

COAL MINING RESEARCH --- ENERGY WITH SAFETY

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INTRODUCTION

This morning I would like to place the issue of coal mine safety within a big picture. The big picture is the importance of coal to our nation's future, in particular to our growing dependence on coal to supply our future energy needs. Within that picture I will discuss the role that the Federal government, principally through the Bureau of Mines, must play to meet this challenging growth in demand while reducing the social and economic costs attributed to injuries and fatalities in underground mining.

I would like to share with you a few interesting facts and projections with respect to our Nation's energy picture--the distribution of our reserves, and the projected role of coal in the energy and economics of the nation's future. I will show that underground mining will continue to be a very important part of the means to provide this coal. And I will discuss how the Bureau of Mines' research program addresses the problems of health and safety that grow out of the demand for coal.

FUTURE PROJECTIONS

Let me first share with you a synopsis of salient facts and projections concerning our nation's situation with respect to energy and the economy.

Here is a picture (Figure 1) that dramatically depicts the relative quantities of recoverable energy reserves in the United States by their type. We all are aware of the nation's utilization of oil, we hear a lot about natural gas, and are aware of the controversy over the use of nuclear energy. But while you look at this chart, ask yourself the question, "Where will our fuel to meet the demand for energy in the future most certainly have to come from?" With 82% of the nation's recoverable fuel reserves being coal, the answer is irrefutable. Coal will be the source.

Let us examine some facts and trends to discover what these mean to the future of the coal industry.

First look at the present market for coal (Figure 2). This chart shows that 77% of the coal that is mined goes to supply electric utilities. Therefore, the coal industry as a

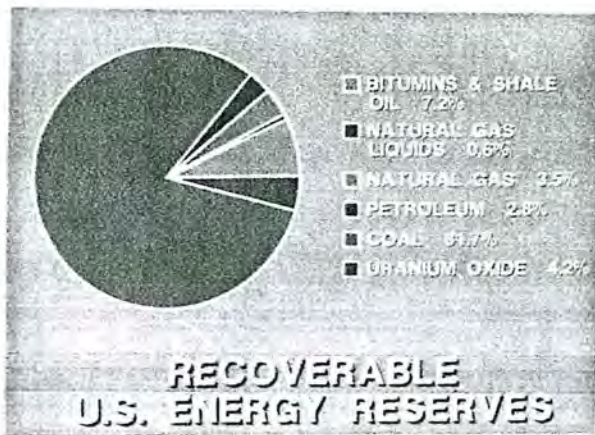


Figure 1



Figure 2

whole is most sensitive to the trends and demands for electricity, and is less affected by what happens in other markets, such as export and direct industrial use. In fact the coal industry is three times more sensitive to the electric utility market than to all other markets combined. This fact or relationship implores us to examine the trend in the demand for electricity.

Demand for electricity is expected to increase steadily over the next fifteen years. It is projected to grow from a present 2,346 billion kilowatt-hrs per year to 3,520 billion kilowatt-hrs per year in 2000, a net increase over 1985 of 50%. The fuel to supply this increase in demand for electricity must come from somewhere. The question is "How much of this extra fuel will be coal?"

Although the demand for electricity is predicted to increase, the demand for coal does not necessarily follow as a corollary. Only if the coal maintains its fraction of the energy sources used for the generation of electricity will the demand for coal increase at the same or greater rate as the demand for electricity. In fact, except for a near term dip owing to a slight increase in nuclear capacity, the domestic electric generation accruing to coal goes from 56% in 1985 to over 60% in 2005. Thus the predicted trend is for coal to become a larger part of the fuel mix for electric power generation.

Similarly, looking at the most recent forecast for Total Coal Consumption trends we see that for electric power generation alone, the coal industry must be able to supply an additional 348.5 million short tons per year by the year 2000 (Figure 3).



Figure 3

Before going on, I want to stress that without significant improvements in mining safety, we can easily predict that injuries and fatalities will increase in proportion to the increase in coal production. Do we as a society consider that acceptable? I do not believe that we do.

Briefly let us examine the effect of coal prices on the price of electricity (Figure 4). The projections show that the already high proportion of fuel cost will become an increasingly greater fraction of the consumer price for electricity. Specifically, in 1985, 36% of the price of electricity was the cost of the fuel; in 1995, 46% of the price of electricity will be the fuel cost.

COMPONENTS OF ELECTRIC PRICE

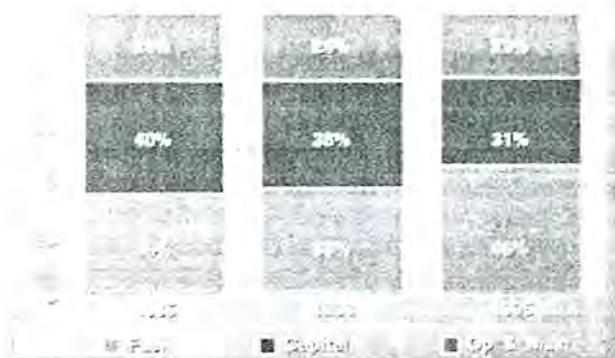


Figure 4

That implies that the price of coal will have an increasing influence on the price that we all pay for electricity. Thus as coal is used more to generate electricity relative to other fuels, and as the fuel becomes a greater part of the price of electricity, the cost of coal becomes more important. As you all know, the cost of electricity is a major component in the cost of living, both directly in your own electric bills and indirectly in the cost of producing goods and services.

To sum this all up, coal will play an increasingly important role as a source of energy and have an increasing influence on the price of electricity. The nation will have to turn more and more to coal as a primary source of energy. The numbers speak for themselves. The goal is to obtain the increased production while simultaneously reducing the absolute numbers of

injuries and fatalities while increasing the efficiency of production. This is the challenge of the 80's and 90's, so that we can meet with ease the challenge of the next century.

MEETING THE DEMAND FOR COAL

To direct research to appropriate areas, one must examine where the expansion in mining will occur. Specifically, one must determine where the reserves lie and then the type of mining method that will be needed.

Our objective should be to focus the limited resources available for research on the areas in which research can create the greatest effect. It would be unwise to focus our attention on improving a mining technology which is not expected to be used for the next 25 years or longer.

After these areas have been identified they must be examined for the safety hazards that may be expected.

The United States possesses one quarter of the world's recoverable coal reserves, the largest of any single nation. Of these reserves, two thirds lie deep underground and will require underground mining methods.

Of the underground reserves, the geological conditions favor room-and-pillar methods for the foreseeable future. In particular, coal regions east of the Mississippi River contain a substantial coal reserve, most of which cannot be mined economically by longwall methods. The present situation, wherein two thirds of the coal is mined using continuous mining machines, is expected to continue. Less than a third of the mining is and will be done by drilling and blasting methods. Longwall, although on the increase, is not estimated to become the dominant

mining method in the future. Thus the focus of Bureau research is in underground coal mining and, for the most part, on room and pillar type mining methods.

In simple terms, injuries and fatalities can be expected to continue at the present rate unless something is done to improve room-and-pillar mining. This implies that, as coal production from room-and-pillar mines increases, so will the number of disabling injuries and fatalities, unless research can change the present course to one which will decrease the exposure of workers to hazards and increase productivity.

Although great strides have been made in making the underground mining work place a safer environment, injury rates continue to be unacceptably high. For example, as recently as the 1980's, the disabling injury rate for underground coal mining was approximately twice the rate for manufacturing, agriculture, forestry, and fishing, and nearly twice the rate for all of mining and construction.

The majority of fatal accidents occurs within twenty-five feet of the working face. The dollar costs of these injuries and fatalities to society, not including the cost associated with the loss of production caused by the incident and its investigation, exceeded \$170 million total for the five-year period of 1978 to 1982.

The Bureau of Mines ranked the most hazardous mining activities by examining the MSHA injury data and using the total accident cost to society as a criterion. This study revealed that activities concerned with the handling of supplies and materials dominated the accident cost with an average yearly cost of \$20 million. When all the activities associated with roof bolting were grouped together, these ranked second with an average yearly

cost of over \$14 million. Machine maintenance and repair ranks third at a little over \$7 million dollars per year.

Further examination of the safety problem revealed that materials handling activities are very diverse and virtually unlimited in scope, as contrasted to the roof bolting activities, which are confined to a local area and to a specific machine.

A study by the National Academy of Sciences concluded that if significant additional accident prevention progress is to be made, then attention must be directed to problems associated with human performance and management practices. The Bureau has conducted research in improving both human performance and management through improvements in equipment design and human factors. An emerging thrust of the Bureau's research program is to reduce human error and human risk by reducing direct human participation in the activities at the face.

RESEARCH FOR SAFE MINING

The ultimate goal for research in safe mining is to create a working environment in which the worker does not encounter (or is not exposed to) hazards. The implications are far ranging:

1. Research should concentrate on removing the hazard or removing the need for human involvement in hazardous activities.
2. Research should concentrate on methods for improving decisions and mining skills to reduce the incidence of situations requiring human involvement in hazardous emergency or corrective tasks.

3. Research should maintain or improve productivity so that the real-dollar cost and the intangible (human) costs of coal are reduced. Then, the projected demand for coal can be met using domestic resources without an increase in social cost.

It appears that these goals are no longer as much of a "pipe dream" as they have been in the past. The so-called area of High Technology offers the means for pursuing these goals productively. The area of robotics promises to remove the need for the presence of the human at the work site; artificial intelligence promises the potential for improved and consistent decisions, as well as management/supervisory capability. The availability of powerful microprocessors makes possible the packaging and the marriage of robotic systems and artificial intelligence into highly functional tools. Together they provide new solutions to problems that previously were difficult, if not impossible, to solve.

The Bureau cannot perform all of this research alone. It will depend in a large part on the developments of others. The Bureau's objective is to conduct research that can utilize and build on technology developed by others. That is, the Bureau's research should be focused on the mining problem, and yet be able to mesh with this emerging technology as it becomes available.

In particular, the removal of a human from the active work site will require the functional equivalent of the senses and perceptions needed for decision making that is normally found in the human. Long-term research must focus on sensors that can identify the presence of the rib, the height of the coal seam, the orientation of the equipment, and the condition of the machine systems with respect to their normal

performance, as well as with respect to the task to be accomplished. In other words, it must know how to do a good job and how well it is performing. Through the use of expert systems it will be able to decide how to cope with deviations and difficulties. In the early stages of development, much human involvement will be expected in order to gain experience that can be transferred as knowledge to the eventual computer supervisory program.

The Bureau has established a program of research that contains elements of both long-term and short-term milestones utilizing newly available high technology. All of these short-term milestones are necessary to the accomplishment of the end goal, yet provide an immediate and direct benefit in and of themselves.

I will briefly describe four such projects.

Mine Environmental Monitoring

Dilution of an explosive gas or control of a mine fire depends almost entirely on rapid detection of the hazard, decision making, and communication of information to underground personnel. Until recently, the main method for detection of hazards was through periodic, manual inspections of the underground workings. An exception is machine-mounted methane monitors and thermal detectors along beltways. Since many mines cover vast areas, and since conditions in mines can change rapidly, these personal inspections are not always sufficient.

Computerized monitoring, which provides continuous, real-time information on the status of the underground mine environment to a manned location on the surface, is now a viable alternative to personal inspection. Sensors can be placed in areas of the mine that are dangerous or difficult for miners to

travel to, or in areas that are not frequently traveled. Sensors commonly used with computerized monitoring measure methane, to detect potentially explosive methane buildups; carbon monoxide, to provide early fire detection; and air velocity, to determine if the mine ventilation system is operating properly.

Today, about 50 U.S. underground coal mines have installed computerized monitoring systems to monitor the underground environment. Many of these systems, installed to gain a variance to use the belt entry as an intake aircourse, consist of carbon monoxide sensors installed along the belt for rapid fire detection. Current research is concentrating on a state-of-the-art mine fire protection system that would use a ventilation simulator and prediction model in conjunction with real-time monitoring, and a miner warning system to provide for escape of miners during emergencies.

Adaptive signal discrimination

One of the most important advancements in roof control for underground mines has been the development of roof bolts that are held in place by a powerful epoxy resin. These resin roof bolts give generally superior performance but also present a serious potential hazard. Once installed they cannot be tested. If the bonding between bolt and rock is poor for any reason (improper installation, degradation with age, etc.) the bolts can create a greater hazard than the one they were installed to protect against. Researchers have tried for years to develop a testing device or procedure for measuring the bonding integrity of these bolts. Nothing has yet been successful.

The Bureau has addressed this problem by the use of powerful microprocessors and software that can perform complex signal analysis that distinguishes well-bonded from

poorly bonded resin roof bolts. In this technique, signals are injected into roof bolts of known bonding integrity and mathematical signal discriminants are computed and stored in memory. These discriminants are used to create predictive equations. When challenged with signals from "unknown" roof bolts, the system mathematically compares the unknown signals to the prelearned discriminants and indicates whether the unknown bolt is adequately or poorly bonded. Pilot research with laboratory prototype hardware and software has been highly encouraging. Extensive in-mine evaluation is planned to determine the effects of different roof geologies.

Expert Systems

As mine operations become more complex and larger in scale, the use of automated processes and centralized control is being looked upon as a means of increasing productivity and as a necessity for management. The integration of information on coal extraction, haulage, and preparation into one overall management information system is a reality in mining today. Several U.S. mines have such systems installed and operating; however, human operators still monitor the entire system and must make key decisions whenever problems arise. The quality of these decisions is dependent upon the skill and knowledge of the person on duty at that time. The point of this discussion is that even with today's sophisticated computer-controlled systems, the human operator must process large volumes of information rapidly in his or her brain, sometimes in highly stressful situations. If the operator is very experienced and understands the ramifications of decisions for the entire system, problems are handled in the proper manner; however, personnel of this skill level are very scarce at most mine complexes.

Answers to this problem might involve providing more training for the operators or, alternatively, improving the capability of the control systems. Training may take a long time and be very costly because of the depth of knowledge required; also, knowledgeable personnel tend to be highly mobile in the mining industry. Improving conventional state-of-the-art computer control may not be the answer either, since this type of control involves a step-by-step procedure for accomplishing its purpose. Sometimes the problems to be solved depend upon rules-of-thumb or rely on the operator's opinion based on previous experience. This type of information is very difficult to program with conventional computer techniques. A promising solution involves the use of Expert Systems, a new form of computer software that provides uniform and high quality decisions to be made. This software utilizes concepts and the relationships between them and can be used for control where normal mathematics cannot be applied. For example, the control of mine ventilation is difficult, but rules of thumb provided by experts can be used with satisfactory results, once programmed into a computerized system. The Bureau is experimenting with this concept in the Safety Research Mine at Bruceton.

Robotics

If advances are to be made in removing workers from the face area, software that contains the "intelligence" (decision knowledge) to recognize, evaluate and control the activities of machines in the face area must be embodied in a knowledge based expert system. This knowledge will grow as experience is gained through the development and operation in real or simulated mines of tele-operated (remote controlled) prototypes, initially with little computer control, toward a final version that is weaned of human

control. The goal is NOT to have total non-human control but sufficient control to drastically reduce the exposure of humans to hazards.

Machines that can perform operations by themselves will require the use of control and manipulative techniques being developed for construction robots. An active Bureau project is the development of a "pre-mine bolter", a machine that can install permanent roof support ahead of the extraction of the supporting coal. Such a procedure effectively eliminates the ever present hazard and killer--unsupported roof. A machine of this ability will be complex and require control technology associated with the combination of expert systems and robotics.

These are but a few of the projects at the Bureau which are exploiting the availability of advances in high technology. These projects provide a mix of both short-term and long-term results so that underground coal mining productivity and social cost can meet the needs of future demand on a timely basis.

Government-- specifically, in this case, the Bureau of Mines -- cannot and should not perform all of this research alone. The role of government should be to foster an environment in which the collective creativity of its citizens can work unrestrained to find solutions to problems. Certainly, government research should not compete for limited resources with research that could be done in the private sector. Nevertheless, some problems are so far-reaching in their effects, or so complex, that they do not lend themselves to solution by the private sector alone. Historically, this has been the case in the field of public health, for example. A similar case can be made for health and safety needs in mining; however, even though a government role may be appropriate in this research field,

a better case can be made for research in partnership with the private beneficiaries of such research. We would welcome an opportunity to discuss ways to strengthen this partnership, as it applies to research planning, execution and, yes, even funding, to achieve our common objectives. And we should start this cooperation and planning now. Although there is no time to waste, there should be no panic either; we have the time to plan and spend the research dollars wisely.

A closer government-industry research relationship has several benefits:

1. The industry will become aware of the capabilities of the Bureau and hence be in a better position to draw upon its talents.
2. The Bureau will be more knowledgeable of the industry and its needs.
3. Pooled research monies will enable more efficient operation directed towards industry and national benefit.

I would like to conclude with the following summary. The Bureau, as a federal agency, exists to enhance the common good of this nation as a whole. There is no dispute that coal is extremely important to the nation's future standard of living, its economic well-being and to the national security. In fact the enormity of the importance of coal far exceeds the proportion of the national research resources committed to solving health, safety, and productivity problems associated with freeing coal for use. We are motivated therefore to make the best use of the resources available. I am suggesting that the cooperation and pooling of industry and government resources, consisting of our money and our talented people, will provide a technical

organization with much greater capabilities than the sum of our individual capabilities if we work separately. We should do this now to secure our future for ourselves and the generations to come, as well as for the short-term common benefit of industry and the nation.

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