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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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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 Kiekhoff 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 0.01 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 1.2 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
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.

![Diagram of track angle measurement technique]

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 useable 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

START

INITIALIZE

INPUT
BIAS, ANGLE, ROLL
SAMPLES

RECORD DATA
ON TAPE

CALCULATE
COAL FACE
PROFILE

DISPLAY
PROFILE
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.
Figure 3.3  Bias and Track Angle Measurement Technique
Figure 3.3.1  Data Acquisition Sequence

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 Raymond 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:

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

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:

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

\[ A_{\text{i}} \text{ (i)} \] - corrected angle value
\[ A_{\text{i}} \text{ pres} \] - present angle value
\[ A_{\text{i}} \text{ init} \] - initial run angle value
\[ A_{\text{i}} \text{ man} \] - 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:

\[
A_{\text{i}} (I) = \sum_{j=1}^{I} \sum_{i=1}^{j} (A_{\text{i}} (i) - B)
\]

where:

\[ A_{\text{i}} (I) \] - referenced angle value
\[ A_{\text{i}} (i) \] - corrected angle value
\[ B \] - average bias value

Figure 3.5.1 clearly shows the summation process.

Figure 3.5.1  Graphic Summation of Measurement Angles
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. \( Y(\emptyset) \) equals zero. \( Y(1) \) equals zero because the initial angle is assumed zero.

Figure 3.5.2 Uncorrected Y Coordinate Graph
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.

The initial angle would be derived most accurately by using:

$$\theta_i \ (\text{actual}) = \arctan \ (Y \text{ last}/X1)$$

where:

- $\theta_i \ (\text{actual})$ - accurate initial angle value
- $Y \text{ last}$ - last uncorrected Y coordinate value
- $X1$ - accurate X distance
A very close approximation to this would be:

$$\theta_i \text{ (practical)} = \arcsin \left( \frac{Y_{\text{last}}}{L \times N} \right)$$

where:

- $\theta_i \text{ (practical)}$ - practical initial angle value
- $Y_{\text{last}}$ - last uncorrected coordinate value
- $L$ - length of rack section
- $N$ - 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:

- $R$ - initial value
- $Y(\emptyset)$ - $Y$ value for rack zero
- $Y(N)$ - $Y$ value for last rack
- $L$ - length of rack section
- $N$ - 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

![Diagram showing corrected Y coordinate graph](image)

**Figure 3.5.4 Corrected Y Coordinate Graph**

### 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.

```
Ø 1 1 2 2 3 2 1 Ø - - - - - Ø FACE
Ø - - - - - - - Ø 1 2 3 2 1 Ø GOB
```

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

<table>
<thead>
<tr>
<th>ACTION</th>
<th>RESULT</th>
</tr>
</thead>
</table>

### II. POSSIBLE FUNCTIONS


### III. SELECT FUNCTION

<table>
<thead>
<tr>
<th>A. Release FUNCTION Button when desired function is displayed.</th>
<th>Displays &quot;DISPLACEMENT OF RACK&quot; or Displays &quot;PRESENT ROLL&quot; or Displays &quot;ROLL OF RACK SECTION&quot; or Displays &quot;PRESEN'T DISTANCE&quot; or Displays &quot;EXIT FROM ROUTINE&quot;.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Push and Hold ENTER Button</td>
<td>Displays answer or requests information.</td>
</tr>
<tr>
<td>C. Release ENTER Button</td>
<td></td>
</tr>
</tbody>
</table>

**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>
</tr>
</thead>
<tbody>
<tr>
<td>To be performed after selection</td>
</tr>
<tr>
<td>A. Momentarily Push STEP Button</td>
</tr>
<tr>
<td>B. Push and Hold STEP Button</td>
</tr>
<tr>
<td>C. Release STEP Button</td>
</tr>
<tr>
<td>D. Push and Hold LEFT/RIGHT switch to either side</td>
</tr>
<tr>
<td>E. Release LEFT/RIGHT Switch</td>
</tr>
<tr>
<td>F. Push and Hold ENTER Button</td>
</tr>
<tr>
<td>G. Release ENTER Button</td>
</tr>
<tr>
<td>H. Push and Hold UP/DOWN switch to either side</td>
</tr>
<tr>
<td>I. Release UP/DOWN switch</td>
</tr>
<tr>
<td>J. Push and Hold FUNCTION Button</td>
</tr>
<tr>
<td>K. Release FUNCTION Button</td>
</tr>
<tr>
<td>L. Push EXIT Button</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displays &quot;PUSH STEP FOR RACK #&quot;</td>
</tr>
<tr>
<td>Displays &quot;USE LEFT/RIGHT SW.&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td>Displays &quot;TO SELECT DIGIT&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td>Displays &quot;PUSH ENTER WHEN OK&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td>Turns on Light Emitting Diode over 100's digit.</td>
</tr>
<tr>
<td>Displays numbers which increment every second.</td>
</tr>
<tr>
<td>No longer increments numbers.</td>
</tr>
<tr>
<td>Turns on Light Emitting Diode over successive digits.</td>
</tr>
<tr>
<td>Light Emitting Diode designates digit which may be incremented.</td>
</tr>
<tr>
<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>Displays &quot;TO CHANGE RACK NUMBER&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td>Displays &quot;PUSH EXIT TO EXIT&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td>Displays &quot;6 FUNCTION TO RETURN&quot;, Delays 4 sec.</td>
</tr>
<tr>
<td>Displays answer.</td>
</tr>
<tr>
<td>Increments or decrements rack section number.</td>
</tr>
<tr>
<td>Displays answer for appropriate rack section.</td>
</tr>
<tr>
<td>Returns to allow new function selection.</td>
</tr>
<tr>
<td>Selects function.</td>
</tr>
<tr>
<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)

ACTION
(To be performed after selection)
A. Push and Hold FUNCTION Button
B. Release FUNCTION Button
C. Push EXIT Button

RESULT
Displays "PUSH EXIT TO EXIT", Delays 4 sec.
Displays "& FUNCTION TO RETURN", Delays 4 sec.
Displays answer.
Returns to allow new function selection.
Selects function.
Exits from routine and displays previous
general curvature.

VI. FUNCTION 5 (EXIT FROM ROUTINE)
(To be performed after selection)
A. Push EXIT Button

VII. RESULTS
FUNCTION 1 (Previous Displacement of any rack)
FUNCTION 2 (Present Roll)
FUNCTION 3 (Previous roll of any rack)
FUNCTION 4 (Present Distance)

DISPLAY
RACK_XXX_F_X.XX_FEET
RACK_XXX_G_X.XX_FEET
ROLL_F_XX.X_DEGREES
ROLL_G_XX.X_DEGREES
RACK_XXX_F_XX.X_DEG
RACK_XXX_G_XX.X_DEG
LOCATION_XXX.X_FEET

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.
Figure 4.1  Test Facility
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.
Figure 4.2.1 Face Bow Track Contour

Track Geometry - Feet

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24
Figure 4.2.2  GOB Bow Track Contour
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 "brains" and two I/O boards allow the "heart and brains" 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
<table>
<thead>
<tr>
<th>PROGRAMS</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>INPUT/OUTPUT SETUP</td>
<td>4K EPROM</td>
</tr>
<tr>
<td>RUN NUMBER</td>
<td></td>
</tr>
<tr>
<td>STARTING POINT</td>
<td></td>
</tr>
<tr>
<td>CONTOUR DISPLAY</td>
<td></td>
</tr>
<tr>
<td>ARC-TANGENT</td>
<td></td>
</tr>
<tr>
<td>EPROM PROGRAMMER</td>
<td></td>
</tr>
<tr>
<td>EPROM READER</td>
<td></td>
</tr>
<tr>
<td>REGISTER SETUP</td>
<td></td>
</tr>
<tr>
<td>BASIC</td>
<td>4K EPROM</td>
</tr>
<tr>
<td>INPUT/STORE</td>
<td>2K EPROM</td>
</tr>
<tr>
<td>DATA TRANSFER</td>
<td></td>
</tr>
</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.4-1  BASIC Program Flowchart
Figure A.4-2  BASIC Program Listing
Figure A.4-3 BASIC Program Listing continued
1440 POKE 188.61: POKE 189.214: Y = (Y1-Y2/K2) * K-Y
1450 V = Y/(M1+1); R = A
1460 D(1) = K*SIN(R)
1470 FOR N = 1 TO M1 + 1
1475 D(N) = D(N-1) + K*SIN(C(N)+R) + D(N)
1480 NEXT
1490 FOR N = 1 TO M1 + 1
1500 E(N) = D(N); IF D(N) THEN GOSUB 1560
1510 IF D(N) = 0 THEN 1515
1520 C(N) = INT(-D(N)) * K2 + K3 + 48; IF C(N) = 48 THEN 1560
1530 D(N) = 45: GOTO 1510
1540 END
1600 PRINT "PUSH FUNCTION BUTTON" "TO BEGIN": GOSUB 1180
1610 PRINT "PRINT" "TO ENTER" "END-POINT LOCATION" "PRINT STEP TO ENTER": GOSUB 1180
1620 PRINT "PRINT" "TO BEGIN" GOSUB 1160
1630 IF X76 THEN 1640
1640 T = 0; R = 0
1650 PRINT "PUSH FUNCTION BUTTON": GOSUB 1180
1660 PRINT "PRINT" "TO ENTER" "END-POINT LOCATION" "PRINT STEP TO ENTER": GOSUB 1180
1670 IF X76 THEN 1700 IFPEEK(37633) = 25 THEN 1730
1680 PRINT "PRINT" "TO BEGIN" GOSUB 1160
1690 PRINT "PRINT" "TO ENTER" "END-POINT LOCATION" "PRINT STEP TO ENTER": GOSUB 1180
1700 IFPEEK(37633) = 25 THEN 1730
1710 IF = 50 THEN 1730
1720 T = T+1; GOTO 1690
1730 PRINT "PRINT" "TO BEGIN" GOSUB 1160
1740 PRINT "PRINT" "TO ENTER" "END-POINT LOCATION" "PRINT STEP TO ENTER": GOSUB 1180
1750 IFPEEK(37633) = 25 THEN 1730
1760 IF = 50 THEN 1730
1770 T = T+1; GOTO 1690
1780 PRINT "PRINT" "TO BEGIN" GOSUB 1160
1790 PRINT "PRINT" "TO ENTER" "END-POINT LOCATION" "PRINT STEP TO ENTER": GOSUB 1180
1800 PRINT "PRINT" "TO BEGIN" GOSUB 1160
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.
Figure A.5-1 Register Setup Program Flowchart
NORMALIZE ROUTINE

;SAVE ZERO CONSTANT
A0FF LDY #$FF
==6402 L
C8 INY
B9000 LDA $0000,Y
48 PHA
C012 CPY #$12
D0F7 BNE L

;CLEAR DISPLAY
20F0E9 JSR #$E9F0 CRL F

;NORMALIZING
A000 LDY #$00
==6410 LOADNO
B91E64 LDA $MSGNOR,Y
C938 CMP #$'
F012 BEQ ALT
2005E9 JSR #$EF05 OUT D
C8 INY
4C1064 JMP LOADNO

==641E MSGNOR
4E4F BYT 'NORMALIZING'

;ALTER NMI VECTORS

==642A ALT
A900 LDA #$00
8D02A4 STA #$A02
A968 LDA #$68
8D02A4 STA #$A03

;SYSTEM POWER STATUS

==6430 ALT
A900 LDA #$00
8D0296 STA PBD
3003 BMI AAA
4CD866 JMP BATERR

;TURN OFF DELAY
209566 JSR DELAY

;CASSette LOaDed?
AD0095 LDA PAC
0A ASL A
1028 BPL CCC

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

;TAPE POWER STATUS

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

;TURN RECORDER OFF

==647A DDD
A900 LDA #$00
8D0296 STA PBD

;TURN-OFF DELAY
209566 JSR DELAY

Figure A.5-2 Register Setup Program Listing
bc 262-400

; ZERO-PAGE CONSTANTS
A300 LDA #00 ID
85F2 STA #F2
A946 LDA #46
85F3 STA #F3

; =643B R
A900 LDA #00 BI
85F4 STA #F4
A932 LDA #32
85F5 STA #F5
A900 LDA #00 AI
85F6 STA #F6
A936 LDA #36
85F7 STA #F7

; =6449 A
A900 LDA #00 BP
85F8 STA #F8
A950 LDA #50
85F9 STA #F9
A900 LDA #00 ROLL
85FA STA #FA
A940 LDA #40
85FB STA #FB

; =6459 A
A900 LDA #00 AP
85FC STA #FC
A934 LDA #34
85FD STA #FD

; TEMP. RAM CONSTANTS
A934 LDA #84 AIPR
8D0745 STA #4507
A980 LDA #80
8D04A5 STA #450A RTY

; =64BC
8D04B5 STA #450B PNT
A921 LDA #21
8584 STA $04
A946 LDA #46
8505 STA $05
A8045 STA #450D DRF

8D1445 STA #4514 ZFR

; MANUAL DATA START
A900 LDA #00
8500 STA #00
==64CE
8D0A48 STA #480A TFR
A938 LDA #38
8501 STA #01
8D0945 STA LOCA+1

; MANUAL DATA END
20BF66 JSR LIMIT

; MANUAL DATA EPROM
A91E LDA #1E
8502 STA #02
==6521
A902 LDA #02
8503 STA #03
2000DA JSR RPROM

; INITIAL KEY TURNED?
AD0193 LDA FUNC
C97F CMP #7F
F003 BEQ YES
4C0166 JMP RUN

; =6532
; TURN RECORDER ON
==6532 YES
A908 LDA #08
8D0296 STA PBD

; TURN-ON DELAY
20A866 JSR DEL4

; TAPE TO LOAD POINT
; LOAD COMMAND READY
A977 LDA #77
8D0295 STA PBC

; INTERMEDIATE DELAY
209566 JSR DELAY

Figure A.5-3 Register Setup Program Listing continued
Figure A.5-4  Register Setup Program Listing  continued
Figure A.5-5  Register Setup Program Listing  continued
; DATA END POINT
==66BF LIMIT
A200 LDX #00
A02046 LDA NUMANG
0A ASL A
2001 EEC LOW
E8 INX
==66C8 LOW
D8 CLD
18 CLC
600345 ADC LOCA
8504 STA #04
8A TIA
D8 CLD
18 CLC
600945 ADC LOCA-1
8505 STA #05
60 RTS
==66D8
; BATTERY ERROR
==66D8 BATERR
20F0E9 JSR #E9F0 CRL
F
A000 LDY #00
==66DD LOADBE
B9EB66 LDA MSBERRY
C9EB CMP #0
F0F4 BEQ BATERR
2005EF JSR #EF05 OUT
D
C8 INY
4C0066 JMP LOADBE
==66EB MSBEBER
504F BPL #POWER F
AILURE;

; GET ZERO CONSTANTS
==66F9 RETURN
A012 LDY #12
==66F9 LP
68 PLA
990000 STA #0000,Y
88 DEY
10F3 BPL LP
60 RTS
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
<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bc 262-400</td>
<td>INPUT/STORE ROUTINE</td>
</tr>
<tr>
<td><strong>00F4</strong></td>
<td><strong>INPUT/STORE ROUTINE</strong></td>
</tr>
<tr>
<td><strong>00F4 ELOC1</strong></td>
<td><strong>INPUT/STORE ROUTINE</strong></td>
</tr>
<tr>
<td><strong>00F6 ELOC1</strong></td>
<td><strong>INPUT/STORE ROUTINE</strong></td>
</tr>
<tr>
<td><strong>00F8 ELOC1</strong></td>
<td><strong>INPUT/STORE ROUTINE</strong></td>
</tr>
<tr>
<td><strong>03FA ELOC1</strong></td>
<td><strong>INPUT/STORE ROUTINE</strong></td>
</tr>
<tr>
<td><strong>00FC ELOC1</strong></td>
<td><strong>INPUT/STORE ROUTINE</strong></td>
</tr>
<tr>
<td>TEMP. RAM REGISTERS</td>
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</tr>
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<td><strong>00FE</strong></td>
<td><strong>INPUT/STORE ROUTINE</strong></td>
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<td><strong>4500</strong></td>
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<tr>
<td><strong>450A</strong></td>
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<tr>
<td><strong>450B</strong></td>
<td><strong>INPUT/STORE ROUTINE</strong></td>
</tr>
<tr>
<td><strong>450C</strong></td>
<td><strong>INPUT/STORE ROUTINE</strong></td>
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<tr>
<td><strong>450D</strong></td>
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<tr>
<td><strong>4801</strong></td>
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<td><strong>4802</strong></td>
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<td><strong>4804</strong></td>
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</tr>
<tr>
<td><strong>4805</strong></td>
<td><strong>INPUT/STORE ROUTINE</strong></td>
</tr>
<tr>
<td><strong>4800 FBD=</strong></td>
<td><strong>INPUT/STORE ROUTINE</strong></td>
</tr>
</tbody>
</table>

**Figure A.6-2** Input/Store Program Listing
bc 262-400

; LOAD/SAVE ROLL DATA
LDA RAL
STA (BLOC), Y
INY
LDA RBL
STA (BLOC), Y
JMP EXIT

; STORE COUNTER
STX COUNTR

; STORE POINTER
STY POINTR

; INITIAL RUN?

; LOAD/SAVE ROLL DATA
LDA RAL
STA (BLOC), Y
INY
LDA RBL
STA (BLOC), Y
JMP EXIT

; LOAD/SAVE ANGL DATA

; INITIAL RUN?

; INITIAL RUN?

; LOAD/SAVE ANGL DATA

; INITIAL RUN?

; LOAD/SAVE ANGL DATA

; INITIAL RUN?

; LOAD/SAVE ANGL DATA

; INITIAL RUN?

; LOAD/SAVE ANGL DATA

; INITIAL RUN?

; LOAD/SAVE ANGL DATA

; INITIAL RUN?

; LOAD/SAVE ANGL DATA

; INITIAL RUN?

; LOAD/SAVE ANGL DATA

; INITIAL RUN?

; LOAD/SAVE ANGL DATA

; INITIAL RUN?

; LOAD/SAVE ANGL DATA

; INITIAL RUN?
GET ZERO CONSTANTS

==6006 EXIT
A012 LDY #12
==6906 LP
68 PLA
990000 STA #0000,Y
88 DEY
10FF 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 BATERR
20F0E9 JSR #E9F0 CRL
A000 LDY #00
==69DA LOADBE
B9E669 LDA MSBERR,Y
095B CMP #1
F0F4 BNE BATERR
2000EF JSR #EF00 OUT
D
08 INC
4CDA69 JMP LOADBE

==69E8 MSBERR
554F STY POWER FAIL

Figure A.6-5 Input/Store Program Listing continued
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
**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 WELoop
A00095 LDA PBC
2901  AND #01
D0F9  BNE WELoop

:WRITE-END-OFF-LOOP

==666D WELoop
A00095 LDA PBC
2901  AND #01
F0F9  BNE WELoop

:WRITE-START-OFF
:WRITE-FILE-MARK-OFF
:DATA ENABLE HIGH

A936  LDA #96
800295 STA PBC

;STOP/START DELAY
;72MSEC

A223  LDY #19
==887B SIDEL1
A0FF  LDY #FF
==888D YLOOP1
88  DEY
D0FD  BNE YLOOP1
CA  DEM
D0F6  BNE SIDEL1

;DATA ENABLE LOW

;DATA READY ON LOOP

==66B3 DRLOOP
A00095 LDA PBC
2902  AND #02
F0F9  BNE DRLOOP

;DATA READY ROUTINE

==66BA IDLOOP
B1FE  LDA (LOC),Y
8D0096 STA PBC

;DATA READY ROUTINE

205A6D JSR DRLOOP

A0086  LDA #84
8D0295 STA PBC

;DATA ERROR 1

A00095 LDA PBC
2904  IND #04
==6680 S0.8 BNE CLEAR
A00645 LDA ERR
C904  CPE #04
B006  BCS JUMP
EE0645 INC ERR
4C616B JMP STRT

;CASSETTE TAPE ERROR

==669C JUMP
4C726C JMP ERROR

;CLEAR ERROR COUNTER

==669F CLEAR
A980  LDA #80
800045 STA ERR

;JUMP PORTION
;TRANSFER ID REG.

A5F2  LDA IDLOC
85FE  STA #FE
A5FF  STA #FF
A000  LDY #00

;TRANSFER ROLL DATA

==66B0 ;SET-UP ROLL TRANSFER
CE2046 DEC NUMANG

A5FE  LDA RLOC
85FE  STA #FE
A5FF  STA #FF
20696D JSR TRANSF

;TRANSFER LOW BYTE

==66B3 LDA (LOC),Y
B1FE  LDA PBC
8D0295 STA PBC

;DATA READY ROUTINE

C8  INY
B1FE  LDA (LOC),Y
205A6D JSR DRLOOP

;TRANSFER LAST BYTE

;DATA READY ROUTINE

C8  INY
B1FE  LDA (LOC),Y
8D0096 STA PBC
Figure A.7-4  Data Transfer Program Listing  continued
bc 262-400

; PUT CODE ON EPROM
A915 LDA #15
8500 STA #00
==6CA1
A945 LDA #45
8501 STA #01
A917 LDA #17
8502 STA #02
A902 LDA #02
8503 STA #03
A916 LDA #16
8504 STA #04
==6CB1
A945 LDA #45
8505 STA #05
2000D8 JSR FFROM
; PUT RML ON EPROM
==6CB8 LOWER
2050D1 JSR FRML
2000D8 JSR FFROM
; TURN-OFF DELAY
==6CBE OFF
20106D JSR DELAY
; STABILIZE RECORDER
A957 LDA #57
800295 STA PBC
; TURN-OFF DELAY
20106D JSR DELAY
; TURN RECORDER OFF
A900 LDA #00
800296 STA PBO
==6CCE
; RUN #1 ?
A00248 LDA RMH
C090 CMP #90
D047 BNE DRFLAG
A0D148 LDA RML
C091 CMP #91
D048 BNE DRFLAG
A5F4 LDA BLOCK1
8500 STA #00
8D0845 STA LOCA
A5F5 LDA BLOCK1+1
8501 STA #01
8D0945 STA LOCA+1
A5F0 LDA #00
8502 STA #02
A00745 LDA AIPROM
8503 STA #03
200760 JSR LIMIT
A900 LDA #00
==6CEF
8502 STA #02
A00745 LDA AIPROM
8503 STA #03
; BIAS-INITIAL START
A5F6 LDA ALOCI
8500 STA #00
8D0845 STA LOCA
==6D00
A5F7 LDA ALOCI+1
8501 STA #01
8D0945 STA LOCA+1
A5F6 LDA ALOCI
8500 STA #00
8D0845 STA LOCA
==6D00
A5F7 LDA ALOCI+1
8501 STA #01
8D0945 STA LOCA+1
; BIAS-INITIAL END
A900 LDA #00
==6D1E
8D0845 STA LOCA
EE0745 INC AIPROM
==6D1F
EE0745 INC AIPROM
A00745 LDA AIPROM
8503 STA #03
; GO PROGRAM FROM
40 RTI
; JDATA REDUCTION SET
==6D1C OPFLAG
A9FF LDA #FF
800045 STA OPF
; EXIT FROM ROUTINE
A012 LDY #12
==6D23 LP
68 PLA
990000 STA #0000.Y
88 DEY
10F9 BPL LF
; FULL Y, X, A FR STACK
68 PLA
A8 TAY
68 PLA
AA TXA
68 PLA
; RETURN FROM INTERRUPT
; JDELAY SUBROUTINE
; 1 SECOND
==6D20 DELAY
A901 LDA #01
8D0745 STA PLIER
==6D25 DELAY
A9FF LDX #FF
==6D17 NXY
A9FF LDY #FF
==6D19 NXY
88 DEY
D0FD BNE NXY
CD DEX
D0F5 BNE NXY
CE1745 DEC PLIER
D0F1 BNE DELA
60 RTS

Figure A.7-5  Data Transfer Program Listing  continued
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 #$00
A005 SEC
A00E SBC #$0E
A01E BPL LOOPDV
A028 PHP
A02E BNE 1145
A034 BPL ANSWER
A03E BNE ADDITN
A040 BNE NEXT1
A04E BNE ADDITN
A050 LBY
A058 BPL EOL
A05E BNE LOOPDV
A068 BNE LAST1
A06E BNE LAST1
A070 ROL ANSWER

DISPLAY DATA

A1045 LDY ANSWER
A108 DEY
A11E LDA (LOC),Y
A21E JSR OUTD
A25E LDA PLIER
A2DE STA PLIER
A30E LDA PLIER
A36E CMP #$0E
A37E BNE DONE
A3E6 INC PLIER
A3EE INC PLIER
A402 JMP MULTIP
A427 DONE
A435 RTS

DELAY/ERROR SUB

A42E DELREP
A432 JSR DELQUE
A438 JSR ERROR
A444 JSR DELQUE
A450 JSR ERROR
A456 RTS

START?/DELAY 1/2 S

A528 DELQUE
A538 JSR START
A53E JSR DDD
A54E JSR START
A550 JSR DDD

RESOLVER ANGL ERR?

A62A ERROR
A638 LDA RAE
A648 BEQ CASE

DISPLAY RAE

A600 LDY #$00

A711 LOADAE
A718 LDA EM51,Y
A71E CMP #$00
A728 BNE SUB1A
A735 JSR #EF05 OUT
A73D LDA SUB1A
A743 LS183 JMP LOADAE

A83F EM51
A845 BYT (RESOLVE R ANGLE ERROR)

A934 JSR DDD

A93A CASE
A948 LDA CTE
A958 BEQ FULL

Figure A.8-3 Contour Display Program Listing continued
DISPLAY CASEERR

A000  LDY $00

==8341  LOADCE
B4FA  LDA EM5G2,Y
00EB  CMP #1
F01C  BEO SUB1B
2005EF  JSR #EF05 OUT
D
C8  INY
404183  JMP LOADCE

==8394  JUMP TO SUBROUTINE

==8194  SUB1C
4541  BYT CASSSET
E TAPE ERROR

==8364  JUMP TO SUBROUTINE

==8164  SUB1B
200582  JSR DELQUE

CLEAR DISPLAY

20F0E9  JSR #E9F0 CRL
F

TAPE FULL CONDITION

==836A  FULL
A00483  LDA TFR
F028  BEO OUT

DISPLAY FULERR

A000  LDY $00

==8171  LOADTF
B4FA  LDA EM5G3,Y
00EB  CMP #1
F01C  BEO SUB1C
2005EF  JSR #EF05 OUT
D
C8  INY
407183  JMP LOADTF

==837F  EM5G3
5441  BYT (TAPE FU
LL-EXCHANGE )

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
**STARTING POINT PROGRAM LISTING**

**PROGRAM CONSTANTS**

```
ZERO POSITION DETECT

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

;DISABLE NMI

;SET BASIC STRT CODE

;RESET DISTANCE

;BACK TO START ?
;ZERO FLAG SET ?

AD1445 LDA ZFR
D013 BNE ZZZ

;ENABLE NMI

;POSITIVE DISTANCE ?

AD029F LDA DISTPB
C920 CMP #"20
B041 BCS NOPE

;GREATER THAN 1 FT ?

A9CE LDA #"CE
AD099F LDA DISTPA
C908 CMP #"08
==8181
903A BCC NOPE

;RESET ZERO FLAG

;YES; SET ZERO FLAG

AD01 LDA #"01
8D1445 STA ZFR

A900 LDA #"00
8D1445 STA ZFR

==81BD NOPE
60 RTS
```
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.
**=8100
EPROM SETUP FOR RMH
**=8100 HCOUNT=#450E
**=8100 LCOUNT=#450F
**=8100 RMLHIB=#4516
SETUP FOR DRAM USE
A00E45 LDA HCOUNT
8502 STA #02
A902 LDA #02
8500 STA #00
8503 STA #03
A903 LDA #02
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
A0DF45 LDA LCOUNT
8502 STA #02
A01645 LDA RMLHIB
8503 STA #03
A901 LDA #01
8500 STA #00
A902 LDA #02
**=8160
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

<table>
<thead>
<tr>
<th>Memory Address</th>
<th>Hexadecimal Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2F80</td>
<td>0B 76 B3 83</td>
<td></td>
</tr>
<tr>
<td>2F84</td>
<td>6D D3 79 1E</td>
<td></td>
</tr>
<tr>
<td>2F88</td>
<td>F4 A6 F5 7B</td>
<td></td>
</tr>
<tr>
<td>2F8C</td>
<td>63 FC B0 10</td>
<td></td>
</tr>
<tr>
<td>2F90</td>
<td>7C 0C 1F 67</td>
<td></td>
</tr>
<tr>
<td>2F94</td>
<td>CA 7C CE 53</td>
<td></td>
</tr>
<tr>
<td>2F98</td>
<td>CB C1 7D 14</td>
<td></td>
</tr>
<tr>
<td>2F9C</td>
<td>64 7E 4C 7D</td>
<td></td>
</tr>
<tr>
<td>2FA0</td>
<td>57 EA 51 7A</td>
<td></td>
</tr>
<tr>
<td>2FA4</td>
<td>7D 63 30 88</td>
<td></td>
</tr>
<tr>
<td>2FA8</td>
<td>7E 92 44</td>
<td></td>
</tr>
<tr>
<td>2FAC</td>
<td>99 3A 7E 4C</td>
<td></td>
</tr>
<tr>
<td>2FB0</td>
<td>CC 91 C7 7F</td>
<td></td>
</tr>
<tr>
<td>2FB4</td>
<td>AA AA AA 13</td>
<td></td>
</tr>
<tr>
<td>2FB8</td>
<td>81 00 00 00</td>
<td></td>
</tr>
<tr>
<td>2FBC</td>
<td>00</td>
<td></td>
</tr>
<tr>
<td>2FBF</td>
<td>48 PHA</td>
<td></td>
</tr>
<tr>
<td>2FC0</td>
<td>10 BPL 2FC5</td>
<td></td>
</tr>
<tr>
<td>2FC2</td>
<td>20 JSR CCB8</td>
<td></td>
</tr>
<tr>
<td>2FC4</td>
<td>15 LDA A9</td>
<td></td>
</tr>
<tr>
<td>2FC7</td>
<td>48 PHA</td>
<td></td>
</tr>
<tr>
<td>2FC8</td>
<td>C9 C7 #81</td>
<td></td>
</tr>
<tr>
<td>2FC9</td>
<td>91 04 2FD3</td>
<td></td>
</tr>
<tr>
<td>2FCF</td>
<td>F7 4 #FB</td>
<td></td>
</tr>
<tr>
<td>2FEC</td>
<td>47 4C C6</td>
<td></td>
</tr>
<tr>
<td>2FDD</td>
<td>64 0 C84E</td>
<td></td>
</tr>
<tr>
<td>2FDE</td>
<td>A9 LDA #80</td>
<td></td>
</tr>
<tr>
<td>2FDF</td>
<td>A0 LDY #2F</td>
<td></td>
</tr>
<tr>
<td>2FE0</td>
<td>CD44</td>
<td></td>
</tr>
<tr>
<td>2FE1</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>2FE2</td>
<td>90 BCC 2FE6</td>
<td></td>
</tr>
<tr>
<td>2FE3</td>
<td>A9 LDA #4E</td>
<td></td>
</tr>
<tr>
<td>2FE4</td>
<td>R0 LDY #CE</td>
<td></td>
</tr>
<tr>
<td>2FE5</td>
<td>20 JSR C58F</td>
<td></td>
</tr>
<tr>
<td>2FE6</td>
<td>68 PLA</td>
<td></td>
</tr>
<tr>
<td>2FE7</td>
<td>10 BPL 2FEC</td>
<td></td>
</tr>
<tr>
<td>2FE8</td>
<td>4C JMP CCB8</td>
<td></td>
</tr>
<tr>
<td>2FE9</td>
<td>60 RTS</td>
<td></td>
</tr>
<tr>
<td>2FEC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;M&gt; = D800</td>
<td>A0</td>
<td>20</td>
</tr>
<tr>
<td>D804</td>
<td>A9</td>
<td>CC</td>
</tr>
<tr>
<td>D808</td>
<td>A0</td>
<td>02</td>
</tr>
<tr>
<td>D80C</td>
<td>A9</td>
<td>EC</td>
</tr>
<tr>
<td>D810</td>
<td>8F</td>
<td>EC</td>
</tr>
<tr>
<td>D814</td>
<td>A0</td>
<td>03</td>
</tr>
<tr>
<td>D818</td>
<td>D9</td>
<td>99</td>
</tr>
<tr>
<td>D81C</td>
<td>88</td>
<td>10</td>
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<tr>
<td>D820</td>
<td>00</td>
<td>48</td>
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<td>13</td>
<td>AD</td>
</tr>
<tr>
<td>D828</td>
<td>C9</td>
<td>88</td>
</tr>
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<td>D82C</td>
<td>A2</td>
<td>0F</td>
</tr>
<tr>
<td>D830</td>
<td>F0</td>
<td>07</td>
</tr>
<tr>
<td>D834</td>
<td>D0</td>
<td>01</td>
</tr>
<tr>
<td>D838</td>
<td>8E</td>
<td>86</td>
</tr>
<tr>
<td>D83C</td>
<td>D9</td>
<td>85</td>
</tr>
<tr>
<td>D840</td>
<td>03</td>
<td>B1</td>
</tr>
<tr>
<td>D844</td>
<td>0A</td>
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<td>F8</td>
<td>A0</td>
</tr>
<tr>
<td>D84C</td>
<td>1F</td>
<td>91</td>
</tr>
<tr>
<td>D850</td>
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<td>C8</td>
</tr>
<tr>
<td>D854</td>
<td>A0</td>
<td>0E</td>
</tr>
<tr>
<td>D858</td>
<td>81</td>
<td>06</td>
</tr>
<tr>
<td>D85C</td>
<td>A0</td>
<td>0D</td>
</tr>
<tr>
<td>D860</td>
<td>91</td>
<td>06</td>
</tr>
<tr>
<td>D864</td>
<td>A0</td>
<td>0E</td>
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<tr>
<td>D868</td>
<td>81</td>
<td>06</td>
</tr>
<tr>
<td>D86C</td>
<td>A0</td>
<td>0C</td>
</tr>
<tr>
<td>D870</td>
<td>91</td>
<td>06</td>
</tr>
<tr>
<td>D874</td>
<td>91</td>
<td>08</td>
</tr>
<tr>
<td>D878</td>
<td>A0</td>
<td>02</td>
</tr>
<tr>
<td>D87C</td>
<td>A0</td>
<td>03</td>
</tr>
<tr>
<td>D880</td>
<td>81</td>
<td>08</td>
</tr>
<tr>
<td>D884</td>
<td>A5</td>
<td>02</td>
</tr>
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<td>D888</td>
<td>A0</td>
<td>00</td>
</tr>
<tr>
<td>D890</td>
<td>91</td>
<td>06</td>
</tr>
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Figure A.10-3  EPROM Programmer Program Code
<table>
<thead>
<tr>
<th>Address</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA00</td>
<td>A0 20 A2 02</td>
</tr>
<tr>
<td>DA04</td>
<td>A9 CC D0 06</td>
</tr>
<tr>
<td>DA08</td>
<td>00 00 00 00</td>
</tr>
<tr>
<td>DA0C</td>
<td>00 00 84 11</td>
</tr>
<tr>
<td>DA10</td>
<td>86 10 85 12</td>
</tr>
<tr>
<td>DA14</td>
<td>A0 03 B9 18</td>
</tr>
<tr>
<td>DA18</td>
<td>DB 99 05 00</td>
</tr>
<tr>
<td>DA1C</td>
<td>88 10 F7 A9</td>
</tr>
<tr>
<td>DA20</td>
<td>00 48 28 A2</td>
</tr>
<tr>
<td>DA24</td>
<td>13 A0 FD FF</td>
</tr>
<tr>
<td>DA28</td>
<td>C9 8B F0 0A</td>
</tr>
<tr>
<td>DA2C</td>
<td>A2 0F C9 E0</td>
</tr>
<tr>
<td>DA30</td>
<td>F0 07 A2 17</td>
</tr>
<tr>
<td>DA34</td>
<td>D0 02 20 06</td>
</tr>
<tr>
<td>DA38</td>
<td>DB 86 0E A9</td>
</tr>
<tr>
<td>DA40</td>
<td>03 B1 0E 99</td>
</tr>
<tr>
<td>DA44</td>
<td>0A 00 08 10</td>
</tr>
<tr>
<td>DA48</td>
<td>F8 EA EA EA</td>
</tr>
<tr>
<td>DA4C</td>
<td>EA EA EA EA</td>
</tr>
<tr>
<td>DA50</td>
<td>EA EA EA EA</td>
</tr>
<tr>
<td>DA54</td>
<td>A0 0E A9 7F</td>
</tr>
<tr>
<td>DA58</td>
<td>91 06 91 08</td>
</tr>
<tr>
<td>DA5C</td>
<td>A0 0D A9 FF</td>
</tr>
<tr>
<td>DA60</td>
<td>91 06 91 08</td>
</tr>
<tr>
<td>DA64</td>
<td>EA EA EA EA</td>
</tr>
<tr>
<td>DA68</td>
<td>EA EA EA EA</td>
</tr>
<tr>
<td>DA6C</td>
<td>A0 0C A5 12</td>
</tr>
<tr>
<td>DA70</td>
<td>91 06 EA EA</td>
</tr>
<tr>
<td>DA74</td>
<td>EA EA EA A9 FF</td>
</tr>
<tr>
<td>DA78</td>
<td>A0 02 91 06</td>
</tr>
<tr>
<td>DA7C</td>
<td>A0 03 91 06</td>
</tr>
<tr>
<td>DA80</td>
<td>EA EA A0 01</td>
</tr>
<tr>
<td>DA84</td>
<td>A5 02 91 06</td>
</tr>
<tr>
<td>DA88</td>
<td>A0 00 A5 03</td>
</tr>
<tr>
<td>DA8C</td>
<td>91 06 4C CD</td>
</tr>
</tbody>
</table>

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>
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</table>

Figure A.11-1 System Memory Map