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INTRODUCTION

Getting the most from your explosive energy requires optimization of every blasting parameter. Initiation systems have evolved from packed straw fuses into electronic programmable detonators and remote control firing switches. Explosives have not only become safer to handle and use, but also offer a wider array of options at a lower cost. Throughout this technological revolution, energy confinement innovation has remained relatively stagnant. Considering that energy is approximately five times as expensive in powder form than when purchased as electricity, it is startling that energy confinement has avoided the intense scrutiny applied to every other aspect of the blasting process.

PRODUCT HISTORY AND DEVELOPMENT

The StemPlug Blast Control Plug was conceived and developed by Dr. Paul Worsey, Senior Research Investigator for the Rock Mechanics & Explosive Research Center at the University of Missouri – Rolla. U.S. Patent # 4,754,705 and several foreign patents protect this product.

The product was first introduced with the 3-inch diameter StemPlug Blast Control Plug in 1991. Originally intended for use in small diameter boreholes in the quarry and construction industries, the StemPlug Blast Control Plug has expanded to cover a full range of borehole sizes from 3 to 12 ¼-inches. To date, over 2 million plugs have been used worldwide to increase the efficiency of the blasting process.

EVALUATION OF A BLAST

Once the dust has settled and the fumes have dispersed, an inspection of the blast area should be carried out. The main features of a satisfactory blast are illustrated in Figure 1.

- The front row should have moved out evenly, but not too far, as excessive throw is unnecessary and expensive to clean up. The heights of most open pit benches are designed for efficient shovel operation. Low muck piles, due to excessive front row movement represent low productivity excavation volumes.

- The main charge should be lifted evenly and cratering should, at worst, be only an occasional occurrence. Flat or wrinkled areas are indicative of misfires or design flaws.

- A substantial power trough, indicating good free face movement, should characterize the back of the blast.

- Excessive back break represents damage to the slope and wasted explosive energy.

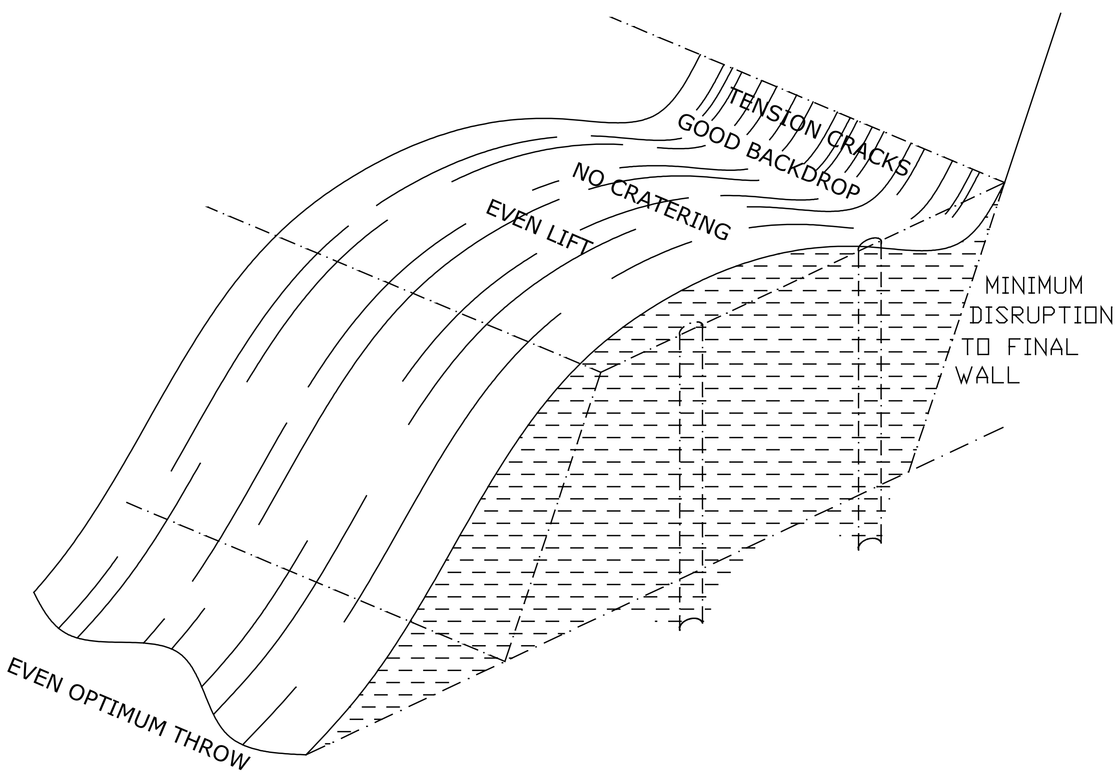


Figure 1: Features of a satisfactory production blast

PARAMETERS INFLUENCING BLAST EFFICIENCY

1. Type, weight and distribution of explosives
2. Borehole diameter
3. Effective burden
4. Effective spacing
5. Sub-drill depth
6. Borehole inclination
7. Stemming
8. Initiation sequence for detonation
9. Delays between successive hole and row firing
10. Direction of firing

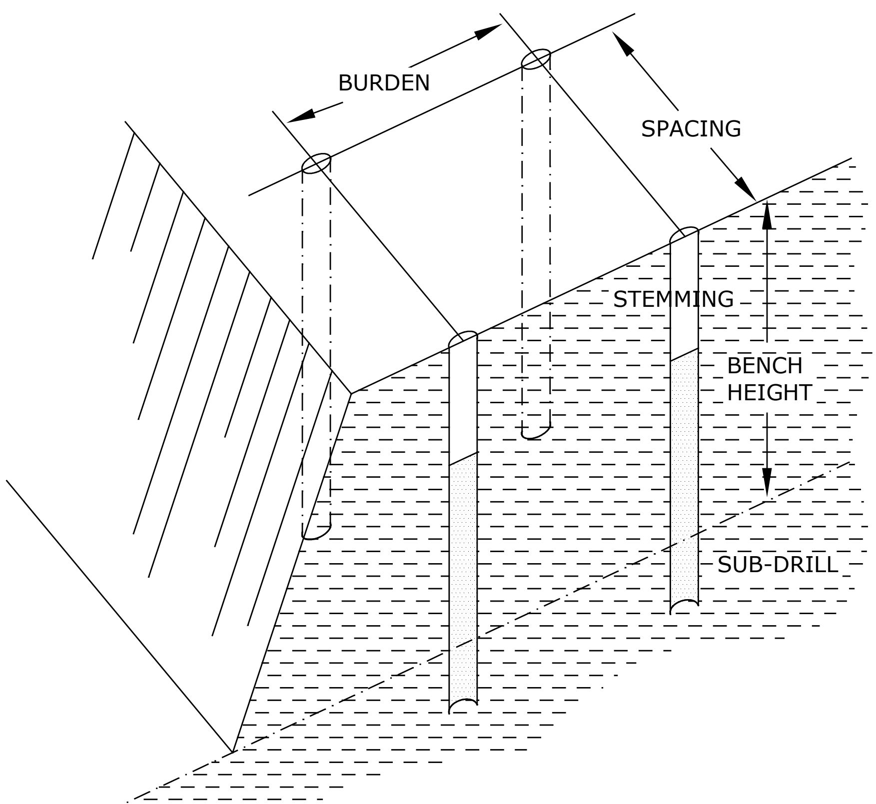


Figure 2: Bench blasting terminology

ROLE OF STEMMING

Traditionally, the accepted procedure for directing the explosive energy into the surrounding rock mass is to load the blast hole with explosives and the remainder of the hole is filled with drill cuttings or imported aggregate. Drill cuttings are the most convenient stemming material, but are generally inadequate to fully contain explosive gasses if used with the optimum charge height for maximum blast efficiency. The stemming length is usually increased in an attempt to compensate for the loss of explosive energy. This results in mediocre blast results, usually with oversize material at the top of the shot.

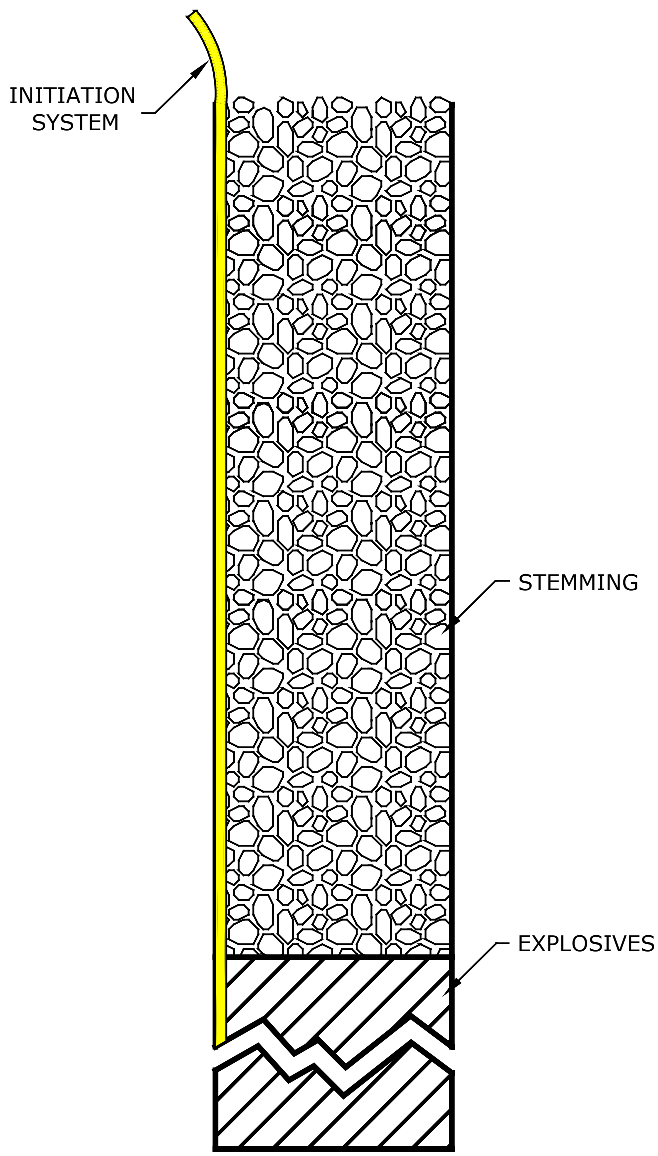


Figure 3: Traditionally stemmed blast hole

ROLE OF STEMMING

- Too little stemming will allow the explosive gasses to vent, creating fly rock and air blast problems as well as reducing the effectiveness of the blast.

- Too much stemming will result in poorly fragmented rock near the top. This is especially apparent with hard cap rock formations.

The introduction of StemPlug Blast Control Plugs will enhance whatever stemming material is used, including the best-crushed stone available. The efficiency of a shot is increased by improving the confinement of explosive energy within the rock mass.

- It is generally accepted that the shock from the initial detonation of explosives in a blast hole is responsible for the cracking, spalling and weakening of the rock around a blast hole. The following rapid expansion of gasses provides the heave and resultant fragmentation. Thus, confining the gasses in the hole for as long as possible is important in maximizing the blast efficiency. This has been substantiated by studies indicating an inverse relationship between stemming ejection velocity and face velocity.

PRODUCT DESCRIPTION

The StemPlug Blast Control Plug is a cone-shaped device constructed of high impact polystyrene. This material has a 15,000-psi compressive strength and is highly resilient.

StemPlug Blast Control Plugs are available in 12 standard diameters ranging from 3-inches (76mm) to 12 ¼-inches (311mm). See Appendix B for a complete list.

Figure 4: StemPlug Blast Control Plug

METHOD OF APPLICATION

The first step in utilizing the StemPlug Blast Control Plug is to create a buffer between the explosive column and the plug. This buffer should be 1 ½ times the diameter of the borehole and consist of a competent stemming material. The purpose of the buffer is to protect the plug from superheated gas while still allowing the plug to provide the desired energy confinement.

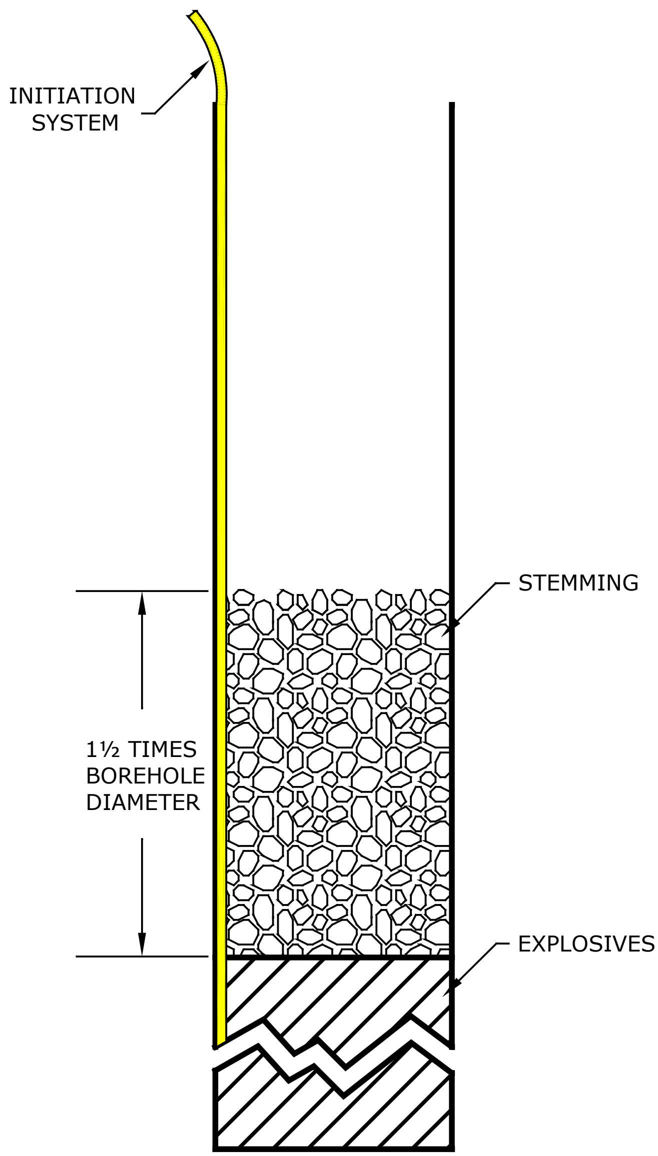


Figure 5: Installation step 1

METHOD OF APPLICATION

Next, the StemPlug Blast Control Plug is lowered onto the buffer with the appropriate insertion tool (see section on insertion tools). Tamp the plug on the buffer to ensure that it is properly seated.

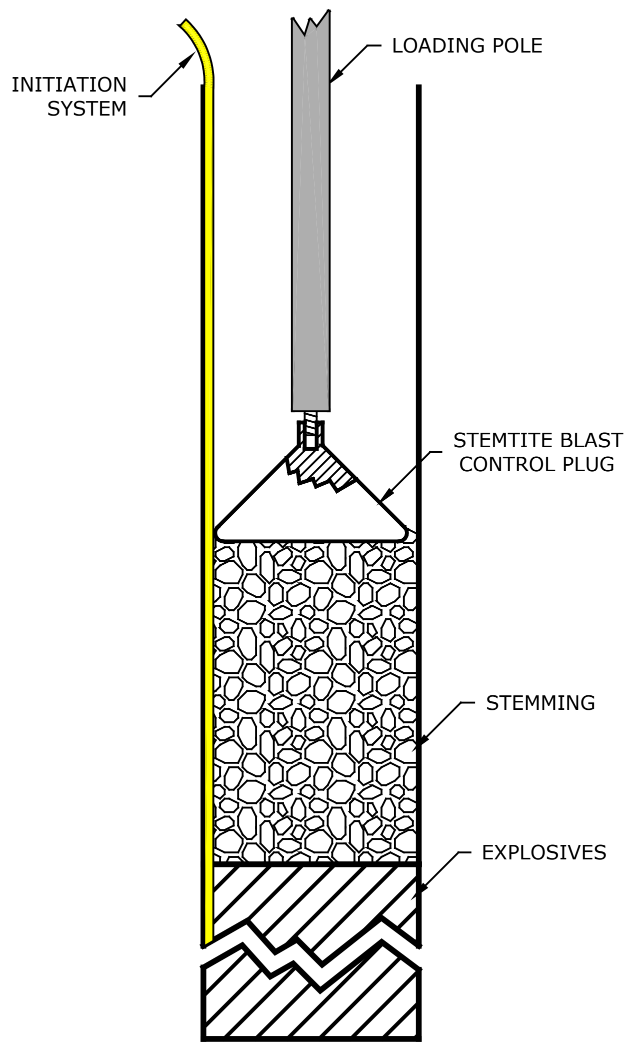


Figure 6: Installation step 2

METHOD OF APPLICATION

Prior to disengaging the insertion tool from the StemPlug Blast Control Plug, add at least one borehole diameter of stemming material to the borehole. This will secure the plug in place, allowing the insertion tool to be removed from the borehole while leaving the plug properly positioned within the stemming column.

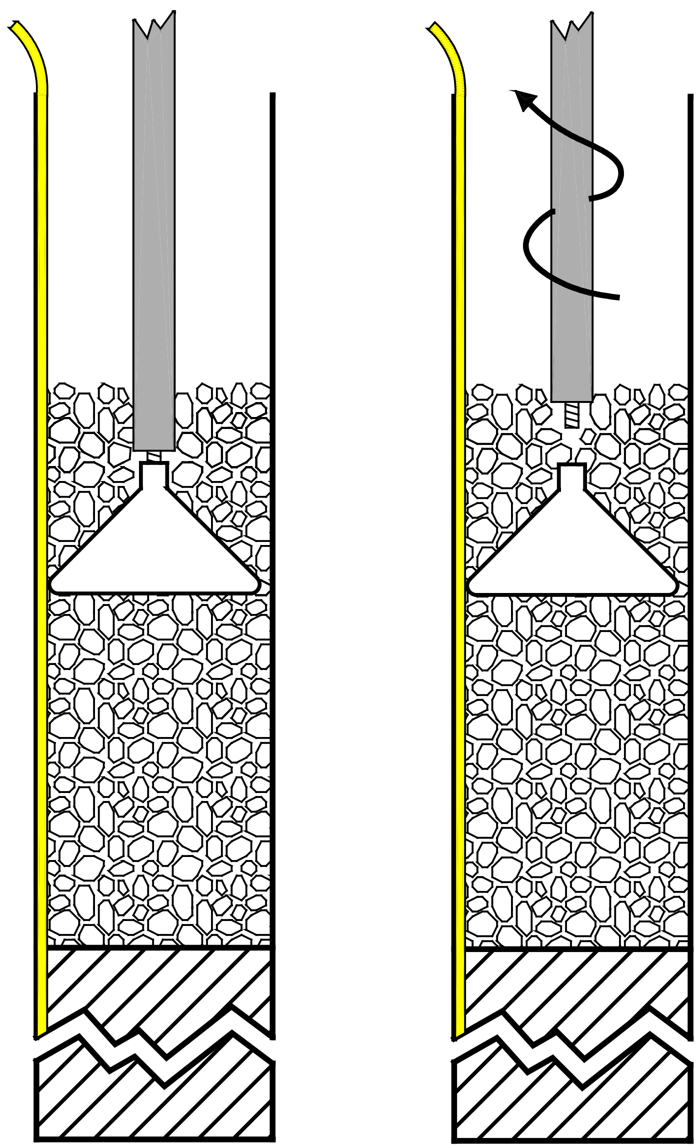


Figure 6: Installation steps 3 & 4

METHOD OF APPLICATION

Continue stemming the charged borehole to the collar or designated height. The stemming column is now equipped with the best available technology in blast energy confinement.

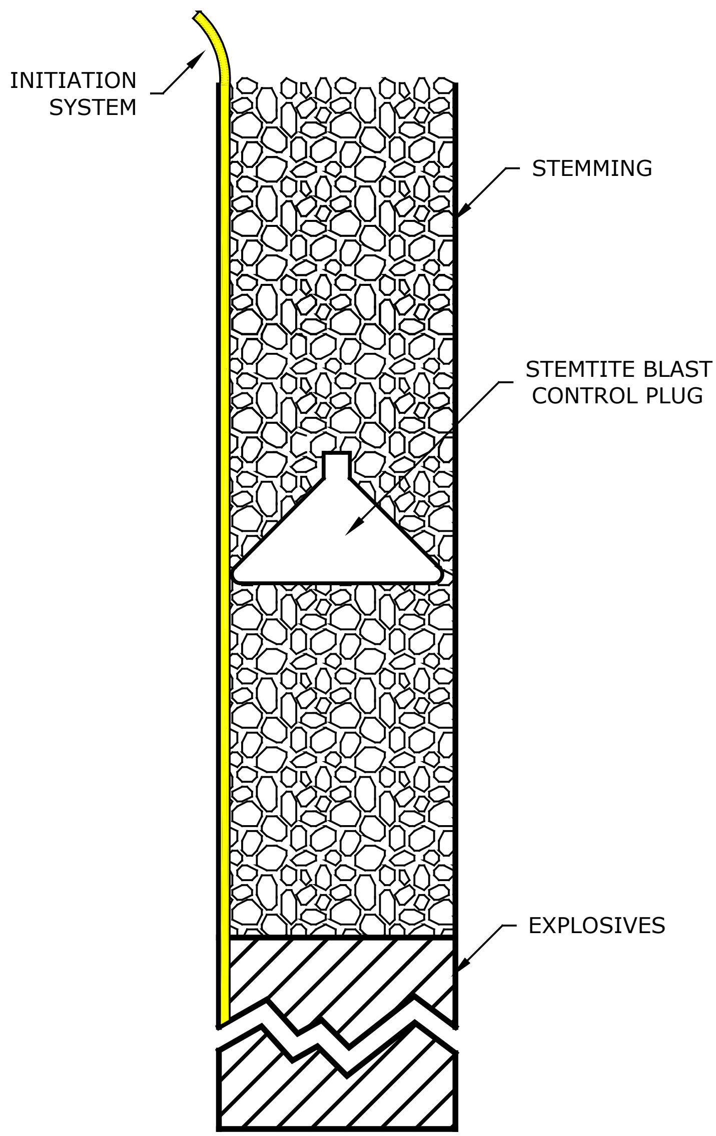


Figure 7: Installation step 5

METHOD OF APPLICATION

Upon detonation, explosive energy drives the StemPlug Blast Control Plug upwards into the stemming column, the typical path of least resistance, and engages the stemming material in the borehole wall. Essentially a self-driving wedge, the StemPlug Blast Control Plug will consistently replicate the "clogged gun barrel" effect to confine blast energy otherwise wasted on troublesome flyrock and noise.

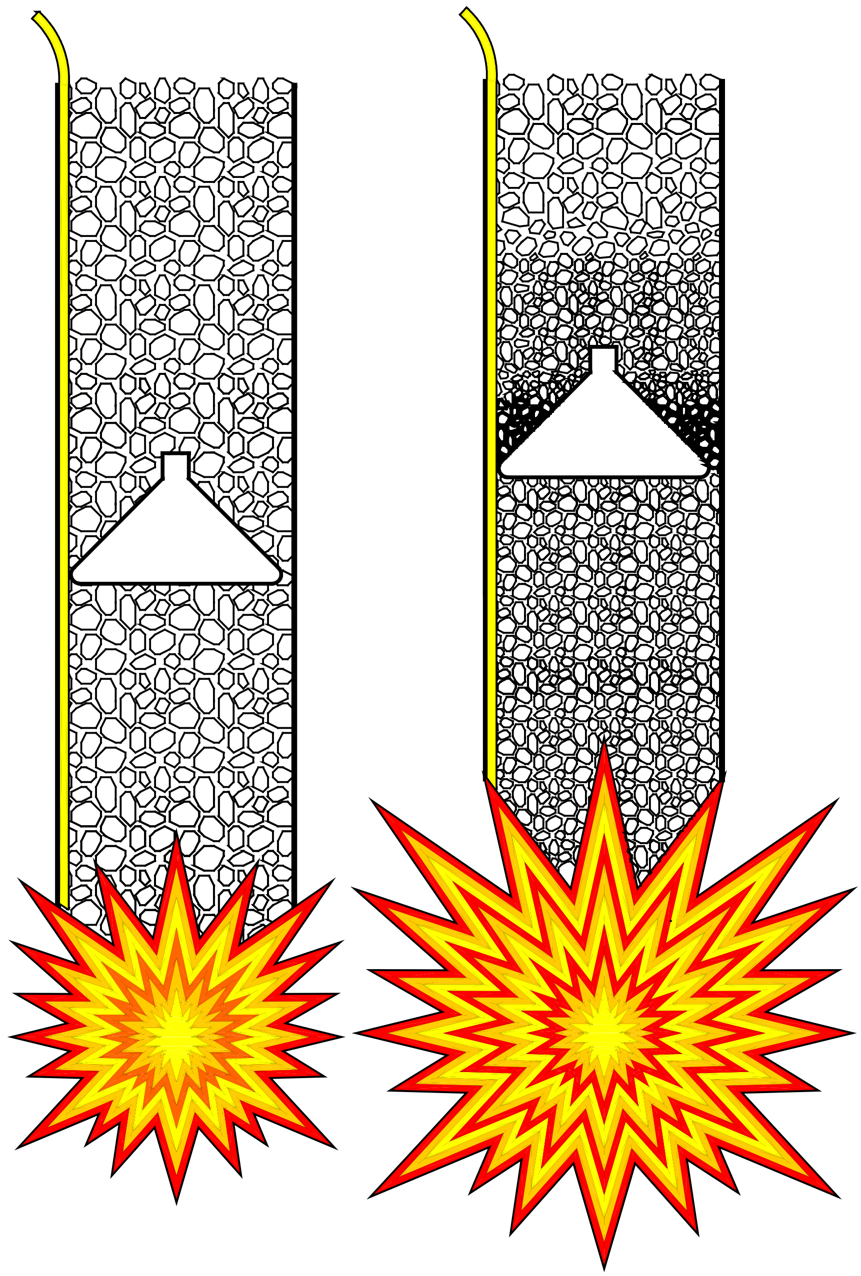


Figure 8: StemPlug mechanism

INSERTION TOOLS

Installing the StemPlug Blast Control Plug is a simple process for most applications. Given our rule of thumb for stemming column length, one foot of stemming per inch of borehole diameter, the majority of plugs are installed shallow enough that the traditional StemPlug loading pole is efficient. This pole is available in a variety of 3-foot sections that may be joined together to accommodate most applications. Note the reverse thread on the tip. This allows the plug to be disengaged from the tip without loosening the pole sections. An alternative to the traditional StemPlug loading pole is specified in Appendix D-loading pole alternatives.

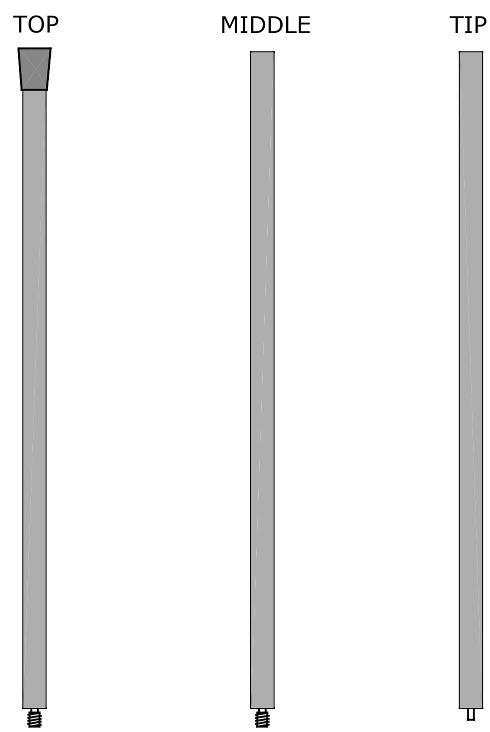


Figure 9: standard loading pole sections

INSERTION TOOLS

Plugs 9-inches in diameter and larger require a specific loading device for installation. A recently developed stainless steel loading pole allows the larger plugs to be lowered by rope to any depth necessary, even through water. These parts are interchangeable with the standard StemPlug loading pole.

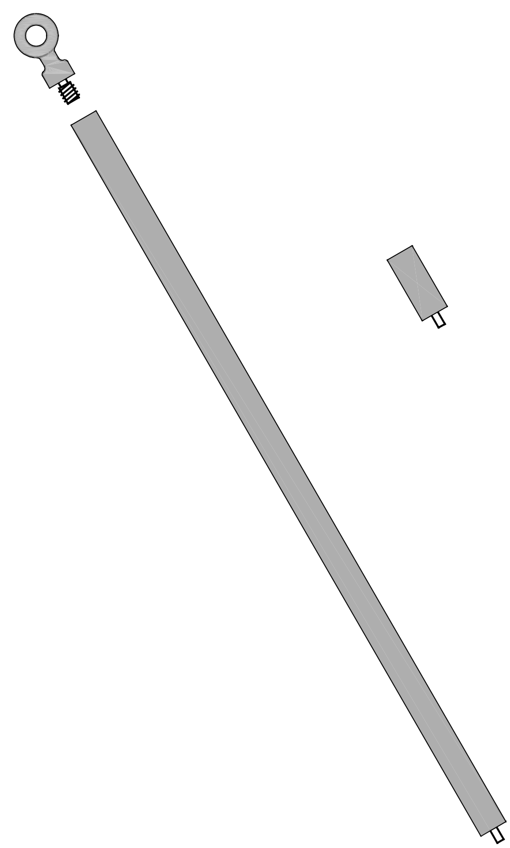


Figure 10: Stainless steel eye bolt, loading pole and tip

BLASTING BENEFITS

The StemPlug Blast Control Plug has one primary function – **TO SEAL THE STEMMING COLUMN UPON DETONATION**. When applied correctly to a properly functioning shot, the benefits of this plug can be tremendous.

HIGHER POWDER COLUMNS

With improved stemming efficiency, the powder column can be safely raised to utilize more of the borehole. The improved energy distribution reduces oversize generated by excessive stemming column lengths. This is especially valuable with troublesome cap rock, where satellite holes may be eliminated altogether.

PATTERN EXPANSION

Shorter stemming columns translate to a higher percentage of the borehole being filled with explosives. This resultant increase in powder factor may permit the expansion of drill patterns while maintaining satisfactory fragmentation. In addition to reduced drilling costs, substantial savings may be realized through the reduction of initiation systems.

IMPROVED DECKING EFFICIENCY

Studies show that maximum utilization of energy is obtained with a combination of the longest air deck and the shortest stemming deck that will provide adequate confinement of borehole gasses. The plug is ideal for this application.

AIR BLAST AND DUST REDUCTION

Lower stemming ejection velocities and reduced venting translate to reduced air blast, which is often the most startling aspect of blasting to sensitive neighbors. Reductions between 8 and 25 decibels may be achieved, depending on the rock type.

FLYROCK CONTROL

In all applications, it has been found that eliminating the venting of explosive force through the borehole collar greatly reduces or even eliminates fly rock. Thus, in addition to improving blasting safety in general, it is possible to extend the safe use of explosives into areas in which it would otherwise be marginal.

DOWNSTREAM BENEFITS

Consistently well-fragmented material is beneficial to the entire mining cycle. Unfortunately, many mines reject the systems approach in favor of a more traditional departmentalized management scheme. Instead of reducing overall processing costs, these individual departments focus on reducing their own costs, often at the expense of the entire operation. The following benefits should redirect attention to the bottom line, increasing profitability.

LESS REHANDLE

Reduction in oversize means fewer secondary blasts. Mechanical breakers may be eliminated altogether.

REDUCED LOAD TIMES

Improved fragmentation and heave translate to better diggability, reduced load times and better equipment utilization.

EXTENDED EQUIPMENT LIFE

Improved diggability reduces wear and tear on cutting edges and undercarriages. In addition, controlled blasting will prevent unnecessary tire damage around the muck pile and on haulage roads.

INCREASED THROUGHPUT

Improved fragmentation means material will travel through the crushing circuit faster, not to mention the downtime avoided in jammed primary crushers. Increases greater than 25% are common with the addition of StemPlug Blast Control Plugs.

LOWER PEAK ENERGY REQUIREMENTS

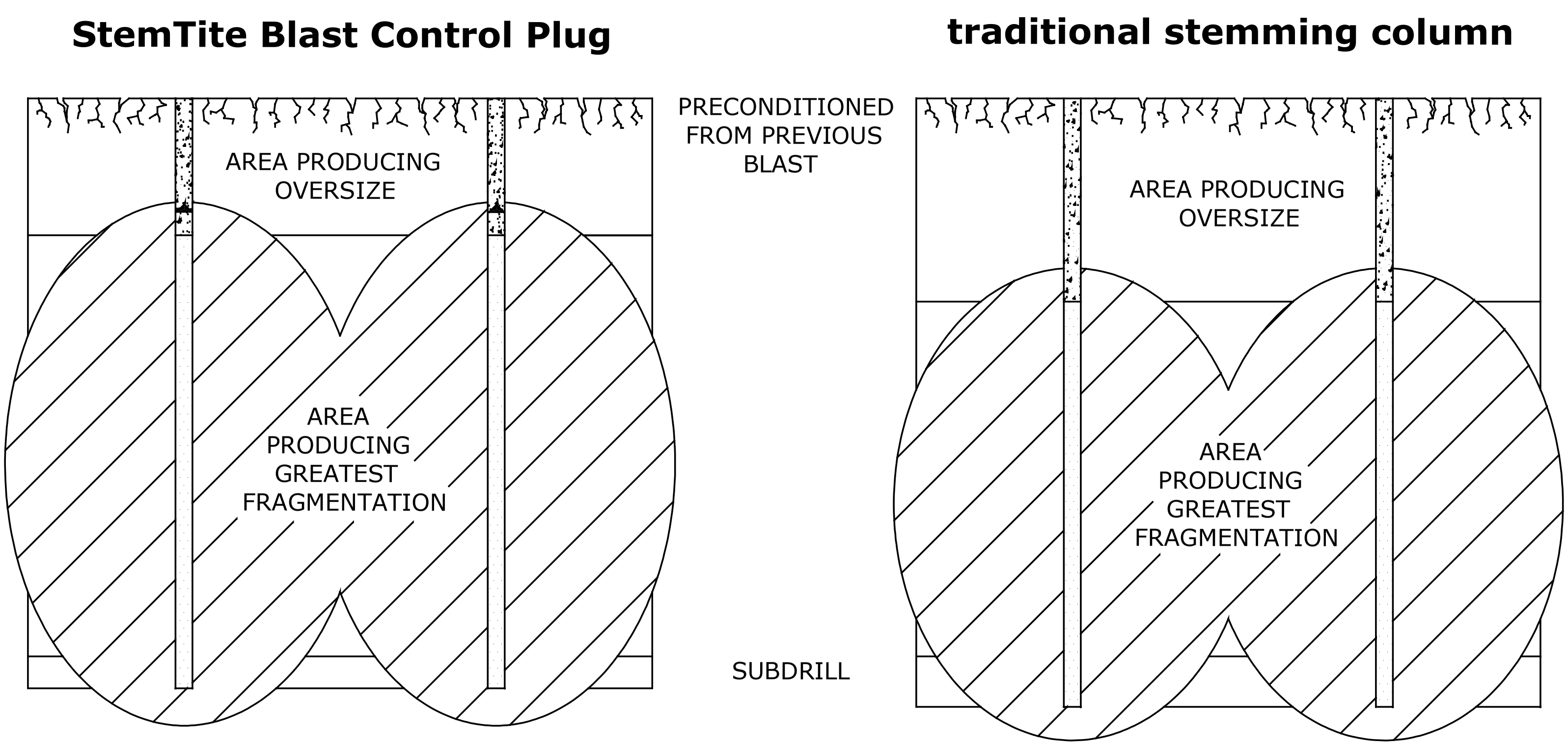
Even with increased throughput, primary crushers routinely draw fewer amps when running well-fragmented material. This has as much to do with blast induced micro-fractures as it does ROM particle size.

INCREASED RECOVERY

For the same reason StemPlug Blast Control Plug users experience lower peak energy requirements at the primary crusher, leaching operations can expect greater ore liberation and increased metal recovery.

APPENDIX A

AREA OF INFLUENCE COMPARISON



The diagram using **StemTite Blast Control Plugs** shows:

- increased blast hole efficiency with higher % of explosives per hole
- area producing oversize significantly reduced
- less subdrill required
- more uniform distribution of blast energy

APPENDIX B

NOMINAL PLUG SIZE (INCHES)	(MM)	ACTUAL DIAMETER (INCHES)	(MM)	TO FIT BOREHOLE DIAMETER RANGE (INCHES)	(MM)
3	76	2.70	68.6	3 - 3 3/8	76 - 86
3 ½	89	3.15	80.0	3 ½ - 3 7/8	86 - 98
4	102	3.70	94.0	4 - 4 3/8	102 - 111
4 ½	114	4.15	105.4	4 ½ - 4 7/8	114 - 124
5	127	4.70	119.4	5 - 5 3/8	127 - 137
5 ½	140	5.18	131.6	5 ½ - 5 7/8	140 - 149
6	152	5.65	143.5	6 - 6 3/8	152 - 162
6 ½	165	6.18	157.0	6 ½ - 7 3/8	165 - 187
7 7/8	200	7.38	187.5	7 ½ - 8 3/8	191 - 213
9	229	8.25	209.6	8 ½ - 9 ¾	216 - 248
10 5/8	270	9.63	244.6	9 7/8 - 11	251 - 276
12 ¼	311	11.0	279.4	11 1/8 - 13	283 - 330

EACH PLUG IS DESIGNED TO OCCUPY APPROXIMATELY 90% OF THE ACTUAL BOREHOLE DIAMETER FOR THE FOLLOWING REASONS:

*ALLOW SPACE FOR PLUG TO FREELY PASS DOWN WIRES

*COMPENSATE FOR DRILL BIT WEAR

FOR MAXIMUM EFFECTIVENESS ALWAYS USE THE CORRECT NOMINAL SIZE PLUG FOR THE STATED BOREHOLE DIAMETER RANGE. FOR EXAMPLE, USE THE 6” PLUG FOR A 6” DIAMETER BOREHOLE.

APPENDIX C

A Good Rule of Thumb for Stemming

BOREHOLE DIAMETER (INCHES)	BOREHOLE DIAMETER (MM)	RECOMMENDED STEMMING SIZE (INCHES)	RECOMMENDED STEMMING SIZE (MM)
3	76	1/4 – 3/8	6.4 – 9.5
3 1/2	89	3/8	9.5
4	102	3/8	9.5
4 1/2	115	3/8 – 1/2	9.5 – 12.7
5	127	1/2	12.7
5 1/2	140	1/2	12.7
6	152	1/2 – 5/8	12.7 – 16.0
6 1/2	165	5/8 – 3/4	16.0 – 19.0
7 7/8	198	3/4	19.0
9	229	3/4 – 1	19.0 – 25.4
10 5/8	270	1	25.4
12 1/4	311	1 – 1 1/4	25.4 – 32.0

*USE CLEAN, CRUSHED STONE WHENEVER POSSIBLE

*STEMMING SIZE SHOULD BE APPROXIMATELY 1/10 THE BOREHOLE DIAMETER

APPENDIX D

ALTERNATE LOADING POLE FOR USE WITH 3" - 7 7/8" STEMTITE BLAST CONTROL PLUGS