk estimates are discussed by NIOSH in the report. MSHA is requesting input in the ANPRM relative to this and other issues.

CONCLUSION

To illustrate the impact of the variables to be addressed in setting a DEP PEL, the information discussed in the assessment of control and assessment of risk can be considered together. Assuming that the mine where the pleated DEP filter was tested by MSHA is typical, and assuming a risk of one in one thousand for discussion purposes, a matrix of results can be used to see the impact of model choice in assessing risk and the feasibility of either relying on dilution air alone or other controls. The DEP generation at this mine using 3 diesel ram cars and other support equipment was 1.91 grams per minute without filters and 0.10 grams per minute with filters. Using the concentrations for a 1/1000 risk for the various models discussed in the previous section, the required return air quantity was calculated and is shown in Table 3.

This illustrates the interrelationship and sensitivity of the application of risk assessment and control technology in setting a PEL for DEP. Furthermore, it shows the need for as complete information as possible in response to the ANPRM for a Permissible Exposure Limit for Diesel Particulate.

REFERENCES

1. Marple, V.A., et al., 1986, "Methods for the Selective Sampling of Diesel Particulates in Mine Dust Aerosols," Bureau of Mines OFR 44-87.

2. Rubow, K.L., et al., 1988, "Measurement of Coal Dust and Diesel Exhaust Aerosols in Underground Mines," Proceedings of the 7th International Conference on the Pneumoconiosis.

3. Cantrell, B.K., et al., 1987, "Source Apportionment Analysis Applied to Mine Dust Aerosols: Coal Dust and Diesel

Emissions Aerosol Measurement," Proceedings of the 3rd U.S. Mine Ventilation Conference.

4. Cantrell, B.K. and Rubow, K.L., 1988, "Mineral Dust and Diesel Aerosol Measurements in Underground Metal and Nonmetal Mines," Proceedings of the 7th International Conference on the Pneumoconiosis.

5. Cantrell, B.K., et al., 1991, "Pollutant Levels in Underground Coal Mines Using Diesel Equipment," SME 1991.

6. Haney, R.A., 1990, "Diesel Particulate Exposures in Underground Mines," SME 1990.

Table 1 - Typical Diesel Exhaust Particulate Concentrations

Location	DEP Concentration mg/cubic meter
Section Intake	0.10
Continuous Miner Operator	0.70
Ram Car Operator	0.90
Section Haulageway	1.10
Section Return	0.82

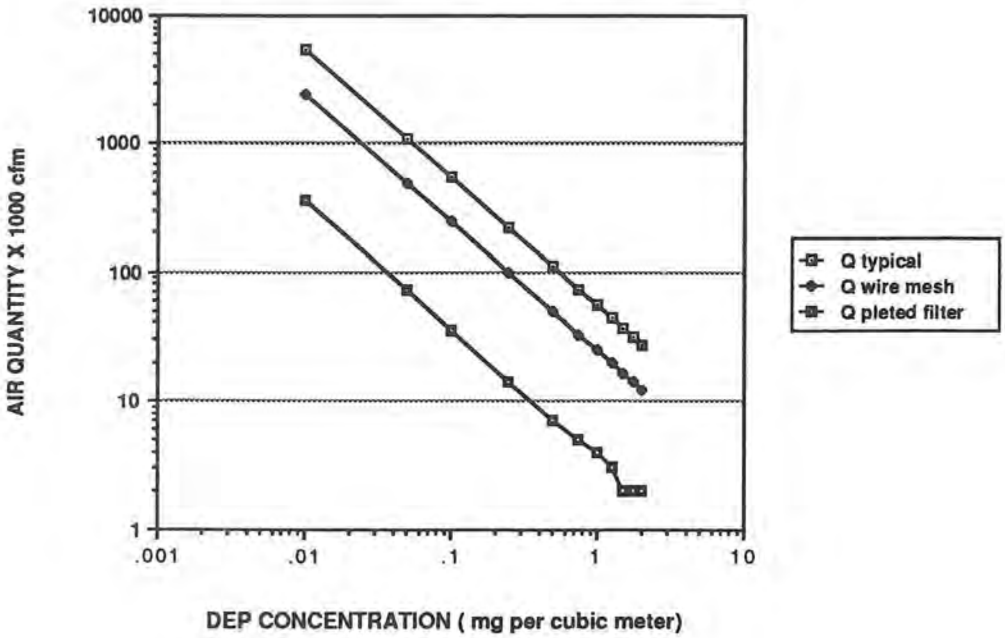
Table 2 - Return Air Quantity Impact On DEP Concentrations

DEP Concentration (mg/cubic meter)	Q typical (1000 cfm)	Q wire mesh (1000 cfm)	Q Pleated Filter (1000 cfm)
0.01	5,474	2,472	353
0.05	1,095	494	71
0.10	547	247	35
0.25	219	99	14
0.50	109	49	7
0.75	73	33	5
1.00	55	25	4
1.25	44	20	3
1.50	36	16	2
1.75	31	14	2
2.00	27	12	2

Table 3 - Return Air Quantity for Various Risk Estimate Models and the Impact of Using a Pleated DEP Filter

Risk Estimate Model	Concentration for 1/1000 risk (mg per cubic meter)	Return Air Quantity in 100 cfm	
		Without Filter	With Filters
Armitage-Doll	0.045	1,500	78
Multistage	0.20	340	18
Weibull	1.00	67	4
Probit	1.10	61	3

Figure 1- Return Air Quantity Impact on DEP



MEASUREMENT AND CONTROL OF DIESEL EXHAUST AEROSOL

Bruce K. Cantrell, Robert W. Waytulonis, and Jeffrey L. Ambs

U.S. Department of the Interior
Bureau of Mines
Minneapolis Minnesota

ABSTRACT

During the 1980's, the Mine Safety and Health Administration (MSHA) proposed new regulations for the use of diesel equipment in underground coal mines. In addition, the National Institute for Occupational Safety and Health (NIOSH) recommended that whole diesel exhaust be regarded as "a potential occupational carcinogen," and that reductions in exposure to exhaust pollutants would reduce excess risk. In this period, the U.S. Department of the Interior, Bureau of Mines (Bureau), developed and tested new diesel emission measurement techniques and exhaust control technology.

Threshold limit values (TLVs) have been recommended for diesel-associated gaseous pollutants; CO, CO_2, NO, NO_2, SO_2, and some hydrocarbons (HC) emitted in diesel exhaust. There is, however, no TLV recommended for diesel exhaust aerosols nor is there yet a standard method for sampling these aerosols. The Bureau and the University of Minnesota have developed a personal diesel exhaust aerosol sampler. Air-quality measurements made during field tests of this sampler indicate that average diesel exhaust aerosol concentrations in the haulage entry for the mines surveyed were 0.8 ± 0.2 mg/m^3. Also, gas concentrations, i.e., CO, CO_2, NO, NO_2, and SO_2, were well below regulated levels.

Emission controls for underground diesel vehicles include work practices, engine maintenance, and exhaust aftertreatment. Work practices to control or minimize diesel exhaust pollutants begin with the use of engines known to have good emission characteristics. Engine manufacturers have developed diesels to be a balance of performance, durability, and emissions. Deviation from proper engine maintenance methods and intervals results in poor performance, increased engine wear, and higher emissions.

Exhaust aftertreatment controls are used to modify exhaust characteristics and remove pollutants. Waterbath exhaust conditioners, water scrubbers, are currently used to provide cooling and prevent flames, sparks, or backfires reaching gassy atmospheres. They also remove between 10 and 30 pct of exhaust aerosol and a high percent of sulfates. Oxidation catalytic converters oxidize CO and HCs into less toxic gases. Catalyzed and noncatalyzed ceramic diesel aerosol filters are used on selected heavy-duty diesel vehicles in

noncoal mines. These are 80 to 95 pct efficient in removing exhaust aerosol. Catalyst coatings on diesel exhaust filters reduce regeneration temperatures and have effects upon gaseous emissions similar to the coatings on catalytic converters.

The Bureau has recently completed tests of a disposable, pleated-media diesel exhaust aerosol filter conducted at a high altitude coal mine in Utah. Filters were shown to reduce diesel exhaust aerosol concentrations in the mine environment by 95 $\pm$ 4 pct.

INTRODUCTION

The underground mining industry recognizes that diesel-powered equipment has many advantages over its electric counterparts such as greater mobility, flexibility, and high power density, which can result in increased productivity. There is, however, an attendant health risk for miners exposed to diesel exhaust.

A miner working in an underground mine using diesel equipment is exposed to a wide array of pollutants from the diesel exhaust. These include carbon monoxide (CO), carbon dioxide (CO_2), nitric oxide (NO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), diesel exhaust aerosol, and a variety of hydrocarbon (HC) compounds. Diesel exhaust aerosol consists mainly of carbonaceous soot, sulfates, trace metals, and adsorbed or condensed soluble organic compounds (1). A quantitative definition of the health risk resulting from these exposures remains elusive, but during the past several years progress has been made in defining the problem.

Results from epidemiological studies, animal inhalation studies, and in vitro studies have provided sufficient data for NIOSH to recommend that "whole diesel exhaust be regarded as a potential occupational carcinogen." NIOSH further stated that although this excess risk of cancer has not been quantitatively estimated, it is logical to assume that reduction in exposure to diesel exhaust would reduce the excess risk (2). In addition, the International Agency for Research on Cancer has declared that "... diesel engine exhaust is probably carcinogenic to humans" (3).

The consensus of most studies is that diesel exhaust aerosol carries the potential carcinogens into the worker's lungs. The Bureau has measured concentrations of diesel exhaust aerosol in diesel equipped underground coal mines that use no diesel exhaust aerosol controls. Average of the concentrations measured is 0.8 $\pm$ 0.2 mg/m^3 (4).

As a result of concern over exposure to diesel exhaust aerosol in the mine environment, new regulations governing the use of diesels in underground mines are forthcoming. These could affect productivity and competitiveness, as well as the health and safety of mine workers. The Bureau is therefore working to reduce diesel exhaust exposure in mines by developing new, cost-effective control technology. One such is the use of a disposable filter to remove aerosol from diesel exhaust.

DIESEL HEALTH ISSUE

Diesel exhaust contains pollutant gases and diesel exhaust aerosol. A partial list of the more common exhaust gas components and underground mine air quality standards are shown in Table I.

Diesel exhaust aerosol is also a pollutant, but no exposure standards have been established at this time. It is of particular concern because it is almost entirely respirable in size, with more than 90 pct of the particles by mass, having an aerodynamic diameter less than 1.0 μm (6). This means that the aerosol can penetrate to the deepest regions of the lungs and, if retained, cause or contribute to the development of obstructive or restrictive

Table I. Common gaseous pollutants in diesel exhaust and the standards used in coal and noncoal mines†, ppm

Pollutant	Noncoal FSEL	Noncoal STEL	Coal FSEL	Coal STEL
CO	50	400	50	400
CO_2	5,000	15,000	5,000	5,000
NO	25	37.5	25	NA
NO_2	NA	5	3	5
SO_2	5	20	2	5

FSEL = Full-shift exposure limit
STEL = Short-term exposure limit
NA = Not applicable
†Proposed standards are found in Federal Register (5)

lung disease. Of even greater concern is the ability of diesel exhaust aerosol to adsorb other chemical substances such as mutagenic polynuclear aromatic hydrocarbons, gases such as SO_2 and NO_2, and acids such as H_2SO_4 and HNO_3. The aerosol acts as a carrier to bring these substances into the lung where they may be leached out and carried by body fluids to other regions of the body and cause problems (7). Solvent extracts of collected diesel aerosol have shown the presence of mutagens (8-10) and animal inhalation studies (11-13) have shown increased rates of cancer in exposed animals. A recent epidemiological study of deaths among U.S. railroad workers found that occupational exposure to diesel exhaust slightly increased the risk of lung cancer (14).

It is in response to these studies that NIOSH (2) and the International Agency for Research on Cancer (3) have recommended the classification of diesel exhaust as an occupational carcinogen. Additionally, the Mine Safety and Health Administration (15) received a recommendation from an advisory committee to establish a diesel exhaust aerosol standard and regulations to minimize exposure to all diesel pollutants in underground coal mines.

MEASUREMENT OF DIESEL EXHAUST AEROSOL

Two measurement techniques have been advanced for measurement of diesel exhaust aerosol in underground mines. These focus on measurement of the two primary parameters by which this aerosol can be described: 1) by its mass concentration and 2) by its carbon content. The first is measured using gravimetric analysis. The second, by analysis of the elementary carbon content of the aerosol. In both cases, size-selective sampling is used to provide a sample that contains most of the diesel aerosol portion of the sampled respirable aerosol.

Gravimetric Analysis

The Bureau has collaborated with the University of Minnesota to develop and field test a personal diesel exhaust aerosol sampler based on the principle of size-selective sampling (16). The sampler, pictured in Figure 1, has three stages and employs inertial impaction for separating and collecting the diesel and mineral dust fractions of the sampled respirable aerosol. The first stage is an inertial preclassifier that separates and collects the larger, nonrespirable aerosol. The preclassifier used in this design is a 10-mm Dorr-Oliver cyclone. Its second stage is a four nozzle impactor with a sharp 50 pct cut point of 0.8 μm aerodynamic diameter. Most aerosols larger than 0.8 μm are deposited on an impaction substrate. The third stage, which is a filter, collects most of the remaining aerosol less than 0.8 μm aerodynamic diameter. The sampler operates at a sampling flow rate of 2 L/min and is designed to be compatible with commercial personal sampler pumps. The development of the personal diesel exhaust aerosol sampler has been described elsewhere (17). Coupled with gravimetric analysis it can provide measurement of diesel exhaust aerosol concentrations in coal mines which are accurate to within 10 pct.

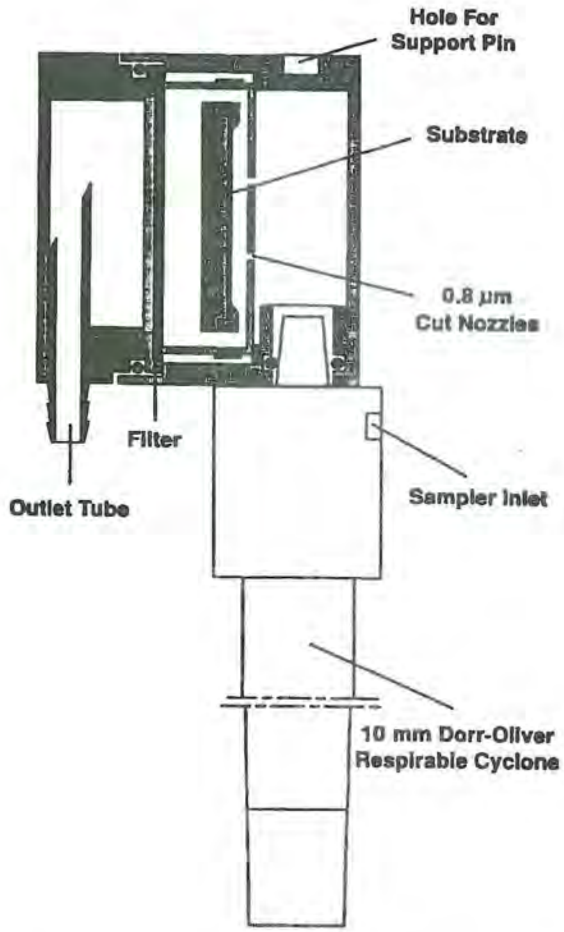


Figure 1. Cut away view of the personal diesel exhaust aerosol sampler for underground coal mines.

During field tests of the personal diesel exhaust aerosol sampler, numerous air quality measurements were performed in underground coal mines that utilize diesel equipment. In addition to the measurement of pollutant gasses, aerosol size distributions were measured using micro-orifice, uniform deposit (cascade) impactors (MOUDI) and diesel exhaust aerosol concentrations using personal respirable aerosol samplers. Analysis of MOUDI-derived size distributions provided accurate concentrations of diesel exhaust aerosol and respirable coal mine dust aerosol. These were used to validate the performance of the personal diesel exhaust aerosol sampler as an impactor sampler and, given the demonstrated accuracy for diesel aerosol, to access its performance as a sampler for diesel exhaust aerosol.

Figure 2 summarizes respirable aerosol concentrations determined from the personal diesel exhaust aerosol samples collected in the test mines in the haulage entry, on the shuttle car, and in the return entry. Figure 3 summarizes the diesel exhaust aerosol concentrations for the same samples. These are log-probability plots of the measured concentrations. They permit estimation of the mean value for these concentrations and some measure of the variance.

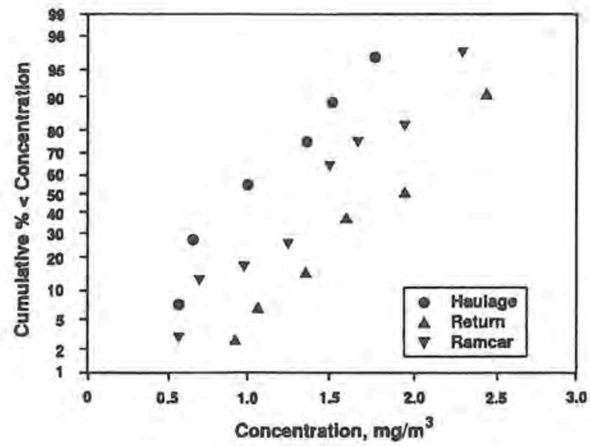


Figure 2. Probability plot of the PDEAS respirable aerosol distribution.

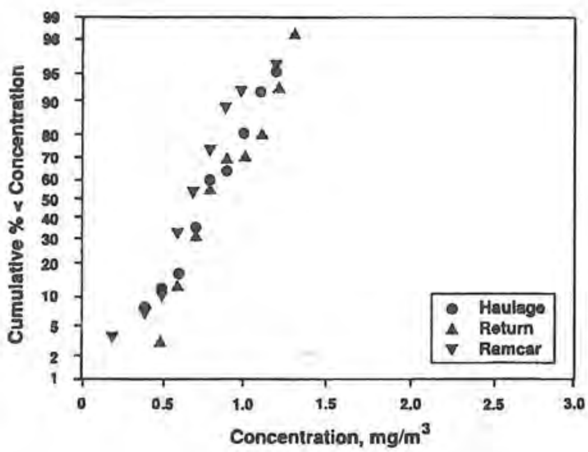


Figure 3. Probability plot of the PDEAS diesel exhaust aerosol distribution.

The haulage, shuttle car, and return locations have similar distributions for the diesel exhaust aerosol portion of the respirable total. This implies that exposure to diesel exhaust is uniform, regardless of where the worker is in the section. Total respirable aerosol concentrations are different depending on where the samples are taken. The highest is in the ventilation return and the lowest is the area sample collected in the haulageway. Implication of this is that exposure to the mineral dust component is location, and hence occupation, dependent.

The mean diesel exhaust aerosol concentration determined from both the personal sampler and MOUDI samples at the haulage location for the three mines surveyed was 0.8 $mg/m^3 \pm 0.2$ mg/m^3. Diesel aerosol contributed 65 pct of the respirable aerosol at this location. It is clear from these data that diesel exhaust aerosol can contribute significantly to respirable coal mine dust aerosol concentrations in mines using diesel haulage and that reductions in such concentrations will improve mine-air quality.

Measurements for CO, CO_2, NO, NO_2, and SO_2 were made at the intake, shuttle car, haulage, and return sampling sites in two of the test mines (4). Typical results are summarized in Table II. All reported concentrations are well below regulated levels.

Elementary Carbon Analysis

The use of size-selective sampling with gravimetric analysis is only intended for measuring diesel exhaust aerosol concentrations at current levels and cannot be used to support a standard below 150 $\mu g/m^3$. Because control technology is currently capable of reducing diesel exhaust aerosol below this level, there is a need for an analytical technique that is accurate for very low levels of diesel exhaust aerosol. One such method, currently under development by both the Bureau and NIOSH, is the use of aerosol elementary carbon content as a surrogate for the diesel aerosol. Such a technique promises to be a more sensitive measure of diesel aerosol and can also be used on samples collected in noncoal mines. Several analysis techniques of this type have been developed for atmospheric aerosol. They generally operate by converting aerosol carbon to carbon dioxide in a furnace as the temperature is slowly increased over a range of 0 to 700° C. Measurement of this evolved gas can be used to quantify volatile carbon, carbonate carbon, and graphitic carbon in the aerosol sample at very low levels.

The evolved gas analysis technique is presently being adapted by the Bureau for elementary carbon analysis in cooperation with MN Research, San Pablo, CA[1]. A similar thermo-optical technique is being developed by NIOSH in cooperation with Sunset Laboratories, Forest Grove, OR (18). As an alternate to this technique, NIOSH is also developing the use of an atomic emission detector with multi-element detection capability in conjunction with a thermal desorption/ pyrolysis unit for elementary carbon analysis. These methods are all in the research stage and have yet to be validated for use in the underground mining environment. They promise, however, to provide sensitive techniques for the measurement of diesel exhaust aerosol at low concentrations.

DIESEL EXHAUST EMISSIONS CONTROL

There are various methods used to control both gaseous and aerosol (particulate) emissions from diesels (19-21). The primary method now used to control emissions in underground mines is through ventilation. Ventilation is necessary to dilute and purge exhaust emissions, as well as to replace oxygen consumed in the engine combustion process.

Table II. Summary of typical gaseous pollutant concentrations, ppm.

Position	CO	CO_2	NO	NO_2	SO_2
Intake	1.6±1.6	540±120	1.7±1.2	0.18±0.06	0.16±0.1
Shuttle	6.8±1.7	1110±90	4.3±2.8	0.61±0.12	0.66±0.07
Haulage	6.9±3.6	950±170	2.8±1.3	0.51±0.16	0.52±0.15
Return	8.5±3.0	1115±50	4.1±1.9	0.52±0.03	0.69±0.04

A second method to reduce overall engine emissions is through proper engine selection. Diesel engine emission characteristics vary widely. By utilizing modern engine designs, engine emissions can be reduced.

Administrative controls and exhaust aftertreatment devices affect engine emissions and are often necessary to keep worker exposure to exhaust pollutants acceptably low. Some important administrative controls and exhaust aftertreatment devices are discussed below, as they relate to specific emissions problems.

Gaseous Emissions Control

Administrative Controls/Maintenance: Engine manufacturers have developed diesels to be a balance of performance, durability, and emissions. Deviation from proper servicing methods and intervals will result in poor performance, increased engine wear, and higher emissions. Maintenance information in the service manual should be strictly followed by trained mechanics to prevent these problems. Table III shows the effects of engine faults on HC, CO, and NO_x, with the increase above baseline given in percent. These faults are maintenance related and effectively change the engine's fuel-air ratio. For convenience, the percentage increases are given in groups, i.e., <50, 50 to 200, and >200. In general, engine faults increase pollutant concentrations in the exhaust. The level of emission caused by a pair of faults occurring individually is not as severe as the level when the same faults are combined (22).

Dirt is very detrimental to engines. The diesel engine requires large volumes of air to function and regular maintenance of the air induction system is necessary for peak performance and low emissions. One of the most common causes of excessive exhaust aerosol and CO concentrations is intake air restriction caused by dust-saturated air cleaners. Overheating is a frequent cause of premature engine failures. Lubrication oil of the correct viscosity must be kept at the proper level and all radiators or heat exchangers must be kept free of accumulated dirt and open to circulating air.

Fuel system tampering should not be tolerated. Changing the calibration of the fuel pump or installing larger capacity injectors results in greater pollutant production and possible engine damage.

Exhaust Aftertreatment: Waterbath exhaust conditioners, usually referred to as water scrubbers, are intended to provide cooling and protection from flames, sparks, or backfires from reaching gassy atmospheres. Tests have shown that water scrubbers have no measurable affect on regulated gaseous emissions (23).

An oxidation catalytic converter's function is to oxidize some exhaust constituents and render them less toxic. The effectiveness of catalytic converters is dependent on their operating temperature, fuel quality, and catalyst formulation and configuration. As shown in Table IV, the positive effects of conventional catalysts are to reduce CO, HC, and aldehydes, usually associated with odor. Negative effects are their tendency to increase

Table III. Effects of engine faults on exhaust composition, increase above baseline, percent.

Fault Description	HC	CO	NO_x	DEA[†]
Intake Restriction				
25 in. H_2O	<50	<50	<50	<50
Exhaust Restriction				
3 in. Hg	<50	<50	<50	<50
Timing Advance[‡]				
Minus 4°	>200	50-200	50-200	<50
Plus 4°	<50	<50	>200	<50
Overfueling				
10%	<50	50-200	<50	50-200
Combined Faults				
25 in. H_2O intake restriction, minus 4° timing advance	50-200	<50	<50	<50
25 in. H_2O intake restriction, 10% overfueling	<50	50-200	50-200	50-200
10% Overfueling, plus 4° timing advance	<50	<50	<50	<50
3 in. Hg exhaust restriction, 10% overfueling	50-200	50-200	50-200	>200

[†]Diesel exhaust aerosol production at most severe engine operating mode
[‡]Deviation from manufacturers specifications

Table IV. Reduction of exhaust constituents by oxidation catalytic converters.

Constituent	Percent Change (Maximum)
Carbon Monoxide	-40 to -90
Hydrocarbons	-2 to -70
Aldehydes	up to -55
Nitrogen Dioxide	up to +25
Sulfate	+10 to >1000

nitrogen dioxide emissions and promote the conversion of sulfur dioxide to sulfates and sulfuric acid. The use of conventional catalytic converters is generally not recommended unless they are used on machines that operate under a sustained moderate to heavy-duty cycle i.e., with exhaust temperatures 200° C or greater, and with low sulfur, < 0.1 wt. pct, fuel (24).

New catalyst formulations that do not have the negative effects of current catalysts are being tested in cooperation with manufacturers. New formulations are being evaluated for their ability to reduce the soluble organic fraction (SOF) of particulate emissions, and to oxidize CO and HC to carbon dioxide and water vapor. The catalysts are foreseen to be used as stand-alone exhaust purifying devices when used with low sulfur fuel.

Aerosol Emission Control

Diesel research projects are underway in an effort to reduce exhaust pollutants to levels lower than conventional techniques can achieve. Diesel exhaust aerosol is composed of three primary constituents; a carbonaceous fraction, SOF, and oxides, primarily oxides of sulfur. The formation of carbon particles is inherent in the combustion process and they form the nucleus upon which the SOF condenses. The SOF is important because this fraction contains organic hydrocarbons that are a suspected health threat (2). The oxides of sulfur originate from the sulfur contained in the diesel fuel. No single control method is effective in removing all three constituents, however, methods are being pursued to reduce them individually.

Administrative Controls/Maintenance: As discussed above, maintenance can play an important role in the emissions of CO, HC, and NO_x from a diesel engine. This also holds true for aerosol emissions. Since they are directly related to the fuel-air ratio, any engine faults that increase the fuel-air ratio will tend to increase aerosol levels. These include the same faults that adversely affect CO and HC emissions. The effect of faults on aerosol levels are also shown in Table III.

Fuel composition affects diesel emissions. Generally, increased cetane number and volatility, as indicated by the 90 pct distillation temperature, reduces CO and smoke. The most important fuel properties for low aerosol emission rates are the aromatic hydrocarbon and sulfur content. Reducing the aromatic content would reduce HC emissions and the carbonaceous fraction of particulate emissions. Reducing fuel sulfur would reduce sulfur dioxide emissions and the sulfate fraction of the exhaust aerosol. This has the added benefit of reducing corrosive wear and would extend engine life. Low sulfur fuel is becoming more widely available due to legislative actions taken by the Environmental Protection Agency to reduce aerosol emissions on over-the-road diesels (25). Table 5 is a list of property limits for good quality diesel fuel.

Fuel additives, such as barium- and calcium-based compounds, can be effective in small quantities in reducing smoke opacity. Bureau research has found that although smoke opacity can be reduced, total aerosol emissions are frequently increased because carbonaceous particles are replaced with oxides and sulfates of barium and calcium (26).

Table V. Property limits for good quality diesel fuel.

Property	Limit
Cetane number	>48
Aromatic content	<20 pct
90% distillation temperature	<320° C
Sulfur content	<0.05 pct by mass

Exhaust Aftertreatment: The ceramic (wall-flow) diesel particulate filter (DPF), pictured in Figure 4, is an outgrowth of the extruded cellular ceramic technology used in the production of monolithic catalyst supports. It is a square cell shaped honeycomb with parallel channels running the length of the unit. The body of the structure is a porous cordierite which has the necessary mechanical strength, chemical resistance, thermal fracture resistance, and melt resistance to survive effectively in the hostile environment of diesel engine exhaust. Exhaust entering one end of the filter can only exit the filter after passing through the wall between adjoining cellular tubes. Exhaust aerosol is deposited on the wall of the cell as particulate. DPF's are being used on selected heavy-duty diesel vehicles in noncoal mines, and research is ongoing to expand their use to coal mine equipment (27).

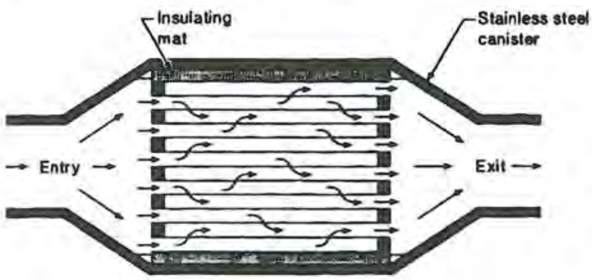


Figure 4. Schematic diagram of a ceramic diesel particulate filter.

Ceramic DPF's are 80 to 95 pct efficient in removing aerosol mass from the exhaust. However, the successful application of DPF's in underground mines depends on their ability to store the collected particulate over a useful operating period without creating excessive backpressure, which could jeopardize the engine warranty or mine safety. Heavy-duty vehicles that consistently generate exhaust temperatures 400° C or higher are the best candidates for DPF technology. Vehicles with moderate or light-duty cycles will require a method to supply heat to burn off the collected diesel particulate matter, i.e., regenerate the filter. Regeneration can be assisted by using a catalyst coating on the DPF which lowers to the regeneration temperature.

In addition to acting as a regeneration aid on DPF's, the catalytic coating also acts to reduce the CO and HC emissions. While providing this benefit, the catalyst may also cause the same problems that occur with oxidation catalytic converters.

Controlling the rate of particulate burn-off in the DPF can be a problem under some operating conditions. It can result in cracking or melting of the ceramic substrate causing unsafe operating conditions. During uncontrolled regeneration, high DPF surface and exhaust temperatures, and high CO emissions result. However, if engine backpressure is kept below the recommended maximum, uncontrolled regeneration is not likely (28). It is therefore necessary to mount a backpressure sensor upstream of the DPF to signal excess exhaust backpressure and remedial action.

The principal application of the disposable diesel exhaust filter (DDEF) system, depicted in Figure 5, is on diesel-powered haulage vehicles certified under 30 CFR Part 36 for use in underground coal mines. In underground coal mines, safety standards require water scrubbers to control exhaust temperatures and arrest flames and sparks that could be emitted from diesel engines. The exhaust passes through the water bath before being emitted from the machine. Water scrubbers limit the exhaust temperature to a maximum of 77° C. The DDEF system was developed to take advantage of these low exhaust temperatures exiting the water scrubber. The filter media used in the DDEF system has a maximum temperature rating of 100° C.

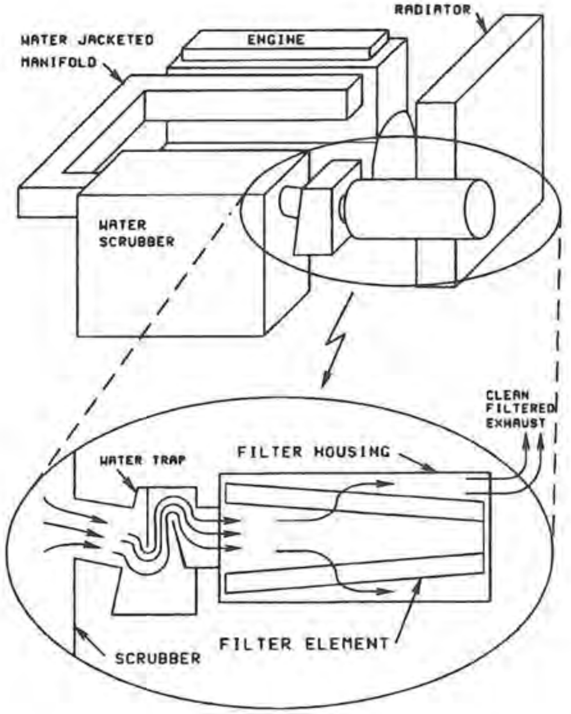


Figure 5. Schematic diagram of the disposable diesel exhaust filter system showing mounting to vehicle power pack.

The DDEF system consists of adapters, a water trap, filter element, filter housing, and exhaust backpressure indicator. The water trap is bolted directly to the outlet of the water scrubber. It is required to prevent water droplets, that are carried out of the water scrubber by the exhaust flow, from reaching the filter. Water droplets reaching the filter cause high flow resistance, reducing the effective service life of the filter. Water vapor passes through the filter and is not a problem.

The DDEF is quite similar to intake air filters used on over-the-road diesel vehicles and cost $40. At present, it is a cone-shaped, 24-in-long filter with 270 2-in pleats, and is constructed of a fibrous mat saturated with resin for wet strength and structural stability. The DDEF is designed to have a collection efficiency of over 99 pct for a standard road dust aerosol. While the initial collection efficiency of the filter media is lower for the submicron aerosol, the filter loading characteristics cause the collection efficiency to increase rapidly as material is collected on the filter (29).

The Bureau, in cooperation with the Donaldson Company, Inc., and Utah Fuel Company, evaluated the life and efficiency of the DDEF in an underground coal mine. The exhaust systems of three Jeffrey 4114 Ramcars and one Wagner LST-5 scoop were equipped with the Bureau's new DDEF exhaust control system. This equipment comprised all diesel vehicles operating in a continuous miner section.

A week-long field study was conducted to evaluate the performance of the DDEF system. During this period, the diesel equipment was operated with and without the filters in place. The reduction of diesel exhaust in the mine environment was measured with size-selective aerosol sampling followed by gravimetric analysis. Aerosol samples were collected using the personal diesel exhaust aerosol sampler, operating with an inertial cut size of 0.8 μm and flow rate of 2 lpm. Samples were collected during normal production shifts in the ventilation intake entry, haulageway entry, on the diesel Ramcars, and in the return air entry.

Analysis of the personal diesel exhaust aerosol sampler results provided accurate concentrations of diesel exhaust aerosol and respirable coal mine dust aerosol. In addition to the determination of exhaust aerosol reduction using aerosol size, a tracer material, a nominal 10 parts per billion of indium as indium 2,4 pentanedionate in xylene, was added to the fuel supply for the vehicles operating in the test section of the mine. This provided a direct tag for the diesel component of the aerosol collected by the dichotomous sampler and permitted an independent determination of the reduction in diesel exhaust aerosol. The trace element analysis technique used on these samples was instrumental neutron activation analysis.

Table VI summarizes the results of measurements with and without the filter in place. Concentration averages presented are actual exposures measured during the experiment. Reductions quoted have been corrected for day-to-day changes in both ventilation and mine production. Ventilation varied from 56k to 81k CFM during the experiment. Coal production, measured by tonnage, varied from 600 to 1040 tons/shift. Measurements made using the personal diesel exhaust aerosol samplers yielded average reductions in the range 95 $\pm$ 4 pct.

Table VI. Diesel exhaust aerosol reduction.

Sample Site	Concentrations Filter Status With mg/m$_3$	Without mg/m^3	$\Delta^\dagger$ pct.
Intake	0.06$\pm$0.02	0.06$\pm$0.02	- -
Haulage	0.12$\pm$0.02	0.50$\pm$0.02	93$\pm$6
Return	0.09$\pm$0.03	0.80$\pm$0.03	98$\pm$4
Ram Car	0.17$\pm$0.05	0.81$\pm$0.03	94$\pm$7
Personal			
Foreman	0.13$\pm$0.02	0.48$\pm$0.02	90$\pm$8
MSHA	0.09$\pm$0.02	0.46$\pm$0.02	100$\pm$5

† Δ= Reduction corrected for ventilation and production changes.

Average measured indium tracer concentrations in the submicron aerosol were 1.1 $\pm$ 0.1 ppm in the haulage entry without the filters, 0.10 $\pm$ 0.02 ppm in the haulage entry with the filters, and 0.05 $\pm$ 0.01 ppm in the intake entry. This yields a reduction in diesel aerosol produced on the section of 95 $\pm$ 3 pct. The nonzero concentration in the intake indicates that some recirculation may have occurred in this section.

The DDEF systems used in this study are practical to control diesel exhaust particulate emissions from permissible coal haulage vehicles. The usable life of the filters on the test vehicles was approximately 10 hours before engine backpressure required filter removal. This filter life is directly related to duty cycle and usage. The filter on the Wagner scoop was not changed during the field study. The loading of the filters was between 360 and 490 gm. This gives a filter loading from 2.0 to 2.7 gm/ft^2. The wide range of loading was due to variation in duty cycle and water being absorbed by the filter. Overall, the DDEF system was successful in controlling diesel exhaust aerosol in the mine environment.

Work is continuing to identify other less expensive, longer lasting filters. Filters made of various types of treated natural and synthetic materials, and different geometries are being tested. For example, prototype "Z-flow" filters were tested on two 4114 Ramcars at the Skyline mine. These filters are the same size as the original pleated filters but contain twice the filter surface area. The filters were removed after approximately 25 hours and a filter-associated backpressure restriction of about 10 in of H_2O.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Donaldson Co., Inc. for supplying hardware and the Utah Fuel Co. for extensive field support during the development of the DDEF. Also, the assistance of Dr. Kenneth Rubow, University of Minnesota, in collecting size distributions and personal diesel exhaust samples, and Dr. Kenneth Rahn and his staff, University of Rhode Island, in performing the instrumental neutron activation analysis used in the evaluation of the DDEF.

REFERENCES

1. Ian W. French and Associates: Health Implication of Exposure of Underground Mine Workers to Diesel Exhaust Emissions. Contract No.23SQ.23440-9143, Department of Energy, Mines and Resources, Ottawa, Canada, 1984.

2. NIOSH. Carcinogenic Effects of Exhaust Exposure to Diesel Exhaust. CIB 50, DHHS (NIOSH) Pub. No. 88-116, 1988, 30 pp.

3. International Agency for Research on Cancer. Diesel and Gasoline Engine Exhausts and Some Nitroarenes. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, v. 46, 1989, 458 pp.

4. B.K. Cantrell, K.L. Rubow, W.F. Watts, Jr., and D.H. Carlson. Pollutant Levels in Underground Coal Mines Using Diesel Equipment. Presented at the SME Annual Meeting, Feb. 25-28, 1991, Denver, CO, Preprint No. 91-35, 5 pp.

5. Mine Safety and Health Administration. Air Quality, Chemical Substances, and Respiratory Protection Standards; Proposed Rules. Federal Register, 1989, Vol. 54, No. 166, pp. 35760-35852.

6. V.A. Marple, D.B. Kittelson, K.L. Rubow, and C. Fang. Methods for the Selective Sampling of Diesel Particulates in Mine Dust Aerosols. Bureau of Mines OFR 44-87, 1987, NITS PB 88-130810, 94 pp.

7. Watts, W.F., Jr., Industrial Hygiene Issues Arising from the Use of Diesel Equipment in Underground Mines. Bureau of Mines IC 9141, 1987, pp. 4-8.

8. Bagley, S.T., L.D. Dorie, D.G. Leddy, and J.H. Johnson. An Investigation Into the Effects of a Ceramic Particle Trap on the Chemical Mutagens in Diesel Exhaust. Health Effects Inst. Res. Rep. 5, 1987, 67 pp.

9. Draper, W.M., H. Hartmann, D.B. Kittelson, W.F. Watts, Jr., and K.J.

Baumgard. Impact of a Ceramic Trap and Manganese Fuel Additive on the Biological Activity and Chemical Composition of Exhaust Particles from Diesel Engines Used in Underground Mines. SAE paper 871621, 1987, 18 pp.

10. Draper, W.M. Impact of a Ceramic Trap on Particulate Emissions from an Air Cooled Diesel Engine Used in Underground Mines. Paper presented at the American Chemical Society Division of Environmental Chemistry Meeting, Toronto, Canada, June 5-11, 1988.

11. Mauderly, J.L., R.K. Jones, R.O. McClellan, R.F. Henderson, and W.C. Griffith. Carcinogenicity of Diesel Exhaust Inhaled Chronically by Rats. Carcinogenic and Mutagenic Effects of Diesel Engine Exhaust, Elsevier (New York), 1986, pp. 397-409.

12. Iwai, K., T. Udagawa, M. Yamagishi, and H. Yamada. Long-Term Inhalation Studies of Diesel Exhaust on F344 SPF Rats. Carcinogenic and Mutagenic Effects of Diesel Engine Exhaust, Elsevier (New York), 1986, pp. 349-360.

13. Brightwell, J., X. Fouillet, A-L. Cassano-Zoppi, R. Gatz, and F. Duchosal. Neoplastic and Functional Changes in Rodents After Chronic Inhalation of Engine Exhaust Emissions. Carcinogenic and Mutagenic Effects of Diesel Engine Exhaust, Elsevier (New York), 1986, pp. 471-485.

14. Garshick, E., M.B. Schenker, A. Munoz, M. Segal, T.J. Smith, S.R. Woskie, S.K. Hammond, and F.E. Speizer. A Retrospective Cohort Study of Lung Cancer and Diesel Exhaust Exposure in Railroad Workers. American Review of Respiratory Disease, Vol. 137, 1988, pp. 820-825.

15. Mine Safety and Health Administration. Report of the Mine Safety and Health Administration Advisory Committee on Standards and Regulations for Diesel-Powered Equipment in Underground Coal Mines. Report to the Secretary of Labor, July, 1988, 90 pp.

16. Cantrell, B.K. Measurement of Diesel Exhaust Aerosol. Proc. 21st Ann. Institute on Coal Mining Health, Safety and Research, E. Hugler, et.al. eds., Blacksburg, VA, Aug 28-30, 1990, pp. 173-181.

17. Rubow, K.L., V.A. Marple, Y. Tao, and D. Liu. Design and Evaluation of a Personal Diesel Aerosol Sampler for Underground Coal Mines. Presented at the SME Annual Meeting, Feb. 26 - Mar. 1, 1990, Salt Lake City, UT, Preprint No. 90-132, 5 pp.

18. Birch, M.E. A Sampling and Analytical Method for Airborne Diesel-Exhaust Particles. Research Plan, NIOSH, 4676 Columbia Parkway, Cincinnati, OH, 45226, February 1991, 34 pp.

19. Baumgard, K.J., and K.L. Bickel. Development and Effectiveness of Ceramic Diesel Particle Filters. Diesels in Underground Mines, US Bureau of Mines Technology Transfer Seminar, IC 9141, 1987, pp. 94-102.

20. Waytulonis, R.W. Bureau of Mines Diesel Research Highlights. Proceedings of the Fourth International Mine Ventilation Congress, Brisbane, Australia, July 3-6, 1988. The Australasian Institute of Mining and Metallurgy, Melbourne, Australia, pp. 627-633.

21. Watts, W.F., Jr., K.J. Baumgard, B.K. Cantrell, and K.L. Rubow. Control of Diesel Particulate Matter in Underground

Coal Mines. Bureau of Mines RI 9276, 1989, 11 pp.

22. Waytulonis, R.W. The Effects of Maintenance and Time-In-Service on Diesel Engine Exhaust Emissions and Performance. Proc. 2nd US Mine Ventilation Symposium, Reno, NV, Sep 23-25, 1985, A. A. Balkema, Boston, MA, pp. 609-617.

23. Cantrell, B.K., K.S. Olson, and O.L. Lantto. Effect of Waterbath Exhaust Conditioners on Diesel Exhaust Aerosol Emissions. Proc. Third Symposium on Respirable Dust in the Mineral Industries, Generic Mineral Tech. Center for Resp. Dust., Penn. State Univ., Univ. Park, PA, October 1990, 6 pp.

24. McClure, B.T., K.J. Baumgard, W.F. Watts, Jr. Effectiveness of Catalytic Converters on Diesel Engines Used in Underground Mining. IC 9197, US Bureau of Mines, 1988, 13 pp.

25. Environmental Protection Agency. Control of Air Pollution. Federal Register, Vol. 50, No. 51, March 15, 1985, Environmental Protection Agency.

26. Zeller, H.W. Effects of Barium-Based Additive on Diesel Exhaust Particulate. RI 9090, US Bureau of Mines, 1987, 40 pp.

27. Waytulonis, R.W. Control of Diesel Exhaust Emissions. Proc. 21st Ann. Institute on Coal Mining Health, Safety and Research, E. Hugler, et.al. eds., Blacksburg, VA, Aug 28-30, 1990, pp. 165-172.

28. Baumgard, K.J. and K.L. Bickel. Development and Effectiveness of Ceramic Diesel Particle Filters. Bureau of Mines IC 9141, 1987, pp. 94-102.

29. Ambs, J.L., B.K. Cantrell, and A.D. Klein. Evaluation of a Disposable Diesel Exhaust Filter. Proc.AFS Annual Meeting, 22-24 April 1991, Minneapolis, MN, 5 pp.

[1] Reference to specific products does not imply endorsement by the Bureau of Mines.

AWARD

Professional Award for Coal Mining Health, Safety and Research

Professional Award for Coal Mining Health, Safety and Research

Joseph L. Patrick has been associated directly with mining for over 34 years. Ten years were in overseas mining and development, with about eleven years devoted largely to research in mining, health and safety.

Mr. Patrick received Bachelor and Master of Science degrees in Geology from Michigan State University in the late 1940s. His experience in the mining industry includes exploration and mining of iron ore in Michigan, Liberia, West Africa and Brazil; bauxite in Brazil, copper in Michigan, and coal in West Virginia, South Africa and Australia. He has held the positions of chief geologist, assistant general manager of mining, manager of mines, and vice president of research and development.

Before his retirement, Mr. Patrick was Director of the Division of Health and Safety for the Bureau of Mines, U.S. Department of the Interior. In addition, he served for a number of years as co-chairman of the Annual Institute for Coal Mining Health, Safety and Research.

It is in recognition of a lifetime of achievement in coal mining health, safety and research that the Twenty-Second Annual Institute presents him with this award.

LUNCHEON SESSION

Peter B. Lilly
President
Kerr-McGee Coal Corporation
Oklahoma City, Oklahoma

"State of the Coal Industry"

"STATE OF THE COAL INDUSTRY"

Peter B. Lilly

President

Kerr-McGee Coal Corporation

Good Afternoon. Thank you, Mike, for inviting me. And, thank you all for joining us, for your concern for the safety and health of our nation's coal miners, and your interest in the viability of our industry.

I have chosen to talk about the "State of the Coal Industry" because it is a topic that is so important to the livelihood of everyone here, and because the state of our industry - particularly as perceived by the public - is influenced by safety performance and by health related issues resulting from both mining and burning coal.

What I would like to discuss with you this morning is perspective -- the capacity to view things in their relative importance. You see, the state of the American coal industry depends on your perspective. 700 years ago, King Edward, the something, promulgated the first known Clean Air Act in response to complaints about London's dirty air. His law had real teeth! It said, "He who burns coal will be beheaded." Compared to the English coal industry in 1300, the present-day American coal industry is infinitely better off.

Let me start by sharing with you a common perspective of today, one that is all too familiar for many of us. It is today's perspective from the viewpoint of us coal miners.

The Clean Air Act was amended after ten years of scientific study and public debate. To some in the coal industry, it represents a battle lost, with policy ignoring many of the scientific facts. Scores of regulations and interpretations of the new law are yet to be written. Our electric utility customers are developing and starting to implement their fuel supply strategies, creating opportunities for many coal suppliers while eliminating or sharply reducing markets for others.

Second, on the heels of the Clean Air Act Amendments is the greenhouse gas/global climate change issue. Once again, policy is outpacing science. Public opinion that favors action to reduce fossil fuel combustion emissions is rapidly gaining momentum. While the United States is at least debating the issue to some degree in editorial columns, the citizens of many foreign countries and their governments have already made up their minds. They are not pausing to collect and evaluate substantive scientific evidence, but rather are pressing for immediate carbon dioxide emissions reductions. Naturally, large stationary emitters such as coal-fired power plants are easy targets. It remains to be seen whether these aggressive, foreign CO_2 emission reduction programs are actually implemented and enforced as they would be if they became U. S. policy.

Third, our economy continues to shrink. Electrical demand is virtually flat and raw steel production is down about 15% compared with last year. These factors, combined with the mild winter and the consequent large utility inventories, have resulted in decreased coal production and rock-bottom prices. Mines have closed and miners are out of work. Market activity has slackened as utilities evaluate their Clean Air compliance alternatives. As one eastern broker put it, "things are so bad even the guys who don't pay aren't buying."

Finally, in the midst of these events and following a war over oil, our coal industry endures considerable uncertainty while Congress debates, or more accurately, fails to debate coal's role in our National Energy Strategy.

Admittedly, this perspective commonly shared by many of us coal miners is not encouraging, but for the moment it is realistic.

Let me share with you another perspective -- that of the public.

Much of the public now views coal as the environmental villain. They believe coal mining scars the earth, is dangerous and unhealthy, and coal operators are now being framed as imprudent and dishonest as a result of the recent dust sampling controversy.

Moreover, the public believes that coal energy is dirty, polluting, inefficient, and a threat to the viability of our environment. And the additional costs to burn coal cleaner give coal an image as an unnecessarily expensive source of electrical energy.

Face it -- coal has a serious image problem. To some degree, we've earned it. Much of our image problem stems from the media coverage that our industry receives. Who can forget the images of dense, black smoke pouring out of the Wilberg Mine, or the desperate faces of the families of unemployed coal miners? Coverage of the recent dust sampling controversy confirms the public's negative perception of our industry.

Most of us here would agree that the public views coal from the wrong perspective. But this negative public perception does exist and has existed for a long time. It clearly affects our ability to shape public policy and, in fact, impacts the demand for our products. We must remember that in politics, and for the public, perception is more important than facts. Therefore, for the public, perception _is_ reality.

Now before you throw me off the podium, let me share with you a third and final perspective. I believe that in spite of the current adverse and challenging business conditions and the negative public perception, the American coal industry stands at the threshold of opportunity. We have an opportunity for leadership in energy, technology, work place safety and environmental stewardship. Tapping this opportunity will require innovation, creativity, diligence, and courage. We must be ready for change and the immense challenges of our global business.

World population will grow at an explosive rate during the next 20 to 35 years. Accordingly, projections indicate that world energy demand will increase 35% by the year 2000 and nearly 160% by the year 2025. Electric energy is a necessity for economic development. Coal _will_ play a large role in the continued electrification of the world. In fact, coal _must_ play a major role if global electricity needs are to be met. World coal use is expected to equal world oil use by the year 2000 and double oil consumption by 2025. More specifically, world coal use is projected to increase by 1.8 billion tons from 3.9 billion tons per year currently to 5.7 billion tons by the year 2000. It will then more than double to 13 billion tons annually by 2025. And while major oil reserves are geographically limited to a few nations, world coal reserves are more widely distributed and contain more than three times the energy equivalent of world oil.

Except for the environmental concerns over the combustion process, world economic and energy needs form an imperative for coal as the fuel of first choice. And the U.S. is well positioned to play a leading role in satisfying the world's growing appetite for coal.

However, fundamental market factors and logic can evaporate in the midst of an emotional public, and it is up to _us_ to better educate the public and implement operating and safety standards that are worthy of praise.

Clean coal combustion technologies are a large part of the answer, particularly here in America. Current fluidized-bed combustion technology can burn coal 11% more efficiently while removing 99% of the sulfur and releasing 20% less carbon dioxide than conventional technology. Second-generation combustion technologies promise efficiency gains exceeding 25% and carbon dioxide reductions of up to 42% compared with conventional technology.

However, coal gasification will, I believe, prove to be the premier international fossil technology of the 21st Century. Coal gasification makes absolute sense from an environmental standpoint because gasification separates the energy and non-energy components of coal without going through the conventional combustion processes. Therefore, coal gasification eliminates or substantially reduces unwanted emissions inherent in the combustion process. Long-term supplies of coal can be safely transported across continents and oceans to coal refineries near the point of end-use where the coal can be converted to gas and used to generate electricity in an environmentally prudent manner. Moreover, gasification is basically indifferent to coal quality, and plant design is similar for all grades of coal. This technology is already being demonstrated and, with further research, can be made economically available to energy-hungry developing countries. These countries, with emerging economies, must have access to stable and reliable long-term supplies of energy at reasonable and predictable prices. Coal gasification will satisfy this requirement while ensuring minimal adverse global environmental impact.

Recently, Dow Chemical Corp. began a national advertising campaign that subtly explains how the world will be a better place because of their new coal gasification process. The coal industry needs more of this positive image building.

Nuclear power will also play an important role in meeting future energy needs. However, the complexity and highly politicized nature of nuclear technology will tend to limit its widespread international use, particularly in developing nations where the coal option is perhaps better suited to their current technical and managerial capabilities. Coal gasification also has the advantage of producing high-value energy and chemical products in addition to generating electricity. In this long-term perspective, the prospects for coal are tremendous.

These three different perspectives place the coal industry at a crossroads. While the first two perspectives of coal - from the viewpoints of coal miners and the public - are indeed clear, they make the mistake of viewing the future based upon the traditions of the past. We must differentiate the coal mining and coal burning of the past from coal mining and use in the future. The vision of coal as the fuel of first choice is only an illusion if we fail to distinguish the future from the past.

What can we do to lead the world in coal use in the next century - less than a decade from now?

First, we must educate the public on coal's future capability to provide energy to the world in an environmentally prudent and sensitive manner. The old arguments for coal as a cheap and plentiful resource no longer suffice. Policy is now being shaped by issues dealing with the quality of life. Voters no longer cast their ballots based merely on their pocketbooks. The Clean Air Act Amendments of 1990 again demonstrate the public's willingness to pay for improvements to the environment. We must emphasize our ability to tap coal's tremendous benefits to meet human <u>and</u> environmental requirements.

Second, we must establish a new basis for coal utilization in the next century. The technologies under development will set us apart from the traditional modes of burning coal. Further research at this time is critical, because these technologies represent our opportunity to shape the future of coal. We should urge that Round 5 of the Clean Coal Technology Program focus on coal use in the next century and demonstrate coal's safe, economic and environmentally prudent use.

Actions always speak louder than words. The public will be skeptical about our words if positive, progressive actions are not forthcoming. Unfortunately, commercial deployment of new, clean coal-use technologies will not occur overnight, and a number of years will pass before the public is convinced that coal is the environmentally correct answer. We can and must concurrently take actions that quickly achieve results the public can see -- results such as demonstrating prudent mining and reclamation; reducing, even eliminating accidents; ensuring the health and safety of our miners by complying with the intent, not just the letter of the law; and working with the public and regulatory officials to resolve issues such as subsidence mitigation prior to, not after, the event.

In fact, we must be willing to go beyond the regulations, when necessary, to ensure the welfare of our nation's coal miners and protect our environment.

Finally, we must continue to develop the human talent necessary to ensure this vision becomes a reality. A broad array of skills in international finance, marketing, technology, environment, transportation, languages and project development will be required in addition to traditional leadership and operations management expertise, if American coal is to aid and influence developing countries in embracing new coal utilization technologies.

I admit this perspective seems distant, perhaps remote from today's very real trials and tribulations. But we in the coal industry must address the needs of our customers, publics and governments if we are to regain control of our destiny and shape the future.

So, what is the "State of the Industry"? To paraphrase Dickens, it's the best of times, and the worst of times. I'd like to think that our talents and energies can make the coal industry, as well as the world, more prosperous tomorrow than it is today.

Thank you.

TECHNICAL SESSION IV: RECENT DEVELOPMENTS

Chairmen:

George R. Bockosh
Research Supervisor
Mining Systems & Human Engineering
Bureau of Mines Pittsburgh Research Center
U.S. Department of the Interior
Pittsburgh, Pennsylvania

James Gallimore
Mining Consulting Services, Inc.
Tri-State Engineering Division
Lexington, Kentucky

HEALTH AND SAFETY ISSUES RELATED TO EXTENDED LONGWALLS

Edward D. Thimons, Robert A. Jankowski, and Gerald L. Finfinger

Pittsburgh Research Center
U.S. Bureau of Mines
Pittsburgh, PA

ABSTRACT

Longwall mining has always been associated with high productivity and increased resource recovery. To optimize these benefits, there has been a trend in the industry to increase the size of longwall coal panels. These extended longwall panels, sometimes referred to as "super longwalls", offer some major benefits in terms of fewer panel moves, less entry development, and increased resource recovery. However, the use of extended longwalls does change the mining environment and this may positively or negatively impact health and safety concerns. For example, fewer panel moves could reduce injury rates since more accidents occur during moves than during actual longwall mining. Also, the frequency of accidents in longwall mining is lower than in continuous mining. Since extended longwalls reduce the amount of continuous miner development, accident rates should be lower. On the other hand, extended panels could introduce concerns in the areas of dust, methane, ground control, ventilation, and fire and escape. In this paper we will take a look at these issues and what some current extended longwall operations are doing in terms of operating changes to address them.

INTRODUCTION

The underground coal mining industry has undergone a number of significant changes over the past century one of which has been the introduction of the longwall mining system. The first longwalling operations were small advancing faces radiating from a central point and were mined by manual labor (1). Production rates on these early longwalls were low by today's standards with maximum production being about 750 tons per day. Highly mechanized longwall mining in the U.S. was first tried in a Bureau of Mines sponsored study in 1954 at the Stotesbury Mine near Beckley, WV (2). Early longwall mining in the U.S. was not an immediate success with production rates averaging only about 530 tons per shift. However, longwall technology developed rapidly and in 1990, 96 longwalls were operating in this country. The average longwall currently produces over 1,200,000 tons per year and longwall mining accounts for about 38 pct of underground coal production. In 1990, more than 30 longwall faces claimed to be capable of producing in excess of 6,000 tons of raw coal per shift, up from 7 faces in 1987 (3). Efforts are underway to further increase longwall productivity. One approach being used is to increase the size of longwall panels (Table 1) (4). These larger panels tend to be more productive for a number of reasons:

Table 1. Data For All Longwalls.

YEAR	NUMBER OF LONGWALLS	AVERAGE WIDTH, FT	MAXIMUM LENGTH, FT	PRODUCTION FROM LONGWALLS PERCENT
1973	55	461	N/A*	4
1974	72	460	N/A	3
1975	70	465	N/A	4
1976	72	482	6200	5
1977	80	484	6200	6
1978	91	487	7000	7
1979	111	491	7000	18
1980	100	495	7000	14
1981	112	525	N/A	14
1982	112	527	N/A	15
1983	118	541	8000	16
1984	112	541	8000	17
1985	118	605	8000	18
1986	109	656	9400	22
1987	102	630	10000	25
1988	92	658	10000	32
1989	95	649	N/A	36
1990	96	707	13000	38

* N/A - Information not available

* An increased recovery of coal reserves results because longer panels mean fewer submains and wider panels mean fewer gateroads within a given reserve.

* The reduction in the number of submains and gateroads means that fewer continuous miners may be needed and it is easier for continuous miner development to stay ahead of longwall panel mining. One mine reported that the equivalent of 1.5 to 2 continuous miners were needed to stay ahead of longwall mining on their extended longwall panels where as 3 to 4 continuous miners were needed to stay ahead of longwall mining on their previous conventional size panels.

* Construction costs are reduced because of the elimination of gate intersections. Fewer overcasts and belt drive installations are needed.

* The use of longwall mining equipment is maximized because the number of longwall panel moves is reduced. Panel moves require both more supervisory personnel and miners than when mining is taking place. This increases personnel costs at a time when no coal is being mined.

Another reason that productivity has the potential to be higher on extended longwalls is that more reliable, heavy-duty equipment is required to insure that it will last through the panels. Therefore, mines are purchasing beefed-up tailgate transition pans, conveyor drives, and face conveyor components. Heavier duty shearers and shearers of a modular design are being employed in some cases. One mine using an extended longwall specifies that all longwall face conveyor components must be guaranteed for six million tons of raw coal before rebuild. Therefore, some, maybe even most, of the productivity gains on extended longwalls result from the use of more reliable equipment on the face. One mine estimated that their shift production levels increased about 12 pct from going to an extended longwall. Other mines using extended panels agree that the larger panels and associated heavier equipment do result in higher productivity.

Average panel widths and lengths are increasing yearly (Table 1) (4). In 1980, the average panel width of the operating longwall faces in the U.S. was 495 ft. In 1990, the average width of the 96 operating longwall faces was 707 ft, an increase of 43 pct. In 1980, only 24 longwall panels exceeded 5,000 ft in length with the longest being 7,000 ft long. In 1990, 50 longwall faces exceeded 5,000 ft in length; 6 of these exceeded 10,000 ft in length, with the longest of these being 13,000 ft. Indications are that this trend will continue as long as productivity gains can be achieved. Therefore, it is important to be aware of the health and safety considerations accompanying the use of extended longwalls and the more reliable equipment associated with them. The implementation of larger panels does not necessarily present a degraded health and safety environment for miners. In fact, it may even offer some safety advantages. However, it does introduce changes in the mining situation which may require different approaches to maintain a safe and healthy work environment. The following looks at some of the key health and safety issues that the Bureau of Mines believes can be impacted by the use of extended longwall panels. It is important to note that this discussion is generic in nature, and that every mine will be affected differently by the use of extended longwalls depending upon factors such as the gas content of the coal seam, the geologic conditions, the roof conditions, the physical properties of the coal, the age of the mine, the degree of automation, and other mine conditions.

It must also be pointed out that a direct health and safety comparison cannot always be made between an extended panel and a conventional size panel. In some cases the extended panel must be compared to two or three conventional panels, whose total size equals the size of the extended panel. For example, with respect to spontaneous combustion concerns, it could be argued that the perimeter of an extended panel gob is much larger than the perimeter of a conventional panel. Therefore, the extended panel is more likely to have a spontaneous combustion occurrence since they generally occur around gob perimeters in spontaneous combustion prone mines. For a true comparison, the total perimeter of the extended panel gob must be compared to the sum of the perimeters of the two or more conventional panel gobs that would occupy the same space.

DUST CONTROL

As more coal is mined, more dust is generated (fig. 1). Dust generation is primarily a function of coal production rate.

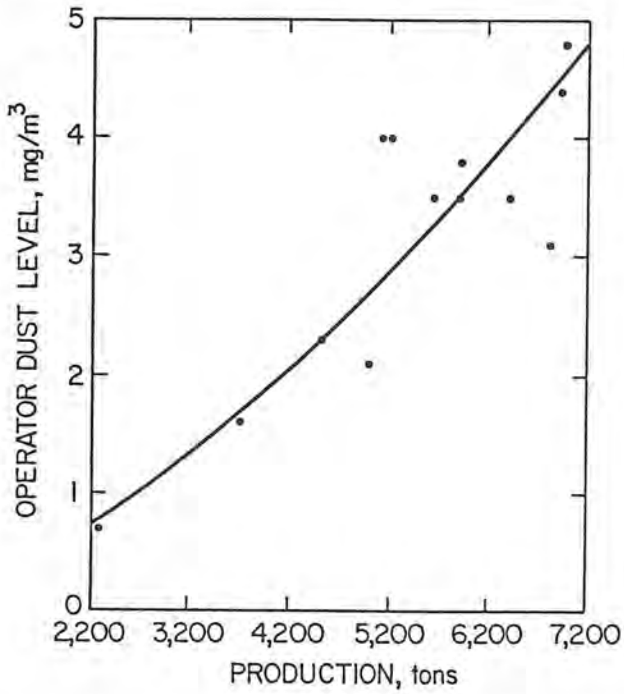


Figure 1. Dust generation as a function of coal production per shift.

Extended longwalls could result in increased dust levels for two reasons, both resulting from production increases. First, as stated earlier, extended longwall operators tend to use more reliable, heavy-duty face equipment, which generally results in higher productivity. Second, because of operational considerations, extended face longwalls will favor the use of the bi-directional cutting sequence. Productive mining time of bi-directional vs. uni-directional cutting faces improves significantly with wider faces. As an example, simulation studies have shown a 9.5 pct increase in production can be achieved with bi-directional cutting when face length is extended from 500 to 1,000 ft (fig. 2). Uni-directional cutting showed a slight decrease in production (5). However, bi-directional cutting increases the face workers exposure to respirable dust since the machine is cutting a larger portion of the time. Dust avoidance

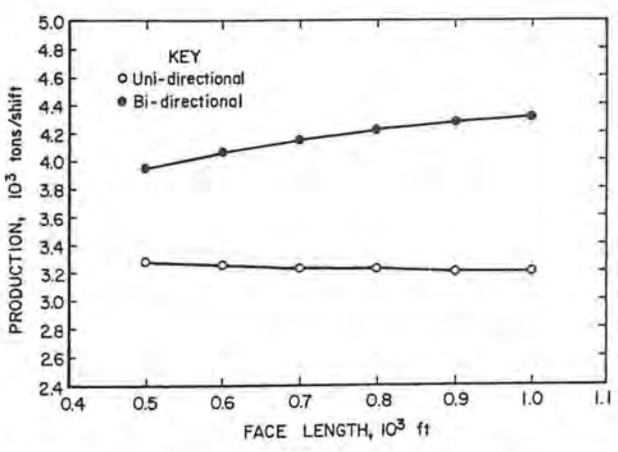


Figure 2. Impact of face length on coal production for uni-directional and bi-directional cutting.

procedures, commonly employed to reduce dust exposure on uni-directional faces, may well have limited success since the bi-directional cutting sequence will place face workers downwind of dust sources during all phases of the mining cycle. During the downwind cutting pass, the shearer operator(s) will be downwind of support advance; during the upwind cutting pass, the support movers will be downwind of the shearer.

The primary source of respirable dust on longwall faces is still the cutting action of the shearer (6). Techniques that several mines have implemented for the control of shearer-generated dust on extended longwall faces have included high drum water flow rates, deep cutting, radio-remote control, and high pressure drum spray systems. Novel approaches which are being tried at one high production, extended longwall face include the addition of water-powered scrubbers on the shearer, and the use of a combination foam/surfactant. A second extended longwall mine is currently experimenting with a compressed-air/foam generation system built into the cutting drums. Although these attempts have been quite successful, additional operating costs are associated with their implementation.

Dust generation from roof support advance and stage loader/crusher operations may contribute up to half of a longwall worker's dust exposure. Wider faces will tend to slow face advance which can allow immediate roof quality to deteriorate. Poor quality roof is responsible for debris on support canopies and results in more dust during support advance. Several mines with extended longwall faces have installed water sprays on the support canopies in an effort to wet the accumulated debris. One Western extended longwall operator is attempting to use foam, applied to the top of the canopies. The success of this approach is currently being determined. If extended panels and the associated better equipment do increase productivity, then more rapid and constant coal transport will be needed. The stageloader/crusher system will be handling more coal and thus producing more dust. Coal transport on the face conveyor may lead to potential dust problems. A novel approach being tried at one extended longwall face in Pennsylvania involves the addition of a high-pressure, water-powered scrubber on the crusher. An extended longwall mine in Kentucky has installed a scrubber in the support-line, at the headgate, in an effort to catch crusher dust as it enters the face. Some mines are increasing face air volumes and, in some cases, utilizing belt air, in an effort to improve ventilation on extended longwall faces. Increased ventilation quantities will help to remove and dilute face dust levels; however, additional attention may be needed to control dust levels along these high capacity beltlines.

METHANE CONTROL

If extended longwall panels do prove to be more productive, some of these potential productivity gains could be limited in the more gassy coal seams. It is likely that extracting gassy coal at a faster rate from larger panels could add to methane emission problems. Additional ventilation capacity or more gob gas drainage boreholes might be needed. Research conducted at a mine operating in the lower Kittanning Coalbed in Pennsylvania, revealed that when a more efficient, higher capacity conventional size longwall was installed, the time to mine a panel was reduced from 261 days to 191 days. Total methane production from the gob gas vent hole on the new panel (same size) increased only 13 pct over the life of the panel. However, the daily production increased by 56 pct from 2.5 MMcfd to 3.9 MMcfd. It appears that while the total volume of gas available to flow was only slightly increased, the higher extraction rate exposed that volume of gas to the mine in a shorter time, therefore, increasing the daily exposure volume. If extended panels do result in higher production rates due to better equipment and bi-directional cutting, then methane emission rates may be higher.

In a study of gas emissions from longwall panels in a moderately gassy area of the Pocahontas No. 3. Coalbed in Virginia, it was found that expanding panel width only 11 pct from 630 ft to 700 ft, while maintaining the same panel length, increased the total methane emissions by almost 70 pct (fig. 3). The vast majority of this additional gas occurred in the gob and was vented out of the gob gas boreholes. The increased emissions resulted from the 11 pct larger panel and from the associated changes in the caving patterns. This level of increased methane emissions could have been an exceptional case,

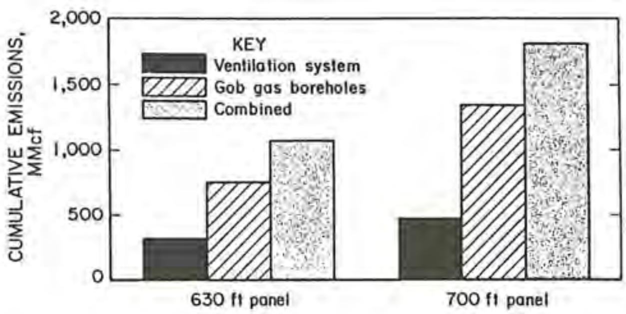


Figure 3. Impact of panel width on methane emissions in a Pocahontas No. 3 coalbed.

but it does imply that larger panels in gassy mines could require more ventilation or improved methane drainage.

While methane emissions on the larger dimension longwall panels will be higher if production rates increase, the majority of the increased emissions will most likely be in the gob areas from superjacent and subjacent strata. The additional methane load can best be handled by installing a larger number of gob gas drainage boreholes. In the experience of some mines it has been necessary to install 8 or 9 gob gas boreholes for each extended longwall panel. While the cost of these boreholes can be significant, they do provide an efficient method of dealing with the increased emissions. Figure 4 shows that gob gas boreholes on an extended longwall panel in the Pocahontas No. 3 coalbed captured double the amount of methane that was carried away by the mine's ventilation system over the life of the panel.

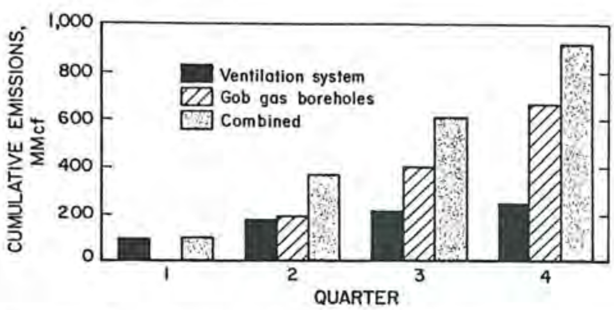


Figure 4. Gas emission patterns on a longwall as a function of time.

GROUND CONTROL

Extended longwalls contain as much as three times as much coal as conventional size panels, and therefore, require significantly more time to mine. As a result, the service lives of the gateroads are extended considerably. Additionally, on extended longwalls, gate development must begin earlier relative to face start-up, because the longer gates take more time to mine. It is well known that the longer a mine opening needs to remain open, the more likely it is that conditions will deteriorate. This is particularly true for entries like longwall gates that are subject to heavy abutment loads from full-extraction mining (7). These gates may require larger protective chain pillars and/or additional artificial support (8).

One issue with extended longwalls is increased abutment loads due to the additional face width. Analysis suggests that in many instances this should not be a concern. Once a panel reaches a "critical" width, all additional abutment loads are actually carried by the gob. Most extended panels will fit into this category, however, there can be specific geologic conditions that may result in instabilities depending on the behavior of the strata in the gob (9).

Recently, longwall face bumps have been associated with the inability of massive strata to break upon coal extraction in a timely fashion. A limited number of deep longwall mines are subject to these incidences. It appears that this massive roof strata spans over the extraction panel, avoiding failure until the adjacent panel is pulled. The cantilevering of large volumes of roof strata adjacent to active longwall faces exerts tremendous stress on the longwall panel and adjacent gate entry pillars, increasing the potential for coal bumps. How extended panels will be impacted by this phenomena is not clear. It is believed by many that the wider panels on extended longwalls can produce a critical span which will assure the proper caving of the roof strata. Unfortunately, the influence of the strength, thickness, and geometry of the massive roof strata at different overburdens is poorly understood. Therefore, widening a longwall panel in massive strata may or may not escalate the potential for longwall face bumps (10,11).

Past studies have shown that the face alignment can significantly affect the loading gates on longwall faces and make ground control more difficult. The profile of the caving line largely follows the profile of the face position and portions of the face that lag behind will generally see higher loading rates on the supports and coal face. These conditions degrade the stability and control of the face area. The wider faces on extended longwalls could make face alignment more difficult.

Longwall operators have implemented a variety of modifications to their longwall systems to help alleviate potential ground control problems that may arise during mining of the larger dimension panels. To counteract the potential for increased abutment loads during a slower retreat operation, some mines are installing larger shields. Average support capacities have increased significantly over the past 20 years (fig. 5). The higher capacity supports provide an additional protection against increased abutment loads if the retreat of the panel is interrupted or delayed. Some operators are also increasing the number of mining shifts per week on the panels to ensure panel retreat is keeping ahead of the gob loading. One mine using an extended panel, found it necessary to mine seven days a week to keep the increased weight from catching up with them on the face. There has also been an increase in the use of automated shield advance systems, which help in maintaining a straight face alignment. At least one extended longwall mine has found

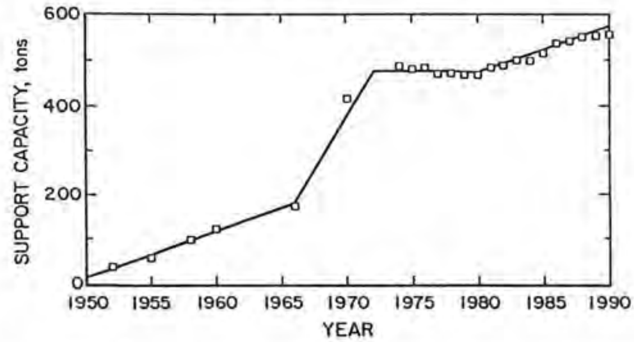


Figure 5. Increasing average support capacities as a function of time.

it necessary to do additional roof supporting in the headgate and tailgate entries, especially in the area within 150 ft of the face. In several instances, roof falls in this area partially closed off the tailgate escapeway and required immediate cleanup.

VENTILATION

Ventilation will play a key role with respect to dust control, methane control, and escapeway planning on extended longwalls. The longer entry lengths and face widths result in higher ventilation pressure drops than are encountered on more conventional size longwall panels. This will be particularly true in low seam coal mines. Higher ventilation pressures are not only needed to adequately ventilate the face during panel mining, but also to provide enough air during the driving of the long gate entries. Careful consideration must be given to designing ventilation systems which overcome the pressure drops associated with extended panels. Limiting air leakage along stopping lines becomes more important on extended panels. Good stopping construction techniques, capable of handling the higher than normal differential pressures, are vital. Reliable mechanical reinforcement of entries to maintain their original shape is also critical to minimize their airflow resistance. If, after doing the above, the overall mine ventilation system is still not of adequate capacity and configuration to provide enough pressure at the outby end of the gate entries, then several approaches can be tried.

* The air carrying capacity of the entries may have to be increased by increasing the number of entries, or obtaining a petition for modification and taking the necessary precautions to use the belt entry to carry ventilation air.

* The fan capacity of the mine can be increased to a level where the needed flow and pressure are delivered to the longwall entries.

* Additional shafts can be drilled to exhaust air at the backsides of the extended panels.

One mine that went from using conventional size longwalls to extended longwalls, found that they were able to reduce the number of entries from 4 to 3 on the extended panels by introducing exhaust boreholes at the tailgate ends of the panels (fig. 6). Both the headgate and tailgate entries are used as intakes, with all 125,000 cfm of ventilation air exiting out of the 4 ft diameter exhaust ventilation borehole. One borehole is drilled for every two panels. To keep velocities and resistances lower, the belt entries are used as intakes. Panel air is supplied from two separate splits of intake air.

A second mine now using extended longwalls originally increased the number of panel entries from the 4 they were using on their conventional size panels to 5 on one extended panel and 6 on another extended panel.

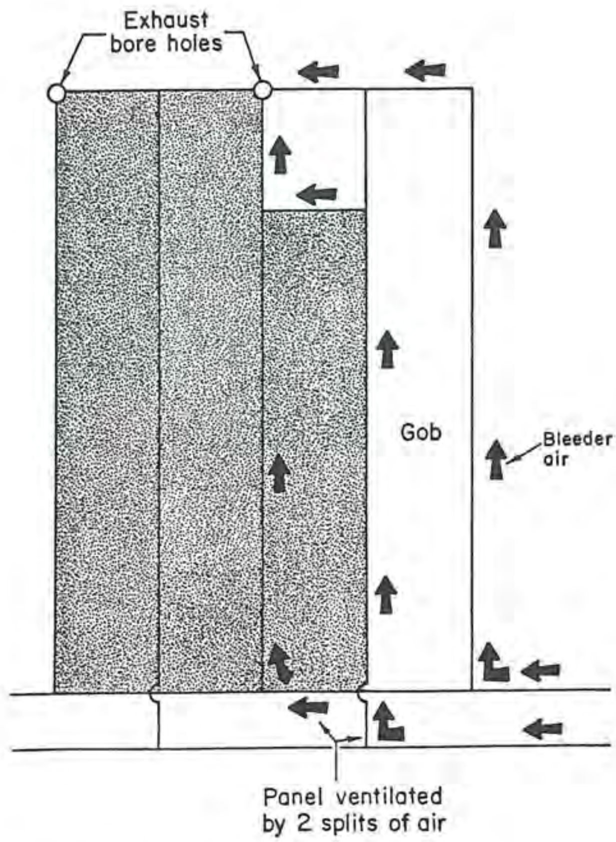


Figure 6. One mine's approach to ventilating extended panels.

They felt this was needed to handle the additional ventilation needs. However, the introduction of increased mine fan capacity and additional exhaust shafts allowed them to go back to 4 entry systems. They drill an exhaust shaft capable of handling 150,000 cfm at the backside of a series of panels. This shaft handles all of the bleeder entry air and a portion of the exhaust air from each panel as it is mined.

FIRE AND ESCAPE

The use of extended longwalls raises a number of issues related to mine fires and escapeways. These issues are not unique to the larger panels, but can be somewhat magnified by the size of the panels.

In the limited number of mines prone to spontaneous combustion, the extensive gobs resulting from extended longwalls may pose some unique concerns in terms of fire detection and suppression. The detection and suppression of spontaneous combustion fires in the gobs is already a problem on a few conventional longwall sections. If these same mines had extended longwalls, it could be an even more difficult task because of the somewhat slower face advance rates, and the higher ventilation pressures required. Spontaneous combustion fires in gobs generally occur along the perimeters of the gobs where ventilation air provides the needed oxygen and in the caved area just behind the face because air escapes into the gob in this area. The gob area just behind the face will be ventilated for longer periods because face advance will be slower. The higher ventilation pressures required to supply air on extended longwalls may force air further into the gob, thus increasing the potential for spontaneous combustion to occur.

Some people in the industry believe that extended longwalls will require improvements on both fixed and mobile fire suppression equipment. Because of the longer distances involved on extended panels, available water hoses and foam generator equipment will have to be more mobile or more readily available.

Extended longwalls obviously result in longer escape routes off of the panels. It could be argued that this has a negative impact on mine escape since escapeway distances are longer. The critical factor is how long it takes for a miner to get outby the fire. If the increased panel lengths cause miners to have to travel a further distance to get outby of a fire, then the extended panels will impact safe escape.

A recent Bureau fault tree analysis showed that the most critical factor in escaping a mine fire was how quickly miners were notified of a fire and attempted to get outby the fire. Therefore, automated fire warning systems, which detect the products of combustion, such as carbon monoxide (CO) or smoke, are critical on extended longwalls. Early warning of a fire is imperative for successful escape. At least two mines now using extended panels have CO monitors at 1,000 ft spacings along their belts. In one mine the belt is used as an intake, necessitating the use of monitors by law, while in the other mine the belt is a neutral entry. The CO monitors in the neutral beltway will probably be slower to detect a fire, but they still provide an added degree of safety.

Additionally, several other considerations can improve the chances of escape from extended panels. Careful ventilation planning of escape routes and the use of reliable doors and stoppings are important. Innovative designs of ventilation systems can improve the potential for safe egress during a mine fire. For example, having the panel ventilated by two pressure balanced intake airways, each from a separate split of air, increases the chance for escape through clean air. The closer to the escape shaft that the separate splits of air originate, the better. It is important that such a ventilation system be properly designed or flow may stagnate across the face or in the bleeders. As pointed out in the ventilation discussion, one extended longwall mine is bringing two separate splits of intake air to the face through both the headgate and tailgate entries and exhausting all of the panel air out of a shaft at the back of the panel. This method improves the escapeway integrity since it becomes more difficult for contaminant-laden air to pervade both escape entries. Provision should be made for miners to ride out of the panel in the event of a fire, rather than having them walk. This not only speeds up escape time, but reduces the possibility that miners will have to travel through smoke.

FEWER PANEL MOVES MEAN FEWER ACCIDENTS

While extended longwalls may raise some health and safety issues, they are not without potential advantages in this area also. By reducing the number of longwall moves, there is a corresponding decrease in the number of longwall related accidents. In discussions with several longwall operators, there was general agreement that the frequency of accidents is much higher during longwall moves than during actual mining of a panel. There are several likely reasons for this increase in accidents. A major reason is that significantly more non-routine work is done during longwall moves. Also, larger crews are required to move a longwall, than to operate one. As many as 30 personnel may be involved in a longwall move as opposed to about 7 or 8 to mine coal on a longwall face. Many of the people involved in a longwall move may not be as well trained and experienced in underground safety practices as are the daily longwall crews. Additionally, many mines bring extra management personnel underground to assist in longwall moves. They also may not have as much experience as the individuals who supervise the daily longwall operations. Finally, during longwall moves there is a significant amount of support equipment in the area, which introduces an additional hazard. Additional diesel support equipment may increase the number of nuisance alarms on CO monitoring systems which defeats the benefit of the warning systems. Several mines reported an increase in back injuries along with injuries to hands, arms, and feet during longwall moves. These are injuries typically associated with the moving of large equipment such as occurs in a longwall move. Therefore, minimizing the number of longwall moves by going to extended panels could have a beneficial safety advantage.

ACCIDENT RATES WITH CONTINUOUS MINERS HIGHER THAN WITH LONGWALLS

The use of extended panels reduces the amount of continuous miner development because fewer submains and gateroads are needed. As noted earlier, one mine reported that going to extended panels reduced the number of continuous miners needed to stay ahead of panel development to the equivalent of 1.5 to 2 on their extended panels from 3 to 4 on their conventional size panels. Table 2 shows that accident rates are considerably higher for continuous miners than for longwalls both in terms of accidents per 200,000 manhours and per million tons of coal mined. Data for years 1988 and 1989 show that accident rates with continous miners were almost three times higher than with longwalls on a per manhour basis and more than two and a half times higher on a per ton basis. Therefore, if the use of extended panels can decrease the amount of continuous miner development, accident rates should be lower in mines using extended panels.

Table 2. Longwall vs Continuous Miner Accident Rates.

Mining Method	Year	Per 200,000 manhours	Per 1,000,000 tons
Longwall	1988 1989	6.12 4.94	10.11 9.43
Continuous Miner	1988 1989	16.09 14.94	28.57 25.00

SUMMARY

Many of the health and safety issues associated with extended panels are related to increased production rates. The increased production may result less from the use of larger panels than from the use of more reliable, heavy-duty equipment designed to last through the larger panels. Additionally, care must be taken in comparing health and safety concerns on extended panels to more conventional size panels. In many cases, to obtain a true comparison, the extended panel has to be compared to the two or three conventional size panels that would occupy the same area as the extended panel. There are, however, potential health and safety concerns in the areas of dust, methane, ground control, ventilation, and fire and escape associated strictly with the use of larger panels. It is essential to be aware of these potential concerns if extended panels are to be operated in a safe, healthy, and efficient manner. Several current extended longwall operators have made changes in their operating procedures to address these concerns. On the other hand, there are potential safety advantages to using extended panels. Fewer panel moves and less continuous miner development should translate into lower accident rates.

REFERENCES

1. Laird, W. "Longwall Mining". SME Mining Engineering Handbook, American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., 1973, Vol. 1, pp. 12-74.
2. Haley, W.A., and H.A. Quenon. Modified Longwall Mining with a German Coal Planer. BuMines RI 5062, 1954, 13 pp.
3. Merritt, P.C. As Time Changes So Do Longwalls. Coal, February, 1991, Vol. 96, No. 2, pp. 40-49.
4. Much of the data in this table obtained from Coal Age and Coal Magazine annual longwall census reports and from DOE coal mine productivity reports.
5. Organiscak, J.A., K.L. Whitehead, and D. Wiltsey. A Flexible, User-Friendly Longwall Simulation Model for Production Optimization. Published in the Proceedings of Longwall USA, Pittsburgh, PA, Sept. 1988.
6. Jankowski, R.A., and J. Hake. Dust Sources and Controls for High Production Longwall Faces. Published in Proceedings of Longwall USA, Pittsburgh, PA, May 1989.
7. McWilliams, J.K. Super Longwall Panels - Practical Limits on Longwall Size. 1990 Joint Meeting PCMIA/SME, Washington, PA, October 30-31, 1990, 20 pp.
8. Pothini, R. Panel Width Effects on Shield Supports. Coal Magazine, October 1989.
9. Peng, S.S. Longwall Mining. Wiley & Sons, 1984, pp. 274-280.
10. Haramy, K.Y., and J.P. McDonnell. Causes and Control of Coal Mine Bumps. BuMines RI 9225, 1988, 35 pp.
11. Campoli, A.A., C.A. Kertis, and C.A. Goode. Coal Mine Bumps - Five Case Studies in the Eastern United States. BuMines IC 9149, 34 pp.

COPING WITH SPONTANEOUS COMBUSTION PROBLEMS AT THE NO. 5 MINE OF JIM WALTER RESOURCES

by

J. W. Stevenson
General Manager, Ventilation

and

T. E. McNider
Deputy Manager, Ventilation

INTRODUCTION

The first spontaneous heating that occurred at the Jim Walter Resources No. 5 Mine was reported to MSHA on November 15, 1986.

Figure 1 - As of October 1990, there have been eight reportable spontaneous heatings. A reportable heating is defined as one with an elevated surface temperature of the floor strata greater that 20°F above the ambient. The last three heatings were located near the start line of "**K**" Longwall Panel in the southwest where longwall mining started on May 21, 1990.

GENERAL MINE VENTILATION

Figure 2 - To ventilate the mine, three exhausting axial flow fans are used. Total horsepower dedicated to ventilation is 10,500. Mine fans are (10 - 12 ft) in diameter, 900 rpm, and require 3500 hp per fan. The fans used by No. 5 mine are unique in that the fan blade attack angle can be adjusted while the fan is in operation. To maintain methane dilution to acceptable limits, exhaust mine fans are used that can develop 15 inches water gauge total fan pressure at 1,125,000 cfm of air. Two fans are installed on the 5-5 fan shaft with a single fan in operation on the 5-3 fan shaft. There are four intake airshafts. A total air volume of 2,850,000 cubic feet per minute is exhausted from the mine.

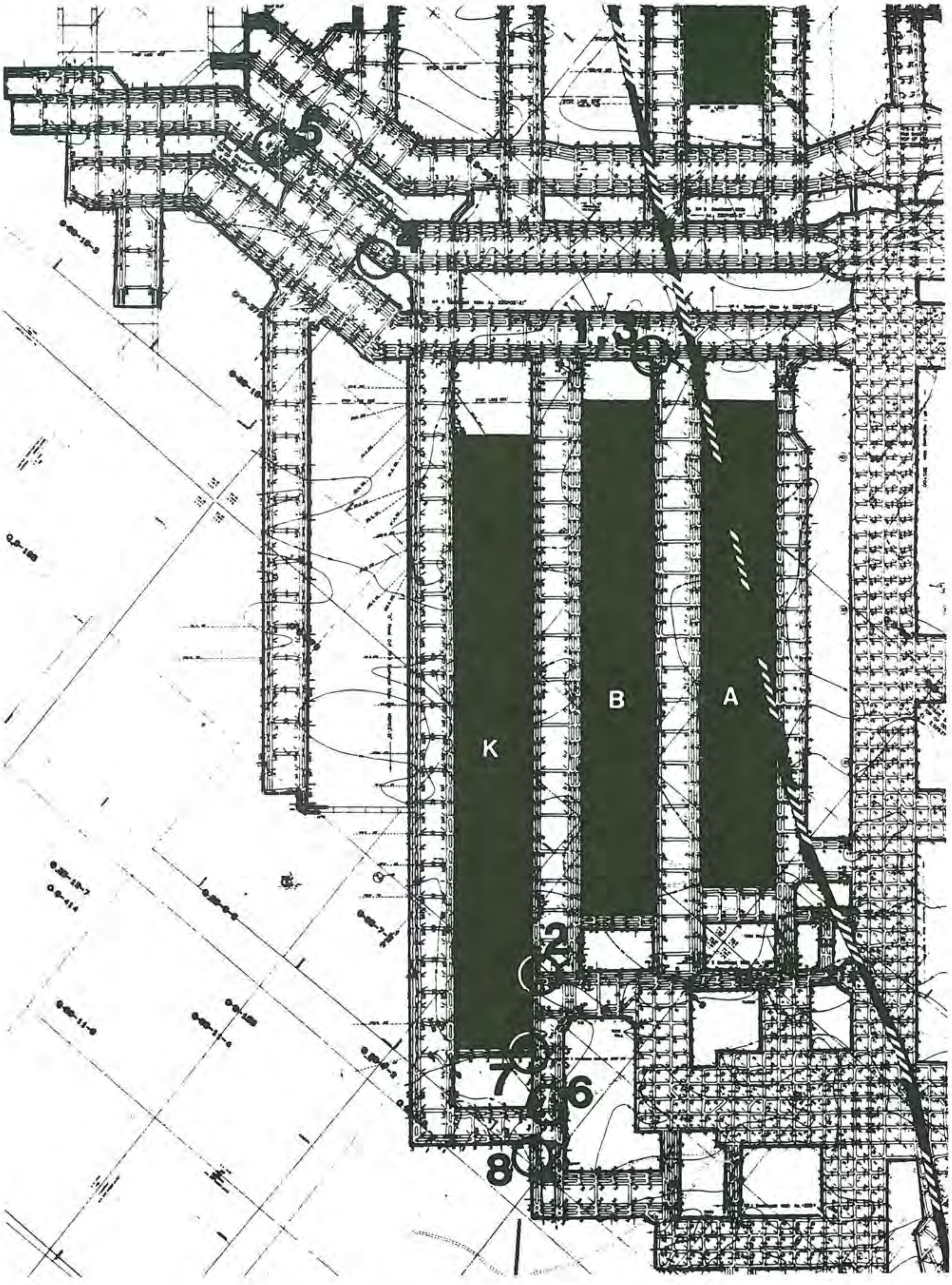


Figure 1

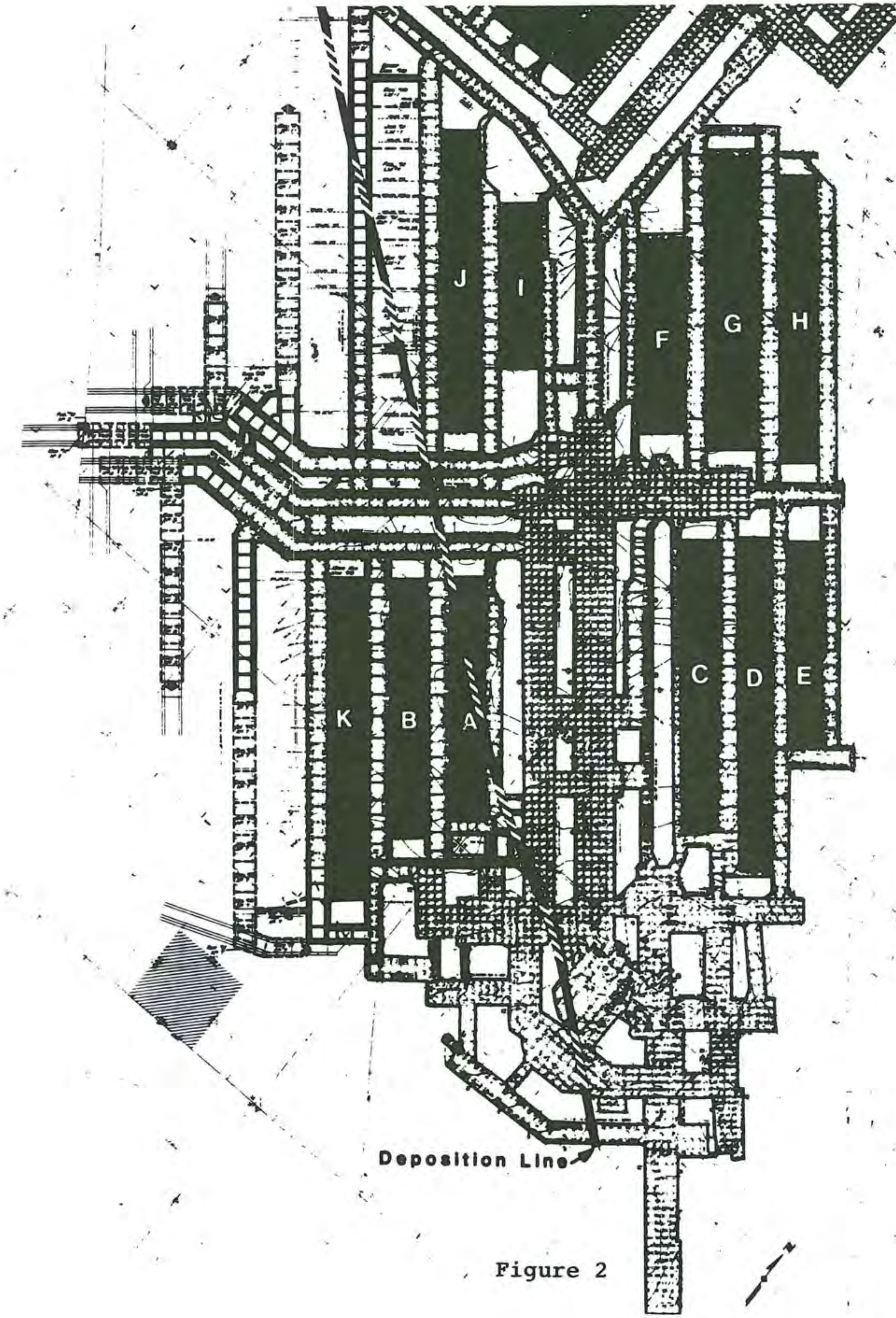


Figure 2

CONVENTIONAL LONGWALL VENTILATION

Longwall faces are ventilated from headgate to tailgate (anti-tropal). The primary intake is coursed through the headgate entries with a secondary intake coursed through the tailgate entry. Approximately 250,000 cfm of air is coursed through a longwall system to the bleeder entries for methane dilution. Pressure differentials across the gob from the headgate of the face to the tailgate of the bleeder can vary from 3 to 9 inches. Face volumes can vary from 50,000 to 100,000 cfm depending upon methane liberation. This system of longwall ventilation is generally used at all of the Jim Walter Mines.

As the longwall face retreats, pressure differentials across the gob change. Tailgate resistance from the face to the bleeders increases as the face retreats causing pressure differentials across the gob to increase. Air volume flowing from the face of the longwall through the tailgate to the bleeders can be as high as 150,000 cfm. With increased resistance, this flow can drop to as low as 20,000 cfm. This change in air volume and pressure differential can, on the one hand feed air to the pyrite material thus starting the oxidation process whilst at the same time creating a situation where there is not sufficient air available to cool the products of the combustion. In this way the heating process accelerates until an open fire occurs. The tailgate area between the gobs is an area that cannot normally be inspected. Therefore this area of longwall is of particular concern to us. Should a heating occur in this area, it is questionable whether a person could physically get to the location to apply water to cool it. From the ventilation status before and at the time of detection of the heatings, the heatings appear to require a flow of air sufficiently low through the actual reaction area to allow heat to build up. This situation can occur under high pressure differentials combined with limited crack permeability or low pressure differentials and high rock permeability. To reduce the possibility of such heatings occurring in the tailgate entry behind the longwall face, the following plan was proposed by JWR and approved by MSHA.

SPONTANEOUS COMBUSTION CONTROL PLAN

The objectives of the Spontaneous Combustion Control Plan, as compared to conventional longwall bleeder control techniques, were as follows:

1) Reduce the pressure differential across the active gob.

2) Minimize air flow into the gob.

3) Allow methane and inert gases to build up in the

active gob.

4) Displace oxygen in the active gob air to the lowest practicable level with methane and inert gases.

5) Reduce explosive fringe of CH_4 and air mixture zones to only that in contact with the mine's ventilation system directly behind the face line. This is compared to four sides in the explosive range with conventional ventilation.

To achieve these objectives and limit the amount of air allowed to enter the gob, seals had to be constructed in the connectors between the gob and bleeder entries. The seals constructed were built of either thirty inch long wood crib blocks or cross-coursed solid concrete blocks. Two older adjacent gobs were sealed together with the active gob. This was done because the Spontaneous Combustion Control Plan was not attempted until the active wall had advanced to such a point that the active wall could not be separated from the older gobs. A total of fifty-five seals were constructed during the process of trying to implement this plan.

Primary air coursed up the headgate entries across the face and returned out the tailgate. A secondary split of intake was coursed up the tailgate entry that is adjacent to the longwall panel. The total longwall air, except a small split coursed up the headgate was vented out the remaining tailgate entries. To prevent fresh air from migrating into the gob a metal stopping was used across the No. 2 entry and an air check curtain across the No. 1 entry on the headgate adjacent to the longwall face line. Also, light weight cement plugs were placed in the No. 1 and No. 2 entry every 125 ft. behind the face.

Increased monitoring was implemented in order to protect the active works from the potential hazards created by the sealed gob. Three additional methane sensors were engineered into the longwall electrical system. These sensors, in addition to the one on the tailgate, were spaced approximately every 200 ft. along the face. The sensors were placed on the back of the shields to protect the face from methane which could be pushed out of the gob by severe roof caves. All monitors were set to give a warning at 1% and to shut off electric power to the longwall at 2% methane.

Carbon monoxide and methane were monitored in the tailgate return entry prior to mixing with another split. These air samples were drawn through tubing by a vacuum pump to sensors and monitors located in intake air. The concentrations were continuously monitored by a person in a control room who had communication with a responsible person underground who could immediately investigate and determine the cause for an abnormal rise in the concentrations of either gas.

The Spontaneous Combustion Control Plan was approved on July 20, 1990 by MSHA.

DIFFICULTY IMPLEMENTING THE PLAN

The major difficulty in applying the control concept resulted from the problem of controlling leakage at the numerous seals. The number of seals is a direct consequence of attempting to merge the traditional bleeder system used in all the Blue Creek Mines with the bleederless system which Jim Walter Resources proposed as a means of controlling the spontaneous combustion hazard. Leakage at the seals had been excessive at times, thus defeating the objectives of the plan. Control of this leakage was minimized by pressure balancing and additional guniting on the seals themselves.

Once leakage was controlled by pressure balancing and additional guniting on the seals, Mine Management was hopeful that sufficient methane would be generated from mining and the creation of new gob to adequately inert the atmosphere within the sealed gob area. Methane did begin to climb, but at a slower rate than anticipated. The association with the two older gobs which liberated very low amounts of methane, together with the time the active wall had been idle and not producing coal, delayed the time it would normally take to generate enough methane to create an inert atmosphere within the sealed area. The plan was revoked because methane and oxygen levels tested behind the seals, in the gob area where spontaneous combustion could occur, were at explosive levels. The mine operated under the plan for 29 shifts.

The rank of the Blue Creek Seam also compounded the problem. The Blue Creek seam is a low to medium volatile, high rank coal. The coal does not readily oxidize to generate carbon dioxide. Therefore, the primary means of reducing the oxygen was by displacement with methane. In order to lower the oxygen levels to a range considered by the Bureau of Mines to be low enough to see a significant reduction in the oxidation process and maximum temperatures achieved, methane would have to increase to a concentration in excess of 60%, thus lowering the oxygen level to 8%. To achieve methane concentrations of 60%, a near perfect balance would have to be maintained on the seals. In a dynamic situation this was impractical to maintain.

MODIFIED SPONTANEOUS COMBUSTION CONTROL PLAN

Longwall mining was completed in "**K**" Panel using an approved modified spontaneous combustion control plan.

This plan incorporated the following:

1) The longwall face was basically ventilated by a wrap-around system.
2) Intake airflow on the tailgate was extremely reduced.

3) Air quantities and velocities in and around the gob areas were reduced to as low as possible.

4) Air monitoring and backup continuous carbon monoxide monitoring of return air splits was increased. Low level alert and alarm levels were transmitted to the command center where a communications supervisor was always on duty when miners were underground.

The longwall moved from **"K"** Panel in the south to **"L"** Panel in the north in February of this year. The panel is ventilated in accordance with the general longwall ventilation plan used in all of our mines.

Longwall panels A, B and K have since been sealed from the active workings of the mine because of spontaneous combustion problems associated with the heaved floor strata west of the expanded coal seam line that traverses the mine property in a northwest-southeast direction. The ventilation and safety problems associated with mining **"K"** Panel demonstrated to Jim Walter's that different ventilation principles must be used if the coal reserves in this area are to be successfully mined.

The United States coal mining industry is currently mining slightly gassy coal beds that are prone to spontaneous combustion. Europeans are successfully mining coal beds that are prone to spontaneous combustion and that also liberate high quantities of methane. In every case, the solution is the same: **"KEEP OXYGEN OUT OF THE GOB."**

In the 1970's, the U.S. Department of Energy funded the British National Coal Board Consultants Limited (NCB) in association with Dames and Moore, U.S. Consultant Engineers, to prepare a report titled **"A REVIEW OF SPONTANEOUS COMBUSTION PROBLEMS & CONTROLS WITH APPLICATION TO U.S. COAL MINES."** The report was published in September 1978 under contract number U.S.D.O.E. ET-77-C-01-8965.

Figure 3 is a sketch illustrating European longwall retreating face ventilation practices using single entry headgate and tailgate development. It is contained in the NCB consultants' report. With this system in mind, we are suggesting that the following mining plan be researched, engineered, and implemented to mine the area west of the fault where our core drill findings indicate that the expanded seam is prevalent and where spontaneous heatings are likely. This plan should be considered for any coalbed where there is spontaneous combustion potential.

PROPOSED PLAN

Development entries (Figure 4) are mined using the yield-stable-yield pillar configuration that has proven so successful in our deep mines to maintain egress off the tailgate. Intake air flows toward the faces in the No. 2 and No. 3 entries; one of which is the intake escapeway, the other is the carbon monoxide monitored belt conveyor entry. Fishtail split ventilation is used in the face region to reduce the possibility of working or roofbolting in the dust contaminated airstream downwind of the continuous miner. Entries No. 1 and No. 4 are return air courses with one of them designated the alternate escapeway.

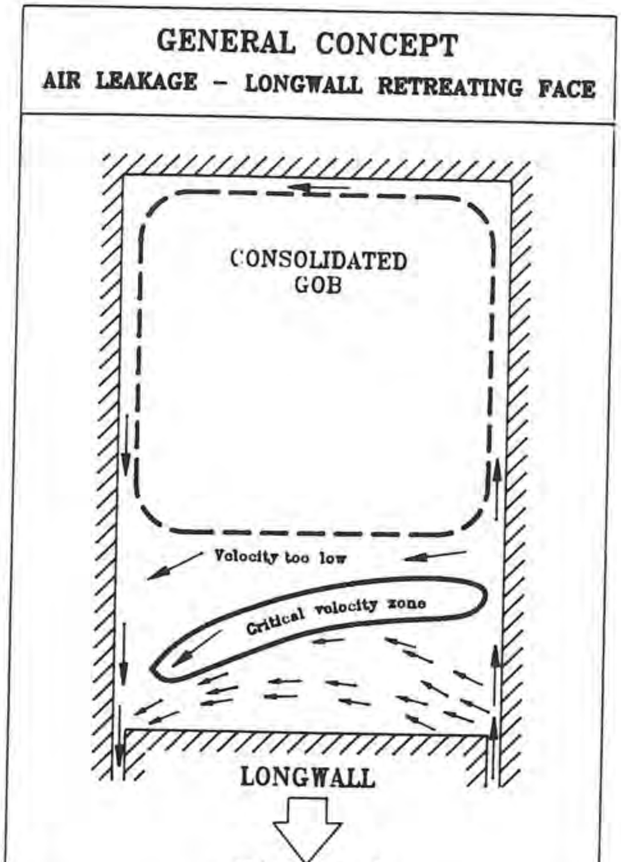


Figure 3

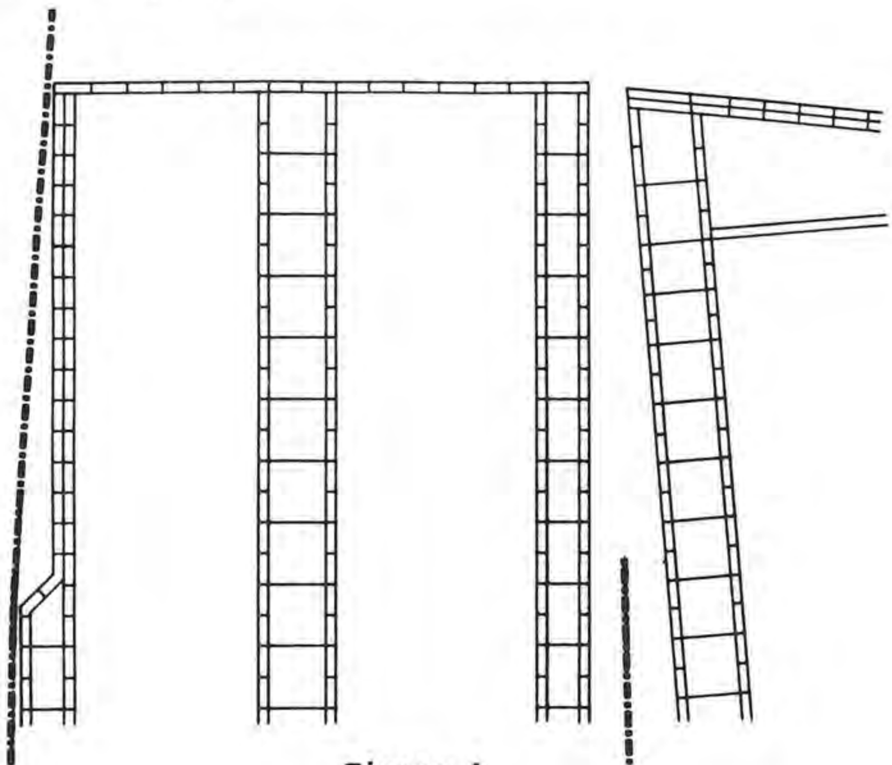


Figure 4

Figure 5 - At the end of the continuous miner development, the two longwall rooms are connected. It is our practice to set up the longwall face in the No. 2 or outby room. Our experiences in the southwest **"K"** Panel indicated that, with the partially collapsed yield pillars adjacent to the longwall gob in both the headgate and tailgate entries, minor airflow continued in the headgate airways in a **"U"** shape, across the inby setup room and out the tailgate entries adjacent to the gob. This airflow occurred in the caved entries even with the installation of Kennedy stoppings, plastic check curtains, rockdust and tekfoam plugs behind the longwall face. The wood-cribbed No. 1 setup room (our normal practice) is thought to be a major contributor to the fugitive **"U"** shaped gob airflow.

In the proposed plan, the longwall would be set up in the No. 1 or inby room. Longwall mining would commence by mining the yeild pillar separating No. 1 and No. 2 or outby room, and then mining the longwall block would follow. Near the midpoint of the longwall face startline, a plug of rockdust/tekfoam would be injected behind the shields to reduce the likelihood of fugitive **"U"** shaped gob airflow.

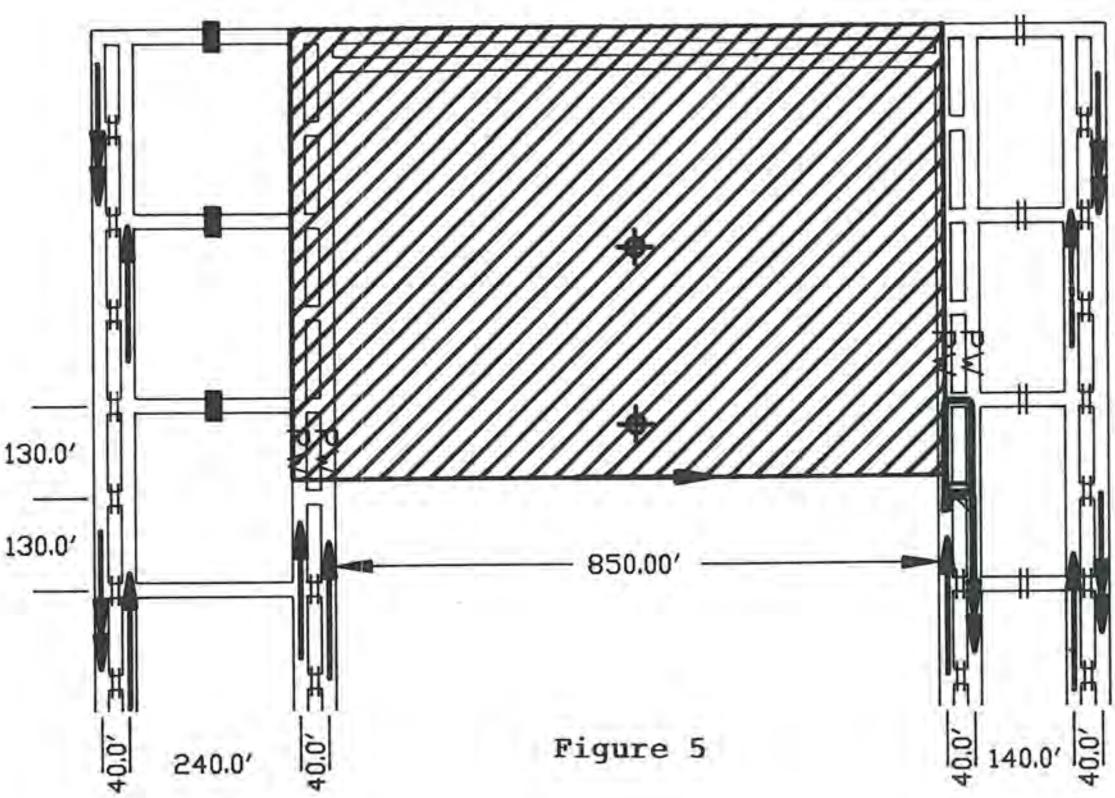


Figure 5

In the proposed mining plan, development entries do not connect into the existing bleeder entries of the mine. Full reliance is placed on the number and the capability of the gob wells to extract methane from the rock strata horizons above and behind the coal face. Gob wells played a critical role in our original spontaneous combustion control plan and will continue to do so in the propposed mining plan in order to maintain compliance with Subsection 75.305 of 30 CFR.

The longwall face ventilation approximates the British **"Back Return System"** in that the lowest ventilating pressure in the face area is in the cross-cut behind the longwall face. Due to ventilating pressure, it is to this cross-cut that gob methane will migrate. Of course, face velocity and quantity must be adequate to maintain less than one percent methane concentration.

In the two entries adjacent to the longwall gob area on both the headgate and tailgate, packwalls will be installed using either bagged rockdust, tekfoam or similar non-combustible material.

Jim Walter Resources has been working closely to solve this problem with the various centers of the U.S. Bureau of Mines since the original heating in 1986. It will soon be five years. Within two years, No. 5 Mine will be longwall mining west of the fault and in a suspect spontaneous combustion prone area.

The mining and ventilation plan that has been proposed today, we believe, meets the requirements of Part 75 of the Code of Regulations. Based upon our experiences in **"K"** Panel, we believe it is the better plan to successfully mine the area in question.

We suggest that a working committee comprised of interested personnel from the U.S. Bureau of Mines, MSHA, UMWA, academia, and affected coal mining companies visit British and European coal mines to investigate their solutions to this perplexing problem. Solutions are available that will allow JWR No. 5 Mine to continue safe mining operations. If a mining and ventilation plan does not offer adequate protection to the miners, it is totally unacceptable to Jim Walter Resources, Inc.

Ground Control in Multi-Seam Mining

C. Haycocks

Department of Mining and Minerals Engineering
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0239

INTRODUCTION

The problems caused by underground mining in a multi-seam environment continue to escalate, and today there are few mining companies that do not suffer some effects from interaction. Such problems not only significantly increase mining costs due to accidents, increased support cost and production delays, but are also inhibiting the development of new seams. Outright reserve losses are now becoming very apparent and there is an increasing reluctance to start mining in seams that are going to be subject to significant levels of interaction. The problem is very complex in mining areas where the mining layouts and conditions in the affecting seam are unknown. Research into the problems of interaction have outlined many of the basic mechanisms and quantified some of the factors affecting stability. These now allow a starting point for realistic layout design as well as a technique to determine recoverable reserves.

As in all ground control design the results cannot be better than the quality of input data. Utilizing data interpolated from boreholes that may be up to a mile apart can be a tenuous occupation frequently leading to either gross over or under design. However, assuming a reasonable estimate can be made of ground conditions, interaction effects can be determined with an acceptable level of confidence.

SITE CONDITIONS

Interaction between multi-seam mines will continue to increase as one of the biggest sources of ground control problems in underground coal mining. The complexity of the problem can be demonstrated by considering the three possible mining systems: longwall, room and pillar, and pillaring. Then considering three possible mining sequences of over, under and simultaneous mining, up to 27 possible mining combinations can be arranged. When one considers that over twenty mineable seams exist in some areas, it can be seen that the possible combinations involving multi-seam mining are enormous. It has been estimated that 156 of the 229 billion tons of bituminous coal in the U.S. may be subject to interaction (Engineers International, 1981).

Already, damage between seams is causing considerable friction between mining companies attempting to mine on different horizons. Accidents, some with loss of life, high production costs, and lost reserves are also resulting from multi-seam interaction. How bad the conditions will be on each horizon will depend to a large extent upon the geologic conditions that exist where mining is to occur. Typically the site conditions which will determine whether interaction occurs and the degree of damage are (Haycocks and Zhou, 1990):

Uncontrollable:
(a) Geology and structure
(b) Depth to upper seam
(c) Innerburden thickness
(d) Stress field including depth
(e) Water

Possible control:
(f) Time between mining
(g) Mining system

UNDERMINING

Interactive Probability

Whatever mining method is selected for the lower seam, the net effect of the upper seam mining system will be either in the location and magnitude of stress concentrations affecting the lower seam or in block shearing. Operational variables during undermining are:

(a) Extraction ratio
(b) Relative position of the workings
(c) Mining height
(d) Pillar dimensions
(e) Opening widths
(f) Mining directions
(g) Time delay
(h) Mining method

Remnant structures in the upper seam such as pillars or the gob/solid coal boundaries serve to concentrate stresses (Figure 1). The magnitude of these stresses and how they distribute themselves downwards will determine the effect they have, if any, on lower seam structures

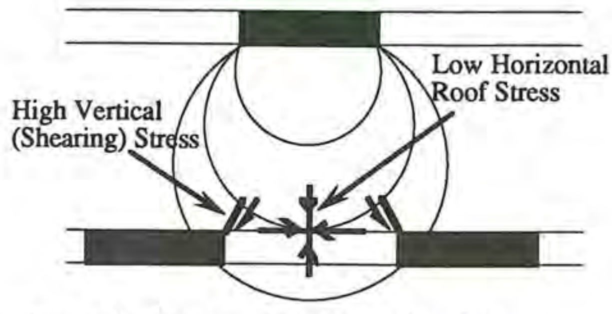


Figure 1. Pressure bulb formed under remnant upper seam pillar.

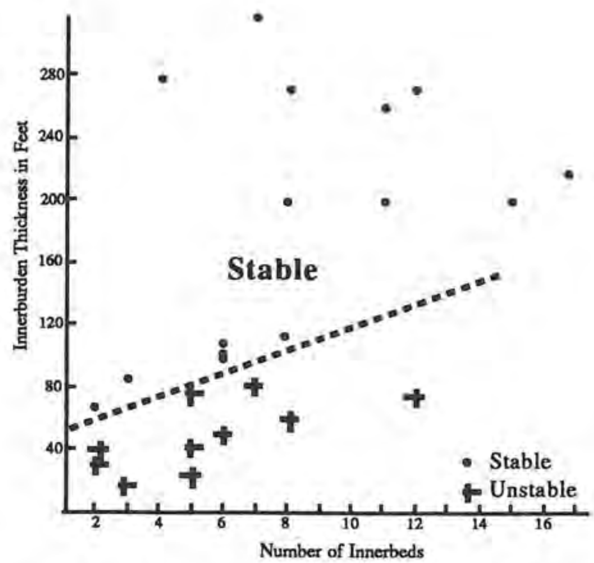


Figure 2. Influence of number of innerbeds on interaction between room and pillar mines (After Ehgartner, 1982).

(Chekan et al., 1986). For room and pillar and pillared operations plots of raw field data as shown in Figure 2 show that the limit of weight transfer is about 115 feet for soft highly laminated shales reducing to 65 feet for massive sandstones (Haycocks et al., 1982). An alternative approach relates the load transfer to the number of bedding planes in the innerburden, a result that agrees with other researchers (Ehgartner, 1982). The data is approximate, but whether or not an increase in stress level affects an underlying excavation depends in part on the geologic and structural integrity of its environment. Soft shale roofs are a lot more susceptible than massive sandstones.

Longwall operations are traditionally reported to transfer loads over much greater distances to the detriment of underlying operations. In a British mine stresses are reported to have been felt from rib pillars left in an overlying seam 750' overhead. (Figure 3, Scurfield, 1970).

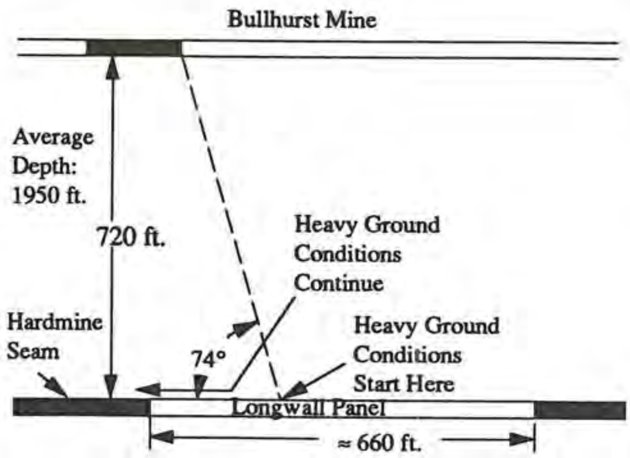


Figure 3. Influence of an upper seam rib pillar on a lower seam longwall face.

If true then these stress transfers reflect the extraordinarily high levels of stress that can concentrate in the longwall abutment zones.

Massive shear failure has been observed to occur between multi-seam mines (Holland, 1951; Hasler, 1951). Barko (1982) demonstrated that the phenomenon is most likely to occur when the distance between the two seams approximates 52 feet. To achieve massive shear failure would require opening an excavation on the lower seam in excess of 40 feet. This situation is unlikely to occur in modern mines except during pillaring.

Analysis of Intensity

Evaluating what effect if any the upper seam structure has on lower seam operations starts by determining the actual load being concentrated in the upper seam pillar or gob interface edge. Mechanisms have already been devised for doing this based on pillar load equations for single seam operations (Grenoble et al., 1985). After the load on the upper seam structure has been determined, the next problem is to determine how far it will propagate downwards before being effectively diffused. This will depend upon the nature of the intervening strata with highly laminated shell type beds transferring the pressure bulb down far further than massive sandstone type structures. Figure 4 shows the effects of bedding planes on stress transfer compared to a homogeneous massive sandstone type innerburden.

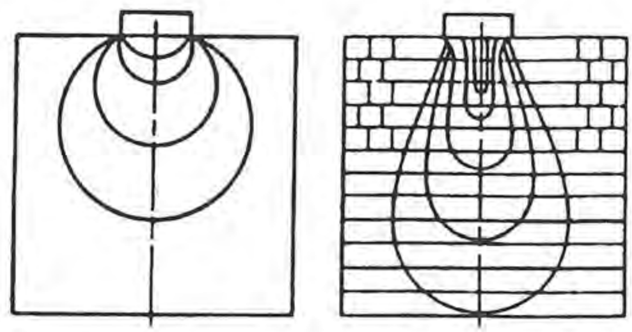


Figure 4. Influence of bedding planes on stress transfer.(Gaziev, 1971)

Remedial Actions

These will depend upon the nature of the strata surrounding the lower seam mining operation. The primary consideration will be given to what is most vulnerable. Typically either the coal pillars themselves, the roof or the floor, or possibly combinations of these will prove most susceptible to the high stresses encountered under upper seam structures. The first line of defense is to simply avoid the high seam stress fields if possible, and if it is known precisely where they do occur.

However with longwall type operations, avoiding high level stress concentrations from the upper seam is rarely practical and therefore a realistic decision must be made as to exactly where the stresses are going to be accepted. The choice is between either the face area of the longwall or on the head and tail entry pillars. Classically the latter is selected rather than risking interference with longwall face production. Pillar design in the lower longwall seam must therefore be modified to accept the heavy loads. Difficulty may be experienced driving the entries because the roof formations will be particularly vulnerable in the high stress field.

In summary, methods for ameliorating undermining interaction effects are:

(a) Avoid high stress areas
(b) Use large pillars
(c) Delay mining as long as possible
(d) Use narrow openings
(e) Increased support

OVERMINING

Interactive Probability

Interaction due to overmining a previously mined seam can be due to one or more of three basic mechanisms, pillar load transfer, arching or subsidence. Where a room and pillar system has been used without pillaring and the roofs are intact, the upward extent of the pressure bulbs will be almost identical to that experienced for under mining, or about 110 feet, depending on the make up of the innerburden.

As caving occurs due to pillaring or longwall mining, but prior to the sub-critical subsidence condition, an arch is formed (Stemple, 1956). The arch concept gives the engineer a valuable conceptual mechanism for identifying where overmining high stressed areas can appear in an overlying seam which is not subject to trough subsidence. The arch concept can be quite useful for design purposes. Figure 5 shows a case study of the arch concept being used to explain upper seam damage over a lower seam gob zone. The high stress area around the perimeter of the arch can be identified as well as the destressed zone inside the arch itself. Offsetting of the high stressed area over the lower seam gob edge clearly demonstrates the arch concept in its application to upper seam design.

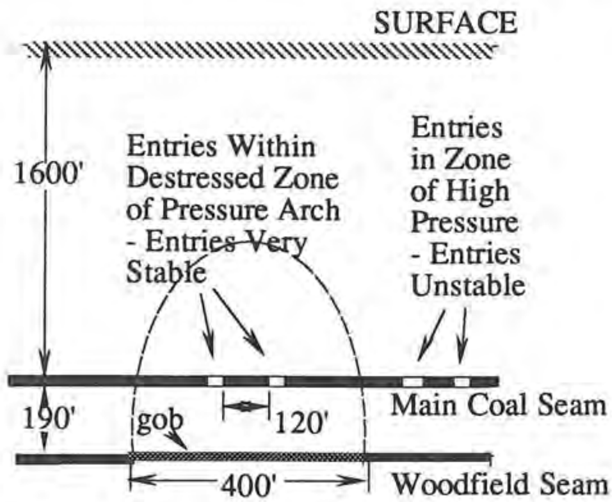


Figure 5. Example of arching controlling stability in upper seam operations.

Where caving has occurred to the point of permitting surface subsidence, either flexure or shearing in the overlying strata will take place. A major source of damage in overmining is normally due to encountering the subsidence wave over a lower seam structure such as a remnant pillar or solid coal interface. The bending of the strata produces both a tensile and compressive zone in the upper seam. The tensile zone has been shown to create the greater damage during upper seam mining as shown in Figure 6 (Webster et al., 1985). Efforts to determine whether undermining will cause damage in the upper seam have been carried out by a number of investigators. Webster et al.

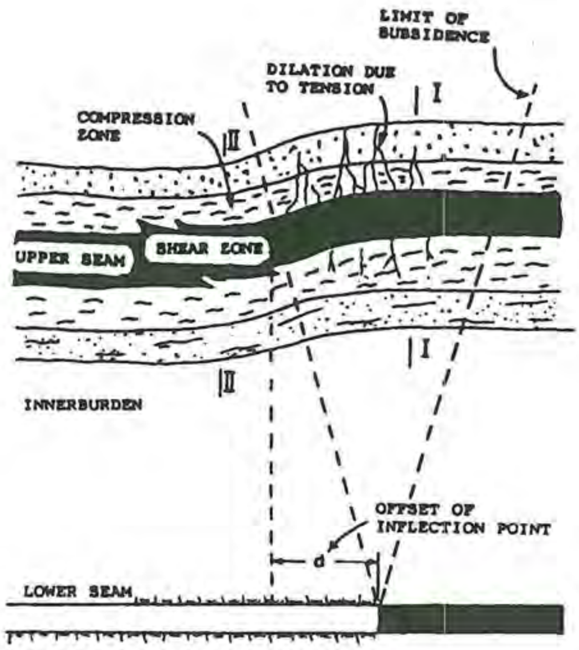


Figure 6. Tension zone formed over a lower seam gob edge.

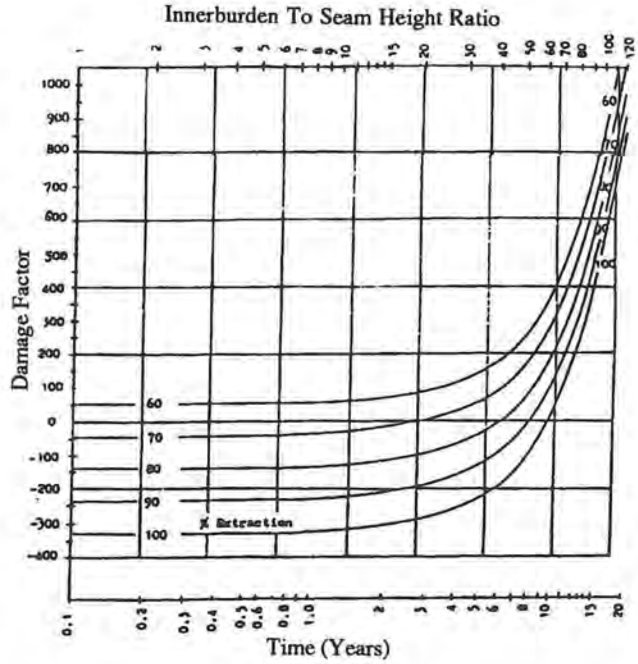


Figure7. Nomograph showing damage factor relative to innerbed to seam height ratio, time and % extraction.

(1984) produced a nomogram for determining whether or not damage would occur in the upper seam as shown in Figure 7. The nomogram has proved quite successful for predicting whether damage will occur, but will not contribute towards estimating the levels of damage. The M factor, which is the ratio between the lower seam thickness and the innerburden is also a viable method of predicting whether or not damage will occur (Hladysz, 1985; Zhou et al., 1988).

Analysis of Intensity

Quantization of the arch phenomena for upper seam design was carried out by a number of authors (Hudock, 1983; Wu et al., 1987; Zhou and Haycocks, 1986). Stress orientation will vary around the boundary of the arch and should be utilized accordingly. It should be noted that the zone inside the arch both above and below is destressed and can be used to site very stable openings.

To determine specific damage levels in the upper seam due to subsidence, a roof rating index was incorporated relating maximum subsidence at the upper seam elevation to a damage rating. The roof rating index utilizes lithology, jointing, time, ground water and distance to the first competent strata to characterize the upper seam roof using a weighted average (Table I). Once upper seam displacement is determined, Figure 8 can be used to determine the roof damage according to Table II.

Remedial Actions

As with many other types of interaction, remedial actions during overmining should first start with trying to avoid affected areas where mining may be difficult or impossible. Where this is not practical, or the levels of damage are not anticipated to be sufficient to prevent mining, then the alternative would be to select a mining direction forty-five degrees from the direction of maximum tensile stresses. High compression zones resulting from arching that cannot be avoided must be evaluated in terms of

Table I. Rating system for multi-seam roof conditions

Factors ⬇ \Rating ➡	1	2	3	4	5
Rock Type of the Innerburden	Massive, clean, smooth gray sandstone or sandy sandstones; some massive hard shale	Thick, clean gray sandstone or sandy sandstones; Thick, smooth clean, shale or sandy shale	Interbedded shale and sandstone; crystalized sandstones and conglomerate	Finely interbedded shale and sandstone; massive thinly laminated shale beds	Slumps, deposits, channel scours, fire clays, kettlebottoms, slickensides, pinchouts
Innerburden Layering	1 - 4	5 - 8	9 - 11	12 - 19	> 20
Hard Rock in Innerburden (%)	> 70	51 - 70	31 - 50	11 - 30	< 10
Distance to First Competent Strata	< 5 ft. (< 1.5 m)	5 - 10 ft. (1.5 - 3.3 m)	10 - 25 ft. (3.3 - 7.6 m)	25 - 35 ft. (7.6 - 10.7 m)	> 35 ft. (> 10.7 m)
Joint Sets	JIC* < 2.5	2.5 - 3.5	3.5 - 6.0	6.0 - 10.0	JIC > 10.0
Time Between Mining	> 5 years	2 - 5 years	1 - 2 years	0.5 - 1 years	< 0.5 years
Ground Water	Completely dry in both seams	Mostly dry in lower seam; dry in upper seam	Moist only in both seams	Moderate pressure upper seam wet	Very wet, rock very sensitive to water

* JIC = Joint Influence Coefficient (Zhou et al., 1988)

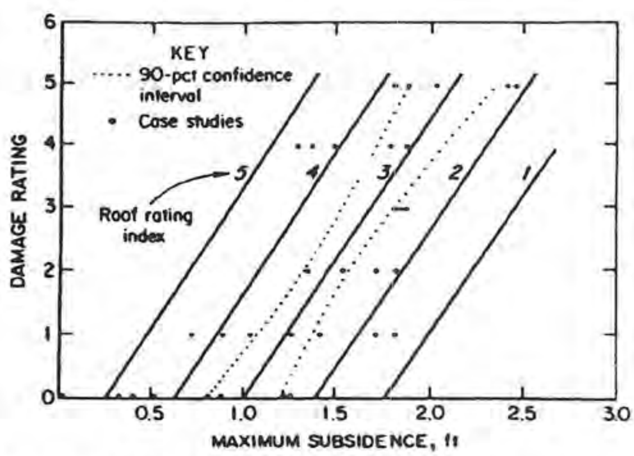


Figure 8. Graph for determining upper seam roof damage due to subsidence (Webster, 1984)

Table II. Damage Scale

0 - No Damage

1 - Fractures present in the upper seam (no roof problems)

2 - Fractures with movement visible

3 - Roof problems encountered

4 - Major roof problems encountered (entire entries caved)

5 - Coal abandoned due to roof control problems

their magnitude, and alterations in design made to compensate for the anticipated stress level. This would include increasing pillar dimensions as well as decreasing opening widths. Floor bolting may be necessary if floor instability is anticipated. Again, if possible, avoiding high stress zones would be most advantageous and designs should be modified accordingly.

In summary, ameliorating overmining interactions can be achieved by:

(a) Avoiding tensile zones
(b) Timing
(c) Narrow openings
(d) Increased support
(e) Pillar sizes and locations
(f) Orientation of workings.

SIMULTANEOUS MINING

Simultaneous mining has been tried on many occasions to ameliorate the effects of multi-seam mining, frequently with some success. In spite of its obvious benefits there are many practical difficulties in keeping the two faces at the same advance rate and the pillars accurately columnized (Matetic and Chekan, 1988).

Simultaneous mining is in fact a solution, or an attempt at a solution, to multi-seam mining interaction problems that has had some success, particularly in advancing room and pillar mining. If one face lags behind the other it can move into the destressed zone, which is ideal; however, if the face attempts to catch up with the other face and it moves into the high stressed zone running ahead of the other face then considerable difficulties can develop. At vertical distances between the two seams in excess of 25 feet, precise columnization is not necessary; therefore, the best success of simultaneous mining has been at distances of between 25 to 60 feet. Numerous examples of success have been recorded at these distances (Holland, 1951; Stemple, 1956).

ULTRA-CLOSE SEAM MINING

Field observations show that ultra-close workings of less than 25 feet frequently involve unique failure mechanisms of the total innerburden. (Zhou et al., 1991). Such failures can also affect the structural behavior of both upper and lower seam pillars by increasing their effective height. The decision on how closely vertically two mines can operate is a complex one, but dependent in large part on a combination of the structural integrity of the innerburden and mining factors. (Zhou and Haycocks, 1989; Zhou and Haycocks, 1990). The mining factors have a major influence on stability through the selection of opening widths, pillar sizes and pillar location, and give the engineer some flexibility to achieve a stable design.

Stability assessment across a mining area involves the following major factors in determining whether or not the innerburden will be stable:

- Fixed:
  - Innerburden characteristics
  - Innerburden thickness
  - Depth
- Operational Variables:
  - Relative pillar sizes and locations
  - Opening widths
  - Mining sequence and system
  - Opening widths
  - External loading factors

Innerburden Characterization

This involves the following four major categories: lithology, structure, water and time. In practice, lithology and structure can be difficult to determine and new mines must characterize the innerburden based on interpolation between boreholes. Existing operations, where accessible, can investigate the innerburden by drilling and mapping of discontinuities with optimum results. To overcome the difficulties in quantifying geologic data and to provide initial guidelines, it is necessary to develop a system that can model the innerburden. The final geologic characterization of the innerburden was included in a rating system as shown in Table I with the distance to first competent strata row removed.

Design Protocol

Results from studies show that pillar load transfer mechanisms in ultra-close seam mining do not differ significantly from that in multi-seam mining with greater innerburden thicknesses. In ultra-close seam mining the innerburden is the predominant structural component determining the stability of the two seams being mined. Failure of the innerburden can cause pillar instability with damage to both operations. A stable innerburden design is therefore essential, taking into account all the complex and interrelated geologic structural and mining conditions.

To evaluate whether innerburden failure is likely to occur at a specified innerburden thickness, a protocol has been developed. Initial analysis is aimed at pillar stability as innerburden failure can rapidly destabilize pillars designed for a single seam environment.

Initial innerburden design is carried out by following a simplified beam or plate theory. Requirements for innerburden stability are then modified to accommodate the effects of offsetting pillars, great depth, and less than ideal geological conditions.

Application of the site characterization approach is best carried out minewide by contouring the differences between the final modified design thicknesses and the actual thickness of the overburden.

Plots of raw field data offer considerable support to this approach as shown in Figure 9. It should be noted that the

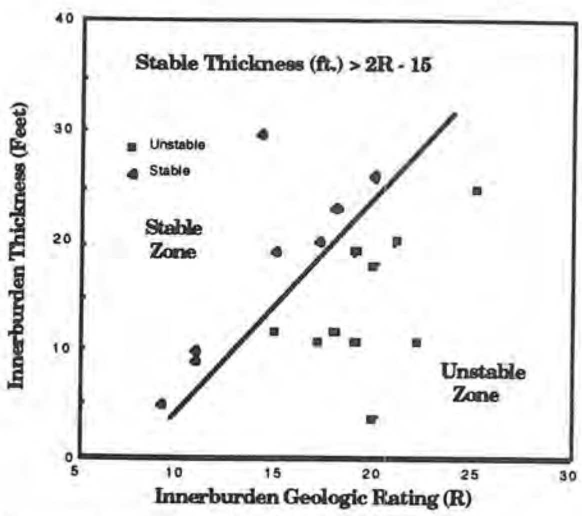


Figure 9. Ultra-close raw data plot of innerburden thickness vs. geologic characterization

upper and lower rating ranges are missing from the graph as these represent extreme conditions. The lower range, because pure unbedded sandstone is very unlikely to be encountered, and the upper range, because any mining under such adverse conditions would be extremely difficult.

CONCLUSIONS

A considerable body of information is now accumulating in the design of mine openings in a multi-seam environment. A lot of general information is already known but considerable research remains to be done on the interaction effects that can occur under specified geologic and environmental conditions. The major conclusions that can be arrived at to date are:

1) That four basic mechanisms control interaction between seams, these are: pillar, low transfer subsidence, massive shear and arching.

2) That the effects of interaction can be quantified in a general sense to determine the levels of damage that can be expected in the damaged seams.

3) That a hazard map approach appears to offer excellent potential for evaluating interaction effects in new seams.

4) That interaction continues to be a major, if not the major source, of ground control problems in underground mining and this can only be expected to grow as new seams are opened up and the mining industry continues to expand.

REFERENCES

Barko, E.N, 1982, "Mechanics of Interseam Failure in Multiple Horizon Mining," **M.S. Thesis**, Virginia Polytechnic Institute and State University, Blacksburg, VA, June, 195 pp.

Chekan, G. J., Matetic, R. J. and Galek, J. A., 1986, "Strata Interactions in Multiple-Seam Mining - Two Case

Studies in Pennsylvania," **RI 9056**, U.S. Bureau of Mines, 17 pp.

Ehgartner, B. L., 1982, "Pillar Load Transfer Mechanisms in Multi-Seam Mining," **M.S. Thesis**, Virginia Polytechnic Institute and State University, Blacksburg, VA, May, 164 pp.

Engineers International, Inc., 1981, "Investigation of Problems and Benefits of Underground Multiple Seam Coal Mining," **Final Technical Report**, Dept. of Energy Contract DE-AC01- 70ET14242, 292 pp.

Gaziev, E. and Erilikhman, S., 1971, "Stress and Strain in Anisotropic Foundations," **Proceedings**, Sym. on Rock Fractures, ISRM, Paper II-1, 10 pp.

Grenoble, A., Haycocks, C. and Wu, W., 1985, "Computerized Evaluation of Near-Seam Interaction," **Proceedings**, 2nd Annual Conf. on the Application of Computers to the Coal Industry, Tuscaloosa, AL, pp. 317-322.

Hasler, H. H., 1951, "Simultaneous vs. Consecutive Working of Coal Beds," **Transactions**, AIME, Mining Engineering, May, pp. 436-440.

Haycocks, C., Ehgartner, B., Karmis, M. and Topuz, E., 1982, "Pillar Load Transfer Mechanisms in Multi-Seam Mining," SME-AIME **Preprint** No. 82-69.

Haycocks, C. and Zhou,Y., 1990, "Multiple-Seam Mining-A State-of-the-Art Review," **Proceedings**, 9th International Conference on Ground Control in Mining, Morgantown, WV, June, pp. 1-11.

Hladysz, Z., 1985, "Analysis of Risk in Multiple Seam Mining," **Preprint**, SME-AIME Fall Meeting, Albuquerque, NM, 11 pp.

Holland, C. T., 1951, "Multiple-Seam Mining," **Coal Age**, August, pp. 89-93.

Hudock, S. D., 1983, " The Effects of the Pressure Arch Upon Multiple Seam Mining," **M.S. Thesis**, Virginia Polytechnic Institute and State University, Blacksburg, VA, August, 196 pp.

Hsiung, S. M. and Peng, S. S., 1987, "Design Guidelines for Multiple Seam Mining," Part I, **Coal Mining**, September, pp. 42-46.

Matetic, R. J. & Chekan, G. J., 1988, "Comparative Study of Pillar Load Transfer Associated with Multiple-Seam Mining," U.S. Bureau of Mines, **RI 9176**, 20 pp.

Stemple, D. T., 1956, "A Study of Problems Encountered in Multiple-Seam Mining in the Eastern United States," **M.S. Thesis**, Virginia Polytechnic Institute and State University, Blacksburg, VA, July, 125 pp.

Scurfield, R. W., 1970, "Staffordshire Mining Layout for the Mid-1970's," **Mining Engineer**, Vol. 130, pp. 73-84.

Webster, S., Haycocks C. and Karmis, M. 1984, "Subsidence Interaction Effects in Multi-Seam Mining," **Proceedings**, 2nd International Conference on Stability in Mining, Lexington, KY, August, pp. 589-604.

Wu, W., Haycocks, C. and Zhou, Y., 1987, "Designing for Interaction in Close-Proximity Multi-Seam Mining," **Proceedings**, 28th U.S. Symposium on Rock Mechanics, Univ. of Arizona, June 29-July 1, pp. 1107-1114.

Zhou, Y. and Haycocks, C., 1986, "Designing for Upper Seam Stability in Multiple Seam Mining," **Proceedings**, 5th Conf. on Ground Control in Mining, Univ. of West Virginia, Morgantown, WV, June, pp. 206-212.

Zhou, Y. and Haycocks, C., 1990, "Pillar Stability in Ultra-Close Seam Mining," **Proceedings**, 31st U.S. Symposium on Rock Mechanics, W. A. Hustrulid & G. A. Johnson (Eds.), Golden, CO, pp. 137-144

Zhou, Y. and Haycocks, C., 1989, "Failure Mechanisms in Ultra-Close Seam Mining," **Proceedings**, 30th U.S. Symposium on Rock Mechanics, West Virginia University, Morgantown, pp. 613-620.

Zhou, Y., Haycocks, C. and Wu, W., 1988, "Designing for Upper Seam Stability in Multi-Seam Mining," **Preprint**, SME-AIME Fall Meeting, Phoenix, AZ, 9 pp.