FABRICATION AND TESTING OF
A PROTOTYPE LONGWALL FACE
ALIGNMENT SYSTEM

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Final Tecnical Report
Modification No. S/A 1
Contract NAS8-34185

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The work reported herein was conducted under contract NAS8-34185 with the National Aeronautics and Space Administration, Marshall Space Flight Center, Alabama 35812. The results and opinions do not necessarily represent the official opinions of this agency.

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1. INTRODUCTION

This Final Technical Report summarizes fabrication and testing performed under Modification 2 to NASA Contract No. NAS8-34815 pursuant to the findings and recomendations of work reported to NASA in Adjunct Syrtems Technical Report AS03040R1, January 1981. That report, titled "Design of a Laser System for Instantaneous Location of a Longwall Shearer," summarized calculations and measurements for the design of a laser-based system for monitoring and controlling the trajectory of the shearing machine as it progresses along the longwall face. It was determined during the course of that analysis that an early version could be fabricated by employing simple mechanical contrivances and a standard miner's lamp. This system could evolve into the laser/electronic version with only modest changes required. The advantage of the early version is the ability to test at the longwall face without procuring certain approvals from the Mine Safety and Health Aministration which typically take a long period of time.

The Tasks to be performed under the contract modification were as follows

1. Design, fabricate, assemble, and perform laboratory and in-mine tests of an experimental optical alignment system having the following characteristics.

   (a) The light sources used shall be existing, mine permissible units.

   (b) No electronic components shall be used in the experimental optical alignment design.

(c) The device shall be capable of satisfactory operations in recording received, reflected light from a shearer at distances of up to 600 feet along an operating longwall face.

(d) The system shall provide a photographic (hard copy) record of received pulsed light beams showing the path of the longwall shearer as it proceeds along the face cutting coal in the horizontal plane (xz) and the vertical plane (yz). This includes a clear plastic overlay to be used in interpreting the film strip in terms of clock locations.

(e) The design shall be structured in such a manner as to permit a simple conversion from the experimental demonstration model to an electronic version capable of automatic real-time trajectory control.

2. Adjunct Systems Inc was to be fully responsible for making all arrangements pursuant to conducting an in-mine test of this instrument. All MSHA rules, regulations and requirements were to be met in performing the in-mine test.

3. Adjunct Systems Inc was to conduct suitable investigations as to the feasibility of integrating the above mentioned sensor into a face alignment system including

(a) The use of such components as a display/processor having overall dimensions approximately 6" x 8" x 6", accepting signals from four external sources in either digital or analog (0-5 v dc.) format, at input rates of up to one sample per second

(b) A visual display consisting of at least three differently colored lights individually distinguishable at up to fifty feet.

(c) A means of recording the data on a small single channel tape recorder having a internal clock will also be investigated, and its ability to record four inputs on a single channel by multiplexing the signal shall also be verified.

4. Adjunct Systems Inc was to supply to the Government all hardware developed or procured under the terms of this Scope of Work together with

(a) drawings (complying with good engineering practice) of the hardware

(b) operating instructions and a final report in two parts; the first consisting of details of development of the optical alignment device, design and test results augmented by such illustrations as necessary to clarify the text, and the second, dealing with the results of the feasibility investigations

According to the fourth requirement, this report is divided into the two delineated parts. Appended to the report are "stand-alone" data sheets

The summary remark to this introductory section is that all requirements were either met or exceeded

PART 1

DETAILS OF THE DEVELOPMENT OF THE

OF THE OPTICAL ALIGNMENT DEVICE

(including design and test results)

2. CONCEPT OF THE FACE ALIGNMENT RECORDING SYSTEM

The longwall face alignment recorder is a development oriented toward immediate use in coal mine environments, with expansion to real time control if desired. The concept involves the use of a retroreflector on the shearing machine body, a standard miner's lamp as a source, mechanical (as compared with an electrical motor) drive, along with photographic recording using Polaroid color photographic film. The retroreflector shown in the picture of Figure 1 is mounted on a vertical carriage that moves up and down according to the forces as a follower moves along the drive cogs. In the down position, he reflector is not visible. In the up position, it is visible. (Actually, the unit need not move up and down with each cog cycle. A mechanical mechnism can divide the motion so the positions change only once per roof support or other selected interval. The only electrical component is a standard miner's lamp. No modification is made to the lamp. Thus, the entire system is immediately mine usable. The hardware can be modified to an electronic version with modest changes. Outputs such as shown in Figure 2 are available, and are immediately useful to coal mine personnel. They are made using an apparatus which sits stationary at the fresh air end of the longwall. This apparatus, with cover removed, is shown in Figure 3.

The recording film is moved in a steady manner in a plane perpendicular to the optical axis. Light returning from the retroreflector passes through a long focal length lens and through a dove prism to be imaged with an offset indicative of the angle to the shearer. Horizontal and vertical displacements are decoupled by use of a cylindrical lens near the film plane. The dove prism rotates such that it eliminates the need for rotating cylindrical lenses.

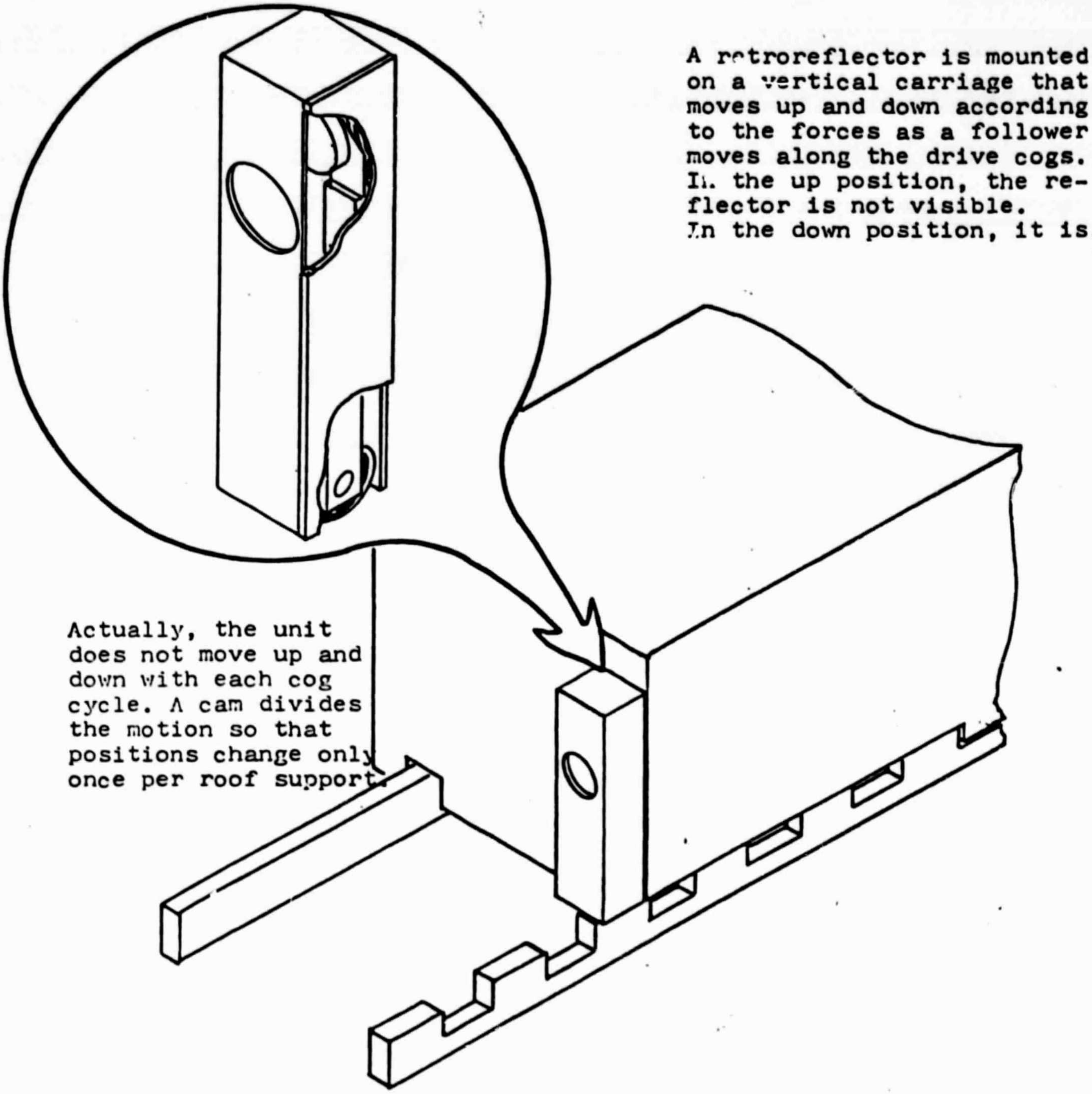


Figure 1. The Retroreflector Portion of the "Quick Response" Concept.

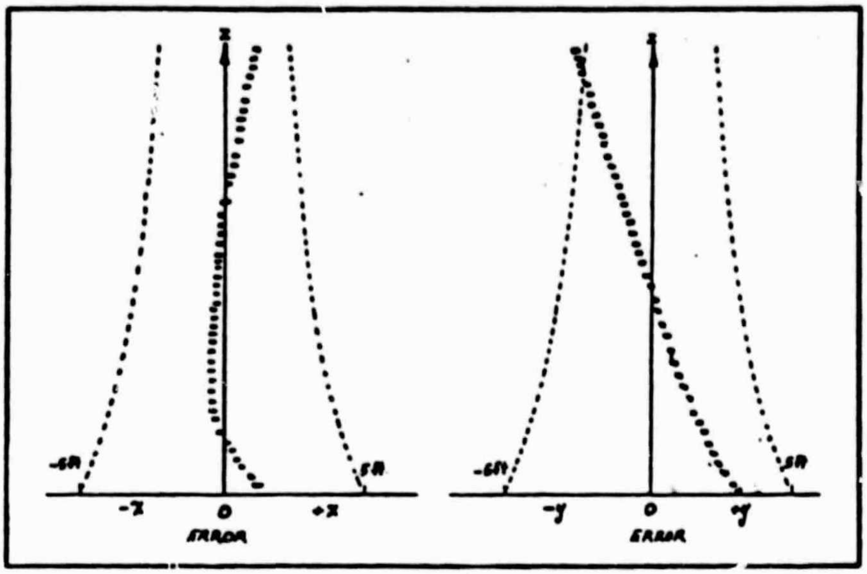


Figure 2a. TRAJECTORIES SHOWING MISALIGNMENTS OF UP TO 2-FEET AND 5-FEET RESPECTIVELY.

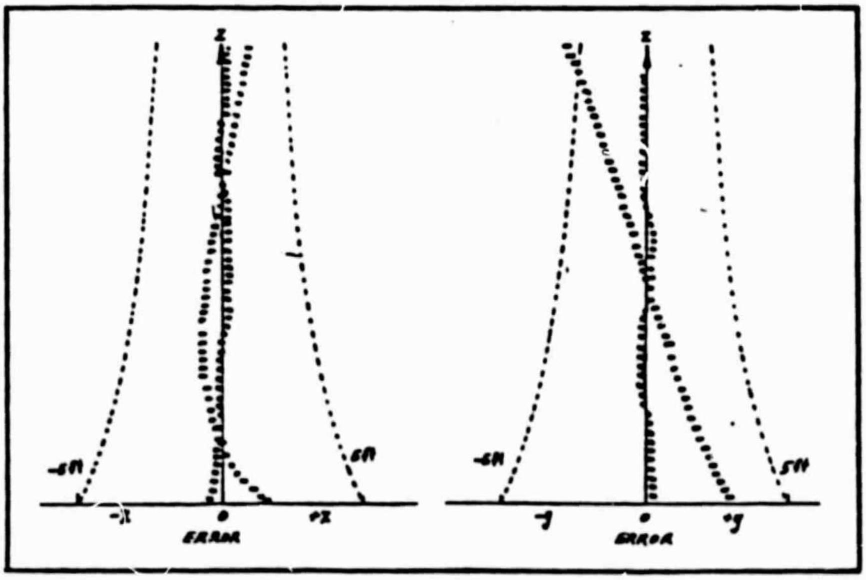


Figure 2b. OVERLAY OF NEW XZ & YZ TRAJECTORIES SHOWING THAT CONSIDERABLE CORRECTION HAS BEEN OBTAINED.

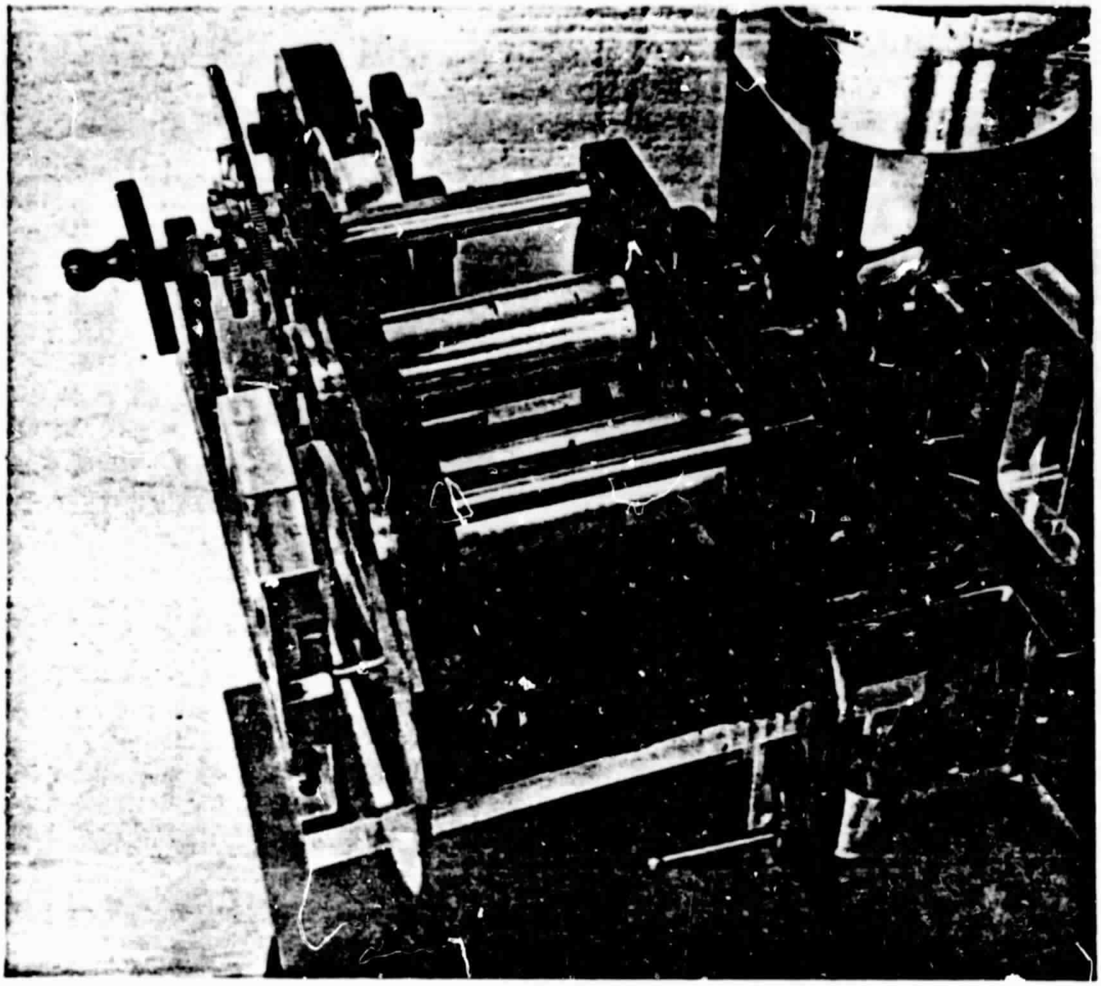


Figure 3. Closeup of Optical Arrangement for Recording

(See Fig. 4 for call out diagram)

This rotating prism system has two advantages. The first is that slaved rotation at the prism plane is easier to implement than rotation in the film plane. Further, rotation of the prism assembly can be used to interject colored filters into the path of light returned from the retroreflector. The colored filters assure separation of the horizontal and vertical exposures of the colored film such that they can be independently interpreted when the developed film is read through appropriately colored analysis filters.

Analysis of the film is accomplished by observing the image through overlays which are ruled in such a way as to include the triangulation considerations relating displacement on the film to offset of the shearer as a function of distance down the face. That distance is obtained simply by counting the number of point-like exposures along the distance axis and multiplying by the distance of one "pop up cycle" of the retroreflector assembly.

3. PHOTOGRAPHICALLY CONFIGURED FACE ALIGNMENT SYSTEM

A prototype Face Alignment System was fabricated for use in both coal mine and laboratory tests. The system was configured such that it can evolve into a laser-based electronic unit, but was set up for near-term photographic recording. Figure 4 shows callouts for the recording portion of the system. A miner's lamp (1) produces light which is collimated and reflected from a front surface mirror (2) affixed to the escapement of a pendulum (3) which drives a clock motor (4). The light travels through a Dove prism (5) that is rotated periodically by 45 degrees in accordance with a release mechanism driven by the clock motor. This causes the light to intermittently scan horizontally and vertically, depending upon the prism orientation.

The light scan pattern is boresighted to the retroreflector shown earlier in Figure 1. Intercepted light is returned to the collecting objective (6) and is passed through a filter wheel (7) which is mechanically linked to a second Dove prism (8). Both Dove prisms are directly linked as suggested by the dashed line. This brings about a relationship in which synchronism is maintained between the two filter colors in the wheel and the positions of the prisms. This second Dove prism serves to rotate the image being formed by the collecting objective in 90 degree steps. This image, while still being formed, is passed through the two cylindical lenses (9 and 10). These lenses cause what would have been a focussed point, due to the retroreflected light, to instead appear as a vertically oriented focussed line passing through a narrow horizontal slit (11). This arrangement affords complete decoupling of horizontal and vertical movements of the retroreflector as a series of small

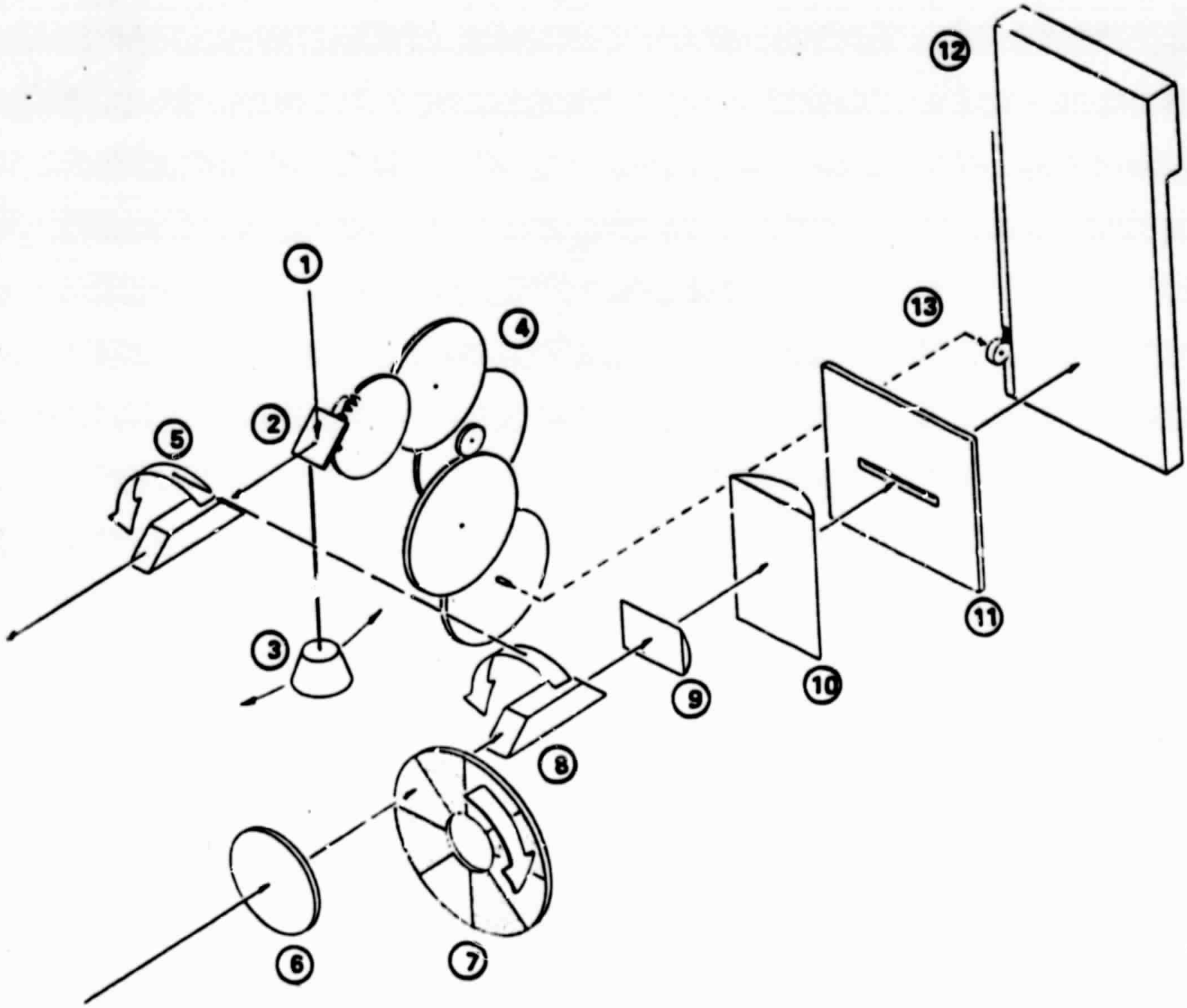


Figure 4. Schematic of Face Alignment Recording System

spots recorded on color film housed in a transport assembly (12) allowed to drop slowly, and in a constant manner, by a rack and pinion pair (13) regulated by the clock motor. On color spot represents vertical data, another indicates horizontal data.

As will be discussed in subsequent sections, complete success was obtained in recording and decoupling the two movement axes, such that sideways displacement on the film represents the angle of boresight differences while the perpendicular displacement is associated with elapsed time.

It is important to note that much of the optical mechanism is not needed if the system is purely dedicated to photographic records. The front surface mirror attached to the pendulum mechanism, as well as the first Dove prism, were not needed for the photographic tests made in the laboratory and in the coal mines. They are needed, however, if the unit is converted to an electronic version. Should the unit be so converted, the pendulum mechanism can be replaced with a motor drive. This has advantages for reduction in complexity and in size.

The system used for the mine tests has the following physical characteristics:

RETROREFLECTOR ASSEMBLY	7"W X 7"D X 16"H Approx. 20 pounds (without brackets) 10 cogs up / 10 cogs down reflector diameter 2" (2 arc minutes)
RECORDING ASSEMBLY	14"W X 14"D X 17"H

Approx. 45 pounds
(without clock weight)
30 second intervals between
prism rotations
Film travel 16.5 mm per hour
Format on 4X5 Polaroid film
Type 58, ASA 75
Horizontal data uses no filter
Vertical data uses amber filter
Uses MSA "Mine Spot" lamp

An electronic system would use the same retroreflector assembly, but the recording assembly could be reduced by approximately 80% in volume and 50% in weight.

4 TEST RESULTS

Several laboratory tests were made using the system descibed in the previous section. These tests established the viability of the face alignment system in both the photographic and the electronic configurations. Following the laboratory work, tests were made at a longwall operation in a coal mine. The results obtained in both testing regimes are summarized in the subsections below.

4.1 LABORATORY TESTS

Two categories of laboratory testing were undertaken. The first catagory was oriented toward establishing credibility to extend the basic concept to a laser based electronic version. The second category of tests was directed toward ascertaining the readiness of the prototype system for coal mine testing on an operating longwall shearer.

4.1.1 Electronic Viability Tests

The prototype system was fabricated such that the light source could be reflected from a front surface planar mirror attached to the pendulum escapement. In this manner, the beam can be swept in the YZ plane, where Z is along the system pointing axis and Y is the vertical axis. This beam sweep is needed in the electronic version to facilitate meeting Bureau of Radiological Health requirements for laser safety. Furthermore, the sweeping in the laser based electronic version is monitored by directly attaching an angular shaft encoder to the mirror rotational axis. The use of the encoder to determine shearer off-axis position in real time is detailed in the earlier referenced Technical Report (submitted to NASA in January 1981).

Although not needed for the photographic coal mine tests, the inclusion of the mirror scanner in this prototype allowed determination that:

(a) The field of coverage of a scanned beam would be appropriate to anticipated shearer trajectories.

(b) The "transmit Dove prism" would provide needed orthoginal scan rotations.

A miner's lamp was used to confirm the sweep angles and their rotations. Tests showed a sweep extent of 15-degrees half angle, as well as the clearly defined 90-degree rotations needed to decouple vertical and horizontal shearer displacements. Accordingly, the conclusion was reached that conversion to the laser based electronic system was a reasonable future step.

One observation was made, however, that care must be taken in the selection of the cylindrical beamspreading lens to allow for dispacements resulting from offset of the transmit Dove prism.

The tests on this critical scanning process were conducted during the months of June and July, 1981, at Adjunct Systems Inc. and were confirmed by NASA Mineral Extraction Office personnel.

4.1.2 Mine Readiness and Calibration Tests

The mine readiness and calibration tests were made at Adjunct Systems during the month of July and the first two weeks of August to "shake down" the photographic configuration in preparation for coal mine testing. The key areas of investigation were:

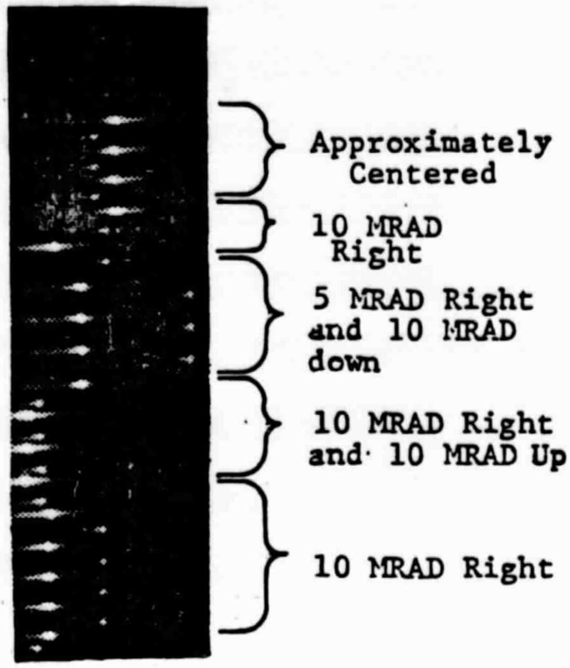
(a) The ability to maintain constant movement of all optical and film devices for the period of several hours.

(b) Sensitivity of the film recording unit at ranges up to 600 ft.

(c) The ability of the rotating Dove prism to achieve completeness of decoupling between horizontal and vertical displacements.

Laboratory tests were positive on all counts. The pendulum arrangement was operated several times for periods in excess of five hours under the load of both the prism assembly and the film transport. Nighttime tests were made at ranges of just over 600 feet along Howe Avenue, alongside the Adjunct Systems building, in the presence of intermittent automobile traffic with lights turned on. Acceptable exposures were achieved with the amber colored filter in place, but the green filter exposure proved to be only marginal. Therefore the color combinations were changed from amber/green to amber/white for the vertical/horizontal records. This assures dependable exposure levels at distances of 600 feet or more.

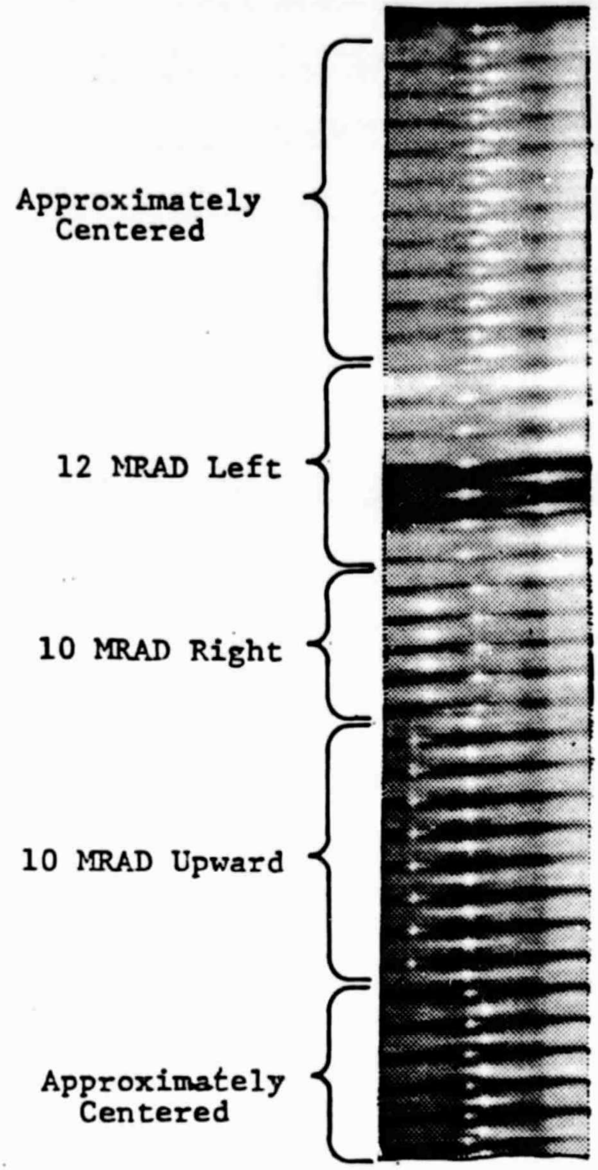
Complete decoupling of horizontal and vertical displacements was clearly demonstrated with the Dove prism rotation. Figure 5 shows a photograph of a decouple test made at short range. The notations on the figure indicate the amount of movement off boresight. The speed of the color film used is ASA 75. Data was taken with all room overhead fluorescent lights on. Nevertheless, data dots were clearly discerned on the color film (to a degree greated than that reproduced in this black and white report copy).



Key ◄ Horizontal

• Vertical

(b) Results in fully lighted room with short baffle in front of receiving lens.



(a) Results in fully lighted room with no baffle

Figure 5 Laboratory Results showing complete decoupling of Horizontal and Vertical displacements. Figures (a) and (b) are Four Times the origional Color Film size.

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A 2.0 neutral density filter is used at ranges less than 100 feet to keep the film from totally saturating, which causes the image to spread. This is done as an aid to estimating resolution at long range. In practice, due to the trigonometry, this is not necessary because high resolution is not needed at close ranges. Furthermore, at very close ranges, much of the retroreflected light does not enter the receiving aperture because the beam divergence is low, thereby avoiding extreme film exposure.

Both the inside and outside laboratory tests show that resolution in both vertical and horizontal displacement is very close to 1.0 milliradian. This suggests a positional resolution of approximately seven inches at the tail gate of a 600-foot longwall track.

A calibration overlay was calculated for the face alignment system based on simple trigonometry. This overlay was made as oversize art, then photoreduced to fit as a reticle in a magnifier routinely used in optics work. A copy of the oversized art is shown as Figure 6.

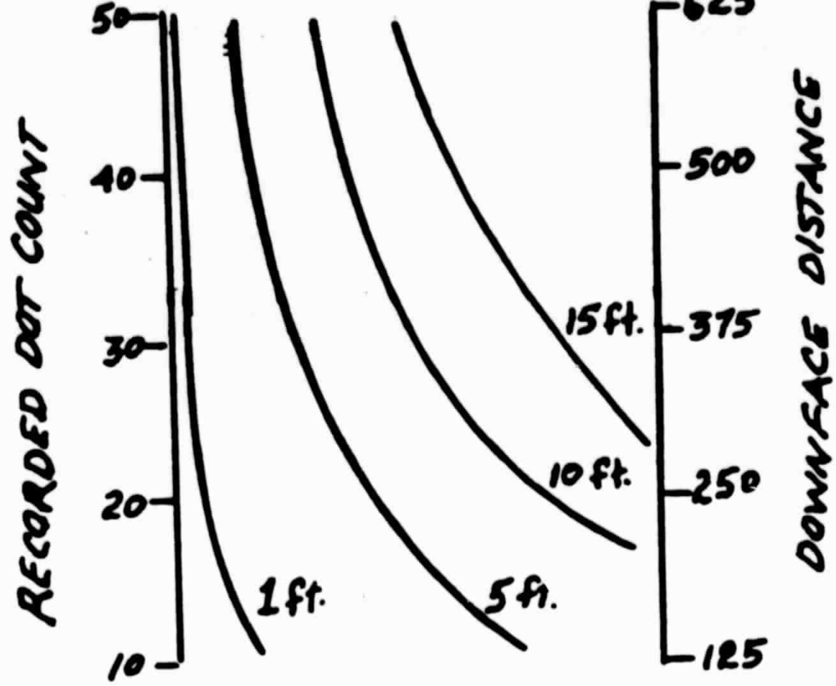

Figure 6. Blowup of Overlay Used for Tests at Jim Walter Resources Mine #3.

5. COAL MINE TESTS

Arrangements were made with Jim Walter Resources to make tests at their #3 mine in Bessemer, Alabama. This mine had been visited before and the mine manager was familiar with Adjunct Systems. Two trips were undertaken. The first to make preparations by examining the sight and making measurements for mounting the retroreflector to the shearer. The second trip involved operation of the Face Alignment Svstem on the longwall.

5.1 PREPARATION TRIP

The Jim Walter Resources #3 mine was visited on 14 August to make preparatory contacts and observations. The recording unit was not taken along, as it has no machine interface complexities. The retroreflector unit was taken into the mine, however, for attachment measurements.

Mine #3 has recently opened a new longwall operation. This operation differs considerably from that #3 mine visited in the past in that it is completely lighted and is longer than average. The lights used are standard mine permissible fluorescent fixtures. These have the potential to interfere with the photographic version of the Face Alignment Recorder, but were not likely to be negating. In fact, most of the laboratory testing had been conducted in rooms fully lighted with lamps of similar spectral output. The electronic version of the system would be completely unaffected by the lights because they have very little emission at laser diode wavelengths.

The longwall operation was found to use cogging that was slightly different than what had been planned on. This was not considered a major concern because the differences were simply a matter of scaling. It was found that the roof supports spanned a distance of eight cogs rather than ten. This is of no serious consequence. It simply means that the distance multiplier increases by 25%. The cog shapes at this face offer the advantage that the free space betwen them is about eight inches. This leaves plenty of swing room for the rachet arm on the retroreflector.

The shearer progression rate on this wall was found to be unusually high. On the average, the shearer moved approximately 20 feet per minute. This is many times faster than anticipated, but was of no lasting concern because a simple shortening of the pendulum arm would speed up the Face Alignment Recorder enough to follow the movement. Of greatest concern was the existence of significant undulations in the shearer path. This mandates mounting the recorder system at a high point near the head gate.

The Jim Walter Resources mining machinery mechanic escorting Adjunct Systems on the preparatory visit helped design a mounting arrangement that would be suitable for placing the retroreflector assembly on the shearer. He requested that the unit be left with him for making the installation brackets in his own shop. This was done.

5.2 LONGWALL OPERATION RESULTS

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Jim Walter Resources Mine #3 was revisited August 25 for testing of the Face Alignment Recorder during the night shift. The recording unit pendulum, was shortened to increase the film and optical movement speeds by better than 50%. This was done on the basis of the rate information aquired during the first visit. However, this adjustment proved unnecessary because the shearer during the second visit operated at approximately 12 feet per minute and because manual simulations were made for reasons discussed below.

The process of making the retroreflector mounting bracket involved opening the housing to bolt a steel plate to its bottom. This, as mentioned above, was generously undertaken by personnel at Jim Walter Resources. Unfortunately, the retroreflector assembly was already welded onto the shearer body before it was evident the corner cube element had been knocked loose inside the housing. The decision was made by Adjunct Systems Inc to avoid holding up the longwall operation for the length of time that would have been required to tear the assembly back out to replace the corner cube. A second corner cube had been taken along for such a contingency. This second cube was used for manual tests to be discussed shortly.

The retroreflector unit, shown being mounted to the shearer in Figure 7, was left on the shearer body to monitor:

(a) The durability of the unit in a working environment
(b) The reliability of the ratchet movement in raising and lowering the corner cube holder.
(c) Vulnerability to damage if the two ratchet direction controls were not switched when the shearer direction was reversed.
(d) Buildup of coal dust and water spray on the unit window.

The findings were very favorable on all accounts. The unit was at no time in danger of being hit by any moving part of the shearer or wiped against the mine roof. Vibrations were of no observable consequence. The up/down movements were reliable and it is likely that the unit would stay in working order for extended periods of time, short of some catastrophe such as a roof fall.

With the addition of a small plate above the unit, which would be easily welded onto the shearer at the location used for this test. However, at this location the shearer operator has a tendency to walk in front of the light beam. This can be aided by moving the unit's position toward the head-gate side on the shearer. There is room for this to take place and preserve the aforementioned features.

The ratchet movement was watched carefully and found to be as needed. With the lever suspended into the cog spaces, the requisite one step at a time was observed. Furthermore, it was found that an extension to the lever was needed. A rubber high pressure hose was cut and press fitted to the lever to achieve the extention. This need turned out to be fortuitous. This gives a low cost, easily replaced, easily adjusted lever which is stiff enough to accomplish the movement of the corner cube, while being flexible enough to protect the unit during shearer backup.

Observation while the shearer progresses down the face suggests that the window is likely to make a complete pass without needing wiping. At most, the window might need wiping every 200 to 300 feet. The buildup is water spray, not coal dust. Therefore, as water drops get large they may coalesce and drip free of the window. From a dust standpoint, using the system while the shearer is receding from the headgate has the advantage that the cutting drum is in its low position between the reflector and the recorder. Which helps a little in suppressing the floating of particles near the window.

The recording unit was positioned near the head gate. It is shown in Figure 8 with a miner sitting next to it. The ideal location appears to be directly in line with the outflow of the longwall conveyor.

Since the retroreflection tests were made with manual placement of the corner cube, the top of the recording unit was removed to allow direct look at the focal plane as the cube was moved to various X, Y and Z positions along the face. Light shining into the recording optics was found to properly focus and to move correctly in response to source movements up/down and left/right. This was a source of enthusiasm not only because it was proof-positive of functioning in the dusty mine conditions, but also because it suggests that a beam splitter could be used to allow real-time observation of the movements.

The longwall face was completely lighted with fluorescent lamps. The question arises, therefore, whether this lighting will unduly compete with the retroreflected light. Figure 8 shows the results of some tests on the possibility. A retroreflector was carried to various distances down the face. Photograpghs were then made along the supports and along the conveyor. Even with reduced quality of the printing in this report it can be seen that at near distances the retroreflected light is significant in comparison with the roof support lights. At longer distances, the roof lights do not give enough light to make a photorecord. In contrast to the loss of imagery from the roof lights, the reflected light was still recorded at better than 350 feet. The only reason longer records were not made was the curvature of the face made for geometrical blocking. However, the laboratory tests have already shown that line-of-sight signal is high enough that the observed levels of dust in the mine will not negate ranges of 600 feet or better.

5.3 MINE TEST SUMMARY REMARKS

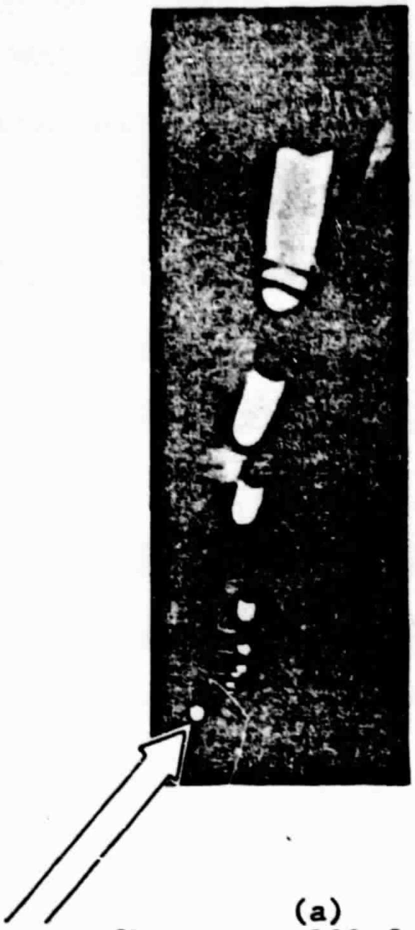
As a summary one can state that the viability of the Face Alignment Recorder was firmly established. Of course, components and housings need to be optimized and integrated into the shearer for long term survival and maintenance.

Mine cooperation and interest was high. Before the system intent was even explained to the crew chief, he had already volunteered the fact that he would like some kind of alignment device. His needs are, however, real time. The observations described above indicate that this would be possible even while photorecording is ongoing.

Adjunct Systems Inc recommends that further work on the unit is merited. This would include establishment of a long term test arrangement with a mine operation, as well as modification of the recording unit for size reduction and nutation (as opposed to rotation) of the Dove prisms and filters.

Figure 7.
Retroreflector Assembly being
Mounted on Shearer Body

Figure 8.
The Recording System Adjacent to
Support at Headgate Conveyer End



(a)
Retroreflector at 120 feet viewed from headgate roof support

(b)
Retroreflector at 200 feet viewed from under headgate roof support

(c)
Retroreflector viewed at 350 feet from portion at head gate conveyer end

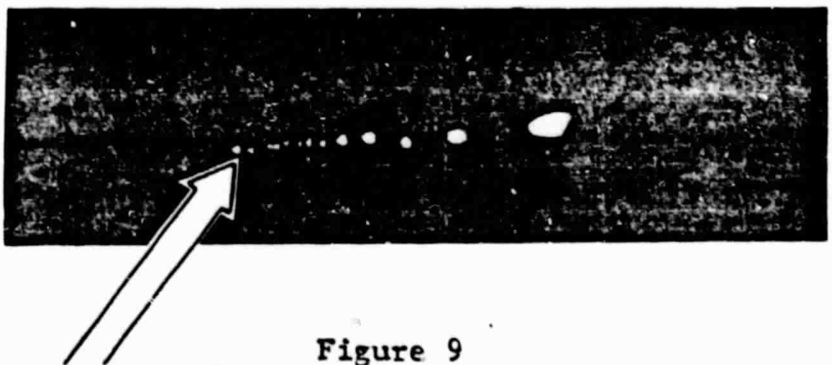


Figure 9
Examples of Retroreflector Contrast in Region of roof support Lights at various distances.

PART II

DISPLAY/PROCESSOR FEASIBILITY

INVESTIGATIONS

6. DESIGN CRITERIA

Adjunct Systems Inc made a survey of available electronics to ascertain he viability of incorporating off-the-shelf items into a display/processor meeting the specifications outlined below. A breadboard demonstration was made of the recommended system, which led to an implementation of the specified system under a subcontract relationship with Foster-Miller Associates. The results of tests made by Adjunct Systems using the FMA unit is discussed in the following section. The last section shows a descriptor sheet provided to the Mine Safety and Health Administration.

Adjunct Systems Inc. considered a controller and data logger that could be configured in a mine permissible arrangement. The basic system was to be packaged in an approximately 6 in. x 6 in. x 8 in. interior dimensioned explosion proof box.

The system was to have four analog input channels and one 8-bit digital input ports. The analog input port channels were to accept 0 to 5 VDC signals nd the digital input port was to accept an 8-bit message. The analog inputs were to be of differential form to help noise suppression. An additional input port would accept and count pulses from the Natural Background Sensor. Counts as high as 4096 would be accomodated. Count periods were to be programmable up to 10 seconds duration. The internal handling of counts would be in accord with the objective of the Natural Background Sensor to determine coal seam thickness in an effective manner with respect to practical manual control.

The controller/data logger was to be supplemented with a mine-permissible battery pack for its prime power. This battery was to power all controller/

logger electronics, the digital data tape recorder and three output display lights. The design goal was for 24 hours off a single battery charge. The display lights were to be of different colors and observable at a distance up to 50 ft. They were to be programmable to turn on in accord with modifiable software which could accept readings through the various input ports and use those readings calculations to determine the status of the shearing drum vertical settings with respect to a controlling algorithm.

The indicator lights were to have programmable pulse rates allowing duty cycles from 5 percent to 100 percent (continuous on). At least one software configuration must allow light activation such that if the shearer drum is out of tolerance low, then one color light appears. If the drum is within tolerance the option must be allowed that either no light is activated, or a third color light is activated. While not a mandated specification, consideration was to be given to augmenting the up/down color indications with a spatial cue such as upper and lower halves of a circle, up/down arrows, etc.

The controller subsystem was to be capable of update at rates compatable with man-in-the-loop control, but this rate should be variable by easily implemented software change. The data logger was to be capable of up to 130,000 bytes. The data logger tape recorder was to be capable of playing the recorded date back through the system with the following features.

1. The calculator portion of the system can be programmed to reduce and analyze the recorded data.

2. Output, either processed or raw, can be shown on the calculator display.

3. Output, either processed or raw, can be output directly

on a printer for the purpose of hard copy.

All of the above mentioned requirements have been met. Tests of the system in a man-in-the-loop operation were made at the mock longwall in Bruceton. An outline of the tests results are given in the next section.

7. BRUCETON TEST SUMMARY

The system was taken to Bruceton early in August to test its function with a Man-in-the-Loop arrangement using:

(a) The acoustic follower,

(b) The shearer arm potentiometer,

(c) A pulse generator to simulate the Natural Background Sensor and

(d) The downface distance measuring potentiometer.

A photograph of the configuration is given as Figure 10.

Cutting tests were not made because the roof overhang had not been cut back. Therefore, tramming tests were made in which the arithmetic sign of the Natural Background Sensor reading was reversed. Operationally, the shearer vertical control was guided manually by observation of three lights on the controller output window. Each light cued the operator as to the drum height adjustment required to bring the cut within the preprogrammed error window. The Adjunct Systems Inc technician changed the pulse generator frequency to simulate different coal thicknesses. These simulations caused the operator to respond with a vertical drum height adjustment. The acoustic follower, placed in a present cut location on the body of the shearer, then determined the actual height from the body to the cut, which was recorded both with the Adjunct Systems and Foster-Miller units as a function of downface distance.

A plot of one run is shown in Figure 11. This figure shows a record

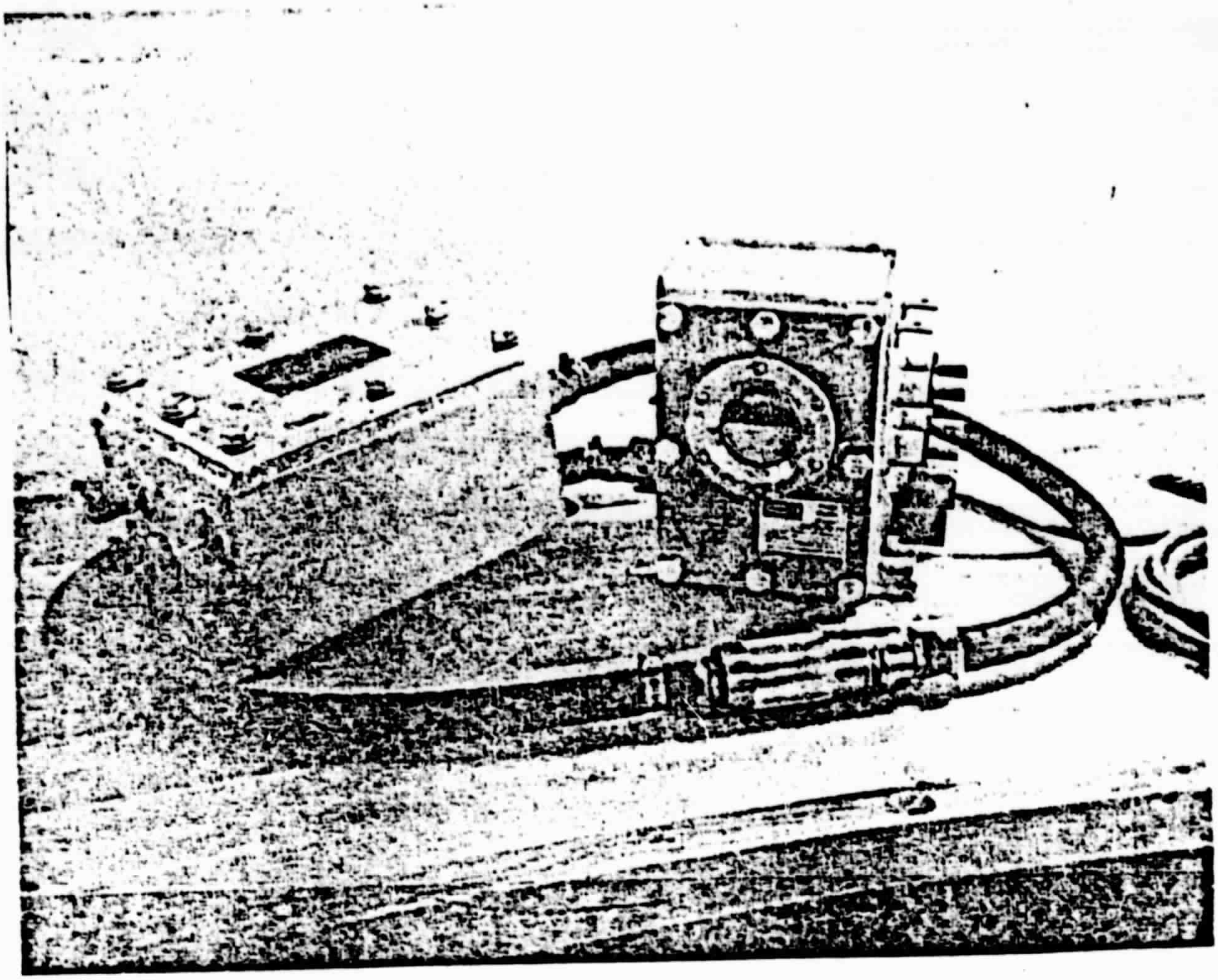


Figure 10. Configuration Used in Bruceton Test. Battery Box is on Left and Controller/Data Logger is on Right. Lights and Calculator Display are Visible through the Window.

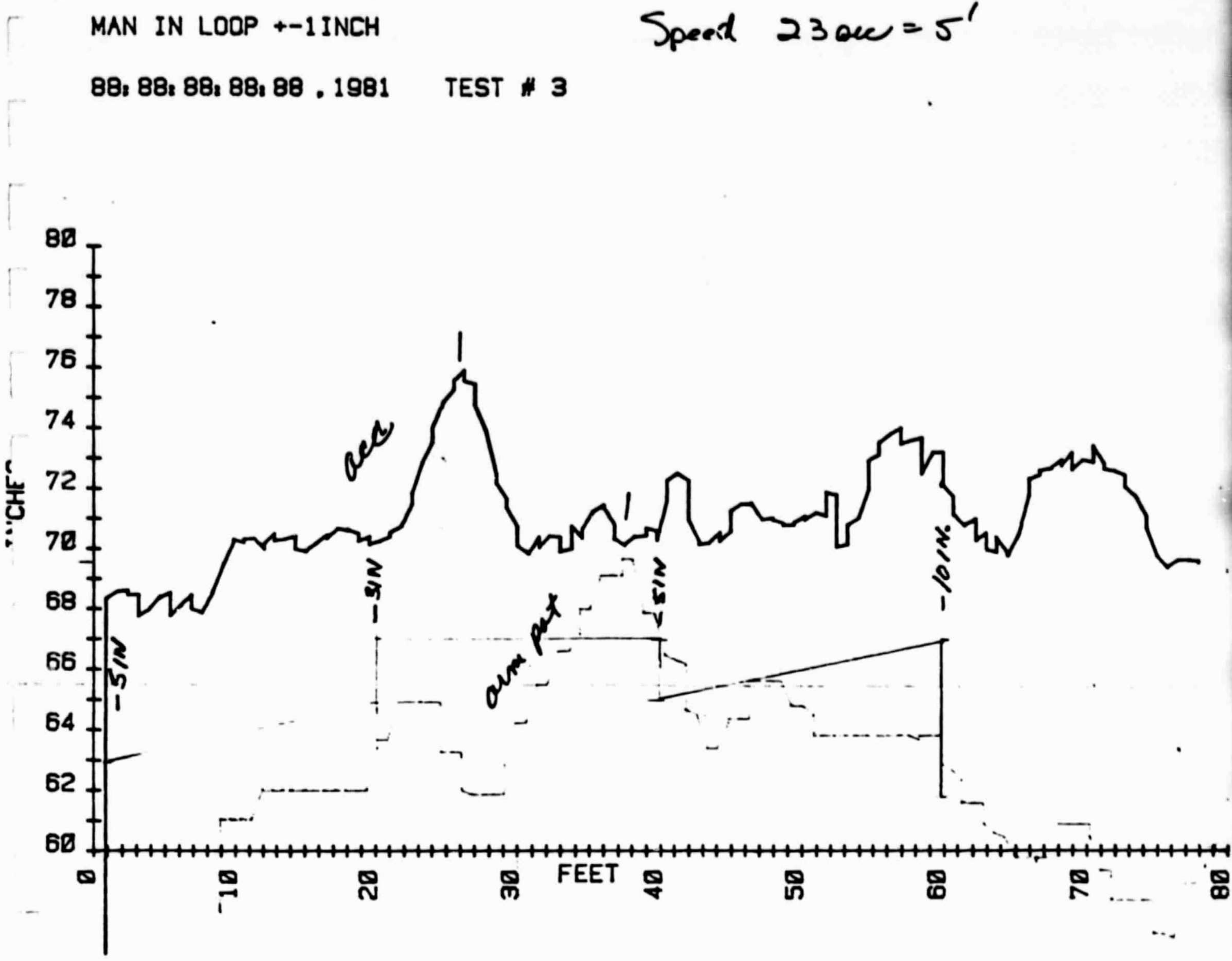


Figure 11. Results of Third Run at Bruceton Mock Longwall

which indicates the operator was able to respond to the instruction lights and put the drum height inside the error band within approximately two to four feet of travel. The shearer progression for the test was about 12 feet per minute. This is slightly less than many longwalls operate, but not so much less that it negates the value as a first order conclusion.

The system recorded some voltage fluctuations corresponding to approximately one inch. It was not possible to track down their source, which mav well have been the result of the unusual arrangement in which both the Adjunct Systems and the Foster Miller analog-to-digital convertors were in use at the same time.

The program cycle time was about seven seconds. Increased efficeincy of the coding might reduce this time to five seconds.

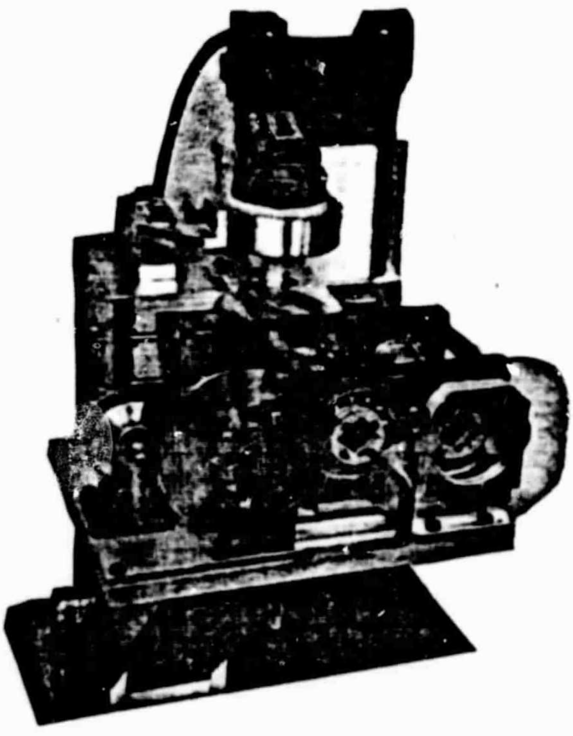
Complete documentation on the system, which uses both proprietary and non-proprietary devices from Hewlett-Packard, as well as Adjunct Systems fabricated microprocessor electronics and mechanical assemblies, has been supplied to Foster-Miller Associates to pursue MSHA permits.

APPENDICES

LONGWALL FACE ALIGNMENT RECORDING SYSTEM

The longwall face alignment recorder is a development oriented toward immediate use in coal mine environments, with expansion to real time control if desired. The concept involves the use of a retroreflector on the shearing machine body, a standard miner's lamp as a source, mechanical (as compared with an electrical motor) drive, along with photographic recording using Polaroid color photographic film. The retroreflector shown in the picture to the right is mounted on a vertical carriage that moves up and down according to the forces as a follower moves along the drive cogs. In the down position, the reflector is not visible. In the up position, it is visible. (Actually, the unit need not move up and down with each cog cycle. A mechanical mechanism can divide the motion so the positions change only once per roof support or other selected interval. The only electrical component is a standard miner's lamp. No modification is made to the lamp. Thus, the entire system is immediately mine usable. The hardware can be modified to an electronic version with modest changes.

Outputs such as shown in the figures on the next page are available, and are immediately useful to coal mine personnel. They are made using an apparatus which sits stationary at the fresh air end of the longwall. This apparatus, with cover removed, is shown in the figure below.

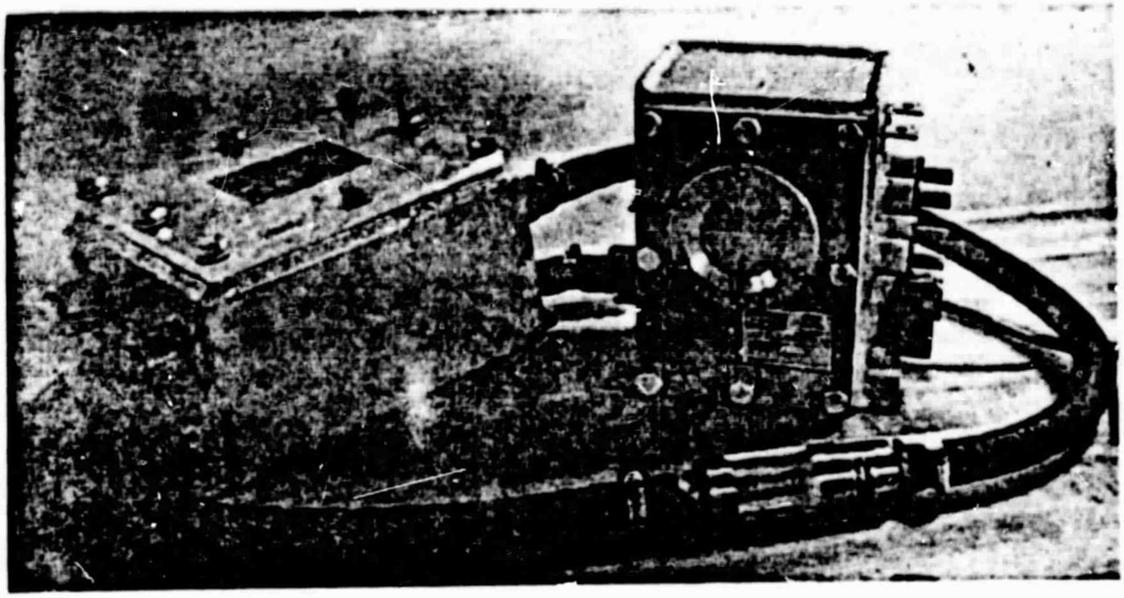


The recording film is moved in a steady manner in a plane perpendicular to the optical axis. Light returning from the retroreflector passes through a long focal length lens and through a dove prism to be imaged with an offset indicative of the angle to the shearer. Horizontal and vertical displacements are decoupled by use of a cylindrical lens near the film plane.

The dove prism rotates such that it eliminates the need for rotating cylindrical lenses. This rotating prism system has two advantages. The first is that slaved rotation at the prism plane is easier to implement than rotation in the film plane. Further, rotation of the prism assembly can be used to interject colored filters into the path of light returned from the retroreflector. The colored filters assure separation of the horizontal and vertical exposures of the colored film such that they can be independently interpreted when the developed film is read through appropriately colored analysis filters.

Analysis of the film is accomplished by observing the image through overlays which are ruled in such a way as to include the triangulation considerations relating displacement on the film to offset of the shearer as a function of distance down the face. That distance is obtained simply by counting the number of point-like exposures along the distance axis multiplying by the distance of one "pop up cycle" of the retroreflector assembly.

MINE PERMISSIBLE ELECTRONIC MONITOR AND DATA LOGGER



The electronic monitor and data logger has been specifically designed for use in coal mines. The system has the ability to operate several days on battery power or continuously on primary sources. System design makes it possible for an operator to perform even the most sophisticated operations with very little training. This results from the availability of prepackaged computer software which is called into action at the push of a single button.

GENERAL CHARACTERISTICS

- Records on magnetic tape
- Analyses data in either real time or off line
- Controls machinery in either real time or off tape
- Displays in lights, audio and/or digital LCD output
- Reprogrammable with magnetic cards or remotely with an optical reading head
- Talks to other computers
- Housed in an explosion proof 6"x6"x10" box
- Powered from a single six volt source
- Requires less than one ampere current
- Accepts multiple analog inputs (up to 20 ports)
- Accepts pulsed inputs (up to 4 ports)
- Accepts digital inputs (8-bit words, up to 4 ports)
- Has up to 6 ports for command output
- Weighs 6 lbs without XP box, 75 lbs with

RECORDING CHARACTERISTICS

- Can record continuously without computer control
- Can be activated by the computer, which executes turn on based on the sensor inputs or preprogrammed times
- Holds 2000 words in the computer and 100,000 on the tape
- Can play back through built-in computer (which can process and plot data at same time) or to an outside computer
- Has matching paper tape printer/plotter

ANALYSIS OPTIONS (PUSHBUTTON CONTROL OF PREPACKAGED SOFTWARE)

- Standard Statistics, including:
  - Mean
  - Standard deviation
  - Cross correlation
- Non-parametric Statistics, including:
  - Rank order
  - Trend tests
  - Quality control algorithms
  - Curve fitting and projections
- Other mathematical and control programs can be prepackaged on request.
- Programs can be pushbutton activated
- Input from simple magnetic card