

FINAL TECHNICAL REPORT  
November 1, 2000, through October 31, 2001

Project Title:                   **IDENTIFICATION OF COST CUTTING STRATEGIES  
FOR UNDERGROUND MINES IN ILLINOIS**

ICCI Project Number:       00-1/1.1A-1  
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ABSTRACT

Over the past two decades, coal prices have been declining while labor, material and other costs have been increasing. For the Illinois coal industry, this difficult situation is augmented by environmental challenges arising from the 1990 Clean Air Act Amendments and other regulatory issues. The lasting solution to these issues must be based on economics. If the production cost of coal is reduced sufficiently, the ability to deal with price and environmental issues improves. The goal of this project was to identify specific cost cutting strategies that will reduce the cost of coal delivered to the customer by at least 20% of the mine sale price, or roughly \$4 per ton. This project is focused on strengthening the overall industry by developing strategies that benefit most, if not all, of the operations in the State.

Industry support played a significant role in this project. An industry steering committee, consisting of representatives from all major coal operations in the State, demonstrated that support by attending meetings and hosting mine visits and discussions. These meetings and mine visits led to the identification of the following specific research areas and the expected production cost reductions associated with each: 1) high-voltage continuous miners – 8%, 2) alternative face haulage systems – 15%, 3) “best practices” training to reduce out-of-seam dilution – 10%, 4) managing coarse coal processing waste underground – 9%, 5) dewatering fine coal waste disposal areas – 3%. Cooperating partners were secured and proposals developed and submitted to ICCI for each area.

Actual research on one project, an industrial engineering/productivity study on a high-voltage continuous miner with batch haulage, was initiated with the objective of determining if the high-voltage machine provides a 15% productivity gain as claimed. Twenty full-shift time studies indicate that the high-voltage machine is capable of increasing loading rates by 30%, tons per car by 9%, and tram rates by 8%. However, overall productivity remained unchanged due to change-out delays associated with batch haulage, highlighting the need for a more continuous haulage system to realize productivity gains. Dust and coal samples collected during the study indicate about 40% decrease in both dust concentration and minus 100 mesh fines. Such results would have a major impact for the Illinois coal industry but require more studies at different operations.

## EXECUTIVE SUMMARY

### **Background**

The past twenty-five years have seen a downward spiral in the selling price of coal coupled with a steady increase in the cost of labor and materials needed to produce coal. A national energy crisis, changing political climates, and an unsettled world situation have combined to reverse this trend within the current calendar year. However, the coal industry continues to face many difficult challenges, not the least of which are the environmental impacts that result from the mining, processing, and burning of coal to provide energy. This is particularly true of Illinois' vast high sulfur coal reserves.

Whether the issues are environmental or otherwise, the successful and lasting solutions are based on economics. If the delivered cost of the coal is reduced, the ability to overcome challenges, including environmental issues, is increased. The lower the cost, the greater the effort to either utilize existing technology to overcome high emissions, or find new technologies that will enable electric utilities to use Illinois coal and still maintain compliance with increasingly stricter environmental regulations.

The coal industry has a history of reducing costs and increasing productivity, making coal today's dominant energy source in the United States. However, maintaining that position will depend on making further strides. This is particularly true in Illinois where the coal industry has suffered despite significant productivity gains and cost reductions. Additional and continuing improvements are the key to revitalizing the Illinois coal industry. Towards that end, this project was undertaken. A 20% cost-cutting goal, with respect to the current typical FOB price of \$19/ton, was established.

### **Overall Approach to Identifying High Priority Cost Cutting Areas**

Industry involvement has been the key to success for this project. The project management team of Dr. Chugh, Mr. Mike McGolden and Mr. Joseph Hirschi began by putting together a steering committee of industry professionals. Nine companies, representing 90% of Illinois' underground coal production in 2000, participated.

In the steering committee's first meeting, mining costs from the face to the customer were analyzed. Five primary cost centers and the cost breakdown of a typical coal mine were identified. They are shown in Table 1. Subcommittees were designated for each area to generate cost reduction ideas. Mine visits from the project management team helped these subcommittees to identify several top priority ideas, which were discussed in depth at the subsequent steering committee meeting.

Not surprisingly, industry recommendations were that increasing face productivity should be the highest priority. Two other top priority issues, controlling out-of-seam dilution and alternative waste management practices, were also identified. The project management team synthesized all of the subcommittee information and developed five specific research proposals, each with a host and cooperating partners from the

industry. Each proposal represents a specific strategy for reducing costs throughout the Illinois coal industry.

Table 1. Typical Coal Mine Cost Centers and Cost Breakdown

<u>Cost Centers</u>	<u>Production Cost (PC) per ton</u>
Face Production (50% of Production Costs)	Labor \$6.00 Benefits \$3.00
High Extraction Systems	Operating Supplies \$2.00
Partial Extraction Systems	Maintenance Supplies \$1.60
Outby Construction Areas (25% of Production Costs)	Other Direct Costs \$1.00 Power \$1.00
Materials Handling	Royalties \$0.50
Coal Processing / Waste Management (15% of Production Costs)	Taxes \$1.30 Depreciation \$2.00
Transportation to Market  (10 to 50% of Production Costs)	Overhead – G&A <u>\$0.60</u>
(Education/Training – part of each center)	<b>Total \$19.00</b>

### **Proposed Top Priority Near Term Research Projects**

#### *Strategy 1 – Using High-Voltage Continuous Miners*

The steering committee proposed an industrial engineering study on a new high-voltage (2300V) 14CM27 continuous miner operating side-by-side with the widely used (995V) 14CM15 on a super-section. The study will analyze productivity improvements that may be capable with a high voltage machine. Increased productivity in the face area will affect dust concentrations and may affect the size-consist of the mined product as well as the out-of-seam dilution, which in turn impact coal processing and waste handling costs. This proposal deals with all of these issues in a consolidated manner.

#### *Strategy 2 – Alternate Face Haulage Systems*

Increasing loading rates with high-voltage miners exposes delays involved with transporting mined material away from the loading machine. To overcome this problem, the steering committee proposes that the potential of the surge car option be investigated. The surge car idea is to have sizable loading capacity behind the miner while haulage

units are changing out. Increasing the miner’s loading time while maintaining the flexibility of batch haulage achieves some of the gains available with continuous haulage.

*Strategy 3 – Education and Training Program to Control Out-of-Seam Dilution*

The third strategy focuses on the significant cost of processing in a non-traditional way. Rather than studying processing systems, the committee proposes examining the way coal is mined, concentrating on identifying best practices for reducing the amount of waste material mined. By reducing the amount of unwanted product, the costs of mining, conveying, processing and waste disposal are all reduced. Mining practices, in this sense, are human actions. Thus, the focus will be on workforce education and training.

*Strategy 4 – Alternate Systems for Waste Management*

Even with best practices, as much as 35% of the product from Illinois mines is waste. The fourth strategy focuses on waste management options. Most mines dispose of fine waste in diked ponds, which tie up large tracts of land. Methods to economically dewater these ponds, thereby increasing the disposal capacity of the land, will be investigated. White County Coal Company’s Pattiki Mine currently disposes of their fine refuse underground as a dilute slurry. The feasibility of crushing intermediate size refuse (½ inch X 28 mesh) for pumping underground with the fines slurry will be investigated.

**Continuous Miner Industrial Engineering Study**

Between mid June and early August, 28 full-shift time studies were conducted on two continuous miners at Black Beauty Coal Company’s Riola Mine. These studies were performed with Riola’s existing batch haulage system of battery-powered ramcars. Dust and product samples were also collected. The objective was to compare productivity levels, dust generation and product size distribution of a standard continuous miner and a high-voltage continuous miner. Characteristics of these miners are compared in Table 2.

Table 2. Continuous Miner Comparison

<u>Characteristic</u>	<u>Joy 14CM15</u>	<u>Joy 14CM27</u>
Voltage	995 (standard)	2300 (high)
Cutting	2 X 235 HP	2 X 295 HP
Loading	3 arm CLA	6 arm CLA
Tram	2 X 50 HP	2 X 65 HP
Hydraulic Pump	40 HP	50 HP

Each time study tracked all operational aspects of the miners for a nine-hour shift including loading, car change-out, set-over and delay times. The data indicates that:

- cutting and loading rate – 14CM27 > 14CM15 by 29.89%
- tons per car – 14CM27 > 14CM15 by 8.64%

- tram rate – 14CM27 > 14CM15 by 7.84%
- tons per shift – 14CM27 = 14CM15

While the production potential of the high-voltage miner is apparent, true productivity gains were not realized because of the batch haulage system delays. The time study results and analysis show that the miner must be matched with some type of enhanced haulage system to realize the potential it offers. Four different cases were evaluated using the time study results as a basis. The evaluation is presented in Table 3.

Table 3. Evaluation of High-Voltage Miner Under Different Haulage Scenarios

CASE:	14CM27 w/ Continuous Haulage	14CM27 w/ Batch Haulage	14CM27 w/ Surge Car	14CM15 w/ Surge Car
Section Type	Single Miner	Super-section	Super-section	Super-section
Production Increase (raw tons/unit shift)	370	90	550	400
Increase in Clean Tons/Year	114,000	29,000	177,100	128,200
Revenue Increase	\$1,368,000	\$348,000	\$2,125,200	\$1,538,400
Cost Reduction/Ton	\$1.06	\$0.10	\$1.30	\$1.10
% Cost Reduction	5.6%	0.5%	6.8%	5.8%
% Profit Increase	55.40%	6.80%	72.50%	56.80%

Mine Safety and Health Administration analyzed the dust samples, which showed that the 14CM27 miner generates 43% less dust. Surfactants reduce that by an additional 6%. Commercial Testing and Engineering screened the product samples, which showed 2.68% by weight less fines (– 100 mesh) in the 14CM27 output, a 35% reduction. The dust and fines results have major significance for the Illinois coal industry but require further research to verify their validity over the entire State.

### Future Direction

Five proposals for demonstrating cost cutting technologies have been submitted to ICCI for funding. All of the projects can be completed within a one-year time period. Each project requires substantial industry involvement, which increases the likelihood of successful implementation of the proposed technologies throughout Illinois. The project management team and industry steering committee believe that implementation of the proposals will result in a 20% reduction in the cost of producing coal in Illinois.

Development and implementation of the surge car concept, even without the high-voltage miner has significant potential for increasing productivity and reducing costs. The project management team and industry steering committee believe development of the surge car concept should be the highest priority for increasing mine productivity.

## OBJECTIVES

### **Project Goals**

Obviously, the ultimate goal of this project is to strengthen the coal industry in Illinois. More specifically, the goal is to identify strategies for reducing the production cost of coal and develop opportunities for competing in a difficult market. The project is multi-faceted in an attempt to identify those opportunities that provide the greatest return, and those that can be utilized by multiple operations throughout the State. Using the representative cost of \$19 per ton of saleable coal FOB mine, described in Table 1 of the Executive Summary, a target of 20% cost reduction, or \$4 per ton of coal, was established. No single strategy or project is capable of achieving the desired cost reduction at one operation, let alone every operation in the State. But a combination of ideas, differing for each operation, is capable of accomplishing the objective.

Industry involvement is the key to successfully accomplishing the project goal. The project is led by a blend from both academia and the industry. The coal industry consists of many companies that historically work independently to optimize their individual operations. There are several organizations and associations serving the mining industry, but they usually do not generate significant cooperation between coal operators. This project depends upon developing such a cooperative effort among all of the producers in the State. Much of the input and development of ideas will come from industry labor and management. Utilization of these resources will not only help to identify the greatest potential gains, but will also increase the likelihood that resulting solutions will develop into applied strategies and eventually into standard practices.

### **Benefits, Costs and Timing**

With pressure coming from all sides, the coal industry has sought relief from various Federal and State agencies. However, government incentives provide short-term, temporary relief and legislative measures seem unstable in the ever-changing political environment. The true benefit of this project is that through successful cost reduction, the long-term profitability of the Illinois coal industry is controlled by the industry itself. The goal of 20% reduction in production costs is a significant stretch for Illinois' coal operators, but there is no better way to ensure the long-term viability of the industry.

A significant portion of the cost of this project involved matching support funds from industry participants. That will continue to be the case as research, development and demonstration move forward in each of the proposed areas. Five of the participating companies have agreed to host research and demonstration work at their facilities with considerable matching support involved. Research will be performed on site with mine personnel closely involved. In addition, two major equipment manufacturers, Joy Mining Machinery and Phillips Machine, have committed expensive equipment to the studies. The objective is to achieve commercialization in the process of demonstrating the proposed technologies, which should be done in a one-year period of time. The actual cost to take the technologies to commercialization will not be some external development

cost, but an internal budgeting process at each operation. When and if each individual operation chooses to incorporate the technologies will depend on their site-specific agendas.

The timing for this work could not be more favorable. With the recent upswing in the coal industry, coal operators are in a position to look at different alternatives without severely affecting their bottom line. Successful demonstration leading to implementation of these strategies will position the coal industry to remain profitable into the future.

### Project Approach and Required Tasks

A flow chart of the research program is shown in Figure 1.

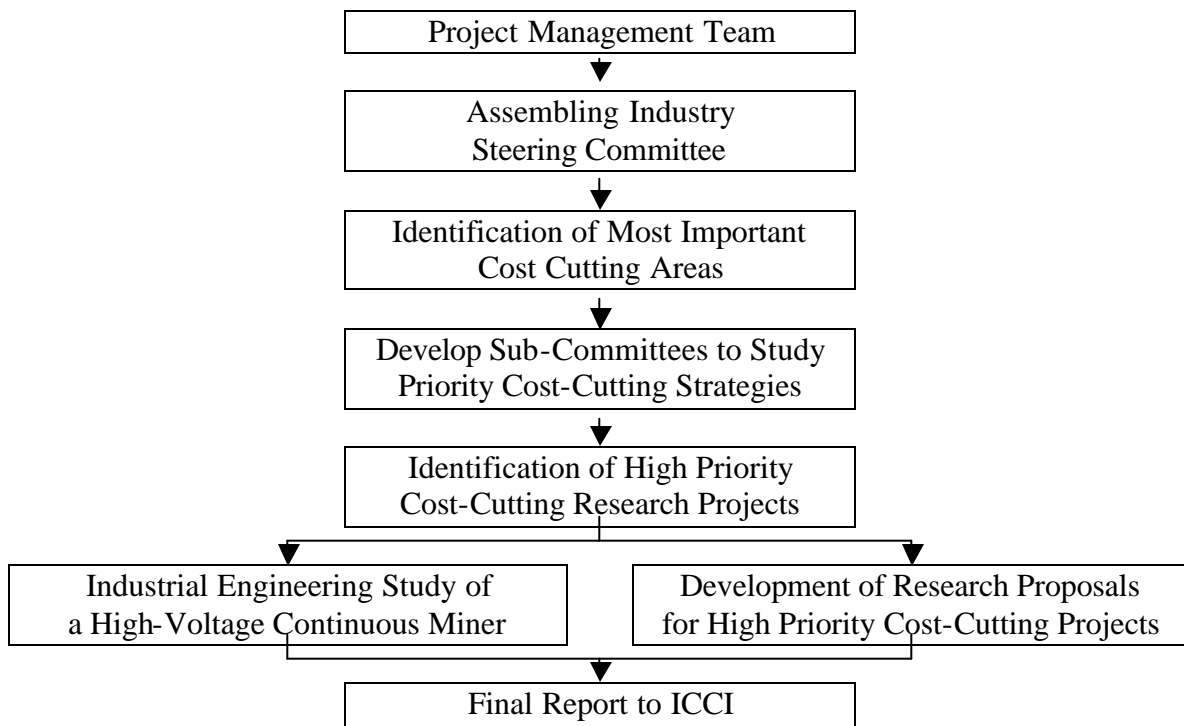


Figure 1. Research Program Flow Chart

The tasks required to achieve the project objectives are summarized below:

#### *Task 1 – Identify committee memberships and cost cutting areas*

Each participating company designated a representative to serve on the project steering committee. In most cases, the representative was the company's general manager or the equivalent. The project management team met with the steering committee for the first time on January 12, 2001 to begin the work of broadly classifying cost-cutting areas that

require significant attention. The cost centers listed in Table 1 of the Executive Summary were identified in that meeting.

*Task 2 – Identify projects within each cost-cutting area*

For each cost center, steering committee members were appointed to subcommittees to generate cost reduction ideas. Professionals from each participating operation were invited to participate on the subcommittee level. The project management team visited participating operations to discuss ideas and observe the current status of each mine relating to the issues being reviewed. The steering committee assembled again on March 23, 2001 to present the ideas that had been generated and to prioritize these ideas according to their potential benefit for the Illinois coal industry.

*Task 3 – Develop project solutions and identify actions to implement solutions*

With a prioritized list of cost-cutting strategies, the project management team began in-depth discussions with each of the various operations, equipment manufacturers, and industry suppliers to formulate research plans for demonstrating different proposed cost-cutting strategies. This included continued mine visits by the project management team. As a result of these discussions and visits, a host operation was selected and a research program developed for each of the six proposed projects.

*Task 4 – Prepare draft proposals for each project*

The project management team, in concert with steering committee members and representatives from the six designated host sites, prepared a draft proposal for each project. These proposals were distributed to the entire steering committee and approved during May 2001.

*Task 5 – Development of research proposals for each project*

Further discussions regarding the draft proposals between individual project participants, industry steering committee members and the project management team led to the development of five specific research proposals. These were submitted to ICCI for consideration during the next funding period. They were submitted as five independent projects under one umbrella.

Because of favorable equipment scheduling, work on one proposal got underway in June 2001. This project, an industrial engineering study on a high-voltage continuous miner, involved conducting time studies of the performance of two different machines, analyzing the size consist of the machine output, and collecting mine atmosphere samples to measure dust concentrations generated by the equipment. In all, 28 full-shift (9 hours) time studies were performed, one ton of coal was screened for size analysis and 32 dust samples were collected.



*Task 6 – Synthesize research proposals to develop final report*

The final report to ICCI describes the creation of an industry steering committee to examine the cost of mining Illinois Basin coal and ways to reduce that cost. The final report presents the committee's outputs, which are five proposals for achieving a minimum of 20% cost reduction throughout the industry. It also includes a full report on the industrial engineering study of a high-voltage miner that was undertaken as part of this project.

*Task 7 – Information transfer workshop*

The final report will be distributed to all members of the steering committee. When the industrial engineering study portion of the report has been reviewed and approved by participants in the study, an information transfer workshop will be scheduled to formally present the collected information to the industry. A presentation of the findings will be made at the Clearwater Conference in March 2002.

## BACKGROUND AND PROBLEM STATEMENT

Since the end of the 1970s, coal prices in the United States have been in a steady decline. Although there are currently some indications of a change in this pattern, the overall trends have been consistently downward. This has been due to the competition from other energy sources, as well as competition throughout the world.

During that same period, the cost of labor and material has increased at a similar rate to the overall inflation rate in the country. This means that in order for the coal industry to survive, they must be more productive. They must also look at methods of producing coal without using the same resources that have built the industry in the past. For example, union labor scale in the mid-1970s was \$6.00 to \$7.00 per hour. This has increased by approximately \$10.00 per hour over the past 25 years.

As difficult as it seems to overcome these barriers, the coal industry in Illinois has an even more difficult task. In addition to a lowering realization for their product, they have been facing increased pressure from environmental regulations that require monitoring the emissions of the utilities using their product. As the Clean Air Act is amended and these amendments take effect, regulations controlling emissions of certain gases have become increasingly more restrictive. The major focus of this legislation has been the control of sulfur emissions; and since the great majority of Illinois coal reserves are high in sulfur content, there has been a dramatic effect on the Illinois coal industry.

The markets for Illinois coal are almost exclusively the domestic utility and small industrial markets. A lack of metallurgical properties in the coal eliminates the steel industry, and the transportation cost virtually eliminates foreign markets. These restrictions force the Illinois coal industry to devote their entire efforts in this one area.

These customers of the Illinois coal industry have faced almost identical challenges over the past decade. They were forced to evaluate how they could best address changes in their operating guidelines due to new regulations. Utility companies basically had three options:

1. Switch their fuel source to a lower sulfur product – This option eliminates most Illinois mines from competing for the business. It thus reduces the overall sales capacity of the State and increases competition for the business that remains committed to the local coal industry. Disappointingly, this was the choice of many utilities, including some large coal-fired plants within the State of Illinois.
2. Utilize sulfur credits and continue to burn high sulfur coal – This option allows the Illinois operations to remain in competition, but the strategy is a short-term one. Also, the cost of credits is an added cost of fuel, thus placing the high sulfur producers at a tremendous disadvantage.
3. Install scrubbers to remove the sulfur emissions – This is the best option for the Illinois coal industry. But the economics of this decision are based on the fact that the customer believes that high sulfur producers can continue to provide a low cost fuel, in order to offset the capital and operating cost of scrubbers.

Regardless of the option that each customer selects, the Illinois coal industry is still placed at a disadvantage compared to other fuel sources, and even within portions of its own industry. Therefore, not only has the coal industry in Illinois been faced with the tightening of the overall coal markets; but they have also been subjected to a much tougher challenge requiring increased cost reductions if they are to remain in business.

Unfortunately, this points to one important issue facing the coal industry in Illinois. It is not sufficient for the industry to keep up with improvements in the United States, and the rest of the world. Due to their competitive disadvantage, they must be ahead of the rest of the industry, and be leaders in the advances that are made. Their only chance is to perform better than the competition, and remain at the forefront of innovation. This situation is providing momentum for this project.

The greatest question is how to address the issue. There have been tremendous amounts of money used in various ways to keep the industry intact. Most of this money has been directed at areas where the sulfur in the coal reserves is too high to comply with Clean Air Act standards using conventional operating methods. States have subsidized the construction of scrubbers for utilities in order to entice them to scrub and continue to use high sulfur coal. The State of Ohio pays the utilities \$3.00 per ton for every ton of Ohio coal that they use, another method of providing an incentive to use the high sulfur coal. Unfortunately, all of these programs are only temporary measures, and none of them provide a long-term solution. The ideal solution to the problem is to lower the cost of using Illinois coal to the customer so that it is the best economic option for them. This includes the cost of environmental compliance, so the task is even greater.

Another key issue is how to approach the problem and lower the cost of producing Illinois coal. Many programs in the past address the concerns of individual operations. While this may benefit a particular site, it does not help to solve the problem of the industry as a whole. In fact, this solution usually provides one Illinois mine a slight advantage over another Illinois mine, and they fight to obtain contracts from each other. The best approach is to develop improvement strategies that will involve a collection of mines and will provide benefits to multiple operations, and ideally to them all. By accomplishing this goal, it allows coal operators an opportunity to go after any contracts, not just those in the Illinois Coal Basin. This plan will increase the opportunities available for the Illinois operators and will allow them to compete in a larger market, instead of simply undercutting each other to survive from year to year.

The key to solving this problem is a cooperative effort from the coal industry. Such an effort will make this endeavor a success; and will provide opportunities that could not be obtained individually. This is a unique solution and is radically different from the traditional corporate mentality. However, the situation is not traditional – it is different from anything the industry has ever faced. Maybe it is time for a new approach to revive our industry!

## RESULTS AND DISCUSSION

### **Project Management**

One of the major keys to the success of this project is the management of the process. Due to the high level of competition and pressure that exists in the coal industry, most management teams are focused on obtaining results that improve their business. This forces those individuals to evaluate any projects based on the time involved and the value that it brings to their organization. These factors make it difficult to bring coal operators into many research projects, since they cannot immediately see the value of the project and how it relates to their business.

This project has been carefully designed to incorporate leadership from both industry and research backgrounds. This blend provides the expertise to develop the project, while still maintaining the viewpoint of the coal operator, who understands the demands on time and resources. This optimizes input from the industry by getting maximum involvement with minimal time invested.

In order to accomplish the project goals, a two-phase plan was developed. First, the academic sector of the group would provide most of the necessary labor enabling the participating coal operators to maximize their value by focusing resources in the areas where they have the most expertise. The second phase involves creating working committees to formulate ideas, prioritize proposals and commit resources to projects.

## Identifying Committee Memberships and Cost-Cutting Areas

The leadership of the project is comprised of a project management team and an industry steering committee. The project management team consists of Dr. Paul Chugh, Mr. Mike McGolden and Mr. Joseph Hirschi. Table 4 lists the individuals that participated on the steering committee and the companies and operations that they represent. Each mine's production in the year 2000 is also shown. As stated in the Executive Summary, the industry steering committee represents 26 million of the 29 million tons produced by Illinois' underground coal operations in 2000.

Table 4. Coal Industry Steering Committee

<u>Committee Member</u>	<u>Company Name</u>	<u>Mine Name</u>	<u>Production</u>
Tom Denton	American Coal	Galatia	7,518,829
Matt Haaga	Black Beauty Coal	Riola	995,000
Mike Blevins	CONSOL Energy	Rend Lake	2,739,424
Mike Caldwell	Freeman United Coal	Crown II	1,585,514
		Crown III	2,073,543
Howard Schulz	Monterey Coal	Mine #1	2,678,957
Mark Cavinder	Old Ben Coal	Zeigler #11	2,420,000
William Kelly	RAG-American	Wabash	1,505,399
Roger Dennison	Turriss Coal	Elkhart	1,953,847
Michael Meighen	White County Coal	Pattiki	2,442,334

In assembling this group, the project management team sought to involve every underground operation in the State. This goal was very nearly achieved, as only two out of twelve operations did not participate. The steering committee also includes a representative of the United Mine Workers of America (UMWA), the chief labor organization in the State. While the steering committee does not include every coal company and operation in the State, it does represent the entire industry in the State. There are mines from every geographical region, mining coal from all of the major coal seams in the State. Furthermore, there is a combination of large and small operations, continuous miner and longwall operations, union and non-union operations.

The key element in the development of this project is the expertise of the committee members. By combining the technical and research capabilities of the academic sector with the operational knowledge and experience of coal industry leaders, this project has the personnel with the ability to identify optimum areas to address in making the greatest impact on the cost structure of the underground mines in the State.

During the first month of the project, the project management team met at SIU to formulate a plan of action. Commitments obtained from industry officials when the project was proposed were confirmed and efforts began to include those operations that had not responded initially. An outline of the agenda for the first meeting of the industry steering committee was prepared.

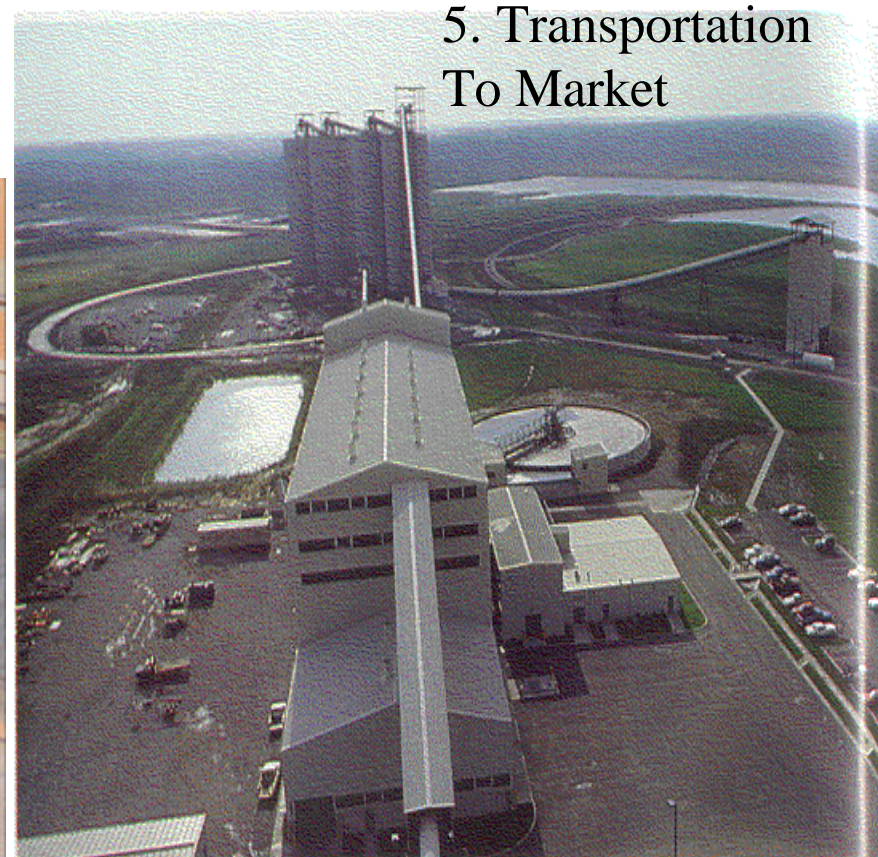
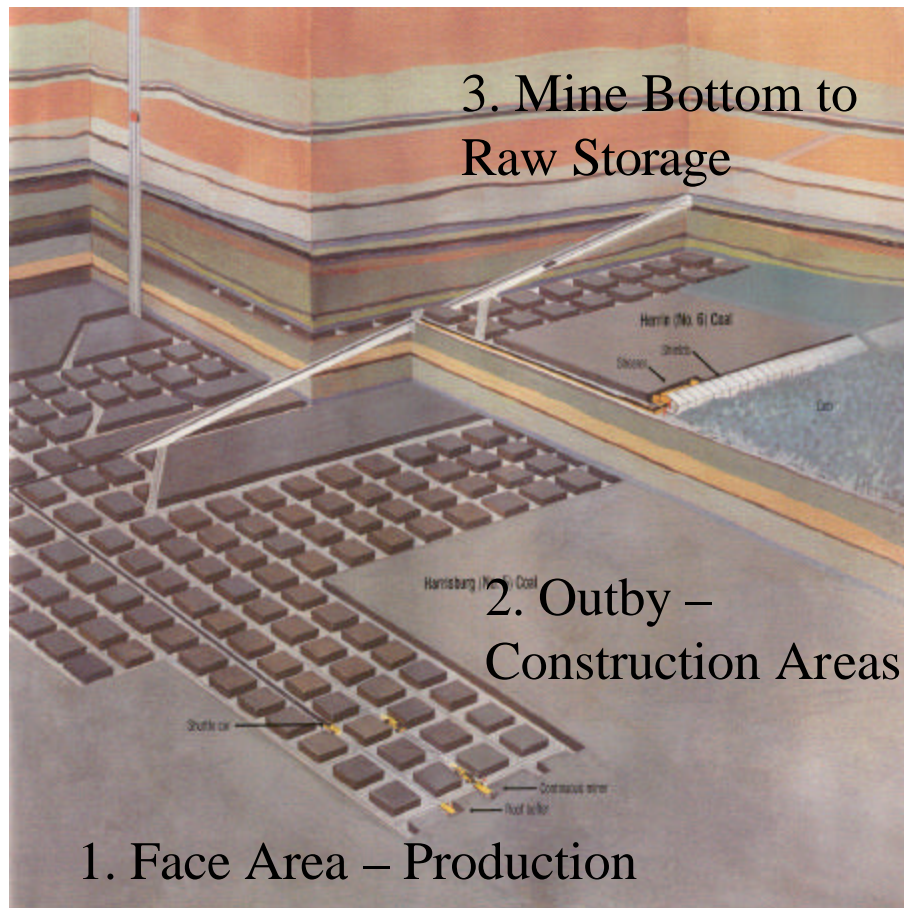
In the second month, the project management team prepared a power point presentation to introduce the steering committee to the goals and objectives of the project and to focus attention on the major cost centers of a typical operation. These cost centers are shown in Figure 2. They also met again to finalize the agenda for the steering committee meeting and distribute announcements and invitations for the meeting. Contact was made with American Coal Company and they came on board with the project.

The group's first meeting, held in Mt. Vernon, Illinois on January 12, 2001, was devoted to identifying areas in which projects would provide the greatest gains. In discussing more than a dozen possible projects, five areas were identified as the major cost centers in a typical coal mining operation. A summary of ideas discussed follows:

1. Face production and productivity

- Productivity gains in the face area offer the greatest potential for reducing costs.
- Maximizing miner production rate seems to be the current objective of equipment manufacturers. However, improved production rates reveal other bottlenecks. Time study comparisons on different miners could eventually evolve into studying improved haulage systems as well.
- The environmental issues of dust and noise control are closely related to miner productivity and need to be studied simultaneously as an integrated system. Diesel particulates will be the next big issue after dust and noise regulations stabilize. Ideas that have shown promise in reducing exposure to dust and noise should be an integral part of any miner productivity study.
- Research on dust control at SIU, West Virginia University, and Penn State; on simulating mine ventilation systems at University of Kentucky; and on mining simulation at SIU should be utilized where possible.
- Black Beauty Coal is considering using a new 14CM27, a high-voltage, low profile machine from Joy. It will be placed on a super-section along side a 14CM15. Detailed industrial engineering studies will show any incremental difference in throughput of the new machine. This project has potential for longwall gate entry development also. According to Matt Haaga, the 14CM27 should arrive in mid February and be ready to study by late March.

Figure 2. PROPOSED COST CENTERS



4. Processing and Waste Management

- Dilution is an area that has significant potential for reducing costs. Using rough numbers, Dr. Chugh suggested that increasing recovery by 10% would yield a 15% increase in revenue.
  - Ground control costs are as much as \$2/ton. Taking a close look at alternate mine layouts with a mine simulation program could yield substantial improvements.
  - Dilution and ground control expenses are often a function of operator experience and skills. A diminishing pool of skilled labor is becoming a significant issue. Education and training can benefit not only the face area but also every cost center.
2. Outby construction areas
    - Education and training are keys to reducing costs outby. Training programs need to be more than just classroom training. Mines that are still in operation are running leaner and meaner, so the worker must be empowered to do his/her job.
    - One drawback of good training is that we are training people for other industries. The more trained our workforce becomes, the harder it is to keep them.
    - Materials handling costs are a function of mine size. Studies need to look at improved technology for shaft and slope construction to optimize mine size. Capitalizing new portals can minimize the cost of maintaining vast outby areas.
    - Regarding supplies, the greatest cost reduction potential is in labor costs rather than material costs. An outby laborer can spend as much as 1/4<sup>th</sup> of the time waiting for materials. Management needs training to schedule work and supply of materials more efficiently.
    - Technology exists to automate some of the examinations performed every shift. Using this technology would result in the loss of a few jobs. The resulting cost savings would open up markets thereby increasing coal sales. In the long run, selling more coal would mean more jobs.
  3. Transportation of product from the coal seam to the surface
  4. Coal processing and management of coal mine waste or refuse
    - Because 10% improvement in recovery yields 15% increase in revenue, plant processes should be looked at for ways to improve recovery.
    - Managing coal combustion by-products has been successfully demonstrated in Illinois and offers some potential for improving the bottom-line.
  5. Transportation to final customer
    - Being dependent on rail service is a major issue. Politicians should define a national energy policy, which must include transportation.

### **Identifying Projects Within each Cost-Cutting Area**

With this basis, subcommittees were designated with steering committee members as committee chairs and co-chairs, as shown in Table 5. Each subcommittee focused on potential cost reduction strategies within their area. One of the most attractive features of this plan is that each operation can involve its people and resources in the area or areas

that have the greatest impact for them. A concerted effort was made to allow the steering committee participants to be involved where they thought they would do the most good.

Table 5. Cost Area Subcommittees

<p><b><u>Partial Extraction Mining Systems</u></b>            Matt Haaga – Chair            Mark Cavinder – Co-chair            Mike McGolden – Project Liaison</p>	<p><b><u>High Extraction Mining Systems</u></b>            Howard Schulz – Chair            Tom Denton – Co-chair            Mike McGolden – Project Liaison</p>
<p><b><u>Outby (Construction) Areas</u></b>            Roger Dennison – Chair            Tom Denton – Co-chair            Joseph Hirschi – Project Liaison</p>	<p><b><u>Processing and Waste Management</u></b>            Mike Caldwell – Chair            Bill Kelly – Co-chair            Dr. Chugh – Project Liaison</p>
<p><b><u>Transportation to Market</u></b>            Mike McGolden – Chair            Mike Meighen – Co-chair            Joseph Hirschi – Project Liaison</p>	<p><b><u>Education and Training</u></b>            Bill Kelly – Chair            Joe Angleton – Co-chair            Dr. Chugh – Project Liaison</p>

Although the goal of the project is to develop some cost cutting measures that will apply to the industry as a whole, there are obviously going to be certain operations that will derive a greater benefit from individual projects. By following the format just described, the subcommittees were responsible for developing their own individual projects and then reporting the ideas and findings back to the main committee for evaluation. The project management team participated in the work of the subcommittees by visiting each mining operation to observe and discuss the current state of affairs and the most pressing critical issues.

The industry steering committee assembled again on March 23, 2001, at SIU in Carbondale, Illinois. With the addition of CONSOL's Rend Lake Mine and White County Coal Company's Pattiki Mine, representatives of eight companies and the UMWA attended the meeting along with the project management team and Dr. Ron Carty representing the ICCI. Subcommittee reports identified three primary focus areas.

### *1. Face productivity*

The area of face productivity stands out from all other areas in importance. Since roughly 50% of the total mining cost is labor and employee benefits, the fastest way to reduce the cost of producing a ton of coal is to produce more tons per man. Many operations have spent valuable resources searching for ways to reduce their manpower. This provides a measurable benefit, but is not always sustainable. The general rule of thumb is that each employee represents between \$0.03 and \$0.05 per ton. However, the greatest impact to the labor and benefit cost is not reducing the manpower, but increasing



the tons produced. In order to increase this total without a proportionate increase in manpower, the face productivity must be increased. The group thought that this area was so important that they identified two projects in this area – increasing the production rate of the continuous miner, and improving the face haulage systems to carry coal away from the miner.

## *2. Out-of-seam dilution*

Next to face productivity, the most significant issue that coal operators need to address is their processing plant yield. Since most of the costs of the operations are associated with the actual mining, transporting, and processing of the material, an increase in the yield will result in an increase in revenues with an extremely low increase in cost. While most operations are forced to live with the inherent impurities in their coal seam, they have the opportunity to reduce the amount of out-of-seam dilution that they produce. Controlling this quantity of waste material provides a tremendous opportunity for cost reduction to the operations.

## *3. Solid Waste management*

Finally, the third major area of opportunity is the cost of managing the waste disposal. Once again, the group not only examined the cost structure of their operations, but also the potential to impact that cost. There are several new technological improvements in the waste disposal area that can create significant cost reductions. This opportunity is not available to all of the operations involved in the project, but there are a high percentage of these mines that can take advantage of these savings.

There are many other areas where significant improvements can be made such as outby areas, health benefits, material costs, coal preparation, etc. However, the committee concluded that these three areas were clearly of utmost importance. The savings potential of this project does not end with these three areas. But the goal of the group was to identify those areas that provide the most significant improvement for all mining operations in the State. Therefore, the above-mentioned areas became the subjects of the initial projects undertaken by the group.

## **Develop Project Solutions and Identify Actions to Implement Solutions**

The second steering committee meeting identified operations with a particular interest in the top priority projects. During the month of April, 2001 the project management team met with the management and engineering staffs of these operations to put together plans of action for evaluating and demonstrating new technologies. These meetings included visits to mine sites and consultations at SIU.

As expected, industry involvement played a key role in the successful development of specific plans for potential research projects. The companies, mines, and individuals who actively participated are as follows:

Proposed Project: Industrial engineering studies of a high-voltage continuous miner  
 Company and Mine: Black Beauty Coal Company's Riola Mine  
 Participants: Matt Haaga, Charlie Austin

Proposed Project: Alternative haulage systems  
 Company and Mine: Turriss Coal Company's Elkhart Mine  
 Participants: Roger Dennison, Guy Hunt  
 Tom Cushman of Phillips Machine

Proposed Project: Underground management of coarse processing waste (gob)  
 Company and Mine: White County Coal Company's Pattiki Mine  
 Participants: Mike Meighen, Chris Russell

Proposed Project: Dewatering fine coal waste disposal areas  
 Company and Mine: Old Ben Coal Company's Zeigler #11 Mine  
 Participants: Mark Cavinder, Mark Mormino

### **Prepare Draft Proposals for Each Project**

The project management team then synthesized all of the information collected to this point and prepared draft proposals for four highly focused research projects. The proposals were designed to develop appropriate technical, health and safety, operational, and economic data for commercial implementation of the cost-cutting strategies. The proposals, which were submitted to members of the steering committee for approval in May, 2001, are as follows:

#### *Industrial Engineering and Dust Control Studies on a High Production Rate, High-Voltage Continuous Miner*

One of the prominent trends in the mining industry in the last decade has been the move towards higher voltage mining equipment. Higher voltage machines offer more horsepower, which translates into faster loading rates. Increased productivity in turn lowers operating costs. Since the high-voltage machine has a higher price tag, the bottom line question is whether the operating costs can be reduced enough to provide a sufficient return on the investment required for the machine.

This project consists of a side-by-side comparison of a Joy 14CM15 (995 volt) continuous miner and a new Joy 14CM27 (2300 volt) machine. One of the participating companies was asked by the equipment manufacturer to place the new machine in their mine, which has one super section, for the purpose of collecting comparison data. The project will result in a third party analysis, which is beneficial to all involved. The equipment vendor gets an outside analysis of their new product, the mine operator gets a complete engineering study without having to commit scarce manpower, and the research group gets an ideal project without any extreme set-up costs.

Congruent to the productivity cost issue are two other issues that can also affect costs. The first is dust control. Increasing production rates can result in higher dust concentrations throughout the mine. Of course, dust levels in the mine, and particularly at the face, are a sensitive regulatory issue. Furthermore, the maximum exposure limit is not affected by production rates. Since dust is controlled most effectively at the point of mining, unless control measures are in place when the high production machine is placed in operation, the mining section will quickly fall out of compliance and production rates will have to be lowered despite the capabilities of the machine.

Dust control studies currently being conducted at SIU have shown that scrubber filter thickness and the use of surfactants can reduce dust concentrations in the air being discharged by the continuous miner scrubber. The productivity study will be coupled with dust control monitoring and implementation of research findings at SIU and elsewhere to control dust. This will also permit verification of laboratory results in an actual mining scenario. The objective will be to maintain regulatory compliance while allowing an evaluation of the full production capabilities of the mining equipment.

The second related issue is the cost of processing fines. For most of the participating operations, coal fines below 100 mesh are treated as waste and disposed in slurry impoundments. Any technology that reduces the percentage of fines in the run-of-mine product can positively affect the waste management costs of the operation. This project will also consist of a size analysis of the output from the high-voltage machine. The new machine has more horsepower on the cutting head but it also has wider bit spacing. The output from both machines will be collected and analyzed to determine if the new machine produces a coarser or finer product.

Industry representatives believe that face productivity has the greatest impact on total operating costs. The equipment vendor suggests that the high-voltage machine will provide a 15% gain in productivity. Such a gain would result in lowering total costs by 8% to 10% at most operations.

### *Alternate Face Haulage Systems*

Over the past few decades, there have been tremendous improvements in underground face productivity. These increases have been even more substantial over the past 10 years. Many of these improvements are due to the evolution of the improved continuous miners. These machines are more powerful and more reliable than ever before. However, in order to optimize the capabilities of these machines, the coal operator must be able to transport the mined material away from the machine.

Changes in haulage systems over the past several years have been as dramatic as the evolution of the continuous miner. Continuous haulage systems, and the use of battery and diesel haulers, have replaced many of the traditional electric-powered cable shuttle cars. Even mines utilizing shuttle cars are now using three or four cars in situations that traditionally only saw two cars in service. All of these changes took place in an attempt

to optimize the “continuous” miner. But, in spite of all of these efforts, the continuous miners of today are still limited by haulage systems.

Continuous haulage systems provide the greatest opportunity to optimize the production of continuous miners. Unfortunately, many mines do not have the proper conditions to utilize these systems. Adverse roof and floor conditions, seam undulations, pillar geometry, and reserve configurations are some of the factors that limit the ability of the operator to use this system. Thus, a batch haulage system utilizing shuttle cars or haulers is the only feasible option.

In a batch haulage system, production delays result from changing cars behind the miner. Even with multiple cars in the system, there is still a time period where production is stopped while the cars switch out. This time period can be reduced by various methods: smaller pillars, better change locations, shorter face to feeder distances, higher capacity cars, and even more haulage equipment. However, a production delay still exists in a pure batch haulage system. Some mines, particularly longwall mines, will have greater delays, generally due to pillar configuration. Reducing or eliminating this bottleneck makes it possible to improve productivity by as much as 20%.

One potential solution to this problem is to have loading capacity behind the miner during the periods when cars are changing out. This capacity, in the form of a “surge” car, needs to be able to keep the miner cutting and loading coal while the cars are changing places. Doing so increases the operating time of the miners and thus improves productivity. While the surge car cannot match the gains that are seen with continuous haulage, it can provide an opportunity to achieve some of those gains and still maintain the flexibility of a batch haulage system.

The concept is much simpler than it initially appears. A typical deep cut with a continuous miner is broken down into four segments. The miner penetrates approximately 20 feet, sets over, and repeats the process. Then the miner sets over and follows the same procedure until the final depth of the cut is reached. The value of a surge car is not to be able to handle the entire production of the miner during the cut, but to simply handle the surges in production during each segment of mining. If the surge car can allow the miner to operate without interruption during each segment, the batch haulage system can “catch up” while the miner is repositioning for the next segment. This concept provides the potential to gain all of the time lost due to typical batch haulage, without becoming overly cumbersome. The surge car only needs to have the capacity to handle the surges, and also be able to discharge at a rate that will improve the cycle time of the haulage vehicles. The initial design concepts are for a car with approximately 15 to 20 tons of capacity and a discharge rate of 30 to 40 tons per minute. The idea is to allow the miner to operate independent of the haulage system and use the surge car to provide the buffer between the two components.

This project will involve the use of a surge car behind the miner in at least one of the operations of the group of coal operators. The existing haulage systems of each operator will be evaluated, and using computer simulation, the benefits that are measured during

the actual tests can be programmed into each operation to determine their potential benefit. The car to be used will be supplied by Phillips Machinery. It has been developed as a battery-powered shuttle car rather than an electric car with a trailing cable. Ultimately the car will be a remote-operated machine, but for testing purposes the car will have an operator in the deck. The improvements in face productivity will be time-studied under a variety of conditions to determine the results that can be reasonably expected under all of those conditions. Due to the tremendous amount of variables that exist in a normal production section, the monitoring efforts will be quite extensive in order to provide results that operators feel are sustainable and transferable between mining sections and mines. The results of the tests need to be reliable to the point that the operators feel confident in making capital expenditure decisions based on them.

When analyzing the potential benefits to the coal industry, this project is clearly the greatest opportunity. Compare a well-run batch haulage single miner section with a continuous haulage system in like conditions. Assuming that the conditions are ideal for the use of continuous haulage, there is generally an increase of over 50% in production during peak shifts. Due to the complexities of continuous haulage, this is usually not a sustained result. However it demonstrates the potential that is available. It is not feasible to capture all of the miner production capacity, but a significant portion is available through the use of this system. Using rough approximations, a 5% increase in productivity will equate to a decrease in overall mine costs of around \$0.50 per ton. When mines are operating at slim profit margins, many at no more than \$1.00 per ton, this represents an increase in profits of 50%. The development of this type of system could potentially have a major impact on the Illinois coal industry.

#### *Education and Training Program to Control Out-of-Seam Dilution*

In the coal industry, one of the major costs of operation is the processing of raw material to produce a marketable product. As customers become more cost aware and their processes become more refined, the need to provide a product that meets specifications is essential to staying in business.

The cost of processing, or rather the control of that cost, begins at the face, where the coal is mined. Obviously, the higher the quality of the mined product, the lower the cost of processing to make it marketable. By reducing the amount of extraneous material mined, the costs of mining, conveying, processing, and disposing of the refuse are all reduced. While it sounds easy, there are difficulties associated with mining cleaner coal. When coal operators focus on being more selective in their mining processes, generally productivity decreases. Therefore, the gains from improved product quality can be offset by lower production rates. Technological improvements in machinery that assist the operator with staying in-seam are at the forefront of mining research. These also come at a cost and, depending on conditions, can also add additional problems to the mine.

This project will focus on identifying “best practices” in order to provide an education and training program for all operations in the State. Studies show that when equipment operators are given information and training, output improves dramatically. Throughout

the State, there is a wide range in the ability to control dilution. This range exists despite the fact that most operators are using the same equipment and are operating under similar conditions. This project will identify the best procedures and determine the economic value in controlling dilution. Then, an education and training program will be developed to distribute this information throughout the industry.

The potential benefit to some mines is significant. A 10% reduction in production costs is possible by improving their dilution percentage, and this could be greater depending on the circumstances. For example, if a mine can keep from building a new impoundment, or if it already has high refuse handling costs, potential benefits are even greater. Some mines have the opportunity to ship some raw product, a situation that greatly benefits from improved quality mining.

#### *Alternate Systems for Solid Waste Management*

About 35% of the run-of-mine (ROM) coal ends up as coal processing waste (CPW). The CPW may be subdivided into coarse coal waste (CCW) or gob, and fine coal processing waste (FCPW), typically known as slurry. The ratio of CCW to FCPW is approximately 2:1. The CCW and FCPW can be sources of environmental problems. A typical mine spends \$0.35 - \$0.50 per ton of ROM for management of CPW.

Currently, CCW is typically disposed in refuse piles, compacted and covered with a suitable cover, which will support vegetation. The FCPW is typically disposed in diked ponds as a low solids concentration (10 to 15%) slurry. It is estimated that about 50% of the slurry disposal pond space is occupied by water. The decant water is mixed with make-up fresh water and used in the coal processing plant. A few mines are attempting to dispose slurry in underground works as a low solids concentration stream. The decant water is pumped back to the surface and used in the processing plant.

Current management techniques are expensive and the industry agrees that there is considerable room for cutting costs in this area. A 50% reduction in cost, relative to the numbers indicated above, may be achievable. Industry representatives have identified three high priority approaches for research in an effort to achieve the desired cost reductions.

The first approach is underground management of FCPW (slurry) alone or mixed with crushed gob and/or coal combustion byproducts (CCB). White County, Wabash, Freeman, Turris, and Galatia mines have expressed interest in participating. The management practices may involve low solids concentration slurry or paste backfill.

The second approach is dewatering of existing slurry ponds to increase available pond space for solids disposal. Research and demonstration studies should pursue economic approaches for dewatering slurry ponds. This could have a major positive impact on disposal costs since the approach will reduce capital costs of constructing ponds. Zeigler and Galatia mines have expressed significant interest in pursuing this project. A

technical and economic feasibility study needs to be conducted to establish its commercial viability.

The third approach is co-management of CCBs and FCPW, or CCBs and CCW to neutralize acid generation potential and possibly minimize cover requirements for sustained vegetation to achieve State reclamation requirements. This approach has been discussed with the Illinois Office of Mines and Minerals who expressed interest. However, they indicated that the approach will require considerable field demonstration work before it will be accepted by regulatory agencies.

### **Development of Research Proposals for Each Project**

The project groups were expanded during the month of June, 2001 as the project management team sought matching support from mining equipment manufacturers, drilling contractors, process equipment suppliers and research consultants. Steering committee members and the project management team met with numerous industry experts to discuss the formulation of research projects that would meet the critical needs of the Illinois coal industry and the cost-cutting objectives of this project. The importance of these projects to the industry was demonstrated when every member of the steering committee submitted a letter of support including the committing of substantial matching funds.

In July, 2001, the results of this project were submitted to ICCI in the form of five specific research proposals. A brief description of each proposed research topic, the amount of committed matching funds, and the project duration are presented below:

*Industrial Engineering and Dust Control Studies on a High-Voltage Continuous Miner*  
*Industry Matching Support: \$293,225      Project Duration: 1 year*

One of the prominent trends in the coal mining industry has been the development and use of higher voltage mining equipment. This project will attempt to identify the productivity improvement potential of a high-voltage continuous miner. These machines have proven to be effective when used in conjunction with continuous haulage systems. However, none of the operators associated with this project currently employ continuous haulage. Therefore, possible productivity improvements will have to be demonstrated with some type of batch haulage system to meet the needs of the Illinois coal industry.

Joy Mining Machinery has provided a 14CM27 machine to conduct an industrial engineering study under reasonably controlled conditions. This is a 2,300-volt machine, and is the first 14CM miner to operate at this voltage. Joy has previously manufactured a 12CM high-voltage machine for higher seam applications. The study will be conducted at Riola mine near Catlin, Illinois. The mine operates one supersection where the 14CM27 will operate side-by-side with a standard voltage (990-volt) 14CM15 machine.

Production increases always raise the issue of dust control. Characteristics of the high-voltage machine should result in lower dust concentrations and the production of a

coarser product. This project will include analyses in both areas. Monitoring of dust concentrations will take place simultaneously with the industrial engineering study. Research being conducted at SIU on the use of surfactants to reduce dust concentrations will be implemented during the study. The output from both miners will be screened to determine the size distribution.

*Industrial Engineering Study of an Alternative Face Haulage System*

*Industry Matching Support: \$224,000      Project Duration: 1 year*

The Coal Industry Research Steering Committee has identified increasing productivity in the face area as the highest priority for achieving a 20% reduction in production costs. This project will attempt to develop alternate haulage systems to maximize the production capacity of new high capacity continuous miners. The project should benefit both room-and-pillar and longwall mining operations.

There will be two distinct phases of this project. A Phillips Machine battery-operated shuttle car will be used behind a continuous miner in two different applications. First, it will be used as designed to provide a trial for a shuttle car without any trailing cable. The objective of this phase is to show the benefits of the shuttle car, without the liabilities of the cable. The host site for this test has not been determined. Next, the Phillips car will be used as a “surge car” to minimize shuttle car change out time delays. An industrial engineering study of this batch haulage system will be performed to assess if it can match or enhance the productivity gains of high capacity continuous miners. This study will be performed at Turriss Coal Company’s Elkhart mine.

*A “Best Practices” Training Program for Reducing Out-of-seam Dilution*

*Industry Matching Support: \$56,600      Project Duration: 1 year*

The cost of out-of-seam dilution at most mining operations in Illinois may vary from \$ 2 to \$4 per ton. Based on recent visits to most Illinois mines by the project team, it has been determined that there is a significant need to minimize out-of-seam dilution. The industry agrees that the first step toward achieving this goal is to develop a “Best Practices” training program, which can be implemented throughout the State. For a typical mine producing 3.0 million tons of raw coal annually, the direct and indirect costs associated with out-of-seam dilution (≈35%) may be as high as \$5 to \$10 million. Minimizing out-of-seam dilution may result in 10% cost reduction. Additional benefits accrue from reduced environmental impacts of coal processing waste disposal.

*Feasibility of Managing Coarse Coal Processing Waste as a Slurry Underground*

*Industry Matching Support: \$67,750      Project Duration: 1 year*

A typical mine in Illinois recovers only about 65% of the run-of-mine (ROM) coal processed. The 35% reject consists of two components: coarse coal processing waste (CCPW) which is larger than 28 mesh (25%), and fine coal processing waste (FCPW) which is smaller than 28 mesh (10%). The cost for managing these rejects on the surface varies from \$1.00 to \$1.50 per ton. It can be even more in specific situations. For a 3



million raw tons per year operation, an estimated reject management cost would be over \$1 million. Therefore, alternative management options that are more economic and more environmentally friendly than surface disposal must be considered.

One such option being considered is to fill the underground voids created in mining with the coarse and fine processing waste as slurry. White County Coal Company's Pattiki Mine has already successfully accomplished this with their FCPW. They will host this project, which has two objectives. The first is to perform a techno-economic feasibility study of underground management of CCPW in conjunction with FCPW. The second is to demonstrate a proposed system in the field on a pilot scale. This is expected to decrease the cost of waste management by about 50%, while simultaneously overcoming most of the environmental disadvantages of surface disposal.

*Feasibility Study of Dewatering Fine Coal Waste Disposal Areas*

*Industry Matching Support: \$59,120      Project Duration: 1 year*

Approximately 9 to 12% of the run-of-mine coal processed is disposed as fine coal processing waste (FCPW) in incised or diked ponds. The capital cost/ton of deposited solids in ponds is a strong deterrent to the development of new ponds. Therefore, effective utilization of disposal space in ponds can have a very positive impact on the production cost of coal. FCPW contains 40 to 50% water by volume, which evaporates from the pond surface through capillary action. If technologies can be developed to effectively dewater a disposal area economically, space utilization can be increased significantly. In addition to reducing capital cost/ton of FCPW disposed, dewatering reduces the potential for liquefaction in a seismic event and the overall surface area impacted by mining.

The proposed study would modify existing technology to drain FCPW. This is a field research project, but it is not full-scale. The test drains installed in FCPW refuse areas would be smaller than those necessary to drain an entire impoundment. The study would determine drain performance by measuring the density, moisture content, and hydraulic conductivity of the FCPW during draining. In addition, the quantity and quality of drain effluent would be monitored in order to assess drain lifespan and environmental impacts. The overall goal is to develop a plan for a full-scale demonstration of the technology on an FCPW impoundment.

Successful development of this technology would 1) lower the production cost of coal through reduced waste management cost, 2) improve stability of waste impoundment structures, and 3) reduce environmental problems associated with FCPW. All of these benefits could have a major positive impact on Illinois coal prices and markets.

## INDUSTRIAL ENGINEERING STUDIES OF A HIGH-VOLTAGE CONTINUOUS MINER

### **Problem Statement**

As the coal industry improves through both operational and technological advances, it continues to search for new ways to sustain this trend. Many of the quantum leaps forward that the industry has experienced have been directly associated with improvements in the equipment being used. Remote control miners, cable-less haulage, and longwall systems are examples of equipment improvements that have made the industry more competitive. To keep the industry strong, such developments must continue providing the coal mine operators with methods to improve their business.

One of the greatest challenges facing equipment manufacturers is improving on the design of the continuous miner. The changes from the first continuous miners, less than 50 years ago, to the current machines of today, are staggering. However, every time there is an improvement in the machine, the mining systems improve to maximize the gains, and the manufacturers are urged to seek additional improvements. As the industry moves into a new century, there are different issues that are being faced. Increased productivity has placed an increasingly greater importance on the ability of the continuous miner to control dust. New miners are being designed to increase the output of the machine in tons per minute, as well as to improve machine reliability. As continuous haulage, highwall miners, and high-performance super-sections are developed, the load on the cutting motors and tram circuits of miners is increased. Higher productivity is exposing the weaker components of the existing machines.

In an attempt to alleviate some of these problems, Joy has developed a high-voltage miner. The machine has a much higher horsepower cutter head, and is much heavier than the current machines, giving the machine more cutting force. These improvements also allow wider bit spacing, which generates deeper cutting penetration and produces a coarser coal product. The result is a better product for coal preparation, as well as a reduction in respirable dust generated. Higher horsepower also means a faster tramming machine, which improves cutting rates and decreases miner place change times. The goal for this machine is to provide the industry with a more reliable machine, especially in high production systems; a machine capable of greater productivity; and a machine that generates lower dust concentrations and less fines in the product.

Joy's initial efforts with this machine were very successful. In a higher profile model (12CM27), they coupled the high-voltage machine with a continuous haulage system and saw improved productivity of 15%. However, the same machine was used in a standard batch haulage mine and the results did not show any improvement over existing systems. The machine had proven that it was capable of improved productivity, but the haulage system controlled the output, so the end results were not an improvement. Logically, the dust control and size consist improvements should have been the same, but this was not tracked in the above study.

## Goals and Objectives

This study was undertaken to specifically examine the performance of the high-voltage miner utilizing existing batch haulage. The cost (\$1.8 million for the high-voltage machine versus \$1.2 million for the standard machine) is relatively easy to justify if projected productivity improvements are realized. However, without productivity gains, any other benefits would not justify the increased expenditure. The technology has proven successful elsewhere, but participating coal operators want to realize those improvements at their mines. Since there are no continuous haulage systems currently operating at any of the mines participating in this study, demonstrating the high-voltage machine's potential using batch haulage is critical. This study will examine miner performance only. Haulage systems can then be designed based on the estimated production potential of the miner.

The study had the following objectives:

1. Identify any productivity gains of a 14CM27 versus a 14CM15 in identical conditions.
2. Identify the ability to transfer those productivity gains to improvements in tons per unit shift, assuming appropriate haulage systems can be used.
3. Identify any issues concerning the high-voltage miner, such as health and safety or maintenance, that need to be addressed to realize the full potential of the machine.
4. Identify improvements in the size consist of the product mined as compared to the existing 14CM15.
5. Identify the same improvements in decreased generation of respirable dust.
6. Experiment with the use of surfactants to determine their effect on the control of respirable dust.
7. Quantify any bottlenecks in the system for use in developing alternate haulage methods that may be able to take better advantage of the increased production potential of the machine.

## Description of the High-Voltage Continuous Miner

The Joy Mining Machinery (JOY) 14CM15 is probably the most widely used machine in the industry. It is a medium to low profile machine particularly popular in the Illinois Basin. There are operations that have additional height and are operating 12CM12 machines, but generally the 14CM15 machine has the highest usage. The high-voltage miner to be studied is a 14CM27. The basic design of the machine is the same as the 14CM15. A comparison of the two machines was given in Table 2 of the Executive Summary. The significant differences are highlighted again here:

1. The 14CM27 machine operates at 2,300 volts, instead of 995 volts for the 14CM15. This changes the machine from a medium-voltage machine to a high-voltage machine according to the regulatory code meaning different standards for maintenance and cable handling.
2. The 14CM27 machine has more horsepower at the cutter head to improve productivity and reliability.

3. The tram circuit also has more horsepower and is geared differently to increase tramping speed.
4. The 14CM27 machine has more weight to provide more cutting power and reduce the amount of bouncing on the machine while cutting.
5. Increased power enables the bit lacing on the head to be increased, reducing the generation of fine particles and respirable dust. The bit lacing on the 14CM27 machine is 6 inches. The bit lacing on the 14CM15 is 4 ½ inches, which is typical of most machines in the Illinois Basin.

JOY's new 14CM27 high-voltage machine was built for a company that could not take delivery. Consequently, they offered the machine to Black Beauty Coal Company (BBC) to put into production at the Riola Mine, where the production potential could be studied. Matt Haaga, BBC's representative on the industry steering committee, suggested that the university conduct the study as an independent third party and as part of this project, to which JOY was agreeable.

### **Description of the Riola Mine**

BBC owns and operates the Riola Mine with two production units in the Herrin #6 coal seam near Catlin, Illinois. Roof and floor conditions are good and coal height is between 6 and 7 feet. One production unit is a super-section with two continuous miners producing coal. The 14CM27 machine went into production at the mine in February 2001 on a spare single-miner production unit. After a three month period to work out bugs and train operators, the machine was moved to the mine's super-section. Time studies on the machine began on Monday, June 18, 2001. They were conducted only on the day shift, which runs from 7:00 a.m. to 4:00 p.m., even though the mine produces coal two shifts per day. Studies were done for four shifts during the first two weeks. After a three week break to allow for a crew changes and vacation schedules, the studies continued for two more weeks with three studies done per week.

The super-section layout at the Riola Mine is shown in Figure 3. Mine entries are on 80-foot centers with crosscuts on 70-foot centers. The 14CM15 mined the #1 through #4 entries and connecting crosscuts. The 14CM27 mined the #5 through #8 entries and connecting crosscuts. The machine with the first opportunity to mine the crosscut between entry #4 and #5 did so. A single split of air ventilates the entire super-section so only one machine can be operating at any given time. Four battery-powered cars are used to transport the mined coal from the face to the conveyor loading point. Radio communication is used to direct the cars to the machine that is loading coal.

Personnel on the super-section include one foreman, two miner operators with one assigned to each machine, four roof bolters, four haulage car operators, one scoop operator and one mechanic, for a total of thirteen people. The foreman instructed the miner operators on their cut sequences and made sure the car operators knew which machine was loading.

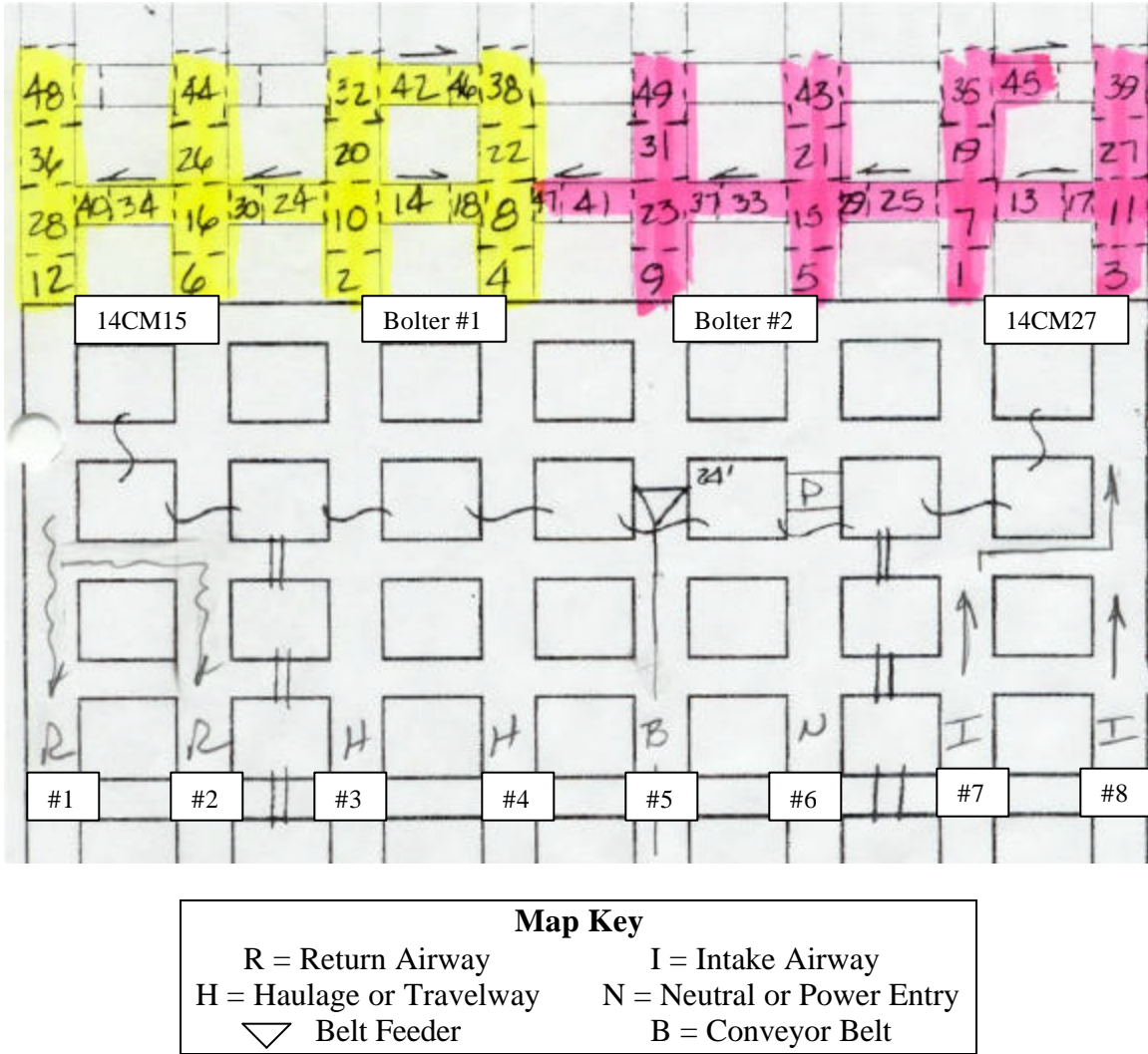


Figure 3. Super-section layout and cut sequence map

One of the most difficult tasks in testing underground systems is controlling all of the variables in a mine environment. It is impossible to establish the controls of a true laboratory experiment, but good conditions and the Riola staff provided as many of those controls as could be expected. Perhaps the biggest variable was equipment operators. Riola’s workforce is young and inexperienced operators were a factor, but the mine tried to keep that variation to a minimum by altering training, vacation, and shift schedules. All in all, the conditions for obtaining good representative data were excellent.

**Industrial Engineering Studies – Time Studies**

*Hypothesis*

Previous experience with other high-voltage equipment allowed JOY to predict a 15% gain in productivity with the 14CM27 high-voltage miner. Critical components of this

productivity increase will be measurable improvements in cutting and loading rates, tons loaded per car, and tram speed, which will be reported. However, since none of these components in and of itself affects the bottom-line tons per unit shift, predicted targets were not established. The focus of this study was on determining the productivity gain of the 14CM27 in actual tons per unit shift gained over the 14CM15, using the same batch haulage system.

#### *Data Collection and Analysis*

Time studies were conducted by an experienced coal mine industrial engineer and a recent SIU Industrial Technology graduate. The two individuals alternated between the two machines every day. Snap-back stopwatches were used to time every operation of the continuous miner operator and his machine from the time he left the surface until he returned at the end of the shift. This information was recorded on data collection sheets, as shown in Figure 4. A different sheet was used for each individual cut that a continuous miner made during the shift.

Start <u>3:28pm</u>		Height <u>6.20 ft</u>		Cut # <u>8</u>			
Stop <u>4:02pm</u>		Width <u>19.50 ft</u>		Place <u>3 left-blow thru</u>			
Time <u>34</u>		Depth <u>14.00 ft</u>		Miner <u>15 or 27</u>			
Car #	Car ID	Change Out	Load Time	C	Reset Time	Other Delays	Comments
1	4	xxxxxxxx	0.49			17.55	Wait on other CM
2	1	0.51	0.49				
3	3	0.49	0.75				
4	2	0.57	0.66		0.64		
5	4	0.64	0.51				
6	1	0.69	0.32		0.42		
7	3	0.64	0.51			9.75	Belt Down
8	2	0.69	0.32	C	0.42		

Figure 4. Sample Time Study Data Collection Sheet

Inexperience was a factor not only with the miner operators but also with some of those conducting the time study and compiling the data. Training was particularly important in how to correctly compile the time study data so that every minute of the shift is accounted for accurately. For that reason, the first week of studies, four on each machine for a total of eight studies, was used as a training period. All actual data was collected, compiled and reported. However, only data from the final three weeks of time studies were used in the final analysis of the time studies.

At the completion of each nine-hour time study, the data was checked for accuracy. All times were totaled and every minute of the shift accounted for. This process took two to three hours after every shift. Full shift summaries were prepared once a week for all the time studies completed during the week. Completing the shift summaries for a full week was a four to five hour process.

Following the completion of each two-week time study period, “Mineit” computer software was used to compile all of the time study data. This software performs checks on the accuracy of the data; generates summary information on each measured and computed variable; and produces easily readable reports summarizing the data. Three eight-hour days were required to input data and produce reports for a two-week period of time studies.

### **Industrial Engineering Studies – Product Size Distribution Analysis**

#### *Hypothesis*

With a wider bit lacing (6 inches versus 4 ½ inches) on the 14CM27, the size distribution of the product should indicate a coarser product. Selecting the optimum bit spacing involves in-depth research beyond the scope of this project. The objective of this portion of the study was simply to determine if there is a difference in the product size distribution of the two miners, and if so, to determine how much the difference is.

#### *Data Collection and Analysis*

Following completion of all of the time studies, a 1,000-pound sample (3 X 55 gallon barrels) was collected from each miner. The samples were collected right where the miner discharges into the haulage car. This was done to avoid any size reduction caused by haulage, feeder breakers, conveyor transfer points, and any other mechanism unrelated to the actual mining that takes place at the cutting head of the miner. Six barrels were placed in the scoop bucket and transported to the face area. Upon beginning a new cut, one of the miner operators loaded two or three cars and then filled the pan of the miner. Then the cutting head was turned off to avoid churning up the coal in the pan and the scoop pulled in behind the miner. With the cutting head still off, the miner operator started the conveyor motors and filled three barrels with the coal in the pan of the miner. This process was repeated for the second miner also. The barrels were then transported out of the mine in the scoop bucket.

Commercial Testing and Engineering picked up the two samples and performed a size distribution analysis by screening the coal at their Henderson, Kentucky laboratory. The top screen size was made at less than 5% of the sample, then at one-inch increments down to 2rd. Below two inches, the screen sizes were 1 ¾rd, 1 ½rd, 1 ¼rd, 1rd, ¾rd, ½rd, ¼rd, 16mesh, 28mesh, and 100mesh. Fractions below ¼rd were wet screened per ASTM standards.

## Industrial Engineering Studies – Dust Concentration Sampling

### *Hypothesis*

Wider bit spacing should also mean less contact points on the cutting head of the miner. This will translate into less dust generation during the mining process. Once again, determining the optimum bit spacing for dust generation purposes was beyond the scope of this project. The objective of this portion of the study was simply to determine if there is a difference in the dust generated by each of the two miners, and if so, to determine how much the difference is. The study allowed implementation of research being done at SIU on using surfactants to improve the dust collection efficiency of continuous miner scrubbers. A 25% improvement from using surfactants had been observed in the SIU/Joy Dust Control Laboratory located at the Illinois Coal Development Park in Carterville, Illinois.

### *Data Collection and Analysis*

Before the start of each time study shift, two MSA Escort LC Dust Sampling Pumps were calibrated at 2 liters/min using a wet test meter. The pumps were then attached to a Dorr-Oliver cyclone assemble and equipped with a MSA Coal Mine Dust Sampling Filter Cassette. These pumps were then taken into the mine and hung from roof bolt plates in the mine roof just outby the tail of the miner in its starting position. The pumps were placed on the return side of the entry, away from any face curtain, to monitor the air coming across the miner and from the scrubber. The pumps were moved as the miner moved from cut to cut and were started and stopped so that they were only running from the time that the miner first began a cut until the cut was finished. One pump stayed exclusively with the 14CM15 machine and the other with the 14CM27 machine.

At the completion of the shift, the pumps removed from the mine and the dust filter cassettes were taken out of the Dorr-Oliver cyclone assembly. The outer surface of the cassette was wiped clean with a rag cloth. A dust data card was supplied with each filter cassette. The card contained an identification number (cassette number) and the initial weight, in grams, of the filter capsule inside the filter cassette. The sample date, time, and length were filled in on the dust data card. The sample was then shipped to the Mine Safety and Health Administration (MSHA) for analysis.

Upon receipt of the cassettes, MSHA conducted a standard analysis using their Automated Weighing System (AWS). The filter capsule, contained inside the cassette shell, was the only part of the dust cassette that was weighed. The final weight of each sample was determined to the nearest 0.001 milligram. This weight was then input into the formula:

$$\text{Dust Concentration} = [(\text{weight gain} * 1000 * 1.38) / [2 * (\text{sampling time})]]$$

where weight gain is the number reported by MSHA (in grams) and sampling time is the test period (in minutes). The 1.38 factor is a Mine Research Establishment (MRE)



standard. MRE is a British group responsible for developing epidemiological studies on the relationship between coal dust and disease. This formula is an industry standard.

## **Results and Conclusions of the Industrial Engineering Studies**

### *Analysis of Time Study Elements and Results*

The time studies focused on key elements of the miner operation. The continuous miner mining cycle is divided into distinct and measurable elements. Since the production unit being evaluated is a super-section, it is not necessary to time the place change portion of the cycle. This simplifies the study and confines the information to the actual period in the cut. The various elements of the cycle are as follows:

1. Delays – the production time lost that is not an actual part of the cycle. This includes problems with equipment, delays caused by mining conditions, coordination delays created by people, and outby delays. Examples of each are: equipment – breaker tripped on the miner; conditions – removing rock that fell on miner; coordination – pulling slack cable to finish a cut; outby – slope conveyor down.
2. Loading – the actual time that the machine is loading coal into a car.
3. Change out – the time that the miner is ready to load but cannot because a full car has left the miner and an empty car is not yet in position.
4. Reset – the time involved in repositioning that is not change out time is captured as reset time. Each cut is divided into four segments. The miner will cut the width of the machine on the fresh air side of the entry to a depth of 20 feet. Then it will “set over” and cut a slab to widen the entire entry width to between 18 and 20 feet. Then, the miner will reposition back to the curtain side and repeat the first two segments until the final depth of the cut is reached. Due to Riola Mine conditions, cut depths are typically 32 to 33 feet. This involves at least three reset times per cut.
5. Clean up – loading time required to clean up any material that has spilled during mining of the cut. When the final cut depth and width are reached, the miner will back out make one clean up pass on each side of the entry to pick up all loose material. The material can usually be loaded into one car. This car is noted as a clean up car with the letter “C” after the load time.

These time elements for the collected data are summarized in Table 6. An analysis of times and comparative rates measured during the studies shows the potential improvements available with the high-voltage system.

### *Production Potential of High-Voltage Miner*

Comparing results from the two miners reveals four key points:

1. The 14CM27 had faster loading rates by over 20%.
2. The 14CM27 had faster tram speeds of almost 8%.
3. The 14CM27 loaded more coal per haulage car by almost one ton.
4. The average unit shift production of the two miners was almost identical.

The above results were very close to what the industry steering committee expected to see from the tests. The high-voltage miner can provide productivity increases only if the haulage system can remove the coal from the miner. In spite of improved miner performance, total production is still a function of the weakest link in the system, and in this case it is the haulage system.

Table 6. Average Time Study Elements Per Unit Shift

<b>Measured Element</b>	<b>14CM15</b>	<b>14CM27</b>
Minutes/Shift: Cutting	88.77	60.42
Clean up	16.45	13.14
Car Change	85.87	79.53
Reset	37.96	34.36
Delays – Equipment	25.71	71.19
– Conditions	28.18	12.52
– Coordination	244.35	253.39
– Outby	3.35	4.60
Number of Cars: Cutting	119	108
Clean up	13	11
Total	132	119
Tons per Car	9.14	9.93
Tons per Minute: Cutting	9.85	13.36
Clean up	3.32	4.11
Total	8.43	10.95
Loading Minutes per Car: Cutting	0.75	0.56
Clean up	1.27	1.19
Total	0.80	0.62
Tram Rate (feet per minute)	31.37	33.83
Tons Mined	1,206	1,182

One mistake that can be made in analyzing the data is with the cutting rate comparison. Loading rates for the two machines shows almost a 30% improvement with the 14CM27. However, this does not compare the cutting rates, only the loading rates. Since the miner is often cutting coal during the car change out time period, this time period should be included in cutting times. If the miners were feeding a continuous haulage system, cutting and loading time would be the same. When change out times are included with loading times, the improvement in cutting time is approximately 16%. This is very close to results that were observed with the high-voltage 12CM27 machine used with continuous haulage at the Marissa Mine.

#### *Comparative Evaluation of Continuous Miners Projected to Haulage Systems*

The above data provides a good basis from which to make comparisons and draw conclusions as to the benefits of the high-voltage miner. It also provides enough

information to be able to make a good simulation of the improvements that alternate haulage systems would provide, both with and without the high-voltage miner. An analysis of the value of the high-voltage miner will be done with the following set of conditions assumed:

1. The above listed improvements will be used for the evaluation.
2. The cost of new machines will be used to conduct the cost analysis.
3. Ongoing maintenance costs will be assumed to be the same. Obviously, the manufacturer claims that the increased horsepower will result in lower ongoing maintenance costs, but this has not been proven.
4. Improvements in dust control and size consist could have huge economic benefits. These gains need further evaluation before they are used as part of any economic comparison. Therefore, they will be assumed as neutral in this analysis.
5. While not measured in this study, improvements in place change times are directly related to the miner, and can be easily evaluated, but will not be part of this analysis.

The evaluation will consider four operating scenarios as requested by the industry steering committee in order to consider the full potential of the high-voltage miner while staying within the operational constraints of the majority of the coal operators:

- continuous haulage to show the maximum possible result
- typical batch haulage with a high-voltage machine
- batch haulage with a type of surge car and a high-voltage miner
- batch haulage with a type of surge car and a miner with the standard voltage

The parameters for each case are described in detail below. The comparative evaluation showing the production increase, cost reduction, and profit increase for each case is summarized in Table 3 of the Executive Summary. The most straightforward analysis involves continuous haulage, but an operation must have proper conditions to use this option. The surge car option is useable in almost every application, but actual design and testing of such a system remains to be done.

#### CASE 1: High-voltage continuous miner with continuous haulage

A base production rate of 2,500 raw tons per unit shift with a 14CM15 is assumed. Also, all availabilities are assumed equal between the two systems.

A 16% production increase yields an additional 400 tons per unit shift. This causes the crew to execute two additional place changes. These additional moves are partially offset by the increased tram speed of the miner. These factors decrease available production time resulting in 30 tons of the 400 tons production increase being lost. The production rate for this case is 2,870 tons per unit shift compared to the baseline of 2,500 tons per unit shift, an increase of 14.8%. Thus, the high-voltage continuous miner has about 15% higher production potential provided that all the mined coal can be transported out of the face area.

### CASE 2: High-voltage continuous miner with batch haulage

Batch haulage introduces tremendous variability into the operation. The analysis will evaluate upper and lower bounds of the system and average the results. Using parameters experienced at the Riola Mine, the following assumptions were made:

1. Two high-voltage miners are used in a super-section.
2. Production rates are based on actual performance of 2,700 tons per unit shift.
3. This equates to 15 cuts per shift with an average cut time of 36 minutes.
4. Improved loading rates will be realized in the optimum situation. Ideally, if the haul distance is short enough and the pillar configuration allows a quick car change out, the cars will not hinder production.
5. Conversely, with a longer haul or increased dump times, the cycle times of the cars will dictate productivity. The worst-case scenario is that all improvements are lost due to haulage bottlenecks.

**BEST CASE** – Approximately 200 cars per shift are loaded with a decrease in loading times of 0.18 minutes per car. This gives a total time saving of 36 minutes per shift, resulting in one more full cut per shift and increasing production from 2,700 raw tons per shift to 2,880; an increase of 6.67%.

**WORST CASE** – Haulage bottlenecks eliminate all loading time gains. Shorter loading times allow the miner more available time to load additional cars, but because the cycle times of the cars is greater than the loading times plus the normal change out times, the miner will be delayed waiting on the cars to return. The combination of shorter loading times and higher change out times will provide no improvement.

The time study data can be used to evaluate potential gains under a multitude of different situations. For this evaluation, the average of the two cases is used to determine economics. The average of the two cases is a 3.3% productivity gain from using a high-voltage continuous miner with the current batch haulage system.

### CASE 3 and 4: Continuous miner comparison with a surge car

Alternative face haulage systems were identified by the industry steering committee as potentially providing tremendous opportunities for the coal industry. One such system is a surge car, which combines continuous haulage productivity with the flexibility of batch haulage systems. These cases consider the surge car concept utilized on a super-section such as at the Riola Mine. The concept is to simply include surge capacity behind the miner in the form of a haulage car that does not haul coal but unloads it into the regular haulage cars. The car accepts surges from the miner during the time period that the haulage cars are absent. Gains come in two distinct ways. First, the miner becomes independent from the haulage cars and can continue to load into the surge car when a haulage car is not present. Second, it improves the batch haulage system by making the

haulage car trips more efficient because their load is already in the surge car and the time to load the haulage car is greatly reduced.

For example, Riola loads approximately six cars before the miner has to set over. With four cars hauling behind the miner, the miner and surge car system can load as quickly as the miner can load without the cars becoming a bottleneck. By the time the cycle time of the cars becomes an issue, the miner has to set over and the cars can catch up and restart their cycle.

Based on the operating times at Riola, a cut requires approximately 36 minutes. If the improved loading rates of the high-voltage miner are realized, this time is reduced to 34 minutes. Calculating loading times assuming the ability to continuously mine reduces the cut time to 24 minutes. Taking into account the delays in the existing system, a good estimate is that use of a surge car should recover 50% of the 10 minute time reduction for continuous mining, reducing the cut time to 29 minutes.

Using this estimate and the same assumptions as Case 2, Case 3 evaluates using a surge car with a high-voltage miner. The expected result is a 20% increase in raw tons per unit shift. Case 4 removes the gains due to the high-voltage miner, and evaluates using the surge car with the existing miner. The data indicates that a 15% increase in unit shift productivity can be realized with the addition of a surge car to existing continuous miner and batch haulage systems.

A summary of the production improvements and economics for the four cases is shown in Table 7.

Table 7. Summary of Cases

CASE:	<b>14CM27 w/ Continuous Haulage</b>	<b>14CM27 w/ Batch Haulage</b>	<b>14CM27 w/ Surge Car</b>	<b>14CM15 w/ Surge Car</b>
Section Type	Single Miner	Super-section	Super-section	Super-section
Production Increase (raw tons/unit shift)	370	90	550	400
Increase in Clean Tons/Year	114,000	29,000	177,100	128,200
Revenue Increase	\$1,368,000	\$348,000	\$2,125,200	\$1,538,400
Cost Reduction/Ton	\$1.06	\$0.10	\$1.30	\$1.10
% Cost Reduction	5.6%	0.5%	6.8%	5.8%
% Profit Increase	55.40%	6.80%	72.50%	56.80%

*Analysis of Product Size Distribution and Implications for the Mining Industry*

On September 27, 2001, 1,309 pounds of 14CM15 product and 1,059 pounds of 14CM27 product were obtained from the Riola Mine and sent to Commercial Testing and Engineering for size distribution analysis. The results, shown in Table 8, suggest that the wider bit spacing on the cutting drum does indeed produce a coarser product. In particular, there was 2.68% by weight less –100 mesh material in the 14CM27 product, a 35 percent reduction. Most of the participating operations dispose of all –100 mesh material in slurry ponds, so the high-voltage miner has the potential to significantly reduce coal preparation and waste handling costs.

Table 8. Results of Product Size Distribution Screening

Particle size	14CM15		14CM27	
	% weight	Cumulative %	% weight	Cumulative %
–100 mesh	7.70	7.70	5.02	5.02
100 X 28 mesh	2.81	10.51	2.43	7.45
28 X 16 mesh	2.17	12.68	2.16	9.61
16 X 8 mesh	8.21	20.89	8.19	17.80
8 X 4 mesh	6.31	27.20	5.50	23.30
4 mesh X ¼ inch	3.09	30.29	2.70	26.00
¼ X ½ inch	15.41	45.70	14.16	40.16
½ X ¾ inch	12.21	57.91	11.20	51.36
¾ X 1 inch	9.98	67.89	7.46	58.82
1 X 1 ¼ inch	6.33	74.22	6.42	65.24
1 ¼ X 1 ½ inch	3.45	77.67	5.60	70.84
1 ½ X 1 ¾ inch	4.10	81.77	5.62	76.46
1 ¾ X 2 inch	2.54	84.31	3.55	80.01
2 X 2 ½ inch	5.27	89.58	5.69	85.70
2 ½ X 3 inch	3.20	92.78	4.14	89.84
3 X 4 inch	2.80	95.58	4.93	94.77
4 X 5 inch	4.42	100.00	2.14	96.91
5 + inch			3.09	100.00

*Analysis of Dust Sampling Data and Implications for the Mining Industry*

A total of 34 filter cassettes were sent into the mine for dust concentration sampling while the time studies were being conducted. Two were lost or destroyed when they came in contact with haulage equipment. Five cassettes were never used. Only those tests where the miner's shift production exceeded 1,000 tons were used causing another four samples to be discarded due to insufficient tonnage. Table 9 is a summary of the results from the remaining 23 samples.

Table 9. A Two-Tailed t-Test Summary of Dust Sample Results

	<b>14CM15 w/o surfactant</b>	<b>14CM27 w/o surfactant</b>	<b>14CM15 w/ surfactant</b>	<b>14CM27 w/ surfactant</b>
Mean(mg/m <sup>3</sup> )	5.25	2.34	2.23	2.19
Variance	3.258	0.499	1.469	0.698
Observations	5	6	5	7

The high and low samples for the 14CM27 miner were then discarded to give an equal number of samples for both miners and both spray medium conditions so that an analysis of variance could be conducted. The results are shown in Table 10.

Table 10. Two-Factor ANOVA with Replication

		<b>14CM15</b>	<b>14CM27</b>	<b>Total</b>
Count	<b>w/o Surf</b>	5	5	10
Sum		26.26	10.6	36.86
Mean		5.25	2.12	3.69
Variance		3.258	0.261	4.289
Count	<b>w/ Surf</b>	5	5	10
Sum		11.17	10.69	21.86
Mean		2.23	2.14	2.19
Variance		1.469	0.345	0.809
Count	<b>Total</b>	10	10	
Sum		37.43	21.29	
Mean		3.74	2.13	
Variance		4.631	0.270	

Owing to the high variability in the sample results, particularly for the 14CM15 machine, it is difficult to draw any definite conclusions from the data. The data does clearly suggest that the high-voltage machine generates as much as 40% less dust than its counterpart, but the fact that the 14CM15 operates on the return side of the section must be taken into account. When just the high-voltage miner samples are considered, the data suggests that the addition of surfactant to the spray water of the miner further reduces dust concentrations by an additional 6%. Because the same individuals conducting the time studies collected the samples, and their attention had to remain on the time studies, the results shown above must be replicated to confirm their validity.

## FINAL CONCLUSIONS AND RECOMMENDATIONS REGARDING FUTURE RESEARCH AND DEVELOPMENT

### **Conclusions**

1. There is consensus among members of the industry steering committee that improvements in face productivity have the highest potential to achieve the desired production cost reduction. Other high priority areas include control of out-of-seam dilution and alternate systems for waste management
2. The high-voltage continuous miner has potential to increase face productivity by about 20% provided that it is matched with suitable capacity to remove coal from the face area.
3. The high-voltage continuous miner should reduce fines in the product by 30 to 40%. This should reduce coal processing costs, increase recovery, and reduce waste management.
4. The high-voltage continuous should also produce less respirable dust. This would allow even higher production rates if continuous haulage can be implemented.
5. No health and safety issues were identified that would hold back application of high-voltage continuous miners. The only apparent issue dealt with cable handling. Federal mine regulations require that anyone who handles high-voltage cable must wear high-voltage gloves. During time studies, readily available gloves were always observed. There was not one instance where special handling of the high-voltage cable caused any delays.
6. Productivity from existing continuous miners can be significantly improved in the near term by focusing on improved face haulage systems, including the concept of a surge car.

### **Recommendations**

1. Industry recommended projects should be approved for research, development, and demonstration. The Illinois coal industry enthusiastically participated in this project and ICCI should follow their recommendations in order for the industry to maintain momentum on cost-cutting strategies to improve the production cost of Illinois coal.
2. Development of high production batch haulage systems in the face area should be given the highest priority.
3. Reducing out-of-seam dilution should be another area of high priority.
4. Improved face productivity will require efforts in the area of dust control in order to meet regulatory standards. Dust control research should be an integral part of any project that deals with production at the coal face.
5. Alternate methods of solid waste management need to be developed. A recent National Academy of Engineering study has recommended additional research in this area, as did the industry steering committee established for this project.



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