Blasting and Explosives Quick Reference Guide 2010

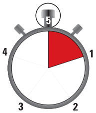
DYNO

Dyno Nobel

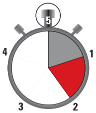
Groundbreaking Performance

Rapid Hazard Assessment

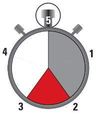
- Is the task new?
- Is anything different?
- Has anything changed since you last performed this task?
- If so, STOP, THINK and apply the Take 5 steps!



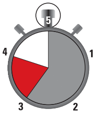
1 Describe the task.
What is the task you are about to do?



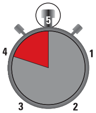
2 List the Hazards.
What are the main hazards involved in carrying out the task?



3 List the controls.
What controls will you use to reduce the risk?

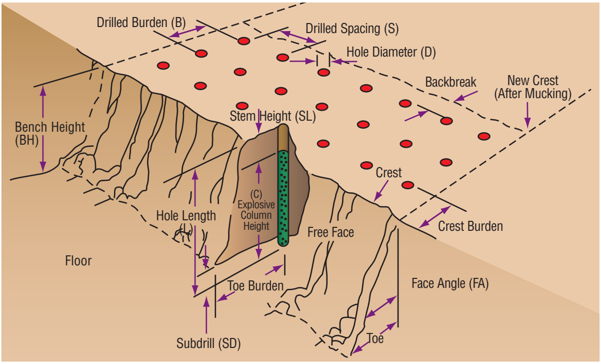


4 Assess the risk.
Use the Hazard Assessment Tool (HAT) to determine the risk after controls are applied.



5 Decide what is next.
Apply the controls.
Is it safe to proceed with the task?
Are additional controls required?

Blast design terminology and formulas



Hole length (L) =	BH + SD
Charge length (C) =	L - SL
Blast volume (V) =	B x S x BH x N
Blasted tonnes (T) =	V x Density of rock in t/m^3
Volume of blasthole (Vb) =	π x D^2/4000 x L
Mass of explosive per hole (kg) =	Volume of hole length charged x Explosive density
PF (kg/m^3) =	Total explosives in the blast/volume of rock blasted (for kg/Tonne, divided by blasted tonnes T)
RWS =	AWS of explosive/AWS of ANFO x 100
RBS =	(RWS explosive x explosive density)/ (ANFO density)
Energy factor =	PF x RWS
Vertical length of angled holes =	Measured hole length x cos $\propto$

$\propto$ **=** Angle subtended from the vertical by the inclined hole

π **=** 3.1416 (the ratio of the circumference of a circle to its diameter)

AWS = Absolute weight strength

B = Drilled burden (m)

BH = Bench height (m)

C = Explosive column height or charge length (m)

D = Hole diameter in millimetres

L = Hole length (m)

N = Number of holes in a blast

PF = Powder factor

RBS = Relative bulk strength

RWS = Relative weight strength

S = Drilled spacing (m)

SD = Subdrill (m)

SL = Stemming length (m)

T = Blasted tonnes

V = Blast volume (m^3)

Rules of thumb

These rules provide a first estimate in the absence of any better data.

Blast hole diameter in mm ≤	15 x Bench height (BH) in metres
Bench height (BH) in metres ≥	(Blast hole diameter (D) in mm)/15
Burden (B) =	(25 to 40) x (D)
Spacing (S) =	1.15 x B (This gives an equilateral pattern)
Subdrill =	(3 to 15) x D
Charge length (C) ≥	20 D
Stemming ≥	20 x D or (0.7 - 1.2) x B
Burden stiffness ratio =	BH/B : 2 to 3.5 good fragmentation : > 3.5 very good fragmentation
Stemming material size =	D/10 to D/20 (Angular material with minimum fines)

Presplit blasting

Spacing =	Hole diameter x 12
Burden =	0.5 x production blast burden (B)
Uncharged length at top =	10 x D
Powder factor =	0.5kg per square metre of face

Do not stem holes.

Fire all holes on the same delay, or in groups of ≥ 5 holes

Smooth Blasting

Spacing =	15 x Hole diameter (hard rock) 20 x Hole diameter (soft rock)
Burden =	1.25 x Spacing

Fire as many holes as possible on one delay.

Stem holes.

Powder factors

Typical powder factors used in mass blasts

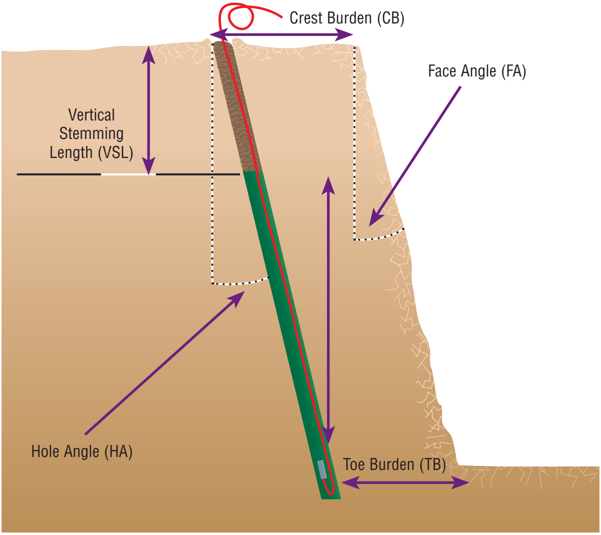
Rock type	PF (kg/m³)
Hard	0.7 - 0.8
Medium	0.4 - 0.5
Soft	0.25 - 0.35
Very Soft	0.15 - 0.25

Typical powder factors used in presplit and smooth blasting

Hole diameter	PF (kg/m³)
Hard	0.6 -0.9
Medium	0.4 - 0.5
Soft	0.2 - 0.3

Angle faced holes

Calculating burdens



Crest Burden (CB)	=	Distance blasthole collar is from crest
Vertical Stemming Length (VSL)	=	(measured stemming length x cos [HA])
Toe Burden (TB)	=	Burden at floor level
	=	([tan (FA) x bench height] + CB) - (tan [HA] x bench height)

Loading density

Hole Diameter mm	Hole Diameter in	Kg of explosive per meter of column for given density (g/cm³)* 0.60	0.80	0.82	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.30	1.35	1.40	Hole Diameter mm	Hole Diameter in
25	1	0.29	0.39	0.40	0.42	0.44	0.47	0.49	0.52	0.54	0.56	0.59	0.64	0.66	0.69	25	1
32	1 1/4	0.48	0.64	0.66	0.68	0.72	0.76	0.80	0.84	0.88	0.92	0.97	1.05	1.09	1.13	32	1 1/4
38	1 1/2	0.68	0.91	0.93	0.96	1.02	1.08	1.13	1.19	1.25	1.30	1.36	1.47	1.53	1.59	38	1 1/2
45	1 3/4	0.95	1.27	1.30	1.35	1.43	1.51	1.59	1.67	1.75	1.83	1.91	2.07	2.15	2.23	45	1 3/4
51	2	1.23	1.63	1.68	1.74	1.84	1.94	2.04	2.14	2.25	2.35	2.45	2.66	2.76	2.86	51	2
57	2 1/4	1.53	2.04	2.09	2.17	2.30	2.42	2.55	2.68	2.81	2.93	3.06	3.32	3.44	3.57	57	2 1/4
64	2 1/2	1.93	2.57	2.64	2.73	2.90	3.06	3.22	3.38	3.54	3.70	3.86	4.18	4.34	4.50	64	2 1/2
70	2 3/4	2.31	3.08	3.16	3.27	3.46	3.66	3.85	4.04	4.23	4.43	4.62	5.00	5.20	5.39	70	2 3/4
76	3	2.72	3.63	3.72	3.86	4.08	4.31	4.54	4.76	4.99	5.22	5.44	5.90	6.12	6.35	76	3
83	3 1/4	3.25	4.33	4.44	4.60	4.87	5.14	5.41	5.68	5.95	6.22	6.49	7.03	7.30	7.57	83	3 1/4
89	3 1/2	3.73	4.98	5.10	5.29	5.60	5.91	6.22	6.53	6.84	7.15	7.47	8.09	8.40	8.71	89	3 1/2
95	3 3/4	4.25	5.67	5.81	6.02	6.38	6.73	7.09	7.44	7.80	8.15	8.51	9.21	9.57	9.92	95	3 3/4
102	4	4.90	6.54	6.70	6.95	7.35	7.76	8.17	8.58	8.99	9.40	9.81	10.62	11.03	11.44	102	4
108	4 1/4	5.50	7.33	7.51	7.79	8.24	8.70	9.16	9.62	10.08	10.54	10.99	11.91	12.37	12.83	108	4 1/4
114	4 1/2	6.12	8.17	8.37	8.68	9.19	9.70	10.21	10.72	11.23	11.74	12.25	13.27	13.78	14.29	114	4 1/2
121	4 3/4	6.90	9.20	9.43	9.77	10.35	10.92	11.50	12.07	12.65	13.22	13.80	14.95	15.52	16.10	121	4 3/4
127	5	7.60	10.13	10.39	10.77	11.40	12.03	12.67	13.30	13.93	14.57	15.20	16.47	17.10	17.73	127	5
133	5 1/4	8.34	11.11	11.39	11.81	12.50	13.20	13.89	14.59	15.28	15.98	16.67	18.06	18.76	19.45	133	5 1/4
140	5 1/2	9.24	12.32	12.62	13.08	13.85	14.62	15.39	16.16	16.93	17.70	18.47	20.01	20.78	21.55	140	5 1/2
146	5 3/4	10.04	13.39	13.73	14.23	15.07	15.90	16.74	17.58	18.42	19.25	20.09	21.76	22.60	23.44	146	5 3/4
152	6	10.89	14.52	14.88	15.42	16.33	17.24	18.15	19.05	19.96	20.87	21.78	23.59	24.50	25.40	152	6
159	6 1/4	11.91	15.88	16.28	16.88	17.87	18.86	19.86	20.85	21.84	22.83	23.83	25.81	26.81	27.80	159	6 1/4
165	6 1/2	12.83	17.11	17.53	18.18	19.24	20.31	21.38	22.45	23.52	24.59	25.66	27.80	28.87	29.94	165	6 1/2
172	6 3/4	13.94	18.59	19.05	19.75	20.91	22.07	23.24	24.40	25.56	26.72	27.88	30.21	31.37	32.53	172	6 3/4
178	7	14.93	19.91	20.41	21.15	22.40	23.64	24.88	26.13	27.37	28.62	29.86	32.35	33.59	34.84	178	7
187	7 1/4	16.48	21.97	22.52	23.34	24.72	26.09	27.46	28.84	30.21	31.58	32.96	35.70	37.08	38.45	187	7 3/8
200	7 1/2	18.85	25.13	25.76	26.70	28.27	29.85	31.42	32.99	34.56	36.13	37.70	40.84	42.41	43.98	200	7 7/8
203	8	19.42	25.89	26.54	27.51	29.13	30.75	32.37	33.98	35.60	37.22	38.84	42.08	43.69	45.31	203	8
216	8 1/2	21.99	29.31	30.05	31.15	32.98	34.81	36.64	38.48	40.31	42.14	43.97	47.64	49.47	51.30	216	8 1/2
229	9	24.71	32.95	33.77	35.01	37.07	39.13	41.19	43.25	45.31	47.37	49.42	53.54	55.60	57.66	229	9
251	9 1/2	29.69	39.58	40.57	42.06	44.53	47.01	49.48	51.95	54.43	56.90	59.38	64.33	66.80	69.27	251	9 1/2
254	10	30.40	40.54	41.55	43.07	45.60	48.14	50.67	53.20	55.74	58.27	60.80	65.87	68.41	70.94	254	10
270	10 1/2	34.35	45.80	46.95	48.67	51.53	54.39	57.26	60.12	62.98	65.84	68.71	74.43	77.29	80.16	270	10 5/8
279	11	36.68	48.91	50.13	51.97	55.02	58.08	61.14	64.19	67.25	70.31	73.36	79.48	82.53	85.59	279	11
311	12 1/4	45.58	60.77	62.29	64.57	68.37	72.17	75.96	79.76	83.56	87.36	91.16	98.75	102.55	106.35	311	12 1/4
381	15	68.41	91.21	93.49	96.91	102.61	108.31	114.01	119.71	125.41	131.11	136.81	148.21	153.91	159.61	381	15
445	17 1/2	93.32	124.42	127.53	132.20	139.98	147.75	155.53	163.30	171.08	178.86	186.63	202.19	209.96	217.74	445	17 1/2

Calculation $Kg/m = 3.14159 \times D^2 \times P / 4{,}000$ **Where** D is the hole diameter in mm P is the explosive density in g/cm³

To determine the loading factor for explosive densities not listed, select the loading factor for the size hole in the 1.00g/cm³ column then multiply it by the required density in g/cm³.

*For non-gassed products only. The density of gassed products varies according to depth in an explosive column and the open cup density. Please consult the "Gassing density for Titan blends" table for further information.

Gassing density for Titan blends

Density of Titan 2000 emulsion blends in an explosive column at different depths for different open cup densities

Depth (m)	Open Cup Density (g/cm^3)							
0	**0.90**	**0.95**	**1.00**	**1.05**	**1.10**	**1.15**	**1.20**	**1.25**
1	0.92	0.97	1.02	1.07	1.12	1.17	1.21	1.26
2	0.95	0.99	1.04	1.09	1.13	1.18	1.22	1.26
3	0.97	1.01	1.06	1.10	1.15	1.19	1.23	**1.27**
4	0.98	1.03	1.08	1.12	1.16	1.20	1.24	**1.27**
5	1.00	1.05	1.09	1.13	1.17	1.21	1.24	**1.28**
6	1.02	1.06	1.10	1.14	1.18	1.21	1.25	**1.28**
7	1.03	1.07	1.11	1.15	1.19	1.22	1.25	**1.28**
8	1.04	1.08	1.12	1.16	1.19	1.23	1.26	**1.28**
9	1.06	1.10	1.13	1.17	1.20	1.23	1.26	**1.29**
10	1.07	1.11	1.14	1.18	1.21	1.24	1.26	**1.29**
12	1.09	1.12	1.16	1.19	1.22	1.24	**1.27**	**1.29**
14	1.10	1.14	1.17	1.20	1.23	1.25	**1.27**	**1.29**
16	1.12	1.15	1.18	1.21	1.23	1.26	**1.28**	**1.30**
18	1.13	1.16	1.19	1.22	1.24	1.26	**1.28**	**1.30**
20	1.14	1.17	1.20	1.22	1.25	**1.27**	**1.28**	**1.30**
24	1.16	1.19	1.21	1.24	1.25	**1.27**	**1.29**	**1.30**
28	1.18	1.20	1.23	1.24	1.26	**1.28**	**1.29**	**1.30**
32	1.19	1.22	1.23	1.25	**1.27**	**1.28**	**1.29**	**1.31**
36	1.20	1.22	1.24	1.26	**1.27**	**1.29**	**1.30**	**1.31**
40	1.21	1.23	1.25	1.26	**1.28**	**1.29**	**1.30**	**1.31**
45	1.22	1.24	1.26	**1.27**	**1.28**	**1.29**	**1.30**	**1.31**
50	1.23	1.25	1.26	**1.27**	**1.28**	**1.29**	**1.30**	**1.31**
55	1.24	1.25	**1.27**	**1.28**	**1.29**	**1.30**	**1.30**	**1.31**
60	1.25	1.26	**1.27**	**1.28**	**1.29**	**1.30**	**1.31**	**1.31**
65	1.25	1.26	**1.27**	**1.28**	**1.29**	**1.30**	**1.31**	**1.31**
70	1.26	**1.27**	**1.28**	**1.29**	**1.29**	**1.30**	**1.31**	**1.31**
75	1.26	**1.27**	**1.28**	**1.29**	**1.30**	**1.30**	**1.31**	**1.31**
80	1.26	**1.27**	**1.28**	**1.29**	**1.30**	**1.30**	**1.31**	**1.31**

Densities in **bold and highlighted** are at or above the critical density of the explosive and these open cup densities ***should not*** be used for that depth of explosive column.

Comments

1. This table applies for Titan 2000 emulsion blends with an emulsion content of 60 wt % or greater. For higher density Titan 3000 and Titan 5000 emulsion blends, it may be used as a conservative guide.
2. For 50:50 wt % gassed blends, due to the relatively low emulsion content the minimum open cup density should be no lower than 1.20 g/cm^3.
3. To determine the required open cup density for an explosive column of 50m (say), find 50m in the Depth column. Moving to the right, read off the density immediately before the bolded density data begins (here, 1.26g/cm^3 in the 1.00 g/cm^3 open cup density column). This indicates that sufficient gassing chemicals should be added to the gassed explosive blend during delivery so that an open cup density of 1.00g/cm^3 is achieved. This level of gassing chemicals will ensure that the density at the bottom of the column will be below the critical density, and the column will detonate upon initiation.
4. The gassing reaction takes 30-40 minutes to achieve the desired open cup density at 20°C. It is necessary to allow at least this time to elapse between completion of loading and stemming the charged blasthole. A longer period should be allowed at lower temperatures.

Volume table

CUBIC METRES OF ROCK PER METRE BLASTHOLE

HOLE BURDEN (Metres)

1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.50	4.00	4.50	5.00	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	11.00	12.00	SPACING (Metres)
1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.50	4.00	4.50													**1.00**
1.25	1.56	1.88	2.19	2.50	2.81	3.13	3.44	3.75	4.38	5.00	5.63	6.25												**1.25**
1.50	1.88	2.25	2.63	3.00	3.38	3.75	4.13	4.50	5.25	6.00	6.75	7.50	9.00											**1.50**
2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	7.00	8.00	9.00	10.00	12.00	13.00										**2.00**
2.25	2.81	3.38	3.94	4.50	5.06	5.63	6.19	6.75	7.88	9.00	10.13	11.25	13.50	14.63	15.75									**2.25**
2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50	8.75	10.00	11.25	12.50	15.00	16.25	17.50	18.75								**2.50**
2.75	3.44	4.13	4.81	5.50	6.19	6.88	7.56	8.25	9.63	11.00	12.38	13.75	16.50	17.88	19.25	20.63	22.00							**2.75**
3.00	3.75	4.50	5.25	6.00	6.75	7.50	8.25	9.00	10.50	12.00	13.50	15.00	18.00	19.50	21.00	22.50	24.00	5.50						**3.00**
	4.38	5.25	6.13	7.00	7.88	8.75	9.63	10.50	12.25	14.00	15.75	17.50	21.00	22.75	24.50	26.25	28.00	29.75	31.50					**3.50**
	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	14.00	16.00	18.00	20.00	24.00	26.00	28.00	30.00	32.00	34.00	36.00	38.00				**4.00**
	5.63	6.75	7.88	9.00	10.13	11.25	12.38	13.50	15.75	18.00	20.25	22.50	27.00	29.25	31.50	33.75	36.00	38.25	40.50	42.75	45.00			**4.50**
		7.50	8.75	10.00	11.25	12.50	13.75	15.00	17.50	20.00	22.50	25.00	30.00	32.50	35.00	37.50	40.00	42.50	45.00	47.50	50.00	55.00		**5.00**
		9.00	10.50	12.00	13.50	15.00	16.50	18.00	21.00	24.00	27.00	30.00	36.00	39.00	42.00	45.00	48.00	51.00	54.00	57.00	60.00	66.00	72.00	**6.00**
			11.38	13.00	14.63	16.25	17.88	19.50	22.75	26.00	29.25	32.50	39.00	42.25	45.50	48.75	52.00	55.25	58.50	61.75	65.00	71.50	78.00	**6.50**
			12.25	14.00	15.75	17.50	19.25	21.00	24.50	28.00	31.50	35.00	42.00	45.50	49.00	52.50	56.00	59.50	63.00	66.50	70.00	77.00	84.00	**7.00**
			13.13	15.00	16.88	18.75	20.63	22.50	26.25	30.00	33.75	37.50	45.00	48.75	52.50	56.25	60.00	63.75	67.50	71.25	75.00	82.50	90.00	**7.50**
				16.00	18.00	20.00	22.00	24.00	28.00	32.00	36.00	40.00	48.00	52.00	56.00	60.00	64.00	68.00	72.00	76.00	80.00	88.00	96.00	**8.00**
				17.00	19.13	21.25	23.38	25.50	29.75	34.00	38.25	42.50	51.00	55.25	59.50	63.75	68.00	72.25	76.50	80.75	85.00	93.50	102.00	**8.50**
				18.00	20.25	22.50	24.75	27.00	31.50	36.00	40.50	45.00	54.00	58.50	63.00	67.50	72.00	76.50	81.00	85.50	90.00	99.00	108.00	**9.00**
					21.38	23.75	26.13	28.50	33.25	38.00	42.75	47.50	57.00	61.75	66.50	71.25	76.00	80.75	85.50	90.25	95.00	104.50	114.00	**9.50**
					22.50	25.00	27.50	30.00	35.00	40.00	45.00	50.00	60.00	65.00	70.00	75.00	80.00	85.00	90.00	95.00	100.00	110.00	120.00	**10.00**
					24.75	27.50	30.25	33.00	38.50	44.00	49.50	55.00	66.00	71.50	77.00	82.50	88.00	93.50	99.00	104.50	110.00	121.00	132.00	**11.00**
						30.00	33.00	36.00	42.00	48.00	54.00	60.00	72.00	78.00	84.00	90.00	96.00	102.00	108.00	114.00	120.00	132.00	144.00	**12.00**

Note: Tonnes of rock blasted can be calculated by multiplying the volume of rock by the density of the rock.

Calculation Cubic metres of rock / metres blasthole (V) = burden (B) x spacing (S)

Conversion table

This unit ▶ Multiplied by ▶ Converts to

Length

This unit	Multiplied by	Converts to
metres (m)	3.280	feet (ft)
	39.370	inches (in)
inches (in)	25.400	millimetres (mm)
kilometres (km)	0.621	miles

Mass

This unit	Multiplied by	Converts to
kilogram (kg)	2.20	lb
metric tonne (t)	1.10	short tons
ounce Avoirdupois (oz)	28.35	grams (g)
ounce Troy (oz)	31.10	grams (g)
grains	0.06	grams (g)

Energy

This unit	Multiplied by	Converts to
joule	0.24	calorie
	0.74	ft-lb
calorie	3.09	ft-lb
kilowatt	1.34	horsepower

Volume

This unit	Multiplied by	Converts to
cubic centimetres (cm^3 or cc)	0.06	in^3
cubic metres (m^3)	1.31	yd^3
cubic feet (ft^3)	0.03	m^3
US gallon	3.79	litres (l)
ounces (US fluid)	29.57	cm^3

Converts to ◀ Divided by ◀ This unit

This unit ▶ Multiplied by ▶ Converts to

Density

This unit	Multiplied by	Converts to
lbs / ft^3	16.02	kg / m^3
gm / cm^3	62.43	lbs / ft^3

Powder Factor

This unit	Multiplied by	Converts to
kg / m^3	1.69	lb / yd^3

Speed

This unit	Multiplied by	Converts to
m / sec	3.28	ft / sec
in / sec	25.4	mm / sec
km / hour	0.62	miles / hour

Pressure

This unit	Multiplied by	Converts to
psi	6.89	kPa
atmosphere (Atm)	14.70	psi
bar	14.50	psi
bar	100	kPa

Temperature

This unit	Multiplied by	Converts to
fahrenheit -32	0.56	centigrade
centigrade + 17.78	1.8	fahrenheit

Area

This unit	Multiplied by	Converts to
cm^2	0.16	in^2
m^2	1550.00	in^2
ft^2	0.09	m^2

Converts to ◀ Divided by ◀ This unit

Properties of typical rock types

Material

	Solid Density (t/m^3)	Unconfined Compressive Strength (MPa)	Young's Modulus (GPa)	Poisson's Ratio
Basalt	3.00	78 – 412	20 – 100	0.14 – 0.25
Bauxite	2.05			
Clay – dense, wet	1.70			
Coal, Anthracite	1.60	8 – 50		
Coal, Bituminous	1.36			
Dolerite	2.80	290 – 500		
Dolomite	2.96	15 – 118	20 – 84	0.1 – 0.2
Earth, moist	1.80			
Gneiss	2.88	78 – 240	25 – 60	0.1 – 0.19
Granite	2.72	100 – 275	25 – 70	0.15 – 0.34
Gypsum	2.80			
Iron ore	4.89			
Limestone	2.64	10 – 245	10 – 80	0.1 – 0.23
Limonite	3.76			
Magnetite	5.05			
Marble	2.48	50 – 200	60 – 90	0.2 – 0.35
Mica-Schist	2.70			
Porphory	2.56			
Quartzite	2.50	85 – 350	26 – 100	0.15 – 0.2
Sandstone	2.40	50 – 160	5 – 86	0.1 – 0.3
Shale	2.58	20 – 150	8 – 30	0.1 – 0.3
Silica Sand	2.56			
Siltstone	2.25			
Slate	2.72	98 – 196	30 – 90	0.1 – 0.44
Talc	2.64			

Perimeter control

Perimeter blasting is a technique to reduce the overbreak/backbreak on a blast. It usually utilises decoupled charges in closely spaced blastholes.

The following formula can be used to estimate the centre to centre distances of cartridged product for pre-splitting.

$$PF = \frac{L \times S}{0.5}$$

PF = Required powder factor (usually 0.3 to 0.6 kg/m^2)
L = Length of charged hole
S = Spacing between holes

$$D = \frac{L \times Q_L}{B \times S \times PF}$$

D = Centre – centre distance between cartridges (mm)
Q_L = Charge density of the explosive, in kg/m
B = Burden

Airblast

An airblast is an airborne shock wave that results from the detonation of explosives. The severity of an airblast is dependant on explosive charge, distance, and especially the explosives confinement.

$$P = K \left[\frac{R}{Q^{0.33}} \right]^{-1.2}$$

Where

P = pressure (kPa)

K = state of confinement

Q = maximum instantaneous charge (kg)

R = distance from charge (m)

Typical K factors

Unconfined	185
Fully confined	3.3

Expected damage

kPa	
0.3	Windows rattle
0.7	1% of windows break
7	Most windows break, plaster cracks
30	Risk of damage to ear drums

Minimum levels quoted AS 2187.2 – 1993

Human discomfort	120db(in)
Onset of structure damage or historic buildings where no specific limit exists	130db(in)

Ground vibration

When an explosive is detonated in a blasthole, a pressure wave is generated in the surrounding rock. As this pressure wave moves from the borehole it forms seismic waves by displacing particles. The particle movement is measured to determine the magnitude of the blast vibration.

Maximum particle vibration can be estimated using the following formula.

$$V = K \left[\frac{R}{Q^{0.5}} \right]^{B}$$

Where

V = peak particle velocity (mm/s)

K = site and rock factor constant

Q = maximum instantaneous charge (kg)

B = constant related to the rock and site (usually -1.6)

R = distance from charge (m)

Typical K factors

Free face – hard or highly structured rock	500
Free face average rock	1140
Heavily confined	5000

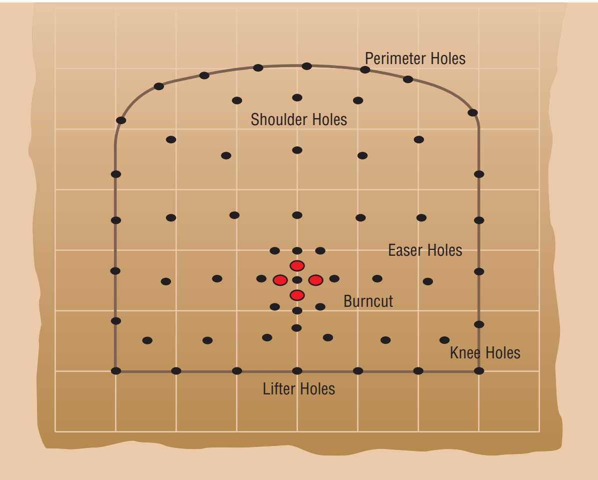
Recommended maximum Peak Particle Velocities (AS 2187.2 – 1993)

Housing and low rise residential buildings, Commercial buildings not included below	10 mm/s
Commercial and industrial buildings or structures of reinforced concrete or steel constructions	25 mm/s
For high rise, hospitals, long floor spans, dams or historic buildings where no specified limit exists	5 mm/s

Expected damage

PPV (mm/s)	
13	Lower limit for damage to plaster walls
19	Lower limit for dry wall structures
70	Minor damage
140	>50% chance of minor damage to structures
190	50% chance of major damage

Underground blast design



Shoulder hole	These refer to those holes immediately below the back perimeter holes.
Burncut	The burncut consists of a group of blastholes arranged in a regular pattern around one or more uncharged relief holes. The first firing blasthole breaks both into the void offered by the uncharged relief holes and towards the free face provided by the tunnel face.
Easer	Hole adjacent to cut area.
Lifters	The blastholes along the bottom of the developed round. Proper performance of the lifters are essential in achieving good floor control.
Perimeter blastholes	Perimeter blastholes are those which form the boundary of the tunnel. Explosive loading densities in these blastholes are generally lower than those in the remainder of the blast, as their prime requirement is to minimise back-breakage and provide a good contour.

Underground blast design

Design of cut

The following formulae are used for the geometric design of the cut area:

For multiple reamer holes: $ø = d\sqrt{n}$

Where: d = diameter of empty reamer holes

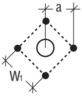
n = number of reamer holes

The cut:

1st square: $a = 1.5ø$

$W_1 = a\sqrt{2}$

ø mm	=	76	89	102	127	154
a mm	=	110	130	150	190	230
W_1 mm	=	150	180	210	270	320

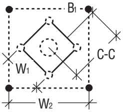


2nd square: $B_1 = W_1$

$C\text{-}C = 1.5W_1$

$W_2 = 1.5W_1\sqrt{2}$

ø mm	=	76	89	102	127	154
W_1	=	150	180	210	270	320
C-C	=	225	270	310	400	480
W_2 mm	=	320	380	440	560	670

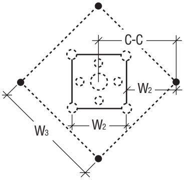


3rd square: $B_2 = W_2$

$C\text{-}C = 1.5W_2$

$W_3 = 1.5W_2\sqrt{2}$

ø mm	=	76	89	102	127	154
W_2 mm	=	320	380	440	560	670
C-C	=	480	570	660	840	1000
W_3 mm	=	670	800	930	1180	1400

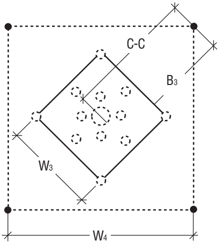


4th square: $B_3 = W_3$

$C\text{-}C = 1.5W_3$

$W_4 = 1.5W_3\sqrt{2}$

ø mm	=	76	89	102	127
W_3 mm	=	670	800	930	1180
C-C	=	1000	1200	1400	1750
W_3 mm	=	1400	1700	1980	2400



Underground blast design

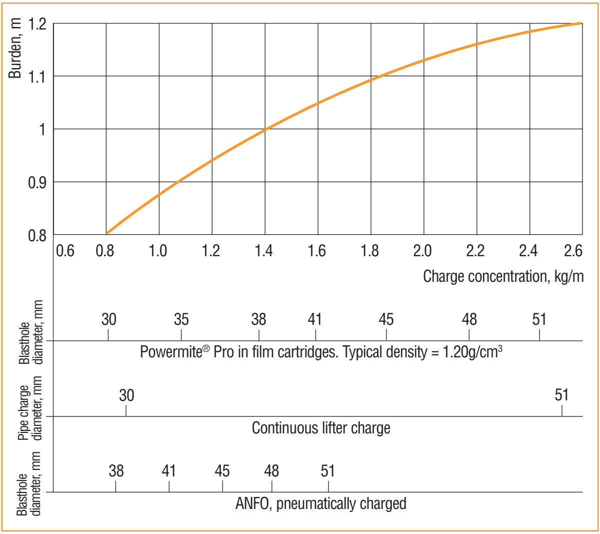
Design of lifter & easer holes

When the cut holes have been calculated, the rest of the development round may be calculated.

The round is divided into:

- lifter holes
- side holes
- back holes
- easer holes with breakage upwards and horizontally
- easer holes with breakage downwards

To calculate burdens (B) and charges for the different parts of the round the following graph may be used as a basis.



Bulk products

TITAN® Emulsion Product	% ANFO (wt%)	Density* (g/cm³)	Energy (MJ/kg)	Recomm sleep time (days)	Recomm minimum hole diameter (mm)	Water Resistance
TITAN 2000G (Gassed)	0	1.05 - 1.25*	2.5	12	102	Excellent
TITAN 2010 (Heavy ANFO)	90	0.86#	3.6	14ø	102	Poor
TITAN 2020 (Heavy ANFO)	80	0.97#	3.4	14ø	102	Poor
TITAN 2030 (Heavy ANFO)	70	1.10#	3.3	14ø	102	Poor
TITAN 2040 (Heavy ANFO)	60	1.25#	3.2	14ø	127	Poor
TITAN 2050 (Blend)	50	1.32#	3.1	14	203	Average
TITAN 2050G (Gassed)	50	1.20 - 1.25*	3.1	12	102	Average
TITAN 2060G (Gassed)	40	1.05 - 1.25*	3.0	12	102	Good
TITAN 2070G (Gassed)	30	1.05 - 1.25*	2.9	12	102	Excellent
TITAN 2080G (Gassed)	20	1.05 - 1.25*	2.7	12	102	Excellent
TITAN 2090G (Gassed)	10	1.05 - 1.25*	2.6	12	102	Excellent
TITAN 3000G (Gassed)	0	1.05 - 1.25*	2.7	12	76	Excellent
TITAN 3010 (Heavy ANFO)	90	0.86#	3.6	14ø	89	Poor
TITAN 3020 (Heavy ANFO)	80	0.93#	3.5	14ø	89	Poor
TITAN 3030 (Heavy ANFO)	70	1.05#	3.4	14ø	102	Poor
TITAN 3040 (Heavy ANFO)	60	1.23#	3.3	14ø	127	Poor
TITAN 3060G (Gassed)	40	1.05 - 1.25*	3.1	12	89	Good
TITAN 3070G (Gassed)	30	1.05 - 1.25*	3.0	12	76	Excellent
TITAN 3080G (Gassed)	20	1.05 - 1.25*	2.9	12	76	Excellent
TITAN 3090G (Gassed)	10	1.05 - 1.25*	2.8	12	76	Excellent
TITAN 4000G (Gassed)	0	1.05 - 1.25*	2.4	12	102	Excellent
TITAN 4010 (Heavy ANFO)	90	0.85#	3.6	12ø	102	Poor
TITAN 4020 (Heavy ANFO)	80	0.96#	3.4	12ø	102	Poor
TITAN 4030 (Heavy ANFO)	70	1.10#	3.3	12ø	102	Poor
TITAN 4040 (Heavy ANFO)	60	1.26#	3.2	12ø	152	Poor
TITAN 4050 (Blend)	50	1.32#	3.0	12	152	Average
TITAN 4050G (Gassed)	50	1.05 - 1.25*	3.0	12	102	Average
TITAN 4060G (Gassed)	40	1.05 - 1.25*	2.9	12	102	Good
TITAN 4070G (Gassed)	30	1.05 - 1.25*	2.8	12	102	Excellent
TITAN 4080G (Gassed)	20	1.05 - 1.25*	2.6	12	102	Excellent
TITAN 4090G (Gassed)	10	1.05 - 1.25*	2.5	12	102	Excellent
TITAN 5000G (Gassed)	0	1.05 - 1.25*	2.7	^	102	Excellent
TITAN 5010 (Heavy ANFO)	90	0.88#	3.6	^	102	Poor
TITAN 5020 (Heavy ANFO)	80	0.94#	3.5	^	102	Poor
TITAN 5030 (Heavy ANFO)	70	1.05#	3.4	^	102	Poor
TITAN 5040 (Heavy ANFO)	60	1.21#	3.3	^	152	Poor
TITAN 5050 (Heavy ANFO)	50	1.31#	3.2	^	203	Average
TITAN 5060 (Blend)	40	1.32#	3.0	^	250	Good
TITAN 5060G (Gassed)	40	1.05 - 1.25*	3.1	^	102	Good
TITAN 5065G (Gassed)	35	1.05 - 1.25*	3.0	^	102	Good
TITAN 5070G (Gassed)	30	1.05 - 1.25*	3.0	^	102	Excellent
TITAN 5080G (Gassed)	20	1.05 - 1.25*	2.9	^	102	Excellent
TITAN 5090G (Gassed)	10	1.05 - 1.25*	2.8	^	102	Excellent
TITAN 7000 (Gassed)	0	0.80 - 1.25	2.9	30†	35	Excellent
TITAN 7000i (Gassed)	0	0.80 - 1.25	2.9	^	35	Excellent
TITAN 7000SX (Gassed)	0	0.80 - 1.25	2.8	^	35	Excellent

* Inhole gassed product density is dependent on hole depth.
# Densities may vary due to variations in the AN prill density. For blends with 50% emulsion or greater, please consult your Dyno Nobel representative to ensure the product is suitable for your application.
ø For unreactive ground in dry hole conditions with no water present. Dewatered holes may reduce sleeptime.
^ For applications in reactive ground conditions please consult your Dyno Nobel representative to undertake the appropriate test work prior to the development of suitable site specific procedures.
† For up hole applications, sleeptimes are dependent on geology, water and inhole conditions.

Packaged products

Powermite® Pro

ANFO – bulk

ANFO – bagged

Powermite® Pro

Typical density (g/cm³)	Theoretical energy comparison Energy (MJ/kg)	RWS	RBS	VoD (m/s)
1.16 - 1.23	<= 32mm 2.78 >= 45mm 2.72	121	183	3400

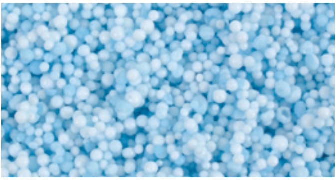
Packaging	Quantity per 25kg case	Average cartridge weight (g)	Case weight kg
25mm x 200mm	219	114	25
25mm x 700mm	60	416	25
32mm x 200mm	135	185	25
32mm x 700mm	34	736	25
55mm x 400mm	33	758	25
65mm x 400mm	21	1190	25
80mm x 400mm	15	1670	25

ANFO – bagged

Typical density (Poured) g/cm³		Theoretical energy comparison (MJ/kg)	RWS	RBS	Recomm min hole (mm)
Poured	0.8 - 0.85	3.7	100	100	75
Blow loaded	0.85 - 0.95	3.7	100	116	25

Packaged products

SANFOLD®



SANFOLD®

	Typical density (Poured) g/cm³	Typical density (Blow loaded) g/cm³	Theoretical energy comparison (MJ/kg)	Recomm min hole (Poured) (mm)	Recomm min hole (Blow loaded) (mm)
SANFOLD® 70	0.75	0.87	3.63	40	32
SANFOLD® 50	0.55	0.67	3.51	50	–
SANFOLD® 30	0.3	0.54	3.28	50	40

Z-BAR® Edge

Z-BAR® Lifter

Z-BAR®

	Diameter (mm)	Charge (kg/m)	VoD	Maximum case weight (kg)
Z-BAR® Edge	Tube - 19	Tube - 0.30	6500	20
	Primer - 29	Primer - 0.50		
Z-BAR® Lifter	29	0.50	6500	25

	Z-BAR® Edge		Z-BAR® Lifter	
Length	**Quantity per case**	**Length per case**	**Quantity per case**	**Length per case**
2.5 m	20	50	15	37.5
3.0 m	18	54	12	36
3.5 m	16	56	10	35
4.0 m	13	52	9	36
4.5 m	12	54	8	36

Initiation systems – downhole

NONEL® MS Series

NONEL® MS Heavy Duty Series

NONEL® MS Series

Delay period (ms)	Clip colour	Nominal firing time (ms)	Time between delays (ms)
1	Red	25	25
2	Blue	50	25
3	Brown	75	25
4	Orange	100	25
5	Aqua	125	25
6	Gold	150	25
7	Lime Green	175	25
8	Pink	200	25
9	Dark Green	225	25
10	Purple	250	25
11	Light Blue	275	25
12	Light Green	300	25
13	Mauve	325	25
14	Mustard	350	25
15	Crimson	375	25
16	Yellow	400	25
17	Dark Blue	425	25
18	Green	450	25
19	Orange	475	25
20	White	500	25
21	Rubine Red	550	50
22	Grey	600	50
23	Black	650	50
24	Brown	700	50
25	Red	750	50
26	Blue	800	50
27	Brown	900	100
28	Orange	1000	100

Length (m)	Packaging Units per case	Winding configuration	NONEL® Tube Standard or Heavy Duty
3.6	250	Coiled	Standard
4.8	200	Coiled	Standard
6.0	150	Coiled	Standard
7.2	150	Coiled	Standard
9.0	100	Coiled	Standard + HD
12.0	75	Sleeved	Standard + HD
15.0	75	Sleeved	Standard + HD
18.0	50	Sleeved	Standard + HD
24.0	30	Spooled	Standard + HD
30.0	30	Spooled	HD
36.0	30	Spooled	HD
45.0	30	Spooled	HD
60.0	30	Spooled	HD
80.0	30	Spooled	HD

NONEL® tube:	Standard	Heavy Duty
Colour	Red	Orange
Diameter	3.0mm	
Detonator	# 12 Strength	

Initiation systems – downhole

NONEL® LP Series

NONEL® LP Series

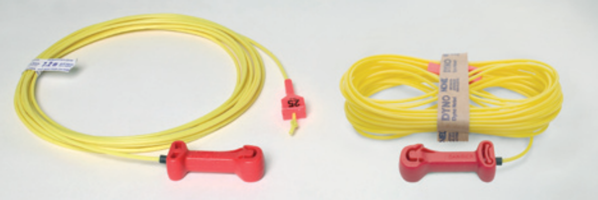
Delay period (ms)	Clip colour	Nominal firing time (ms)	Time between delays (ms)
0	White	25	25
1	Red	500	475
2	Blue	800	300
3	Brown	1100	300
4	Orange	1400	300
5	Aqua	1700	300
6	Gold	2000	300
7	Lime Green	2300	300
8	Pink	2700	400
9	Black	3100	400
10	Purple	3500	400
11	Light Blue	3900	400
12	Dark Green	4400	500
13	Mauve	4900	500
14	Mustard	5400	500
15	Crimson	5900	500
16	Yellow	6500	600
17	Dark Blue	7200	700
18	Green	8000	800

Packaging

Length (m)	Units per case	Winding configuration
3.6	250	Sidewinder
4.8	200	Sidewinder
5.4	150	Sidewinder
6.0	150	Sidewinder
15.0	75	Sleeve
24.0	30	Spool
36.0	30	Spool

NONEL® tube:	Standard
Colour	Yellow
Diameter	3.0mm
Detonator	# 12 Strength

NONEL® EZTL Series



NONEL® EZTL Series

Delay period (ms)	Clip colour
0	Green
9	Violet
17	Yellow
25	Red
42	White
67	Blue
109	Black
150	Dark Green
176	Orange
200	Gold

Packaging

Length (m)	Units per case	Winding configuration
3.6	200	coiled
4.8	150	coiled
6.0	150	coiled
7.2	150	coiled
9.0	100	Figure 80
12.0	75	Figure 80
15.0	75	Figure 80
18.0	50	Figure 80

Tube colour	Yellow
Detonator	Low strength
Clip capacity	6

Initiation systems – open-cut

NONEL® MS Connector

NONEL® MS Connector

Delay period (ms)	Clip colour
9	Violet
17	Yellow
25	Red
42	White
67	Blue
109	Black
150	Dark Green
176	Orange
200	Gold

Packaging

Units per case	200

Tube

Standard	Orange

NONEL® Lead Line

Reel-off initiation system (no detonator)	
Length	1000m (two per case)
VOD	2100m/sec (+/- 300)
Tube	Standard Yellow

NONEL® Lead Line

NONEL® Starter

Packaging

Length (m)	Units per case	Winding configuration
100	15	Spooled
300	4	Spooled
500	4	Spooled

Tube

Standard	Yellow

NONEL® Starter

Initiation systems

Cast Boosters

Trojan Spartan

Trojan NBU

Trojan Ringprime®

	Nominal weight (g)	Diameter (mm)	Length (mm)	Units per case	Priming
Trojan Spartan 150	150	36	119	95	Cap sensitive
Trojan Spartan 400	400	55	119	40	Cap sensitive
Trojan NBU 400	400	55	119	40	Primacord 4
Trojan Ringprime	250	46	175	42	Cap sensitive

NB: Spiders for Ringprime® have 125mm diameter and come in separate 70 unit lots.

Detonating Cords

PrimaCord® 5

PrimaLine® 10

	Core load (g/m)	Diameter (mm)	Minimum strength (kg)	Packaging
PrimaCord® 5	5	4.2	68	2 x 500m rolls
PrimaLine® 10	10	5	68	2 x 350m rolls

Initiation systems

Electric Super™ Starter

Description	
Delay time (ms)	0
Fuse Head resistance (ohm)	1.92
Firing current, minimum recommended, (A)	
Series wiring	3 amps AC or 1.5 amps DC
Parallel wiring	1 amp AC or DC per detonator
Series-in-parallel wiring	2 amps AC or DC per series
Leg wires (m)	3.5
Strength (#)	10

The maximum recommended continuous firing current is 10 amps per detonator.

Electric Super™ Starter

The SmartShot System

SmartShot Electronic Detonator System

Packaging

Length (m)	Units per case
10/7	18
20/10	18
20/15	18
35/0.2	18
45/0.2	18
60/0.2	8

Blasting accessories

DynoStart (DS2)

DynoStart (DS2)

ELECTRONIC BLASTING MACHINE

DynoStart is a battery powered electronic blasting machine for initiation of NONEL® tube. Electrical energy is converted into a strong shock wave of high temperature that, when applied inside a NONEL® tube by the means of an electrode, initiates the tube. DynoStart uses a common 9V battery and a durable electrode. Both battery and electrode are easy to change. The electrode can be removed from the blasting machine at any time to prevent unauthorised usage. DynoStart is designed to require the use of both hands when initiating the blast. This is to avoid unintentional firing of a blast.

NONEL® Starter Gun

NONEL® Starter Gun

BLASTING MACHINE

The NONEL® Starter Gun is a simple and highly effective hand held blasting machine, robustly constructed from metal alloys and stainless steel. It has an integral safety device and uses Shot Shell Primers No. 20 as primer caps. It is a complete blasting machine, no other equipment being needed to initiate a NONEL® tube.

Blasting accessories

Stinger Exploder 10 Shot

Stinger Exploder 10 Shot

The SB10 is a compact capactive discharge exploder. The unit is powered by 1.5V AA batteries. A removable magnetic key controls security of the firing mechanism and a push button operates the firing circuit. A ready light illuminates when the firing capacitor is fully charged.

Scorpion®

Scorpion®

The Scorpion® is a device used to centralise detonators in the borehole. Constructed from extruded plastic, Scorpion® comprises of four fins attached to a central spine and facilitates direct priming of ANFO and Titan 7000 bulk emulsion in small diameter, dry blastholes, used in tunnelling and underground mine development.

Length	130m
Diameter	38mm
Construction	extruded plastic

Blasting accessories

Lo-Stat ANFO Hose

Lo-Stat ANFO Hose

The Lo-Stat ANFO Hose is a conductive thermoplastic tube used for delivery of explosives in underground applications.

Description	Product specification	
	20mm hose	**25mm hose**
Internal Diameter	18.4mm - 19.6 mm	24.6mm - 25.4 mm
Outside Diameter	26.4mm - 27.6 mm	29.8mm - 30.2 mm
Wall Thickness	3.7mm - 4.4 mm	2.3mm - 2.7 mm
Resistance/m metre	15 - 25 K	15 - 25 K
Total Resistance (whole coil)	<1.6 M	<1.6 M
Nominal Weight	330-370 g/m	210-230 g/m

Stempac

The stempac is a stemming device constructed using Stemtite blast control plugs and crushed aggregate in a scaled plastic package. The stempac enables blastholes that have been drilled horizontal or at an angle above horizontal to be stemmed. It is designed to be placed in a blast hole after the loading has been completed and be located 80cm below the explosive column. Disassembled components shown. Assembled product include synthetic sleeve. Size of Stempac can vary depending on hole diameter.

Stempac

Blasting accessories

Twin Twist Bell Wire

Twin Twist Bell Wire

Insulation colour	Red and White Twist
Roll size	500 metres
Number of cores	2
Current rating (A)	1.8
Electrical Resistance @ 20^{c}(m /m) per core	62

Firing Cable – Heavy Duty

Firing Cable – Heavy Duty

Insulation colour	**Red – Fig 8 outer sheath, Red and White core**
Roll size	100 metres
Number of cores	2
Electrical Resistance @ 20^{c}(m /m) per core	12.9

Glossary

Airblast Airborne shock wave resulting from the detonation of explosives.

Back break Rock broken beyond the limits of the last row.

Borehole pressure The pressure which the gasses of detonation exert on the borehole wall.

Charge weight The amount of explosive charge in kilograms.

Column charge A continuous charge of explosives in a borehole.

Critical diameter The minimum diameter for propagation of a stable detonation.

Cutoffs A portion of an explosive column that has failed to detonate due to rock movement.

Decoupling The use of explosive products having smaller volume than the volume of the blasthole it occupies.

Delay blasting The use of delay detonators or connectors to separate charges by a defined time.

Density mass per unit volume.

Detonation pressure The pressure created in the reaction zone of a detonating explosive.

Explosive Any chemical or mixture of chemicals that can react to produce an explosion.

Free face A rock surface that provides the rock with room to expand when blasted.

Flyrock Rock that is propelled through air from a blast.

Fragmentation Measure to describe the size of distribution of broken rock after blasting.

Ground vibration Ground movement caused by the stress waves emanating from a blast.

Initiation The act of detonating explosives by any means.

Line drilling A method of overbreak control which uses a series of closely spaced holes that are not charged.

Loading density The weight of explosives per metre of borehole.

Maximum Instantaneous Charge (MIC) Mass of explosive detonating in some defined time period, usually 8 milliseconds.

Overbreak Excessive breakage of rock beyond the desired excavation limit.

Particle velocity The speed of movement in a given direction of a rock or soil mass.

Pre-split A controlled blast in which decoupled charges are fired in holes on the perimeter of the excavation prior to the main firing.

Relative Bulk Strength (RBS) The energy yield per unit volume of an explosive compared to ANFO.

Relative Weight Strength (RWS) The energy yield per unit mass of an explosive compared to ANFO.

Spacing The distance between boreholes in the same row.

Stemming Inert material used to confine the gasses generated during detonation.

Swell factor The ratio of the volume of broken rock to the volume of in-situ rock.

Velocity of detonation The velocity at which a detonation progresses through an explosive.

DISCLAIMER

The information and suggestions contained in this document concern explosive products that should only be dealt with by persons having the appropriate technical skills, training and licence. The results obtained from the use of such products depend to a large degree on the conditions under which the products are stored, transported and used.

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