



# An Overview of the 'Drift' Tunnel Blast Design Software

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# Introduction

Fall of ground continues to be a significant source of accidents and injuries in the US underground hardrock mining industry.

Poor blasting practices which result in excessive overbreak and excessive wall rock damage are a possible contributing factor in many of these accidents.



# Project Goal

As part of an effort to reduce accidents and injuries caused by fall of ground, the National Institute of Occupational Safety and Health (NIOSH) is developing the “Drift” tunnel blast design software.

The intent is to provide an easy to use tunnel blast design software package that will allow engineers to study the complex interactions of blast design factors such as hole diameter, explosive properties, and careful perimeter blasting strategies, with the overall goal of reducing unnecessary overbreak and wall rock damage.



# Major Program Features

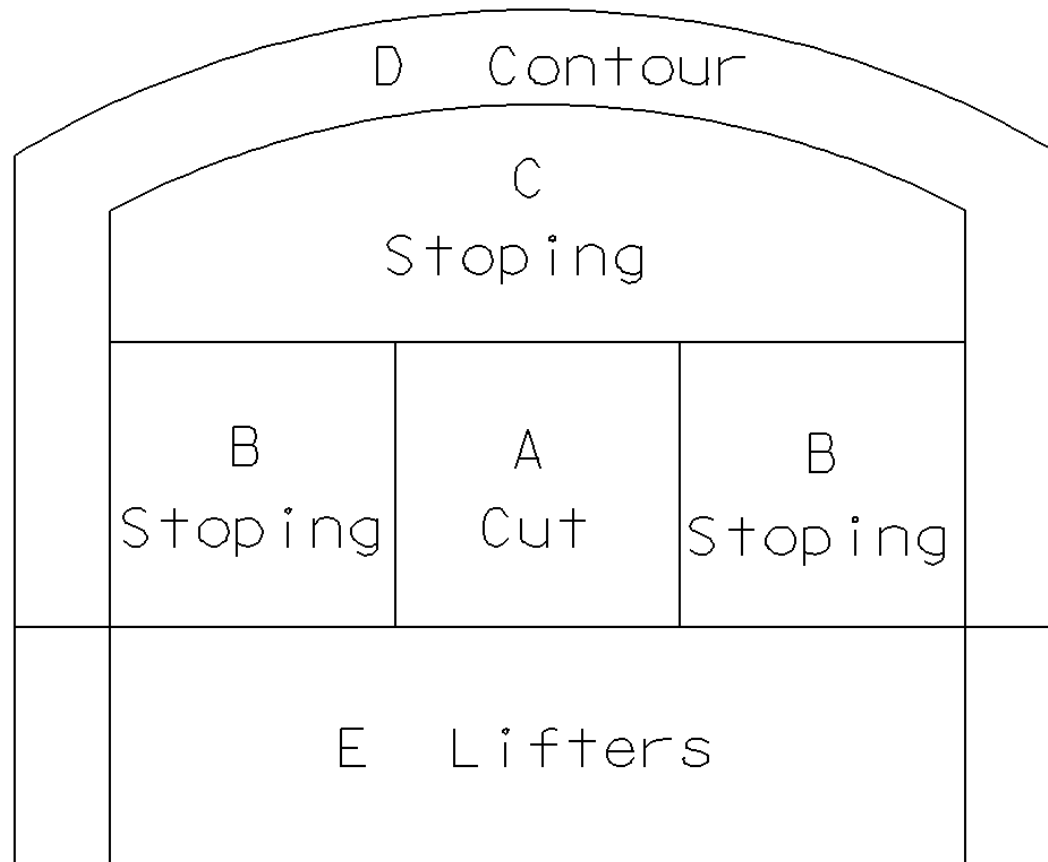
Major features of the program include:

- The ability to generate a blast pattern automatically using the “Holmberg” blast design algorithm (Swedish algorithm).
- The ability to display a blast pattern graphically.
- The ability to interactively enter or edit a blast pattern using the graphical user interface.
- The ability to study wall rock damage using several alternative equations for predicting Peak Particle Velocities.
- Report generation.



# The Holmberg Blast Design Algorithm

With the Holmberg Algorithm, the face is divided into five regions, each requiring slight variations in the calculation of the appropriate hole burden and spacing.





# The Holmberg Blast Design Algorithm

The Holmberg Algorithm makes use of the Langefors/Kihlström equation for calculating the burden required in the various blast pattern sections:

$$B = 0.9 \left[ \frac{l S_{\text{anfo}}}{c f (S/B)} \right]^{1/2} \quad (\text{m})$$

Where:

$B$  is the burden (m)

$l$  is the explosive charge concentration (kg/m)

$S_{\text{anfo}}$  is the explosive weight strength relative to ANFO

$c$  is the rock constant (usually 0.4 or 0.5)

$f$  is the fixation factor, (adjustment for the blasting direction)

$(S/B)$  is the spacing to burden ratio



# The Holmberg Blast Design Algorithm

When using the Holmberg Algorithm program input includes:

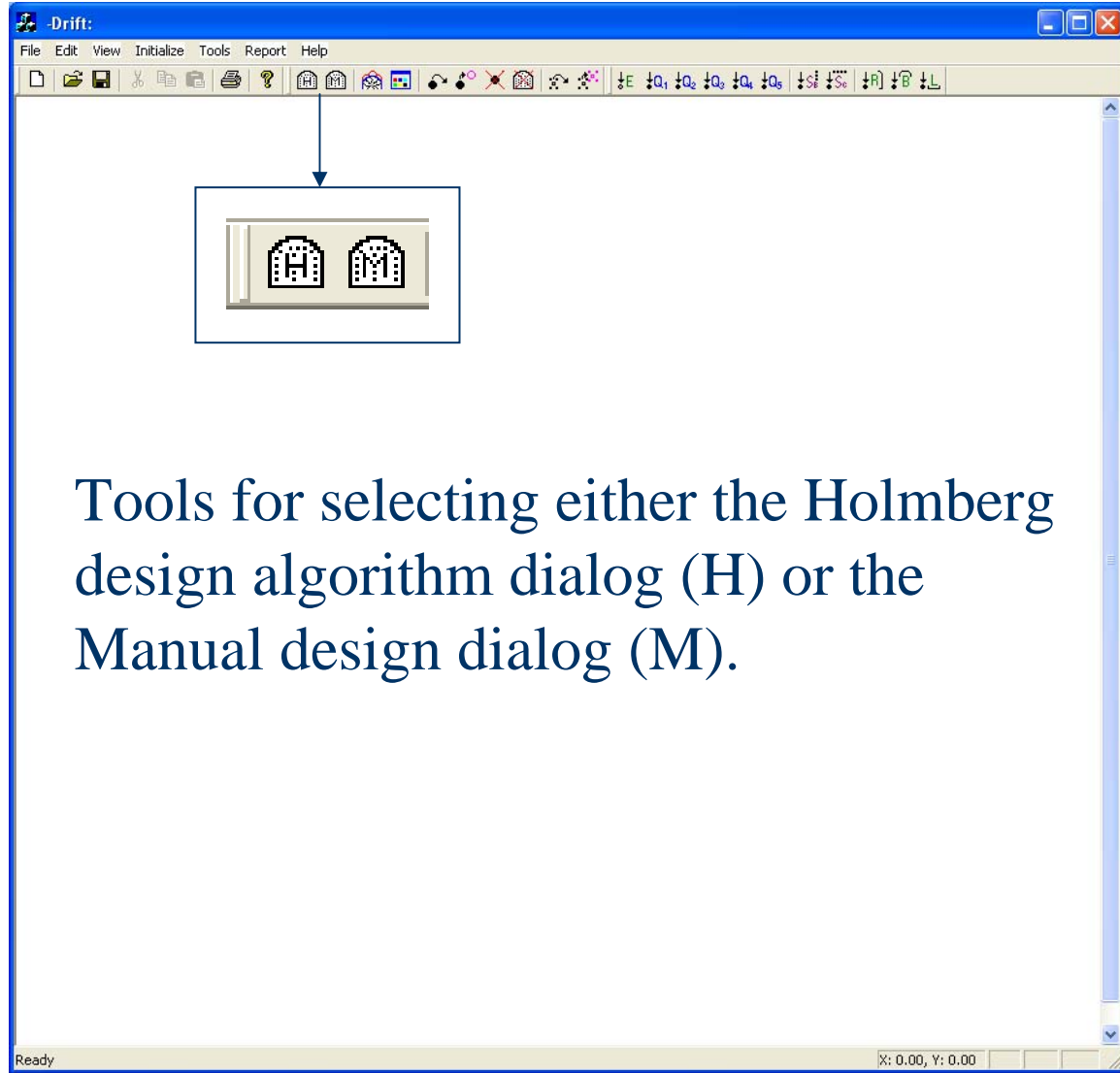
- Tunnel geometry
- Blast hole diameters
- Explosives properties
- Charging strategies (i.e. smoothwall blasting)

And program output includes:

- Hole locations
- Amounts of the various explosives required



# Initial Blank Document



Tools for selecting either the Holmberg design algorithm dialog (H) or the Manual design dialog (M).



# Project Definition

**Blast Design Parameters for the Holmberg Algorithm**

Charging and Explosives Properties	Rock Properties
Project	Hole and Cut Properties

Project name:

Unit system:

OK Cancel Apply



# Rock Constant

The image shows a software dialog box titled "Blast Design Parameters for the Holmberg Algorithm". The dialog has a blue title bar with a close button (X) in the top right corner. It contains several tabs: "Project", "Drift/Tunnel Geometry", "Hole and Cut Properties", "Charging and Explosives Properties", and "Rock Properties". The "Rock Properties" tab is currently selected. Inside this tab, there is a label "Rock constant:" followed by a text input field containing the value "0.4". At the bottom of the dialog, there are three buttons: "OK", "Cancel", and "Apply".



# Tunnel Geometry

**Blast Design Parameters for the Holmberg Algorithm**

Charging and Explosives Properties		Rock Properties
Project	Drift/Tunnel Geometry	Hole and Cut Properties

Drift Measurements

Width (m):

Abutment height (m):

Arch height (m):

OK Cancel Apply



# Hole and Cut Properties

**Blast Design Parameters for the Holmberg Algorithm**

Charging and Explosives Properties		Rock Properties
Project	Drift/Tunnel Geometry	Hole and Cut Properties
<b>Cut properties</b>		
Empty hole diameter (m):	<input type="text" value="0.102"/>	
Number of empty holes:	<input type="text" value="1"/>	
<b>Hole properties</b>		
Hole length (m):	<input type="text" value="3"/>	
Hole diameter (m):	<input type="text" value="0.045"/>	
Angular deviation (m/m):	<input type="text" value="0.01"/>	
Collar deviation (m):	<input type="text" value="0.02"/>	
Lookout angle (degrees):	<input type="text" value="3"/>	
<input checked="" type="checkbox"/> Snap perimeter holes to drift boundaries		

OK Cancel Apply



# Charging and Explosives Properties

**Blast Design Parameters for the Holmberg Algorithm**

Project | Drift/Tunnel Geometry | Hole and Cut Properties

Charging and Explosives Properties | Rock Properties

Define charging methods

Charging by: Charge by cartridge explosives only

Smoothwall back

Smoothwall ribs

Define explosives properties

Number	Type	Available	Cartridge diameter (m)	Cartridge length (m)	Density (kg/cu m)	Weight strength
1	Cartridge	<input checked="" type="checkbox"/>	0.025	0.6	1200	1.09
2	Cartridge	<input checked="" type="checkbox"/>	0.032	0.6	1200	1.09
3	Cartridge	<input checked="" type="checkbox"/>	0.038	0.6	1200	1.09

OK Cancel Apply





# Charging and Explosives Properties

**Blast Design Parameters For Manual Editing**

Project | Drift/Tunnel Geometry | Hole and Cut Properties | Explosives Properties

Define explosives properties

Number	Type	Available	Cartridge diameter (m)	Cartridge length (m)	Density (kg/cu m)	Weight strength
1	Cartridge	<input checked="" type="checkbox"/>	0.025	0.6	1200	1.09
2	Bulk	<input checked="" type="checkbox"/>	0.032	0.6	1200	1.09
3	Cord	<input checked="" type="checkbox"/>	0.038	0.6	1200	1.09

Define charging for holes in blast pattern section:

Quad. 1   Quad. 2   Quad. 3   Quad. 4   Quad. 5

Stope B   Stope C   Back   Ribs   Lifters

OK   Cancel   Apply



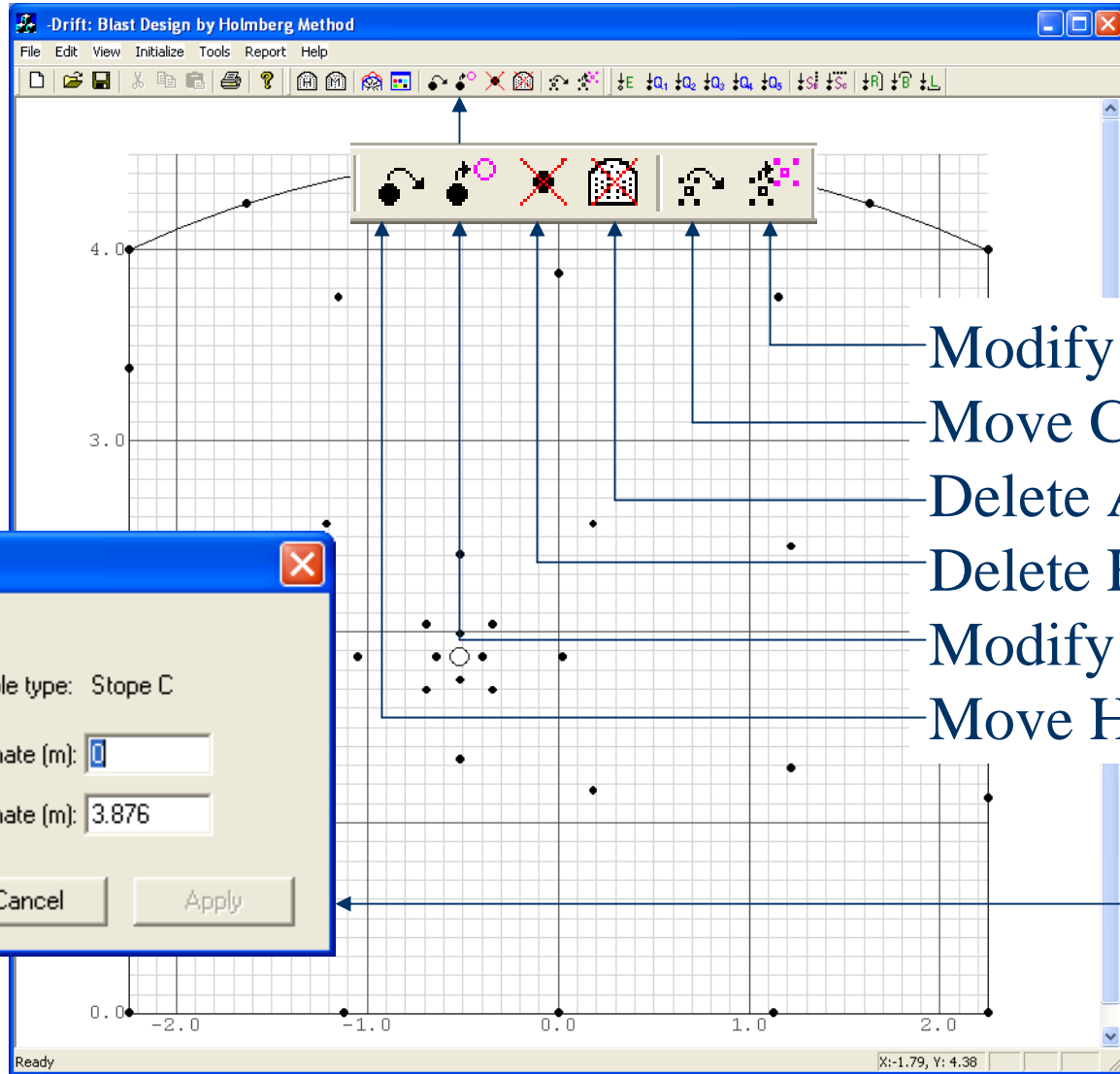
# Pattern Section Charging

**Define Charging for Back Holes** ✕

	Bottom charge	Column charge	Top charge
Explosive number:	<input type="text" value="1"/>	<input type="text" value="2"/>	<input type="text" value="1"/>
Specified charged length (m):	<input type="text" value="0.5"/>	<input type="text" value="2.5"/>	<input type="text" value="0"/>
<hr/>			
Number of cartridges:	1.000	4.000	
Actual charged length (m):	0.600	2.400	0.000
<hr/>			
Hole length (m):	3.218		
Total charged length (m):	3.000		
<hr/>			
<input type="button" value="Apply This Charging To All Pattern Sections"/>			
<hr/>			
<input type="button" value="OK"/>	<input type="button" value="Cancel"/>		



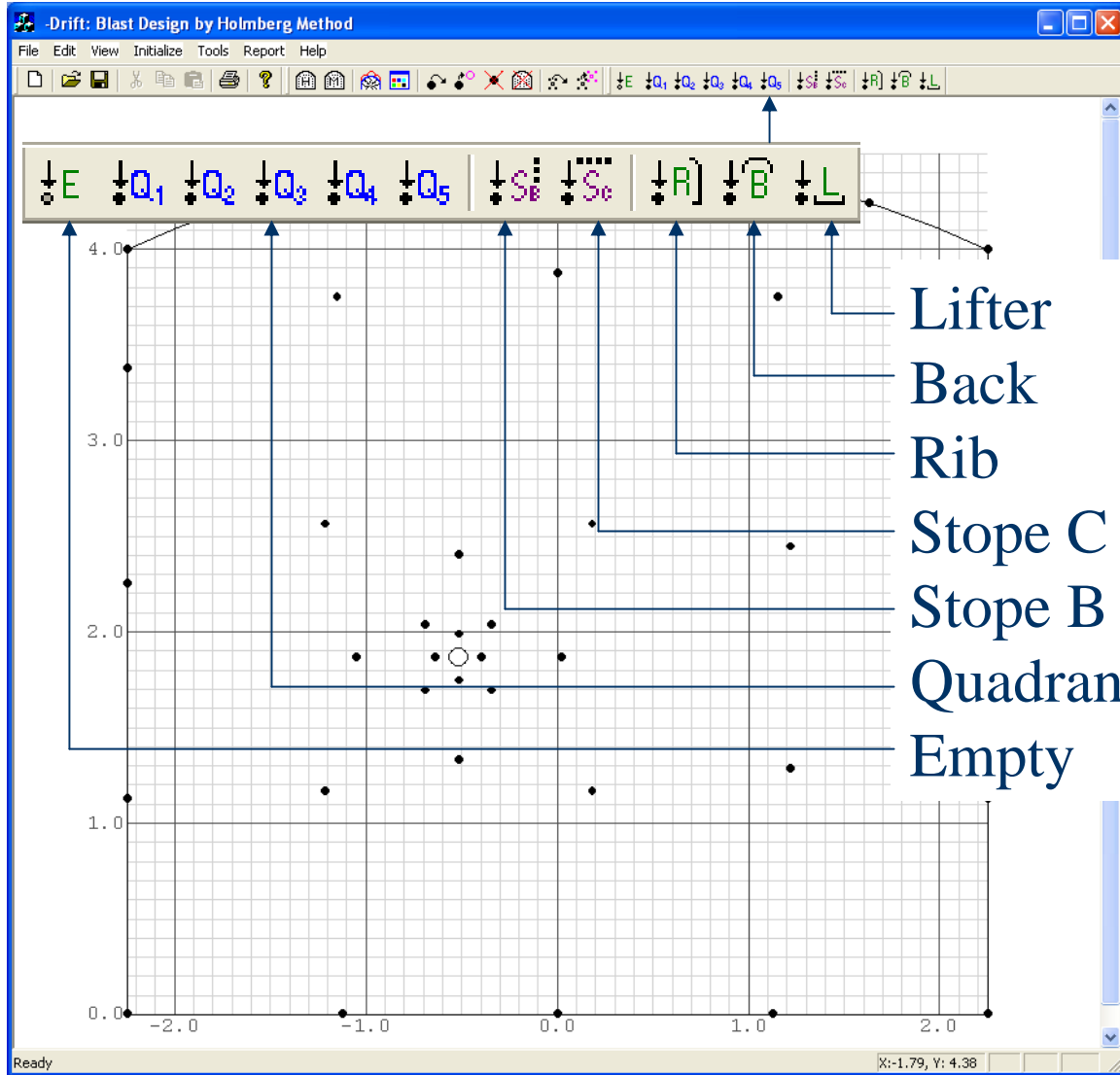
# Blast Design Editing



- Modify Cut
- Move Cut
- Delete All Holes
- Delete Hole
- Modify Hole
- Move Hole



# Insert Hole Into Blast Design





# Configure Display

The screenshot shows a software window titled "-Drift: Blast Design by Holmberg Method". The main area is a 2D plot with a grid. The x-axis ranges from -2.0 to 2.0, and the y-axis ranges from 0.0 to 4.0. A curved line represents a drift outline, and several points are scattered on the grid. A dialog box titled "Display Attributes for Screen Graphics" is open, showing settings for various graphic elements. The "Colors" tab is selected. The settings are as follows:

Element	Line weight	Color
Drift outline	1 pts	Black
Major grid lines	1 pts	Dark Gray
Minor grid lines	1 pts	Light Gray
Empty hole perimeter	1 pts	Black
Empty hole fill		White
Charged hole perimeter	1 pts	Black
Charged hole fill		Black
Highlight		Magenta



# Blast Damage Distances

The following variables are used in the Peak Particle Velocity (PPV) calculations:

$k$  = constant (0.7 for brittle hard rock)

$a$  = constant (0.7 for brittle hard rock)

$b$  = constant (1.4 for brittle hard rock)

$q$  = charge concentration (kg/m)

$r$  = perpendicular (radial) distance from the charge to the measurement point (m)

$s$  = the starting x coordinate of the charge (m)

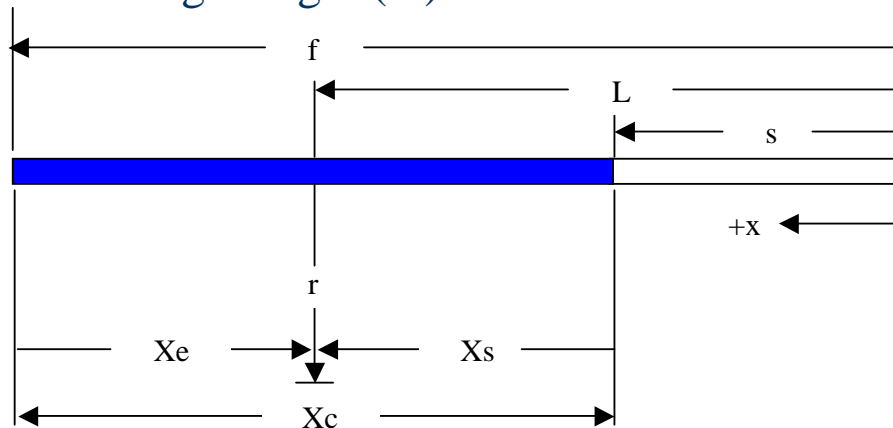
$f$  = the ending x coordinate of the charge (m)

$L$  = the x coordinate of  $r$  (m)

$X_e = f - L$  = distance from the end of the charge to the measurement point (m)

$X_s = L - s$  = distance from the start of the charge to the measurement point (m)

$X_c = f - s$  = the charge length (m)





# PPV by Rbar Method

The following can be used to calculate the radial PPV value using the Rbar integration method:

$$H_e = (X_e^2 + r^2)^{1/2}$$

$$H_s = (X_s^2 + r^2)^{1/2}$$

$$V = k \cdot (q \cdot X_c)^a$$

$$P_e = X_e \cdot H_e + r^2 \cdot \ln(X_e + H_e)$$

$$P_s = -X_s \cdot H_s + r^2 \cdot \ln(-X_s + H_s)$$

$$R_{bar} = (P_e - P_s) / (2 \cdot X_c)$$

$$\mathbf{PPV = V / (R_{bar})^b \text{ (m/s)}}$$



# PPV by the Inverse Rbar Method

The following can be used to calculate the radial PPV value using the inverse Rbar integration method:

$$H_e = (X_e^2 + r^2)^{1/2}$$

$$H_s = (X_s^2 + r^2)^{1/2}$$

$$V = k * (q * X_c)^a$$

$$P_e = \ln( X_e + H_e)$$

$$P_s = \ln(-X_s + H_s )$$

$$IRbar = (P_e - P_s)/X_c$$

$$PPV = V * (IRbar)^b \text{ (m/s)}$$



# PPV by the Weighted Rbar Method

The following can be used to calculate the radial PPV value using the weighted Rbar sum method:

$n$  = the number of segments to divide the charge into

$D = Xc/n$  = the segment length

$X_1 = D/2.0$  = the X coordinate of the center of first charge segment

$X_{i=2..n} = X_{i-1} + D$  = the X coordinate of the center of charge segments 2 to n

$$H_i = (Xs - X_i)^2 + r^2$$

$$R1 = \sum_{i=1}^n H_i^{(1-b)/2}$$

$$R2 = \sum_{i=1}^n H_i^{(-b)/2}$$

$$V = k*(q*Xc)^a$$

$$PPV = V/(R1/R2)^b \text{ (m/s)}$$



# PPV by Holmberg/Persson Equation

The following flawed definite integral can be used to calculate the radial PPV values using the Holmberg/Persson method with  $b$  set to  $\frac{1}{2} a$  :

$$\text{PPV} = k * [q/r]^a * [ \text{ATAN}( (f-L)/r ) + \text{ATAN}( (L-s)/r ) ]^a \quad (\text{m/s})$$



# PPV by Holmberg/Persson Sum Method

The following can be used to calculate the radial PPV value using the HP sum method:

$n$  = the number of segments to divide the charge into

$D = Xc/n$  = the segment length

$X_1 = D/2.0$  = the X coordinate of the center of first charge segment

$X_{i=2..n} = X_{i-1} + D$  = the X coordinate of the center of charge segments 2 to n

$$PPV = k * \left( q * D * \sum_{i=1}^n ((X_s - X_i)^2 + r^2)^{-b/2a} \right)^a$$



# Blast Damage Distances

**Drift: Blast Design by Holmberg Method**

File Edit View Initialize Tools Report Help

Peak particle velocity (mm/sec): 1000

Calculate blast damage at hole charge length midpoint

Distance from hole bottom at which to calculate blast damage distance (m): 1.6

Blast damage calculation method: Holmberg/Person integration

**Blast Damage Zone Calculation Method and Parameters**

Blast damage calculation properties

Blast damage graphic properties

Line weight

5 pts		<input checked="" type="checkbox"/> Plot blast damage circles around back holes
5 pts		<input type="checkbox"/> Plot blast damage circles around rib holes
5 pts		<input type="checkbox"/> Plot blast damage circles around lifter holes
5 pts		<input type="checkbox"/> Plot blast damage circles around stope B holes
5 pts		<input checked="" type="checkbox"/> Plot blast damage circles around stope C holes
5 pts		<input type="checkbox"/> Plot blast damage circles around last quadrangle holes

Plot blast damage envelope around drift

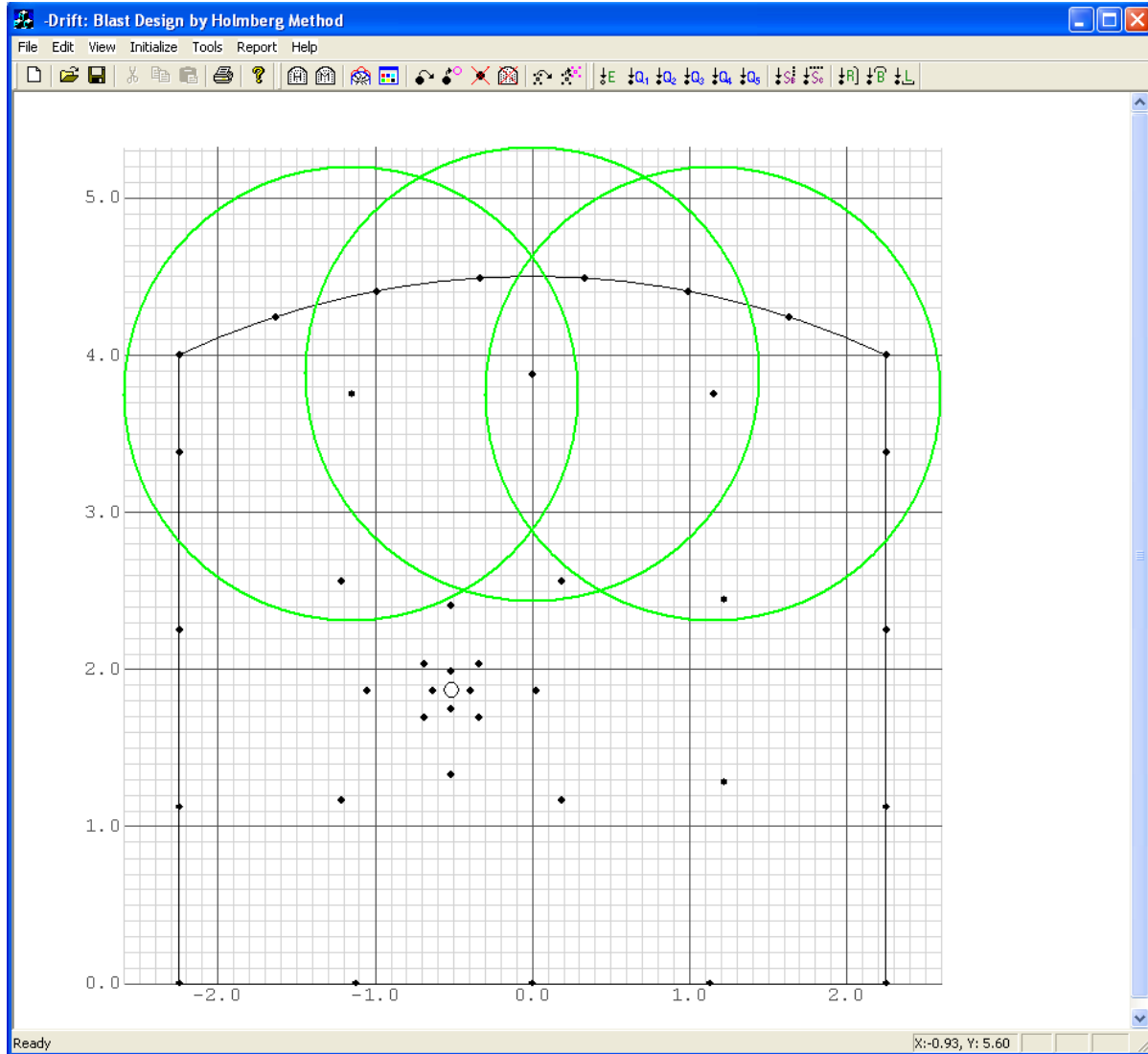
Clip blast damage circles to drift boundaries

OK Cancel Apply

Ready X:-1.79, Y: 4.38

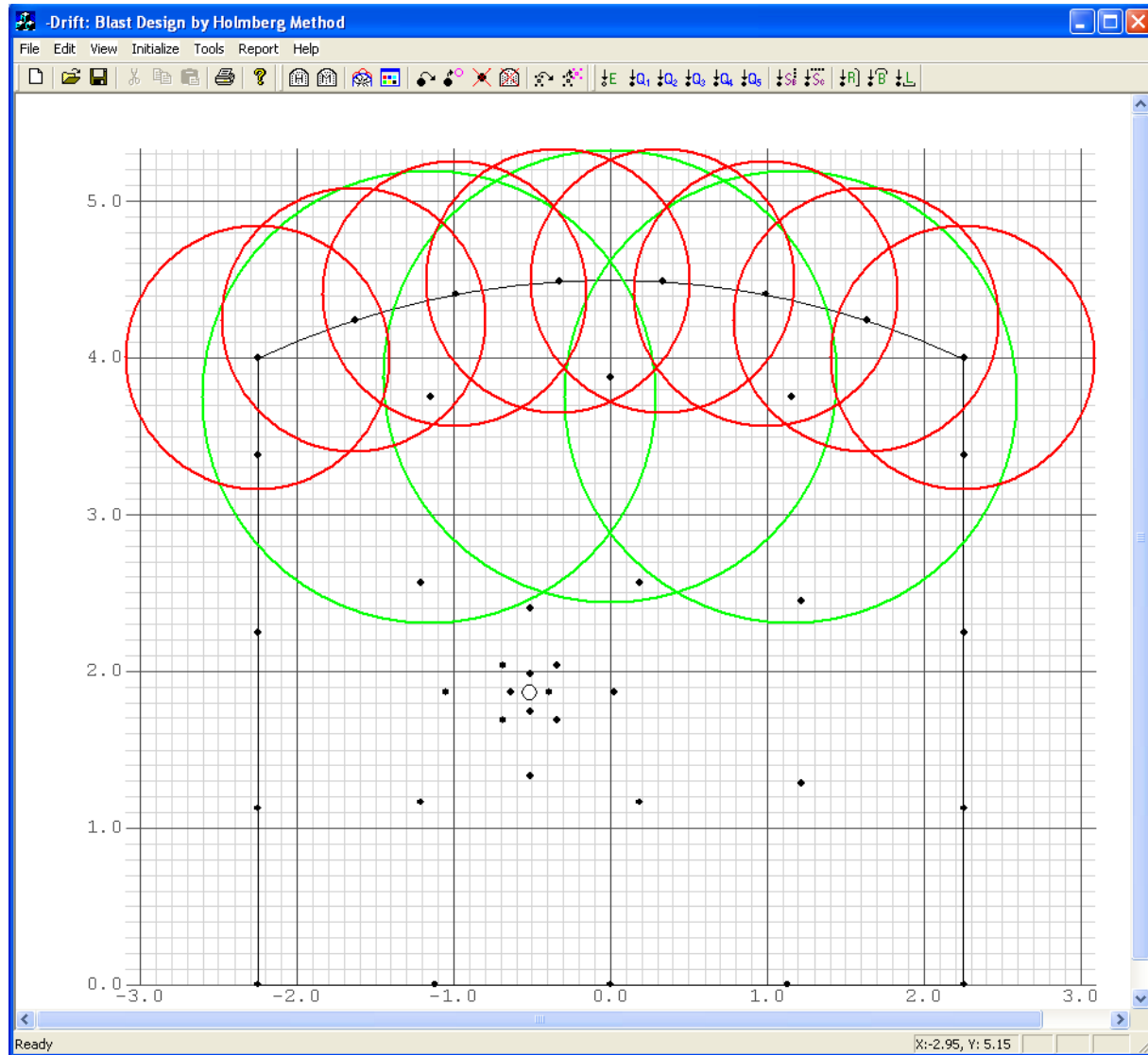


# Blast Damage Distances



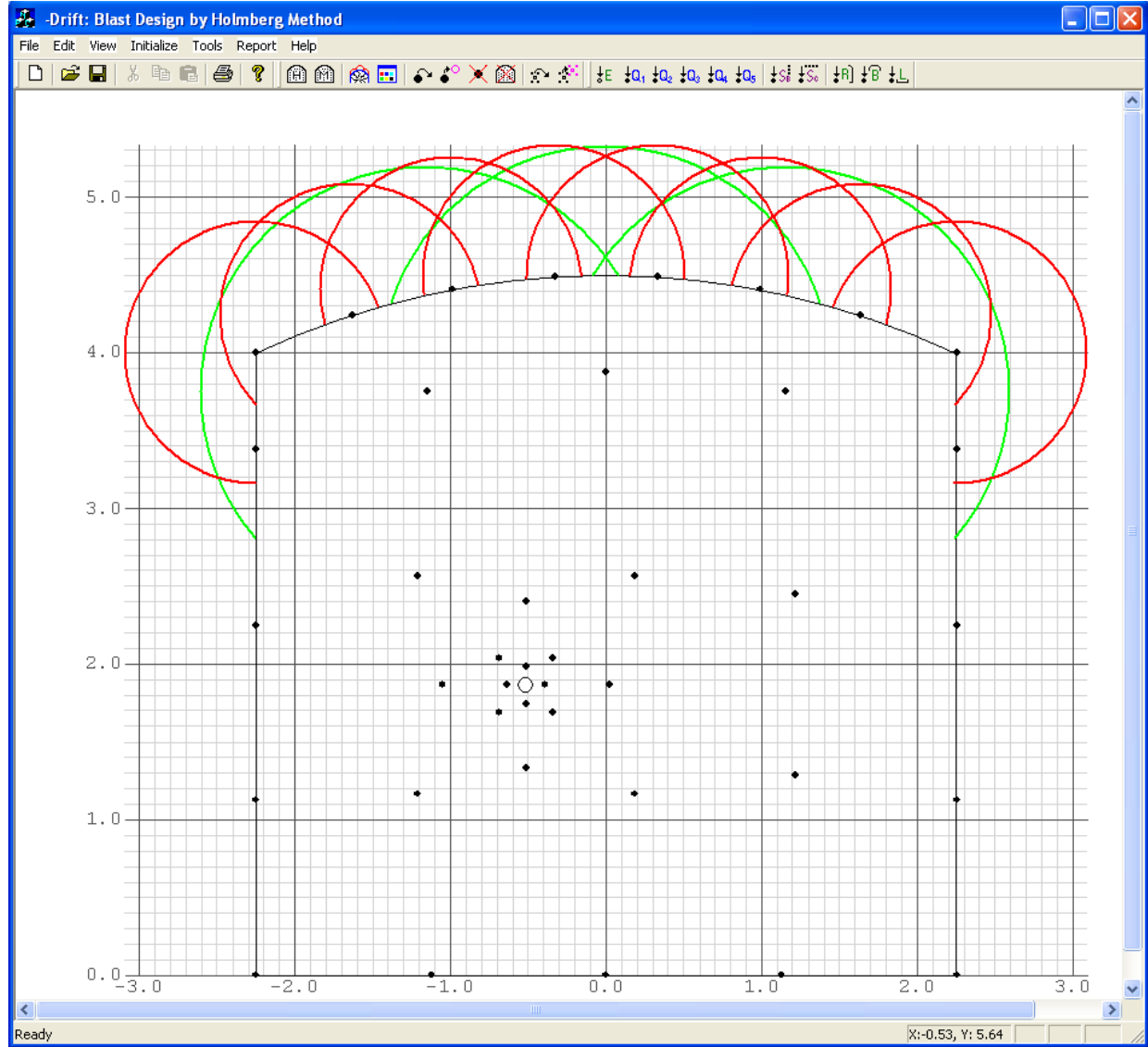


# Blast Damage Distances





# Blast Damage Distances





# Summary Report (partial)

## Drift

Area: 19.515 (sq. m)  
Arch Radius: 5.313 (m)  
Arch Sweep Angle: 0.875 (radians)  
Volume of Rock Broken: 59.664 (cu. m)

## Drilling and Charging Summary

Hole Type	No. of Holes	per hole				Charge (kg)	Charge Total (kg)
		Cart. 25 (mm)	Cart. 32 (mm)	Cart. 38 (mm)	Charge (kg)		
A: Empty Holes	1						
A: 1st Quad:	4	4.5			1.59	6.36	
A: 2nd Quad:	4		4.5		2.61	10.42	
A: 3rd Quad:	4			4.5	3.67	14.70	
A: 4th Quad:	4			4.5	3.67	14.70	
B: Stopping:	2		2.0	2.5	3.20	6.40	
C: Stopping:	3		2.0	2.5	3.20	9.60	
D: Contour Back:	8	5.5			1.94	15.55	
D: Contour Ribs:	6		2.0	2.5	3.20	19.20	
E: Lifters:	5		2.0	2.5	3.20	16.00	
Totals:	41	62.0	50.0	76.0		112.92	

Specific drilling: 2.21 (m/cu. m)  
Specific charge: 1.89 (kg/cu. m)



# Conclusions

An easy to use tunnel blast design software package that will allow engineers to study the complex interactions of various blast design factors is being developed by NIOSH.

The overall goal of the project is to provide engineers with a tool that can be used to improve tunnel blast designs and reduce unnecessary overbreak and wall rock damage.

It is believed that improved blasting practices will reduce accidents caused by fall of ground, a significant cause of accidents and injuries in underground mining.

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# Questions?

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# Questions??