Explosives Engineers’ Guide
Who we are, what we do

Explosives users in the mining, quarry, construction, pipeline and geophysical exploration industries know that Dyno Nobel, a global leader in commercial explosives, delivers Groundbreaking Performance through Practical Innovation by focusing on Safety and Continuous Improvement.

Our founder, Alfred Nobel, changed the world with his invention of dynamite and the detonator in the 1860s and changed it again when he founded the world famous Nobel Prizes. Dyno Nobel’s roots also include William Bickford’s invention of Safety Fuses in 1831. Our corporate history is built on this legacy of safety and innovation.

With Zero Harm as our goal - for our employees, our customers and the environment - our safety standards are among the highest in the industry. Because we are all responsible for working safely, we rigorously apply internationally recognized safety standards at all our locations and in everything we do, from storage and transport to handling and use.

Together with our owners, Incitec Pivot Limited, we are a global force in nitrogen-based chemical manufacturing, holding foremost positions in the commercial explosives and fertilizer markets. Incitec Pivot’s explosives business will continue to be identified by the well known Dyno Nobel brand as we take care of our customers in the industries we serve.

Contact Information
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e-mail: explosivesengineer@am.dynonobel.com

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STOP

1. Identify the job you are about to do
2. Break the job into steps and identify hazards involved in each step
3. Assess the HAZARDS using the Hazard Assessment Tool
4. Develop CONTROLS and apply to HAZARDS
5. Record the CONTROLS

TAKE 5! Rapid Hazard Assessment

• Is anything different?
• Has anything changed since you last performed this task?
• If so, Take 5! minutes to Take 5! steps
Bulk Explosives

<table>
<thead>
<tr>
<th>Product</th>
<th>Envison Energy kJ/kg</th>
<th>Mass/Lt. Density</th>
<th>Density (vol%)</th>
<th>Strength (kg/m3)</th>
<th>Power (kJ/kg)</th>
<th>Velocity (ms)</th>
<th>Water Resistant</th>
<th>Loading Method</th>
<th>Usage Code</th>
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<td>P</td>
<td>S,R</td>
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Bulk Explosives

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<td>S,R</td>
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<tr>
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<td>S,R</td>
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<td>S,R</td>
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Useage Codes

- S = Surface Blasting
- U = Underground Blasting
- R = Repeatable
- SM = Site-filled
- G = Gassed or Gasable
- SO = Self-Drill One Component

Rainfall Weight Strength (RWS) and Rainfall Bulk Strength (RBS) can be calculated based on ANFO = 1.00 @ density of 0.82 g/cc.
Dynamite Emulsion

Energy cal/g = Absolute Weight Strength     Energy cal/cc = Absolute Bulk Strength

Relative Weight Strength (RWS) and Relative Bulk Strength (RBS) can be calculated based on ANFO = 1.00 @ density of 0.82 g/cc

**Seismic Usage Codes**

- **RS** = Resistant to Sympathetic Detonation
- **P** = Permissible
- **U** = OK for underground Use
- **RD** = Resistant to Dead-Pressing

**Dynamite**

- **DYNOL®**
  - Density (g/cc): 0.82
  - Diameter: 1 to 2
  - Volume: 4 to 7
  - Calorific Value: 1,085
  - Velocity: 3,900
  - Water Resistance: Excellent

- **DYNOL® AP**
  - Density (g/cc): 0.95
  - Diameter: 3/4 to 2
  - Volume: 7 to 9
  - Calorific Value: 1,055
  - Velocity: 3,775
  - Water Resistance: Excellent

- **DYNOL® AP PLUS**
  - Density (g/cc): 0.9
  - Diameter: 3/4 to 1
  - Volume: 7 to 9
  - Calorific Value: 1,055
  - Velocity: 3,775
  - Water Resistance: Excellent

**Emulsion**

- **DYNOL®**
  - Density (g/cc): 0.82
  - Diameter: 1 to 2
  - Volume: 4 to 7
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**Seismic**

- **DYNOL®**
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  - Water Resistance: Excellent

- **DYNOL® AP**
  - Density (g/cc): 0.95
  - Diameter: 3/4 to 2
  - Volume: 7 to 9
  - Calorific Value: 1,055
  - Velocity: 3,775
  - Water Resistance: Excellent

**Packaged Explosives**

- **Dynamite in Paper Tube Shell with NG Vapor Barrier**
  - Density (g/cc): 0.82
  - Diameter (inches): 2
  - Volume: 6 to 8
  - Calorific Value: 1,055
  - Velocity: 3,775
  - Water Resistance: Excellent

- **Emulsion in Plastic Chub**
  - Density (g/cc): 0.82
  - Diameter (inches): 2
  - Volume: 6 to 8
  - Calorific Value: 1,055
  - Velocity: 3,775
  - Water Resistance: Excellent

**Usage Codes**

- **RS** = Resistant to Sympathetic Detonation
- **P** = Permissible
- **U** = OK for underground Use
- **RD** = Resistant to Dead-Pressing

**Dynamite**

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  - Diameter (inches): 2
  - Volume: 6 to 8
  - Calorific Value: 1,055
  - Velocity: 3,775
  - Water Resistance: Excellent
Detonating Cord & Cast Boosters

Trojan® last boosters

Detonating cord downlines may adversely impact explosives in the borehole.

**Trojan** of 1,880 cal/g and 3,120 cal/cc.

- Spartan, Spartan SL Slider, Spartan Twinplex and SuperPrime Stingers are detonator sensitive and are available.

Additional specialty cords:

- PRIMALINE 31
- PRIMALINE 21
- PRIMALINE 8HT
- PRIMALINE 8D
- PRIMALINE 5D
- PRIMALINE
- PRIMACORD 10
- PRIMACORD 8
- PRIMACORD 5
- PRIMACORD 4R
- PRIMACORD 2.5

Detonation Pressure, lbs/ft

- Excellent
- Good
- Fair
- Poor

### Detonating Cord

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Length</th>
<th>Weight</th>
<th>Tensile</th>
<th>Velocity</th>
<th>Density</th>
<th>Detonation Pressure</th>
<th>Rate</th>
<th>Abrasion</th>
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<tbody>
<tr>
<td>0.010</td>
<td>100</td>
<td>2.2</td>
<td>550</td>
<td>1,250</td>
<td>1,650</td>
<td>24,800</td>
<td>7,550</td>
<td>235</td>
</tr>
<tr>
<td>0.014</td>
<td>14</td>
<td>3.7</td>
<td>1,900</td>
<td>4,500</td>
<td>1,450</td>
<td>24,800</td>
<td>7,800</td>
<td>245</td>
</tr>
<tr>
<td>0.020</td>
<td>20</td>
<td>6.7</td>
<td>4,500</td>
<td>9,000</td>
<td>2,700</td>
<td>24,800</td>
<td>7,800</td>
<td>245</td>
</tr>
<tr>
<td>0.025</td>
<td>30</td>
<td>11</td>
<td>13,000</td>
<td>26,000</td>
<td>6,900</td>
<td>24,800</td>
<td>7,800</td>
<td>245</td>
</tr>
</tbody>
</table>

### Cast Boosters

- NBU 350
- 1.65 g/cc
- 25,600 lbs/ft
- 7,800 m/s

- PRIMALINE 31
- 0.365 g/cc
- 25,600 lbs/ft
- 7,800 m/s

- PRIMALINE 21
- 0.265 g/cc
- 25,600 lbs/ft
- 7,800 m/s

- PRIMALINE 8HT
- 0.365 g/cc
- 25,600 lbs/ft
- 7,800 m/s

### Cord Gases

- 0.65 x 3.5
- 2.3 x 4.7
- 2.2 x 4.7
- 2.2 x 4.6
- 2.3 x 4.7
- 2.0 x 4.7
- 2.1 x 4.7
- 1.6 x 4.6

### Cord Velocities

- 9,150 m/s
- 9,000 m/s
- 8,850 m/s
- 8,700 m/s
- 8,550 m/s
- 8,400 m/s
- 8,250 m/s

### Cord Detonation Pressures

- 245 lbs/ft
- 235 lbs/ft
- 245 lbs/ft
- 235 lbs/ft
- 245 lbs/ft
- 235 lbs/ft
- 235 lbs/ft

### Cord Abrasion Resistance

- Excellent
- Good
- Fair
- Poor

### Cord Colors

- Yellow / 1 black
- Pink / 1 black
- Clear / 1 black
- Yellow / 4 black
- Yellow / 5 black
- Red / 1 black
- Red / 2 black
- Orange / 5 black
- Orange / 2 black

### Detonating Cord Downlines

- NBU 350 g
- NBU 450 g
- NBU 400 g
- NBU 350 g
- NBU 500 g
- NBU 400 g
- NBU 350 g
- NBU 250 g
- NBU 150 g

- 12 g
- 24 g
- 48 g
- 72 g
- 90 g
- 20 g
- 10 g
- 5 g

### Detonator Sensitivity

- Spartan, Spartan SL Slider, Spartan Twinplex and SuperPrime Stingers are detonator sensitive and have nominal energy of 1.370 cal/kg and 2.190 cal/cc.

### Additional Specialty Cords

- Available.

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* Detonation cord downlines may adversely impact explosives in the borehole. Please consult your Dyna-Tech® distributor for additional specialty cords available.
Dyno Nobel Electronic Initiation Systems

DigiShot™
• Wired or Wireless Remote Firing (up to 3.5Km line-of-sight)
• Leaky Feeder Underground Remote Firing
• 4-Wire Daisy-Chain Hookup
• Up to 2400 Detonators per Blaster (dependent on shot layout)
• Delays from 0 to 20,000 msec in 1 msec Increments
• Requires Password, Coded Signal & Blast Key to Fire

DigiShot® Plus
• Wired or Wireless Remote Firing
• 2-Wire Busline Hookup
• Up to 1800 Detonators per Blaster (7,200 per blast)
• Fully Programmable with Auto-Programmability
• Delays from 0 to 20,000 msec in 1 msec Increments
• Requires Password, Coded Signal & Blast Key to Fire

SmartShot™
• Wired Firing
• 2-Wire Busline Hookup
• Maximum of 7 Detonators per Array
• Firing Accuracy of <0.1ms Deviation
• Fires Only With encrypted Signal from GeoShot SIU
• High Visibility Orange Cable Color

Electronic Detonator for Initiation of Seismic Charges
• Wired or Wireless Remote Firing (up to 3.5Km line-of-sight)
• Leaky Feeder Underground Remote Firing
• 4-Wire Daisy-Chain Hookup
• Up to 2400 Detonators per Blaster (dependent on shot layout)
• Delays from 0 to 20,000 msec in 1 msec Increments
• Requires Password, Coded Signal & Blast Key to Fire

DriftShot™
• Wired Firing
• 2-Wire Busline Hookup
• Wired or Wireless Remote Firing
• 2-Wire Busline Hookup
• Maximum of 7 Detonators per Array
• Firing Accuracy of <0.1ms Deviation
• Fires Only With encrypted Signal from GeoShot SIU
• High Visibility Orange Cable Color

GeoShot™
Electronic Detonator for Initiation of Seismic Charges
• Wired or Wireless Remote Firing (up to 3.5Km line-of-sight)
• Leaky Feeder Underground Remote Firing
• 4-Wire Daisy-Chain Hookup
• Up to 2400 Detonators per Blaster (dependent on shot layout)
• Delays from 0 to 20,000 msec in 1 msec Increments
• Requires Password, Coded Signal & Blast Key to Fire

DriftShot™
Electronic Detonator for Underground Development
• Pre-Numbered Periods with Electronic Accuracy
• Wired Firing or Wireless Firing via Proprietary Templates in BCU
• Remote Firing Available
• Easy to Use - All Timing via Preset Templates in BCU
• Requires Password, Coded Signal & Blast Key to Fire

GeoShot is available in lengths from 3.5m (12 ft) to 54m (180 ft). See the GeoShot Technical Info Sheet or consult your Dyno Nobel representative for details.

Electronic Initiation
• Wired Firing
• 2-Wire Busline Hookup
• Pre-Numbered Periods with Electronic Accuracy
• Wired Firing or Wireless Firing via Proprietary Templates in BCU
• Remote Firing Available
• Easy to Use - All Timing via Preset Templates in BCU
• Requires Password, Coded Signal & Blast Key to Fire

* Please consult your Dyno Nobel representative for details.

** 2m units are manufactured with bunch block. Additional length configurations are available, please consult your Dyno Nobel representative for details.

DigiShot®, DigiShot® Plus, GeoShot®, DriftShot® and SmartShot™ are registered trademarks of DetNet South Africa (Proprietary) Limited.
An instant electric detonator in a plastic bunch block for easy connection to both shock tube and detonating cord.

**SP Series**

**Nominal Firing Time (msec)**

<table>
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<tr>
<th>Delay Periods</th>
<th>SP Series</th>
<th>LP Series</th>
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<tbody>
<tr>
<td>Instant</td>
<td>Copper Wire (single) = yellow &amp; turquoise</td>
<td>Copper Wire (single) = red &amp; yellow</td>
</tr>
<tr>
<td></td>
<td>Copper Wire (duplex) = turquoise</td>
<td>Copper Wire (single) = red &amp; white</td>
</tr>
<tr>
<td></td>
<td>Copper clad iron (single) = orange &amp; orange</td>
<td>Copper clad iron (single) = red</td>
</tr>
<tr>
<td></td>
<td>LP copper wire (single) = orange &amp; orange</td>
<td>LP copper wire (single) = red &amp; yellow</td>
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</table>

**Delay Periods**

**Legwire Color - SP & LP Series:**

- SP copper wire (single) = yellow & turquoise
- SP copper wire (duplex) = turquoise
- SP copper clad iron (single) = orange & orange
- LP copper wire (single) = red & yellow

**Electric Initiation**

**Average Resistance (ohms):**

<table>
<thead>
<tr>
<th>Series</th>
<th>SP Series</th>
<th>Electric Super Coal</th>
<th>Electric Super Seismic</th>
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<tr>
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<tr>
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<tr>
<td>Resistance</td>
<td>1.92</td>
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</table>

**Electric Super™ Seismic**

A high strength detonator designed to initiate seismic explosives used in geophysical exploration.

**Electric Super™ Coal**

Designed to meet MSHA requirements in underground coal mining.

**Electric Super™ Starter**

An instant electric detonator in a plastic bunch block for easy connection to both shock tube and detonating cord.
NONEL® MS Connector

MS initiators are bi-directional delay connectors assembled to a length of stranded orange shock tube with a white plastic J-hook at the opposite end.

<table>
<thead>
<tr>
<th>Color</th>
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<td>109</td>
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</table>

NONEL® EZ DET

EZ DET units are nonelectric short lead millisecond delay detonators assembled to a length of stranded orange shock tube with a white plastic J-hook at the opposite end.

<table>
<thead>
<tr>
<th>Time (msec)</th>
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<th>Tag</th>
<th>Color</th>
<th>Tag</th>
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<td>375</td>
<td>Red</td>
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<td>Yellow</td>
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<td>Blue</td>
<td>425</td>
<td>Pink</td>
</tr>
<tr>
<td>100</td>
<td>Green</td>
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<td>Purple</td>
<td>650</td>
<td>White</td>
</tr>
<tr>
<td>250</td>
<td>Orange</td>
<td>109</td>
<td>Black</td>
<td>109</td>
<td>Black</td>
</tr>
</tbody>
</table>

NONEL® EZ DRIFTER®

EZ DRIFTER units consist of a 300 ft roll of nonelectric detonator housed in a plastic EZ Connector™ block and linked by a length of orange shock tube.

<table>
<thead>
<tr>
<th>Nominal Time (msec)</th>
<th>EZ Connector Color</th>
<th>Tag</th>
<th>Color</th>
<th>Tag</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Orange</td>
<td>325</td>
<td>White</td>
</tr>
<tr>
<td>150 / 3500</td>
<td>Yellow</td>
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<td>350</td>
<td>Red</td>
</tr>
<tr>
<td>120 / 2500</td>
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<td>375</td>
<td>Pink</td>
</tr>
<tr>
<td>90 / 2000</td>
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<td>Green</td>
<td>400</td>
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</tr>
<tr>
<td>60 / 1700</td>
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<td>Blue</td>
<td>425</td>
<td>Purple</td>
</tr>
<tr>
<td>30 / 1000</td>
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<td>5</td>
<td>Orange</td>
<td>475</td>
<td>Black</td>
</tr>
<tr>
<td>0</td>
<td>Red</td>
<td>6</td>
<td>Red</td>
<td>500</td>
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</tr>
<tr>
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</tr>
<tr>
<td>300 / 3200</td>
<td>White</td>
<td>8</td>
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<td>100</td>
<td>Red</td>
</tr>
<tr>
<td>1000 / 3500</td>
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<td>9</td>
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<td>109</td>
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</table>

NONEL® EZ TL

EZ TL trunkline delay detonators consist of a length of yellow shock tube with a white plastic EZ Connector™ block on one end and sealed with a plastic J-hook at the opposite end.

<table>
<thead>
<tr>
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<th>EZ Connector Color</th>
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<th>Color</th>
<th>Tag</th>
<th>Color</th>
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<td>350</td>
<td>Red</td>
</tr>
<tr>
<td>16 / 400</td>
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<td>Blue</td>
<td>375</td>
<td>Pink</td>
</tr>
<tr>
<td>15 / 450</td>
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<td>Green</td>
<td>400</td>
<td>White</td>
</tr>
<tr>
<td>14 / 500</td>
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<td>425</td>
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<tr>
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<td>500</td>
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<tr>
<td>11 / 650</td>
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<td>Yellow</td>
<td>650</td>
<td>Purple</td>
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<tr>
<td>10 / 700</td>
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<tr>
<td>0</td>
<td>Green</td>
<td>9</td>
<td>Green</td>
<td>109</td>
<td>Black</td>
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</table>

NONEL® EZ Connector

EZ Connectors consist of a precise millisecond delay detonator housed in a plastic EZ Connector™ block on one end and sealed with a white plastic J-hook at the opposite end.

<table>
<thead>
<tr>
<th>Nominal Time (msec)</th>
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<tbody>
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<td>750</td>
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<tr>
<td>800</td>
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NONEL® Nonelectric Initiation

- EZ DET: Nonelectric short lead millisecond delay detonators assembled to a length of stranded orange shock tube with a white plastic J-hook at the opposite end.
- EZ TL: Nonelectric long period delay detonators assembled to a length of stranded yellow shock tube with a 5400 ms in-hole detonator on the other end.
- EZ DRIFTER: EZ DRIFTER units consist of a 300 ft roll of nonelectric detonator housed in a plastic EZ Connector™ block and linked by a length of orange shock tube.
- EZ Connector: EZ Connectors consist of a precise millisecond delay detonator housed in a plastic EZ Connector™ block on one end and sealed with a white plastic J-hook at the opposite end.
- MS Connector: MS initiators are bi-directional delay connectors assembled to a length of stranded orange shock tube with a white plastic J-hook at the opposite end.
- Starter & Lead Line: Starter® is a snap-on snap tube block that is factory-assembled to a nonelectric detonator. Available in 200, 500, or 1,000 foot lengths.
<table>
<thead>
<tr>
<th>Explosive Diameter</th>
<th>Kilograms of Explosive per Meter of Blashole</th>
<th>Loading Density (g/lc)</th>
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</thead>
<tbody>
<tr>
<td>0.75</td>
<td>2.00</td>
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<tr>
<td>0.80</td>
<td>2.25</td>
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<td>0.85</td>
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<td>1.50</td>
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Cubic Meters of Rock per Meter of Blashole = \( \text{Burden} \times \text{Spacing} \times 1 \text{Meter} \)
<table>
<thead>
<tr>
<th>Explosive Diameter (in)</th>
<th>Pounds of Explosive per Foot of Blasting Hole</th>
<th>Cubic Yards of Rock per Foot of Blasting Hole</th>
<th>Spacing (ft)</th>
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<tr>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
<td>1.010 x Diameter</td>
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<td>1.343 x Diameter</td>
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<tr>
<td>20</td>
<td>6.671 x Diameter</td>
<td>6.671 x Diameter</td>
<td></td>
</tr>
</tbody>
</table>

Loading Density (lbs) & Rock Volume (yd³)
Definitions
Airblast The airborne shock wave or acoustical transient generated by an explosion.
Backbreak Rock broken beyond the limits of the last row of blastholes. Same as overbreak.
Blast Area The area of the blast within the influence of flying rock, gases, and concussion.
Blast-In-Charge The blaster who is in charge of and responsible for the design, loading, and firing of a blast at a specific job site.
Blast Site The area where explosive material is handled during loading of blastholes including 50 feet in all directions from the periphery formed by loaded blastholes.
Blasting Agent A mixture intended for blasting that cannot be detonated with a No. 8 detonator when unconfined. Same as Detonator Sensitive Explosive.
Blasting Agent a thin film or layer of explosive material by gravity, centrifugation, spray, or similar methods.
Blasting Agent a mixture of explosive materials by a high energy mechanical process.
Blasting Agent a mixture of explosive materials by a high energy mechanical process.
Blasting Agent a mixture of explosive materials containing a large percentage of unreacted solid materials.
Blasting Agent a mixture of explosive materials containing a large percentage of unreacted solid materials.
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**Expected Ground Vibration**

When an explosive is detonated in the ground, three types of seismic waves are generated; compressive, shear and surface. These waves can result in structure response and on rare occasions, structure damage. Extensive research has provided for safe blasting criteria based on peak particle velocity measured from the wave event. Peak particle velocity (PPV) values can be estimated using the following formulas.

**Where:**
- **PPV** = Peak particle velocity (in/sec)
- **H** = Ground response factor
- **W** = Weight of explosives (lbs)

**Metric**

\[
PPV = \left( \frac{\text{Scaled Distance}}{\text{Distance from explosive to seismograph}} \right)^{1.6} \times H
\]

**Imperial**

\[
PPV = \left( \frac{\text{Scaled Distance}}{\text{Distance from explosive to seismograph}} \right)^{1.6} \times H
\]

**W Factors**
- Lower limit, little or no confinement: 24.2
- Average value, typical confinement: 160
- Upper limit, heavy confinement: 242

**Scaled Distance**

\[
D_S = D \times \sqrt{W}
\]

**Where:**
- **D** = Distance (ft) to nearest structure
- **W** = Weight of explosives (lbs)

The adjoining table provides the maximum pounds of explosives that can be detonated within an 8 millisecond delay at the given distances, without monitoring, according to the Office of Surface Mining (OSM) recommendations.

<table>
<thead>
<tr>
<th>Distance (ft)</th>
<th>Metric</th>
<th>Imperial</th>
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</thead>
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<td>0 - 300</td>
<td>25</td>
<td>0.25</td>
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<tr>
<td>301 - 5,000</td>
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<td>1.00</td>
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<tr>
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<tr>
<td></td>
<td>10,000</td>
<td>23,668</td>
</tr>
</tbody>
</table>

**Safe Level Blasting Criteria**

**USBM RI 8507**

**OSM REGULATIONS**

**Wet Hole Calculations**

1. To determine the final height of water in the borehole when the top of the last cartridge is at water level

\[
FH = \frac{H_O x D_B^2}{D_E^2} - D_E
\]

**Where:**
- **FH** = Final height of borehole water rise (from equation 1)
- **H_O** = Original height of water in feet
- **D_B** = Diameter of borehole in inches
- **D_E** = Diameter of explosive package in inches

2. To determine the number of cartridges needed to build out of borehole water

\[
N_C = \frac{FH x 12}{L_C}
\]

**Where:**
- **N_C** = Number of cartridges needed
- **FH** = Final height of borehole water rise
- **L_C** = Length of cartridge in inches