

Drill Monitoring Systems and the Integration with Drill and Blast Software

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Abstract

There have been a number of recent technological advances in instrumentation for blasthole drills, and more specifically in drill monitoring and HPGPS guidance systems. Likewise, great strides have been made in the development of drill and blast software systems which are user friendly, while providing far greater capability to accurately design and monitor drill and blast patterns.

With today's monitors and guidance systems, operators can view in 3D not only the holes as they are being drilled, but an entire pattern. The addition of sensors to monitor drill performance and a Specific Energy algorithm allow the strata of the pattern to be viewed in real-time by both the drill operators and by engineering in the office. Cameras can now be strategically placed on the drills to provide the operators with better visibility of the drill and the surrounding area, leading to increased safety and productivity.

Optimizing the management and control of the drilling and blasting process requires a comparison between actual drill data and the design or planned data. Drill and blast software is needed to easily integrate these two data sets. Drill monitoring data can then provide those people managing the drill and blast process with information to maintain control. Drill monitors can also collect important data regarding the location, rock type and rock condition encountered during drilling. This data is important to downstream processes, where decisions on the use of explosive and blast firing timing are influenced by the rock type encountered. The benefits of using detailed actual blasthole data are discussed here.

The profitable mining of a blast block begins with the drill and blast process. Poor or uncontrolled drill and blast has significant ramifications on the rest of the mining processes. The drilling of a blast pattern is often the first time a detailed interaction with a block of rock destined to be mined is undertaken. The drilling of blastholes should be considered as a sampling of the rock. In addition, data available from modern drill monitoring systems should be used to provide valuable information for downstream processes and decision makers.

The mining process begins with drilling and blasting activities, and these events have a significant impact on downstream processes such as loading or stripping, hauling, crushing and milling. Optimizing the drilling and blasting will improve the fragmentation, which in turn has a positive impact on the diggability of the material, reducing the time and energy required to load. Better fragmentation will also reduce the energy required to crush and grind the material. Other benefits can include reducing explosive costs, improving the condition of the bench floor, and reducing flyrock and ground vibrations. The key to achieving these benefits is the integration of drilling and blasting data. Unfortunately, there are very few mining operations today that truly integrate the data. However, with advances in drill monitoring and drill and blast software, it is anticipated that more mines will move towards integration of not only the drill and blast data, but data from the entire mining cycle.

In order to collect data on the drilling operation, blasthole drills must be equipped with monitoring systems to log the drilling conditions. Drill monitoring systems can be divided into two basic categories: 1) Drill Monitoring Systems and 2) HPGPS Guidance Systems. The Monitors provide the operator with feedback while drilling (Figure 1). They also record drilling parameters and log the drill activities. The Guidance systems incorporate high precision GPS, which allow the operators to navigate between holes and patterns, to drill to a specified elevation (target depth), and to log the ‘as drilled’ hole location, as shown in Figure 2.

With today’s monitors and guidance systems, operators can view in 3D not only the holes as they are being drilled, but an entire pattern (Figure 3). The addition of sensors to monitor drill performance, as well as a Specific Energy algorithm, allows the strata of the pattern to be viewed in real-time by both the drill operators and engineering in the office. Cameras can now be strategically placed on the drills to provide the operators with better visibility of the drill and the surrounding area. The camera images can be incorporated in the Drill Monitor GUI leading to increased safety and productivity, as can be seen in Figure 4. Most new drill systems utilize the mine’s Wi-Fi network, which greatly enhances the availability of the data within the mine, as well as providing access to this information through the internet.

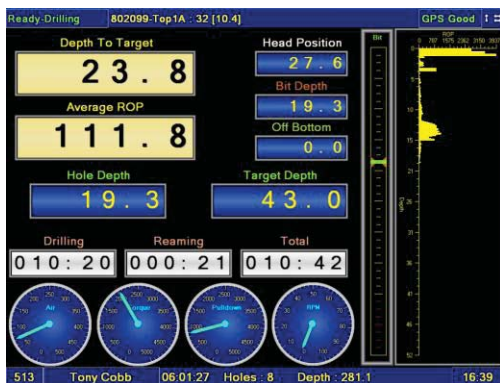


Figure 1: Drilling GUI

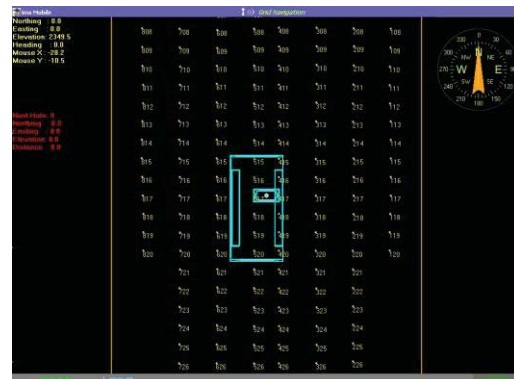


Figure 2: Navigation GUI

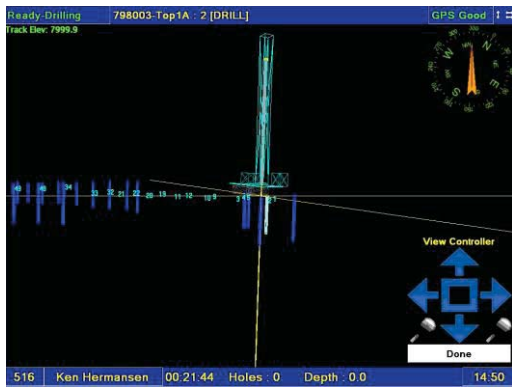


Figure 3: 3D view of drill holes



Figure 4: Camera views on GUI

Drilling patterns for blasts are generally created by an engineering team using mine-related information, such as: blast-face-crest and toe lines; planning requirements as to blocks-to-blast; geology information regarding the nature of the rock; topographic information concerning the description of the surface; and agreed and proven blasting parameters. All these items are brought together in a suitable software package. The resulting drilling pattern as shown in Figure 5 represents the requirements for the drilling pattern, which is the first key step in the drill and blast process.

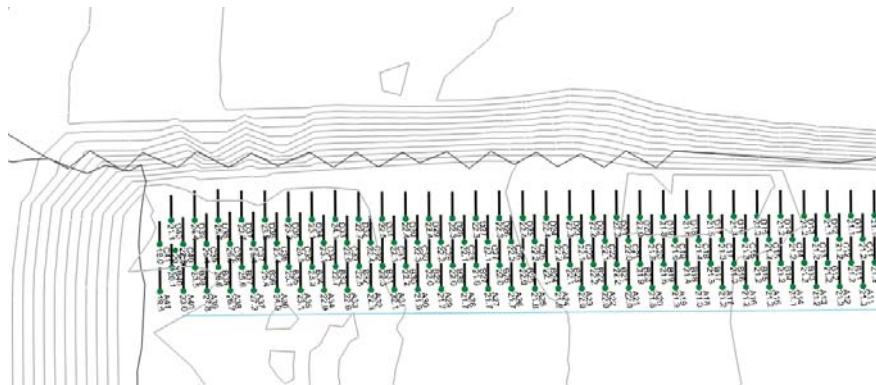


Figure 5: An example of a drilling pattern with surface topography and a blast boundary

Once created, the pattern(s) are uploaded to the Guidance System through the mine's radio or wireless network. Modern systems have the capability of highlighting the patterns closest to the drill's known location making it easier for the operator to select the correct pattern (Figure 6). The systems use the pattern design data to allow the operator to tram the drill to the location of the blastholes, thus eliminating the need to survey and stake the holes. After the drill has trammed to the hole position, the Guidance system provides and logs other hole related information such as hole number, pattern number, drill angle, and other special drilling instructions. Perhaps most important, because the GPS can determine the elevation of drill, it can calculate a target drilling depth to reach a design elevation at the bottom or toe of the hole. This ensures all holes are drilled to the design elevation rather than just a depth, which improves the blast and the resulting bench conditions.

Systems also collect drilling data while the drill is operating. The collected data can be grouped into two general areas: activity based data and blasthole related data. Drilling activity data defines the time events and activities that took place during a drilling operating period, which is generally a shift. The activity structure is defined by the mine, but will cover events that a drill can be involved in, such as drilling or production time, weather delay and mechanical delay, as shown in Figure 7. Drilling activities are broken down from calendar time into sub-categories. Examples of sub-categories are scheduled production, scheduled and unscheduled production delays, and scheduled and unscheduled mechanical delays. Activities are important in order to understand the utilization and effectiveness of the drill, and how productive the drill has been. Production time, particularly drilling or rock cutting time, will assist in calculating Penetration Rates, the most common drilling Key Performance Indicator (KPI). The drilling activity data collected by a drill will usually be validated by dispatch or engineering personnel to ensure the data is correct.

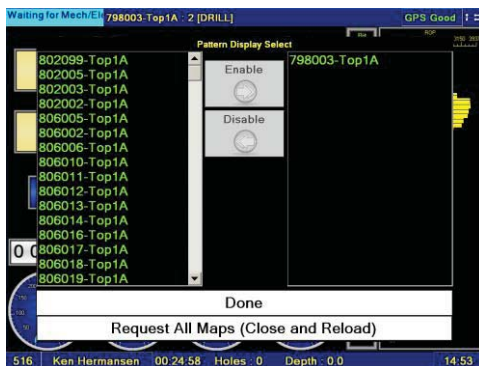


Figure 6: Selecting a drill pattern

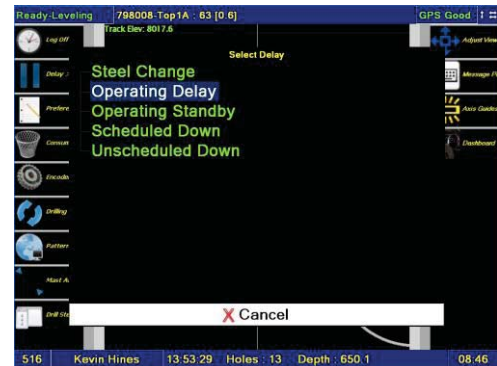


Figure 7: Delay code selection

Blasthole data collected by the Guidance systems will measure the actual drilling values achieved for the monitored parameters of each blasthole. This data can include the position of the blasthole collar, the angle (or dip), bearing (or azimuth), and depth of each blasthole. The system may also monitor important drilling machine parameters such as pull-down, torque, bit RPM, and vibration. Using published algorithms, this data can calculate a Specific Energy of Drilling, Hardness Index, or Drilling Index. The data also allows determination of rock type at intervals down the blasthole, providing an “in-hole” rock profile. There are a number of algorithms that have been developed over the years. One such algorithm is shown in figure 8.

- $SE = F/A + 2\pi/A * NT/R$
- **F = Pull-down force**
- **A = Hole area**
- **N = RPM**
- **T = Torque**
- **R = Penetration rate**
- *Larger SE values => harder rock*

Figure 8: Specific Energy Algorithm

Figure 9 is an example of how a taconite mine utilizes this data. An average Specific Energy value is calculated for each hole and then plotted using the colors across the pattern. The stemming of the holes is then adjusted based upon the colors—lighter areas require more stemming, while darker areas require more explosives. Thus, the blasting is optimized for the ground conditions and the resulting benefits include better fragmentation, improved diggability, less flyrock, and reduced ground vibrations and powder costs. In addition to collecting this information for use by the blast engineer, the SE index can also be displayed to the operator in real-time on the monitor.



Figure 9: Drill pattern with calculated Specific Energy

The Drill Monitor can also record drilling time and total drill footage for drill consumables such as drill bits, hammers, stabilizers, and drill steels, as shown in Figures 10 and 11. This data can be used to determine the performance of the drill stem components. Some mines are using the data to pay suppliers based on a cost per foot or meter drilled.

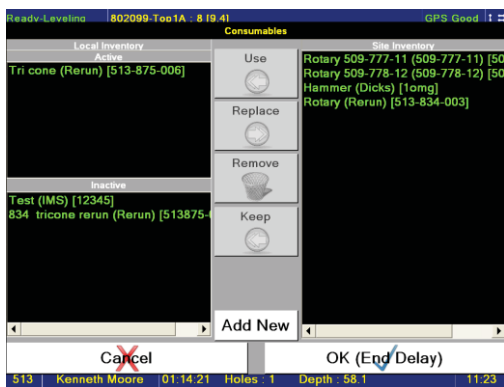


Figure 10: Consumable selection GUI

Bit Comparison 671016 vs. 522107				
	Bit	Driller Report	StrataLogger All 15 to 95	
Feet	671016	3,823	3,838	3,197
	522107	3,920	3,974	2,976
Pulldown	671016		91,515	90,675
	522107		81,419	79,681
<i>Percent Difference</i>			88.97%	87.87%
Net Penetration Rate	671016	40	120	133
	522107	61	144	135
<i>Percent Difference</i>		150.62%	119.92%	102.07%
Torque	671016		7,365	7,606
	522107		7,690	7,501
<i>Percent Difference</i>			104.41%	98.61%
Specific Energy	671016		9,811	8,996
	522107		8,063	8,004
<i>Percent Difference</i>			82.18%	88.98%

Figure 11: Drill bit report

Prior to comparing the ‘as drilled’ blasthole data from the drill with design drill pattern data, this data should be validated. Blasthole drill data collected by a Monitor comes from a number of different sensors on the drill. It is possible that a particular sensor may not be working, has not been calibrated,

or perhaps the system is unable to collect any valid data for the blasthole. For example, there may not be sufficient satellite coverage available for the GPS system to calculate an accurate drill position. However, in this case, the monitoring portion of the depth system would still record a valid drilling depth and correct rock type. Blasthole data validation is therefore broken down into individual components, with validation necessary for each piece of data. Drill and blast software must present the user with the data collected by the Monitor in a format which makes validation easy and efficient. Where possible, software should also use established rules to assist in selecting valid data.

Figures 12, 13 and 14 show examples of how blasthole data collected by a Drill Monitor can be viewed for validation. In this case the user interface is broken into a table view and a map view.

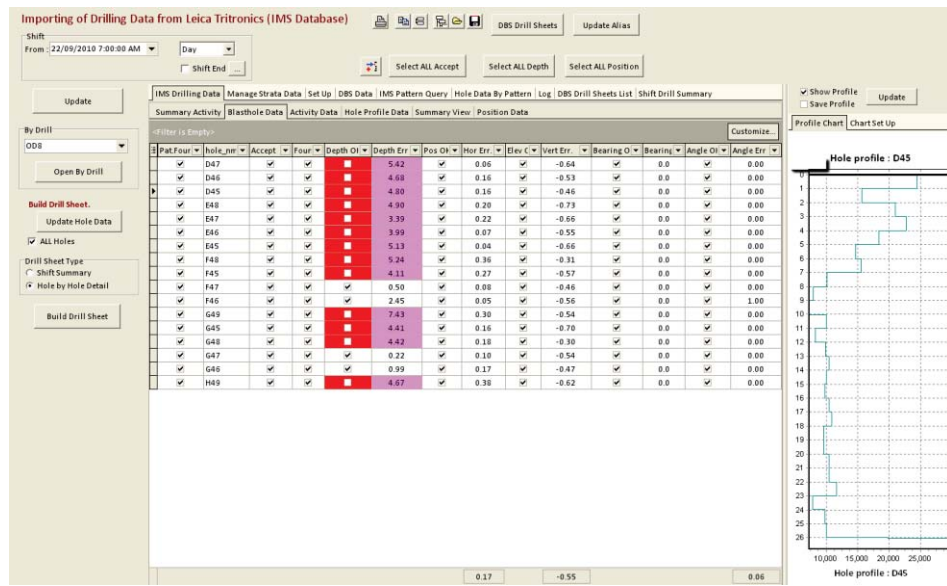


Figure 12: Example of a blasthole validation screen.

The table view in Figure 12 shows a shift of drilling data from a Monitor. Each blasthole drilled appears as a record in the table. The drill pattern and blasthole identifiers are included, and are considered sufficient to uniquely identify the blasthole. Check boxes are used to highlight whether data is found in the reference database or whether the data falls within a specified tolerance. If the box is checked, the validation routine believes the data is acceptable, while if the check box is unchecked, the data falls outside the specified tolerance or cannot be found, and the cell is flagged with red. The person validating the data must decide whether to accept or reject the flagged piece of data. This is signaled to the computer by manually changing the check box. A graph is used to depict the rock profile data, and a table view of the profile is also included in a separate tab in the user interface.

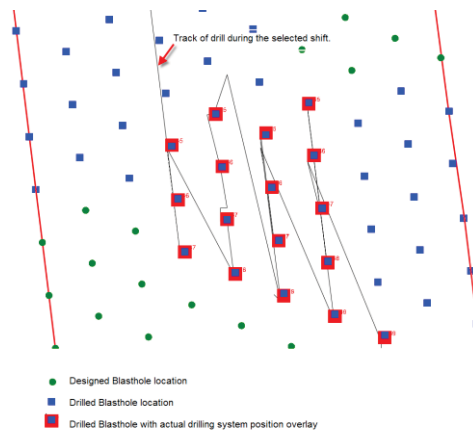


Figure 13: Plotting the actual blasthole positions versus the design positions. Also included is the track of the drill during the shift.

During the validation step, it is helpful to plot the drill's activity and hole positions using plotting software. This plot will assist in validating the position and blasthole ID data logged by the Guidance system. It is important to remember that consideration of each hole in isolation can be misleading. For instance, the pattern displayed in Figure 14 highlights that several of the holes were drilled inaccurately with the result being increased spacing between them, while decreasing the spacing to adjacent holes. The resulting blast, if not corrected by re-drilling or adjusting the loading, could be expected to have oversized material and difficult digging of the muck pile.

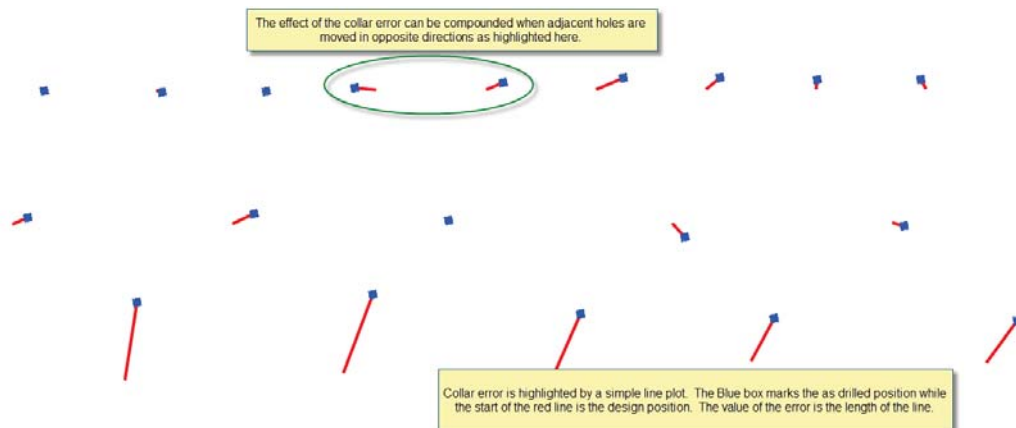


Figure 14: Example of an “out of position” plot using data.

Once the validation process has been completed, drill production reports can be generated. A comprehensive daily drill summary report is shown in Figures 15 and 16.

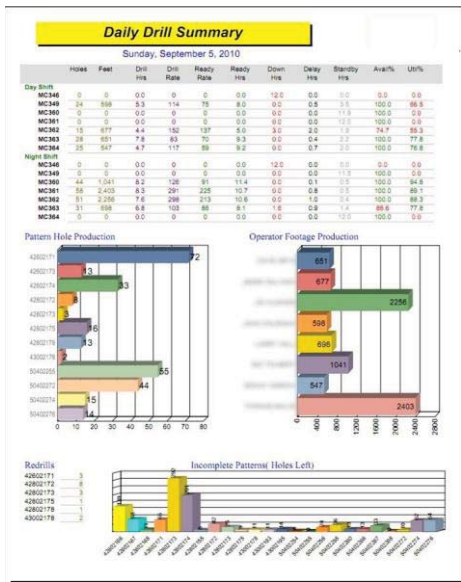


Figure 15: Daily Drill Report—page 1

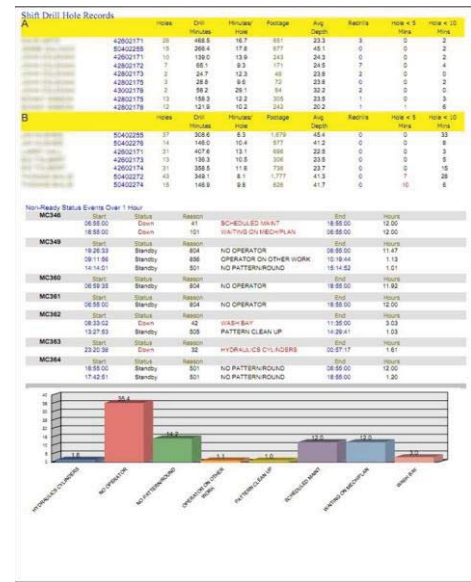


Figure 16: Daily Drill Report—page 2

In addition to reviewing production reports on a regular basis, it is useful to analyze the drilling performance for the KPIs. It is very important that the design team that created this drill pattern review the quality of the actual pattern. The reviewing needs to be automated, quick and meaningful, so that there is an incentive to carry out this analysis routinely. Figures 17 and 18 illustrate several presentations of the drilling data collected by a Drill Guidance system and generated by a drill and blast software program.

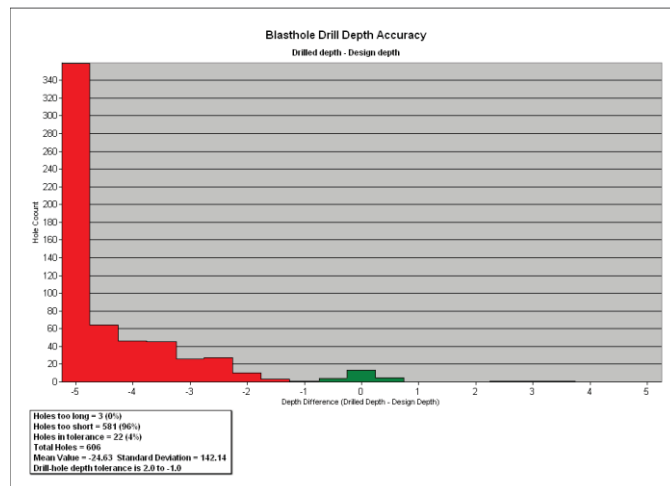
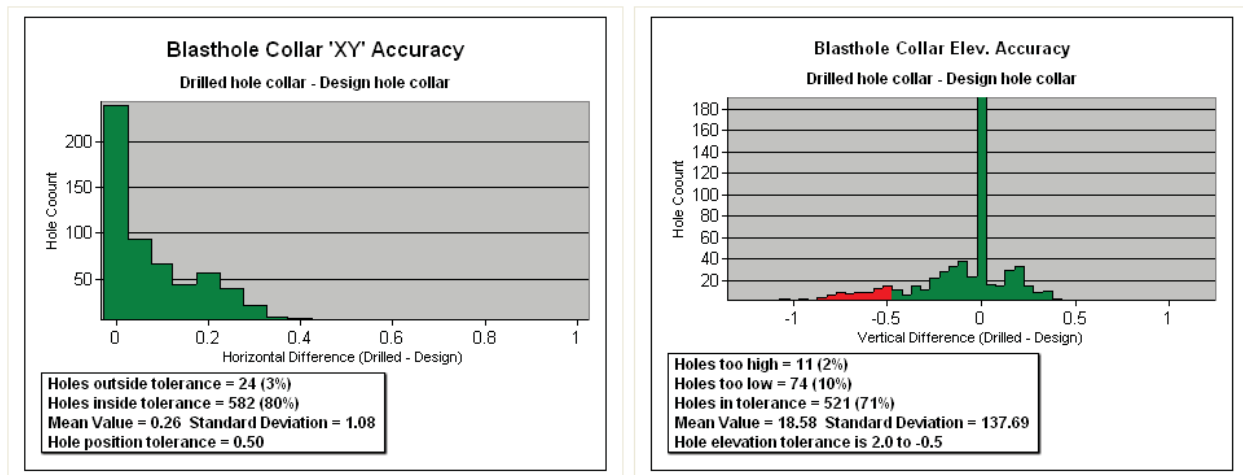


Figure 17: Depth accuracy plot.



Figures 18: Hole location accuracy.

Blasthole drilling parameters fall into two categories: those controllable by the mining process, and those that are not. Typically, the placement and direction of a blasthole are controllable, while the rock properties that the blasthole passes through are not. Table 1 illustrates the main drilling parameters.

Table 1: Main Drilling Parameters

Parameter	Controlled By	Comment
Collar Horizontal Position (X,Y)	Driller	Horizontal distance and direction from Design collar location
Collar Vertical Position (Z)	Topography/Pad Prep	Vertical distance from Design Collar elevation.
Drill Depth	Driller	
Drill Angle (Dip)	Driller	
Drill Bearing (Azimuth)	Driller	
Drill Diameter	Driller	

A quality management system such as Total Quality Management (TQM), proposed by Philip Crosby (Philip Crosby Associates), defines the drill pattern as the basis for measurement of performance of the drilling process. The TQM system also dictates that any significant deviation from the design requirements are termed “non-conformance”. Non-conformance patterns must be managed by “corrective action”, either post-drilling (for example, a re-drill) or for future patterns (for example driller training).

Drill Monitor and Guidance Systems parameters are in the drill operator’s control. Other parameters, such as the elevation of the ground surface, are in the mining process control. Still others relate to the rock itself. Those parameters which can be controlled by the mining process should be controlled and monitored using tolerances and corrective actions. Those parameters not controllable should be monitored with appropriate action taken in downstream processing; for example, changing the explosive

loading and timing to suit the conditions. Drill and blast software can aid in identifying when a hole (or holes) is not within tolerance.

A blasthole that is not within tolerance, or that encounters an unexpected rock type, has a number of immediate corrective actions:

- Re-drill the blasthole;
- Adjust the explosive used to compensate for the actual amount of rock the blasthole is expected to break;
- Adjust the explosive type and quantity based on the rock type encountered within the blasthole;
- Other techniques (such as decking) may be utilized if the rock type varies significantly within the blast hole; or
- Adjust the blasthole firing time based on the actual position relative to the firing plan. This approach will require an advanced timing system, such as that provided by electronic timed detonators.

Longer term corrective actions include:

- Design blasts with final topographic data (after bench clean up and final boundary cleared);
- Understand the limitations of locating the drills, particularly when using angled holes;
- Improve the quality of the models used to design the blasts; or
- Train or mentor drillers in the need for accurate drilling.

In conclusion, significant benefits have been achieved by mines through the use of Drill Monitors and Guidance Systems. These benefits include:

- Reduced under/over-drilling;
- Increased ROP;
- Tracking of time, leading to fewer delays. Results in more feet/meters drilled;
- Identification of weak or strong strata and rock types;
- Locating of coal seams;
- Optimization of blasting, resulting in better fragmentation and diggability;
- Increasing the accuracy of drilled hole locations;
- Improvements in bench quality;
- Reductions in surveying costs;
- Tracking of drill bits and other drill stem components; and
- Improvements in accuracy of data, and the elimination of hand-written reports.

However, without a sophisticated, but user-friendly, drill and blast software package, it can be difficult to convert the raw data from these Monitoring and Guidance systems into information that can be readily used by operations and by drill and blast engineers. There is real opportunity to achieve even more gains in productivity, while at the same time reducing costs and improving safety, through the integration of the various activities in the mining cycle. Specifically, this paper has demonstrated the improvements that can be achieved through the mining process by the use of drill monitoring and drill

guidance systems. Over the next few years, it is expected that more mines will adopt these technologies and systems because of the significant payback on the investment, and tangible benefits they provide.

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