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COAL FACE MEASUREMENT SYSTEM
FOR UNDERGROUND USE
FINAL REPORT

CONTRACT NUMBER NAS8-33792
COAL FACE MEASUREMENT SYSTEM
FOR UNDERGROUND USE

FINAL REPORT

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FORWARD

This report was prepared by the Benton Corporation of Manor, PA under contract NAS8-33792 issued by the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Marshall Space Flight Center, AL. The work was performed under the supervision of the contracting officers' representatives, Messrs. James Currie and Ralph Kissel.
SUMMARY

This report presents the results of work performed in the development and testing of a Coal Face Measurement System. It begins with a review of the measurement method; and the techniques, hardware, and system operation procedures. The next portion of the report is devoted to a description of the tests performed at the Department of Energy facility at Bruceton, PA. Conclusions are given in the final section.
1.0 SYSTEM MEASUREMENT METHOD

1.1 Introduction

A measurement system was developed for the Kickhott longwall shearer to determine the contour of the coal face as it mines coal. Contour data is obtained by an indirect measurement technique based on evaluating the motion of the shearer during mining. Starting from a known location, points along the coal face are established through a knowledge of the machines' positions and yaw movements as it moves past the coal face.

The equipment used in this system can be grouped into three parts. These are:

1) An angle transducer assembly
2) A distance transducer assembly
3) Data storage and reduction electronics

The angle transducers measure the angle between respective track sections as the shearer proceeds along the coal face. The distance transducer functions in conjunction with them to obtain relative angles at known positions. After completely cutting the coal face the accumulated data is stored on cassette tape and the present track profile is computed and displayed.
The transducer assemblies are shown in Figure 1.1. The data storage and reduction electronics is housed in an explosion proof enclosure. See Figure 1.1.1.

The coal face measuring equipment was constructed at the Benton Corporation and then transferred to the Department of Energy test facility at Bruceton, PA. Tests were performed there for three different coal face profiles by physically shaping the track. The system results were compared to manually measured values and after analysis shown to be within 0.1 foot of the correct contour.

1.2 Measurement Surface

The topography for a longwall mine complex is illustrated in Figure 1.2. The survey marks are points for which coordinates have been established. All other points between are unknown.

The technique used to measure the coal profile consists of measuring the angle between "Eicotrack" rack sections over which the shearer moves, and then performing trigonometric calculations to determine its relative shape. The rack sections are approximately two and one half feet in length and are assembled with conveyor "pan" sections to form a path of travel for the machine. The combined length
Figure 1.1 Angle and Distance Transducers

ORIGINAL PAGE IS OF POOR QUALITY
Figure 1.2 Longwall Mine - Top View

Figure 1.2.1 Track Sections
of the unit can total several hundred feet. The actual measurement surface is the "Eicotrack" rack face. It is located on the "gob" side of the conveyor which is the side away from the coal face. See Figure 1.2.1.

2.0 SYSTEM CONFIGURATION

2.1 General

A block diagram of the system is illustrated in Figure 2.1. It is divided into intrinsically safe and unsafe equipment. The safe equipment consists of two high accuracy resolvers, one incremental optical encoder and initiation switches. These pieces are housed in the transducer assemblies. The remaining equipment is housed within an explosion-proof enclosure.

2.2 Angle Measurement

The angle transducers are mounted in a mechanical support structure called the "angle cart". This unit contains the mechanics that allow the transducers to accurately produce repeatable angular positions. The angle transducers are intrinsically safe brushless resolvers and are directly connected to the angle measuring shoes. Figure 2.2 provides an exposed view of the "angle cart".

The angle between rack sections is measured differentially by the two resolvers. They are attached to a common reference
Figure 2.1 Measuring System Block Diagram
Figure 2.2 Angle Transducer Assembly

(a) Side View - Partially Uncovered

(b) Top View - Completely Uncovered
surface and are displaced from one another by a distance that is adequate to bridge two rack sections simultaneously. This relationship is illustrated in Figure 2.2.1.

Figure 2.2.1 Track Angle Measurement Technique

The measuring device is designed so that \( \theta \), the angle between sections, is the sum of \( \theta_1 \) and \( \theta_2 \). This design permits the measured angle value to remain independent of the angle measuring device location.

Wear and vibration may generate errors if the initial relationship between the two resolvers is disturbed. Vibration may produce a change which is static in nature.
and results in an error which occurs at a discrete interval of time. When it does occur, all angle measurements thereafter deviate from the correct value by the same fixed amount. Wear produces a change in the measurements which is gradual but cumulative. These two problems are handled by making a calibration measurement, across a surface that does not change, just prior to measuring a rack angle. This measurement is known as the "bias angle measurement" and is made along each rack section. Uncertainties that arise because of surface irregularities are handled by making a large number of bias measurements over a short distance of track rather than one measurement at a fixed point. In the computation phase, the bias readings are averaged and the result is subtracted from each angle reading to prevent any accumulative error.

2.3 Distance Measurement

Distance measurement is comprised of defining 1) where the coal shearer is relative to a known starting location and 2) when bias and angle measurements should be made. The equipment needed to perform these functions consists of electronic detection and measurement circuitry operating in conjunction with an encoding transducer which is interconnected through gearing to the shearing machine drive rack.
Distance is measured by counting pulses that originate from a 500 line optical incremental encoder. The encoder is located inside a support structure called the distance cart which is mounted overtop the shearer drive rack. A five point starwheel-type gear contained in the distance cart makes contact with the rack and rotates one fifth revolution for each 126 millimeters of forward movement. The starwheel rotation is transferred to the encoder through a system of gears that permit distance measurement to be resolved to every 1260 micrometers of travel. Figure 2.3 illustrates the side and bottom views of the distance transducer assembly.

Before distance can be measured, a known reference point must exist. This point, known as the zero point, is defined by the simultaneous activation of limit switches and the encoder zero pulse. To guarantee that only one reference point occurs along a coal face the limit switches are geared to the starwheel so that one actuates for every 7.14285 rotations and the other for every 357.14285 rotations. This coarse/fine configuration guarantees that only one reference indication occurs for each 885 feet of shearer motion. Once the zero reference point has been defined, absolute distance is measured by an electronic up/down counter which accumulates pulses from the encoder as the shearer moves along the face.
(a) Side View Showing Limit Switches and Gearing

(b) Bottom View Showing Starwheel

Figure 2.3 Distance Transducer Assembly
The position at which bias and angle measurements are made is determined by a second set of electronics that operates in conjunction with the encoder and the absolute up/down counter. The initial point at which the first bias measurement occurs is defined by a comparator network output that goes high when the absolute position value is greater than a thumbwheel set value. As the comparator goes high, another counter network turns on and it is this counter's output which is compared with a distance measurement value, an angle start value and a distance measurement recycle value. The operation of the second counter is cyclic since the shearer rack geometry is cyclic.

2.4 Roll Measurement

The roll transducer is mounted within the explosion-proof enclosure. The transducer produces an electrical signal proportional to angular displacement relative to a vertical reference. The unit consists of a pendulum submerged in damping fluid. The pendulum's position is sensed to provide an analog voltage output of one half volts per degree of inclination. The analog output signal is converted into digital format by a twelve bit D/A (digital-to-analog) converter. The most significant bit weight is 16 degrees and the least significant bit weight is .0078 degrees.
3.0 SYSTEM OPERATION

3.1 General

The measurement system is designed to operate as the longwall shearer makes its numerous passes across the coal face. During this time the hardware electronics is sending transducer readings to the system microprocessor (Rockwell ATM 6500) for temporary storage. Each time the machine moves to the end of the conveyor track the accumulated data is stored on a cassette tape. After this transfer the same temporary data is reduced mathematically by computer firmware (non-volatile software) into a usable format for display.

During the calculation process the present data is reduced with data acquired when the shearer was first installed in the mine. Normally before the first run the conveyor track is aligned as straight as possible. Then manual measurements are made of the conveyor track to obtain the exact alignment. The resulting "manual data" is put on a non-volatile integrated circuit memory chip which is added to the system to become a part of the firmware. Afterwards the shearer traverses the total coal face to obtain angle information defined as the "initial run data". Subsequently this and the "manual data" becomes the basis of all the system calculations.
The system firmware performs the following:

1) Initialize system
2) Input and store transducer data
3) Transfer accumulated data to tape
4) Reduce accumulated data to a display format
5) Display contour of longwall conveyor
6) Provide information on multiple shearer parameters.

A general system flow chart is given as Figure 3.1.

3.2 Power-up and Initialization

At power-up the computer zeroes all of the data and control registers. It then configures each input/output port for correct data flow. The computer also sets numerous control registers and retrieves the conveyor "manual" data from non-volatile memory for later use. After set-up the computer begins to convey visual information to the machine operator. The first display reads "At headgate position push start button". When the operator acts upon this instructive command the distance and angle counters are zeroed and the acquisition of data is enabled.

The operator may alternately set the system for an "initial run" by setting the initial run (key-type) switch to "On" before power-up. When this is done the initialization routine is the same except that the cassette tape is also positioned to its starting point.
Figure 3.1  System Flow Chart
3.3 Data Acquisition

On the physical system the resolvers are displaced by fifteen inches from one another. Each bias measurement is then made across a five inch span of the thirty inch trackage starting at a point that is three and one half inches from the end for the trailing transducer and eighteen and one half inches for the leading transducer. Measurement is complete when the trailing transducer has moved eight and one half inches from the track section end - and the leading transducer has moved to the twenty-three and one half inch location. An angle measurement is initiated when the trailing transducer has moved to the eighteen and one half inch location and the leading transducer has moved onto the next track section three and one half inches. It is completed when the trailing transducer has moved an additional five inches to twenty-three and one half inches and the leading transducer to the eight and one half inch point. Figure 3.3 illustrates the technique used to make these measurements.

The procedure that is used to obtain transducer readings is primarily determined by the distance and angle electronics. In this electrical section the following are switch selectable:

1) Number of angular samples
2) Start location of first bias measurement
3) Start location of angle measurements
4) Measurement cycle repetition distance

See Figure 3.3.1.
Bias and Track Angle Measurement Technique

Figure 3.3

Start - Angle Measurement -

End

Track Sections

Start - Bias Measurement -

Bias Measurement -

30 in.

3.5 in.

15 in.

8.5 in.

3.5 in.

18.5 in.

23.5 in.

8.5 in.
The electrical hardware performs two major functions. First it keeps track of the linear distance traveled by the mining machine from the start point. The second use is to obtain and add up the 100 measurement samples for each angle. After addition the data is temporarily held and the computer is sent an interrupt signal.

Upon receipt of this signal the data is immediately transferred to temporary memory for future application. The computer then takes a roll measurement, saves the result and then waits for the next interrupt.
3.4 Data Storage

After making readings on the last conveyor track section the system transfers to tape the accumulated bias, angle, and roll measurements. This data is stored on a digital cassette recorder in serial phase encoded (Bi-phase-level) format. The recorder used to store this information is a Ray and Model 6406 "Raycorder". This serves as the long term, non-volatile, bulk data storage device for this project.

The information is retained on tape in the form of files. Each file corresponds to one "run" of the mining machine; where a "run" is the action of cutting the complete coal face once. A 300 foot cassette tape was selected and can retain the runs generated over a one month period.

If the mining machine has just completed an initial run, then this original data is also transferred to non-volatile memory for future use.

3.5 Data Reduction

The data reduction consumes the most time of the many system activities. As an example; a mining machine with a conveyor track 600 feet long would require approximately two minutes of system data processing. The numerous calculations that are made by the system computer are outlined as a general flow chart in Figure 3.5.
Figure 3.5  Data Reduction Flow Chart
After the data has been converted to decimal values the program calculates the bias deviation for each reading. This is done by comparing the present bias measurements with the "initial run" bias measurements. Under normal conditions this difference would be very close to zero. As soon as this calculation has been performed for each value then the average bias deviation is determined.

The combined computation performed is:

\[ B = \frac{1}{N} \sum_{i=1}^{N} (B_i - B_{i, \text{init}}) \]

where:

- \( B \) - average bias deviation
- \( B_i \) - present bias value
- \( B_{i, \text{init}} \) - initial run bias value
- \( N \) - number of angles measured

The next program segment calculates the angle change across each rack section by summing the manually measured data to the difference value; the difference value being the deviation of the present angle measurement from the initial run angle value. The computation performed is:

\[ \Delta (i) = (A_i \text{ pres} - A_i \text{ init}) + A_i \text{ man} \]
where:

$A_i$ (i) \ - \ corrected \ angle \ value

$A_i$ pres \ - \ present \ angle \ value

$A_i$ init \ - \ initial \ run \ angle \ value

$A_i$ man \ - \ manually \ measured \ angle \ value

With the results from the two preceding equations we can calculate the actual angles between each rack section.

The equation used is:

$$A (I) = \sum_{j=1}^{I} \sum_{i=1}^{j} (A (i) - B)$$

where:

$A (I)$ \ - \ referenced \ angle \ value

$A (i)$ \ - \ corrected \ angle \ value

$B$ \ - \ average \ bias \ value

Figure 3.5.1 clearly shows the summation process.
At this time the firmware determines the 'Y' coordinate for each rack section referred to the position of the first rack. The general equation is:

\[ Y(j) = Y(j-1) + L \times \sin \left( \sum_{i=1}^{j} A(i) \right) \]

where:

- \( Y(j) \) - uncorrected Y value
- \( L \) - length of rack section
- \( A(i) \) - referenced angle value

Figure 3.5.2 presents a simple example. \( Y(0) \) equals zero. \( Y(1) \) equals zero because the initial angle is assumed zero.
Once the last uncorrected Y coordinate value is determined the conveyor track can be referenced to the position of the zero rack section. This is done by calculating the initial angle. In the following explanation Figure 3.5.3 may be used as an aid.

\[ \theta_i \text{ (actual)} = \arctan \left( \frac{Y_{\text{last}}}{X_1} \right) \]

where:
- \( \theta_i \text{ (actual)} \) - accurate initial angle value
- \( Y_{\text{last}} \) - last uncorrected Y coordinate value
- \( X_1 \) - accurate X distance

Figure 3.5.3 Graphic Initial Angle Determination
A very close approximation to this would be:

\[ \theta_i \text{ (practical)} = \arcsin \left( \frac{Y \text{ last}}{L \times N} \right) \]

where:

\[ \theta_i \text{ (practical)} \quad \text{- practical initial angle value} \]
\[ Y \text{ last} \quad \text{- last uncorrected coordinate value} \]
\[ L \quad \text{- length of rack section} \]
\[ N \quad \text{- number of rack sections} \]

The arcsine equation was used because it does not require the system to calculate all of the X coordinates and thus saves on computer processing time. Also the angles derived from each equation were very similar. The equation used by the computer is:

\[ R = \arcsin \left( \frac{Y(\emptyset) - Y(N)}{L \times N} \right) \]

where:

\[ R \quad \text{- initial value} \]
\[ Y(\emptyset) \quad \text{- Y value for rack zero} \]
\[ Y(N) \quad \text{- Y value for last rack} \]
\[ L \quad \text{- length of rack section} \]
\[ N \quad \text{- number of rack sections} \]

The last major calculation that the microprocessor performs is to determine the Y coordinates for each rack section relative to the initial rack section.
The equation is:

\[ Y(J) = Y(J-1) + L \times \sin \left( \sum_{I=1}^{J} (A(I)+R) \right) \]

where:

- \( Y(J) \) - corrected Y value
- \( L \) - length of track section
- \( A(I) \) - referenced angle value
- \( R \) - initial angle

The resulting coordinate relationship is represented by

![Figure 3.5.4 Corrected Y Coordinate Graph](image)

3.6 System Display

The coal face measurement system provides the longwall machine operator with two useful display routines. The first displays the general curvature of the conveyor track while the second pinpoints particular physical parameters of the mining machine.

As the system operates, the curvature of the conveyor track is automatically displayed each time the mining machine cuts
the complete coal face. This curvature is specified as the physical displacement of the track from an imaginary center-line stretching from one end of the conveyor track to the other. The length of the track is divided into 15 equal segments which allows for a track contour displacement to be presented for 15 locations. The displacement is in feet and the direction of the curve is either toward the coal face (FACE) or away from the coal face (GOB). The operator sees an alternating display showing the displacement to either side of the center line. The display alternates every four seconds. See Figure 3.6.

![Figure 3.6 Conveyor Displacement Display]

During a mining operation the operator can also obtain the following system parameters:

1) Previous displacement of any rack
2) Present roll of the mining machine
3) Roll of any rack previously traversed
4) Actual distance of the mining machine from the starting point
These functions may be called by first momentarily pushing the "function" pushbutton on the XP enclosure. See Figure 3.6.1. This permits the computer to enter the display routine and present instructions to the operator. By following the displayed directions, the operator is lead step by step through the display format. Figure 3.6.2 through 3.6.4 describes the computer activities, the information displayed and the actions required of the machine operator.

The system also signals the shearer operator for any of the following possible conditions:

1) Power failure
2) Resolver angular error
3) Cassette loading error
4) Cassette tape error
5) Cassette tape full

A resolver error is flagged when the computer senses that an angle reading is ten degrees or more. If this occurs the system displays question marks to insure that the operator does not act on erroneous data. A cassette loading error is signalled when a cassette has not been inserted and/or the recorder door has not been closed. A cassette tape error occurs whenever the recorder determines that there was an error in the transfer of data to the tape.
Figure 3.6.1  XP Enclosure
1. ENTRY TO ROUTINE

**ACTION**
Momentarily Push Function Button

**RESULT**
Displays "DISPLAt ROUTINE", Delays 2 sec.
Displays "PUSH FUNCTION BUTTON", Delays 2 sec.
Displays "& THEN ENTER BUTTON", Delays 2 sec.
Loops and displays again.

II. POSSIBLE FUNCTIONS

Push and Hold FUNCTION Button

Displays "DISPLACEMENT OF RACK", Delays 2 sec.
Displays "PRESENT ROLL", Delays 2 sec.
Displays "ROLL OF RACK SECTION", Delays 2 sec.
Displays "PRESENT DISTANCE", Delays 2 sec.
Displays "EXIT FROM ROUTINE", Delays 2 sec.
Loops and displays again.

III. SELECT FUNCTION

A. Release FUNCTION Button when desired function is displayed.

B. Push and Hold ENTER Button

C. Release ENTER Button

Displays "DISPLACEMENT OF RACK" or
Displays "PRESENT ROLL" or
Displays "ROLL OF RACK SECTION" or
Displays "PRESENT DISTANCE" or
Displays "EXIT FROM ROUTINE".

Displays answer or requests information.

Figure 3.6.2 Displayed Parameter Entry Sequence and Result (Part 1)
**IV. FUNCTION 1 (DISPLACEMENT OF RACK) OR FUNCTION 3 (ROLL OF RACK SECTION)**

<table>
<thead>
<tr>
<th>ACTION</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(To be performed after selection)</td>
<td>Displays &quot;PUSH STEP FOR RACK #&quot;</td>
</tr>
<tr>
<td>A. Momentarily Push STEP Button</td>
<td>Displays &quot;USE LEFT/RIGHT SW.&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td></td>
<td>Displays &quot;TO SELECT DIGIT&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td></td>
<td>Displays &quot;PUSH ENTER WHEN OK&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td></td>
<td>Turns on Light Emitting Diode over 100's digit.</td>
</tr>
<tr>
<td>B. Push and Hold STEP Button</td>
<td>Displays numbers which increment every second.</td>
</tr>
<tr>
<td>C. Release STEP Button</td>
<td>No longer increments numbers.</td>
</tr>
<tr>
<td>D. Push and Hold LEFT/RIGHT switch to either side.</td>
<td>Turns on Light Emitting Diode over successive digits.</td>
</tr>
<tr>
<td>E. Release LEFT/RIGHT Switch</td>
<td>Light Emitting Diode designates digit which may be incremented.</td>
</tr>
<tr>
<td>F. Push and Hold ENTER Button</td>
<td>If the entry is &gt; number of rack sections then Displays &quot;ENTRY TOO LARGE&quot; and returns to beginning of function, otherwise it Displays &quot;USE UP/DOWN SWITCH&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td>G. Release ENTER Button</td>
<td>Displays &quot;TO CHANGE RACK NUMBER&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td></td>
<td>Displays &quot;PUSH EXIT TO EXIT&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td></td>
<td>Displays &quot;6 FUNCTION TO RETURN&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td></td>
<td>Displays answer.</td>
</tr>
<tr>
<td>H. Push and Hold UP/DOWN switch to either side</td>
<td>Increments or decrements rack section number.</td>
</tr>
<tr>
<td>I. Release UP/DOWN switch</td>
<td>Displays answer for appropriate rack section.</td>
</tr>
<tr>
<td>J. Push and Hold FUNCTION Button</td>
<td>Returns to allow new function selection.</td>
</tr>
<tr>
<td>K. Release FUNCTION Button</td>
<td>Selects function.</td>
</tr>
<tr>
<td>L. Push EXIT Button</td>
<td>Exits from routine and displays previous general curvature.</td>
</tr>
</tbody>
</table>

*Figure 3.6.3  Displayed Parameter Entry Sequence and Result (Part 2)*
V. FUNCTION 2 (PRESENT ROLL) OR FUNCTION 4 (PRESENT DISTANCE)

<table>
<thead>
<tr>
<th>ACTION</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(To be performed after selection)</td>
<td>Displays &quot;PUSH EXIT TO EXIT&quot;, Delays 4 sec. Displays &quot;&amp; FUNCTION TO RETURN&quot;, Delays 4 sec. Displays answer.</td>
</tr>
<tr>
<td>A. Push and Hold FUNCTION Button</td>
<td>Returns to allow new function selection.</td>
</tr>
<tr>
<td>B. Release FUNCTION Button</td>
<td>Selects function.</td>
</tr>
<tr>
<td>C. Push EXIT Button</td>
<td>Exits from routine and displays previous general curvature.</td>
</tr>
</tbody>
</table>

VI. FUNCTION 5 (EXIT FROM ROUTINE)

<table>
<thead>
<tr>
<th>ACTION</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(To be performed after selection)</td>
<td>Exits from routine and displays previous general curvature.</td>
</tr>
<tr>
<td>A. Push EXIT Button</td>
<td></td>
</tr>
</tbody>
</table>

VII. RESULTS

<table>
<thead>
<tr>
<th>FUNCTION 1 (Previous Displacement of any rack)</th>
<th>DISPLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>RACK XXX F X.XX FEET</td>
<td></td>
</tr>
<tr>
<td>RACK XXX G X.XX FEET</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FUNCTION 2 (Present Roll)</th>
<th>DISPLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROLL F XX.X DEGREES</td>
<td></td>
</tr>
<tr>
<td>ROLL G XX.X DEGREES</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FUNCTION 3 (Previous roll of any rack)</th>
<th>DISPLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>RACK XXX F XX.X DEG</td>
<td></td>
</tr>
<tr>
<td>RACK XXX G XX.X DEG</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FUNCTION 4 (Present Distance)</th>
<th>DISPLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCATION XXX.X FEET</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.6.4 Displayed Parameter Entry Sequence and Result (Part 3)
3.7 Data Retrieval

Each time the coal face is completely cut the accumulated readings are saved on the cassette tape for future evaluation. Thus after approximately one month a new cassette must be installed in the system. For protection from any contaminants, the cassette recorder mechanics is contained within a separate sealed box. So instead of switching tapes, boxes will swapped. In order to retrieve the data from the tape an identical Raymond cassette recorder should be used. And with the appropriate Raymond formatter option, direct input to a computer is accomplished.
4.0 TEST RESULTS

4.1 General

The accuracy specification for the yaw measurement equipment required that the overall system be capable of calculating the true curve for a 600 foot coal face to within ±12 inches of its true position.

System accuracy was confirmed through the performance of nine tests at the Bruceton facility. These tests included measurement across a straight track, a track bowed approximately two feet towards the coal face and a track bowed approximately one foot away from the coal face. All testing was performed utilizing fifteen Eickhoff pan sections to obtain a representative longwall configuration. Figure 4.1 illustrates the straight face track geometry at the Bruceton facility.

4.2 Test Procedure

The initial test to confirm system performance was undertaken on a straight track. The test results were positive. The straight track tests were rerun two additional times to confirm repeatability. Again the results were very good. For the series of measurements the maximum deviation between the manually measured values and the system measured values was .03 inches. See Figure 4.2.
The track was next bowed approximately two feet towards the coal face. The bow was placed about midway between the end points in an attempt to generate large positive and negative angle readings. Three tests were made and compared with the actual track curvature. The actual and computed results were the same to within .29 inches. Figure 4.2.1 illustrates the track geometry and the computed results.

The third configuration was a bow approximately one foot away from the coal face. The results between computed and actual geometries were the same to within .11 inches. Figure 4.2.2 illustrates the track geometry and the computed results for this configuration.
5.0 CONCLUSION

A microprocessor based contour measurement system adaptable to the Eickhoff shearer was developed for underground use.

The equipment was tested successfully at the Bruceton facility for a number of simulated coal face contours. Results indicate that the equipment can repeatedly measure shearer conveyor angles to within ± 0.05 degrees and contours to within 0.1 foot of the correct value.

Several measurement techniques were developed that bear promise for use with other mine related equipment. The resultant equipment includes intrinsically safe angle and distance measuring transducers.

The angle measurement system required that a non-contacting low energy transducer be acquired. A search resulted in the procurement of a low voltage 1 minute accurate size 11 resolver. Circuiting was developed for use with it and the simultaneous goal of accuracy and intrinsic safeness was achieved.

An incremental optical encoder was acquired, combined with energy limiting circuitry and limit switches to achieve an intrinsically safe absolute distance measuring system with a resolution of 0.05 inches.
The complete measurement system is presently under review by MSHA for compliance with intrinsic safety standards. When approval is received the equipment will be taken underground and tested for operability in a mine environment.
APPENDIX A

A.0 COMPUTER OPERATION

A.1 General

The computer developed for the coal face measurement system consists of four integrated circuit boards. The AIM 6500 microcomputer makes up the "heart" of the system. A memory board serves as the "brain" and two I/O boards allow the "heart and brain" to communicate externally. Figure A.1-1 presents the important features of each board.

The computer takes on the character of a measurement system with inclusion of operating programs. These programs are listed as Figure A.1-2 and are located on EPROM (Electrically Programmable Read Only Memory) chips. They thus become a permanent part of the system.

In the following literature the programs are briefly discussed, shown as flowcharts, and completely listed. A system memory map is also provided.
1) AIM 6500 Microcomputer

4K RAM
8K BASIC
8K MONITOR
20 Column LED Display

2) Memory Board

32K Dynamic RAM
16K PROM
EPROM Programmer

3) Input/Output Board

10 8 bit Ports per Board

Figure A.1-1 System Computer Hardware
### Programs

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<tr>
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<td>2K EPROM</td>
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</tbody>
</table>

**Figure A.1-2 System Computer Programs**
A.2 Program Execution Sequence

Immediately after turn-on all of the computer input/output ports are configured for system operation. After this the computer jumps to the BASIC routine which temporarily jumps to a normalization routine. When complete, the computer returns to the BASIC routine which signals the operator when ready.

While the coal is being cut the system is continually moving between the BASIC and Data Handling routines. The Data Handling routine inputs and stores the generated bias, angle, and roll data. At the end of each run, after all data has been input; the accumulated data is transferred to tape.

After replication the data is reduced algebraically to a useable form by the BASIC routine. The computer jumps to the Contour Display routine and presents the calculated results to the system operator.

Figures A.2-1 and A.2-2 provide a very general program execution sequence.
Figure A.2-1 General System Flowchart
Figure A.2-2 Data Handling Flowchart
A.3 Input/Output Setup Program

The very first step that the computer makes is to send the tape recorder a stabilization command. This is done to insure that the tape does not move until required. After this all of the system input/output ports are configured for their particular application. The computer now executes the BASIC driver routine.

Figure A.3-1 shows the flowchart while Figure A.3-2 presents the actual program listing.
Figure A.3-1 Input/Output Setup Program Flowchart
Figure A.3-2 Input/Output Setup Program Listing
A.4 BASIC Program

The main program utilized by the measurement system is the BASIC routine. All operations, if not performed as a part, originate from it. The program completes two major processes. One section calculates the general coal face contour from the accumulated data while another section displays more detail on the mining machine and its operation. The most recent addition to this program requests the operator to enter the mining machine's track end-point locations. This information references the measurement system results to a known coordinate geometry and thus closes the man-machine feedback loop.

Figure A.4-1 shows the flowchart while Figure A.4-2 through A.4-4 presents the actual program listing.
Figure A.4-2  BASIC Program Listing

```
LIST
10 POKE 4,80: POKE5,2
19 N=USR(0)
20 M1=PEEK$(17952):D
INC$(M1+1).D(M1+1):E<
M1+1).S(2)
22 PRINT"".PRINT"A
T HEADGATE POSITION"
:GOSUB180
25 PRINT"".PRINT"P
USH START BUTTON".GO
SUB1180
28 KE=5.E0:IF PEK("17628)<181THEN22
10 POKE40460,236:PO
KE40460,204
40 POKE40462,125
50 POKE40461,110:PO
KE40462,110
60 POKE40460,206:PO
KE40460,204
70 KE=0:3:PRINT"P
*:IFPEEK$(18433)<0THEN
END
75 IFPEEK$(18424)=0T
HENPRINT"INITIAL RUN"
"GOTO90
80 PRINT"PROCEED"
90 POKE4,112:POKE5,
209:NE=USR(0)
100 IFPEEK$(17677)=2
55THEN114
110 IFPEEK$(17677)=2
51THEN290
54THEN120
112 IFPEEK$(18445)=1
THEN70
113 GOTO90
114 E=1 POKE17677,0
115 IFPEEK$(18434)=0
THENIFPEEK$(18433)=1T
HNN17
116 IFPEEK$(18436)=0
THEN1630
117 R=16896:GOSUB11
8 R=17152:GOSUB118:G
OTO1610
119 FORK=1:TM1+1:PO
KER:63
119 R=R+1:NEXT:RETU
RN
120 Y=0:T=0
130 PRINT"".PRINT"
DISPLAY ROUTINE".GO
SUB1180
140 PRINT"".PRINT"
USH FUNCTION BUTTON"
:GOSUB1180
150 PRINT"".PRINT"
THEN ENTER BUTTON"
:GOSUB1180
160 IFPEEK$(37633)=2
54THEN=0:GOTO190
170 IFT=000:THEN12
0
180 T=T+1:GOTO130
190 FORY=1TO5:PRINT
".
200 IFY=1THENPRINT"D
ISPLACEMENT OF RACK"
"GOTO250,
210 IFY=2THENPRINT"P
RSENT ROLL".GOTO25
0
220 IFY=3THENPRINT"R
OLL OF RACK SECTION"
"GOTO250,
230 IFY=4THENPRINT"R
ESSENT DISTANCE".G0
TO250
240 PRINT"EXIT FROM"
ROUTINE"
250 GOSUB1180:IFPEE
K$(37633)=254THENNEXT
Y:.GOT010
260 IFPEEK$(37633)=2
51THEN290
54THEN120
270 IFT=5:GOTO120
280 T=T+1:GOTO260
290 IFY=2THEN90
300 IFT=4THENG60
310 IFT=5THEN120
312 IFY=1THEN320
315 PRINT"".PRINT"
THIS IS FIRST RUN"
317 GOSUB1180:GOTO1
0
THEN630
320 T=0:N=0
330 PRINT"".PRINT"
PUSH STEP FOR RACK #"
".
340 IFPEEK$(37633)=2
53THEN365
350 IFT=5:GOTO120
360 T=T+1:GOTO340
365 GOSUB270:GOSUB4
55:GOTO650
370 PRINT"".PRINT"
USE LEFT/RIGHT SW."
:GOSUB1190
380 PRINT"".PRINT"
TO SELECT DIGIT".GOSUB
UB1190
390 PRINT"".PRINT"
PUSH ENTER WHEN OK"
:GOSUB1190
400 Y1=0:Y2=Y1:Y3=Y
2:PRINT""
404 IFN=0THENPRINTY
1.Y2:Y3:GOTO410
406 IFR="THENPRINTY
1.Y2:Y3:LEFT END"
:GOTO410
408 PRINTY1;Y2;Y3"
RIGHT END"
410 P=1
420 IFF=2THENPOKE39
682.2:GOTO450
420 IFF=3THENPOKE39
682.4:GOTO450
440 POKE39682.1
450 GOSUB1190:RETU
RN
455 IFPEEK$(37633)=2
39THENP=P+1:GOTO500
460 IFPEEK$(37633)<0
24THEN520
470 P=P-1
480 IFF=0THENP=3
490 GOTO420
500 IFF=4THENN=1
510 GOTO420
520 IFFPEEK$(3763)<0
25THENRETURN
520 FORY=0:PRINT"
".
540 IFF=2THENY2=Y:G
OTO570
550 IFF=3THENY3=Y:G
OTO570
550 Y1=Y
570 IFN=0THENPRINTY
1.Y2:Y3:GOTO600
580 IFR=0THENPRINTY
1.Y2:Y3:LEFT END"
:GOTO600
590 PRINTY1;Y2;Y3"
RIGHT END"
600 GOSUB1180
610 IFFPEEK$(37633)=2
52THENNEXT:GOTO550
620 RETURN

Figure A.4-2  BASIC Program Listing

```

ORIGINAL PAGE IS OF POOR QUALITY
Figure A.4-3  BASIC Program Listing  continued
1440 POKE188.61:POK
E189.214:Y=(Y1-Y2/K2)
1450 V=Y/(M1+1):R=A
TN(V/SQR(V*V+1))
1460 D(1)=K*SIN(R)
1470 FORN=1TO1:M1:D(N+
1)=K*SIN(C(N)+R)+D(C
N)
1480 NEXT
1490 FORN=1TO1+1
1500 E(N)=D(N):IFD(N)
00THEN1560
1510 IFD(N)=0THEN15
80
1540 C(N)=INT(-D(N)
*K2+K3)+48:IFC(N)=48
THEN1560
1550 D(N)=45:G0T015
90
1560 D(N)=INT(D(N)*
K2+K3)+48:IFC(N)=48
THEN1560
1570 C(N)=45:G0T015
90
1580 D(N)=48:C(N)=4
8
1590 POKE16995+N.D(N)
N):POKE17151+N.C(N)
1600 NEXT
1610 POKE4:0:POKE5,
210: N=USR(0)
1620 G0T090
1630 PRINT"":PRINT
"END-POINT ROUTINE":
GOSUB1180
1640 PRINT"":PRINT
"PUSH FUNCTION BUTTO
N" :GOSUB1180
1650 PRINT"":PRINT
"TO BEGIN" :GOSUB1180
1660 R=0:IFPEEK(376
33)>254THEN1630
1670 T=0:N=1
1680 PRINT"":PRINT
"PUSH STEP TO ENTER"
GOSUB1180
1690 PRINT"":PRINT
"END-POINT LOCATION"
GOSUB1180
1700 IFPEEK(37633)=
253THEN1730
1710 IFT=500THEN163
0
1720 T=T+1:G0T01680
1730 GOSUB370
1740 GOSUB455
1750 IFPEEK(37633)=
251THEN1780
1760 IFT=500THENPOK
1770 POKE39682,0:G0T01670
1780 POKE39682,0:IF
R=1THEN1800
1790 X=Y1+100+Y2+10
+Y2:R=1:G0T01670
1800 Y2=Y1+100+Y2*1
0+Y3:Y1=X/K2:G0T0124
0
1810 END
A.5 Normalization Program

Whenever the Register Setup program is executed the coal face measurement system is placed on a ready status. In this routine the system power is checked, all of the temporary control registers are setup, and if necessary the tape is rewound.

Figure A.5-1 shows the flowchart while Figure A.5-2 through A.5-6 presents the actual program listing.
START

SYSTEM POWER OK?

Yes

No

SETUP REGISTERS

FETCH MANUAL DATA FROM EPROM

MOVE RECORDER TAPE TO LOAD POINT

Yes

No

INITIAL RUN?

FETCH BIAS AND ANGLE INITIAL DATA FROM EPROM

RETURN

DISPLAY POWER FAILURE

Figure A.5-1 Register Setup Program Flowchart
bc 262-400

NORMALIZE ROUTINE

==6400

SAVE ZERO CONSTANT
A0FF LDY #$FF

==6402 L
C0 INY

B90000 LDA $0000,Y
48 PHA

C012 CPY #$12
D0F7 BNE L

CLEAR DISPLAY
20F0E9 JSR #$E9F0 CRL F

NORMALIZING
A000 LDY #$00

==6410 LOADNO
B9164 LDA MSGNOR,Y
C93B CMP #$'

F012 BEO ALT
2005EF JSR #$EF05 OUT D

C8 INY
4C1064 JMP LOADNO

==641E MSGNOR
4EF6 BYT 'NORMALIZING'

ALTERN NMI VECTOR

==642A ALT
9000 LDA #$00

8D02A4 STA #$A02
968 LDA #$68

8D03A4 STA #$A03

SYSTEM POWER STATUS
AD0296 LDA PBD
3003 BMI AAA
4CD866 JMP BATTER

TURN RECORDER OFF

==6472 CCC
AD0095 LDA PAC
1003 BPL DDD
4CD866 JMP BATTER

TURN-ON DELAY
20A66 JSR DELAY

CASSETTE LOADED?
AD0095 LDA PAC
0A ASL A
1028 BPL CCC

==644A BBB
20F0E9 JSR #$E9F0 CRL F

A000 LDY #$00

==644F LOADCL
B95064 LDA MSGCLE,Y
C93B CMP #$'

F0F4 BEO BBB
2005EF JSR #$EF05 OUT D

C8 INY
4C4F64 JMP LOADCL

==645D MSGCLE
4341 BYT 'CASSETTE LOADING ERR'

==6472

TAPE POWER STATUS

==6472 CCC
AD0095 LDA PAC
1003 BPL DDD
4CD866 JMP BATTER

TURN RECORDER OFF

==6472 CCC
AD0095 LDA PAC
1003 BPL DDD
4CD866 JMP BATTER

TURN-OFF DELAY
209566 JSR DELAY

Figure A.5-2 Register Setup Program Listing
Figure A.5-3  Register Setup Program Listing  continued
Figure A.5-4  Register Setup Program Listing  continued

bc 262-400

==6542

;LOAD COMMAND SENT
;STABILIZE RECORDER

A957  LDA #57
8D0295 STA PBC

;LOAD POINT LOOP

==6547 LPLOOP
AD0095 LDA PAC
2910 AND #10
D6F9 BNE LPLOOP

;TURN-OFF DELAY

209566 JSR DELAY

;TURN RECORDER OFF

A900  LDA #00
8D0296 STA PBD

;SET RUN NUMBER TO 0
;READ RML

A908  LDA #08
==6558
8D0E45 STA HCOUNT

==655B SLREAD
2000D1 JSR PROMH
2000DA JSR PPROM

;EPROM ADDR. EMPTY?

AD0248 LDA RML
C9FF CMP #FFFF
F009 BEO HZERO

;LOOK AT NEXT ADDR.

8D2246 STA RUNHI
==656B
EE0245 INC HCOUNT
4C5585 JMP SLREAD

;PREVIOUS ADDR. =0?

==6571 HZERO
AD0246 LDA RUNHI
D006 BNE HSTORE
8D0248 STA RML
4C5585 JMP SLOW

;EPROM RML ADDR TO 0

==657C HSTORE
EE0248 INC RML
2000D1 JSR PROMH
2000DA JSR PPROM
EE0F45 INC LCOUNT
D003 BNE NORMKE
EE1645 INC RMLHIB

A19

==65C5 LSTORE
EE0248 INC RML
2000D1 JSR PROMH
2000DA JSR PPROM
EE0F45 INC LCOUNT
D003 BNE NORMKE
EE1645 INC RMLHIB

==65D6

;NORMALIZE KEY

==65D6 NORMKE
20F009 JSR #E9FF CRL
A000 LDY #00

==65DB LOADNK
B9E965 LDA MSG1, Y
C98B CMP #88
F015 BEQ KEY
2005EF JSR #EF05 OUT
D
C8 INY
4CDB65 JMP LOADNK

==65E9 MSG1
4E4F .BYT 'NORMALIZE KEY,';

;INITIAL KEY TURNED?

==65F7 KEY
AD0193 LDA FUNC
C97F CMP #7F
F0F9 BEQ KEY
4C966 JMP RETURN

;GET RUN NUMBER
;READ RML

==6601 RUN
A908 LDA #08
8D0E45 STA HCOUNT

==6606 RHREAD
2000D1 JSR PROMH
2000DA JSR PPROM

;EPROM ADDR. EMPTY?

==65BA LZERO
AD0248 LDA RML
C9FF CMP #FFFF
F009 BEO RLOW
Figure A.5-5  Register Setup Program Listing  continued
; DATA END POINT

; =66BF LIMIT
A200 LDX #100
A02046 LDA NUMANG
0A ASL A
2001 BCC LOW
E8 INX
; =66C8 LOW
D8 CLD
1A CLC
600845 ADC LOCA
8504 STA #04
8A TXA
D8 CLD
1A CLC
600945 ADC LOCA-1
8505 STA #05
60 RTS

; =66D8 /BATTERY ERROR

; =66D8 BATTERY
20F0E9 JSR #E9F0 CRL
F
A000 LDY #100
; =66DD LOADBE
B9EE66 LDA MESSAGE/Y
C9EB CMP #1
F0F4 BEQ BATTERY
2005EF JSR #EF05 OUT
D
C8 INY
4C0066 JMP LOADBE

; =66EB MESSAGE
504F LBYT /POWER F
AILURE/

; GET ZERO CONSTANTS

; =66F9 RETURN
A012 LDY #12
; =66F8 LP
68 PLA
990000 STA #$0000,Y
88 DEY
10F3 BPL LP
60 RTS

Figure A.5-6    Register Setup Program Listing    continued
A.6 Input/Store Program

The program that is executed most often by the system is the one that inputs and stores all of the data. This routine occurs each time the angle and distance electronics hardware sends an interrupt signal to the computer. When activated, the input resolver angle sum is divided by the number of samples and the result is temporarily stored for later calculations. The program is also designed to detect resolver failures which would not be averaged out by data reduction.

Figure A.6-1 shows the flowchart while Figure A.6-2 through A.6-5 presents the actual program listing.
Figure A.6-1  Input/Store Program Flowchart
Figure A.6-2  Input/Store Program Listing
DIVISION ROUTINE

==685E DIVIDE
A008 LDY #$08
38 SEC
E964 SBC #64
==6863 DLOOP
08 PHP
2E0045 ROL RESULT
0E0145 ASL LOWBYT
2A ROL A
28 PLP
9005 BCC ADD
E964 SBC #64
4C7563 JMP NEXT
==6873 ADD
6964 ADC #64
==6875 NEXT
88 DEY
D0EB BNE DLOOP
B003 BCS LAST
6954 ADC #64
18 CLC
==687D LAST
2E0045 POL RESULT

; STRAIGHTEN OUT:
800545 STA REMAIN
A0045 LDA RESULT
800145 STA LOWBYT
; ADD 250 ?
E0FE CPX #$FF
D00E BNE SHIFT
==688D
; ADD 250
D8 CLD
28 CLC
A00145 LDA LOWBYT
69FA ADC #FF
8D0145 STA LOWBYT
B002 BCS SHIFT
A260 LDX #100

; NORMALIZE ANSWER
==689B SHIFT
4A LSR A
4A LSR A
4A LSR A
E0FF CPX #$FF
D002 BNE EIGHT
0910 ORA #$10
==6895 EIGHT
8D0345 STA RESHI
A0145 LDA LOWBYT
0A ASL A
0A ASL A
0A ASL A
8D0245 STA RESLOW

; OBTAIN REMAINDER
AD0545 LDA REMAIN
==6895
8D0445 STA HIBYTE
0A ASL A
0A ASL A
0A ASL A
8D0145 STA LOWBYT
AD0445 LDA HIBYTE
4A LSR A
4A LSR A
4A LSR A
==68C5
4A LSR A

; ORIGINAL VALUE NEG?
68 PLA
5CPP BMI NEG
A0FE LDY #$FF

; ADJUST ANSWER
==68ED NEG
AD0245 LDA RESLOW
0D0445 ORA RESULT
8D0245 STA RESLOW

; CHANGE TO 2'S COMP.
C0FF CPY #$FF
F015 BEO POSITIV
4FF EEOR #$FF
8D0245 STA RESLOW
==68FF
AD0245 LDA RESHI
49FF EEOR #$FF
8D0245 STA RESHI
EE0245 INC RESLOW
D08 BNE POITIV
EE0245 INC RESHI

Figure A.6-3 Input/Store Program Listing continued
bc 262-400

==690F
"FETCH DATA POINTER"

==690F POSITV
AC0B45 LDY POINTP

;BIAST(0) OR ANGLE(1)
AD0A45 LDA RTYPF
C0FF CMP #$FF
F052 BEQ ANGLE

;FROM BIAST TO ANGLE
49FF EOR #$FF
8D0A45 STA RTYPF

;INITIAL RUN?
AD0248 LDA RMH
==6921
C900 CMP #$00
D007 BNE BIAS
AD0248 LDA RMH
C900 CMP #$00
F00E BEQ BIAS

;LOAD/SAVE BIAS DATA
==6920 BIAS
AD0245 LDA RESLOW
91F8 STA (BLOC),Y
C8 INY
AD0245 LDA RESHI
91F4 STA (BLOC),Y
88 DEY
AD0240 LDA RMH
==6970
C900 CMP #$00
AD0148 LDA FML
C900 CMP #$00
F00E BEQ ANGL

;ROLL DELAY/BAT STAT
93 TYA
48 PHA
A2A3 LDX #$A3
==693C LXL
A0FF LDY #$FF
==693E LYL
AD0296 LDA FED
5002 BHI 100
40CD69 JMP BATERR
==69A6
93 DEV
D0F5 BNE LYL
CA DEX
D0F0 BNE LXL
68 PLA
A8 TRA

;LOAD/SAVE ROLL DATA
AD009D LDA FAL
91FA STA (ROLL),Y
C8 INY
AD029D LDA FBL
==6957
91FA STA (ROLL),Y
40C669 JMP EXIT

;LOAD/SAVE BIAS DATA
==695C BIASI
AD0045 LDA RESLOW
91F4 STA (BLOC),Y
C8 INY
AD0045 LDA RESHI
91F4 STA (BLOC),Y
88 DEY
40C669 JMP EXIT

;FROM ANGLE TO BIAS
==694B ANGLE
49FF EOR #$FF
8D0A45 STA RTYPF

;INITIAL RUN?

;LOAD/SAVE ANGL DATA

==697E ANGL
AD0245 LDA RESLOW
91FC STA (ALOC),Y
C8 INY
AD0245 LDA RESHI
91FC STA (ALOC),Y
40C9769 JMP COUNT

;LOAD/SAVE ANGL DATA

==6980 ANGL
AD0245 LDA RESLOW
91F6 STA (ALOC),Y
C8 INY
AD0245 LDA RESHI
91F6 STA (ALOC),Y

Figure A.6-4 Input/Store Program Listing continued
; GET ZERO CONSTANTS

==6906 EXIT
A012 LDY #12
==6906 LP
68 PLA
89000 STA #0000,Y
88 DEY
10F9 BPL LP

; PULL Y,X,A FROM STACK
68 PLA
A8 TAY
68 PLA
AA TAX
68 PLA

; RETURN FROM INTERRUPT
40 RTI

; SYSTEM POWER STATUS

==69D5 BATTERY
20F0E9 JSR #69F0 CRL

A000 LDY #00
==69DA LOADE
B9E569 LDA MSGBER,Y
095B CMP #1
F0F4 B6E0 BATTERY
2005EF JSR #EF05 OUT

08 INY
4CDA69 JMP LOADBE

==69E8 MSGBER
554F BYT 'POWER F
AILURE'.
A.7 Data Transfer Program

Each time the coal face is completely cut the Data Transfer Program is executed. If after cutting the coal the system power is still good then the accumulated data is copied to tape. If the system happens to be making an 'initial run' then the generated information is also retained on an EPROM.

Figure A.7-1 shows the flowchart while Figure A.7-2 through A.7-6 presents the actual program listing.
Figure A.7-1 Data Transfer Program Flowchart
PROGRAM CONSTANTS

IDENTIFICATION REG.

==4308

A30

==6829 DUMP
A000  LDY #00
A00143 LDA RML
91F2 STA (IDLOC),Y
C8 INY
A00143 LDA RMH
91F2 STA (IDLOC),Y
C8 INY
A00143 LDA DAY
==583B
91F2 STA (IDLOC),Y

OTHER

CLEAR ERROR COUNTER

==6800 CODE=#4515
==6800 FROMH=#0100
==6800 FROML=#0150
==6800 RRPM=#0800
==6800 RRPM=#0A00
==6800 NUMANG=#4520

TAPE FULL FLAG SET?

FETCH POWER/TRACK

==6800 LDA #00
800645 STA ERR

RECORD ON/TRK SEL

TURN-ON DELAY

204560 JER DELAY1

TAPE POWER STATUS

DISPLAY TRANSFERING

204560 JER DELAY2

TAPE POWER STATUS

FIGURE A.7-2 Data Transfer Program Listing
bc 262-400

; START COMMAND SET
; WRITE-START ON
; WRITE-FILE-MARK ON
; =6661 START
A980 LDA #$80
800295 STA PBC
; WRITE-END ON LOOP
; =6666 WLOOP
A0099 LDA PAC
2901 AND #$01
D0F9 BNE WLOOP
; WRITE-END OFF LOOP
; =6660 WLOOP
A0099 LDA PAC
2901 AND #$01
F0F9 BNE WLOOP
; WRITE-START OFF
; WRITE-FILE-MARK OFF
; DATA ENABLE HIGH
A996 LDA #$96
800295 STA PBC
; STOP/START DELAY
; 72MSEC
A253 LDX #$19
; =667B SIDEL1
A0FF LDY #$FF
; =667D YLOOP1
88 DEY
60FD BNE YLOOP1
CA DEC
60F8 BNE SIDEL1
; DATA ENABLE LOW
; =668A IDLOOP
A0095 LDA PAC
B0FE LDA (LOC),Y
800295 STA PBC
; DATA READY ON LOOP
; =668B ORLOOP
A0095 LDA PAC
2902 AND #$02
F0F9 BNE ORLOOP
; DATA READY ROUTINE
; =668A IDLOOP
B0FE LDA (LOC),Y
800295 STA PBC
; DATA READY ROUTINE
; =668A IDLOOP
B0FE LDA (LOC),Y
205A6D JSR ORLOOP
; INCREMENT LOCATION
C8 INY
; ALL DONE?
C004 CPY #$04
D0F2 BNE IDLOOP
; TRANSFER BIAS DATA
A5F6 LDA BLOC
6FF8 STA $FE
===66CB
A5F5 LDA BLOC+1
6FFFF STA $FF
20696D JSR TRANSF
; TRANSFER ANGLE DATA
A5FC LDA BLOC
6FFFF STA $FE
A5FD LDA BLOC+1
6FFFF STA $FF
20696D JSR TRANSF
; TRANSFER ROLL DATA
A5FA LDA BLOC
6FFFF STA $FE
A0FB LDA BLOC+1
6FFFF STA $FF
20696D JSR TRANSF
; TRANSFER LOW BYTE
C8 INY
B1FE LDA (LOC),Y
800295 STA PAC
; TRANSFER LAST BYTE
C8 INY
B1FE LDA (LOC),Y
800295 STA PAC

Figure A.7-3 Data Transfer Program Listing continued
Figure A.7-4 Data Transfer Program Listing continued
Figure A.7-5 Data Transfer Program Listing continued
bc 262-400

;DELAY SUBROUTINE
; 10 SECONDS

==6045  DELAY1
A915  LDA  #1F
B01745  STA  PLIER
==6045  DELAY1
A2FF  LDX  #FF
==604C  NXXT
==604E  NXXT
==604F  LDY  #FF
==604E  NXXT
88  DEY
D0F8  BNE  NXXT
CA  DEY
D0F8  BNE  NXXT
CE1745  DEC  PLIER
D0F1  BNE  DELA1
60  RTS

;DATA READY OFF LOOP

==6059  DFLOOP
A00095  LDA  PAC
2902  AND  #02
D0F9  BNE  DFLOOP

;DATA READY ON LOOP

==6061  LOOPDFR
A00095  LDA  PAC
2902  AND  #02
F0F9  LOOPDFR
60  RTS

;DATA TRANSFER SUB

==6069  TRANSF
A200  LDX  #00
A000  LDY  #00
==606D  DTLOOP
B1FE  LDA  (LOC),Y
8D0096  STA  PAD

;DATA READY ROUTINE

205A6D  JSR  DFLOOP

;INCREMENT LOCATION

==607E  INCREMENT COUNT
E8  INK

;SET-UP PWRTK REG.

==60AE  PWRTK
A900  LDA  #00
8500  STA  #00
A948  LDA  #48
8501  STA  #01

;IF ALL DONE?

EC2046  CPX  NUMANG
F0F6  BEQ  DONE

;INCREMENT LOCATION

C8  INY

;PAGE DONE?

D0E6  BNE  DTLOOP

;INCREMENT PAGE

E66F  INC  LOC+1
4C606D  JMP  DTLOOP

;INITIAL DATA END

==6097  LIMIT
A200  LDX  #00
A02046  LDA  NUMANG
6H  ASL  A
2001  BCC  LOW
E8  INX

;LOW BATTERY ERROR

==609C  DONE
60  RTS

;BATTERY ERROR

==609D  BATTERY
20F0F9  JSR  #EF0F  CRL
F

;CHECK OUT POWER

A000  LDY  #00
==6092  LOADBE
B9A06D  LDA  MSGBER,Y
C91B  CMP  #7
F0F4  BEQ  BATERR
2005EF  JSR  #EF0F  OUT
D

;DATA READY ROUTINE

C8  INY
4C526D  JMP  LOADBE

;SET-UP PWRTK REG.

==60A0  MSGBER
504F  .BYT  'POWER F
AILURE',

B1FE  LDA  (LOC),Y
8D0096  STA  PAD.

Figure A.7-6 Data Transfer Program Listing continued
A.8 Contour Display Program

After the BASIC routine reduces the coordinate data to a useable form the results are presented to the operator by the Contour Display program. This program is designed to provide the displacement of the track to the nearest one-half foot in either the FACE or GOB direction. Additionally it displays any of the possible system errors which could theoretically occur.

Figure A.8-1 shows the flowchart while Figure A.8-2 through A.8-4 presents the actual program listing.
Figure A.8-1 Contour Display Program Flowchart
Figure A.8-2  Contour Display Program Listing
DIVISION ROUTINE

A003  LDY #08
1B8E  SEC
B90E  SEC #0E
#827E  LOOPDV
081E  PHP
BB148  ROL ANSWER
BE148  ROL LOWMEM
B909E  PHP
B006  SEC ADDITN
4008  IMP NEXT1
1908  ADC #0E
2A90  ADC #0E
2908  ADC #0E
3808  IMP LAST1
2B08  ROL ANSWER
21045  ROL LAST1

DISPLAY DATA

A0145  LDY ANSWER
3B1F  LDA (LOC \y)
2005E  JSR OUTD
A0145  LDA LIPLIER
00245  STA LIPLIER
30245  STA LIPLIER
00245  CMP #3E
30245  CMP #3E
30245  INC LIPLIER
50242  JMP MULTIP
#82E7  DONE
60  RTS

DELAY/ERROR SUB

#82E7  DELERR
60  RTS
AD0140  LDA FUNC
001B2  JSR DELQUE
2005E  JSR ERROR
5008E  JSR DELQUE
5008E  JSR ERROR
5008E  JSR ERROR
50  RTS

START?/DELAY 1/2 S

==82C5  DELQUE
2070D1  JSR START
209882  JSR DDD
2070D1  JSR START
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD
209882  JSR DDD

RESOLVER ANG. ERR ?

==810A ERROR
AD0448  LDA RAQ
F02B  BEQ CASE

DISPLAY RAQ

A000  LDY #00

==8111  LOADAE
B91F83  LDA EM51,y
C90B  CMP #41
F010B  BEQ SUB1A
2005EF  JSR #EF05 OUT
C8  INY
401183  JMP LOADAE

==811F  EM51
5245  BYT (RESOLVE ANGLE ERROR)

==8234  JSR OUTD

JUMP TO SUBROUTINE

==8234 SUB1A
20C582  JSR DELQUE

CLEAR DISPLAY

20F0E9  JSR #E5F0 CRL

CASS SETT E AE ERR ?

==810A CASE
AD0748  LDA CTE
F02B  BEQ FULL

Figure A.8-3 Contour Display Program Listing continued
Figure A.8-4  Contour Display Program Listing  continued
A.9 Starting Point Program

The Starting Point Program enables the coal face measurement system to produce automatic repeatable operations. This program is accessed from the BASIC routine and the Contour Display routine. Whenever the mining machine returns to its' original position this program directs the system to normalize itself for the acquisition of new data.

Figure A.9-1 shows the flowchart while Figure A.9-2 presents the actual program listing.
Figure A.9-1 Starting Point Program Flowchart
**=8170
ZERO POSITION DETECT

**=8170
; PROGRAM CONSTANTS

**=8170 ZFR=#514
**=8170 SCODE=#480D
**=8170 NORMAL=#DB50
**=8170 PCRR=#9E0C
**=8170 IFRR=#9E0D
**=8170 IERR=#9E0E
**=8170 DISTPA=#9F00
**=8170 DISTPB=#9F02

; BACK TO START ?
; ZERO FLAG SET ?
AD1445 LDA ZFR
D013 BNE ZZZ

; NEGATIVE DISTANCE ?
**=8188 ZZZ
AD029F LDA DISTPB
C920 CMP #$20
902E BCC NOPE

; DISABLE NMI
A902 LDA #$02
8D0E9E STA IERR

; SET BASIC STRT CODE
A901 LDA #$01
8D0D48 STA SCODE

; CLEAR SYSTEM
**=8199
; RESTORE SYSTEM
2050DB JSR NORMAL

; RESET DISTANCE
A9EC LDA #$EC
8D0C9E STA PCRR
A9CC LDA #$CC
8D0C9E STA PCRR

; ENABLE NMI
A982 LDA #$82
8D0D9E STA IFRR
**=81AB
8D0E9E STA IERR

; SET DISTANCE

; GREATER THAN 1 FT ?
**=81CE
AD009F LDA DISTPA
C908 CMP #$08
**=8181
903A BCC NOPE

; YES; SET ZERO FLAG
A900 LDA #$00
8D1445 STA ZFR
**=81BD NOPE
60 RTS

Figure A.9-2 Starting Point Program Listing
A.10 Utility Programs

The following are small programs which are used by the measurement system during normal operation:

1) Run Number Program
The Run Number Program enables the EPROM Programmer Program to fetch and save the run number register.

2) Arc-Tangent Program
The Arc-Tangent Program allows the BASIC routine to calculate the ARCSIN (x) function used in its' data reduction section.

3) EPROM Programmer Program
The EPROM Programmer Program enables the system to permanently retain the initial run data and record the latest run number. Thus a battery is not required to back-up the system to retain this information.

4) EPROM Reader Program
The EPROM Reader Program is a dedicated routine to fetch information from the system EPROM.

Listings for these four programs are presented as Figure A.10-1 through A.10-4.
Pure A | 10-1  
Run Number Program Listing

**=8100**
EPROM SETUP FOR RMH
==8100 HCOUNT=#450E
==8100 LCOUNT=#450P
==8100 RMLHIB=#451E
; SETUP FOR DRAM USE

ADD45 LDA HCOUNT
8502 STA #02

A902 LDA #02
8500 STA #00
8503 STA #03

A903 LDA #03
8504 STA #04

A948 LDA #48
==8111
8501 STA #01
8505 STA #05

60 RTS

**=8150**
EPROM SETUP FOR RML
==8150 ; SETUP FOR DRAM USE

ADD45 LDA LCOUNT
8502 STA #02

A901 LDA #01
8500 STA #00

A902 LDA #02
8504 STA #04

A948 LDA #48
8501 STA #01
8505 STA #05

60 RTS

Figure A.10-1  Run Number Program Listing
Figure A.10-2  Arc-Tangent Program Code
Figure A.10-3  EPROM Programmer Program Code
Figure A.10-4  EPROM Reader Program Code
A.11 System Memory Map

The memory usage for the coal face measurement system is presented as Figure A.11-1. It shows the allocation for the 64,000 possible memory addresses. The system programs are found in two groups. The following routines begin at hexadecimal address 5000:

1) BASIC Program
2) Input/Store Program
3) Data Transfer Program

The remaining routines begin at hexadecimal address DO00:

1) Input/Output Setup Program
2) Run Number Program
3) Starting Point Program
4) Display Program
5) Arc-Tangent Program
6) EPROM Programmer Program
7) EPROM Reader Program
8) Register Setup Program

8000 unused address locations provide room for future program expansion.
<table>
<thead>
<tr>
<th>SIZE (BYTES)</th>
<th>ADDRESS (HEX)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>768</td>
<td>0000-02FF</td>
<td>AIM 6500 RAM</td>
</tr>
<tr>
<td>7424</td>
<td>0300-1FFF</td>
<td>BASIC Routine Variables</td>
</tr>
<tr>
<td>4K</td>
<td>2000-2FFF</td>
<td>Available for use</td>
</tr>
<tr>
<td>4K</td>
<td>3000-3FFF</td>
<td>Temporary Data Storage</td>
</tr>
<tr>
<td>4K</td>
<td>4000-4FFF</td>
<td>System Registers</td>
</tr>
<tr>
<td>6144</td>
<td>5000-67FF</td>
<td>BASIC PROGRAM</td>
</tr>
<tr>
<td>1K</td>
<td>6800-6BFF</td>
<td>INPUT/STORE PROGRAM</td>
</tr>
<tr>
<td>1K</td>
<td>6C00-6FFF</td>
<td>DATA TRANSFER PROGRAM</td>
</tr>
<tr>
<td>4K</td>
<td>7000-7FFF</td>
<td>EPROM Programmer</td>
</tr>
<tr>
<td>4K</td>
<td>8000-8FFF</td>
<td>Available for use</td>
</tr>
<tr>
<td>4K</td>
<td>9000-9FFF</td>
<td>Input/Output Ports</td>
</tr>
<tr>
<td>4K</td>
<td>A000-AFFF</td>
<td>AIM 6500 Peripherals</td>
</tr>
<tr>
<td>8K</td>
<td>B000-CFFF</td>
<td>AIM 6500 BASIC</td>
</tr>
<tr>
<td>256</td>
<td>D000-D0FF</td>
<td>INPUT/OUTPUT SETUP PROGRAM</td>
</tr>
<tr>
<td>112</td>
<td>D100-D16F</td>
<td>RUN NUMBER PROGRAMS</td>
</tr>
<tr>
<td>144</td>
<td>D170-D1FF</td>
<td>STARTING POINT PROGRAM</td>
</tr>
<tr>
<td>1K</td>
<td>D200-D5FF</td>
<td>DISPLAY PROGRAM</td>
</tr>
<tr>
<td>512</td>
<td>D600-D7FF</td>
<td>ARC-TANGENT PROGRAM</td>
</tr>
<tr>
<td>512</td>
<td>D800-D9FF</td>
<td>EPROM PROGRAMMER PROGRAM</td>
</tr>
<tr>
<td>336</td>
<td>DA00-DB4F</td>
<td>EPROM READER PROGRAM</td>
</tr>
<tr>
<td>1200</td>
<td>DB50-DFFF</td>
<td>REGISTER SETUP PROGRAM</td>
</tr>
<tr>
<td>8K</td>
<td>E000-FFFF</td>
<td>AIM 6500 Monitor</td>
</tr>
</tbody>
</table>

Figure A.11-1 System Memory Map