Horizon Sensing (Proposal #51)
Quarterly Report (5^{th})
41050R05

Report Period Start Date:	**January 2002**
Report Period End Date:	**March 2002**
Principal Investigator/Author:	**Larry G. Stolarczyk, Sc.D.**
Project Period:	**36 months**
Project Start Date:	**20 December 2000**
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DOE Award No.:	**DE-FC26-01NT41050**
Name of Submitting Organization:	**Stolar Research, Inc.**
Address:	**848 Clayton Highway Raton, NM 87740**
NETL Project Manager:	**David M. Hyman**
Total Project Cost:	**$1,740,039.00**
DOE Share:	$779,750.00
Participant Share:	$960,289.00

NETL

Disclaimer

Abstract

Real-time horizon sensing on continuous mining machines is becoming an industry tool. Installation and testing of production-grade HS systems has been ongoing this quarter at Monterey Coal Company (EXXON), FMC Trona, Twentymile Coal Company (RAG America), and SASOL Coal. Detailed monitoring of system function, user experience, and mining benefits is ongoing. All horizon sensor components have finished MSHA (U.S.) and IEC (International) certification.

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Project Objectives

The objective of this project is to demonstrate the feasibility of real-time stress measurement, bit loading, and horizon sensing on a longwall shearer, boring machine, continuous miner, and loading bucket.

Project Cost Summary

	First Year		Second Year		Third Year		Total	
	Plan+	Actual*	Plan+	Actual*	Plan+	Actual*	Plan	Actual
Participant	320	1,960	320	3,600	320	3,600	960	
DOE	263		258		259		780	
Total	583		578		579		1,740	

Amount in thousands of dollars

Key:

+ Planned costs for the full year

* Actual costs through the reporting period. Based on full Stolar Research staff deployment of the Horizon Sensor Project at $280K/month

Experimental

Site 1 System Operational Testing

Installation of a HS-CM system on a Joy 12CM12-10A at Monterey Coal Company began Friday, January 11, 2002, and was completed on Tuesday, January 15, 2002. The total installation time was approximately 8 hours, although nearly 10 more hours were spent fabricating a protective steel cage and plates for the Horizon Graphics Unit (HGU) and Graphical User Interface (GUI) Modem Aerial (GMA) antenna as well as random double checks and tool problems. In addition, several hours were spent welding boxes and brackets to the cutter drum during machine-shop rebuild of the CM 8 months prior. Once underground, it was determined that additional fabrication was needed to protect the HGU, and two more shifts were devoted to that. The installed system proved rugged, dependable, and maintenance free during duration of testing.

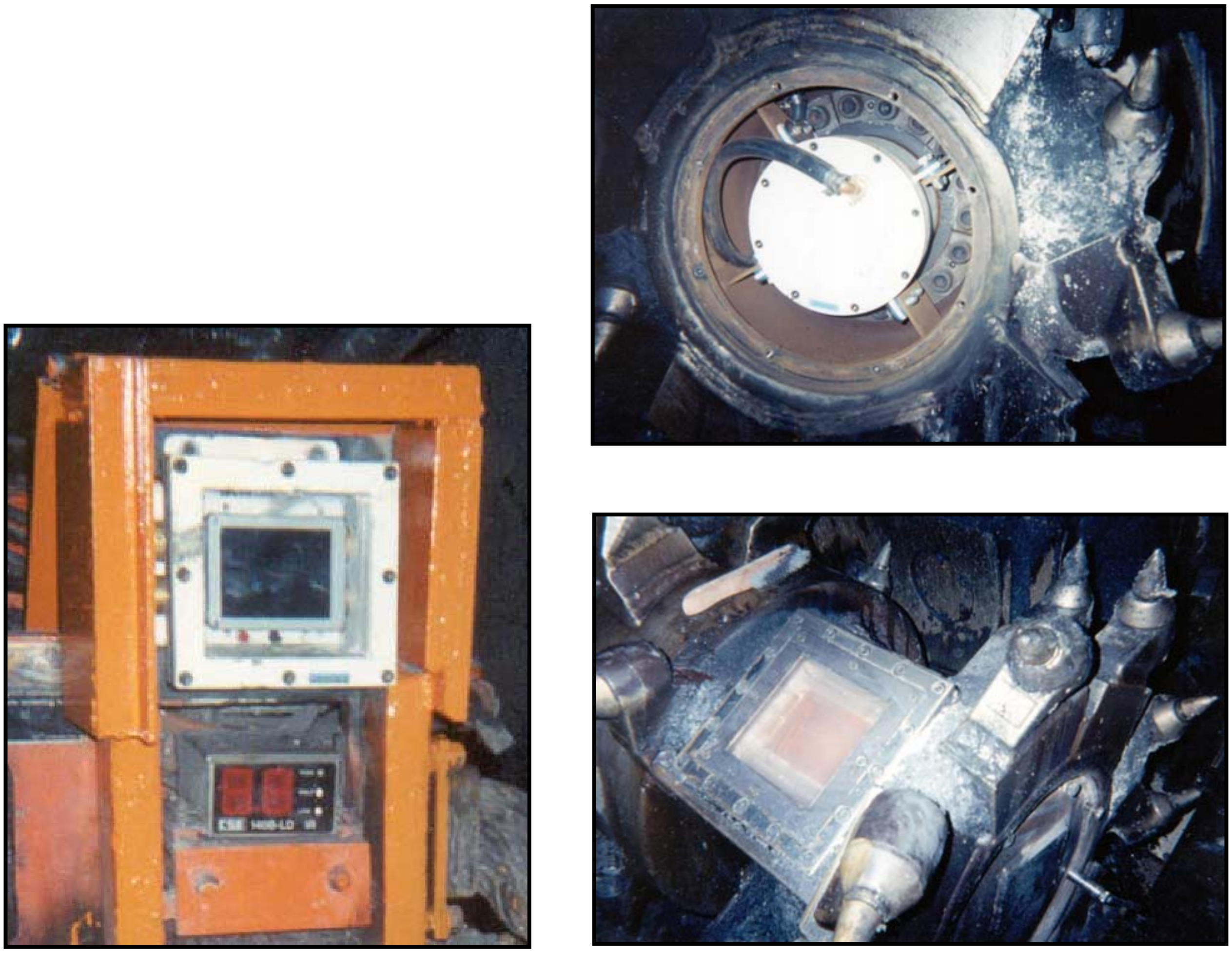

Figure 1. *HS-CM system installed on a Joy 12CM12-10A and in use at Monterey Coal Company: HGU on the rear of the CM (left); Horizon Power Unit (HPU) generator within the cutter drum (upper right); Horizon Sensor Unit (HSU) on the surface of the cutter drum (lower right)*

HS Functionality

The system was checked and double-checked to ensure that all electrical and software functions were performing as intended. Several series of tests were conducted to verify performance on a modular and full-system level. The tests were conducted Tuesday and Wednesday, January 15 and 16, 2002. Highlights included:

- The measurement window was set up using the trigger LED to indicate Triggering Window position and stability. A data average of 3 created a 5–7 degree window at TDC and BDC; the window was stable.

- The Measurement Modes efficiently transitioned from Roof to Floor Modes when the cutter boom passed through mid-angle. Sump Depth and Forward Detector Modes were not tested.

- Data transmission and command timing were found to be stable and dependable. The location of the GUI aerial antenna proved sufficient for reception, but further experimentation may lead to the aerial being relocated back towards the GUI (if not completely inside).

- The power generator output proved stable and reliable with default torque on the detent clutch springs. Pendulum position was stable with no detent loss on start-up (identifiable by modem LED fluctuation and/or trigger LED through lens assembly).

- The Inclinometer angle proved stable and reliable. The boom was initialized at the horizontal and the inclinometer was positioned within its enclosure such that its output was at a null (0 V out in the ± 13-V range).

- GUI power reset timing was adequate. The GUI would reset itself during power trip, and flawless reboots were the norm. The AC diode did blow during a power surge in the section. While this may have protected our power board from damage, it also shorted the AC lines of the control box of the miner and wreaked havoc on the start-up circuitry of the mining machine. The burnt diode was removed to correct the short; additional testing should be done to determine better surge protection.

- The machine's dimensional parameters (boom length, drum diameter, drum speed, and inclinometer scale) were measured and entered into the Setup menu exactly. The measurements provided nearly perfect boom height/distance computation; therefore. the predicted mine height was accurate to within 1 inch.

- Resonant frequency and gain optimization was done once the HSU module was fully installed (battery cable and serial line routed through unpacked gland in lieu of generator cable). The resonant frequency was found to be 510 MHz at a gain setting of 16 dB.

The system functionality tests provided real-world proof that the system is performing as designed.

HS Sensitivity

Time was spent working on antenna sensitivity and resonant frequency during the Functional Testing phase and the calibration issues were worked out during the final testing day on Thursday, January 17, 2002. Highlights include:

- Water spray proved to be reconcilable and at this point water (low level) is not considered to be a problem. The resonant frequency of the antenna without water was 510.25 MHz under rotation (I=1000, Q=-500), with the water spray on the resonant frequency dropped to 509.75 MHz (I=400, Q=-2100) and showed the same range of I/Q sensitivity to air-gap reduction.

- Air-gap-based calibration spirals for the system were analogous to lab versions. Coal-horizon-based calibration spirals are being catalogued and analyzed, but visual inspection of calibration points implied a wide point-for-point variation (imperative for prediction stability).

HS Calibration

The best calibration results occurred when calibration points were stored immediately after coal perforation and clearance from the bit-picks. The miner operator could bump the drum up or down through the coal seam during a calibration sequence allowing the air gap to clear (taking less than a single rotation) and the sensor to see only the uncut coal horizon directly as opposed to a layer or random crushed and saturated coal chunks. This process may prove too difficult for an operator to perform on his own and more investigation should be done to develop alternate calibration processes/methods.

Maximum predicted depth was reduced from 24 inches to 12 inches. The mine is only interested in leaving 1 inch of uncut coal on the roof, so focus will be put on maximizing prediction stability for the lower thickness.

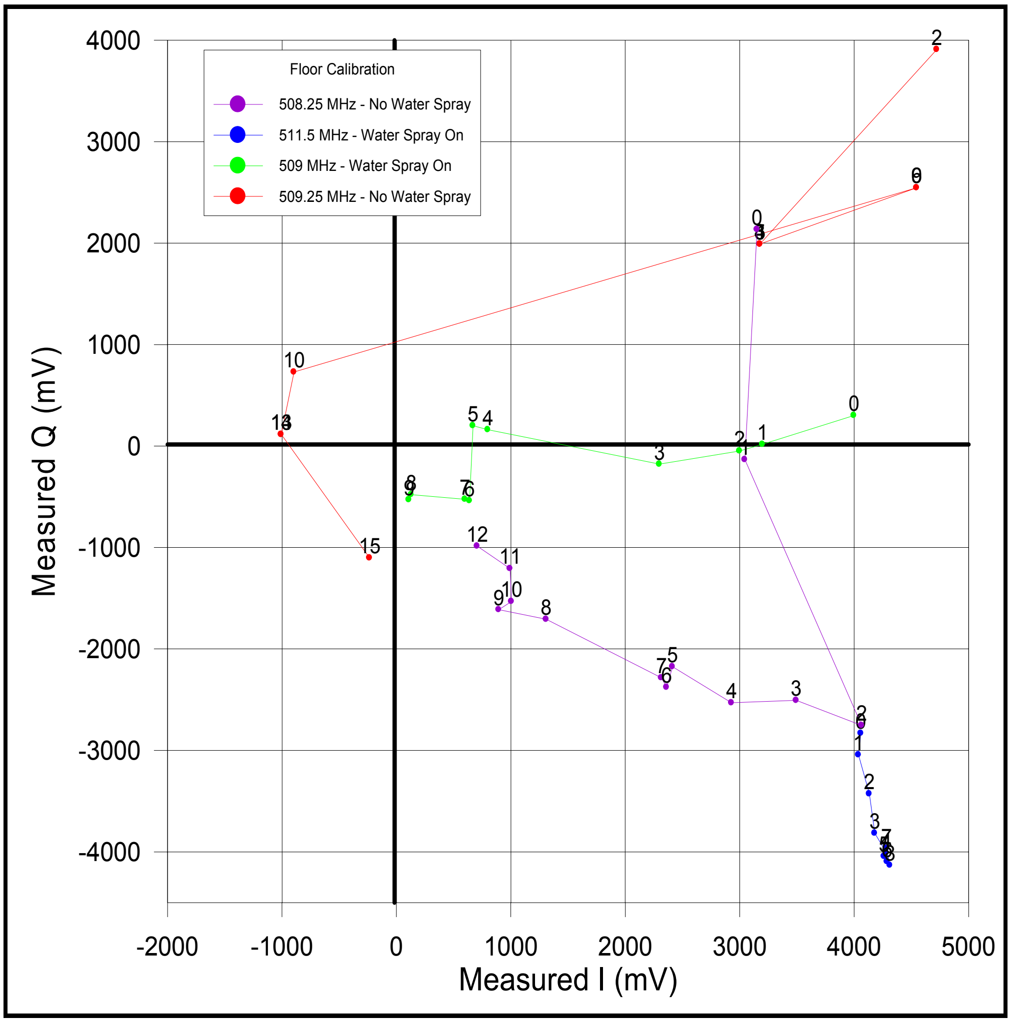

Figure 2. *A series of HS calibration curves under differing frequency settings and water conditions as recorded during floor cutting of the coal seam at Monterey Coal Company*

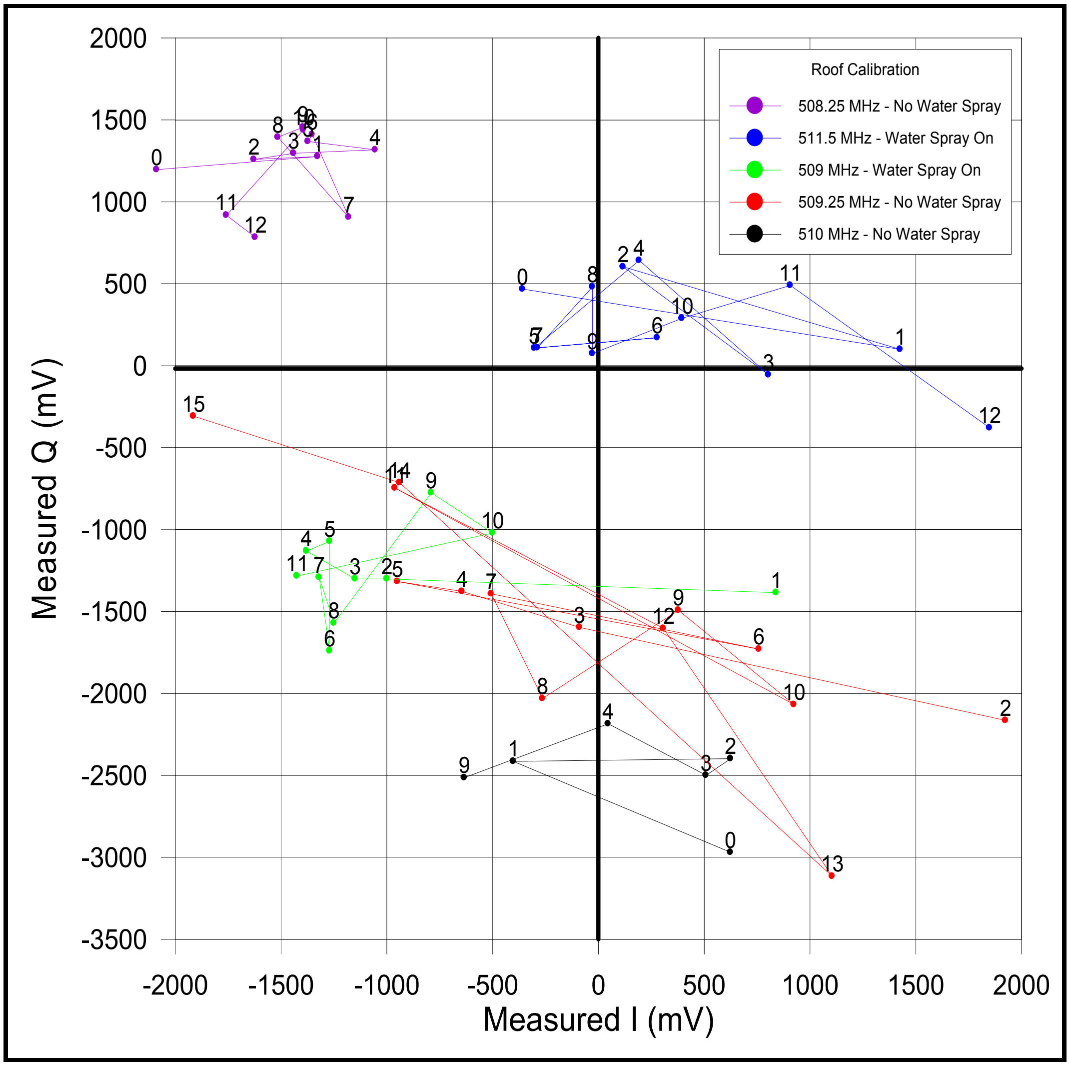

Figure 3. *A series of HS calibration curves under differing frequency settings and water conditions as recorded during floor cutting of the coal seam at Monterey Coal Company*

Mine Height Estimates

Mine height proved to be a critical tool for this particular mine at this point in their developmental sections. The coal seam is at present only 6-feet thick (and thinning inby), however, the section must maintain 7-foot 6-inch entries for machine clearance. Setting the GUI up to display mine height to the operator will have savings in time, bit replacement, and rock reject numbers. This 90-inch mine height was accurately predicted on the HS provided the body of the miner was relatively flat. The GUI graphics are being changed to indicate mine height in larger, easier-to-read font.

System Performance Test Plan

To test the prediction capabilities of the HS-CM system, a series of coal-cutting tests were designed which would allow uncut coal to be left in the roof or floor while logging thickness predictions over these areas. The actual thickness of the roof and floor coal could then be measured directly by hand for comparison to predicted values.

These tests were carried out in a section of the longwall panel gate roads that possessed only 5- to 6-foot coal thickness. Since mine height had to be a minimum of 7.5 feet, roof and floor coal had to be tested in different areas; roof coal was left uncut and bolted in one entry (required floor rock to be removed), while floor coal was left in another (requiring roof rock to be removed). The procedure for measuring coal is separated into the following roof and floor tests.

Floor Prediction/Verification Process per Cut

- While at the face, establish Floor Rock position, place drum on floor rock and initialize boom
- Sump into top of face, cut down while performing HS floor calibration procedure
- Clean the face up after cut and position drum at a height above the floor that will leave the desired uncut coal thickness
- Sump into the face at this point to leave floor coal. Log the thickness prediction and mark the rib for start position (0).
- Complete sump up to minimum mine height (7.5 feet), Log Total Mine Height Reading at this position.
- Continue forward cut with 3 to 4-foot sump depths to normal distance (20–25 feet). Use floor predictions to limit floor cut to the desired range.
- For each sump: mark position and reading # on rib; log forward position, log thickness prediction, and total mine height.
- Log the calibration table when finished with cut.
- Repeat all measurement logs for slab side as well.
- Remove miner from entry and complete roof bolting. Note any roof-fall thickness or floor disruption during bolting.
- Drill/pick through the uncut coal to the floor rock at the positions held by the drum during data logging (center and left side of the entry).
- Measure coal thickness for addition to table and comparison to predictions.

A single 25-foot cut was done to measure uncut floor coal and coal thickness ranged from 1 to 10 inches.

Roof Prediction/Verification Process per Cut

- While at the face, establish roof rock position, place drum on roof rock and initialize boom.
- Sump into center of face, cut up while performing HS roof calibration procedure.
- Clean the face up after cut and position drum at a height below the roof that will leave the desired uncut coal thickness.
- Sump into the face at this point to leave roof coal. Log the thickness prediction and mark the rib for start position (0).
- Complete sump down to minimum mine height (7.5 feet), Log Total Mine Height Reading at this position.
- Continue forward cut with 3 to 4-foot sump depths to normal distance (20–25 feet). Use roof predictions to limit floor cut to the desired range.
- Log the calibration table when finished with cut.
- Repeat all measurement logs for slab side as well.
- Remove miner from entry and complete roof bolting. Note any roof-fall thickness or floor disruption during bolting.
- Drill/pick thru the uncut coal to the floor rock at the positions held by the drum during data logging (center and left side of the entry).
- Measure coal thickness for addition to table and comparison to predictions.

A total of four (4) 25-foot cuts were done to measure uncut roof coal and coal thickness ranged from 2 to 10 inches.

Data Collection

For each sump the following table was used to record cutter head position and HS prediction measurements:

Cut #: 3 Uncut Coal Type: Roof Desired Thickness: <12" Test Location: Entry 3, XC-53 Operator Name: Gary				Operating Freq: 511.5 MHz Machine: 44"diam, 162" boom, 60 RPM Floor Init. Angle: -6.7 Roof Init. Angle: +10.3 Position of head: Slab side			
Sump #	Distance (feet)	Thickness Prediction	Prediction Stability	Sensitivity (mV)	Mine Height Prediction	Actual Coal Thickness	Actual Mine Height
1	0	12"	12, 10	400	7'5"	11"	7'5"
2	2	12"	12, 10	400	7'5"	11.5"	7'4"
3	8	5"	5,6	500	7'9"	4"	7'10"
4	10	2"	2	540	7'11"	3"	7'11"
5	14	1"	1	540	8'1"	3"	8'
6	17	2"	2,3	540	8'1"	2"	8'1"
7	21	3"	3	540	8'1"	2"	8'
8	25	3"	3	540	8'1"	2"	8'1"

Results and Discussion

Five (5) total cuts were performed using the test plan described: four (4) uncut roof coal sections and one (1) uncut floor coal section. The data gathered was used to generate the five (5) bar graphs (Figures 4 through 8) showing predicted coal thickness versus actual thickness. The actual coal thickness, as well as mine height, listed in the data tables (and plots) are average estimates made with a tape measure. The exact position of a planar boundary in the seam is often difficult to delineate due to irregularities in the cut (scoured) surface.

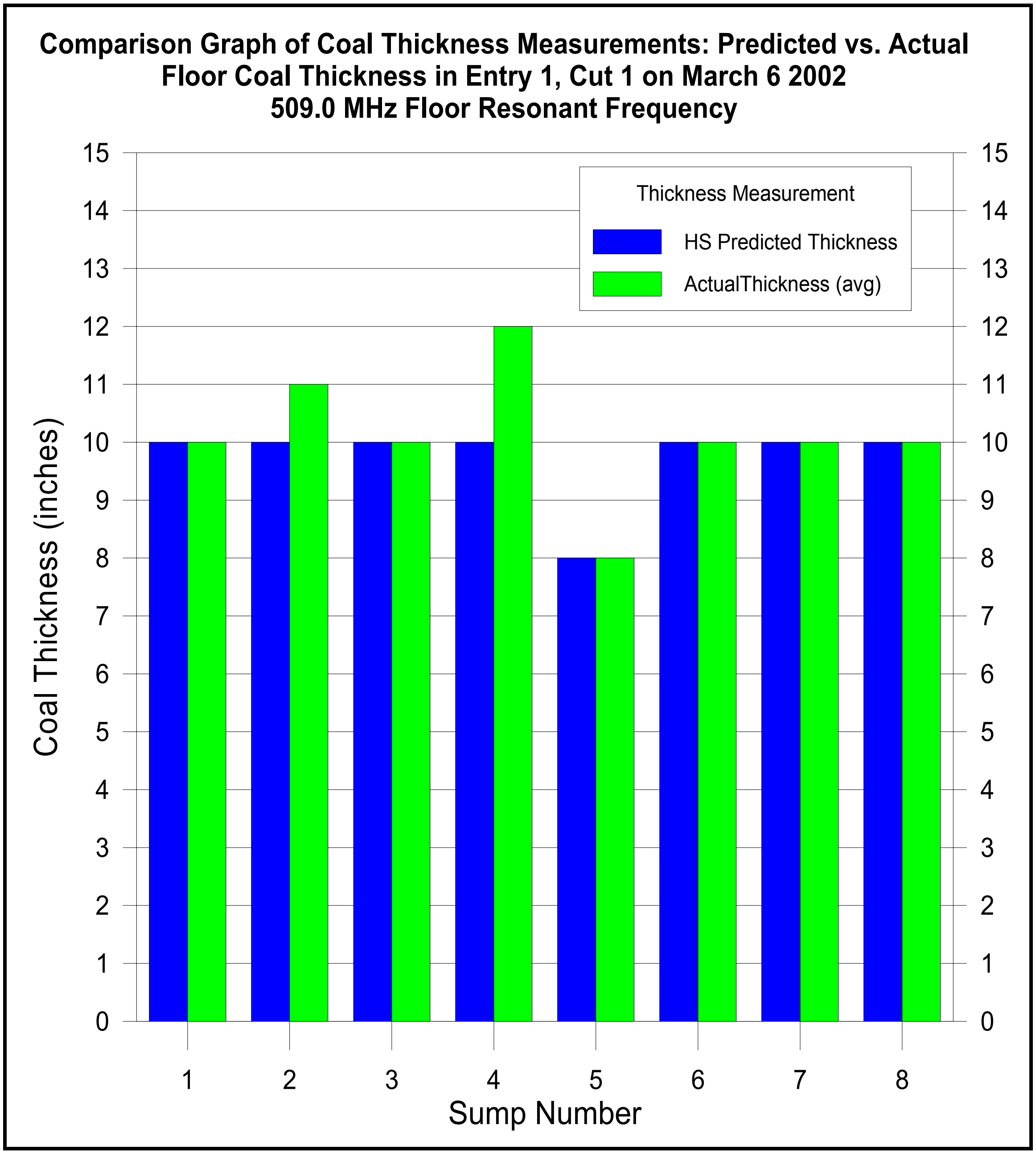

Figure 4. *Uncut floor coal prediction – Entry 1, Cut 1*

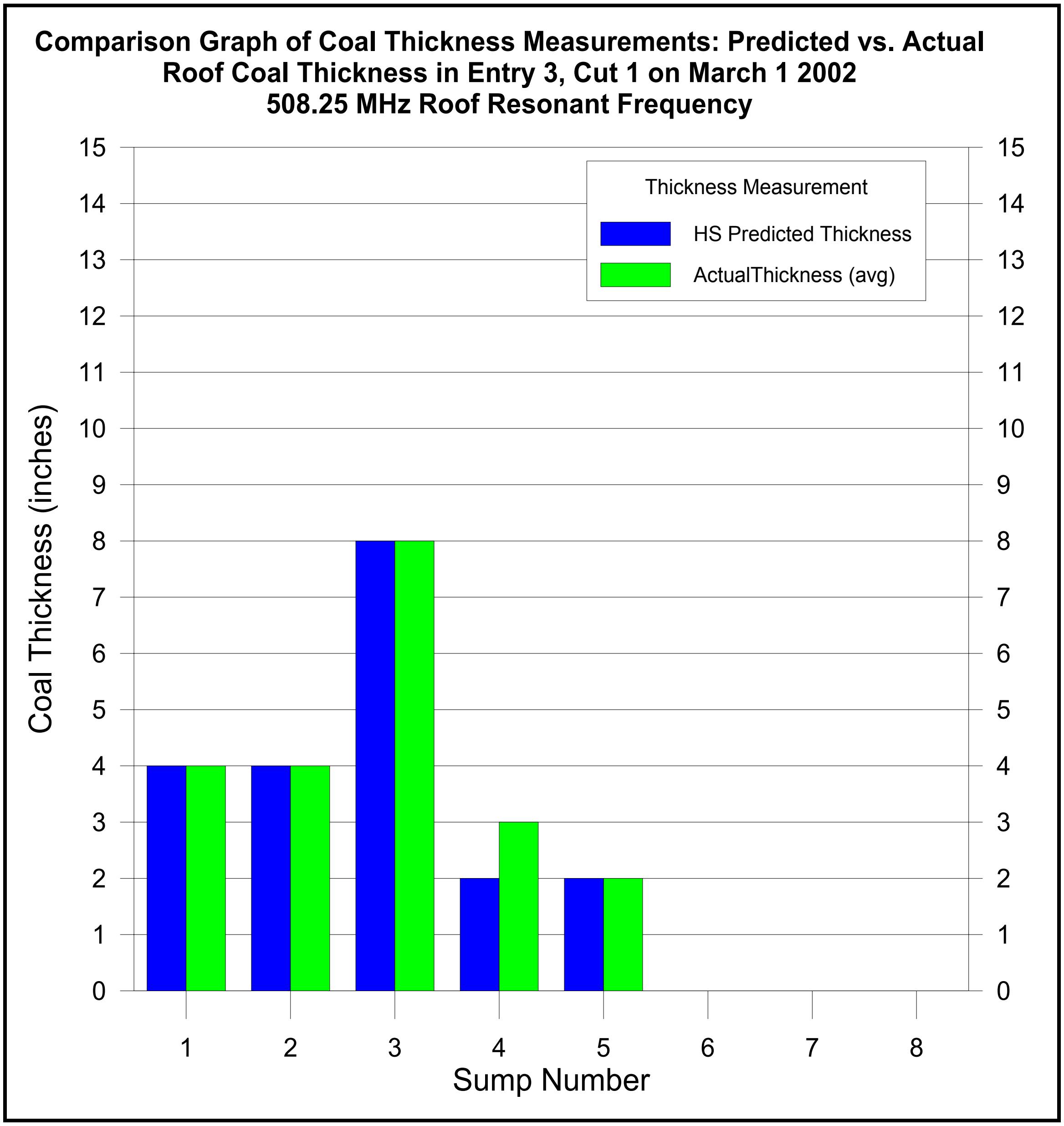

Figure 5. *Uncut floor coal prediction – Entry 3, Cut 1*

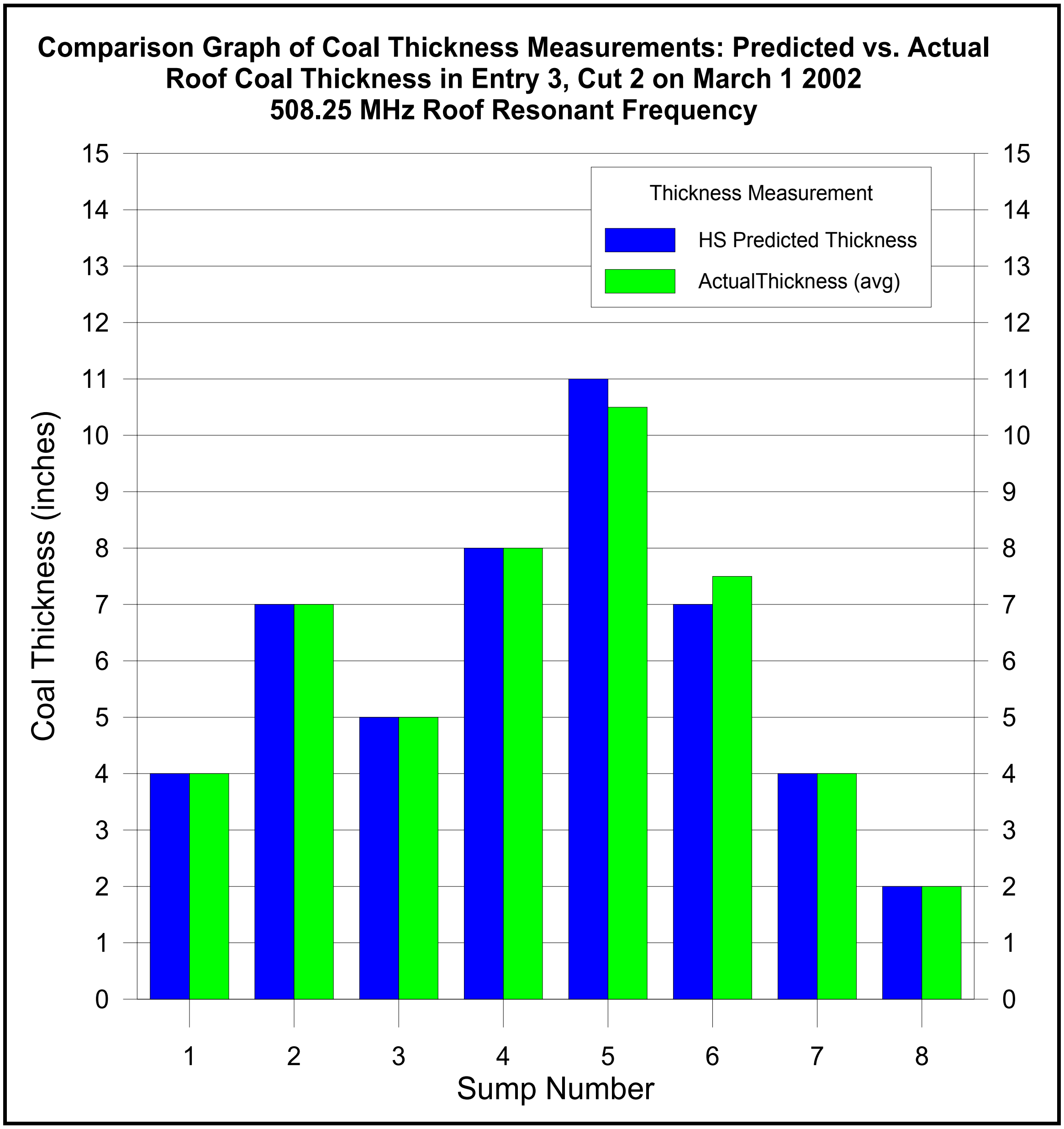

Figure 6. *Uncut floor coal prediction – Entry 3, Cut 2*

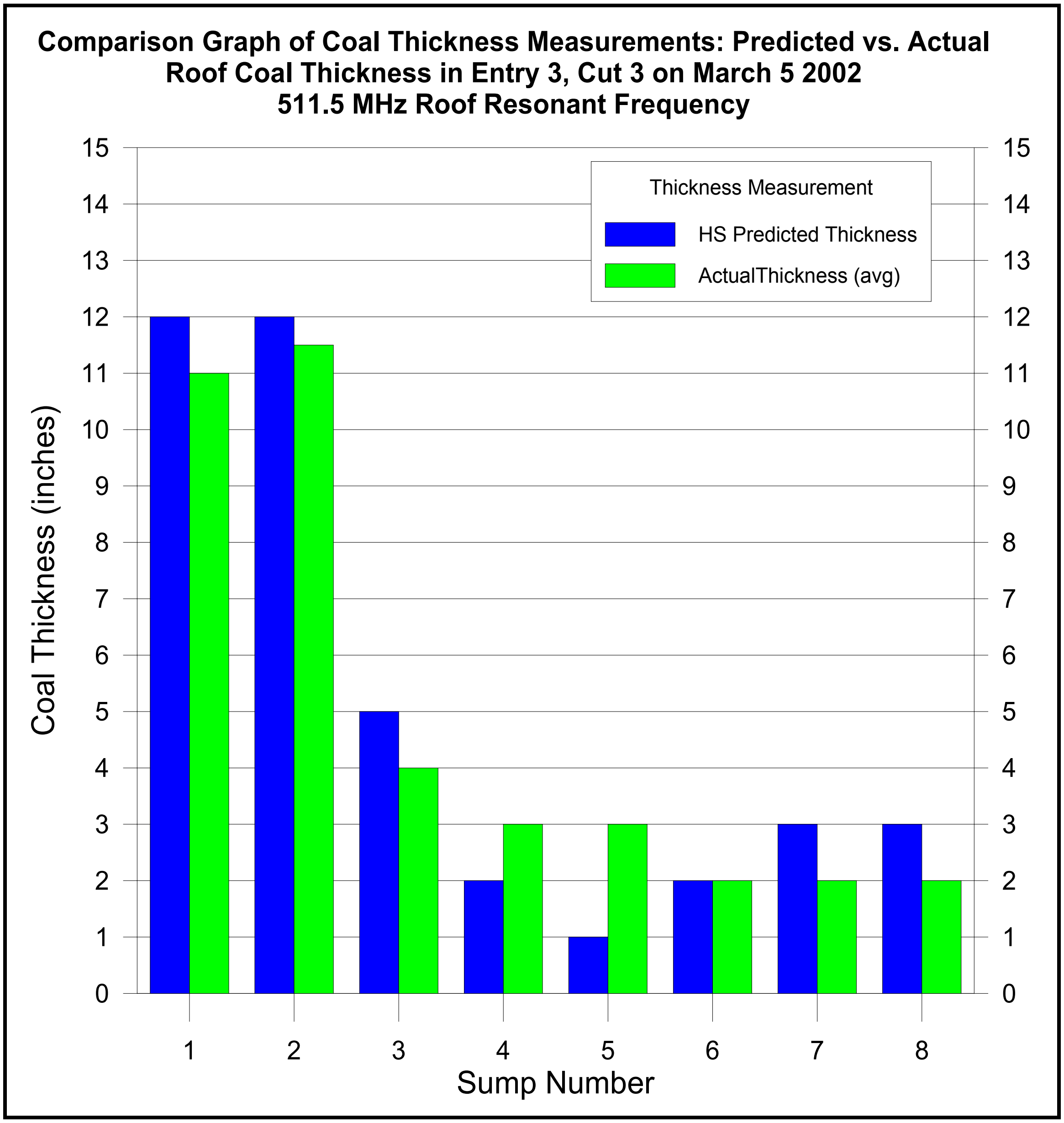

Figure 7. *Uncut floor coal prediction – Entry 3, Cut 3*

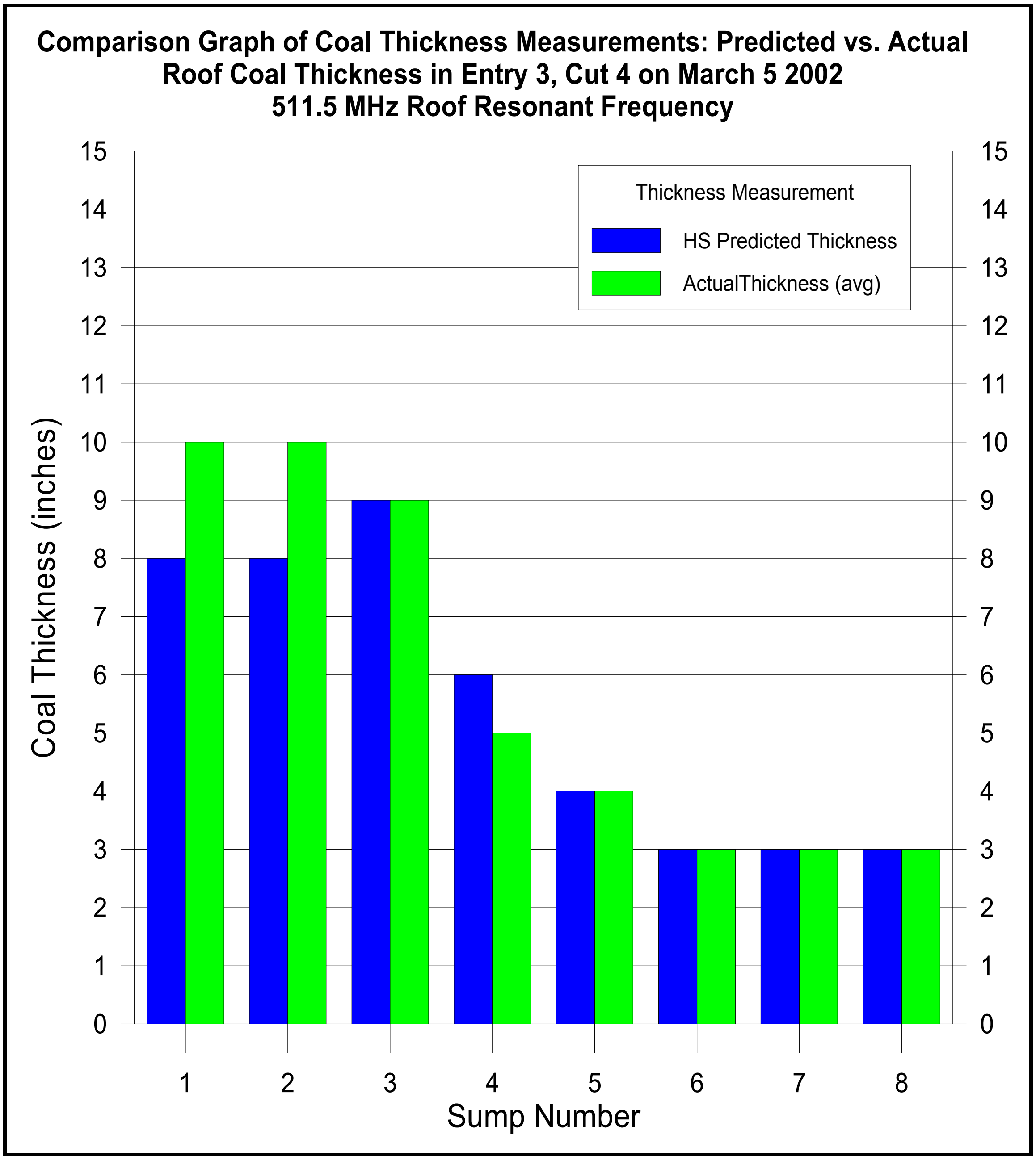

Figure 8. *Uncut floor coal prediction – Entry 3, Cut 4*

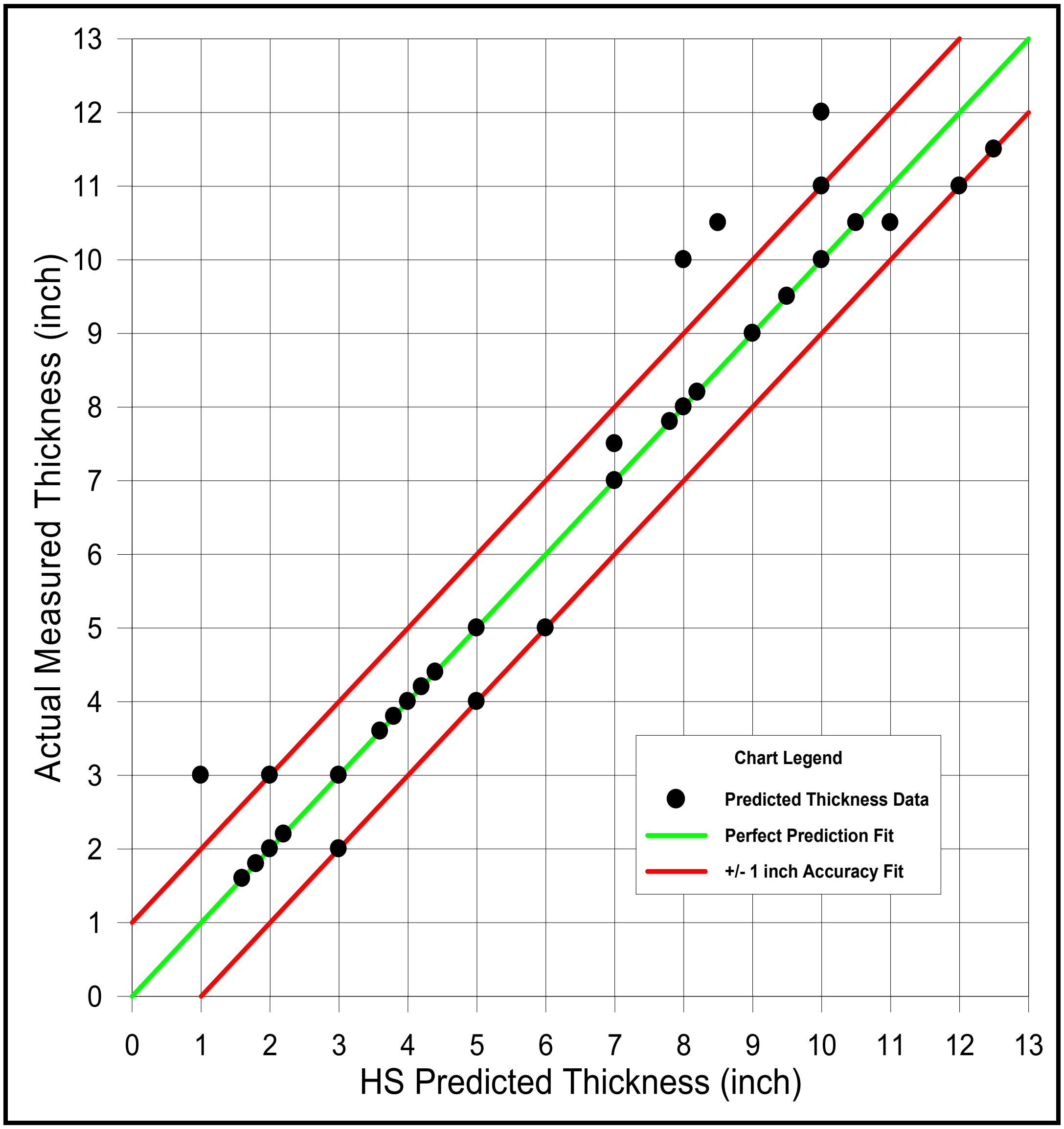

Figure 9. *HS prediction accuracy*

Mine Height Measurements

Mine height predictions were not plotted since there was very little variation from the actual height (± 1 inch over an 8-foot span). Both height indicators (Total Height and Current Height) perform will high precision and good stability.

Mining and Operations History

Table of CM Mining History

Dates	1/12 to 2/2	2/3 to 2/8	2/9 to 3/8	3/9 to 4/9	3 Month Total
Operational Hours	174	55	254		
Raw Coal Cut	29606	8575	31670		
Clean Coal Cut	19541	5680	21924		
Entry Footage Cut	3959	1260	4781		

Conclusions

Horizon Sensor testing at Monterey Coal Company has shown viability of HS technology in a real-world environment. The HS-3 technology is now on Sasol's 12CM-31 and on EXXON-MOBIL's 12CM-12 machines and has survived nearly 9 months (to date) with minimal system damage due to abrasive wear and impact.

RAMP Approval for underground HS-CM installation and testing has been fast-tracked for most applications.

In-mine prediction testing at Monterey indicates HS system capabilities are within advertised sensitivity and detection parameters. Monitoring of the system at this site is ongoing.

Additional installation and testing programs have begun at other mines and will be reported during the next quarter.

The major program milestones to date are on-schedule and include:

Complete	***Date-Percent Completed***
Completed U.S. MSHA Certification	September 15 – 100%
Completed Australian IEC Certification	March 31 – 100%
U.S. In-mine CM Test (EXXON)	January 31 – 100%
U.S. Production CM (EXXON)	March 31 – 100%
U.S. Production Borer Miner (FMC Trona)	March 25 – 100%
U.S. Production CM (Twentymile Coal)	March 31 – 100%
U.S. Longwall Shearer Test (EXXON)	May 28 – 75%
U.S. Production Longwall Shearer (FMC Trona)	May 31 – 50%
U.S. Production Shearer (Twentymile Coal)	May 31 – 50%
U.S. Production Shearer (Blue Mountain Energy)	May 31 – 50%
U.S. Production Shearer (Ohio Valley Coal)	July 31 – 50%

Other Key Program Accomplishments:

- Field Installation Approval (RAMP) complete for EXXON 12CM-12 (and all 2G approved CM models)

- Horizon Sensor (HS-CM) installed at Twentymile Coal (RAG) (Figure 10)

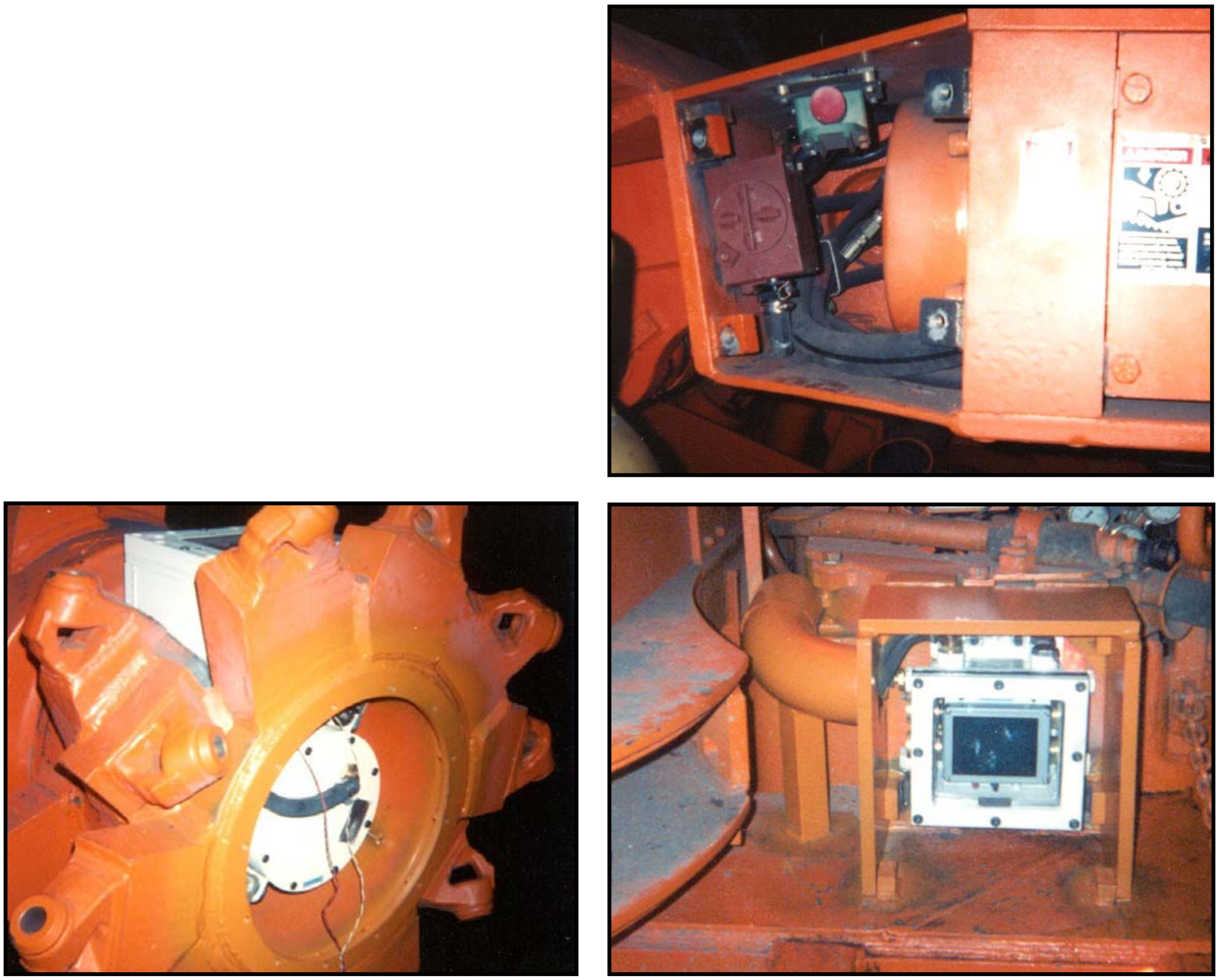

Figure 10. *HS-CM installed on Twentymile Coal 12CM-12*

- Horizon Sensor Longwall (HS-LW) system developed

- Horizon Sensor Bore Miner (HS-BM) system developed and installed (Figure 11)

- Field Installation Approval (RAMP) under way for Marietta Miners, Joy Shearers, and DBT Shearers

- HS-LW installations under way with Monterey (EXXON), Deserado (BME), FMC, and Twentymile (RAG) through March 2002
- HS-CM and/or HS-LW installations pending with CONSOL, SUFCO, Ohio Valley Coal, and BHP through June 2002

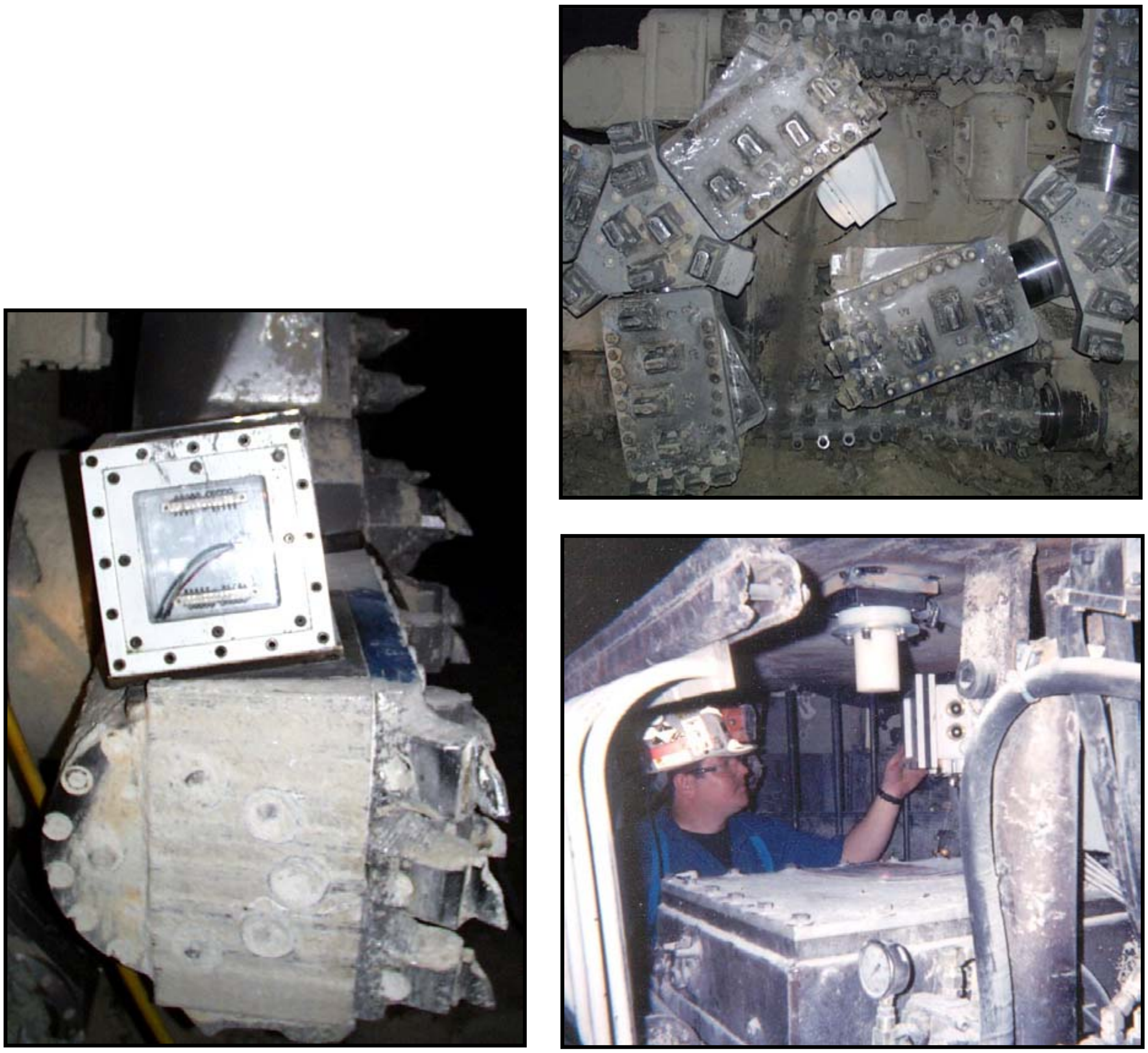

Figure 11. *HS-BM installed on FMC Marietta Bore Miner*

Project Recognition

- Trade show booth featuring HS-2 at the 2002 Annual Meeting of the Society for Mining, Metallurgy & Exploration (SME)
- *World Coal* Magazine feature article May 2002, "Breakthrough Technology"

Project Assessment

(internal DOE use only)

- Open issues and/or problems
  - None noted
- Overall assessment
  - Off to a good start

References

None