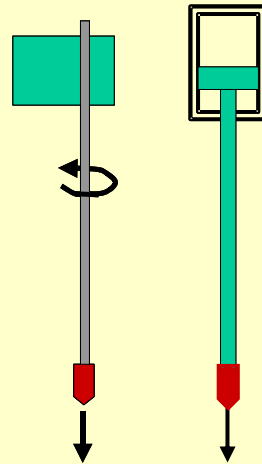

Blasthole Drilling



This blaster-training module was put together, under contract, with Federal funds provided by the Office of Technology Transfer, Western Regional Office, Office of Surface Mining, U.S. Department of the Interior, located in Denver, Colorado.

The module is an example of the technical assistance the Federal government furnishes States to assist them in meeting the requirements of the Surface Mining Control and Reclamation Act of 1977, upon which their State surface coal-mine regulating programs are based. In particular, the module was requested and will be used by the Sheridan District Office, Wyoming Department of Environmental Quality, Land Quality Division.

A word of caution: please note that **this module is not intended to stand alone, nor is it a self-training type module.** Rather, **the information the module provides MUST BE SUPPLEMENTED** by information given by a certified blasting instructor.

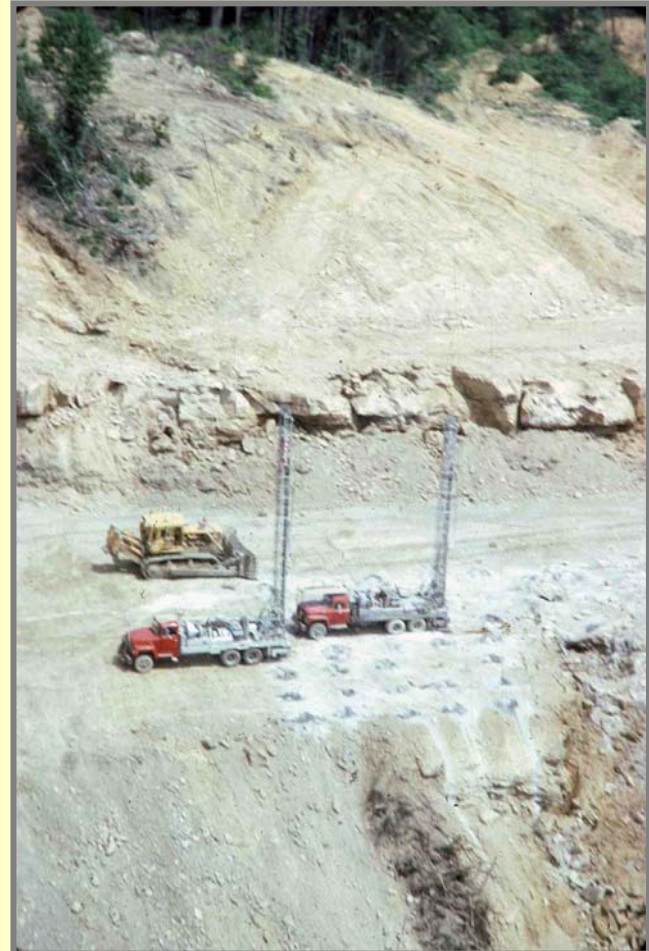
DISCLAIMER

The technologies described in the module are for information purposes only. The mention herein, of the technologies, companies, or any brand names, does not constitute endorsement by the U.S. Department of the Interior's Office of Surface Mining.

Blasthole Drilling

This module presents aspects of surface drilling that are important to blasting operations. The purpose of drilling into rock is to provide a “blasthole” into which explosives can be loaded.

Good drilling practices include carefully monitoring drill-rig operating parameters, taking careful notes of the changes in geology during drilling, and effectively communicating to the blasting crew any unusual conditions encountered during drilling that may affect blasting results or require changes in hole-loading practices.



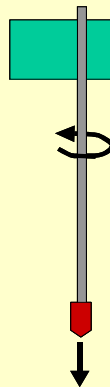
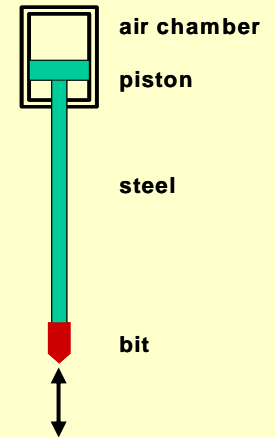
Drilling Methods

The components of a drill rig are (1) the rig itself, which supplies the power to mobilize, drill rock, and remove the drill cuttings from the hole; (2) the mounting; (3) the drill steels or drill string; and (4) the drill bit.

There are two basic drilling methods—percussion and rotary—classified in accordance with the way in which mechanical energy transfers from the rig to the rock.

Percussion Drilling

In percussion drilling, the rock is made to fail by means of a piston that delivers rapid impacts to the drill steel, thereby transferring energy to the drill bit. The “blows” to the rock downhole are delivered by the bit, while a rotational device ensures that the bit impacts a new rock surface with each blow. A feed force is applied to maintain rock/bit contact. Compressed air is used to remove or “flush” the drill cutting from the hole, thereby advancing the hole depth at an efficient rate. The piston can either be mounted out of the hole (OTH) or down the hole (DTH) for quiet and efficient drilling.



Rotary Drilling

In rotary drilling, the rock is made to fail by means of a combination of “pull-down” pressure on the bit and rotation power. Compressed air is used in sufficient volume to ensure a minimum velocity of upward airflow that both flushes drill cuttings and keeps the hole bottom cleaned.

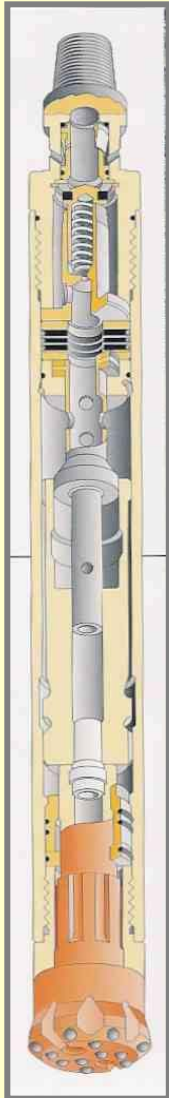
Percussion Drill Rigs

“Drifter” OTH percussion drills can be air- or hydraulic-operated and are generally limited to hole diameters of 5 inches or less.



Percussion drills use button or cross (X-type) drill bits in which the cutting tool is made of hard tungsten carbide. Wing angles and button configurations are designed to accommodate soft to hard formations and come in a variety of configurations.

Percussion Drill Rigs



DTH hammers, with the piston in the hole, tend to drill straighter holes at greater depth as compared to OTH drifters. The air-driven piston hammer causes the bit to rapidly impact the rock while the bit is slowly turned. DTH hammers are efficient in hard-rock types. With the hammer in the hole, drill-pipe vibrations are eliminated.



Rotary Drill Rigs

Rotary drills cut the rock by a rotating bit. The overall performance of rotary drills is most effective when bit load, bit rotation, bit selection, and operator performance all are optimized.



Rotary drills work best in holes sized from 6 to 22 inches in diameter. Optimal hole depths range from 15 to 150 feet (typical) and average from 30 to 60 feet.

Rotary Drill Rigs

Roller-cone or tricone bits are the most common bit used for rotary blasthole drilling. Bits have three or more cones ("rollers" or "cutters")—made with hardened steel teeth or tungsten carbide inserts of varied shape, length, and spacing—on spindles and bearings set at an angle to the axis of the bit.

Bearings within the roller-cone bit must be kept clean and cool by flushing with compressed air.

Roller bits exert a crushing and chipping action, making it possible to cut hard-rock formations. They are designed so that each tooth applies pressure at a different point on the bottom of the hole as the cones rotate. The teeth of adjacent cones intermesh so that self-cleaning occurs.

As a general rule, hard-rock roller bits should be used at much slower speeds and higher bit weight than should bits used for drilling soft formations.



Rotary Drill Rigs

Many rotary rig masts have pinning capabilities that permit drilling at angles as much as 30 degrees out of the vertical. Drilling in this manner is necessary at large surface coal mines where overburden will be cast. Typically, angles range from 10 to 15 degrees on the back row and 20 to 23 degrees along the front row.



Fugitive Dust and Drill-Cutting Controls



Dust-suppression and crushed-rock-cutting collection systems are available on many drill-rig models to help control fugitive dust. Rubber skirts and water-misting controls contain rock fines and dust around the blasthole collar.

Cyclone mechanical dust collectors remove drill cutting from the hole collar and place them alongside the drill rig. Cyclone systems reduce the dust in the air and minimize the chance for drill cuttings to fall back into the hole from the collar region, thereby keeping the hole open for maximum explosives loading.



Drill Mountings



Rigs are either truck- or track-mounted. Rubber-tired rigs can travel quickly between job sites. However, they are not able to move on rough terrain.

On the other hand, track or crawler mounts can easily traverse rugged terrain.



Drill-Rig Performance

Recent technical advances in drill-rig performance include (1) improved operator-cab comfort; (2) automatic control and adjustment of optimum feed force and rotation speed for geologic conditions and bit type and diameter; and (3) incorporation of the latest technology in electric and hydraulic drive systems.

Optimizing drilling parameters requires careful adjustments among rotary speed, thrust on the bit, percussion blow count and energy, and sufficient volume of compressed air at an adequate pressure to remove drilled rock cuttings.

The performance of the drill rig is optimized when the **rate of penetration** and **flushing of drill cutting from the hole** are maximized (or are at their highest) and **drilling cost per foot** and **wear on the bit and drill string** are minimized.



Selection of Hole Diameter

Who selects the type of drill rig and the hole diameter used in blasthole operations?

In some cases, a rig for one operation will be “inherited” from another or will be purchased without consideration of the many different demands that are imposed on drill rigs. In other cases, drilling requirements are weighed carefully before selecting an appropriate drill rig to meet all the needs at one operation.

Considerations include:

- Total drill-hole depth anticipated,
- Geology and surface terrain condition,
- Production requirements,
- Type of explosives and explosive products to be used,
- Fragmentation size requirements matched with removal equipment bucket capacities, and
- Operating and ownership costs.

How is hole diameter determined?

Hole diameters are matched to blasting bench heights. In general, the higher the bench height or cut to be blasted, the larger the blasthole diameter. Large blasthole diameters can accommodate more explosives, allowing for a hole pattern to be designed with wide spacing between the blastholes. This generally means lower drilling costs with fewer holes to be drilled for a given production.

On the other hand, large-diameter holes and wide spacings may generate coarse fragmentation. For operations that use large bucket draglines or shovels, this may not be a problem. However, some quarries, as well as construction blasting applications that use small-bucket front-end loaders, require hole diameters that remain small, thereby generating finer fragments. Fine fragments, in turn, allow for efficient removal and low equipment maintenance.

Selection of Hole Diameter

There are many “rules of thumb” for matching hole diameter to bench height, including charts such as the one shown below. The shaded area in this chart shows the appropriate range of blasthole diameters, d, in inches, matched to bench height, H, in feet.

Bench Height feet	Hole Diameter in Inches																			
	3	3.5	4	4.5	5	5.5	6	6.25	6.5	6.75	7	7.88	9	9.88	10.6	12.3	13	15	16	
3																				
7																				
10																				
13	Shaded																			
16	Shaded	Shaded																		
20	Shaded	Shaded	Shaded																	
23	Shaded	Shaded	Shaded	Shaded																
26	Shaded	Shaded	Shaded	Shaded	Shaded															
30	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded														
33	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded													
36	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded												
39	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded											
43	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded										
46	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded									
49	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded								
52	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded							
56	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded						
59	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded					
62	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded				
66	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded			
69	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded		
72	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	
75	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded
79	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded
82	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded	Shaded

A common method for calculating this relationship is:

$$d \text{ (inches)} \leq H/5 \text{ (in feet).}$$

Thus, for example, the maximum recommended drill-hole diameter for a mine that plans to develop a 60-foot bench would be 60/5 or up to 12 inches. From the chart, the range will be 4.5 to 12.3 inches depending on site conditions.

Selection of Hole Diameter

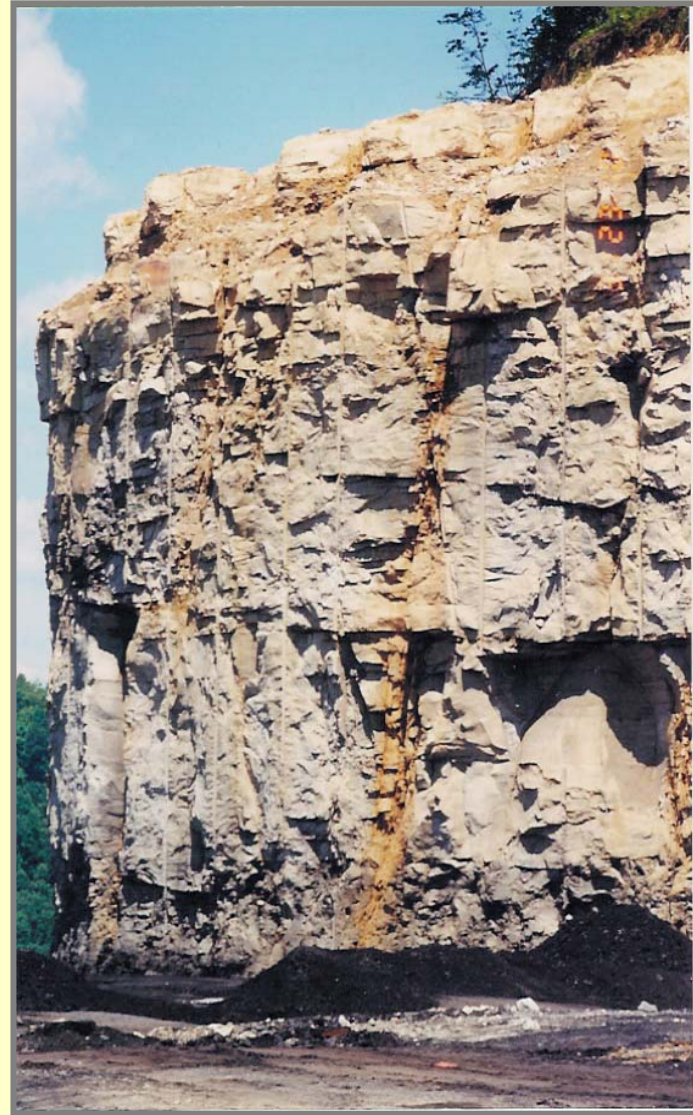
A coal mine may encounter problems if it attempts to use the same diameter drill to blast overburden that is significantly deeper than the parting layer. Fragmentation in the parting layer will be compromised, and flyrock may occur if blast holes are overloaded.

The size of the mast and drill steels carried by the rig are important considerations in drilling efficiency. If a quarry plans to use 30-foot bench heights with 7 feet of sub-drill, a drill rig with 25-foot-long steels may not be a good choice, because two steels will be required to complete one hole. Metal mines generally use 50-foot bench heights, for which steels of 30-foot length make sense.

Drill Accuracy

Mud seams and weathered joints may cause serious borehole deviations. Deviated boreholes, in turn, often result in poorly distributed explosive energy, leading either to poor fragmentation of the rock mass, highwall stability problems, or both.

Can you identify the deviated borehole in the rock face to the right?



Drill Deviation

The hole collared to the left of the joint (the hole shown with yellow dashes and the joint shown with red-brown staining) in this rock face deviated as it intersected the rock-joint region, turning in an alignment nearly perpendicular to the joint. When the hole intersected the joint, the hole turned nearly parallel with it.

Once across the joint, the hole continued on the same trajectory, ending precisely at the bottom of an adjacent hole.

A consequence of detonating two primers together in two adjoining holes that terminate at the same location is to undercut the rock.

Look closely at the rock face to the right to see where undercutting of the rock has occurred.



Drill Deviation

Common sources of drillhole misalignments are:

- *Collaring deviations*, or the lateral displacement of a hole from its planned starting point: this can be caused by (1) the topography of the drill site, (2) poor drill set-up, and/or (3) the inability of the drill to hold the boom and feed beam in a rigid position (worn pins and bushings).
- *Alignment deviations*, or inaccuracies in setting the feed on which a drill is mounted in a planned direction: this can be caused by (1) instabilities of the drill rig, (2) lack of precision in positioning equipment, (3) misaligning the feed beam, (4) topography at the collaring point, and/or (5) structural geology.
- *Trajectory deviations*, or deviations from the designed drill path during drilling of the hole: factors contributing to this include (1) hole design (inclination, diameter, length), (2) drill parameters (thrust, percussion, rotation, flushing velocities), (3) equipment (bits, rods, stabilizers, couplings, etc.), and/or (4) rock properties (structures, hardness, variations in the rock mass).
- *Driller inexperience*.

Planning and Documentation

Drilling and blasting safety and economics dictate that each blast be carried out with a high level of planning, documentation, and communication among all personnel—including planning engineers and supervisors, geologists, drillers, members of the blasting crew, and surveyors—involved with it.

Drilling plans are an important aspect of this process. Drillers must :

- Understand the technology involved in planning the blasthole pattern and explosives loading;
- Communicate effectively and in a timely manner to supervisors and the blasting crew, informing them of the final blasthole pattern, conditions, and any changes in the hole drilling from the planned layout; and
- Prepare drilling logs and other reports that document time, materials, and drill operating parameters.



Planning and Drilling the Blast Pattern

Good drilling and blasting practices start with the accurate layout and drilling of blastholes in planned and, sometimes, unplanned locations. The location of blastholes to be drilled for a single blast rarely form a uniform, rectangular grid. Based on the performance of previous blasts nearby, geology, or production requirements, each blast layout will present new and challenging design elements.



Large mining operations, which may shoot several times a day with high-capacity drilling rigs like the one shown to the

left, may use global positioning satellite (GPS) technology and on-board computers to precisely position their rigs in each planned blasthole location. A planning engineer is often responsible for laying out and entering into a computer coordinates for the locations of planned drill holes. This information, in turn, is transferred to the drill rig's computer, and the drill is guided by the GPS to each drill-hole position.



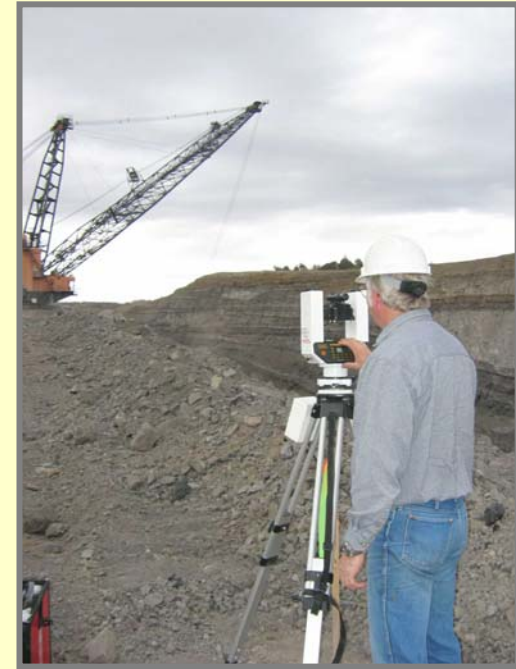
For smaller blasting operations with less frequency in blasting, drill holes may be visually laid out by the blaster and driller together, with stakes or colored rocks comparable to those shown above for the pre-split holes along a highway cut. No computer technology is involved in this case.

Planning and Drilling the Blast Pattern

Remote Laser Profiling

The use of lasers and computer-imaging software as planning tools have advanced safe and economical drilling and blasting since the late 1980's. 3-D laser profiling allows the driller and blaster to both visualize the rock face and determine the face profile on the computer, thereby assisting them in the planning of blasthole patterns, optimum burden dimensions, and explosives loading.

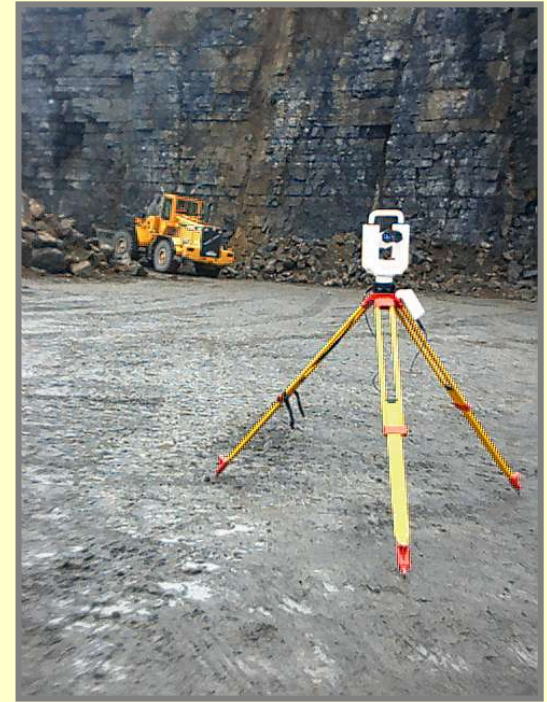
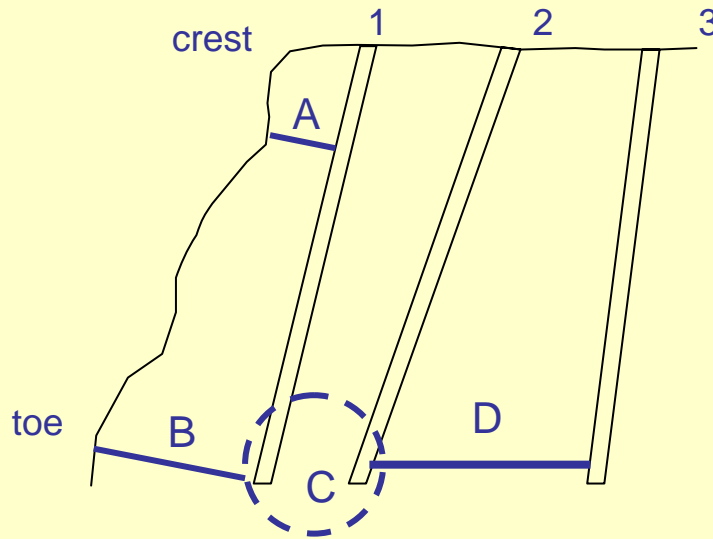
Equipment is used to transmit a laser beam and receive accurate position information (in x-y-z coordinates) from beam reflections for millions of points on the highwall face between the crest and toe of the bench within the bounds of the planned blast. These data are collected in some form of logger and downloaded to the computer.



In 2-D profiling, the proposed drill angle and hole offset from the crest are entered into the software, and profiles of the rock face and planned borehole are created graphically. 3-D profiling includes a survey of the actual drilled blastholes over the hole length from the hole collar, allowing for both calculation of the effect of hole deviations and computation of the explosive loading required from actual burden dimensions.

Planning and Drilling the Blast Pattern

Profiles of a bench, similar to the one shown below, may be interpolated by the software and printed out on a thermal printer in the field. The burdens in front of each blasthole (shown below for three rows) can be computed over the length of the hole and adjustments readily made—in explosive quantities and location or delay timing—to accommodate various considerations. The illustration below shows such considerations as A, a region of critical minimum burden distances that may result in flyrock; B, excessive toe burdens that may inhibit movement and fragmentation; C, hole deviations that may result in explosive overloading; or D, excessive burdens between rows.

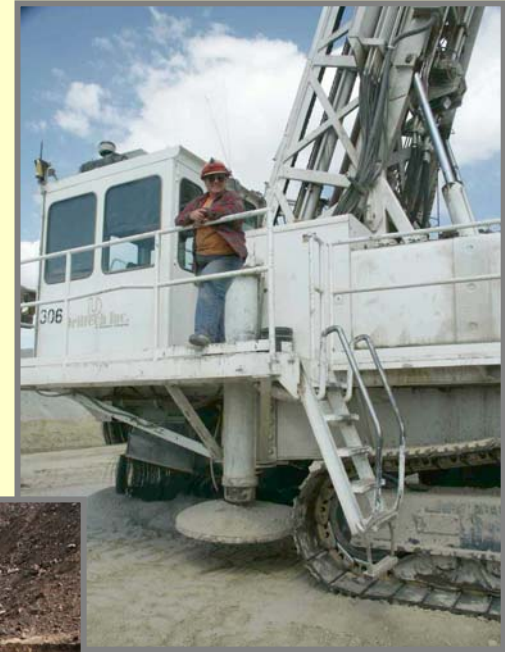


Blasthole Documentation and Communications

Communication between the drilling and blasting crews is essential for all good blasting operations. In operations where the drilling and blasting are performed by separate crews, the supervisors should work together closely to ensure that boreholes are drilled and loaded to design specifications and that crews work together to identify problem boreholes.

Operations where drilling and blasting are performed under the same supervisor or by the same crews are highly recommended, in that this allows both crews to work closely to maintain efficient borehole drilling and loading.

Drilling information can be conveyed from the drilling crew to the blasting crew by means of stakes placed at each blasthole. Such stakes can record useful information such as hole-identification number, total hole depth, water level in the hole, backfill depth, depth of soft/hard layers, location of voids, depth of cracks, etc. that the driller observes during drilling operations.



Drill logs

Drilling allows the blaster to “see” what is behind the highwall face. A drill log provides a means for the drilling information to be conveyed from the drilling crew to the blasting crew. In particular, where multiple drills are used on the same bench, drill logs promoted consistent reporting back to the blaster.



Good drill log will:

- Be on printed log sheets
- Be written
- Illustrate the blast pattern drilled
- Identify the drill holes and locations
- Show the angle of drilling
- Document the completed hole depth
 - Document the depth to cracks, voids, and water
 - Describe changes in geology
 - Document the driller responsible for the hole

Once the true nature of the overburden is revealed, the blast can be designed or modified as appropriate. Communicating this information to the blaster is critical.

DATE 3-7-04 DEPTH OF HOLE 20
AREA OF JOB 444 SPACING 16x16
DRILLER X = HIT COAL O = DIRT HOLE
 ⊗ = CRACKED HOLE

7' wall

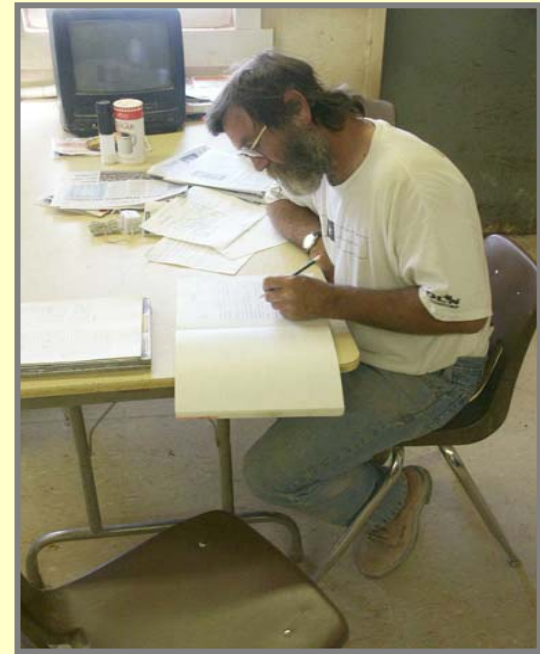
8

8 feet outside Don

Other Summary Reports

The driller is also responsible for producing a number of daily reports that summarize the activities associated with the drill rig for that day's shift. These reports may be company-specific and of different types. For example:

Drill operator's report.—This type of report documents the activities associated with a given drill rig for a specific shift; typically, it includes information regarding the hole number drilled and drilled depths, as well as downtime intervals and the reasons for downtime. From such a report, drill rig *availability* (the actual up-time available for the rig) and *use* (the percentage of available time that drilling actually occurred during the shift) can be computed. In addition, the total yardage drilled, based on known hole spacing, or tons shot, based on rock density, can be computed.



Drill operating parameters report.—For drill rigs with on-board computers, operating parameters such as rotational speed, bit weight, percussion energy blow count, and so forth can be monitored. The rate of penetration in feet/hour or feet/minute can be computed and used to evaluate drilling costs per foot, per ton, or per cubic yards shot. Monitoring operating parameters can help control wear on the drill bit to extend bit life in hours or feet.

The driller may not be directly responsible for the assessment of this information, which is automatically stored and then later evaluated, but he or she must always be mindful of the impact that adjustments to these parameters have on the overall productivity and economics of the drilling and blasting operations.

Review Questions and Discussion

1. Your goal is to load blastholes as safely and efficiently as you possibly can. List as many things as you can think of that you would want a driller to convey to you, after completing the drilling of the blasting pattern, to help you achieve this goal.
2. Drill-hole deviations can be caused by all of the following except:
 - a. Geology
 - b. An inexperienced driller
 - c. The elevation of the drilling bench
 - d. Misalignment of the drill mast from vertical or the intended angle
3. List what you need to know about drill-rig performance in order to help you evaluate the efficiency of your drilling program.



Answers

1. The information regarding blastholes that would be of use to you would be: (a) the total drilled depth of each hole; (b) whether or not there was water present in the holes; (c) whether or not any holes had collapsed; (d) whether any hole contained voids, soft seams, and/or a mixture of hard and soft layers; and (e) whether or not there had been any backfilling in holes.
2. c. is correct.
3. The information regarding drill-rig performance that you need to know is: (a) total hours drilling and total hours of downtime during each shift; (b) total number of holes drilled; (c) total footage drilled; (d) calculated penetration rate; and (e) bits used or bits replaced. With respect to rotary drilling, you need to know the weight on the bit, the rotational speed, and/or the air pressure for flushing; with respect to percussive drilling, you need to know blow count and blow energy.