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DEVELOPMENT AND FABRICATIO OF A CONTINUOUS MINER TRAINING SYSTEM

Contract H0377025
McDonnell Douglas Electronics Company

BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR

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16. ABSTRACT

This Final Report describes the major technical activities that were accomplished to produce a comprehensive continuous miner training system (CMTS) for coal industry utilization. The primary product of this program was a continuous miner part-task trainer. It is composed of an interactive computer graphics system combined with the operating controls of a continuous mining machine mounted in a simulated cab. The cab contains an audio system for reproducing continuous miner operational sounds. The trainer is supplemented with a complete set of cognitive materials that provide instruction in the operation, safety and health of continuous miner operations.

A complete summary of the field test and evaluation of the CMTS is provided along with a set of recommendations for further training program refinements, expansions, and utilization.

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FOREWORD

This report was prepared by McDonnell Douglas Electronics Company under USBM Contract Number H0377025. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of the Pittsburgh Mining and Safety Research Center with Mr. William J. Wienagen acting as the Technical Project Officer. Mr. Patrick J. Neary was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period September 1977 to June 1980. This report was submitted by the authors in February 1981.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the many persons and organizations within the coal mining industry who aided them in the development and evaluation of the continuous miner training system. We are especially indebted to the coal company participants, including Inland Steel, Old Ben, Freeman United, and Morris Coal. We are also grateful to the staff and faculty of the Rend Lake College Mining Department.

CHAPTER 1

EXECUTIVE SUMMARY

The Continuous Miner Training System (CMTS) was developed by the McDonnell Douglas Electronics Company (MDEC) in fulfillment of Contract No. H0377025 with the United States Department of the Interior, Bureau of Mines. This contract provided for the design and development of a prototype continuous miner training device, student training materials, an instructor's manual and a maintenance handbook. The contract specified the development to be accomplished in three phases.

Phase I was initiated in September 1977. It consisted of a review of existing continuous miner designs, a task analysis of operator and helper positions, and the selection of the Joy 12CM as the model for part-task trainer configuration. In addition, Rend Lake College at Ina, Illinois was selected to be the site of training system evaluation and validation during Phases II and III.

Phase II was initiated in September 1978. The design and development of both the part-task trainer and the Plan of Instruction were started concurrently. The continuous miner trainer is a part-task procedures training device. In it, the trainee can gain familiarity with the operating procedures and the mining application of a typical continuous miner. The installation site requires a normal size classroom with controllable lighting, a 115 volt 30 ampere power service outlet, and provisions for maintaining the ambient room temperature below 75 degrees F (24 degrees C). The advantages that the CMTS offers over traditional on-the-job training are:

TEACHING OPERATING PROCEDURES

- Startup
- Shutdown
- Tramming & Turning
- Entry Cutting
- Crosscuts
- Sump-Shear-Cusp
- Stabilizer Jack
- Water Spray
- Shuttle Car Interaction
- Check Conveyor Before Moving

CONCENTRATED TRAINING

- Tasks tailored to Equipment and Mine Dimensions
- Task Selection and Control
- Not Affected by Mining Sequence Delays
- Not Affected by Maintenance Problems

SAFER TRAINING ENVIRONMENT

LESS TENSION AND PRESSURE

Production crew is not waiting for performance

Errors can be made without loss of production, equipment damage, or injury.

Technical advice for course content was solicited from the training staffs of Southern Illinois Coal Companies and the faculty of the Mining Technology Department of Rend Lake College. The coal companies made their facilities available for the collection of task analysis data relative to continuous miner operations, and Rend Lake College provided the students and facilities required for formative evaluation of the preliminary course materials as they were being developed. The training package consists of a comprehensive instructor guide, student guide, lesson workbooks, several sound slide programs, and films.

Phase III was initiated in November 1979. It was devoted to the validation of the trainer and the instructional materials that together constitute the continuous miner training system. It was determined that the trainer can be used to teach basic fundamentals of continuous miner operating procedures, impart safety awareness, and to develop operator skills. There are several things that can be done to improve and enhance the trainer. The trainer improvements as described in the recommendations chapter will correct problems identified during validation. These improvements include revising error slide presentations to improve understanding, removing shuttle car and conveyor position cues from the graphics display to force the student to develop the habit of looking over his shoulder to determine the conveyor position, and improving the methods and procedures required to create a training task for the trainer.

The recommended trainer enhancements will increase the flexibility and expand the capabilities of the trainer. The enhancements include mounting the trainer in a mobile trailer to improve its availability, developing a demonstration capability that will display correct operating procedures, developing conversion modules to simulate other types of continuous miners; and the addition of scrubber, fire suppression, controller side breakers, and retreat mining simulations.

The instructional materials as developed are satisfactory for a vocational education environment, but they are too long, require too much workbook activity, and are too machine specific for use as a short operator training course for the general mining industry. The instructional materials should be revised into a group of generic, standalone, non trainer dependent modules that can be used by coal companies to support on-the-job training. This would fill an immediate industry need.

The minimum recommended plan for continued development of the CMTS includes incorporating the trainer improvements, re-evaluating the system, and revising the instructional materials. The trainer should be upgraded to include the error slide revisions and to remove the shuttle car and conveyor position cues from the graphics display before any additional evaluation of the system occurs. The ideal site for further evaluation would be at a mine site where the students would go through the CMTS course and then go operate a continuous miner. Two possible sites have been identified. The direct involvement of the mining company should produce valuable suggestions for revising and restructuring the instructional materials into a generic standalone continuous miner course that will support on-the-job training for the general mining industry.

CHAPTER 2

CMTS DEVELOPMENT

An Instructional System Development (ISD) approach was used by MDEC throughout this three phase development project. The ISD approach to training system development involves the isolation of behaviors critical to the safe and efficient performance of continuous mining operations and the subsequent development of specific training objectives that direct both instructor and trainee behavior toward the accomplishment of training goals. The essence of ISD is that each learning experience is included in the training program because it is demonstrably and directly related to an occupational goal. Course content and training equipment specifications were determined by an exhaustive analysis of the skills and knowledge required by a continuous miner operator, i.e., a task analysis determined what each member of the continuous mining team must know and do to operate a continuous miner safely and productively in its real world environment.

2.1 TASK ANALYSIS DEVELOPMENT

To ensure that all requisite data were collected during the task analysis effort, the following objectives were established:

A. Identify knowledge, skills and intracrew coordination required for safe and efficient continuous mining.

B. Determine the correct tasks and task sequences required to operate the continuous miner.

C. Identify auditory, visual, and proprioceptive cues, together with their appropriate feedback, to enable an operator to perform each task and task sequence safely and efficiently.

D. Identify operating characteristics of each control, display, and safety device and determine typical machine response time to operator inputs.

E. Identify miscellaneous operator tasks performed in support of other personnel and equipment not directly related to continuous miner operation.

F. Identify tasks requiring high skill level implying repetitive, hands-on training.

The detailed task analysis is documented in Reference 1.

2.1.1 TASK CRITICALITY

Those tasks determined to be critical in the sense of incorrect performance contributing to personnel injury or damage to equipment were coded as follows:

Code 1: Result in injury to operator or helper.

Code 2: Result in injury to other personnel.

Code 3: Result in damage to equipment.

The requirement that several tasks must be performed simultaneously increases the difficulty for a trainee to acquire the requisite skills. An operator must be constantly alert to visual, auditory and motion cues from many sources, and some tasks are more critical than others because of the hazards involved. Therefore, task criticality and the consequences of improper performance were determined for each task. Performance data and error analysis were used to establish tentatively acceptable proficiency levels.

2.2 TRAINING OBJECTIVES

These objectives were formulated from the task analysis data and served to establish the subject matter of the training program. Training objectives identify the skills, knowledge and concepts an operator must possess to be safe, efficient and effective. Such objectives are the basis of the Plan of Instruction for the training program because they integrate the various elements of the ISD approach into a logical and comprehensive product. The objectives direct the learning behavior of the trainee and the teaching behavior of the instructor.

The Plan of Instruction represents a meaningful description of each instructional module or lesson and is structured to facilitate training administration and operations. It was developed during Phase I activities so that the training objectives could be refined to indicate specific types of learning and to organize the training sequence. Detailed descriptions of the training objectives and Plan of Instruction are contained in References 1 and 2.

2.3 PHASE II: SYSTEM DEVELOPMENT AND FABRICATION

2.3.1 PART-TASK/PROCEDURES TRAINER

The requirements analysis indicated that the continuous miner trainer must provide training in each of the following aspects of coal mining operations: tramming and turning, positioning for coal removal, sumping and face cutting, turning a crosscut, and positioning the conveyor for loading a shuttle car.

More than a dozen makes and models of continuous mining machines are available to the American market. Among the most popular in the coal region adjacent to St.Louis are those offered by the Jeffrey Mining Machinery Division of Dresser Industries, Inc., Joy Manufacturing Co., and the Lee-Norse Co. The Joy 12CM was selected as the exemplar for all such machines because design and performance data concerning this make and model were most conveniently available. The mines that were most convenient for on-site observation of continuous mining use the Joy 12CM.

Functional Description

The continuous miner trainer is a combination procedures and part-task training device. In it, the trainee can gain familiarity with the operating procedures, controls, and the mining application of a typical continuous miner. A photograph of the trainer is shown in Figure 2-1. It is a stand-alone procedures training device and can be used in either an individual, self-paced, or an instructor-guided mode. The installation site requires a normal size classroom with controllable lighting, a 115 volt 30 ampere power service outlet and provisions for maintaining the ambient temperature below 75 degrees F.

Manipulation of the controls in the operator's station results in the movement of a graphic representation of the continuous miner projected on the graphics CRT display (CRT) in approximately the same manner, rate of response, and with the sounds as would be experienced

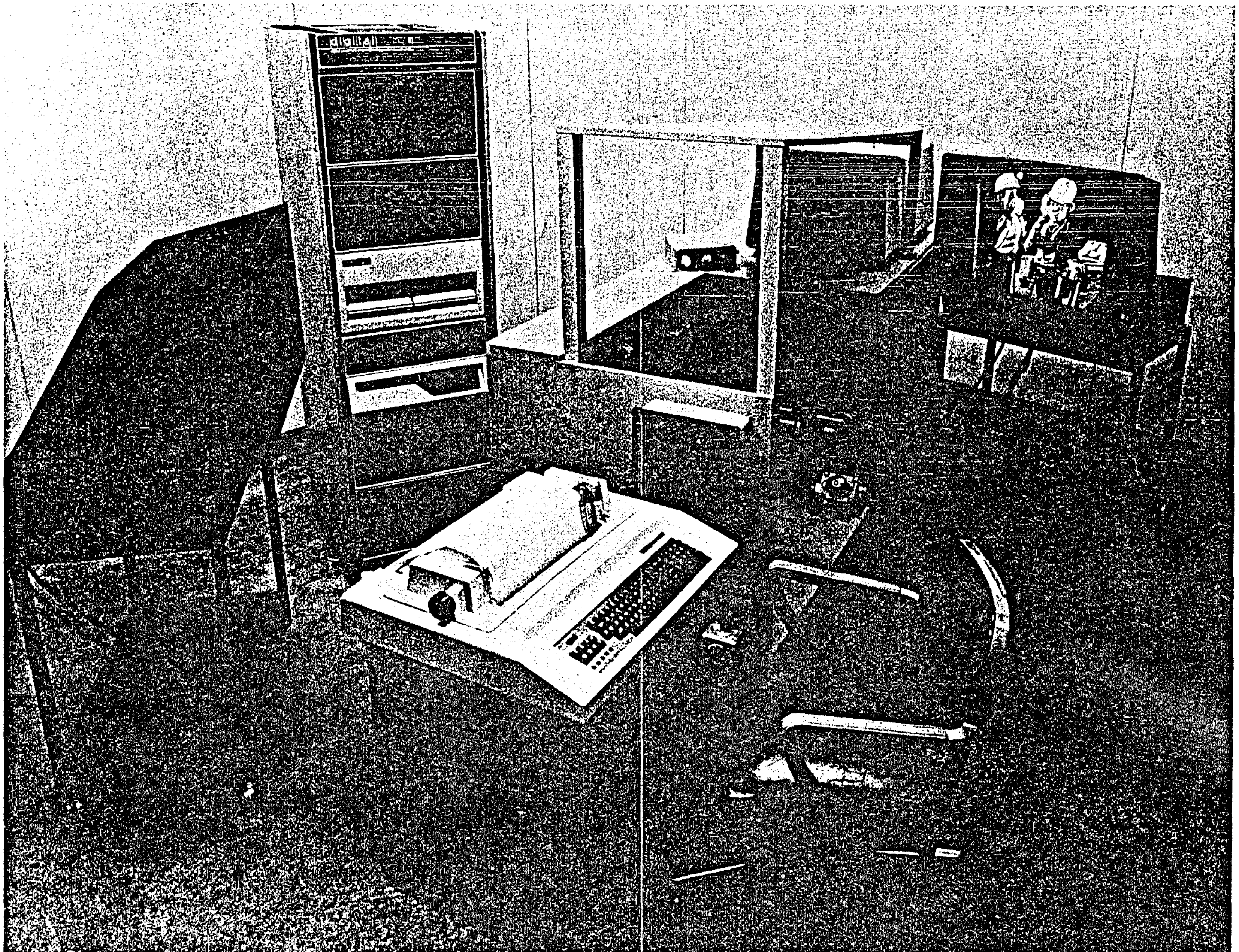

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Figure 2-1. Continuous Miner Training System on a Joy 12CM during actual underground operation. Functional controls on the trainer are the tram levers, cutterhead controls, gathering head controls, conveyor and conveyor boom controls, stabilizer jack, and water spray. Also included are the control and cutterhead circuit breakers and the electric switches to energize the pump and traction motor, conveyor, headlights, panic bar, tram safety pedal, and the methane monitor. The position of the water spray and fire suppression valves in the operator's station are monitored by the computer to ensure proper trainee operation.

Subsystem Descriptions

The major components of the trainer are identified in Figure 2-2. The control panel contains the master circuit breaker for the entire system, power ON/OFF switches for the sound and projection systems, and remote focus switches for the projectors.

Computer System - The trainer is controlled by a PDP 11/34 digital computer. All of the electrical circuit breakers and hydraulic control lever positions are input to the computer which processes the input signals, simulates the continuous miner interlock and control logic, outputs signals to the graphics display, and cues the appropriate sounds and slides.

During the training sessions, the computer informs the trainee of various performance errors. These are displayed both on the CRT and

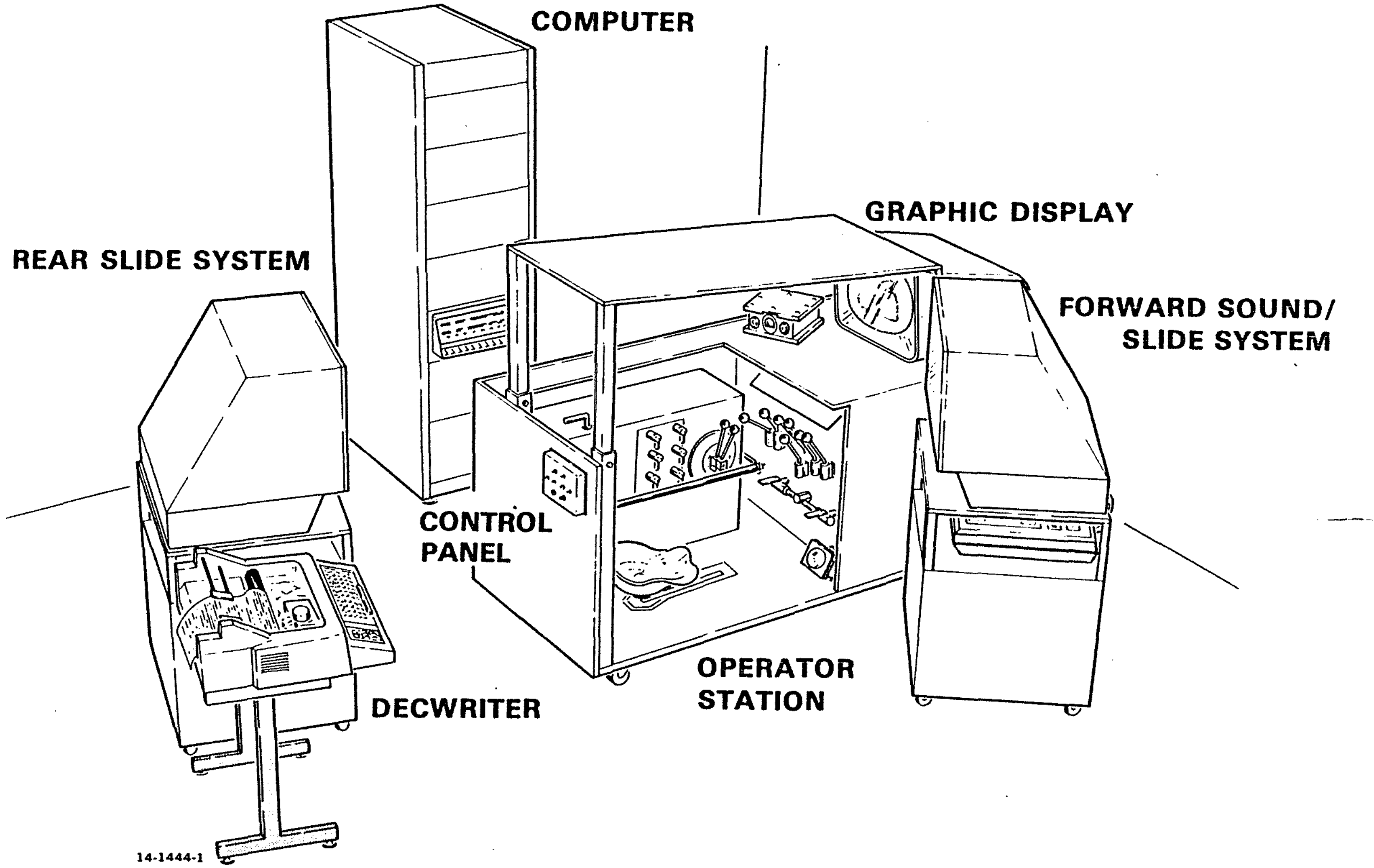

Figure 2-2. Continuous Miner Part Task Trainer

one or both slide projectors. On the CRT, a signal is flashed at the point of contact if the trainee accidentally strikes the roof, rib or bottom with some part of the machine. A performance record is also available in hard copy at the instructor's request.

Graphics System - The trainer utilizes an interactive computer graphics system. The basic information relating to dimensions of the mine sector plan view including pillars, entries, crosscuts, and coal faces is stored in memory along with the essential configuration details and tram speeds of the continuous miner and a shuttle car. These data are processed in the computer and applied to a stroke writing cathode ray tube (CRT) graphic terminal. Dynamic or motion inputs resulting from manipulation of the operator's controls are similarly processed in the computer to update the graphics file. The graphics system then presents a continuous, nonflickering display showing a relatively smooth movement of the continuous miner and its related moving parts.

Projection Systems - The primary function of the forward sound/slide projection system is to display procedural error conditions to the student during his performance of a training exercise. The error slides are displayed until the procedure is corrected. Also, the system can show introductory sound/slide instructional segments describing the task to be performed.

The rear slide projection system depicts actual working mine scenes coordinated with the particular activity of the continuous miner trainer. A random access projector provides a logical sequence of scenes regardless of the training scenario selected. The scenes can depict conveyor boom positions, a helper standing near the conveyor boom, and shuttle cars either loaded or being loaded.

<u>Sound System</u> - The sound system provides six basic sound effects. They are: hydraulic pump, tramming, cutterhead rotation, cutting coal, cutting rock, and the conveyor loading coal.

<u>Instructor's Terminal</u> - All inputs required for the instructor's participation in the training exercises are either delivered verbally to the trainee or entered into the computer via a DECwriter. The DECwriter is located adjacent to the trainee's position in the trainer and permits the instructor a clear view of all the trainee's actions.

<u>Trainer Capabilities</u>

The continuous miner part-task/procedures trainer can be programmed to meet the specific needs of any user. Its inherent flexibility permits the user to generate both the exact dimensions of the cutterhead and of the entries and crosscuts. Programming is accomplished using the DECwriter and the interactive graphic display.

Creating Trainer Exercises - To create a new trainer exercise, the user types "CREATE" on the DECwriter. The system replies with a query for inputs specifying the parameters of the continuous miner, shuttle car and mine dimensions. Following the insertion of the necessary inputs, the CRT displays the mine and machine parameters. The CRT also displays an interactive menu to be used, in conjunction with a lightpen, to generate the dynamics of the training exercise. These dynamics consist of developing the tramming path of the continuous miner and its reset positions during the exercise. Positions of the trailing cable and the shuttle car are established in the same manner.

Training Scenarios - Several training exercises have been developed, stored on a floppy disc, and used in the initial evaluation of the CMTS. These exercises were generated after more than 50 hours of observing continuous mining in both advance and retreat sections. Criteria for the exercises were based upon discussions with coal company training personnel and experimental evaluations of the trainer using experienced Joy 12CM operators as subjects. These exercises cover the following areas of continuous miner operations:

A. Control operation and start-up procedures.

B. Tramming and turning.

C. Cutting and loading coal.

D. Turning a crosscut.

E. Shutdown and parking procedures.

These exercises are available to any user simply by inserting the appropriate floppy disc into the computer.

2.3.2 CLASSROOM MATERIALS

The ISD approach requires two types of information on which to base a training program. First is a definitive subject matter organization derived from a task analysis and expressed in the form of training objectives and their associated tests. Second is information concerning the population for whom the training is designed.

Two conditions had to be met by the classroom materials. First, they had to stand alone and be independent of the part-task/procedures trainer. In this way, they could be equally useful as supplementary materials for an on-the-job training program supported by limited access to an operational continuous miner. Second, they had to be maximally supportive for teaching operational procedures, safety and preventive maintenance concepts using the trainer.

The application of the ISD approach began with the identification of subject areas to be covered. Selection of subject matter was determined by the task analysis of operator and helper positions conducted during Phase I. This analysis produced a comprehensive list of training system requirements. With the assistance of the coal industry experts and mining technologists, these requirements were organized into ten categories of training objectives. These objectives specified what was to be learned, how well it was to be learned and the conditions under which it was to be tested.

To ensure that the most significant material reached those trainees with a reading difficulty, 80% to 85% of the material was presented in sound/slide format. The remaining 15% to 20% of the material was selected for its ease of presentation in lecture format and to stimulate a dialogue between the instructor and the trainees. Lively discussion among the instructor and the trainees in the classroom further encourages active participation by the trainee with a reading handicap.

Four different formats of self-test items were used in composing the written material. These were:

A. Completion questions concerning figures and schematics.

B. Multiple choice questions.

C. Matching questions.

D. True/false questions.

Correct answer feedback was made available immediately. An end-of-lesson test was prepared for each lesson for which such an evaluation was considered appropriate. This provided the instructor with an accurate indication of how well the trainee was responding to the instructional materials.

Lesson Description

The training requirements were categorized under the following topics:

Introduction to Continuous Mining - a general overview of mining methods and the role of the continuous miner in coal mining.

General Safety - personal equipment and the particular hazards to which an operator and helper are exposed.

Introduction to the Continuous Miner - major components of the Joy 12CM; electrical, hydraulic and water piping subsystems; safety devices.

Controls and Displays - functional descriptions of each electric and hydraulic control and display.

Work Place Inspection - federal laws perteining to the workplace and procedures for required inspections within the working section.

Power-Off Inspection - procedures for power center, trailing cable and machine inspection; Joy 12CM servicing requirements and preventive maintenance.

Power-On Inspection - start-up procedure, safety checks of power center, electric and hydraulic subsystems, inspection and replacement of cutting bits.

Tramming - pretramming checks, description of specific hazards; perceptual cues and proper responses while tramming and turning both forward and in reverse; shut-down and parking procedures.

Operations - procedures for cutting and loading coal, cutting crosscuts, shuttle car management.

Special Operations - procedures for cutting overcasts and undercasts, towing, moving the power center, advancing the belt.

One lesson was prepared for each category with the exception of "General Safety." Three lessons (three classroom hours) were required to present this subject adequately. In their final form, the classroom materials required 12 lessons.

Sound/Slide Programs

For the first six lessons, a script was prepared that included from 80% to 85% of the self-test items prepared for the 25 training objectives concerned. This was to ensure that the most critical material being presented to the trainees would be adequately understood by anyone handicapped by a reading deficiency. The visual media to support these scripts were 35MM color slides illustrating a particular instructional point. The format is equally applicable to individualized, self-paced instruction and to a conventional classroom environment. Instructions for the presentation of these programs and their preferred place in the training schedule are contained in the "Instructor's Guide." Each script is included in its proper sequence in the "Student's Guide" available for review by the trainee in conjunction with the workbook for that lesson.

16MM Films

Four 16MM films produced by the National Photographic Laboratories, Inc., from their Trend Program entitled "Continuous Miner," were purchased and incorporated into the CMTS. They were selected for their overall high quality to help the trainee visualize the operation of a continuous miner underground and for their emphasis on the interactions between the operator and helper. These four films were originally produced for the Monterey Coal Company of Carlinville, Illinois, in cooperation with the National Coal Association and the Bituminous Coal Operators' Association. Although these films feature a Jeffrey Heliminer, the operating principles presented apply equally to the Joy 12CM or any other make and model of continuous miner.

Workbook Development

Following the definition of the 77 training objectives and their categorization into 12 homogenous lessons, as many declarative, factual statements as possible were composed bearing on each objective. These were ordered in terms of the criticality of the task to which they related and were then reformatted as self-test items. During the initial development of the student workbooks, each factual statement was written as a self-test item at least twice, once positively and once negatively if in True/False format, or once as the main topic and once as one of a series of alternatives if in multiple choice format. As many as four or five different questions were composed for those statements bearing on tasks with the highest criticality scores. Regardless of the number of training objectives being covered, more than 100 self-test items were written for each lesson and numbered in order by task and criticality score.

An introductory text was prepared for each lesson. Figures, charts and schematics were selected to illustrate the self-test items. Check lists to be used both as an instructional device for trainees and as a standard tool for the trained operator were introduced in Lessons 7, 8 and 9, the three lessons pertaining to inspection procedures. The checklists are in a format suitable for enclosure in plastic covers to be carried by trainees during their underground tour prescribed to culminate these lessons. In an abbreviated form, it is recommended that similarly protected checklists be permanently stored in a steel box welded to the main frame readily available as a job aid at the start of each shift.

Expert Review and Comment

Prior to their formative evaluation, copies of the first drafts of each student workbook were submitted to the training coordinators of the several participating coal companies and to the faculty of the Rend lake College Mining Technology Department. Courtesy copies were also provided to the training department of the Joy Manufacturing Company. The responses to requests for review and criticism were complimentary but unconstructive.

Formative Evaluation

A total of 38 students in three different Machine Operations classes at Rend Lake College participated in small-group tryouts of the student workbooks that had been prepared for each lesson. A 190 item test based on workbook content was administered to each student 20 days before he began utilizing the workbooks. The students were then given three days to complete the workbooks and workbook exercises in a self-paced, self-instructional mode. Instructors provided assistance on an as-required basis. The 190 item test was then readministered.

The mean score on the pretest was approximately 59% (range 98-128), while the mean score on the posttest was 66% (range 115-138). The modest gain in mean score and the slight reduction in performance variability from pretest to posttest provide evidence that some learning did, in fact, occur. The 23-day interval between administration of the pretest and the posttest minimizes the probability that the gain in mean score is simply a function of memory, although the pretest may have served to focus the attention of students on "critical" content. Anecdotal comments from students and instructors indicated that the workbook materials were reasonably well received. Workbooks were revised on the basis of the small-group tryouts, and a new 227 item test was prepared for use as a pretest and posttest during Phase III.

2.4 PRODUCTION COSTS

Standard commercial parts and components were used in the design of the CMTS. In addition, the ground rule was established that commercial parts could not be modified in any way. This design philosophy was established to reduce the number of special purpose designs and to minimize production costs.

The prototype system has been reviewed and several suggestions have been made to reduce production costs. First, the projector interface requirements will be reduced by replacing the present projectors with units that can be driven directly from the computer. The special purpose projector interface circuitry will be eliminated. Second, it will be more economical to fabricate the dead man switch, panic bar and seat assembly rather than purchasing them from the continuous miner manufacturer. Third, the cutouts for the cab subassemblies will be installed by the cabinet shop producing the cab. Fourth, the number of electrical conduit runs will be reduced by combining the control and electrical panels into a single unit and locating it on the rear of the trainer. A duplicate copy of the CMTS, with the above changes, would sell for approximately $150,000. A breakdown of the production costs are shown in Table 2-1.

TRAINER PARTS	COST
Audio System	$ 4,400
Cab Assembly	2,400
Cables	300
Computer System	41,000
Control Panel	100
Electrical Panel	500
Instructional Materials	300
JOY Parts	2,800
Methane Meter	200
Projection Systems	5,100
SUB-TOTAL	$ 57,100
LABOR	
Fabrication	$ 18,400
Assembly	50,300
Checkout and Other	16,700
Installation and Warranty	7,400
SUB-TOTAL	$ 92,800
TOTAL PRICE	$149,900

CMTS PRODUCTION COST ESTIMATES

TABLE 2-1

CHAPTER 3

PHASE III: TRAINING SYSTEM IMPLEMENTATION AND EVALUATION

Arrangements were made during Phase II to evaluate the entire CMTS at Rend Lake College during the period from January through May 1980. The evaluation plan entailed a summative evaluation of the classroom materials and a procedure to validate the part-task/procedures trainer.

3.1 TRAINER EXERCISES

Four training exercises (E10, E20, E30, and E40) were developed for validating the trainer.

3.1.1 TRAMMING STRAIGHT (E10)

This problem, shown in Figure 3-1, requires that the trainee energize the trainer and tram forward from the starting point through two

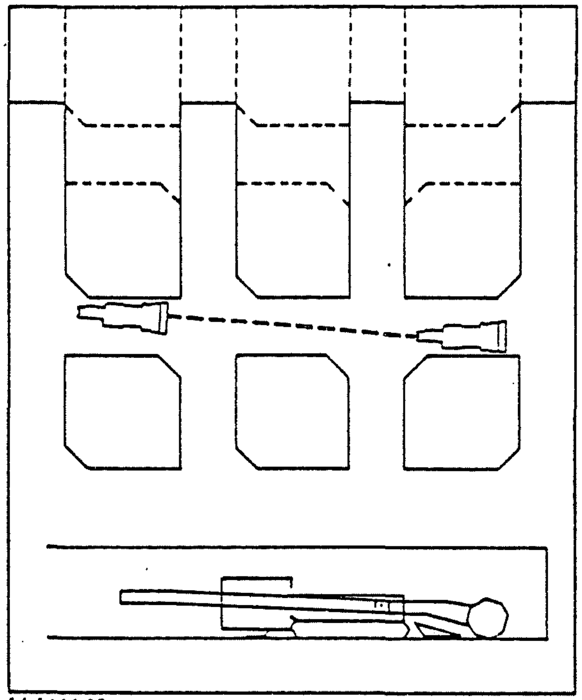

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Figure 3-1. Tramming Straight Exercise

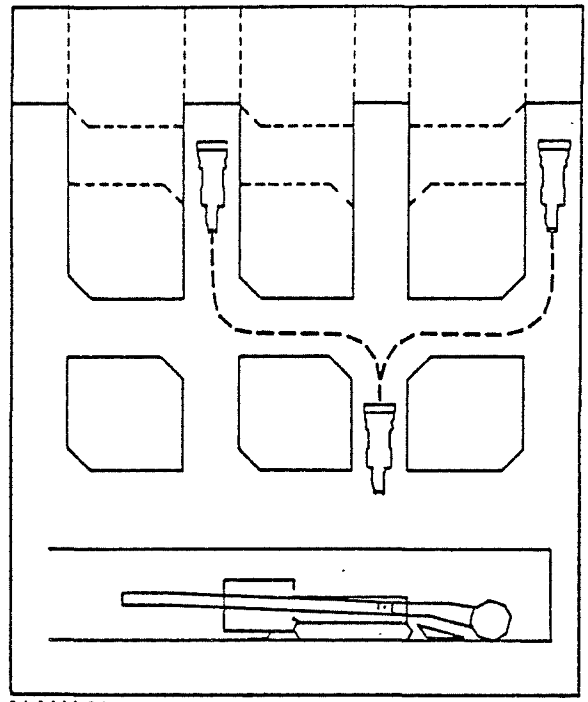

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Figure 3-2. Turning Exercise

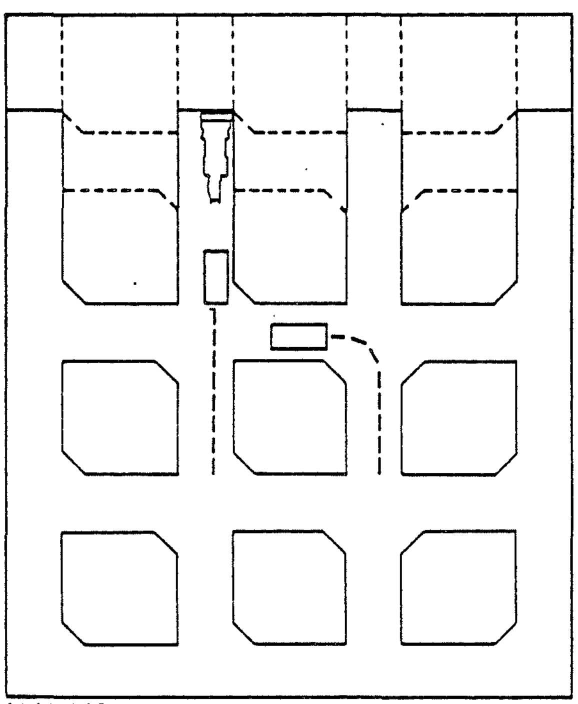

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Figure 3-3. Coal Cutting and Loading Exercise

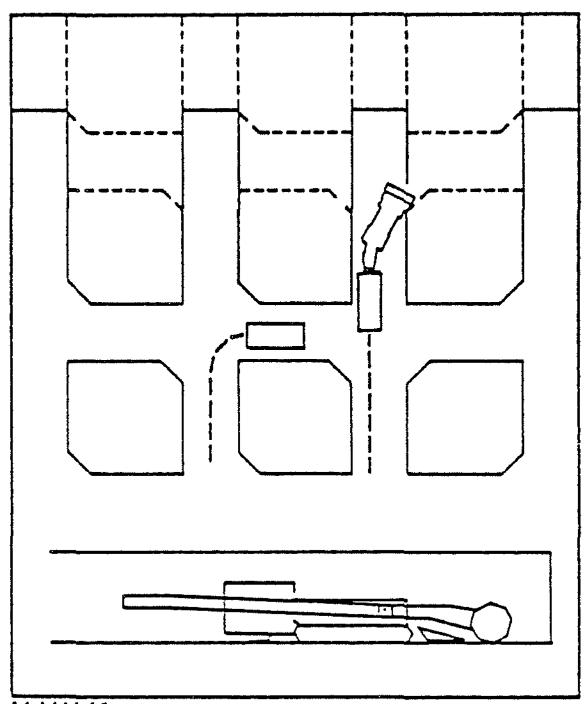

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Figure 3-4. Crosscut Exercise

entries and execute parking and shutdown. Then he restarts the trainer and trams in reverse back to the original starting position where again he parks and shuts down.

3.1.2 TURNING (E20)

The trainee will energize the trainer at the starting position, shown in Figure 3-2, and tram forward to the face, executing a right and left turn. After shutting down at the face, the trainee will restart and tram in reverse back to the starting position and shut down.

3.1.3 CUTTING AND LOADING COAL (E30)

As shown in Figure 3-3, the trainee will energize the trainer, tram to the face and load four shuttle cars. This will advance the continuous miner's canopy to the last roof bolt.

3.1.4 TURNING A CROSSCUT (E40)

Illustrated in Figure 3-4, the trainee will turn a crosscut to the right, loading the coal into shuttle cars. No provisions have been made to simulate roof bolting in the new crosscut.

3.2 RENO LAKE COLLEGE PARTICIPATION

3.2.1 FACILITIES

Two adjoining classrooms in the Department of Mining Technology were dedicated to the Machine Operation course. One classroom was used for lectures and class discussion, and the other was modified for the trainer. This classroom was airconditioned, painted black and equipped with controllable lighting.

3.2.2 MACHINE OPERATION COURSE

With the approval of the Board of Trustees, the curriculum of a two credit hour course entitled Machine Operation was modified to consist of the twelve lessons of the CMTS. One member of the mining department faculty, certified as a Mining Instructor by the State of Illinois, was assigned to teach the course in concert with an MDEC training specialist. As normally presented, the machine operation classes meet once a week for three hours, one hour of classroom and two hours of laboratory work. During this evaluation, that schedule was modified to permit the maximum exposure on the trainer for each trainee.

3.2.3 STUDENT POPULATION

The 41 trainees who completed the course were divided into three classes. One class of 17 students met Tuesdays from 0800 to 1100. The other two classes were designated as "parallel" classes, permitting a student to attend whichever was convenient that day. These classes met on Thursdays from 1300 to 1600 and from 1730 to 2030. Twenty-four students were enrolled in the Thursday group. Attendance on Thursday varied between the two sessions. Usually 17 or 18 came at 1300 and 6 or 7 came to the 1730 session.

All of the students in the Tuesday class were full-time students. Four of the Thursday students were employed full-time as miners, and two more held mining associated jobs. All 41 were high school graduates. Only one had a severe reading handicap. They ranged in age from 19 to 45 with an estimated median age of 27. Exact demographic data are not available.

3.2.4 TRAINING TECHNIQUE

The first class session consisted of the 227 item pretest followed by Lesson 1, "Introduction to Continuous Mining," and a brief, introductory exposure to the trainer. In subsequent sessions, the entire class would receive classroom material during the first hour and then would be divided in half for the remaining two hours. One half of the class would take turns on the trainer for supervised instruction while the other received classroom training. The two sections would change places for the third hour. In this fashion, the trainees averaged less than 10 minutes of hands-on trainer time per week, hardly more than familiarization training.

CHAPTER 4

RESULTS AND CONCLUSIONS

A Continuous Miner Training System such as was evaluated under this program can be used to teach basic fundamentals of CM operation, impart safety awareness, and improve operator skills. Post-test results of the lessons and trainer exercises showed a generally positive trend in improving knowledge and skills related to continuous miner operations. None of the students participating in the validation program went on to become CM operators during the evaluation period, therefore, no data was collected and no further evaluation was possible to determine real benefits derived from exposure to the CMTS. However, qualitative judgements expressed by the participating coal companies were positive.

It was determined that a generic training course may be practical. The training materials should be revised to be general enough to take into account the level of the student (new miner, experienced miner, or experienced CM operator), the type of continuous miner, and the mining procedures used by the company. Less emphasis should be placed on memorizing machine specific dimensions and capacities and more emphasis placed on correct operating procedures.

A generic trainer, however, is not practical. The physical operation of electrical switch controls and associated safety interlock logic can not be duplicated by a single group of switches and a single computer program. Similarly, the tram and hydraulic controls differ in type, location, function, and response. Detailed CM control comparisons for JOY Manufacturing, National Mine Service, Lee Norse, and Jeffery continuous miners are documented in Reference 1. The recommended way to address the differences between different manufacturer's machines is to develop separate interchangeable electrical, tram and hydraulic modules, and computer logic programs for each manufacturer. Generic switches can be used for the fire and dust suppression valves and the deadman footswitch. The conversion from one manufacturer to another would require exchanging panels and computer logic programs.

4.1 CLASSROOM MATERIAL

Three of the 12 lessons are not represented by items on the 227 item posttest to evaluate the cognitive materials. These lessons were:

Lesson 1: "Introduction to Continuous Mining"

Lesson 4: "General Safety, Part II"

Lesson 5: "Controls and Displays"

The CMTS was designed to teach an experienced miner to operate a continuous mining machine and to improve the skills of a continuous miner operator. Lesson 1, "Introduction to Continuous Mining," was prepared for students with a demonstrated interest in becoming coal miners, but with no practical mining experience. Lesson 1 serves as an orientation for these and similar trainees.

Lesson 4, "General Safety Part II," concerns machine related accidents. It was included in the CMTS, because of the interest shown by the mining companies, as an instructional segment. Lesson 5, "Controls and Displays," like Lesson 1, is an orientation. Comprehension and retention of its Joy 12CM content are more validly tested by performance on the trainer or an actual Joy 12CM than by paper and pencil test.

The 227 items of the posttest are unevenly distributed across the remaining nine lessons. Descriptive data from the two administrations of the test instrument are shown in Table 4-1.

TABLE 4-1

COMPARATIVE ERROR SCORES FROM

PRETEST, POSTTEST AND FINAL EXAMINATION

	PRETEST	POSTTEST	FINAL EXAM
MEAN	70.0	38.0	9.0
S.D.	11.0	12.0	5.0

A prerequisite at Kend Lake College for enrollment in Machine Operations is successful completion of Introduction to Mining. In addition to this course, a number of those who took Machine Operations had also completed a course in first aid and one entitled Mine Atmospheres and Strata Control. All three contain factual data within the domains sampled by the test instrument. Hence, the mean error score on the pretest of 70 was not unexpected. The final examination was composed of 100 items taken from the several end-of-lesson tests administered during the course. These tests were used to guide tutorial sessions and for the review periods preceding the final examination. The mean error score of 9 is considered reasonable.

Prior to administration of the posttest, an overall score of 75% was established as the minimum to be considered indicative of an adequately functioning lesson. The results of the lesson level analysis are presented in Table 4-2. The total possible score for any lesson is calculated by multiplying the number of posttest items pertaining to that lesson by the number of trainees who took the posttest, e.g., Lesson 2 was represented by 23 items which, multiplied by 35 students, equals a maximum possible of 805. Correct responses to Lesson 2 items were tabulated and this total divided by the maximum number of correct responses possible, i.e., 583/805 equals 72%.

Lesson	Possible (Items X 35)	Actual (Correct Responses)	Percent (%)
2	805	583	72%
3	1680	673	40%
6	1260	1163	92%
7	315	305	96%
8	1260	1007	80%
9	595	442	76%
10	840	701	83%
11	910	729	80%
12	210	159	76%

POST TEST ITEM ANALYSIS

TABLE 4-2

The scores for Lessons 2 and 3 failed to satisfy the pre-established 75% ciriterion, and the scores for Lessons 9 and 12 were barely satisfactory. Lesson 2, "General Safety, Part I", deals with personal safety equipment and the hazards peculiar to roof, rib and bottom conditions. Lesson 3, "Introduction to the Continuous Miner," treats the dimensions, major components and component specifications of the Joy 12CM.

4.2 TRAINER PERFORMANCE

Baseline performance data was established by using experienced Joy 12CM operators to perform Tasks E10, E20, E30, and E40. The averages of their performances were considered the criterion performances against which trainee performance would be compared.

Every effort was made to find miners scheduled to be trained to become continuous miner operators. These men would have been given CMTS training before being assigned to the traditional underground on-the-job training. Their foremen and the training directors would then be asked to evaluate the benefit derived from the exposure to the CMTS. This effort failed because during the five month period no openings for new continuous miner operators occurred within the participating companies. Therefore, no one had an opportunity to bid on the job of continuous miner operator.

Because there are no standard training procedures for mining machine operator, continuous miner operators have not received any formal training on the machine. They have learned by trial and error with very little, if any, guidance. Typically, each man develops his own modes of operation based on "whatever feels comfortable" to him. His usual operating procedures are often widely at variance from the carefully structured procedures prescribed for the CMTS training.

The three hour, once a week class periods permitted approximately 10 minutes per week for the 17 trainees in the Tuesday class and perhaps twice that figure for those in the Thursday evening class. Availability of the trainer during class periods afforded enough time to familarize the trainees with the controls and displays. There was insufficient class time for any trainee's learning on a training exercise to approach asymptote. The laboratory was available, however, 12 hours a day during the week, except when classes were in session. Anyone who wished, was free to practice on the trainer, and many students did so. No records were kept of such practice.

Training on Task E30, Cutting and Loading Coal, was conducted for approximately ten weeks. After six weeks, each of the 41 students was required to load two shuttle cars using the format of Task E30. Results of these trials for record are shown in Table 4-3. No significant difference in performance of the Tuesday and Thursday classes appear in these data. The performance data have been arranged in order of the time required by the trainee to execute the task of starting the continuous miner, tramming 10 feet to the face configuring the machine and to cut and load two shuttle cars with coal. No coaching was permitted by the instructor during the exercise. Time did not permit six of the trainees who exceeded their instructions to have a second trial. Their data are included in Table 4-3.

TABLE 4-3
TRAINER PERFORMANCE DATA FOR TASK E30
(Cutting and Loading Coal)

CLASS	STUDENT	TIME	DISTANCE	PRODUCTION (TONS)	SHUT CARS	AVER LOAD (TONS)	ERRORS
TH	1	4:06	26.8	18.9	2	9.7	7
TH	2	4:11	25.9	20.4	2	9.9	11
T	3	4:26	24.9	20.2	2	11.5	8
T	4	5:08	29.9	20.4	2	10.2	13
TH	5	5:23	26.4	20.1	2	10.1	3
T	6	5:33	30:3	20.1	2	10.1	9
T	7	5:36	23.1	20.6	2	10.4	9
T	8	5:48	26.9	20.2	2	10.7	12
TH	9	6:06	33.5	20.2	2	9.6	8
T	10	6:09	31.0	20.2	2	10.2	18
TH	11	6:17	29.9	20.1	2	10.4	10
T	12	6:18	22.4	20.4	2	9.6	9
TH	13	6:47	24.5	20.1	2	9.9	4
TH	14	7:00	28.3	20.1	2	10.1	4
TH	15	7:01	31.9	19.6	2	9.7	7
T	16	7:21	26.0	19.6	2	9.9	3
T	17	7.22	32.8	20.1	2	9.7	6
T	18	7:32	36.9	18.9	2	9.4	6
TH	19	7:58	35.1	18.7	2	9.2	4
TH	20	7:59	40.8	21.7	2	10.6	9
TH	21	8:28	29.5	20.1	2	10.1	8
TH	22	8:34	32.9	20.1	2	9.9	7
T	23	8:37	22.3	21.2	2	10.1	13
T	24	8:37	35.6	17.7	2	8.7	4
T	25	8:39	44.5	18.1	2	8.7	4
TH	26	8:54	36.6	20.9	2	10.7	9
T	27	9:00	37.8	19.7	2	9.9	10
TH	28	9:16	37.6	21.3	2	10.6	10
TH	29	9:35	46.6	37.4	3	9.8	17
TH	30	10:20	39.6	13.1	1	8.9	15
T	31	10:26	36.9	20.5	2	10.2	11
TH	32	11:18	44.5	19.9	2	10.4	13
TH	33	11:26	36.6	17.8	2	8.9	13
T	34	12:14	52.6	18.3	2	9.2	7
TH	35	13:20	45.8	40.5	4	9.1	12
TH	36	14:02	38.7	40.1	4	10.1	22
T	37	15:01	35.9	19.9	2	9.9	8
TH	38	16:03	35.9	38.0	4	9.3	15
TH	39	17:25	49.8	38.4	3	10.1	10
TH	40	18:39	50.7	23.8	2	10.1	22
TH	41	20:35	49.4	37.1	3	10.1	27

4.2.1 CORRELATIONAL ANALYSIS

Distance vs. Errors - No provision was made in recording distance data to differentiate between tramming forward and in reverse. The exercise starts with the continuous miner approximately 10 feet from the face. To cut 20 tons of coal, the amount required to load two shuttle cars to capacity, the miner would advance another 10 feet. Any distance greater than 20 feet represents the operator reversing his machine a few feet to cut the cusp remaining in the bottom when a shear was completed or reversing a greater distance to trim the roof smooth. Because of this, a significant, positive relationship was expected between distance trammed and the number of errors. Spearman's Rho did not bear this out ($p = .17$).

Time vs. Production - Nearly perfect performance of the assigned exercise on the trainer would be:

TIME:	4.0 Minutes
DISTANCE:	20 Feet
PRODUCTION:	20 Tons
AVERAGE LOAD:	10 Tons
ERRORS:	0

There was a low positive correlation between time and production ($p = .20$).

Average Load vs. Errors- A negative correlation was expected between average load and number of errors. Except for loads exceeding 10 tons, which indicate coal being dumped on the floor or falling off the edge of an overloaded buggy, the higher the average load, the greater the skill of the operator. The data confirmed this expectation ($\rho = -.37$).

CHAPTER 5

RECOMMENDATIONS

The changes that are suggested in the following paragraphs are aimed at improving the operation of the present system as well as expanding its training capabilities to make it more attractive and acceptable to potential users. The recommendations have come from coal company personnel and faculty members from the mining department of Rend Lake College. The recommendations are categorized in three groups: trainer improvements, trainer enhancements, or trainer related activities.

5.1 TRAINER IMPROVEMENTS

The following recommendations relate directly to the improvement of the training system as it now exists. They do not address new trainer functions or system capabilities. The recommendations are the result of comments received from continuous miner operators, instructors, and students as well as from observation of student classes and trainer demonstrations. The recommended trainer improvements include:

1) Revision to error slides.

2) Removal of the conveyor from the CPT.

3) Improving methods for creating training exercises.

4) Revision of course materials.

5.1.1 ERROR SLIDE REVISIONS

There are currently 22 error conditions that have been defined, see Table 5-1. Each time an error is detected, the appropriate error is displayed on the forward projection unit. The number of occurrences of each type of error is included in the performance report printed at the end of the exercise. The displayed slide is removed when the error condition is corrected. Presently, the error slides display information in three basic formats, incuding:

1) Error Statement and Corrective Action

2) Error Statement and Checklist

3) CM Contact Photograph

Observations of demonstrations and evaluation sessions indicate that the "Error statement and corrective action" presentations are easily understood and facilitate error correction. The "Error statement and checklist" presentations used for the forward tram, reverse tram, and improper shutdown conditions were the least efficient method of providing error feedback. Students were overwhelmed with information

NUMBER	DESCRIPTION
1	FORWARD TRAM
2	REVERSE TRAM
3	CUTTER HEAD CONTACT - LEFT
4	CUTTER HEAD CONTACT - RIGHT
5	CUTTER CONTACT - ROOF
6	CUTTER CONTACT - FLOOR
7	GATHERING POINT CONTACT - LEFT REAR
8	GATHERING POINT CONTACT - RIGHT REAR
9	FRAME CONTACT - LEFT REAR
10	FRAME CONTACT - RIGHT REAR
11	CONVEYOR CONTACT
12	IMPROPER SHUTDOWN
13	BEYOND LAST ROOF BOLT
14	WATER VALVE NOT CRACKED
15	WATER VALVE NOT FULL OPEN
16	SHEARING UP
17	STAB JACK NOT DOWN
18	STAB JACK NOT UP
19	GATHERING PAN CONTACT
20	COAL DUMPED ON THE FLOOR
21	CONVEYOR TOO LOW FOR BUGGY
22	OVERLOADED SHUTTLE CAR

ERROR CONDITIONS

TABLE 5-1

and proceeded methodically to start down through the checklist, item by item. This proved to be time consuming and disrupted the learning process. Several students made the same errors repeatedly and made corrections on the basis of a checklist review. They had not associated their repetitious error with a machine function.

Each "Error statement and checklist" presentation should be replaced by a group of "Error statement and corrective action" presentations. The new presentations will divide the tramming and shutdown configurations into functional machine groupings. The recommended slide replacements are shown in Table 5-2. The performance printout should also be modified to reflect these improvements.

The photographs of the miner contacting the roof, rib and floor are self explanatory. However, the students usually paused to ask what was being displayed. This is an initial orientation problem which can be minimized by overlaying the slide photograph with a brief explanatory statement. Three statements will summarize all of the continuous miner contact slides, they are:

1) Rib Contact
2) Roof Contact
3) Floor Contact

Adding the explanatory overlays and eliminating the checklist presentations should make the error slides easier to understand, thereby reducing initial orientation time and improving student

WRONG TRAM CONFIGURATION

VISION OBSTRUCTED –
LOWER CUTTERHEAD AND CONVEYOR

DANGEROUS TRAM CONFIGURATION

VERIFY THE FOLLOWING SWITCH POSITIONS:

CUTTERHEAD BREAKER	OFF
CONVEYOR SWITCH	OFF
MAIN MOTORS SWITCH	OFF

WRONG PARKING CONFIGURATION

VERIFY THE DUST SUPPRESSION AND
FIRE SUPPRESSION VALVES ARE CLOSED

WRONG PARKING CONFIGURATION

VERIFY THE FOLLOWING:

CUTTERHEAD	DOWN
GATHERING HEAD	DOWN
CONVEYOR	DOWN

WRONG PARKING CONFIGURATION

VERIFY THE FOLLOWING SWITCH POSITIONS:

CONTROL SWITCH	OFF
PUMP & TRACTION SWITCH	OFF
CONVEYOR SWITCH	OFF
MAIN MOTORS SWITCH	OFF

WRONG PARKING CONFIGURATION

VERIFY THE FOLLOWING BREAKER POSITIONS:

CONTROL BREAKER	OFF
CUTTERHEAD BREAKER	OFF

Table 5-2. New Error Slides

comprehension.

5.1.2 CONVEYOR REMOVAL FROM CRT

It has been suggested that removal of the conveyor from the CRT top view of the continuous miner would improve the trainer. The rationale for this change is that the trainee will be forced to look to the rear of the cab to see the conveyor position rather than knowing its location by looking at the CRT display. This makes sense, however there are certain times when the system requires conveyor position to be displayed, e.g., when tramming in reverse. The trainer displays conveyor boom position on the rear screen projector, but not in significantly incremental steps to tram in reverse. Adding a CRT at the rear of the cab would be too expensive. It is recommended that conveyor removal be an instructor option accomplished by typing a command at the DECwriter.

5.1.3 IMPROVED METHODS OF CREATING TRAINER EXERCISES

The trainer is highly flexible and can be programmed by individual coal company users to meet their specific training needs. The mine and machine parameters are programmed into the computer via the system DECwriter and CRT lightpen. As the system currently operates, the programming tasks are fairly complex and may be beyond the capabilities of the intended user. In order to minimize user training time and allow the coal companies to fully utilize the CMTS, it is recommended that the programming methods be modified to simplify their operation. Also, a User's Manual describing the procedures for creating training exercises and program operating instructions should be developed.

5.1.4 COURSE MATERIAL REVISION

It is recommended that the course materials be revised. In their present format, the materials contain machine specific dimensions, capacities, and facts that were included for maintenance information; and redundant orientation and health and safety information. The maintenance information should be eliminated from the CMTS instructional materials and the orientation and health and safety modules eliminated from the course requirements. Many companies already conduct orientation courses for new miners and annual retraining courses to emphasize the health and safety aspects of underground mining. The latter courses emphasize personal equipment and workplace hazards such as the condition of the roof, rib, and bottom, gases, dust and noise.

Less emphasis should be placed on memorizing machine specific facts and figures and more emphasis place on correct operating procedures. The process of cutting and removing the coal is essentially the same regardless of the specific type of continuous miner that is used. The objective of the course material revision should be to develop a generic set of course materials that will support on-the-job training requirements for the general coal mining industry. A generic training course will fill an immediate industry need - training materials for continuous miner operators and helpers.

A generic set of materials can be developed for the basic machine operating procedures, such as: preshift inspection, tramming, turning, entry cutting, cutting crosscuts, shuttle car interaction, stablizer jack usage, and shutdown configuration. Machine specific information such as the location of electrical switches and hydraulic controls, startup interlocks, control responses, and different types of methane monitors should be provided for each continuous miner manufacturer. The machine specific information should be in the form of slides or vuegraphs. The intention is to provide lecture displays for all types of continuous miners and allow the instructor to select the information applicable to his mining machines. The Instructor's Guide should include a checklist of the machine specific information that the instructor should cover during his lecture presentations.

5.2 TRAINER ENHANCEMENTS

The following recommendations emphasize new trainer functions that will increase the flexibility and improve the fidelity of the continuous miner trainer. These additional capabilities will not only enhance the usefulness of the CMTS, but also make the system more attractive to coal company users. The recommended trainer enhancements include:

1) Additional models of continuous miners
2) Mobile trainer
3) Demonstration and playback
4) Scrubber system
5) Fire suppresion
6) Controller side panel
7) Retreat mining

The following paragraphs describe enhancements to the current system that will provide more generic training on the CM and improve the overall training effectiveness of the system.

5.2.1 ADDITIONAL MODELS OF CONTINUOUS MINERS

In addition to training Joy 12CM operators, there is a need to train operators for other continuous miner models, such as Jeffery, Lee-Norse, or Marietta. It is recommended that conversion kits be developed to convert the CMTS to other types of continuous miner. Being able to convert the trainer to different types of continuous miners will expand the trainer capability and increase its usefulness to the coal industry.

A conversion kit should include replacement of the tram levers, electrical control switches, cap circuit breakers, and programs. Interchangeable panels and cover plates would be used to minimize the conversion time. The hydraulic control lever assembly would remain essentially the same. The name plate and detented lever modules, i.e. loader or gathering pan, may need to be exchanged. The programs that simulate the electrical interlock logic, continuous miner responce rates, and procedural error would require some changes.

5.2.2 MOBILE TRAINER

Shifts in personnel training requirements and student availability suggest that a mobile trainer may better suit the needs of the industry than does a fixed training facility. For example, a mobile trainer would save the time lost in transit between the mine and training site. Therefore, it is recommended that the CMTS be mounted in a mobile unit.

5.2.3 DEMONSTRATION AND PLAYBACK

A demonstration and playback capability would permit demonstration of correct coal cutting procedures and techniques and a permanent record of student performance to support feedback and review.

The instructor's command to control the demonstration or playback capability could be entered via the DECwriter. Three steps would be required to record an operator's performance. Specifically,

(1) Type "D<RETURN>" on the DECwriter. This would enable the recording of the operator's performance. To eliminate the recording of idle time, recording could begin when the hydraulic pump is turned on. The maximum demonstration time would be limited to 10 minutes.

(2) Type "DE<RETURN>" on the DECwriter to terminate the recording session, and a message requesting a name for the file would be printed on the terminal.

(3) Type "Filename.DEM<RETURN>" on the DECwriter. The filename could contain a maximum of six characters.

The instructor could select any recorded operator performance session by typing "PE<RETURN>" on the DECwriter. A message requesting the name of the file to be displayed would be printed on the terminal. Type "Filename.DEM<RETURN>" on the DECwriter to initiate demonstration or playback. The trainer would be fully operational at the completion of the playback session, and the training exercise could be resumed at the point of interruption or reinitialized.

5.2.4 SCRUBBER SYSTEM

New continuous mining machines are being delivered with a scrubber system option to suppress dust. The scrubber switch affects the start-up procedure because it is interlocked with the cutterhead motor and prevents cutterhead operation unless the scrubber system is activated. It is recommended that the scrubber switch, sound, and interlock logic be incorporated into the trainer.

5.2.5 FIRE SUPPRESSION

The water spray valves of the Joy 12CM are used for dust suppression, cooling, and fire control. The CMTS provides training in the use of the dust suppression water spray as an integral part of continuous miner operation. However, the CMTS does not have an active function for the fire suppression water spray. The system should be modified to permit an instructor command, via the DECwriter, to generate a flashing "FIRE" signal on the CRT. The trainee would then be required to turn the fire suppression water spray full on to remove the emergency message.

5.2.6 CONTROLLER SIDE PANEL

Safety training on the continuous miner should include instruction in the use of the controller side panel. The side panel provides emergency shutoff for the machine as well as emergency fire suppression. The necessary switches, circuit breakers, and controls should be incorporated into the CMTS along with the additional computer logic.

5.2.7 RETREAT MINING

One of the most dangerous tasks required of the CM operator is removing pillars in a retreat mining section. A highly trained operator is essential if success is to be achieved. Operational errors are liable to cause personal injury and take the continuous mining machine out of production. Coal industry personnel have expressed their desire to have training provided in this area and would like to see the CMTS modified to include instruction on retreat mining.

The present computer-graphics system is incapable of handling the additional program space and computational time required to implement retreat mining. The trainer graphics system is a 1973 vintage and was selected because it was significantly cheaper than other systems available during the design phase. Recent developments in the graphics industry indicate that a low cost raster scan display suitable for retreat mining will be available in late 1980. It is recommended that a study be conducted to define and locate a graphics system suitable for retreat mining.

5.3 TRAINER RELATED ACTIVITIES

The following recommendations include suggestions for additional trainer uses other than CM operator training. The CMTS has the potential to be utilized for continuous miner machine research, and the trainer concept is applicable to other types of mining equipment. The recommended trainer-related activities include:

1) On-board training device development.
2) Human factors design evaluations.
3) Application to other mining equipment.

5.3.1 ON-BOARD TRAINING DEVICE DEVELOPMENT

The procedural errors and corrective actions displayed on the forward projection system are essential to the trainer. The computer detects the errors far more efficiently than an instructor could, and the error slides constantly remind the operator of improper procedures.

Combining this feature of the trainer with microprocessor technological advances, it is now possible to conceive of an on-board training device for actual continuous miners. This device would perform the same function on a continuous miner that the projection system performs on the trainer. The difference would lie in the method of displaying the information to the operator. A two-row alphnumeric display could be used. Methane meters currently use similar devices to display the percentage of methane.

Ruggedized on-board computers, displays, and sensors are currently being developed for draglines, shovels, front-end loaders, and haulage trucks. In addition, some continuous miner sensors have been developed to support the automation of a continuous miner. The results of some of these activities should be directly applicable to an on-board continuous miner training device. The continuous miner training system should be used to develop and evaluate additional procedural errors by simulating additional continuous miner functions such as the scrubber system, drum extension, and floor jacks.

A training device of this type may be more cost effective than the trainer and has the potential to reduce actual machine maintenance problems.

5.3.2 HUMAN FACTORS DESIGN EVALULATIONS

Human engineering studies sponsored by the Bureau of Mines have generated recommendations to improve and standardize the design of the operator work station for underground mining equipment. The proposed changes recommended in these studies appear to have a great deal of face validity; however, the proposed changes to the work station design have not been validated in an operational environment.

It is recommended that the CMTS be reconfigured in accordance with recommended designs of human factor studies and then tested. The CMTS is ideally suited for this project. Many of the design changes recommended for continuous miners utilize tactile coded controls, standardized nomenclature, and improved control locations and functions. The CMTS workstation and controls could be reconfigured to represent a recommended prototype and then evaluated.

The following list identifies research work that could be accomplished utilizing the CMTS:

1) Examination of different type tram controls such as joysticks (force and displacement); a comparison of hand versus foot operated devices; evaluation of exponential versus linear or fixed types of control actuation.
2) Examination of control movement versus movement of corresponding miner parts and functional grouping of controls.
3) Evaluation of tactile coding schemes for hydraulic controls, switches and circuit breakers.
4) Standardization of controls and work station labeling for controls.

It is believed that evaluation of these recommended studies will be a major step towards standardization of controls and improved design and will result in improved safety, health and productivity for continuous miner operators.

5.3.3 APPLICATION TO OTHER MINING EQUIPMENT

A feasibility study should be conducted to determine the industry needs for analogous training for other types of mining equipment. The study would determine the needs along with the necessary cost trade-offs associated with utilization of an interactive graphics system to teach machine related skills.

CHAPTER 6

REFERENCES

Reference is made to the following documents throughout this report using the numerical designation shown below:

1. Development and Fabrication of a Continuous Miner Training System, Report MDC M0023, March 1978.

2. Final Report of Subcontractor Services to the McDonnell Douglas Electronics Company for the U.S. Bureau of Mines Contract No. H0377025, J.J. Davis Associates, Inc., July 1979.