Explosives Engineers' Guide

DYNO®
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Groundbreaking Performance®

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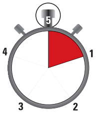
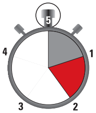
Rapid Hazard Assessment

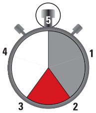
- Is the task new?
- Is anything different?
- Has anything changed since you last performed this task?
- If so, STOP, THINK and apply the Take 5 steps!



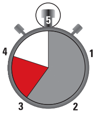
1 Describe the task.
What is the task you are about to do?



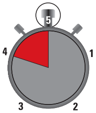
2 List the Hazards.
What are the main hazards involved in carrying out the task?



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?

Glossary

Airblast Airborne shock wave resulting from the detonation of explosives.

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

Blasthole pressure The pressure which the gasses of detonation exert on the blasthole wall.

Burden The distance between adjacent rows.

Charge weight The amount of explosive charge in kilograms.

Column charge A continuous charge of explosives in a blasthole.

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 blasthole.

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.

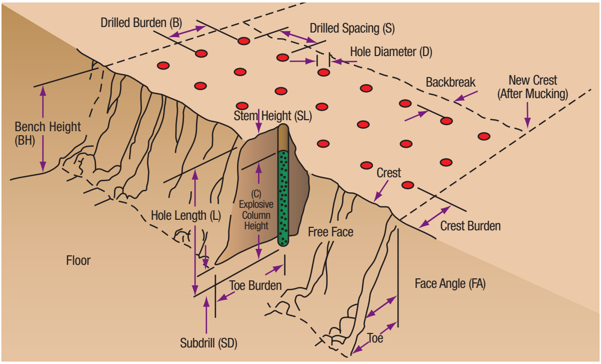
Spacing The distance between blastholes in the same row.

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 (VoD) The velocity at which a detonation progresses through an explosive.

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/blast volume
PF (kg/t) =	Total explosives in the blast/blasted tonnes
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.

Blasthole diameter in mm ≤	15 x Bench height (BH) in metres
Bench height (BH) in metres ≥	(Blasthole 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

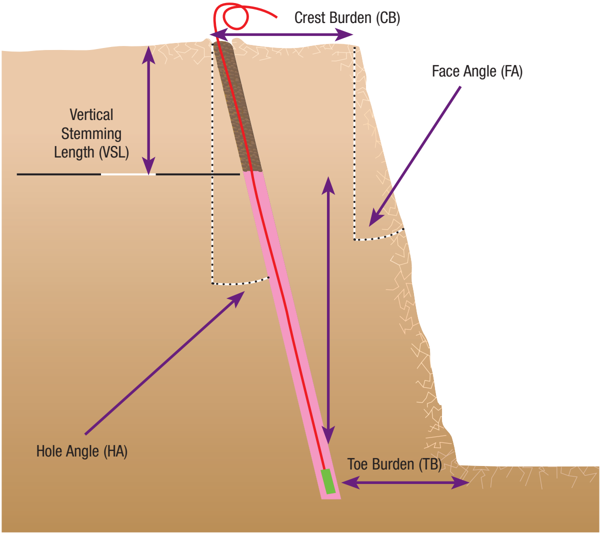
Rock type	PF (kg/m³)
Hard	0.7 – 0.8
Medium	0.4 – 0.5
Soft	0.25 – 0.35
Very Soft	0.15 – 0.25

Typical powder factors used in presplit and smooth blasting

Hole diameter	PF (kg/m²)
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)

Volume table

CUBIC METRES OF ROCK PER METRE OF BLASTHOLE

HOLE BURDEN (Metres)																								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	5.00	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	11.00	12.00	
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 per metre of blasthole (V) = burden (B) x spacing (S)

Loading density

Hole Diameter mm	in	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	in
		Kg of explosive per meter of column for given density (g/cm³)*															
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.

Density of TITAN 2050 and TITAN 2050G blends in an explosive column at different depths for different open cup densities.

	TITAN 2050G Density g/cm³						Ungassed	
Depth (m)	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe
Open Cup	**1.10**	**1.10**	**1.15**	**1.15**	**1.20**	**1.20**	**1.31**	**1.31**
1	1.12	1.13	1.16	1.18	1.21	1.23	1.32	1.33
2	1.13	1.16	1.18	1.20	1.22	1.25	1.32	1.34
3	1.14	1.19	1.19	1.23	1.23	1.26	1.33	1.35
4	1.16	1.21	1.20	1.24	1.24	1.28	1.34	1.36
5	1.17	1.22	1.21	1.26	1.25	1.29	1.34	1.36
6	1.18	1.24	1.22	1.27	1.26	1.30	1.34	1.37
7	1.19	1.25	1.23	1.28	1.27	1.31	1.35	1.37
8	1.20	1.26	1.23	1.29	1.27	1.32	1.35	1.38
9	1.20	1.28	1.24	1.30	1.28	1.33	1.35	1.38
10	1.21	1.29	1.25	1.31	1.28	1.33	1.36	1.39
11	1.22	1.29	1.25	1.32	1.29	1.34	1.36	1.39
12	1.22	1.30	1.26	1.32	1.29	1.35	1.36	1.39
13	1.23	1.31	1.26	1.33	1.30	1.35	1.36	1.39
14	1.24	1.32	1.27	1.34	1.30	1.36		
15	1.24	1.32	1.27	1.34	1.30	1.36		
16	1.25	1.33	1.28	1.35	1.31	1.36		
17	1.25	1.33	1.28	1.35	1.31	1.37		
18	1.26	1.34	1.29	1.35	1.31	1.37		
19	1.26	1.34	1.29	1.36	1.32	1.37		
20	1.26	1.34	1.29	1.36	1.32	1.38		
22	1.27	1.35	1.30	1.37	1.32	1.38		
24	1.27	1.36	1.30	1.37	1.32	1.38		
26	1.28	1.36	1.30	1.38	1.33	1.39		
28	1.28	1.37	1.31	1.38	1.33	1.39		
30	1.28	1.37	1.31	1.38	1.33	1.39		
32	1.29	1.38	1.31	1.39				
34	1.29	1.38	1.31	1.39				
36	1.29	1.38	1.32	1.39				
38	1.30	1.38	1.32	1.39				
40	1.30	1.39						
45	1.30	1.39						
50	1.30	1.39						
55	1.31	1.39						
60	1.31	1.39						

See below for use of table

USE OF TABLE

1. The left hand column in this table (Depth) indicates the height of the product column under dry or dewatered hole conditions.
2. This table applies for TITAN 2000 Matrix blends with an emulsion content of 50% w/w ONLY, i.e. T2050G and T2050.
3. Emulsion explosives behave as liquids when subjected to the gravitational stress in a vertical blasthole, and a pressure gradient in the explosive will be established. The higher the explosive column in the blasthole, the higher the internal pressure at the bottom of the column, and the larger the quantity of gassing chemicals that need to be added to provide sensitisation.
4. The open cup density is a measure of the level of sensitisation of the product. It is necessary to choose an open cup density to ensure that the density of the explosive at the bottom of the blasthole is less than the critical density. Inappropriate sensitisation may lead to poor detonation, fragmentation and generation of excessive post blast fume. Blacked out areas indicate where critical density is reached or exceeded.
5. To determine the required open cup density for an explosive column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the unshaded column under the required open cup density (a Toe density of 1.39g/cm^3 in the 1.10g/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 1.10g/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 at full order upon initiation.
6. To determine the approximate average in-hole density in a column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the shaded column (an Avg. In-Hole density of 1.30g/cm^3 in the 1.10 g/cm^3 open cup density column).

   For depths that are not listed, Dyno Nobel recommends rounding up to the next highest depth e.g. a 25m deep hole should be rounded to 26m and corresponding densities applied.
7. Blast design should be based on average in-hole density whilst blasthole loading requires the MPU operator to achieve the associated open cup density.
8. 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 following completion of loading and before stemming the charged blasthole. A longer period should be allowed at lower temperatures.
9. The density values shown were calculated using a laboratory mathematical model that was validated using a specially designed fit-for-purpose pressure-volume apparatus.
10. The low density explosive grade ammonium nitrate used in the model was assigned a bulk density of 0.77 g/cm^3 and a particle density of 1.58 g/cm^3.

Gassing density for TITAN® blends

Density of TITAN 2060G blends in an explosive column at different depths for different open cup densities.

	TITAN 2060G Density g/cm³													
Depth (m)	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe
Open Cup	**0.90**	**0.90**	**0.95**	**0.95**	**1.00**	**1.00**	**1.05**	**1.05**	**1.10**	**1.10**	**1.15**	**1.15**	**1.20**	**1.20**
1	0.92	0.94	0.97	0.99	1.02	1.04	1.07	1.08	1.12	1.13	1.16	1.18	1.21	1.22
2	0.94	0.98	0.99	1.02	1.04	1.07	1.08	1.11	1.13	1.16	1.18	1.20	1.22	1.24
3	0.96	1.01	1.00	1.06	1.05	1.10	1.10	1.14	1.14	1.18	1.19	1.22	1.23	1.26
4	0.97	1.04	1.02	1.08	1.07	1.12	1.11	1.16	1.15	1.20	1.20	1.24	1.24	1.27
5	0.99	1.07	1.03	1.11	1.08	1.14	1.12	1.18	1.16	1.22	1.21	1.25	1.25	1.28
6	1.00	1.09	1.05	1.13	1.09	1.16	1.13	1.20	1.17	1.23	1.21	1.26	1.25	1.29
7	1.02	1.11	1.06	1.15	1.10	1.18	1.14	1.21	1.18	1.24	1.22	1.27	1.26	1.30
8	1.03	1.13	1.07	1.16	1.11	1.19	1.15	1.22	1.19	1.25	1.23	1.28	1.26	1.31
9	1.04	1.15	1.08	1.18	1.12	1.21	1.16	1.24	1.20	1.26	1.23	1.29	1.27	1.32
10	1.05	1.16	1.09	1.19	1.13	1.22	1.17	1.25	1.20	1.27	1.24	1.30	1.27	1.32
11	1.06	1.18	1.10	1.20	1.14	1.23	1.17	1.26	1.21	1.28	1.25	1.30	1.28	1.33
12	1.07	1.19	1.11	1.21	1.15	1.24	1.18	1.26	1.22	1.29	1.25	1.31	1.28	1.33
13	1.08	1.20	1.12	1.22	1.15	1.25	1.19	1.27	1.22	1.29	1.25	1.32	1.29	1.34
14	1.09	1.21	1.13	1.23	1.16	1.26	1.19	1.28	1.23	1.30	1.26	1.32	1.29	1.34
15	1.10	1.22	1.13	1.24	1.17	1.26	1.20	1.29	1.23	1.31	1.26	1.33	1.29	1.34
16	1.11	1.23	1.14	1.25	1.17	1.27	1.21	1.29	1.24	1.31	1.27	1.33	1.30	1.35
17	1.11	1.24	1.15	1.26	1.18	1.28	1.21	1.30	1.24	1.32	1.27	1.33	1.30	1.35
18	1.12	1.24	1.15	1.26	1.18	1.28	1.22	1.30	1.25	1.32	1.27	1.34	1.30	1.35
19	1.13	1.25	1.16	1.27	1.19	1.29	1.22	1.31	1.25	1.32	1.28	1.34	1.31	1.36
20	1.13	1.26	1.16	1.28	1.19	1.29	1.22	1.31	1.25	1.33	1.28	1.34	1.31	1.36
22	1.14	1.27	1.17	1.29	1.20	1.30	1.23	1.32	1.26	1.33	1.28	1.35	1.31	1.36
24	1.15	1.28	1.18	1.30	1.20	1.31	1.23	1.33	1.26	1.34	1.29	1.35	1.31	1.37
26	1.15	1.29	1.18	1.30	1.21	1.32	1.24	1.33	1.26	1.34	1.29	1.36	1.32	1.37
28	1.16	1.30	1.19	1.31	1.21	1.32	1.24	1.34	1.27	1.35	1.29	1.36	1.32	1.37
30	1.16	1.30	1.19	1.32	1.22	1.33	1.24	1.34	1.27	1.35	1.30	1.36		
32	1.17	1.31	1.20	1.32	1.22	1.33	1.25	1.35	1.27	1.36	1.30	1.37		
34	1.17	1.32	1.20	1.33	1.23	1.34	1.25	1.35	1.28	1.36	1.30	1.37		
36	1.18	1.32	1.20	1.33	1.23	1.34	1.26	1.35	1.28	1.36	1.30	1.37		
38	1.18	1.33	1.21	1.34	1.23	1.35	1.26	1.36	1.28	1.37	1.31	1.37		
40	1.19	1.33	1.21	1.34	1.24	1.35	1.26	1.36	1.29	1.37				
45	1.19	1.33	1.22	1.34	1.24	1.35	1.27	1.36	1.29	1.37				
50	1.20	1.33	1.22	1.34	1.25	1.35	1.27	1.36	1.29	1.37				
55	1.20	1.34	1.23	1.35	1.25	1.35	1.27	1.36	1.29	1.37				
60	1.21	1.34	1.23	1.35	1.25	1.36	1.27	1.36	1.29	1.37				

See below for use of table

USE OF TABLE

1. The left hand column in this table (Depth) indicates the height of the product column under dry hole conditions. In wet hole conditions, the value selected from the left hand column must be the sum of the product column and the height of the water column in the hole. If the length of the product and water column exceeds the depth of the hole then the value selected from the left hand column must be the hole depth.
2. This table applies for TITAN 2000 Matrix blends with an emulsion content of 60% w/w ONLY, i.e. T2060G.
3. Emulsion explosives behave as liquids when subjected to the gravitational stress in a vertical blasthole, and a pressure gradient in the explosive will be established. The higher the explosive column in the blasthole, the higher the internal pressure at the bottom of the column, and the larger the quantity of gassing chemicals that need to be added to provide sensitisation.
4. The open cup density is a measure of the level of sensitisation of the product. It is necessary to choose an open cup density to ensure that the density of the explosive at the bottom of the blasthole is less than the critical density. Inappropriate sensitisation may lead to poor detonation, fragmentation and generation of excessive post blast fume. Blacked out areas indicate where critical density is reached or exceeded.
5. To determine the required open cup density for an explosive column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the unshaded column under the required open cup density (a Toe density of 1.37g/cm^3 in the 1.10 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 1.10g/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 at full order upon initiation.
6. To determine the approximate average in-hole density in a column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the shaded column (an Avg. In-Hole density of 1.29g/cm^3 in the 1.10 g/cm^3 open cup density column). For depths that are not listed, Dyno Nobel recommends rounding up to the next highest depth. e.g. a 25m deep hole should be rounded to 26m and corresponding densities applied.
7. Blast design should be based on average in-hole density whilst blasthole loading requires the MPU operator to achieve the associated open cup density.
8. 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 following completion of loading and before stemming the charged blasthole. A longer period should be allowed at lower temperatures.
9. The density values shown were calculated using a laboratory mathematical model that was validated using a specially designed fit-for-purpose pressure-volume apparatus.
10. The low density explosive grade ammonium nitrate used in the model was assigned a bulk density of 0.77 g/cm^3 and a particle density of 1.58 g/cm^3.

Gassing density for TITAN® blends

Density of TITAN 2070G blends in an explosive column at different depths for different open cup densities.

	TITAN 2070G Density g/cm³													
Depth (m)	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe
Open Cup	**0.90**	**0.90**	**0.95**	**0.95**	**1.00**	**1.00**	**1.05**	**1.05**	**1.10**	**1.10**	**1.15**	**1.15**	**1.20**	**1.20**
1	0.92	0.94	0.97	0.99	1.02	1.04	1.07	1.08	1.11	1.13	1.16	1.17	1.21	1.22
2	0.94	0.98	0.99	1.02	1.03	1.07	1.08	1.11	1.13	1.15	1.17	1.20	1.22	1.24
3	0.96	1.01	1.00	1.05	1.05	1.09	1.09	1.13	1.14	1.17	1.18	1.21	1.23	1.25
4	0.97	1.03	1.02	1.08	1.06	1.12	1.11	1.15	1.15	1.19	1.19	1.23	1.23	1.26
5	0.99	1.06	1.03	1.10	1.07	1.14	1.12	1.17	1.16	1.21	1.20	1.24	1.24	1.27
6	1.00	1.08	1.04	1.12	1.09	1.15	1.13	1.19	1.17	1.22	1.21	1.25	1.25	1.28
7	1.01	1.10	1.05	1.14	1.10	1.17	1.14	1.20	1.18	1.23	1.21	1.26	1.25	1.29
8	1.02	1.12	1.07	1.15	1.11	1.18	1.14	1.21	1.18	1.24	1.22	1.27	1.26	1.30
9	1.04	1.14	1.08	1.17	1.11	1.20	1.15	1.22	1.19	1.25	1.23	1.28	1.26	1.30
10	1.05	1.15	1.08	1.18	1.12	1.21	1.16	1.23	1.20	1.26	1.23	1.28	1.27	1.31
11	1.06	1.16	1.09	1.19	1.13	1.22	1.17	1.24	1.20	1.27	1.24	1.29	1.27	1.31
12	1.06	1.17	1.10	1.20	1.14	1.23	1.17	1.25	1.21	1.27	1.24	1.30	1.27	1.32
13	1.07	1.19	1.11	1.21	1.15	1.23	1.18	1.26	1.21	1.28	1.25	1.30	1.28	1.32
14	1.08	1.20	1.12	1.22	1.15	1.24	1.19	1.26	1.22	1.29	1.25	1.31	1.28	1.33
15	1.09	1.20	1.12	1.23	1.16	1.25	1.19	1.27	1.22	1.29	1.25	1.31	1.28	1.33
16	1.10	1.21	1.13	1.24	1.16	1.26	1.20	1.28	1.23	1.30	1.26	1.31	1.29	1.33
17	1.10	1.22	1.14	1.24	1.17	1.26	1.20	1.28	1.23	1.30	1.26	1.32	1.29	1.33
18	1.11	1.23	1.14	1.25	1.17	1.27	1.20	1.29	1.23	1.30	1.26	1.32	1.29	1.34
19	1.12	1.23	1.15	1.25	1.18	1.27	1.21	1.29	1.24	1.31	1.27	1.32	1.29	1.34
20	1.12	1.24	1.15	1.26	1.18	1.28	1.21	1.29	1.24	1.31	1.27	1.33	1.30	1.34
22	1.13	1.25	1.16	1.27	1.19	1.29	1.22	1.30	1.25	1.32	1.27	1.33	1.30	1.35
24	1.13	1.26	1.16	1.28	1.19	1.29	1.22	1.31	1.25	1.32	1.28	1.34	1.30	1.35
26	1.14	1.27	1.17	1.29	1.20	1.30	1.22	1.31	1.25	1.33	1.28	1.34	1.30	1.35
28	1.15	1.28	1.17	1.29	1.20	1.31	1.23	1.32	1.25	1.33	1.28	1.34	1.31	1.35
30	1.15	1.28	1.18	1.30	1.21	1.31	1.23	1.32	1.26	1.33	1.28	1.35		
32	1.16	1.29	1.18	1.30	1.21	1.32	1.24	1.33	1.26	1.34	1.29	1.35		
34	1.16	1.30	1.19	1.31	1.21	1.32	1.24	1.33	1.26	1.34	1.29	1.35		
36	1.17	1.30	1.19	1.31	1.22	1.32	1.24	1.33	1.27	1.34	1.29	1.35		
38	1.17	1.31	1.20	1.32	1.22	1.33	1.25	1.34	1.27	1.35				
40	1.17	1.31	1.20	1.32	1.22	1.33	1.25	1.34	1.27	1.35				
45	1.18	1.31	1.20	1.32	1.23	1.33	1.25	1.34	1.27	1.35				
50	1.18	1.31	1.21	1.32	1.23	1.33	1.25	1.34	1.28	1.35				
55	1.19	1.32	1.21	1.33	1.23	1.33	1.26	1.34	1.28	1.35				
60	1.19	1.32	1.21	1.33	1.24	1.34	1.26	1.34	1.28	1.35				

See below for use of table

USE OF TABLE

1. The left hand column in this table (Depth) indicates the height of the product column under dry hole conditions. In wet hole conditions, the value selected from the left hand column must be the sum of the product column plus the height of the water column in the hole. If the length of the product and water column exceeds the depth of the hole then the value selected from the left hand column must be the hole depth.
2. This table applies for TITAN 2000 Matrix blends with an emulsion content of 70% w/w ONLY, i.e. T2070G.
3. Emulsion explosives behave as liquids when subjected to the gravitational stress in a vertical blasthole, and a pressure gradient in the explosive will be established. The higher the explosive column in the blasthole, the higher the internal pressure at the bottom of the column, and the larger the quantity of gassing chemicals that need to be added to provide sensitisation.
4. The open cup density is a measure of the level of sensitisation of the product. It is necessary to choose an open cup density to ensure that the density of the explosive at the bottom of the blasthole is less than the critical density. Inappropriate sensitisation may lead to poor detonation, fragmentation and generation of excessive post blast fume. Blacked out areas indicate where critical density is reached or exceeded.
5. To determine the required open cup density for an explosive column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the unshaded column under the required open cup density (a Toe density of 1.35g/cm^3 in the 1.10 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 1.10g/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 at full order upon initiation.
6. To determine the approximate average in-hole density in a column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the shaded column (an Avg. In-Hole density of 1.27g/cm^3 in the 1.10 g/cm^3 open cup density column). For depths that are not listed, Dyno Nobel recommends rounding up to the next highest depth. e.g. a 25m deep hole should be rounded to 26m and corresponding densities applied.
7. Blast design should be based on average in-hole density whilst blasthole loading requires the MPU operator to achieve the associated open cup density.
8. 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 following completion of loading and before stemming the charged blasthole. A longer period should be allowed at lower temperatures.
9. The density values shown were calculated using a laboratory mathematical model that was validated using a specially designed fit-for-purpose pressure-volume apparatus.
10. The low density explosive grade ammonium nitrate used in the model was assigned a bulk density of 0.77 g/cm^3 and a particle density of 1.58 g/cm^3.

Gassing density for TITAN® blends

Density of gas sensitised and ungassed blends containing 50% TITAN 3000, TITAN 5000 or TITAN 9000 in an explosive column at different depths for different open cup densities.

	Gassed blend containing 50% emulsion – Density g/cm³						Ungassed	
Depth (m)	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe
Open Cup	**1.10**	**1.10**	**1.15**	**1.15**	**1.20**	**1.20**	**1.32**	**1.32**
1	1.12	1.13	1.17	1.18	1.21	1.23	1.33	1.34
2	1.13	1.16	1.18	1.21	1.23	1.25	1.33	1.35
3	1.15	1.19	1.19	1.23	1.24	1.27	1.34	1.36
4	1.16	1.21	1.20	1.25	1.25	1.28	1.35	1.37
5	1.17	1.23	1.21	1.26	1.25	1.30	1.35	1.37
6	1.18	1.25	1.22	1.28	1.26	1.31	1.36	1.38
7	1.19	1.26	1.23	1.29	1.27	1.32	1.36	1.39
8	1.20	1.27	1.24	1.30	1.28	1.33	1.36	1.39
9	1.21	1.28	1.25	1.31	1.28	1.34	1.37	1.40
10	1.22	1.29	1.25	1.32	1.29	1.34	1.37	1.40
11	1.22	1.30	1.26	1.33	1.29	1.35	1.37	1.40
12	1.23	1.31	1.26	1.33	1.30	1.36		
13	1.24	1.32	1.27	1.34	1.30	1.36		
14	1.24	1.32	1.27	1.35	1.31	1.37		
15	1.25	1.33	1.28	1.35	1.31	1.37		
16	1.25	1.34	1.28	1.36	1.31	1.37		
17	1.26	1.34	1.29	1.36	1.32	1.38		
18	1.26	1.35	1.29	1.36	1.32	1.38		
19	1.27	1.35	1.30	1.37	1.32	1.38		
20	1.27	1.36	1.30	1.37	1.33	1.39		
22	1.28	1.36	1.30	1.38	1.33	1.39		
24	1.28	1.37	1.31	1.38	1.33	1.40		
26	1.28	1.37	1.31	1.39	1.34	1.40		
28	1.29	1.38	1.31	1.39	1.34	1.40		
30	1.29	1.38	1.32	1.40				
32	1.29	1.39	1.32	1.40				
34	1.30	1.39	1.32	1.40				
36	1.30	1.39	1.33	1.40				
38	1.30	1.40						
40	1.31	1.40						
45	1.31	1.40						
50	1.31	1.40						
55	1.32	1.40						
60	1.32	1.40						

See below for use of table

USE OF TABLE

1. The left hand column in this table (Depth) indicates the height of the product column under dry or dewatered hole conditions.
2. This table applies for TITAN 3000, TITAN 5000 and TITAN 9000 Matrix blends with an emulsion content of 50% w/w ONLY, i.e. T9050/T9050G.
3. Emulsion explosives behave as liquids when subjected to the gravitational stress in vertical and near vertical blastholes and a pressure gradient in the explosive will be established. The higher the explosive column in the blasthole, the higher the internal pressure at the bottom of the column, and the larger the quantity of gassing chemicals that need to be added to provide sensitisation.
4. The open cup density is a measure of the level of sensitisation of the product. It is necessary to choose an open cup density to ensure that the density of the explosive at the bottom of the blasthole is less than the critical density. Inappropriate sensitisation may lead to poor detonation, fragmentation and generation of excessive post blast fume. Blacked out areas indicate where critical density is reached or exceeded.
5. To determine the required open cup density for an explosive column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the unshaded column under the required open cup density (a Toe density of 1.40g/cm^3 in the 1.10 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 1.10g/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 at full order upon initiation.
6. To determine the approximate average in-hole density in a column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the shaded column (an Avg. In-Hole density of 1.31g/cm^3 in the 1.10 g/cm^3 open cup density column). For depths that are not listed, Dyno Nobel recommends rounding up to the next highest depth. e.g. a 25m deep hole should be rounded to 26m and corresponding densities applied.
7. Blast design should be based on average in-hole density whilst blasthole loading requires the MPU operator to achieve the associated open cup density.
8. 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 following completion of loading and before stemming the charged blasthole. A longer period should be allowed at lower temperatures.
9. The density values shown were calculated using a laboratory mathematical model that was validated using a specially designed fit-for-purpose pressure-volume apparatus.
10. The low density explosive grade ammonium nitrate used in the model was assigned a bulk density of 0.77 g/cm^3 and a particle density of 1.58 g/cm^3.

Gassing density for TITAN® blends

Density of gas sensitised blends containing 60% TITAN 3000, TITAN 5000 or TITAN 9000 in an explosive column at different depths for different open cup densities.

	Gassed blend containing 60% emulsion – Density g/cm³													
Depth (m)	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe	Avg. In-Hole	Toe
Open Cup	**0.90**	**0.90**	**0.95**	**0.95**	**1.00**	**1.00**	**1.05**	**1.05**	**1.10**	**1.10**	**1.15**	**1.15**	**1.20**	**1.20**
1	0.92	0.94	0.97	0.99	1.02	1.04	1.07	1.09	1.12	1.13	1.16	1.18	1.21	1.22
2	0.94	0.98	0.99	1.03	1.04	1.07	1.08	1.12	1.13	1.16	1.18	1.20	1.22	1.25
3	0.96	1.02	1.01	1.06	1.05	1.10	1.10	1.14	1.14	1.18	1.19	1.22	1.23	1.26
4	0.98	1.05	1.02	1.09	1.07	1.13	1.11	1.17	1.16	1.20	1.20	1.24	1.24	1.28
5	0.99	1.07	1.04	1.11	1.08	1.15	1.12	1.19	1.17	1.22	1.21	1.26	1.25	1.29
6	1.01	1.10	1.05	1.13	1.09	1.17	1.14	1.20	1.18	1.24	1.22	1.27	1.26	1.30
7	1.02	1.12	1.06	1.15	1.11	1.19	1.15	1.22	1.19	1.25	1.23	1.28	1.26	1.31
8	1.04	1.14	1.08	1.17	1.12	1.20	1.16	1.23	1.19	1.26	1.23	1.29	1.27	1.32
9	1.05	1.16	1.09	1.19	1.13	1.22	1.17	1.25	1.20	1.27	1.24	1.30	1.28	1.33
10	1.06	1.17	1.10	1.20	1.14	1.23	1.17	1.26	1.21	1.28	1.25	1.31	1.28	1.33
11	1.07	1.19	1.11	1.21	1.14	1.24	1.18	1.27	1.22	1.29	1.25	1.32	1.29	1.34
12	1.08	1.20	1.12	1.23	1.15	1.25	1.19	1.28	1.22	1.30	1.26	1.32	1.29	1.34
13	1.09	1.21	1.13	1.24	1.16	1.26	1.20	1.28	1.23	1.31	1.26	1.33	1.29	1.35
14	1.10	1.22	1.13	1.25	1.17	1.27	1.20	1.29	1.23	1.31	1.27	1.33	1.30	1.35
15	1.11	1.23	1.14	1.25	1.17	1.28	1.21	1.30	1.24	1.32	1.27	1.34	1.30	1.36
16	1.11	1.24	1.15	1.26	1.18	1.28	1.21	1.30	1.24	1.32	1.28	1.34	1.31	1.36
17	1.12	1.25	1.15	1.27	1.19	1.29	1.22	1.31	1.25	1.33	1.28	1.35	1.31	1.36
18	1.13	1.26	1.16	1.28	1.19	1.30	1.22	1.31	1.25	1.33	1.28	1.35	1.31	1.37
19	1.14	1.26	1.17	1.28	1.20	1.30	1.23	1.32	1.26	1.34	1.29	1.35	1.31	1.37
20	1.14	1.27	1.17	1.29	1.20	1.31	1.23	1.32	1.26	1.34	1.29	1.36	1.32	1.37
22	1.15	1.28	1.18	1.30	1.21	1.32	1.24	1.33	1.27	1.35	1.29	1.36	1.32	1.38
24	1.15	1.29	1.18	1.31	1.21	1.32	1.24	1.34	1.27	1.35	1.30	1.37	1.32	1.38
26	1.16	1.30	1.19	1.32	1.22	1.33	1.25	1.35	1.27	1.36	1.30	1.37	1.32	1.38
28	1.17	1.31	1.20	1.32	1.22	1.34	1.25	1.35	1.28	1.36	1.30	1.38	1.33	1.39
30	1.17	1.32	1.20	1.33	1.23	1.34	1.25	1.36	1.28	1.37	1.31	1.38	1.33	1.39
32	1.18	1.32	1.21	1.34	1.23	1.35	1.26	1.36	1.28	1.37	1.31	1.38	1.33	1.39
34	1.18	1.33	1.21	1.34	1.24	1.35	1.26	1.36	1.29	1.37	1.31	1.39		
36	1.19	1.34	1.22	1.35	1.24	1.36	1.27	1.37	1.29	1.38	1.31	1.39		
38	1.19	1.34	1.22	1.35	1.24	1.36	1.27	1.37	1.29	1.38	1.32	1.39		
40	1.20	1.35	1.22	1.36	1.25	1.36	1.27	1.37	1.30	1.38	1.32	1.39		
45	1.20	1.35	1.23	1.36	1.25	1.37	1.28	1.38	1.30	1.38	1.32	1.39		
50	1.21	1.35	1.23	1.36	1.26	1.37	1.28	1.38	1.30	1.39	1.32	1.39		
55	1.21	1.35	1.24	1.36	1.26	1.37	1.28	1.38	1.30	1.39	1.33	1.39		
60	1.22	1.35	1.24	1.36	1.26	1.37	1.28	1.38	1.31	1.39	1.33	1.39		

See below for use of table

USE OF TABLE

1. The left hand column in this table (Depth) indicates the height of the product column under dry hole conditions. In wet hole conditions, the value selected from the left hand column must be the sum of the product column and the height of the water column in the hole. If the length of the product and water column exceeds the depth of the hole then the value selected from the left hand column must be the hole depth.
2. This table applies for TITAN 3000, TITAN 5000 and TITAN 9000 Matrix blends with an emulsion content of 60% w/w ONLY, i.e. T9060G.
3. Emulsion explosives behave as liquids when subjected to the gravitational stress in vertical and near vertical blastholes and a pressure gradient in the explosive will be established. The higher the explosive column in the blasthole, the higher the internal pressure at the bottom of the column, and the larger the quantity of gassing chemicals that need to be added to provide sensitisation.
4. The open cup density is a measure of the level of sensitisation of the product. It is necessary to choose an open cup density to ensure that the density of the explosive at the bottom of the blasthole is less than the critical density. Inappropriate sensitisation may lead to poor detonation, fragmentation and generation of excessive post blast fume. Blacked out areas indicate where critical density is reached or exceeded.
5. To determine the required open cup density for an explosive column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the unshaded column under the required open cup density (a Toe density of 1.38g/cm^3 in the 1.10 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 1.10g/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 at full order upon initiation.
6. To determine the approximate average in-hole density in a column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the shaded column (an Avg. In-Hole density of 1.30g/cm^3 in the 1.10 g/cm^3 open cup density column). For depths that are not listed, Dyno Nobel recommends rounding up to the next highest depth. e.g. a 25m deep hole should be rounded to 26m and corresponding densities applied.
7. Blast design should be based on average in-hole density whilst blasthole loading requires the MPU operator to achieve the associated open cup density.
8. 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 following completion of loading and before stemming the charged blasthole. A longer period should be allowed at lower temperatures.
9. The density values shown were calculated using a laboratory mathematical model that was validated using a specially designed fit-for-purpose pressure-volume apparatus.
10. The low density explosive grade ammonium nitrate used in the model was assigned a bulk density of 0.77 g/cm^3 and a particle density of 1.58 g/cm^3.

Gassing density for TITAN® blends

Density of gas sensitised blends containing 70% TITAN 3000, TITAN 5000 or TITAN 9000 in an explosive column at different depths for different open cup densities.

	Gassed blend containing 70% emulsion – Density g/cm³													
Depth (m)	**Avg. In-Hole**	**Toe**	**Avg. In-Hole**	**Toe**	**Avg. In-Hole**	**Toe**	**Avg. In-Hole**	**Toe**	**Avg. In-Hole**	**Toe**	**Avg. In-Hole**	**Toe**	**Avg. In-Hole**	**Toe**
Open Cup	**0.90**	**0.90**	**0.95**	**0.95**	**1.00**	**1.00**	**1.05**	**1.05**	**1.10**	**1.10**	**1.15**	**1.15**	**1.20**	**1.20**
1	0.92	0.94	0.97	0.99	1.02	1.04	1.07	1.08	1.12	1.13	1.16	1.18	1.21	1.22
2	0.94	0.98	0.99	1.02	1.04	1.07	1.08	1.11	1.13	1.16	1.18	1.20	1.22	1.24
3	0.96	1.01	1.00	1.05	1.05	1.10	1.10	1.14	1.14	1.18	1.19	1.22	1.23	1.26
4	0.97	1.04	1.02	1.08	1.07	1.12	1.11	1.16	1.15	1.20	1.20	1.23	1.24	1.27
5	0.99	1.07	1.03	1.11	1.08	1.14	1.12	1.18	1.16	1.21	1.20	1.25	1.25	1.28
6	1.00	1.09	1.05	1.13	1.09	1.16	1.13	1.20	1.17	1.23	1.21	1.26	1.25	1.29
7	1.02	1.11	1.06	1.15	1.10	1.18	1.14	1.21	1.18	1.24	1.22	1.27	1.26	1.30
8	1.03	1.13	1.07	1.16	1.11	1.19	1.15	1.22	1.19	1.25	1.23	1.28	1.26	1.31
9	1.04	1.15	1.08	1.18	1.12	1.21	1.16	1.24	1.20	1.26	1.23	1.29	1.27	1.32
10	1.05	1.16	1.09	1.19	1.13	1.22	1.17	1.25	1.20	1.27	1.24	1.30	1.27	1.32
11	1.06	1.17	1.10	1.20	1.14	1.23	1.17	1.25	1.21	1.28	1.24	1.30	1.28	1.33
12	1.07	1.19	1.11	1.21	1.15	1.24	1.18	1.26	1.22	1.29	1.25	1.31	1.28	1.33
13	1.08	1.20	1.12	1.22	1.15	1.25	1.19	1.27	1.22	1.29	1.25	1.31	1.29	1.34
14	1.09	1.21	1.13	1.23	1.16	1.26	1.19	1.28	1.23	1.30	1.26	1.32	1.29	1.34
15	1.10	1.22	1.13	1.24	1.17	1.26	1.20	1.28	1.23	1.30	1.26	1.32	1.29	1.34
16	1.11	1.23	1.14	1.25	1.17	1.27	1.20	1.29	1.24	1.31	1.27	1.33	1.30	1.35
17	1.11	1.24	1.15	1.26	1.18	1.28	1.21	1.30	1.24	1.31	1.27	1.33	1.30	1.35
18	1.12	1.24	1.15	1.26	1.18	1.28	1.21	1.30	1.24	1.32	1.27	1.34	1.30	1.35
19	1.13	1.25	1.16	1.27	1.19	1.29	1.22	1.31	1.25	1.32	1.28	1.34	1.30	1.35
20	1.13	1.26	1.16	1.27	1.19	1.29	1.22	1.31	1.25	1.33	1.28	1.34	1.31	1.36
22	1.14	1.27	1.17	1.29	1.20	1.30	1.23	1.32	1.26	1.33	1.28	1.35	1.31	1.36
24	1.14	1.28	1.17	1.29	1.20	1.31	1.23	1.32	1.26	1.34	1.29	1.35	1.31	1.37
26	1.15	1.29	1.18	1.30	1.21	1.32	1.24	1.33	1.26	1.34	1.29	1.36	1.31	1.37
28	1.16	1.29	1.18	1.31	1.21	1.32	1.24	1.34	1.27	1.35	1.29	1.36	1.32	1.37
30	1.16	1.30	1.19	1.32	1.22	1.33	1.24	1.34	1.27	1.35	1.29	1.36	1.32	1.37
32	1.17	1.31	1.19	1.32	1.22	1.33	1.25	1.34	1.27	1.36	1.30	1.37		
34	1.17	1.31	1.20	1.33	1.23	1.34	1.25	1.35	1.28	1.36	1.30	1.37		
36	1.18	1.32	1.20	1.33	1.23	1.34	1.25	1.35	1.28	1.36	1.30	1.37		
38	1.18	1.32	1.21	1.33	1.23	1.34	1.26	1.35	1.28	1.36	1.30	1.37		
40	1.19	1.33	1.21	1.34	1.24	1.35	1.26	1.36	1.28	1.37				
45	1.19	1.33	1.22	1.34	1.24	1.35	1.26	1.36	1.29	1.37				
50	1.20	1.33	1.22	1.34	1.24	1.35	1.27	1.36	1.29	1.37				
55	1.20	1.34	1.22	1.34	1.25	1.35	1.27	1.36	1.29	1.37				
60	1.20	1.34	1.23	1.35	1.25	1.35	1.27	1.36	1.29	1.37				

See below for use of table

USE OF TABLE

1. The left hand column in this table (Depth) indicates the height of the product column under dry hole conditions. In wet hole conditions, the value selected from the left hand column must be the sum of the product column and the height of the water column in the hole. If the length of the product and water column exceeds the depth of the hole then the value selected from the left hand column must be the hole depth.
2. This table applies for TITAN 3000, TITAN 5000 and TITAN 9000 Matrix blends with an emulsion content of 70% w/w ONLY, i.e. T9070G.
3. Emulsion explosives behave as liquids when subjected to the gravitational stress in vertical and near vertical blastholes and a pressure gradient in the explosive will be established. The higher the explosive column in the blasthole, the higher the internal pressure at the bottom of the column, and the larger the quantity of gassing chemicals that need to be added to provide sensitisation.
4. The open cup density is a measure of the level of sensitisation of the product. It is necessary to choose an open cup density to ensure that the density of the explosive at the bottom of the blasthole is less than the critical density. Inappropriate sensitisation may lead to poor detonation, fragmentation and generation of excessive post blast fume. Blacked out areas indicate where critical density is reached or exceeded.
5. To determine the required open cup density for an explosive column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the unshaded column under the required open cup density (a Toe density of 1.37g/cm^3 in the 1.10 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 1.10g/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 at full order upon initiation.
6. To determine the approximate average in-hole density in a column of 40m (for example), find 40m in the Depth column. Moving to the right, read off the density in the shaded column (an Avg. In-Hole density of 1.28g/cm^3 in the 1.10 g/cm^3 open cup density column). For depths that are not listed, Dyno Nobel recommends rounding up to the next highest depth. e.g. a 25m deep hole should be rounded to 26m and corresponding densities applied.
7. Blast design should be based on average in-hole density whilst blasthole loading requires the MPU operator to achieve the associated open cup density.
8. 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 following completion of loading and before stemming the charged blasthole. A longer period should be allowed at lower temperatures.
9. The density values shown were calculated using a laboratory mathematical model that was validated using a specially designed fit-for-purpose pressure-volume apparatus.
10. The low density explosive grade ammonium nitrate used in the model was assigned a bulk density of 0.77 g/cm^3 and a particle density of 1.58 g/cm^3.

Gassing density for TITAN® blends

Density of gas sensitised TITAN 9000xero® in an explosive column at different depths for different open cup densities.

	TITAN 9000xero gassed blend – Density g/cm³													
Depth (m)	**Avg in-hole**	**Toe**	**Avg in-hole**	**Toe**	**Avg in-hole**	**Toe**	**Avg in-hole**	**Toe**	**Avg in-hole**	**Toe**	**Avg in-hole**	**Toe**	**Avg in-hole**	**Toe**
Open cup	**0.90**	**0.90**	**0.95**	**0.95**	**1.00**	**1.00**	**1.05**	**1.05**	**1.10**	**1.10**	**1.15**	**1.15**	**1.20**	**1.20**
1	0.92	0.94	0.97	0.98	1.02	1.03	1.06	1.08	1.11	1.12	1.16	1.17	1.21	1.22
2	0.93	0.97	0.98	1.01	1.03	1.06	1.08	1.10	1.12	1.14	1.17	1.19	1.21	1.23
3	0.95	1.00	1.00	1.04	1.04	1.08	1.09	1.12	1.13	1.16	1.18	1.20	1.22	1.24
4	0.96	1.02	1.01	1.06	1.05	1.10	1.10	1.14	1.14	1.18	1.18	1.21	1.23	1.25
5	0.98	1.04	1.02	1.08	1.06	1.12	1.11	1.15	1.15	1.19	1.19	1.22	1.23	1.26
6	0.99	1.06	1.03	1.10	1.07	1.13	1.12	1.17	1.16	1.20	1.20	1.23	1.24	1.26
7	1.00	1.08	1.04	1.12	1.08	1.15	1.12	1.18	1.16	1.21	1.20	1.24	1.24	1.27
8	1.01	1.10	1.05	1.13	1.09	1.16	1.13	1.19	1.17	1.22	1.21	1.25	1.24	1.27
9	1.02	1.11	1.06	1.14	1.10	1.17	1.14	1.20	1.18	1.23	1.21	1.25	1.25	1.28
10	1.03	1.12	1.07	1.15	1.11	1.18	1.14	1.21	1.18	1.23	1.22	1.26	1.25	1.28
11	1.04	1.14	1.08	1.16	1.11	1.19	1.15	1.22	1.19	1.24	1.22	1.26		
12	1.05	1.15	1.09	1.17	1.12	1.20	1.16	1.22	1.19	1.25	1.22	1.27		
13	1.06	1.16	1.09	1.18	1.13	1.21	1.16	1.23	1.19	1.25	1.23	1.27		
14	1.06	1.17	1.10	1.19	1.13	1.21	1.17	1.23	1.20	1.26	1.23	1.28		
15	1.07	1.17	1.10	1.20	1.14	1.22	1.17	1.24	1.20	1.26	1.23	1.28		
16	1.08	1.18	1.11	1.20	1.14	1.22	1.17	1.24	1.21	1.26	1.24	1.28		
17	1.08	1.19	1.12	1.21	1.15	1.23	1.18	1.25	1.21	1.27	1.24	1.28		
18	1.09	1.19	1.12	1.21	1.15	1.23	1.18	1.25	1.21	1.27				
19	1.09	1.20	1.13	1.22	1.16	1.24	1.19	1.26	1.22	1.27				
20	1.10	1.21	1.13	1.22	1.16	1.24	1.19	1.26	1.22	1.28				
22	1.11	1.22	1.14	1.23	1.16	1.25	1.19	1.27	1.22	1.28				
24	1.11	1.23	1.14	1.24	1.17	1.26	1.20	1.27						
26	1.12	1.23	1.14	1.25	1.17	1.26	1.20	1.28						
28	1.12	1.24	1.15	1.25	1.18	1.27	1.20	1.28						
30	1.13	1.25	1.15	1.26	1.18	1.27	1.21	1.28						
32	1.13	1.25	1.16	1.26	1.18	1.28								
34	1.13	1.26	1.16	1.27	1.19	1.28								
36	1.14	1.26	1.17	1.27	1.19	1.28								
38	1.14	1.27	1.17	1.28										
40	1.15	1.27	1.17	1.28										
45	1.15	1.27	1.18	1.28										
50	1.15	1.27	1.18	1.28										
55	1.16	1.27	1.18	1.28										
60	1.16	1.28												

See below for use of table

USE OF TABLE

1. The left hand column in this table (Depth) indicates the height of the product column under dry hole conditions. In wet hole conditions, the value selected from the left hand column must be the sum of the product column plus the height of the water column in the hole. If the length of the product and water column exceeds the depth of the hole then the value selected from the left hand column must be the hole depth.
2. This table applies for TITAN 9000xero Matrix blend with an emulsion content of 80% w/w ONLY.
3. Emulsion explosives behave as liquids when subjected to the gravitational stress in a vertical blasthole, and a pressure gradient in the explosive will be established. The higher the explosive column in the blasthole, the higher the internal pressure at the bottom of the column, and the larger the quantity of gassing chemicals that need to be added to provide sensitisation.
4. The open cup density is a measure of the level of sensitisation of the product. It is necessary to choose an open cup density to ensure that the density of the explosive at the bottom of the blasthole is less than the critical density. Inappropriate sensitisation may lead to poor detonation, fragmentation and generation of excessive post blast fume. Blacked out areas indicate where critical density is reached or exceeded.
5. To determine the required open cup density for an explosive column of 30m (for example), find 30m in the Depth column. Moving to the right, read off the density in the unshaded column under the required open cup density (e.g. a Toe density of 1.28g/cm^3 in the 1.05 g/cm^3 open cup density column). In this example, this indicates that sufficient gassing chemicals should be added to the gassed explosive blend during delivery so that an open cup density of 1.05g/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 at full order upon initiation.
6. To determine the approximate average in-hole density in a column of 30m (for example), find 30m in the Depth column. Moving to the right, read off the density in the shaded column (e.g. an Avg. In-Hole density of 1.21g/cm^3 in the 1.05 g/cm^3 open cup density column).
   For depths that are not listed, Dyno Nobel recommends rounding up to the next highest depth. e.g. a 25m deep hole should be rounded to 26m and corresponding densities applied.
7. Blast design should be based on average in-hole density whilst blasthole loading requires the MPU operator to achieve the associated open cup density.
8. 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 following completion of loading and before stemming the charged blasthole. A longer period should be allowed at lower temperatures.
9. The density values shown were calculated using a laboratory mathematical model that was validated using a specially designed fit-for-purpose pressure-volume apparatus.

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/m³)	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 dependent 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

Sound level calculation

$$Lp(dB) = 20 \log \left[\frac{P}{20 \times 10^{-9}} \right]$$

Minimum levels quoted

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

Please reference AS 2187.2 – 2006 for further information

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 blasthole 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)

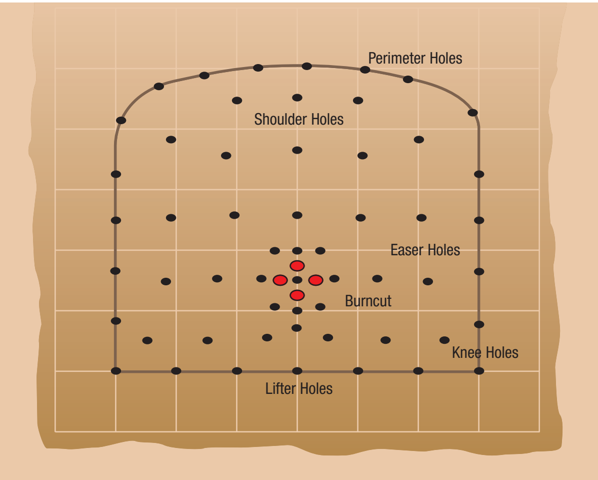
Housing and low rise residential buildings, Commercial buildings not included below	10 mm/s
Commercial and industrial buildings or structures of reinforced concrete or steel constructions	25 mm/s
For high rise, hospitals, long floor spans, dams or historic buildings where no specified limit exists	5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

Please reference AS 2187.2 – 2006 for further information

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.

Design of cut

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

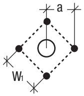
For multiple reamer holes: $ø = d\sqrt{n}$

Where: d = diameter of empty reamer holes; n = number of reamer holes

The cut:

1st square: $a = 1.5ø$

$W_1 = a\sqrt{2}$

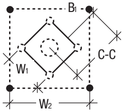


ø mm	**=**	**76**	**89**	**102**	**127**	**154**
a mm	=	110	130	150	190	230
W_1 mm	=	150	180	210	270	320

2nd square: $B_1 = W_1$

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

$W_2 = 1.5W_1\sqrt{2}$

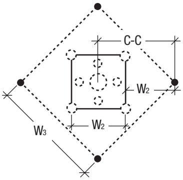


ø mm	**=**	**76**	**89**	**102**	**127**	**154**
W_1	=	150	180	210	270	320
C-C	=	225	270	310	400	480
W_2 mm	=	320	380	440	560	670

3rd square: $B_2 = W_2$

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

$W_3 = 1.5W_2\sqrt{2}$

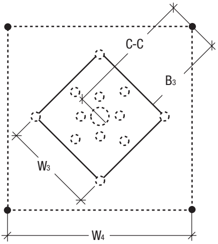


ø mm	**=**	**76**	**89**	**102**	**127**	**154**
W_2 mm	=	320	380	440	560	670
C-C	=	480	570	660	840	1000
W_3 mm	=	670	800	930	1180	1400

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

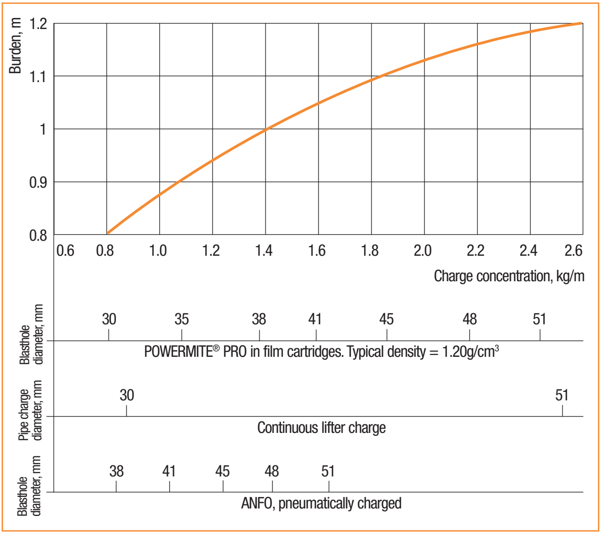
Design of lifter and easer holes

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 Range (MJ/kg)	Recommended Min. Hole Diameter
TITAN 2000G (Gassed)	0	0.90 – 1.25*	2.5	102 mm
TITAN 2070G (Gassed)	30	0.90 – 1.25*	2.8	102 mm
TITAN 2060G (Gassed)	40	0.90 – 1.25*	3.0	102 mm
TITAN 2050G (Gassed)	50	1.10 – 1.20*	3.1	102 mm
TITAN 2050 (Heavy ANFO)	50	1.30#	3.1	200 mm
TITAN 2040 (Heavy ANFO)	60	1.25#	3.2	127 mm
TITAN 2030 (Heavy ANFO)	70	1.10#	3.3	102 mm
TITAN 2020 (Heavy ANFO)	80	0.97#	3.4	102 mm
TITAN 3000G (Gassed)	0	0.90 – 1.25*	2.7	76 mm
TITAN 3070G (Gassed)	30	0.90 – 1.25*	3.0	76 mm
TITAN 3060G (Gassed)	40	0.90 – 1.25*	3.1	89 mm
TITAN 3050G (Gassed)	50	1.10 – 1.20*	3.2	102 mm
TITAN 3050 (Heavy ANFO)	50	1.32#	3.2	200 mm
TITAN 3040 (Heavy ANFO)	60	1.26#	3.3	127 mm
TITAN 3030 (Heavy ANFO)	70	1.10#	3.4	102 mm
TITAN 3020 (Heavy ANFO)	80	0.98#	3.5	102 mm
TITAN 5000G (Gassed)	0	0.90 – 1.25*	2.5	102 mm
TITAN 5070G (Gassed)	30	0.90 – 1.25*	2.8	102 mm
TITAN 5060G (Gassed)	40	0.90 – 1.25*	3.0	102 mm
TITAN 5050G (Gassed)	50	1.10 – 1.20*	3.1	102 mm
TITAN 5050 (Heavy ANFO)	50	1.31#	3.1	200 mm
TITAN 5040 (Heavy ANFO)	60	1.26#	3.2	127 mm
TITAN 5030 (Heavy ANFO)	70	1.10#	3.3	102 mm
TITAN 5020 (Heavy ANFO)	80	0.98#	3-4	102 mm
TITAN 7000 (Gassed)	0	0.80 – 1.25*	2.9	35 mm
TITAN 7000i (Gassed)	0	0.80 – 1.25*	2.9	35 mm
TITAN 7000sx (Gassed)	0	0.80 – 1.25*	2.8	38 mm
TITAN 9000G (Gassed)	0	0.90 – 1.25*	2.7	76 mm
TITAN 9070G (Gassed)	30	0.90 – 1.25*	3.0	76 mm
TITAN 9060G (Gassed)	40	0.90 – 1.25*	3.1	89 mm
TITAN 9050G (Gassed)	50	1.10 – 1.20*	3.2	102 mm
TITAN 9050 (Heavy ANFO)	50	1.32#	3.2	200 mm
TITAN 9040 (Heavy ANFO)	60	1.26#	3.3	127 mm
TITAN 9030 (Heavy ANFO)	70	1.10#	3.4	102 mm
TITAN 9020 (Heavy ANFO)	80	0.98#	3.5	102 mm
TITAN 9000xero® (Gassed)	0	0.90 – 1.20*	2.0	150 mm

* Nominal open cup densities. In hole gassed product densities are dependent on the hole depth.
# Nominal open cup densities. In field densities may vary due to the AN prill density and/or sampling techniques.

How to select the right TITAN® matrix product for your needs

The table below is a guide to choosing the right product for the blasthole condition and desired performance. Please consult your Dyno Nobel representative for more further details.

Product selection guide – blasthole condition

<table>
<tr><th colspan="3">Emulsion Content % w /w</th><th>10</th><th>20</th><th>30</th><th>40</th><th>50</th><th>60</th><th>70</th><th>80</th><th>90</th><th>100</th></tr>
<tr><td rowspan="8">Blasthole Conditions</td><td>Dry [1]</td><td>Use</td><td colspan="10"></td></tr>
<tr><td colspan="2">Delivery Method [2]</td><td>A</td><td>A</td><td>A</td><td>A</td><td>A</td><td>A / P</td><td>A / P</td><td>A / P</td><td>A / P</td><td>A / P</td></tr>
<tr><td>Dewatered [3]</td><td>Use</td><td colspan="3">No</td><td colspan="7">Yes</td></tr>
<tr><td colspan="2">Delivery Method</td><td>–</td><td>–</td><td>–</td><td>A</td><td>A</td><td>A / P</td><td>A / P</td><td>A / P</td><td>A / P</td><td>A / P</td></tr>
<tr><td>Wet [4]</td><td>Use</td><td colspan="5">No</td><td colspan="5">Yes</td></tr>
<tr><td colspan="2">Delivery Method</td><td>–</td><td>–</td><td>–</td><td>–</td><td>–</td><td>P</td><td>P</td><td>P</td><td>P</td><td>P</td></tr>
<tr><td>Dynamic [5]</td><td>Use</td><td colspan="6">No</td><td colspan="4">Yes</td></tr>
<tr><td colspan="2">Delivery Method</td><td>–</td><td>–</td><td>–</td><td>–</td><td>–</td><td>–</td><td>P</td><td>P</td><td>P</td><td>P</td></tr>
<tr><td colspan="3">Sensitisation Required</td><td colspan="4">No</td><td>Note [6]</td><td colspan="5">Yes [7]</td></tr>
</table>

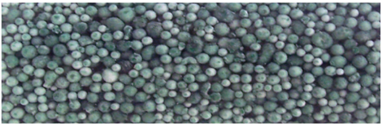
NOTES:

1. Dry hole is defined as a blast hole containing no water including no wet walls.
2. A = Auger, P = Pumped.
3. A dewatered hole is defined as a wet hole where water has been removed and is not recharging.
4. A wet hole is defined as a blast hole containing static water or has a recharge rate of <1m in 30 minutes.
5. Dynamic water is defined as a recharge rate of >1m in 30 minutes. If the level of dynamic water is such that product damage is suspected or observed, the suggested recommended sleep time should be reduced.
6. This product has reduced sensitivity and sensitisation is recommended for all hole. Please consult your Dyno Nobel representative to check which delivery options are available at your location.
7. The TITAN Matrix Blend Gassing Table should be used to determine the appropriate open cup density for the hole depth.

ANFO

Typical density 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

BLAST HI-T™



Typical density 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

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® 50	0.55	0.67	3.51	50	–

DynoSplit® Pro

Density (g/cm³) [1]	Velocity of Detonation (m/s) [2]	Maximum Temperature (°C)
1.15 – 1.21	Min 6500	55

1 Values are indicative average densities only, determined under laboratory conditions. Observed may differ or vary under field conditions. Normal in hole density only.
2 VOD of product is dependent on VOD of detonating cord.

Packaging

Diameter (mm)	Charge (kg/cart)	Quantity (m/case)	Case Weight (kg)
26	0.225	27.0	17
32	0.355	20.0	17

DynoSplit® Pro RiGHT®

Density (g/cm³) [1]	Velocity of Detonation (m/s) [2]	Maximum Temperature (°C) and sleep time [3]
1.08 – 1.12	Min 6500	100°C for 8 hours

1 Values are indicative average densities only, determined under laboratory conditions. Observed densities may differ or vary under field conditions. Nominal in hole density only.
2 VOD of product is dependent on VOD of detonating cord.
3 In hot ground. In reactive ground the maximum sleep time available will vary according to the reactivity of the ground and temperature of use. Please consult your Dyno Nobel customer representative in order for the required testing to ascertain the available sleep to be performed. In hole temperature monitoring, and testing of representative rock samples for the specific site will need to be performed to confirm the specific sleep time able to be achieved for the specific customer site.

Packaging

Diameter (mm)	Charge (kg/cart)	Quantity (m/case)	Case Weight (kg)
26	0.225	27.0	17
32	0.355	30.0	25

Packaged products

Z-BAR®

Diameter (mm)	Charge (kg/m)	VoD	Maximum case weight (kg)
29	0.50	6500	25

Packaging

Length	Quantity per case	Length per case
3.0 m	12	36
3.5 m	10	35

POWERMITE® PRO

Typical density (g/cm³)	Theoretical energy comparison			VoD (m/s)
	Energy (MJ/kg)	RWS	RBS	
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	215	105	25
25mm x 700mm	60	390	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

POWERMITE THERMO®

Nominal Density (g/cm^3)	Energy (MJ/kg) [1]	Relative Weight Strength (%) [1]	Relative Bulk Strength (%) [1]	VOD (m/s) [2]	Sensitivity	Detonation Pressure [3]
1.15 – 1.21	3.60	96	138	5400	8g/m det cord	8.6

1 All Dyno Nobel energy values are calculated using a proprietary Dyno Nobel thermodynamic code. Other programs may give different values. The values given are relative to ANFO at 0.82 g/cm^3.

2 VOD is dependent on product density, diameter, the degree of confinement and other factors.

3 Calculated using an ideal thermodynamic code.

Packaging	Cart Weight (kg)	Chubs per case
540 x 336 x 240mm	25 kg	40

NONEL® MS Series

NONEL MS Series

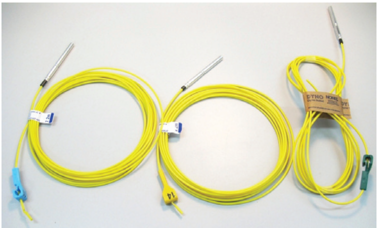
NONEL MS HD Series

Delay period (ms)	J-Hook 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	Black	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	Dark Red	550	50
22	Grey	600	50
23	Black	650	50
24	Dark Brown	700	50
25	Red	750	50
26	Blue	800	50
27	Brown	900	100
28	Orange	1000	100

	Packaging	Winding Configuration	
Length (m)	Units per case	Standard	Heavy Duty
4.8	180	Figure 80	n/a
6.0	180	Figure 80	Figure 80
7.2	180	Figure 80	Figure 80
9.0	120	Figure 80	Figure 80
12.0	90	Figure 80	Figure 80
15.0	75	Figure 80	Figure 80
18.0	60	Figure 80	Figure 80
24.0	40	n/a	Figure 80
30.0	30	n/a	Spooled
36.0	30	n/a	Spooled
45.0	30	n/a	Spooled
60.0	30	n/a	Spooled
80.0	30	n/a	Spooled

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

NONEL® LP Series



Delay period (ms)	J-Hook 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
4.8	180	Figure 80
5.4	180	Figure 80
6.0	180	Figure 80
7.2	180	Figure 80

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

NONEL® EZTL Series

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

Packaging

Length (m)	Units per case	Winding configuration
4.8	150	Figure 80
6.0	140	Figure 80
7.2	125	Figure 80
9.0	100	Figure 80
12.0	80	Figure 80
15.0	70	Figure 80
18.0	50	Figure 80
24 +	30	Spool

Tube colour	Yellow
Detonator	Low strength
Capacity	6 tubes

NONEL® MS Connector

Delay period (ms)	Clip colour
17	Yellow
25	Red
42	White
67	Blue
109	Black
176	Orange

Packaging

Units per case	200

Tube

Standard	Yellow

NONEL® Lead Line 1000

Reel-off initiation system (no detonator)

Length	1000m (two per case)
VOD	2100m/sec (+/- 300)
Tube	Standard Yellow / Red

NONEL® Starter

Packaging

Length (m)	Units per case	Winding configuration
100	16	Spooled
300	4	Spooled
500	4	Spooled

Tube

Standard	Yellow / Red

Cast Boosters

TROJAN SPARTAN

TROJAN TWINPLEX

TROJAN NBU

TROJAN RINGPRIME

	Nominal weight (g)	Diameter (mm)	Length (mm)	Units per case	Priming
TROJAN® SPARTAN 150	150	36	119	48	Detonator sensitive
TROJAN® SPARTAN 400	400	55	119	20	Detonator sensitive
TROJAN® TWINPLEX	450	57	117	18	Detonator sensitive
TROJAN® NBU 400	400	55	119	20	Primacord 5
TROJAN® RINGPRIME®	250	37	175	42	Detonator sensitive

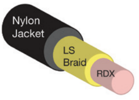
NB: Spiders for RINGPRIME® have 125mm diameter and come in separate 70 unit lots.

Detonating Cords

PRIMACORD 5

PRIMALINE 10

PRIMALINE 8HT



FIRELINE 8/40 RDX

	Core load (g/m)	Diameter (mm)	Minimum strength (kg)	Packaging
PRIMACORD® 5	5.3	4	68	2 x 500m rolls
PRIMALINE® 10	10	5	68	2 x 350m rolls
PRIMALINE® 8HT	8.5	3.2	45	2 x 305m rolls
FIRELINE® 8/40 RDX	8.6	4.3	68	2 x 305m rolls

ELECTRIC SUPER STARTER™

Description	
Delay time (ms)	0
Nominal resistance (ohm)	1.6
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)	4.9
Strength (#)	8

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

BlastWeb® Electronic Initiation System

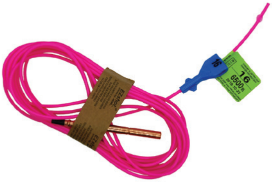
BlastWeb Initiation System is a Centralised Blasting System specifically designed for underground blasting operations.

The BlastWeb system can be used to fire SmartShot, DigiShot Plus & DriftShot Starter electronic detonators.

Properties

Temperature Limits	-10°C to +50°C
Power Supply	110V; 220V; 525V
Battery	User replaceable/ rechargeable 12V 7.2Ah sealed lead acid battery
Weight	±50Kg
Dimensions	L = 539-541mm; W = 480-482mm; H = 731-733mm
External Connectors	SmartKey; USB; (RS-232 & RS-485 for expansion – rear of unit)
Water Resistance	Splash proof (IP64)

EZshot



EZshot® detonator is the newest addition to Dyno Nobel's electronic initiation system portfolio. This exciting technology offers users the benefits of electronic precision and accuracy with the ease of use of NONEL® shock tube in a unique initiation system.

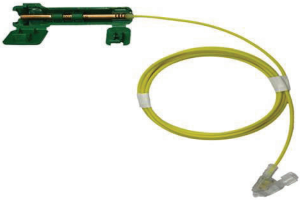
Packaging

Length	6m
Unit/Case	45

Properties

Detonator Shell	Copper
System Operating Temperature (range)	-20°C to +65°C
Delay (ms)	6500
Detonator Strength	#12

DriftShot® Starter Electronic Initiation System



The DriftShot Starter is an electronically initiated detonator intended for the remote firing of detonating cord, generally from the BlastWeb Centralised Blasting System

Packaging

Length	2m
Unit/Case	100 (2 x 1 to 50)

Properties

Tensile Strength	374N
System Operating Temperature (range)	-20°C to +80°C
Detonator Strength	#12

DigiShot® Plus.4G

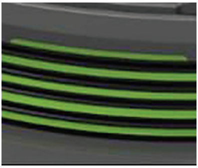
DigiShot Plus.4G electronic initiation system offers accurate timing benefits, quick deployment with robust downline wire and all-weather surface connectors. DigiShot Plus.4G is truly flexible, user friendly and fully programmable.

Properties

Detonator Shell	Copper
Cable Colour	Black with green stripe
Detonator Operating Temperature (range)	-40°C to +80°C
Detonator Strength	#12
Net Explosive Quantity (per 100 units)	0.1kg
Tensile Strength (N)	410 (standard) 460 (XTM)
Maximum Delay	20,000ms
Maximum Detonators per Blaster	16,000 (synchronised 10 x Bench Commanders)
Maximum Surface Wire Length	2.5km

Packaging

Length (m)	Standard Wire Units per case	XTM Wire Units per case
15	60 coils	60 coils
18	52 coils	52 coils
24	40 coils	40 coils
30	32 coils	32 coils
37	24 coils	24 spools
46	20 coils	18 spools
55	16 coils	18 spools
65	16 coils	12 spools
75	16 coils	12 spools



Surface Wire

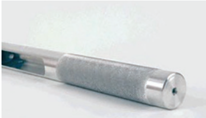
Description	Length (m)	Units per case
DSPWIRE300M	300	3
DSPWIRE500M	500	2

DYNOSTART™ (DS2)

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.

DYNOTRACKER™

The DYNOTRACKER is a device that attaches to the end of a standard charging hose used for loading ANFO. This device allows the use of ANFO as a perimeter charge in tunnelling applications, hereby eliminating the need for more expensive cartridged explosives.



NONEL® Starter Gun

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

The SB10 is a compact capacitive 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.

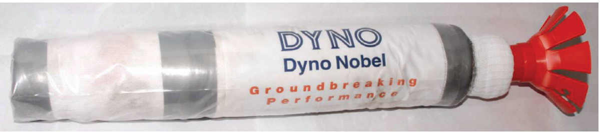
Lo-Stat ANFO Hose

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 KΩ	15 – 25 KΩ
Total Resistance (whole coil)	<1.6 MΩ	<1.6 MΩ
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 sealed 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 blasthole after the loading has been completed and be located 80cm below the explosive column. STEMPAC is available in three (3) different diameter sizes – 76mm, 89mm and 102mm.



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(mΩ/m) per core	62

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