July 14, 2015

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Mr. John R. Hellert
CEO/Senior Geologist
Continental Placer Inc.
II Winners Circle
Albany, NY 12205

Re: Frontier Stone, LLC
Prediction of Ground Vibration
Western New York Science and Technology Manufacturing Park

Dear Mr. Hellert:

Per your request, Vibra-Tech has conducted blasting simulations to determine optimum shot delay patterns to meet the VC-E vibration criteria at the closest STAMP location 7,606 meters (5 miles) south of the proposed quarry. This letter reports the results of the analysis.

Background:

Research conducted by both government and academic agencies has shown that peak particle velocity and frequency of ground vibrations induced by quarry blasting can be controlled and predicted by delay timing. The seismic signal generated by a single underground explosive column when denoted is repeatable. Because of this repeatability, the seismic signal resulting from a full production shot of multiple time delayed explosive columns, can be predicted using the linear superposition of the single hole waveform delayed and summed. Based on this theory computer simulations of multi-holed production shots can be developed using a seismic recording from a single column test explosion. These simulations are then used to identify optimum delay periods between buried explosive columns where maximum interference occurs between the ground vibration waves. This results in less ground vibration amplitudes.

A field test was conducted on September 17, 2014 where a single-hole test blast was detonated using existing monitoring well MW-1 located on the proposed quarry property. The monitoring well was located at N43° 09.50754', W078° 21.69480'. The monitoring well was a 152.4 mm (6 in) diameter hole drilled to a depth of 44.56 meter (156 ft.). The hole was loaded with PowerAN 500 from a depth of 36.5 meter (120 ft) to 14.8 meter (48.5 ft) in the borehole giving a 21.8 meter (71.5 ft) explosive column with an approximate charge weight of 382 kg (843 lbs.). The PowerAN 500 product is a cartridge emulsion (5" x 30") having a density of 1.25 to 1.30 g/cc (0.047 lb./in^3). The remainder of the hole, 14.8 meters (48.5 ft) was stemmed with 12.7 mm (½ in) crushed stone. The explosive column was initiated from three points within the column utilizing 0.454 kg (1 lb.) Pentex AP-16 boosters with Unitronics 600 electronic caps.

Forty-three (43) seismic monitoring stations located between the test charge and the furthest STAMP location at 8,817 meters, were used to record ground vibrations resulting from the single hole charge. Complete details of the measurements and analysis were submitted in Vibra-Tech's previous report.

The measured seismic signal at the nearest STAMP location is used in simulations described in this report to identify the optimum millisecond delay intervals between production shot explosive columns.

Tested Trials:

In order to identifiy shot patterns that would meet the VC-E vibration criteria, eighteen (18) initial explosive column loading configurations were constructed. Variables included explosive type (ANFO, emulsion), borehole diameter (4", 5", 6"), and the number of decks (1, 2, 3). A working bench height of 55 feet (16.76 m) was assumed. Appendix A shows the details of each explosive column loading configuration, and explosive weight per delay calculations. The following table summarizes the different trials.

Table 1- Simulation Trial Parameters

Explosive Type	Borehole Diameter (Inch)	Number Of Decks	Weight of Explosive Charge Per Deck (lbs)	Weight of Explosive Charge Per Deck (kg)
Emulsion	6"	1	704	319
Emulsion	6"	2	314	142
Emulsion	6"	3	184	83
Emulsion	5"	1	510	231
Emulsion	5"	2	231	104
Emulsion	5"	3	138	62
Emulsion	4"	1	340	154
Emulsion	4"	2	156	71
Emulsion	4"	3	95	43
ANFO	6"	1	479	217
ANFO	6"	2	213	96
ANFO	6"	3	125	56
ANFO	5"	1	347	157
ANFO	5"	2	157	71
ANFO	5"	3	94	42
ANFO	4"	1	231	104
ANFO	4"	2	106	48
ANFO	4"	3	65	29

Based on initial simulations, it was found that the **decking of explosives is not required to meet the VC-E vibration criteria**. Simulations were then limited to single decked holes of either ANFO or Emulsion materials with 4", 5" and 6" diameter holes. A limit was placed on the maximum shot time length to not exceed one second. Delays were limited to only commonly available non-electric millisecond delay periods (9, 17, 25, 33, 35, 42, 50, 65, 67, 75, 100, 125, 150).

Two types of shot patterns were investigated, patterns using only one delay period between all holes, and those using a different delays between holes and rows. The following examples show common layouts using single or multiple delay values.

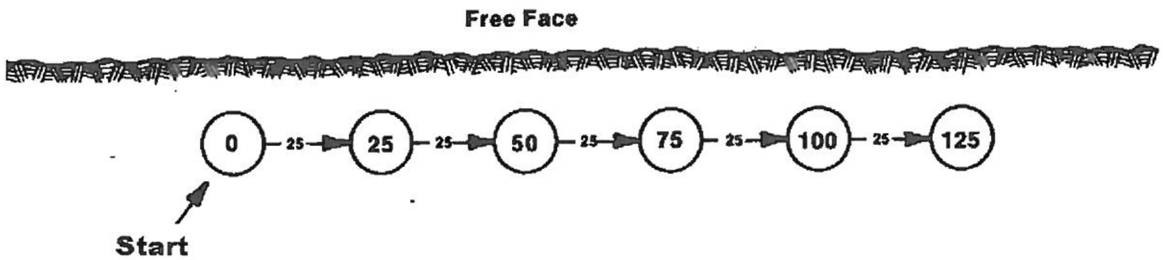


Figure 1- Example Shot Pattern Using Single Delay Period Oriented in Single Row 25ms Delays

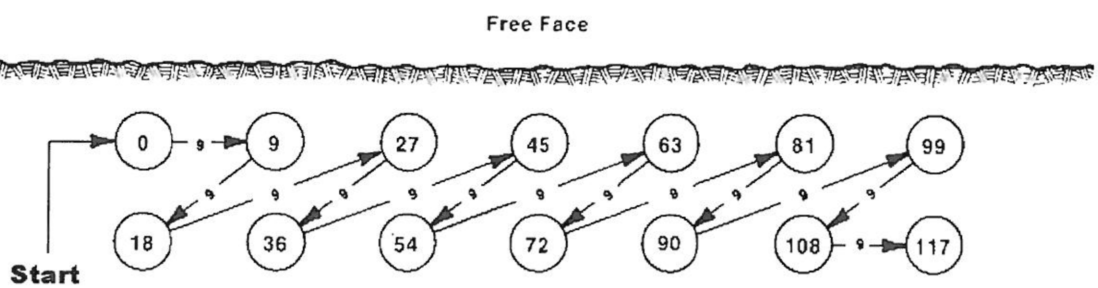


Figure 2 - Example Shot Pattern Using Single Delay Period Oriented in Multiple Rows 9 ms Delays

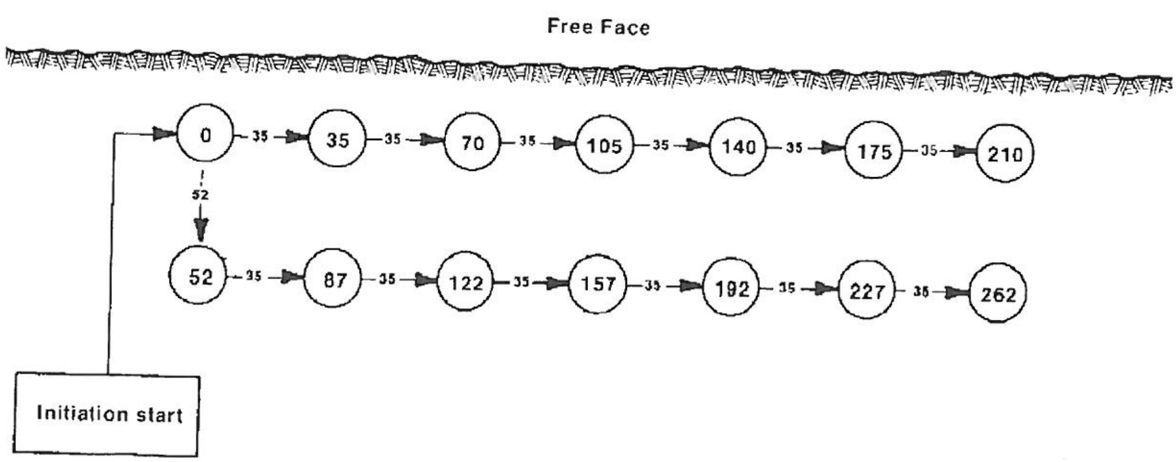


Figure 3 - Example Shot Pattern Using Multiple Delay Period 35 ms Between Holes, 52 ms Between Rows

Results:

An exhaustive search was then performed of both pattern types using all delay intervals with a minimum of seven holes and the maximum number of holes limited by the shot duration of one second. Single hole waveforms were scaled by the upper 95% confidence equation for an unconfined explosion using the charge weight and nearest distance to the STAMP, (7,606 meters). Details of the equations developed using regression analysis are provided in our previously submitted report.

For each of the simulations the 1/3 Octave velocity spectrum is calculated, for the vertical, longitudinal and transverse seismic channels. A comparison is made between the VC-E vibration criteria for all channels. An example of two shot patterns which meet the VC-E criteria (3.125 um/s rms or less) are shown below. The 1/3 Octave and narrow band frequency spectra for the two shot patterns are also shown.

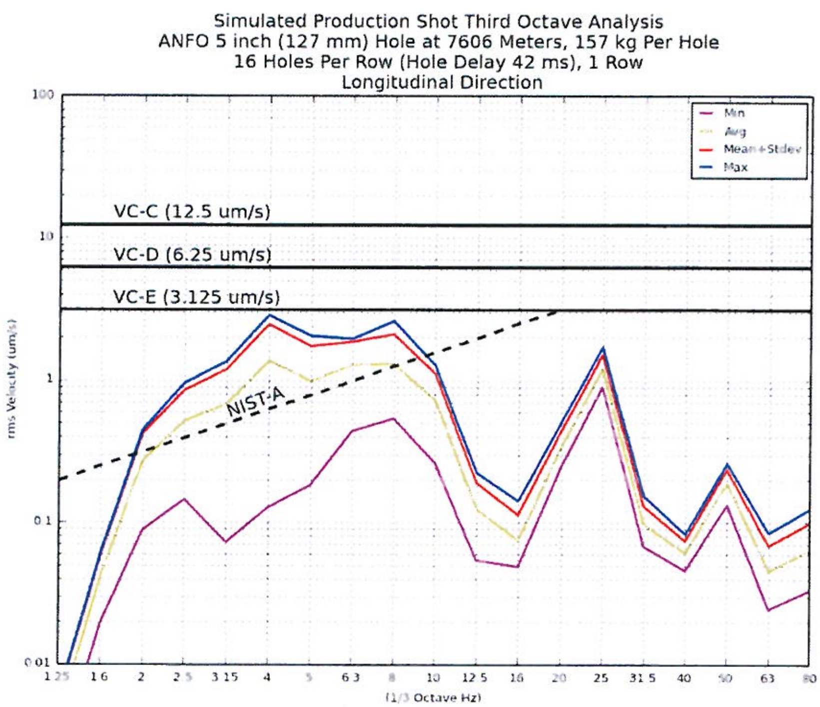


Figure 4

Simulated Production Shot Third Octave Analysis
ANFO 5 inch (127 mm) Hole at 7606 Meters, 157 kg Per Hole
16 Holes Per Row (Hole Delay 42 ms), 1 Row
Transverse Direction

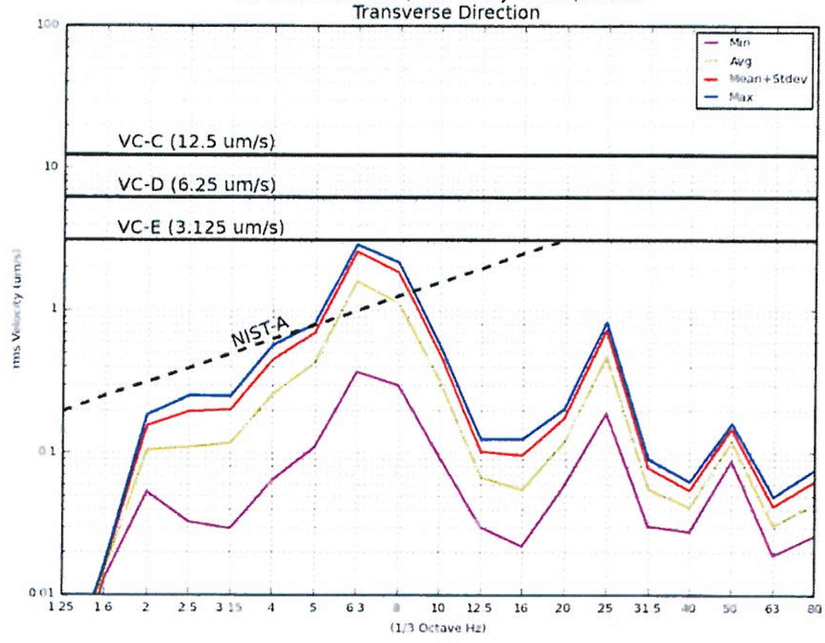


Figure 5

Simulated Production Shot Third Octave Analysis
ANFO 5 inch (127 mm) Hole at 7606 Meters, 157 kg Per Hole
16 Holes Per Row (Hole Delay 42 ms), 1 Row
Vertical Direction

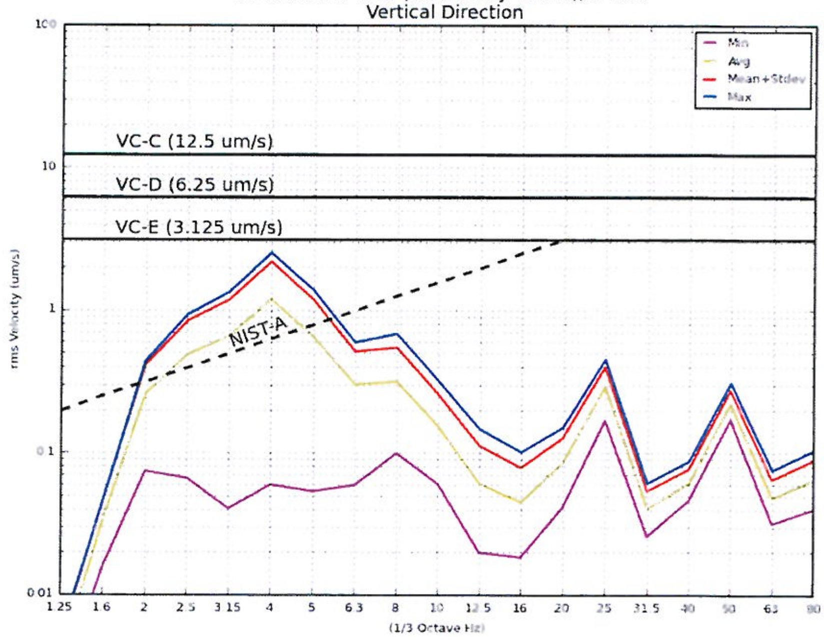
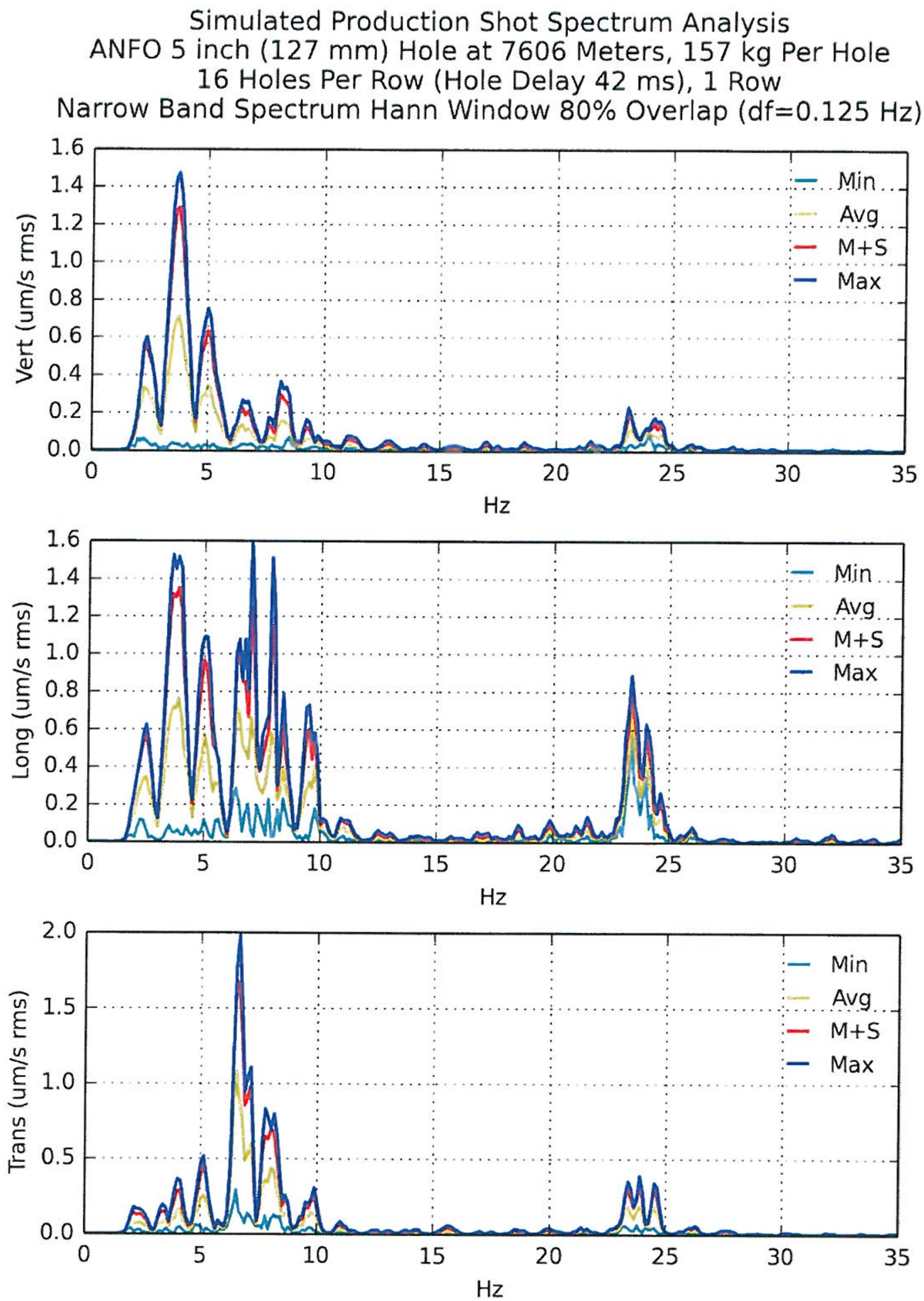


Figure 6



Simulated Production Shot Spectrum Analysis
ANFO 5 inch (127 mm) Hole at 7606 Meters, 157 kg Per Hole
16 Holes Per Row (Hole Delay 42 ms), 1 Row
Narrow Band Spectrum Hann Window 80% Overlap (df=0.125 Hz)
Vert (um/s rms)
Long (um/s rms)
Trans (um/s rms)
Hz
Min
Avg
M+S
Max

Figure 7

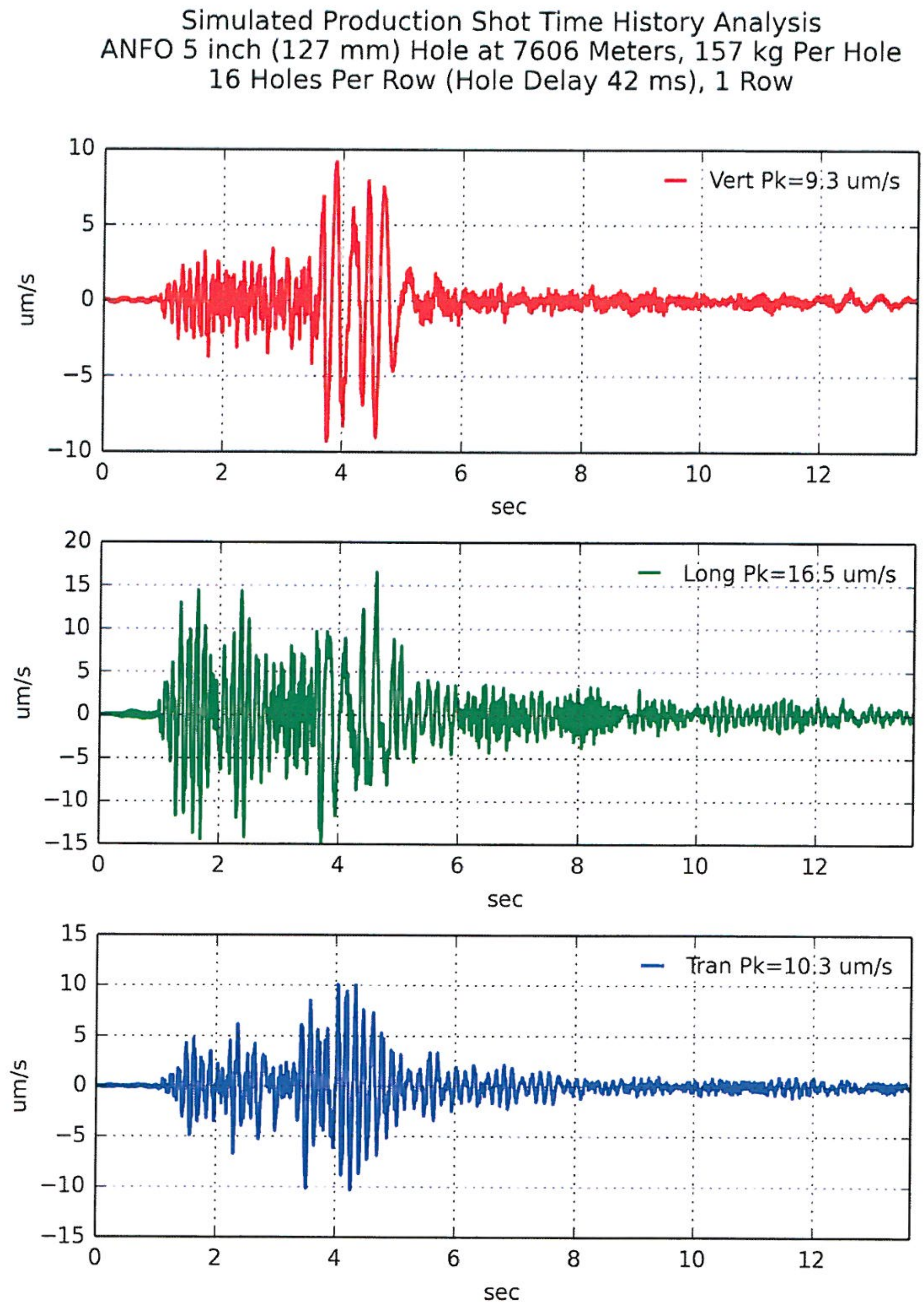

Simulated Production Shot Time History Analysis
ANFO 5 inch (127 mm) Hole at 7606 Meters, 157 kg Per Hole
16 Holes Per Row (Hole Delay 42 ms), 1 Row
Vert Pk=9.3 um/s
Long Pk=16.5 um/s
Tran Pk=10.3 um/s
um/s
sec

Figure 8

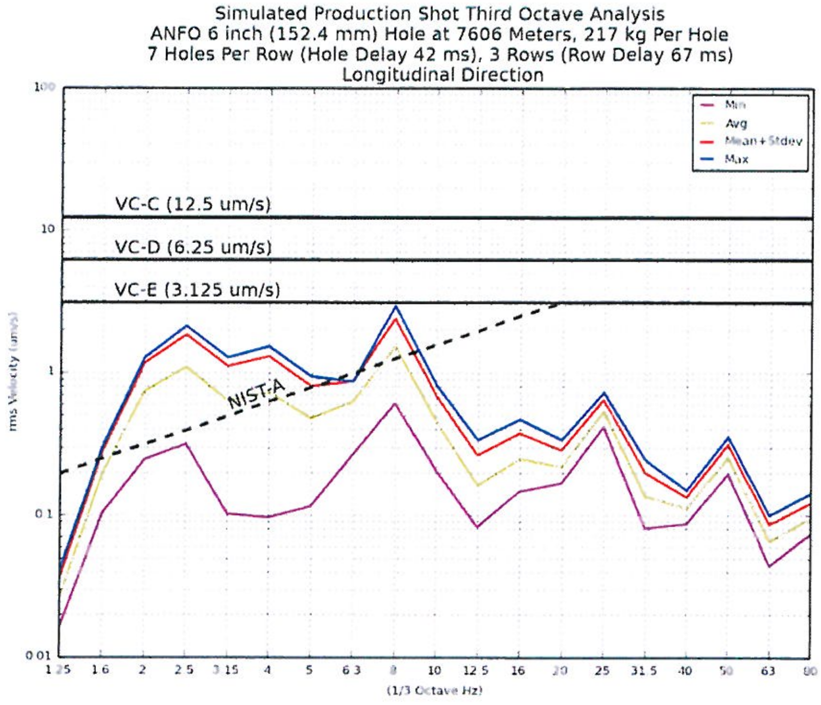


Figure 9

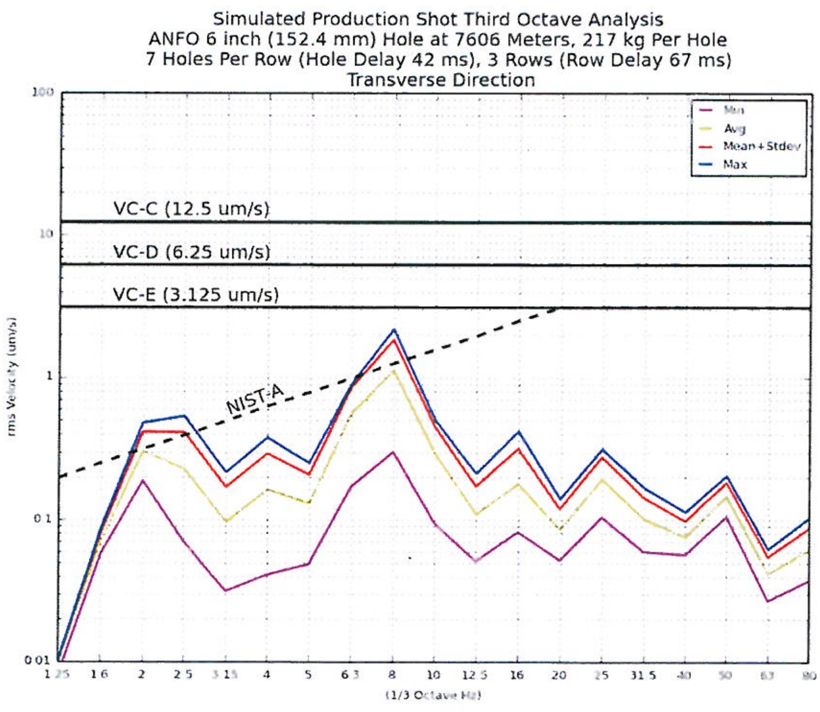
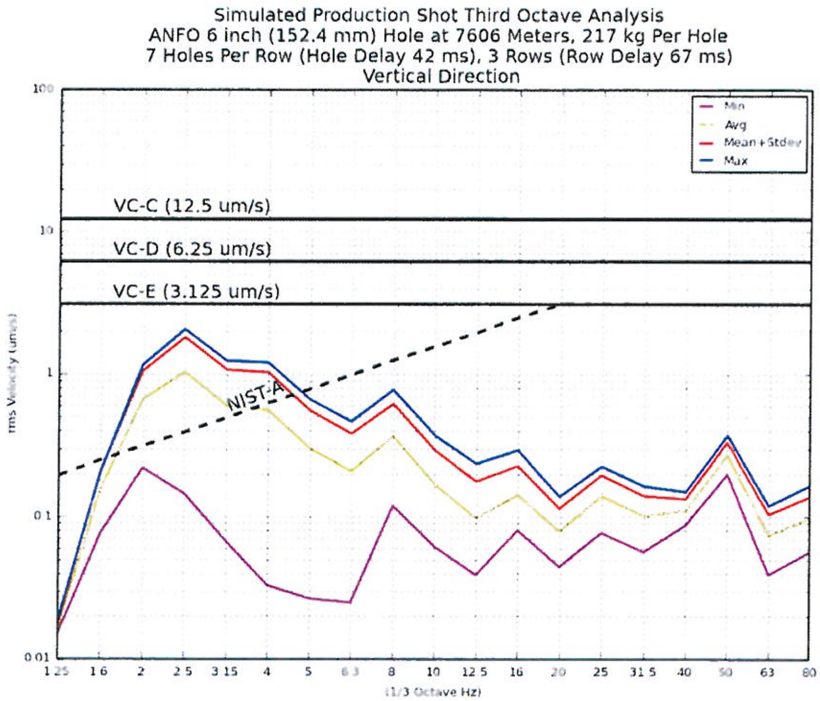


Figure 10



Simulated Production Shot Third Octave Analysis
ANFO 6 inch (152.4 mm) Hole at 7606 Meters, 217 kg Per Hole
7 Holes Per Row (Hole Delay 42 ms), 3 Rows (Row Delay 67 ms)
Vertical Direction
VC-C (12.5 um/s)
VC-D (6.25 um/s)
VC-E (3.125 um/s)
NIST-A
Min
Avg
Mean+Stdev
Max
rms Velocity (um/s)
(1/3 Octave Hz)

Figure 11

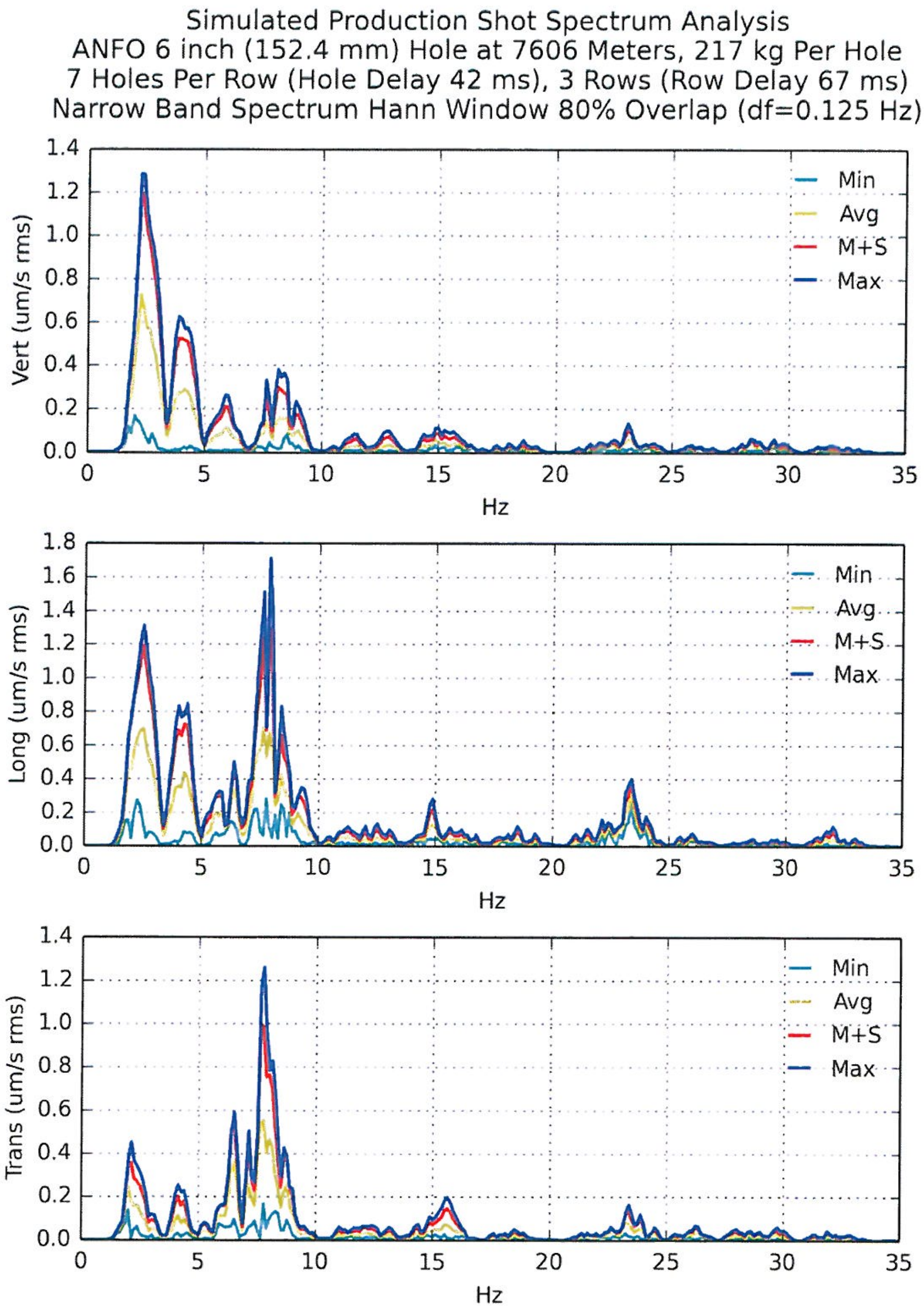

Simulated Production Shot Spectrum Analysis
ANFO 6 inch (152.4 mm) Hole at 7606 Meters, 217 kg Per Hole
7 Holes Per Row (Hole Delay 42 ms), 3 Rows (Row Delay 67 ms)
Narrow Band Spectrum Hann Window 80% Overlap (df=0.125 Hz)
Vert (um/s rms)
Long (um/s rms)
Trans (um/s rms)
Hz
Min
Avg
M+S
Max

Figure 12

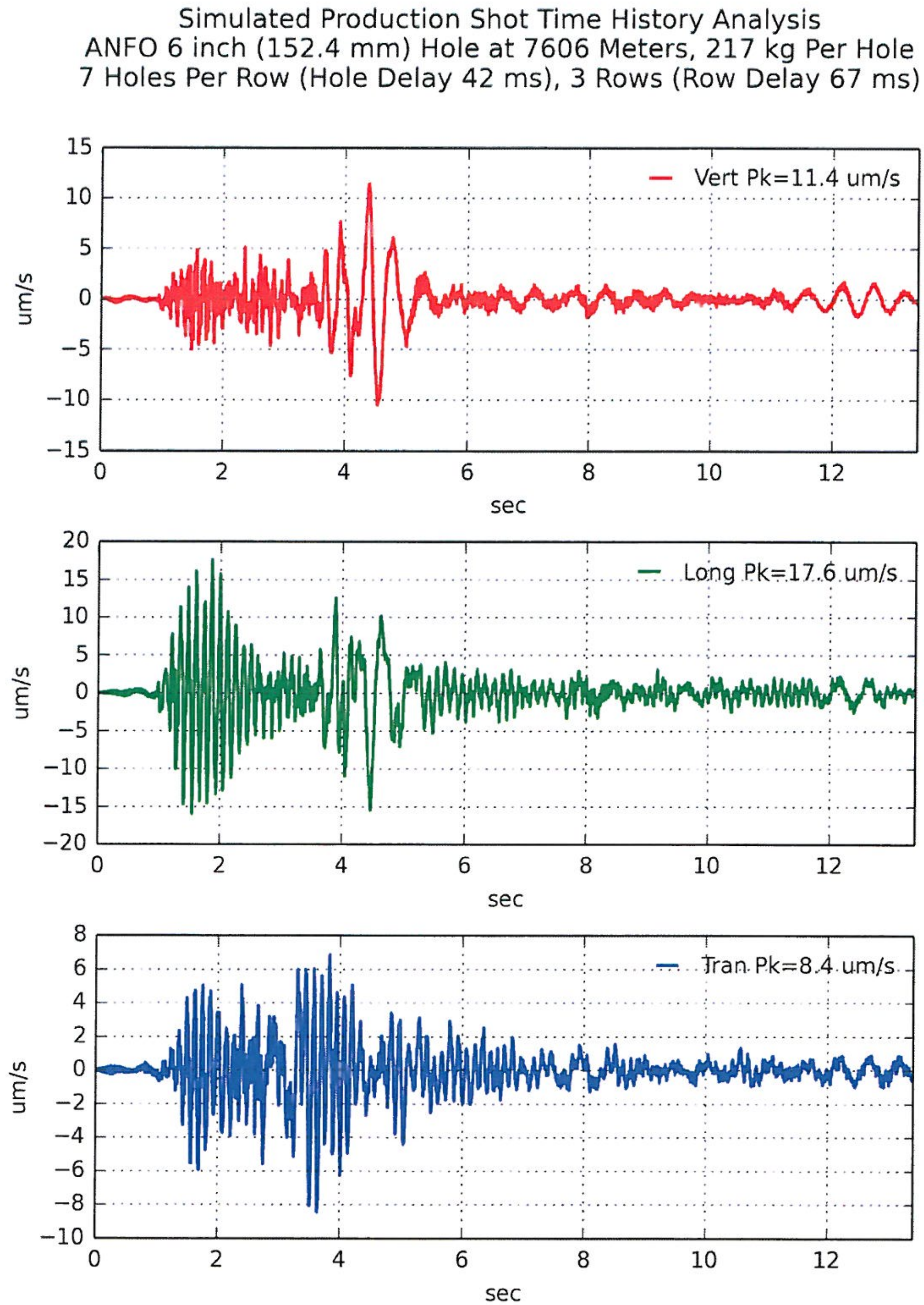

Simulated Production Shot Time History Analysis
ANFO 6 inch (152.4 mm) Hole at 7606 Meters, 217 kg Per Hole
7 Holes Per Row (Hole Delay 42 ms), 3 Rows (Row Delay 67 ms)
Vert Pk=11.4 um/s
Long Pk=17.6 um/s
Tran Pk=8.4 um/s
um/s
sec

Figure 13

Conclusion:

Figures 4, 5, and 6 shown above indicates that ground vibration levels are predicted to meet VC-E vibration criteria for a production blast consisting of 5 inch (127 mm) diameter holes loaded with 157 kg of ANFO provided that the 16 holes are delayed by 42 ms between holes for a single row.

Figures 9, 10 and 11 are a comparison for a three row production blast consisting of 6 inch (152.4 mm) diameter holes loaded with 217 kg of ANFO. Each row of holes contains 7 holes delayed by 42 ms with 67 ms between the rows. The figure indicates that the ground vibration levels are also predicted to meet the VC-E vibration criteria for this design.

We appreciate the opportunity to assist you with this project. If you have any questions or require additional information, please contact our office.

Sincerely,

VIBRA-TECH ENGINEERS, INC.

Brian Warner

Brian Warner
Computer Scientist

Douglas Rudenko

Douglas Rudenko, PG
Vice President

APPENDIX A

Blast Hole Loading Calculations

Bench Height = 55'
Subdrilling = 3'
Total Length = 58''

$\Phi = 6''$ SL = 12'

Explosive column

6'' ⟹ 58' - 12' = 46'

$\text{lbs./ft.} = 0.34 \times De^2 \times d$

$\text{lbs./ft.} = 0.34(6)^2(.85)$ ANFO = ρ = 0.85 g/cc

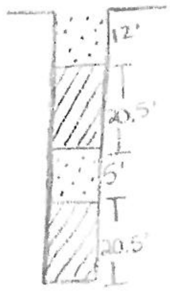
$= 10.4 \text{ lbs./ft.}$

$\therefore 46 \text{ ft.} \times \frac{10.4 \text{ lbs.}}{\text{ft.}} = 478.4 \text{ lbs.}$

$\text{lbs./ft.} = 0.34(6)^2(1.25)$ EMULSION = ρ = 1.25 g/cc

$= 15.3 \text{ lbs./ft.}$

$\therefore 46 \text{ ft.} \times \frac{15.3 \text{ lbs.}}{\text{ft.}} = 703.8 \text{ lbs.}$



Bench Height = 55'
Subdrilling = 3'
Total Length = 58'

$\phi = 6"$ SL = 12"

6" ⟹ 58' − 12' = 46' − 5' = 41

$lbs/ft. = 0.34 \times De^2 \times d$

$lbs./ft. = 0.34(6)^2(.85)$
$= 10.4$ lbs./ft.

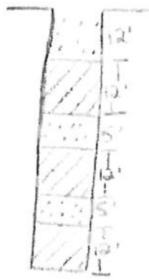
ANFO = ρ = 0.85 g/cc

$\therefore$ 41 ft. × $\frac{10.4 \text{ lbs.}}{\text{ft.}}$ = 426.4 lbs.

$lbs./ft. = 0.34(6)^2(1.25)$
$= 15.3$ lbs./ft.

EMULSION = ρ = 1.25 g/cc

$\therefore$ 41 ft. × $\frac{15.3 \text{ lbs.}}{\text{ft.}}$ = 627.3 lbs.



Bench Height = 55'

Subdrilling = 3'

Total Height = 58'

Explosive column

6" => 58' - 12' = 46' - 10' = 36'

$$\text{lbs./ft.} = 0.34 \times Dc^2 \times d$$

$$\text{lbs./ft.} = 0.34(6)^2(.85)$$

$$= 10.4 \text{ lbs./ft.}$$

$$\therefore 36 \text{ ft.} \times \frac{10.4 \text{ lbs.}}{\text{ft.}} = 374.4 \text{ lbs.}$$

$$\text{lbs./ft.} = 0.34(6)^2(1.25)$$

$$= 15.3 \text{ lbs./ft.}$$

$$\therefore 36 \text{ ft.} \times \frac{15.3 \text{ lbs.}}{\text{ft.}} = 550.8 \text{ lbs.}$$

Bench Height = 55'
Subdrilling = 3'
Total Length = 58'

ϕ = 5" SL = 10'

Explosive column

5" => 58' - 10' = 48'

$$\text{lbs./ft.} = 0.34 \times Dc^2 \times d$$

$$\text{lbs./ft.} = 0.34(5)^2(.85) = 7.23 \text{ lbs./ft.}$$

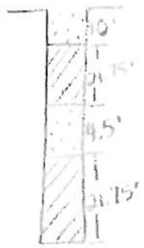
ANFO = ρ = 0.85 g/cc

$$\therefore 48 \text{ ft.} \times \frac{7.23 \text{ lbs.}}{\text{ft.}} = 347.04 \text{ lbs.}$$

$$\text{lbs./ft.} = 0.34(5)^2(1.25) = 10.63 \text{ lbs./ft.}$$

EMULSION = ρ = 1.25 g/cc

$$\therefore 48 \text{ ft.} \times \frac{10.63 \text{ lbs.}}{\text{ft.}} = 510.2 \text{ lbs.}$$



Bench Height = 55'

Subdrilling = 3'

Total Height = 58'

Explosive column

5" => 58' - 10' = 48' - 4.5' = 43.5'

lbs./ft. = $0.34 \times De^2 \times d$

lbs./ft. = $0.34(5)^2(.85)$

= 7.23 lbs./ft.

ANFO = ρ = 0.85 g/cc

∴ 43.5 ft. $\times \frac{7.23 \text{ lbs.}}{\text{ft.}}$ = 314.5 lbs.

lbs./ft. = $0.34(5)^2(1.25)$

= 10.63 lbs./ft.

EMULSION = ρ = 1.25 g/cc

∴ 43.5 ft. $\times \frac{10.63 \text{ lbs.}}{\text{ft.}}$ = 462.4 lbs.

Bench Height = 55'

Subdrilling = 3'

Total Length = 58'

Explosive column

5" => 58' − 10' = 48' − 9' = 39'

$\text{lbs./ft.} = 0.34 \times De^2 \times d$

$\text{lbs./ft.} = 0.34(5)^2(.85)$
$= 7.23 \text{ lbs./ft.}$

ANFO = ρ = 0.85 g/cc

$\therefore 39 \text{ ft.} \times \dfrac{7.23 \text{ lbs.}}{\text{ft.}} = 282 \text{ lbs.}$

$\text{lbs./ft.} = 0.34(5)^2(1.25)$
$= 10.63 \text{ lbs./ft.}$

EMULSION = ρ = 1.25 g/cc

$\therefore 39 \text{ ft.} \times \dfrac{10.63 \text{ lbs.}}{\text{ft.}} = 414.6 \text{ lbs.}$

Bench Height = 55'
Subdrilling = 3'
Total Length = 58'

Explosive column

4" => 58' - 8' = 50'

$$\text{lbs./ft} = 0.34 \times De^2 \times d$$

$$\text{lbs./ft.} = 0.34(4)^2(.85)$$

$$= 4.62 \text{ lbs./ft}$$

ANFO = ρ = 0.85 g/cc

$$\therefore 50 \text{ ft.} \times \frac{4.62 \text{ lbs.}}{\text{ft.}} = 231 \text{ lbs.}$$

$$\text{lbs./ft.} = 0.34(4)^2(1.25)$$

$$= 6.8 \text{ lbs./ft.}$$

EMULSION = ρ = 1.25 g/cc

$$\therefore 50 \text{ ft.} \times \frac{6.8 \text{ lbs.}}{\text{ft.}} = 340 \text{ lbs.}$$

Bench Height = 55'
Subdrilling = 3'
Total Length = 58'

Explosive column

4" => 58' - 8' = 50' - 4' = 46'

lbs./ft = 0.34 × De² × d

lbs./ft. = 0.34 $(4)^2$ (.85)

= 4.62 lbs./ft.

ANFO = ρ = 0.85 g/cc

∴ 46 ft. × $\frac{4.62 \text{ lbs.}}{\text{ft.}}$ = 212.5 lbs.

lbs./ft. = 0.34 $(4)^2$ (1.25)

= 6.8 lbs./ft.

EMULSION = ρ = 1.25 g/cc

∴ 46 ft. × $\frac{6.8 \text{ lbs.}}{\text{ft.}}$ = 312.8 lbs.

Bench Height = 55'
Subdrilling = 3'
Total Length = 58'

Explosive column
4'' => 58' - 8' = 50' - 8' = 42'

lbs./ft. = 0.34 x De² x d

lbs./ft. = 0.34(4)²(.85)
= 4.62 lbs./ft.

ANFO = ρ = 0.85 g/cc

∴ 42 ft. x 4.62 lbs./ft. = 194.04 lbs.

lbs./ft. = 0.34(4)²(1.25)
= 6.8 lbs./ft.

EMULSION = ρ = 1.25 g/cc

∴ 42 ft. x 6.8 lbs./ft. = 285.6 lbs.