FIELD-SCALE VOID DETECTON IN COAL PILES USING RESISTIVITY IMAGING

Rene Rodriguez, Henry Rodriguez, and Michael Lhamond
GECHO Exploration, Lexington, KY USA

Jeffrey C. Johnson and Steve Iverson
Spokane Research Laboratory, National Institute for Occupational Safety and Health, Spokane, WA USA

ABSTRACT: To reduce fatalities resulting from personnel falling into voids formed above feeders in coal piles, the National Institute for Occupational Safety and Health at the Spokane Research Laboratory established a project to monitor coal surge piles to detect the formation of voids. A resistivity imaging method has been developed by GECOH Exploration, of Lexington, KY, in which a geophysical technique known as vertical electrical sounding (VES) is used to scan for these voids. VES operates by measuring the electrical field produced by a current in the ground at the bottom of the coal pile. This paper summarizes the results obtained from a field-scale test and shows that mapping voids within a coal pile is possible.

1. INTRODUCTION

Geophysicists have used a technique called vertical electrical sounding (VES) for more than 100 years to study subsurface structures in the earth. GECHO, Inc., Lexington, KY, has developed a technique using VES [1] that concentrates electrical energy above the ground surface within a coal pile. An electric current is supplied to a uniform grid of electrodes installed at the base of a coal pile before the pile is constructed. The electrodes are made from steel reinforcement bars, and the attachment wires are sealed and insulated from the ground. The insulation prevents the electric current from traveling underground and directs it toward the top of the coal pile. The current induces an electrical field whose characteristics are highly dependent on layer composition, geometry, and moisture content of the coal pile. A strong contrast in resistivity between the air and the coal will delineate the air-coal interface and identify the presence of a void inside a coal pile, which can then be mapped.

2. FIELD EXPERIMENT

The field experiment consisted of creating 15 grid lines, labeled L1 to L15, each containing 24 electrodes. The uniform 24 by 15 grid system made up a total of 360 electrodes. Each electrode was spaced 0.3 m (1 ft) apart over a total area of 33 m^2 (360 ft^2). The electrodes were sealed inside a short length of 1.3 cm (0.5 in) in diameter polyvinyl chloride (PVC) pipe and secured to a 2- by 4- in wood frame.

VES measurements were taken by scanning each grid line. For this small coal pile, the electrical energy was suppled by a standard 12-V, lead-acid auto battery. A plastic tarp was used as a ground insulator to prevent the electric current from discharging into the ground. To simulate a void inside the coal pile, plastic barrels were placed in the pile during its formation. Each plastic barrel was perforated with a large number of small holes, which allowed moisture in the coal pile to collect in the barrels. Figures 1 through 9 show the field layout and instrument set-up.

The scanner is connected to an auto battery, a ABEM 300-C geoelectrical resistivity instrument, and a laptop computer. Resistivity measurements from the scanner are transmitted to a computer where software reduces the data, corrects it, and obtains the inversion model for each sounding. The inversion of each VES shows the structure of the coal pile above the electrode. By combining a number of soundings along a grid line, a cross section of the coal pile is obtained.

Figure 1.—Initial view of site, Lexington, KY.

Figure 2.—Assembly of 1.3 cm (0.5 in) in diameter PVC pipe inserted into 2- by 4-in studs.

Figure 3.—Completed wood frame with PVC pipe holders.

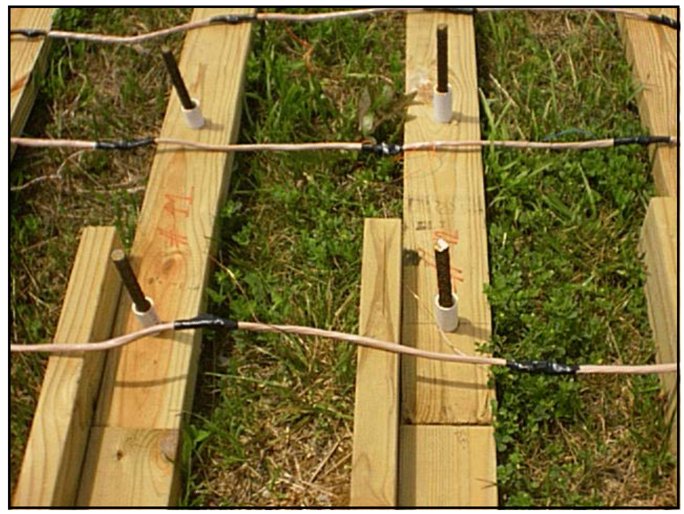

Figure 4.—Close-up of rebar electrodes sealed in plastic pipe and attached to electric cable.

Figure 5.—Completed grid showing insulator plastic tarp ground cover, frame reinforced with railroad ties, and some of 15 electric cable lines

Figure 6.—First layer of coal covering electrode grid and first perforated plastic barrel being covered horizontally on coal pile.

Figure 7.—Second perforated plastic barrel being covered with coal.

Figure 8.—Final coal pile and van containing data acquisition system.

Figure 9.—Data acquisition system with electrode scanner (upper right), ABEM 300-C geoelectrical resistivity instrument (upper middle), auto battery (upper left), and laptop computer (lower middle).

3. DATA AND RESULTS USING THE RESISTIVITY IMAGING METHOD

Measurements are obtained for each grid line and transferred to the computer via a 232-C interface. The system takes 23 measurements, one less than the number of electrodes in a line, along each of the 15 lines. A computer program directs the scanner to sweep the VES readings systematically in a pre-established order that maximizes the effectiveness of the electrode array. The sweeping program compounds readings using pole-dipole readings at the edges of the grid and Schlumberger readings in the middle. Tests conducted at common points showed errors of 1% or less. Readings taken from each sweep are stored in separate files. The readings are corrected for geometric factors associated with each electrode arrangement, and an apparent resistivity is calculated for each electrode. The apparent resistivity values are input to an inversion program to compute vertical soundings and determine coal pile height above each electrode. After all the vertical soundings are made, the data points are used to prepare contour maps.

To determine whether a void is present, an empirical relationship is used to estimate coal pile density from the total resistivity observed in each VES. The 23 VES data points are inverted, and the coal structure is imaged to produce a resistivity pseudo-section that shows the structure of the coal pile for a given cross section. Figures 10, 11, and 12 show three of the cross sections. Figure 10 shows the inverted VES data points along line L-6 and the void produced by the vertical buried barrel. Figure 11 shows two voids formed by the vertical and horizontal barrels buried along line L-7. Figure 12 shows the horizontal barrel buried along line L-8.

Figure 13 is a plan view at an elevation of 1.1 m (3.5 ft) above the coal pile base. Note the two voids. The contouring program SURFER is used to produce the coal pile height contours shown in Figure 14. These contours can be used to calculate the total volume of coal in the pile.

4. CONCLUSIONS

The field experiment showed that voids in coal piles can be detected using the resistivity imaging method developed by GECOH. This method can be used to map not only coal pile voids, but also the volume of the entire coal pile and density contrasts associated with moisture content. The images of the plastic

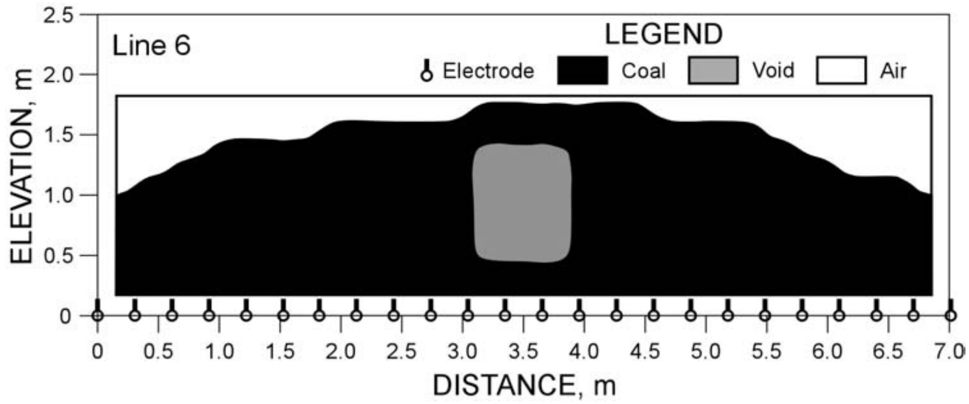

Figure 10.—Inverted VES data along cross section L-6 showing vertical buried barrel.

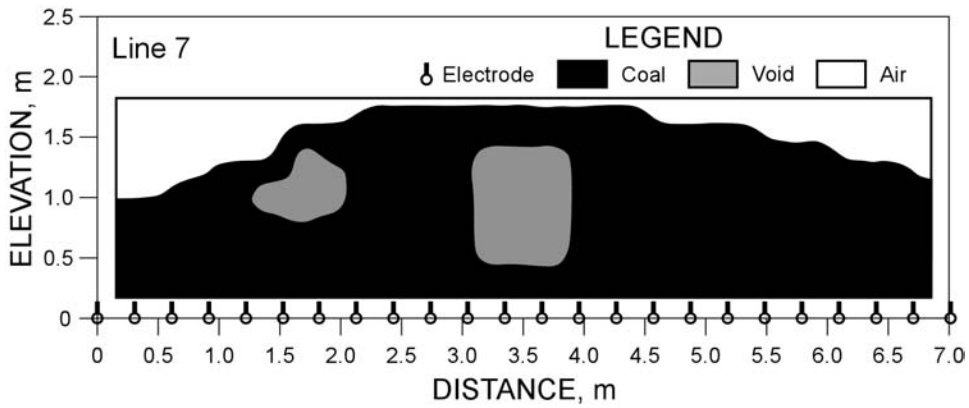

Figure 11.—Inverted VES data along cross section L-7 showing both vertical and horizontal buried barrels.

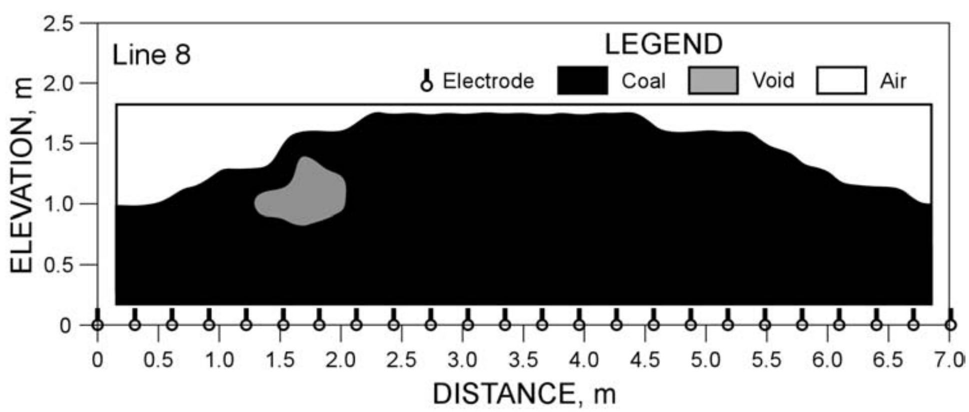

Figure 12.—Inverted VES data along cross section L-8 showing horizontal buried barrel.

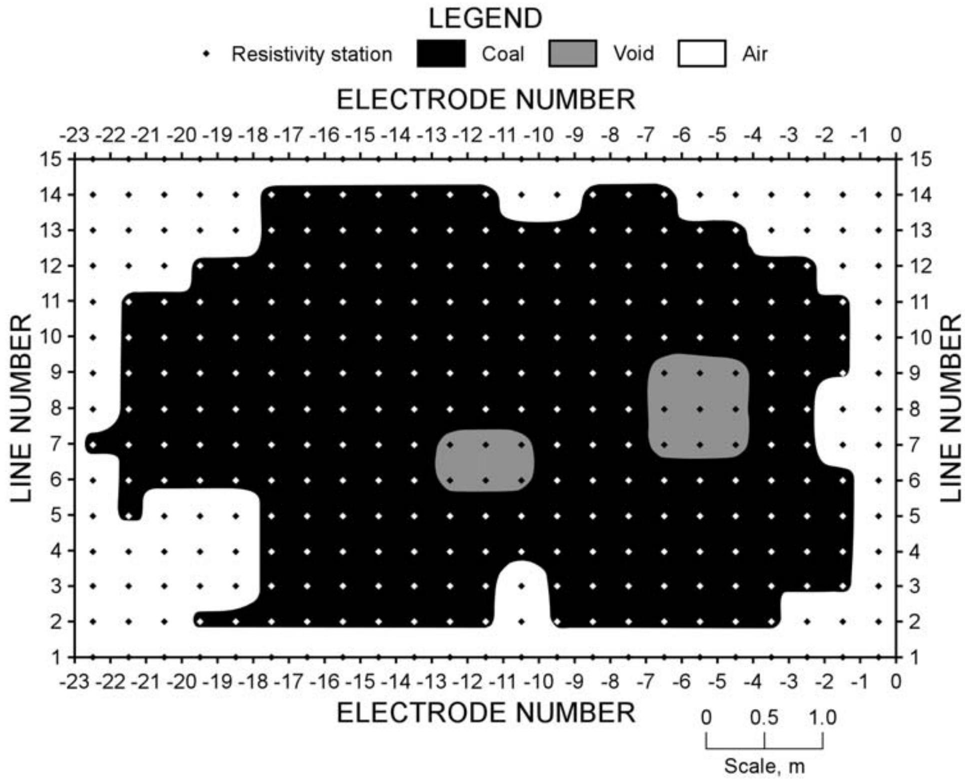

Figure 13.—Plan view map of RIM data at elevation of 1.1 m (3.5 ft) above coal pile base.

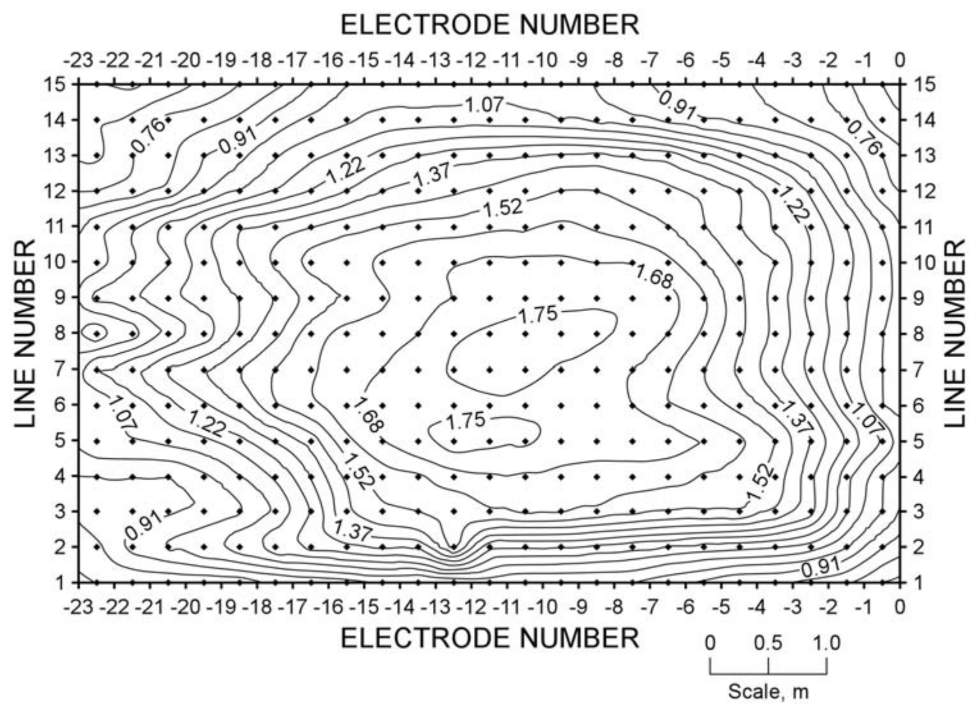

Figure 14.—Coal pile height contours created with SURFER program.

barrels are about 15% larger than actual size. The larger size may be partly explained by the area of high humidity formed in the plastic barrels. Experimental errors in this experiment are still within an acceptable degree of accuracy compared to methods in which coal piles are mapped using photographs and topographic imaging.

REFERENCE

1. Rodriguez, R., and H. Rodriguez. 1999. Real-time monitoring of rock-pile volumes by electrical resistivity. *The Leading Edge*, Vol. 18, No. 12, pp 1398-1401.