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VENTILATION IMPROVEMENT IN LONGWALL RECOVERY FACE USING CONVERGENCE TRANSDUCERS - CASE STUDY

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ABSTRACT

The FMC Westvaco Trona Mine is located near Green River, Wyoming and has an annual production of 4.5M tons. Trona is an evaporite mineral that is processed into several products, mostly soda ash. The underground mine has two active development panels and one longwall (LW) panel. The mining horizon is about 500m below surface and the surrounding strata liberates methane. Three surface-based, blowing fans provide ventilation air as a positive pressure system.

The mine operates a 225m long LW face, built by Joy Mining Machinery. Headgate and Tailgate developments are driven with four entries. The recovery room, at the end of each panel, is 8m wide with three access chutes. Additional recovery room support comes for concrete blocks used with a center to center spacing of 1.5m. As the LW enters this pre-driven recovery room there are notable responses and shifting ground stresses.

This study was undertaken to measure the ground response using seven vibrating wire displacement transducers. These devices were used to monitor the convergence as the LW approached the recovery room. The methane concentration in the air ventilating the recovery room was also monitored. The correlation between convergence and gas liberation was then studied. The results show that the convergence varies from 0.1m to 0.25m along the length of the recovery room. Ventilating the recovery room becomes critical as methane is liberated from oil shale as the more plastic floor material is disrupted. Appropriate methods are employed to ventilate the recovery room.

INTRODUCTION

FMC's Westvaco mine in Green River, Wyoming is the world's largest underground trona mine and producer of soda ash. The mine hoists 4.5 million tons of trona to the nearby plant where it is refined in one of eight processing plants. The mine is relatively shallow and categorized as a gassy mine (MSHA Class III). Currently the mine is being ventilated with about 50 m^3/s. The air is forced into the mine through three shafts with each fitted with a vane axial Jeffrey 8 HU-117 (2 stage Aerodyne) surface fan. There are six exhaust shafts. The mine has two active continuous miners and one longwall section. The room and pillar panels are being driven by bore miner continuous miner machines (Marrietta Miners). These panels are comprised of four rooms with adjoining crosscuts. The amount of 50 m^3/s is desired to ventilate the LW face, This is measured regularly at number 110 shield on the longwall face. This quantity is well above the minimum required by law however high flow rates are desired to control dust, dilute methane and make for a comfortable work environment. Approximately 50 m^3/s is required to maintain ventilation for active faces. The air at the south of the mine is being exhausted from Number 9, 6 and 4 Shafts. Number 4 Shaft does not play an important role due to its long distance (9 km) from active mining sections).

As floor is subject to heave and fracturing as identified by Samuelson and Crookes, 1891, it is relieved from pressures from overhead strata. This disruption creates a means to discharge trapped methane gas upwards especially along lines of dislocation. LW mining creates abutment stress zones around the excavated panel. There are several forms of floor heave in an underground opening. Although situations exist where floor extrusion or buckling can be positively identified, a great majority of the cases are due to a combination of the two. Matsui, 1994 claims that floor penetration by standing support legs aggravates a floor heave problem.

Once the LW approaches to the end of the panel, it breaks into the recovery face. In a structured sequence seven displacement transducers were used to monitor convergence rate throughout the recovery face. This semi-remote approach improved the safety of employees tasked with monitoring the operation as the LW entered the recovery room.

LONGWALL VENTILATION

The output from two of the three blowing, surface fans provides ventilation for the LW headgate. This ventilation air reaches the LW face through the headgate entries and leaves the LW via the tailgate entries. The headgate and tailgate are each driven with four parallel entries connected with crosscuts. Their air enters the mine's bleeder ventilation system coursing air from the LW area to the exhaust shafts. The intake air passes along the LW face and splits at the tailgate. Depending on local conditions, a majority of this flow enters the tailgate and makes its way to the shaft. The balance of the face air travels through the bleeder entries to exhaust out a shaft (Figure 1). All four headgate entries are used to deliver the intake air to the LW face. Two of the entries are contained on the boundary of the longwall block and those two entries are lost as the LW retreats toward the recovery room. There is a "zero" room that has two purposes. It is used as an additional air course to ventilate the face. More importantly it facilitates access as the maintenance crews can better access and service the parked shearer at the face.

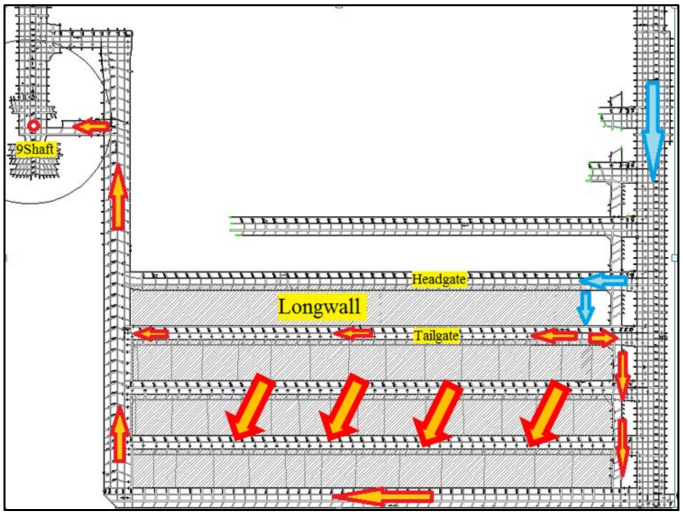

Figure 1. LW Ventilation Network.

The recovery face is ventilated as the air flows through the recovery face from the headgate to the tailgate. Figure two shows the ventilation layout at the LW face and the recovery face. A total amount of 50m^3/s enters the LW block with pproximately 5m^3/s regulated to ventilate the recovery face and the rest to the LW face. Approximately 500 concrete block sets (cribs) were used to support the recovery room entry. Each crib set consists of two concrete blocks, capped with wood blocks and/or wedges. Several different types of bolts were used to support the recovery room.

As the LW approached the panel's end, the production schedule was modified so trona was produced around the clock. This schedule allowed the LW to enter the recovery room at a more rapid pace as ground conditions deteriorate as time passes. Two active Bore Miner panels and associated set-up face and recovery room are all areas that need to be ventilated. The ventilation can be challenging as the LW face liberates gas during operation. The LW tailgate is cribbed using concrete blocks with spacing of 3m. These cribs keep the tailgate entry open to allow for easy access for the face air to of the bleeder system. This cribbing also preserves access for ventilation air to the gob area behind the LW face. It was observed on a number occasions that if one of the two, open tailgate entries fails then the single entry can still be sufficient to ventilate the gob area. If both entries were to fail behind the LW face the face air will travel through and around the previous panel gobs to 9 Shaft.

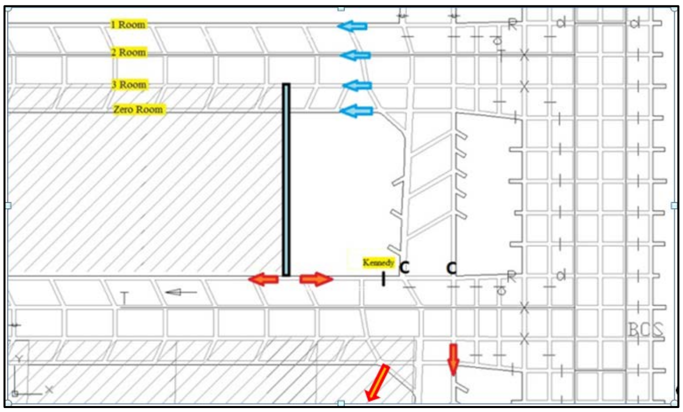

Figure 2. Recovery face ventilation layout.

CONVERGENCE MONITORING

A convergence monitoring system was installed in the recovery room. Seven Geokon convergence meters (displacement transducers) were installed in the recovery room at regular intervals and these meters were used to monitor closure at the recovery room as the LW approached and entered.

Each transducer is comprised of a spring-tensioned transducer, turnbuckle, connecting rod (graphite), rod clamp, and a pair of stainless steel eyebolts. The transducers have convergence range of 300mm with the resolution of 0.025% (full scale) and the accuracy of ±3mm, quoted by manufacturer.

A two twisted pair (4 conductors); 6mm foil shield cable was used to connect the transducers to an electronic datalogger. A handheld gas monitor was used to measure the gas concentrations during the test. The gas content was measured to provide insight into the correlation of convergence rate and methane liberation.

Convergence Transducer Installation

The transducers were custom built by the manufacturer to meet the height requirements of different stations. One or two turn buckles on the units were adjusted at installation to the local height of the entry. The eye hooks on the turn buckles were latched to the ear on the roof bolt plate. Bolts of 30cm length were used to attach anchor plates to the floor. A plumb bob was used to ensure alignment of the eye hooks on both plates. Figure 3 shows a bolt being drilled in the floor.

The monitoring base for the datalogger was located in the first LW face access chute. A communication cable was run from this base to each transducer. A total of 900m of cable was required for this project. The monitoring base was located approximately 15m outby to the recovery room. The intake air was flowing through the cross cut. Figure 4 shows location of transducers and monitoring base.

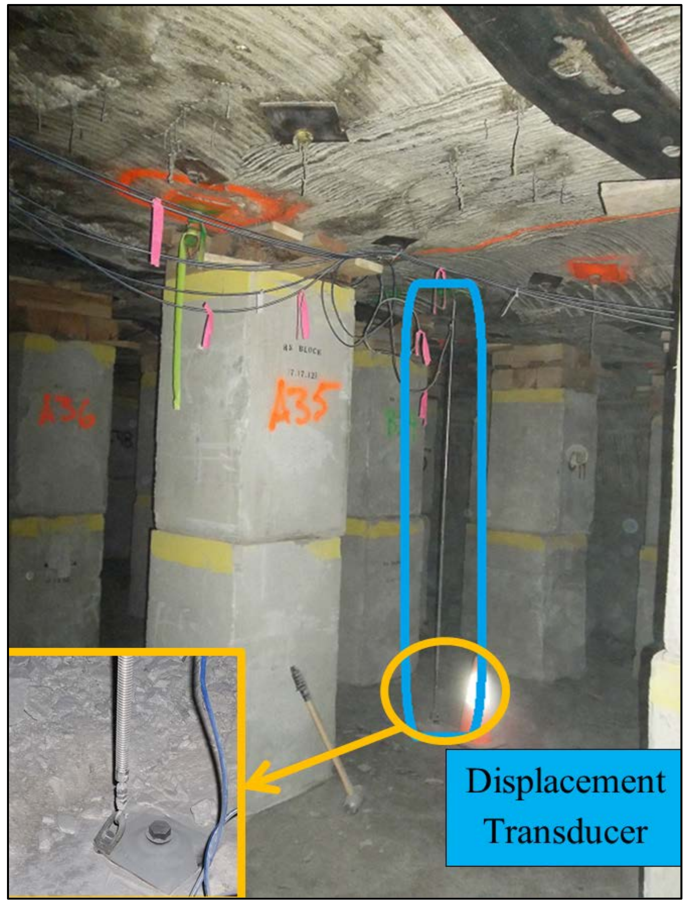

Figure 3. Convergence meter placement.

A 16-channel datalogger was used to read, adjust and store the data from the transducers. The meters were adjusted at installation using the turn buckles. The primary adjustment was important as there is a certain amount of tension needed on each transducer.

The tension, set correctly at installation puts the transducer in a state that allows for the maximum reading range. Figure 5 shows the monitoring base. The datalogger has capacity for 3500 array readings and runs on four D battery cells. Also the datalogger could draw power from an attached laptop.

Monitoring Plan

The transducers were placed throughout the recovery room when the LW was approximately 320m distance from the Recovery Face. Around-the-clock monitoring was conducted by FMC Mine Engineering Department employees when the LW was 35m inby the Recovery Room. During this period the roof and floor behavior, concrete blocks status (cracks, failure), wood cribs and wedges, were onserved. Methane concentration, headgate and tailgate location were all monitored. The transducer data was frequently downloaded to the laptop and the results were analyzed and shared current convergence data was available to the shift foreman. The monitoring system significantly reduced the employee presence time in the recovery room compared to previous events.

The system made the monitoring safer, less labor intensive, and more accurate than traditional methods. The traditional method required the personnel to carry the measuring tool from one station to the other which made the process slow, less accurate and exposed employees to the changing environment for longer periods of time. Figure 6 shows the traditional measuring method.

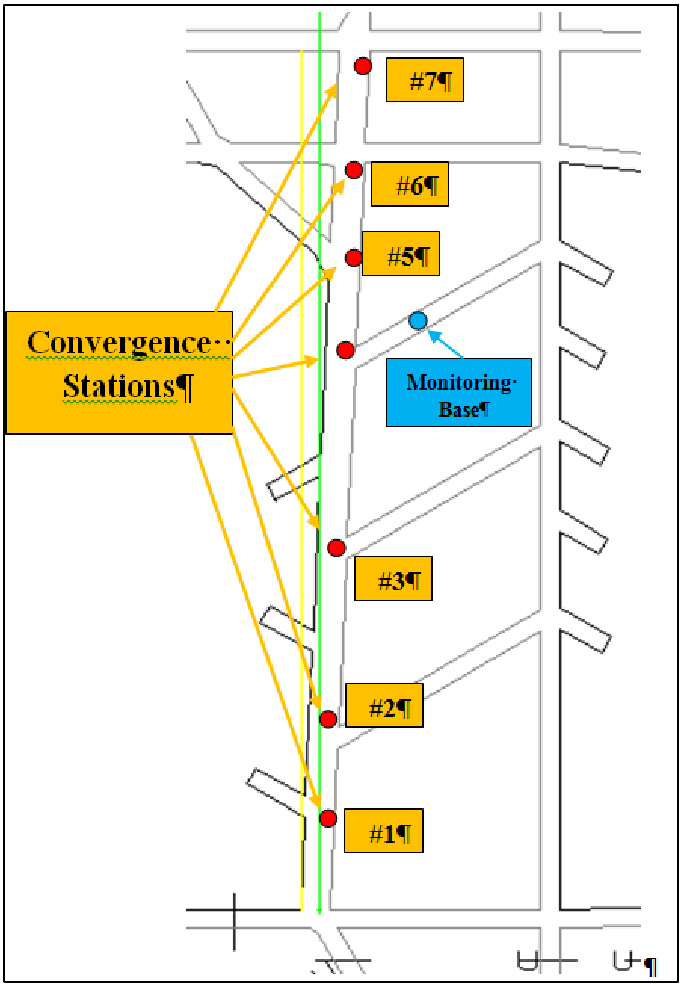

Figure 4. Convergence meters and Monitoring base layout.

Figure 5. Monitoring base located at 1st access chute.

A MSHA approved, permissible, handheld unit was used to read transducers once the LW face broke through into the recovery room at the tailgate. Data was collected as the remaining fender pillar was mined and the LW completed entry into the room. The datalogger was replaced since it didn't meet the permissibility requirements for the gassy environment. Readings were taken manually with the application of a terminal box switching from meter to meter using the selectors on the box. A software solution provided by the manufacture was used to input the calibration equations for each transducer.

Monitoring Results and Discussion

The monitoring was conducted until the LW face equipment had entered the recovery room from the tail to zero room (about 190 meters of the face).The transducers were removed from the area once the fender pillar was compromised. The transducers are reusable.

Crib stability and load carrying capacity are affected by crib width to height ratio and floor heave pattern (Maleki, 1986). Cribs are the most common secondary support employed at the mine. Wooden cribs are advantageous because of their low stiffness and their ability to undergo large deformations. Concrete cribs are stronger and resist deformation better than wood.

The concrete crib dimensions are 0.6m by 0.6 and 1m high. The solid concrete cribs are rated for 20,000 kPa with 0.6m wood capping material-wood blocks or wedges (the load is better distributed when there is sufficient wood capping the concrete crib. The spacing in between the crib sets was 0.6m. Each block could be loaded up to 485 tons.

Figure 6. Traditional Measuring Tool.

The crib monitoring results show 210 crib sets out of 494 sets were cracked or failed during the entry process. The cribs were set in four rows along in the Recovery Face. The crib density increases to five rows from third access chute to the tailgate. The results also show that no activity was observed among the crib sets from zero room to the belt drift. Figure 7 shows the cracks on the floor.

The D crib row (inby and closest to the face) was the most active row. The mid face cribs in all the rows also took significant amount of load. Figure 8 shows a failed concrete block. It was also observed that the top concrete block tends to fail.

The 3m and 6m long cable bolts also were used as additional support system. Both cable bolts are rated for 18.5 tons and were installed with the spacing of 1.2m.

Figure 7. Excessive floor heave and cracks on the floor.

Figure 8. Failed crib at the Recovery Face.

The floor heave was monitored along the recovery room face. As the floor heaved the cribs took the load. The plastic floor material then heaved around the base of each crib. The floor heave in between the rows was also observed. The cracks were observed in the tailgate area when the LW was still 4m away from entering the tailgate side of the recovery room.

The convergence meters were numbered from #1 to #7, from tailgate to headgate. As expected the major activity was measured from tailgate to mid face. Figure 9 shows the results from convergence station #3. The primary vertical axis shows the convergence rate and the secondary vertical axis show the LW face location from the recovery face. The monitoring started 45 days prior to the break through when the face location was 320m inby. As shown in these results, the measured convergence dramatically increases as the LW passed the 25m line.

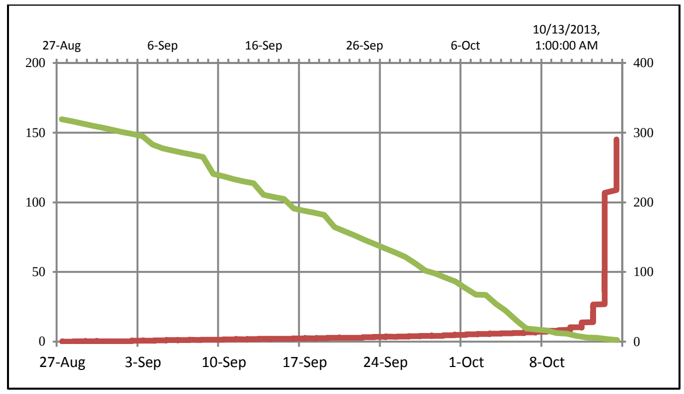

Figure 9. Measured Convergence (left vertical axis, mm) vs. LW Face Location (right vertical axis, m) at Station #3.

Gas liberation in the recovery room started as the cracks became observable in the tailgate. The gas liberates from the oil shale that makes up the floor strata underneath the trona seam. A gas concentration of 0.05% was measured at tailgate (station #1) when the LW was distance of 58m from the recovery face. No significant gas concentration was measured at that time. As the LW got closer to the recovery room, more cracks were observed and the size of existing cracks increased. Higher methane concentrations were also observed. A crack of 4m length and 200mm height was observed when the LW was 10m from the recovery room. The concentration of 0.95% was measured at the station #1, 0.6% at mid face (Station #4), and zero at the headgate (station #7). Figure 10 shows convergence rate for all stations.

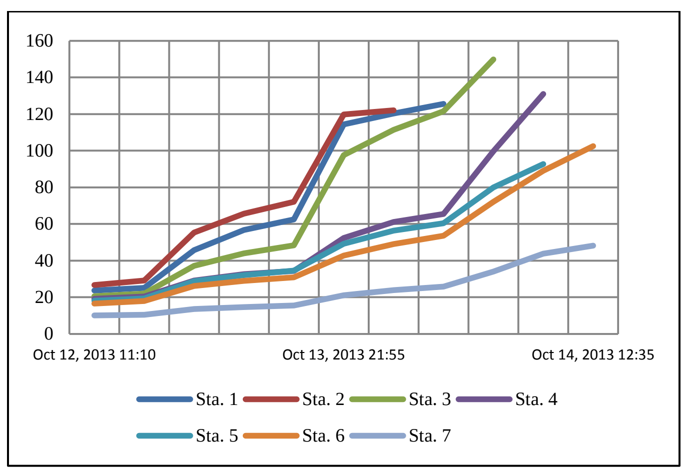

Figure 10. Cumulative Convergence rate for all stations.

As the gas concentration increased in the recovery room, there was a need for more intake air . The curtains at the tailgate end of the recovery room and 3 XCut were installed to prevent the intake air from short circuiting. As the LW passed the last intersection inby the recovery face the stoppings (as shown in Figure 2) were knocked down. This opened up the tailgate aircourse. The curtains were adjusted to insure the air flowing from the recovery face had properly diluted the methane. The concentration of less than 1.0% was maintained throughout.

CONCLUSIONS

A study was conducted on the current LW ventilation system. The displacement transducers were installed throughout the LW recovery face to measure and monitor the convergence rate. The crib sets and gas concentration were continuously monitored during the last 30m of the panel life.

A review of results and observations follows:

- Utilizing the displacement transducers increased the safety of the project by reducing the time the employees were present at the recovery room.
- The displacement transducers worked well. The monitoring intervals can be controlled and readings could be taken in shorter intervals than traditional methods. The other advantage is the ease in handling the logged data. Results can be simply exported to a spreadsheet and analyzed.
- It was observed that the top concrete block on each crib set tended to fail or crack. Most of the cribs that failed were located from tailgate to mid panel. This is perhaps a result of increased loads due to proximity of previous panels located on the tailgate side of current panel.
- The crib log shows that the inby crib row was the most active row. Also, it was observed that areas with a higher density of crib sets reduced the number of failed cribs. This was observed at the tailgate.
- The gas liberation started at the tailgate end of the recovery room and commenced with the observation of floor heave. The cribs started to penetrate into the floor and the area around the cribs heaved. The methane started liberating through the heaved floor.
- It was observed that excessive floor heave can led to creation of cracks in the floor. This significantly increased the gas concentration to 0.95%. The correlation of floor heave and methane liberation vs LW face location was analyzed. The observations show that gas liberation started when LW face was approximately 10m out which may have a direct relation to floor heave.
- Longwall mining creates abutment stress zones around the excavated panel. The front of that abutment stress zone travels in the same direction that the LW advances. This conclusion is the major factor in understanding floor heave at the recovery room.

Finally, several local ventilation changes were made to keep the methane concentration under 1.0%. A maximum gas concentration of 0.95% was read where the LW Face was approaching the recovery room. Two stoppings at the tailgate were knocked down and curtains were used to regulate the air through the recovery face. Further research needs to be conducted to understand and explore the mathematical relation between methane liberation and floor heave in this basin.

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