PREVIOUS
BLAST EFFECTS COMPUTER
PAPERS

BECv1

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THE DDESB BLAST EFFECTS COMPUTER -- FROM CIRCULAR SLIDE RULE TO EXCEL SPREADSHEET

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ABSTRACT

In 1978, the Department of Defense Explosives Safety Board (DDESB) released through the Government Printing Office a circular slide rule called the "Blast Effects Computer (BEC)." This slide rule was designed to solve problems and provide data related to the expected damage to various possible targets due to blast effects resulting from an explosion of ammunition or explosives stored above ground or in earth-covered magazines. In the 20 years that have elapsed since the Blast Effects Computer was designed, the state of the art in predicting both blast effects and damage has progressed significantly. However, the need for a Blast Effects Computer has not disappeared in the intervening years; if anything, this need has increased. As a result, the DDESB has prepared an update to the circular slide rule. This update is in the form of an EXCEL spreadsheet template which will run on any computer upon which EXCEL 5.0 (or later) is installed. Two versions of the BEC spreadsheet template are in preparation. Version 1.0 (BECV1) is a simple computerization of the existing circular slide rule with an update to the airblast pressure-distance model and the elimination of the directional effect correction factor. Version 2.0 (BECV2) is to include additional information on the airblast produced by cased munitions as well as updates to the various damage models. This paper will describe BECV1 and demonstrate its use through several illustrative examples.

BACKGROUND

The Department of Defense Explosives Safety Board (DDESB) has had an active role in producing various types of explosion effects computation aids[1]. In 1978, these culminated in the release of a circular slide rule called the "Blast Effects Computer (BEC)[2]." This slide rule was designed to solve problems and provide data related to the expected damage to various potential targets due to blast effects resulting from an explosion of ammunition or explosives stored above ground or in earth-covered magazines.

The following outline provides a brief description of the circular slide rule and its capabilities:

SIDE 1--BOMBS AND PROJECTILES

Input:
- open revetments/earth-covered magazine
- number and type of weapon
  - MK 82/M117/M437A2 (175 mm shell)/M107 (155 mm shell)
- or total NEW of weapons

Output
- effective yield (pounds of TNT)
  - NEW x FANO Factor x TNT equivalence x 1.2 directional factor
- pressure-distance
- positive phase duration-distance
- dynamic overpressure impulse-distance
- Intraline distance
  - barricaded/unbarricaded
- Inhabited building distance
- Public highway and passenger railroad distance
- frame house damage
    - threshold/50% damage/total/glass breakage
- parked aircraft damage
  - threshold/not flyable/total
- truck damage (crushing)
  - threshold/total
- truck damage (overturning)
  - threshold/total
  - personnel injuries (tertiary effects)
  - body
    - 99%/50%/threshold
  - head
    - 99%/50%/threshold
- personnel injuries (primary effects)
  - lung damage
    - 99%/90%/50%/10%/threshold
  - ear damage
    - 90%/50%/10%/threshold

SIDE 2--BULK EXPLOSIVES AND LIGHT CASED MUNITIONS

Input:
- open revetments/earth-covered magazine
- type of explosive
  - H-6/Tritonal/Comp B/TNT
- total NEW

Output

- effective yield (pounds of TNT)
  - NEW x cover factor x TNT equivalence x 1.2 directional factor
- cube root multiples of effective TNT yield
- pressure-distance
- positive phase duration-distance
- dynamic overpressure impulse-distance
- Intraline distance
  - barricaded/unbarricaded
- Inhabited building distance
- Public highway and passenger railroad distance
- frame house damage
  - threshold/50% damage/total/glass breakage
- parked aircraft damage
  - threshold/not flyable/total
- truck damage (crushing)
  - threshold/total
- truck damage (overturning)
  - threshold/total
- personnel injuries (tertiary effects)
  - body
    - 99%/50%/threshold
  - head
    - 99%/50%/threshold
- personnel injuries (primary effects)
  - lung damage
    - 99%/90%/50%/10%/threshold
  - ear damage
    - 90%/50%/10%/threshold

MODEL DESCRIPTION

The algorithms that were developed for the original BEC are described in detail in Reference 1. These same algorithms have been implemented in this new version with two exceptions. In the first instance, a directional factor of 1.2 that was applied to the explosive weight to account for the maximum directional effect observed in test data has been eliminated. The other change involves the equations used for predicting hemispherical airblast. Instead of the original Kingery[3] work used in Reference 1, revised Kingery equations[4] have been implemented.

HARDWARE/SOFTWARE REQUIREMENTS

The new BEC (hereafter called BECV1) is written as a Microsoft EXCEL spreadsheet template. In order to use BECV1, EXCEL (Version 5.0 or higher) must already be installed on your computer. Simply copy BECV1 to your hard drive. To use the program, either double click on the BECV1 filename or launch EXCEL and then use the ***OPEN*** command located in the FILE menu. Because it is written as an EXCEL template, BECV1 will run on any machine that can run EXCEL. Currently, it has been tested on both Macintosh and WINTEL machines. The MAC was using EXCEL Version 5.0. The WINTEL machines (using Windows 95) were running EXCEL 97 (part of the Microsoft Office 97 suite) and EXCEL 5.0 (part of Office 95).

When you open a template, EXCEL opens a copy of the template for you to use. Changes you make affect only the copy; the original template is preserved. The copy of the template is a new, unsaved document with a temporary name based on the template name. For example, when you open the Blast Effects Computer template named BECV1.XLT, Microsoft EXCEL gives the copy the temporary name BECV11. When you save or close the copy, the Save As dialog box appears. You can type a new name for the document or accept the temporary name suggested by EXCEL.[5] Many of the calculations that are performed by BECV1 are written as EXCEL macros in Visual Basic. The remainder are simply formulae inserted into the appropriate cells of the spreadsheet.

HOW TO USE

When the template is opened, the user is first presented with a splash screen giving the version number of the software and the provenance of the program. After this acknowledgment, the spreadsheet may need to be resized to fit onto the screen of your monitor. The ***ZOOM*** function may need to be used to view the full width of the spreadsheet. For example, on certain systems, a 65% reduction was needed to view the full spreadsheet on a 15" monitor.

Once the spreadsheet is properly sized, the user must select from the various input options. There are seven input dialog boxes. Each of these is described below.

Box 1: SELECT **TYPE OF MAGAZINE**
There are two choices: open revetments and earth-covered magazines

Box 2: SELECT **TYPE OF WEAPON**
There are five choices: MK 82 bomb, M117 bomb, M437A2 (175 mm shell), M107 (155 mm shell), Bulk/Light Cased

Box 3: SELECT **TYPE OF EXPLOSIVE**
There are ten choices: TNT, H6, Tritonal, Comp B, Amatol, Comp A, Comp C-4, Explosive D, HBX, Minol

Box 4: SELECT **NUMBER OF WEAPONS** OR **TOTAL NEW**
If you have Selected a weapon in Box 2, then select the entry "Number of Weapons" in Box 4. If you have selected Bulk/Light Cased in Box 2, then the entry "**TOTAL NEW**" should be selected in Box 4.

Box 5: The title for Box 5 is dependent upon what is selected for Box 4.
If in Box 4, **NUMBER OF WEAPONS** is selected, then the number must be entered in Box 5. If in Box 4, **TOTAL NEW** is selected, then this amount (in pounds) is entered in Box 5.

Box 6 SELECT **RANGE**
Enter the range (in feet) at which you wish to compute the effects

Box 7: SELECT FOR **BACK CALCULATION**
This will be discussed in more detail in the following section.

BACK CALCULATION

Explosion effects depend upon the inter-relationship of three sets of data: (1) the net explosive weight (NEW), (2) the range, and (3) the type of explosion effect (time of arrival, positive phase duration, etc.). If two of these are known, then the third can be computed. When the NEW and range are known, BECV1 computes the effect. It is often useful to reverse this process; i.e., to enter the range and the effect and compute the NEW or to enter the effect and the NEW and compute the range. These latter two combinations constitute the BACK CALCULATION feature of the BEC.

When it is planned to use this feature either the range or the NEW must be entered at the top of the spreadsheet. An arbitrary value for the other input variable must also be used--any number greater than zero.

When the other inputs are complete, use the pull-down ***BACK CALCULATION*** menu to select the combination of variables that is desired. When your selection is made, a dialog box will appear requesting you to enter the value of the third variable. After the value is entered, click ***OK***. The value of the third variable will appear in the input strip at the top of the sheet. Also, all of the other outputs of the BEC are displayed for this combination. The following combinations are available for back calculation:

BACK CALCULATION OPTIONS

INPUT 1	INPUT 2	OUTPUT
Time of Arrival	NEW	Range
Time of Arrival	Range	NEW
Over-pressure	NEW	Range
Over-pressure	Range	NEW
Reflected Pressure	NEW	Range
Reflected Pressure	Range	NEW
Positive Phase Duration	NEW	Range
Positive Phase Duration	Range	NEW
Positve Phase Impulse	NEW	Range
Positve Phase Impulse	Range	NEW
Reflected Impulse	NEW	Range
Reflected Impulse	Range	NEW
Shock Front Velocity	NEW	Range
Shock Front Velocity	Range	NEW
Dynamic Over-pressure Impulse	NEW	Range
Dynamic Over-pressure Impulse	Range	NEW
Intraline Distance (Barricaded)	Range	NEW
Intraline Distance (Unbarricaded)	Range	NEW
Inhabited Building Distance	Range	NEW
Public Highway Distance	Range	NEW

Because of the algorithm used for BACK CALCULATIONS, functions with multiple values are not be identified. This could be a problem when the effect is Positive Phase Duration or

Positive Phase Impulse. For these two functions, the BACK CALCULATION cannot detect solutions that occur at relatively small scaled ranges (distance divided by cube root of NEW). The Positive Phase Duration Back Calculation provides answers for ranges beyond 6 $ft/lb^{1/3}$; Positive Phase Impulse Back Calculation provides answers beyond ranges of 4 $ft/lb^{1/3}$.

CAVEATS

The algorithm for computing the case factor for cased munitions is based on the FANO formula given in Reference 1. As in Reference 1, a factor of 0.8 is used to account for the effect of earth cover on earth-covered magazine storage. The distances for intraline (barricaded and unbarricaded), inhabited building, and public highway are intended as guides for the user to indicate approximate distances. To estimate explosives safety siting distances, use the following options:

Open Revetments
Bulk/Light Cased
TNT
Total NEW.

DOD 6055.9-STD[6] should be consulted for compliance purposes BECV1 is designed to aid in making explosive-safety quantity-distance (ESQD) and damage estimates for relatively simple situations. It is not designed to replace other consequence models or the more detailed analyses available through the use of advanced computer codes such as AUTODYN, CTH, or DYNA.

EXAMPLES

The following examples are intended to illustrate how to solve various problems using BECV1.

Example 1. (Refer to Figure 1)

Statement of problem: A total of 250,000 lbs net explosive weight (NEW) of unspecified light cased munitions are stacked in an open revetment. What are the airblast effects at 2000 ft? At what distance from the stack will undesirable effects result in the event of an accidental explosion? The results obtained for this problem apply to the explosives safety siting of 250,000 lbs NEW in an aboveground magazine.

Inputs:

Type of Magazine	***Open Revetment***
Type of Weapon	***Bulk/Light Cased***
Type of Explosive	***TNT***
Number of Weapons or Total NEW	***Total New***
Total NEW (lbs)	***250,000***
Range (ft)	***2,000***

Outputs:

The output (shown in Figure 1.) indicates that the effective yield of the 250,000 lbs (NEW) of TNT in light cased munitions is 250,000 lbs. The Kingery section of the output gives the airblast effects at 2,000 ft (for example, the over-pressure is 1.59 psi at 2,000 ft). Below the Kingery section of the output - unbarricaded (K18) and barricaded (K9) intraline distances (ILDs) [1134 ft and 567 ft, respectively], inhabited building distance (IBD) for blast effects only [3150 ft], and public traffic route (PTR) distance for blast effects only [1890 ft] are given. The remainder of the output section supplies the damage effects (undesirable effects) resulting from an (accidental) detonation of 250,000 lbs of TNT in an open revetment. Example results from Figure 1. include: 50% glass breakage at 1259.4 ft (using an overpressure criterion of 3 psi), Not flyable parked aircraft damage at 1680.6 ft (using an overpressure criterion of 2 psi), Total truck damage from crushing at 367.3 ft (using an overpressure criterion of 30 psi), Threshold for personnel injury (tertiary) for the head at 747.5 ft (using an impulse criterion of 54 psi-ms), and 10% probability of personnel injury (primary) ear damage at 1320.4 ft (using an overpressure criterion 2.8 psi. Note that the distance for a 99% probability of ear damage (and the criterion) are not included in the spreadsheet.

FIGURE 1. EXAMPLE 1--INPUT AND OUTPUT

INPUT SECTION:

Select Type of Magazine	Select Type of Weapon	Select Type of Explosive	Select Number of Weapons or Total NEW	Enter Total NEW (lbs)	Enter Range (ft)
Open Revetments	Bulk/Light Cased	TNT	Total NEW	250,000.0	2,000.0

OUTPUT SECTION: **Select for Back Calculation** Over-Pressure -> NEW

Total NEW (lb)	250,000.0
NEW per weapon (lb)	1
TNT Equivalence	1.00
Effective Yield (lbs of TNT)	250,000.0

KINGERY SECTION

Time of Arrival at Range (msec)	1394.81
Over-Pressure at Range (psi)	1.59
Reflected Press. at Range (psi)	3.31
Positive Phase Duration at Range (msec)	250.05
Positive Phase Impulse at Range (psi-msec)	174.6
Reflected Impulse at Range (psi-msec)	326.7
Shock Front Velocity at Range (kft/sec)	1.167

Dynamic Overpressure Impulse at Range (psi-msec)	5.5				
	Unbarricaded	Barricaded			
Intraline Distance (ft)	1134	567			
Inhabited Building Distance (ft)	3150	(Blast only)			
Public Highway and Passenger Road dist. (ft)	1890	(Blast only)			
	Glass Breakage	Threshold	50%	Total	
Frame House Damage (ft)	7976.3	3134.7	1259.4	907.4	
criteria (psi)	(0.25)	(0.9)	(3)	(5)	
	Threshold	Not Flyable	Total		
Parked Aircraft Damage (ft)	2881.9	1680.6	1042.1		
criteria (psi)	(1)	(2)	(4)		
Truck Damage	Threshold	Total			
Crushing (ft)	814.5	367.3			
criteria (psi)	(6)	(30)			
Overturning (ft)	599.8	357.0			
criteria (psi-msec)	(90)	(300)			
Personnel Injuries (Tertiary)	Threshold	50%	99%		
Body (ft)	619.1	553.1	519.9		
criteria (psi-ms)	(83.6)	(108.6)	(125.4)		
Head (ft)	747.5	648.8	583.3		
criteria (psi-ms)	(54)	(75)	(96)		
Personnel Injuries (Primary)	Threshold	10%	50%	90%	99%
Lung Damage (ft)	510.9	467.5	433.7	392.3	370.4
criteria (psi)	(14.5)	(17.5)	(20.5)	(25.5)	(29)
Ear Damage (ft)	1471.6	1320.4	791.9	556.1	n/a
criteria (psi)	(2.4)	(2.8)	(6.3)	(12.2)	n/a

Example 2. (Refer to Figure 2)

Statement of problem: A total of 290,000 lbs NEW of H6 loaded in MK80 series bombs are stacked in an open revetment. What are the airblast effects at 2500 ft? At what distance from the stack will undesirable effects result in case of an accidental explosion?

Inputs:

Type of Magazine	***Open Revetment***
Type of Weapon	***MK82 (500 lb Bomb)***
Type of Explosive	***H6***
Number of Weapons or Total NEW	***Total New***
Total NEW (lbs)	***290,000***
Range (ft)	***2,500***

Outputs:

The output (shown in Figure 2.) indicates that the effective yield of the 290,000 lbs (NEW) of H6 in MK 82 Bombs is 251,813 lbs. This result includes a 1.25 TNT equivalence factor for H6 and a 0.69466 casing factor for the MK82 bomb. The Kingery section of the output gives the airblast effects at 2,500 ft (for example, the over-pressure is 1.20 psi at 2,500 ft). Below the Kingery section of the output - unbarricaded (K18) and barricaded (K9) ILDs (1137 ft and 568 ft, respectively), IBD for blast effects only (3157 ft), and PTR distance for blast effects only (1894 ft) are given for the effective yield (251,813 lb), not the 290,000 lbs NEW. The remainder of the output section supplies the damage effects (undesirable effects) resulting from an (accidental) detonation of 290,000 lbs of H6 in an open revetment. Example results from Figure 2. include: Threshold glass breakage at 3142.2 ft (using an overpressure criterion of 0.9 psi), Not flyable parked aircraft damage at 1684.6 ft (using an overpressure criterion of 2 psi), Total truck damage from crushing at 368.1 ft (using an overpressure criterion of 30 psi), 99% probability of personnel injury (tertiary) for the head at 585.3 ft (using an impulse criterion of 96 psi-ms), and 50% probability of personnel injury (primary) ear damage at 793.8 ft (using an overpressure criterion 6.3 psi). Note that the distance for a 99% probability of ear damage (and the criterion) are not included in the spreadsheet.

FIGURE 2. EXAMPLE 2--INPUT AND OUTPUT

INPUT SECTION:

Select Type of Magazine	Select Type of Weapon	Select Type of Explosive	Select Number of Weapons or Total NEW	Enter Total NEW (lbs)	Enter Range (ft)
Open Revetments	M82 (500 lb Bomb)	H6	Total NEW	290,000.0	2,500.0

OUTPUT SECTION: **Select for Back Calculation** Over-Pressure -> NEW

Total NEW (lb)	290,000.0
NEW per weapon (lb)	192
TNT Equivalence	1.25
Effective Yield (lbs of TNT)	251,813.0

KINGERY SECTION

Time of Arrival at Range (msec)	1822.04
Over-Pressure at Range (psi)	1.20
Reflected Press. at Range (psi)	2.47
Positive Phase Duration at Range (msec)	268.68
Positive Phase Impulse at Range (psi-msec)	141.4
Reflected Impulse at Range (psi-msec)	259.8
Shock Front Velocity at Range (kft/sec)	1.155

Dynamic Overpressure Impulse at Range (psi-msec)	3.3				
	Unbarricaded	Barricaded			
Intraline Distance (ft)	1137	568			
Inhabited Building Distance (ft)	3157	(Blast only)			
Public Highway and Passenger Road dist. (ft)	1894	(Blast only)			
	Glass Breakage	Threshold	50%	Total	
Frame House Damage (ft)	7995.5	3142.2	1262.4	909.5	
criteria (psi)	(0.25)	(0.9)	(3)	(5)	
	Threshold	Not Flyable	Total		
Parked Aircraft Damage (ft)	2888.8	1684.6	1044.6		
criteria (psi)	(1)	(2)	(4)		
Truck Damage	Threshold	Total			
Crushing (ft)	816.5	368.1			
criteria (psi)	(6)	(30)			
Overturning (ft)	601.8	358.2			
criteria (psi-msec)	(90)	(300)			
Personnel Injuries (Tertiary)	Threshold	50%	99%		
Body (ft)	621.3	555.0	521.7		
criteria (psi-ms)	(83.6)	(108.6)	(125.4)		
Head (ft)	750.1	651.0	585.3		
criteria (psi-ms)	(54)	(75)	(96)		
Personnel Injuries (Primary)	Threshold	10%	50%	90%	99%
Lung Damage (ft)	512.1	468.7	434.7	393.3	371.3
criteria (psi)	(14.5)	(17.5)	(20.5)	(25.5)	(29)
Ear Damage (ft)	1475.1	1323.6	793.8	557.5	n/a
criteria (psi)	(2.4)	(2.8)	(6.3)	(12.2)	n/a

Example 3. (Refer to Figure 3)

Statement of problem: A total of 500,000 lbs NEW of unspecified light cased munitions are stacked in an earth-covered magazine. What are the airblast effects at 3000 ft? At what distance from the stack will undesirable effects result in case of an accidental explosion?

Inputs:

Type of Magazine	***Earth-Covered Magazine***
Type of Weapon	***Bulk/Light Cased***
Type of Explosive	***TNT***
Number of Weapons or Total NEW	***Total New***
Total NEW (lbs)	***500,000***
Range (ft)	***3,000***

Outputs:

The output (shown in Figure 3) indicates that the effective yield of the 500,000 lbs (NEW) of bulk/light cased is 400,000 lbs. This result includes a 0.8 airblast attenuation factor for the magazine earth cover. The Kingery section of the output gives the airblast effects at 3,000 ft (for example, the over-pressure is 1.16 psi at 3,000 ft). Below the Kingery section of the output - unbarricaded (K18) and barricaded (K9) ILDs (1326 ft and 663 ft, respectively), IBD for blast effects only (3684 ft), and PTR distance for blast effects only (2210 ft) are given for the effective yield (400,000 lb), not the 500,000 lbs NEW. The remainder of the output section supplies the damage effects (undesirable effects) resulting from an (accidental) detonation of 500,000 lbs of TNT in an earth-covered magazine. Example results from Figure 3. include: Glass breakage at 9329.1 ft (using an overpressure criterion of 0.25 psi), Total parked aircraft damage at 1218.8 ft (using an overpressure criterion of 4 psi), Threshold truck damage from overturning at 750.5 ft (using an impulse criterion of 90 psi-ms, 99% probability of personnel injury (tertiary) for the body at 650.5 ft (using an impulse criterion of 125.4 psi-ms), and 50% probability of personnel injury (primary) lung damage at 507.2 ft (using an overpressure criterion 20.5 psi. Note that the distance for a 99% probability of ear damage (and the criterion) are not included in the spreadsheet.

FIGURE 3. EXAMPLE 3--INPUT AND OUTPUT

INPUT SECTION:

Select Type of Magazine	Select Type of Weapon	Select Type of Explosive	Select Number of Weapons or Total NEW	Enter Total NEW (lbs)	Enter Range (ft)
Earth Covered Magazine	Bulk/Light Cased	TNT	Total NEW	500,000.0	3,000.0

OUTPUT SECTION: **Select for Back Calculation** Over-Pressure -> NEW

Total NEW (lb)	500,000.0
NEW per weapon (lb)	1
TNT Equivalence	1.00
Effective Yield (lbs of TNT)	400,000.0

KINGERY SECTION

Time of Arrival at Range (msec)	2197.51
Over-Pressure at Range (psi)	1.16
Reflected Press. at Range (psi)	2.38
Positive Phase Duration at Range (msec)	316.20
Positive Phase Impulse at Range (psi-msec)	160.6
Reflected Impulse at Range (psi-msec)	294.4
Shock Front Velocity at Range (kft/sec)	1.154

Dynamic Overpressure Impulse at Range (psi-msec)	3.6				
	Unbarricaded	Barricaded			
Intraline Distance (ft)	1326	663			
Inhabited Building Distance (ft)	3684	(Blast only)			
Public Highway and Passenger Road dist. (ft)	2210	(Blast only)			
	Glass Breakage	Threshold	50%	Total	
Frame House Damage (ft)	9329.1	3666.3	1473.0	1061.3	
criteria (psi)	(0.25)	(0.9)	(3)	(5)	
	Threshold	Not Flyable	Total		
Parked Aircraft Damage (ft)	3370.7	1965.6	1218.8		
criteria (psi)	(1)	(2)	(4)		
Truck Damage	Threshold	Total			
Crushing (ft)	952.7	429.6			
criteria (psi)	(6)	(30)			
Overturning (ft)	750.5	446.7			
criteria (psi-msec)	(90)	(300)			
Personnel Injuries (Tertiary)	Threshold	50%	99%		
Body (ft)	774.7	692.1	650.5		
criteria (psi-ms)	(83.6)	(108.6)	(125.4)		
Head (ft)	935.3	811.8	729.9		
criteria (psi-ms)	(54)	(75)	(96)		
Personnel Injuries (Primary)	Threshold	10%	50%	90%	99%
Lung Damage (ft)	597.5	546.8	507.2	458.9	433.2
criteria (psi)	(14.5)	(17.5)	(20.5)	(25.5)	(29)
Ear Damage (ft)	1721.2	1544.4	926.2	650.4	n/a
criteria (psi)	(2.4)	(2.8)	(6.3)	(12.2)	n/a

Example 4 (Refer to Figure 4)

Statement of Problem. The boundary of an installation (or of an area that requires IBD level of protection) is 2300 ft from an aboveground magazine. What NEW of MK82 bombs (H6) may be stored in the magazine to give the equivalent IBD level of protection? What is the effective yield for the bombs? This is a back calculation problem.

Inputs:

Type of Magazine	***Open Revetment***
Type of Weapon	***MK82 (500 lb Bomb)***
Type of Explosive	***H6***
Number of Weapons or Total NEW	***Total New***
Total NEW (lbs)	***Not an input***
Range (ft)	***2,300***
Back Calculation	***Inhabited Build. Dist. -> NEW***
Back Calculation IBD (ft)	***2,300***

Outputs:

The output (shown in Figure 4.) indicates that the NEW of MK 82 bombs (H6) that may be stored in an aboveground magazine which result in equivalent IBD level of protection at 2300 ft is 166,857.9 lbs with an effective yield of 144,886.2 lbs. The IBD distance is determined by the equation: $2{,}300 = 2.42*(144{,}886.2)^{0.577}$. The effective yield takes into account the TNT equivalence of 1.25 for H6 and the bomb case factor of 0.69466. As with the other examples above, the output in Figure 4. gives the airblast effects (based on the Kingery curves) at the distance specified (2,300 ft) and gives expected ESQD and damage effects for the effective yield (144,886.2 lbs). It should be noted, however, that for compliance with the requirements of DOD 6055.9-STD, the actual NEW rather than the effective yield must be used for establishing ESQD such as IBD, PTR, and ILD.

FIGURE 4. EXAMPLE 4--INPUT AND OUTPUT

INPUT SECTION:

Select Type of Magazine	Select Type of Weapon	Select Type of Explosive	Select Number of Weapons or Total NEW	Enter Total NEW (lbs)	Enter Range (ft)
Open Revetments	M82 (500 lb Bomb)	H6	Total NEW	166,857.9	2,300.0

OUTPUT SECTION: **Select for Back Calculation** Inhabited Build. Dist. -> NEW

Total NEW (lb)	166,857.9
NEW per weapon (lb)	192
TNT Equivalence	1.25
Effective Yield (lbs of TNT)	144,886.2

KINGERY SECTION

Time of Arrival at Range (msec)	1706.12
Over-Pressure at Range (psi)	1.06
Reflected Press. at Range (psi)	2.16
Positive Phase Duration at Range (msec)	230.40
Positive Phase Impulse at Range (psi-msec)	106.7
Reflected Impulse at Range (psi-msec)	194.5
Shock Front Velocity at Range (kft/sec)	1.150

Dynamic Overpressure Impulse at Range (psi-msec)	2.2				
	Unbarricaded	Barricaded			
Intraline Distance (ft)	945	473			
Inhabited Building Distance (ft)	2300	(Blast only)			
Public Highway and Passenger Road dist. (ft)	1380	(Blast only)			
	Glass Breakage	Threshold	50%	Total	
Frame House Damage (ft)	6650.1	2613.5	1050.0	756.5	
criteria (psi)	(0.25)	(0.9)	(3)	(5)	
	Threshold	Not Flyable	Total		
Parked Aircraft Damage (ft)	2402.7	1401.2	868.8		
criteria (psi)	(1)	(2)	(4)		
Truck Damage	Threshold	Total			
Crushing (ft)	679.1	306.2			
criteria (psi)	(6)	(30)			
Overturning (ft)	462.4	275.2			
criteria (psi-msec)	(90)	(300)			
Personnel Injuries (Tertiary)	Threshold	50%	99%		
Body (ft)	477.3	426.4	400.8		
criteria (psi-ms)	(83.6)	(108.6)	(125.4)		
Head (ft)	576.2	500.1	449.7		
criteria (psi-ms)	(54)	(75)	(96)		
Personnel Injuries (Primary)	Threshold	10%	50%	90%	99%
Lung Damage (ft)	425.9	389.8	361.6	327.1	308.8
criteria (psi)	(14.5)	(17.5)	(20.5)	(25.5)	(29)
Ear Damage (ft)	1226.9	1100.9	660.2	463.7	n/a
criteria (psi)	(2.4)	(2.8)	(6.3)	(12.2)	n/a

Example 5

Statement of Problem. An accidental detonation occurs at an exposed site. Various types of damage are observed at positions around the accident location. Based on the observed damage at these locations, estimates are made of the airblast levels required to produce these effects. Using these airblast levels and the ranges at which they occurred, estimate the size of the event.

Case 1:	Range=600 feet, Reflected Pressure= 2.5 psi
Case 2:	Range=800 feet, Over Pressure= 0.8 psi
Case 3:	Range=1250 feet, Positive Phase Impulse = 13 psi-ms.

Inputs:

Type of Magazine	***Open Revetment***
Type of Weapon	***Bulk/Light Cased***
Type of Explosive	***TNT***
Number of Weapons or Total NEW	***Total New***
Total NEW (lbs)	***Not an input***

Case 1:

Range (ft)	***600***
Back Calculation	***Reflected Pressure. -> NEW***
Back Calculation Reflected Pressure (psi))	***2.5***

Case 2:

Range (ft)	***800***
Back Calculation	***Over- Pressure. -> NEW***
Back Calculation Reflected Pressure (psi))	***0.8***

Case 3

Range (ft)	***1250***
Back Calculation	***Positive Phase Impulse. -> NEW***
Back Calculation Reflected Pressure (psi))	***13***

Output:

Case 1:	**NEW = 3,582.6 pounds**
Case 2:	**NEW = 3,141.0 pounds**
Case 3:	**NEW = 2,464.0 pounds**

Thus, the estimates for the size of the event are 3,583 pounds, 3,141 pounds and 2,464 pounds of TNT, with an average value of 3,063 pounds.

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5. Microsoft EXCEL User’s Guide 1, 1992.

6. DOD-6055.9-STD, DOD AMMUNITION AND EXPLOSIVES SAFETY STANDARDS, 11 August 1997.

BECv2

"The New DDESB Blast Effects Computer," Swisdak, Michael M., and Ward, Jerry M., Minutes of the 28th DoD Explosives Safety Seminar, August 1998.

THE NEW DDESB BLAST EFFECTS COMPUTER

prepared by

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ABSTRACT

In 1978, the Department of Defense Explosives Safety Board (DDESB) released a circular slide rule called the “Blast Effects Computer (BEC).” This slide rule was designed to solve problems and provide data related to the expected damage to various possible targets due to blast effects resulting from an explosion of ammunition or explosives stored above ground or in earth-covered magazines. In the 20 years that have elapsed since the slide rule was designed, the state of the art in predicting both blast effects and damage has progressed significantly. However, the need for a prediction tool has not disappeared in the intervening years; if anything, this need has increased. As a result, the DDESB has prepared an update to the circular slide rule. This update is in the form of an EXCEL spreadsheet template that will run on any computer upon which EXCEL Version 5.0 (or later) is installed. Version 1.0 of the new blast effects computer (BECV1) was a simple computerization of the circular slide rule with an update to the Kingery airblast pressure-distance model and other minor corrections to the algorithms. This version was released in November 1997. Version 2.0 is now available. Incorporated into this version are updated airblast information for earth-covered magazines and hardened aircraft shelters. Also included are updated airblast algorithms for MK 82, MK 83, MK 84 and M117 bombs, as well as M107 155-mm projectiles. This paper describes BECV2, discusses some of the new algorithms that are used, and demonstrates the computer’s use through illustrative examples.

28TH DoD EXPLOSIVES SAFETY SEMINAR
AUGUST 1998

BACKGROUND

The Department of Defense Explosives Safety Board (DDESB) has had an active role in producing various types of explosion effects computation aids[1]. In 1978, these culminated in the release of a circular slide rule called the "Blast Effects Computer (BEC)[2]." This slide rule was designed to solve problems and provide data related to the expected damage to various potential targets due to blast effects resulting from an explosion of ammunition or explosives stored above ground or in earth-covered magazines.

The following outline provides a brief description of the circular slide rule and its capabilities:

SIDE 1--BOMBS AND PROJECTILES

Input:

- open revetments/earth-covered magazine
- number and type of weapon
- MK 82/M117/M437A2 (175 mm shell)/M107 (155 mm shell)
- or total NEW of weapons

Output:

- effective yield (pounds of TNT)
  - NEW x FANO Factor x TNT equivalence x 1.2 directional factor
- pressure-distance
- positive phase duration-distance
- dynamic overpressure impulse-distance
- Intraline distance
  - barricaded/unbarricaded
- Inhabited building distance
- Public highway and passenger railroad distance
- frame house damage
  - threshold/50% damage/total/glass breakage
- parked aircraft damage
  - threshold/not flyable/total
- truck damage (crushing)
  - threshold/total
- truck damage (overturning)
  - threshold/total
- personnel injuries (tertiary effects)
  - body
    - 99%/50%/threshold
  - head
    - 99%/50%/threshold
- personnel injuries (primary effects)
  - lung damage
    - 99%/90%/50%/10%/threshold
  - ear damage
    - 90%/50%/10%/threshold

SIDE 2--BULK EXPLOSIVES AND LIGHT CASED MUNITIONS

Input:

- open revetments/earth-covered magazine
- type of explosive
  - H-6/Tritonal/Comp B/TNT
- total NEW

Output:

- effective yield (pounds of TNT)
  - NEW x cover factor x TNT equivalence x 1.2 directional factor
- cube root multiples of effective TNT yield
- pressure-distance
- positive phase duration-distance
- dynamic overpressure impulse-distance
- Intraline distance
  - barricaded/unbarricaded
- Inhabited building distance
- Public highway and passenger railroad distance
- frame house damage
  - threshold/50% damage/total/glass breakage
- parked aircraft damage
  - threshold/not flyable/total
- truck damage (crushing)
  - threshold/total
- truck damage (overturning)
  - threshold/total
- personnel injuries (tertiary effects)
  - body
    - 99%/50%/threshold
  - head
    - 99%/50%/threshold
- personnel injuries (primary effects)
  - lung damage
    - 99%/90%/50%/10%/threshold
  - ear damage
    - 90%/50%/10%/threshold

The algorithms that were developed for the original BEC are described in detail in Reference 1. Last year, these algorithms were implemented into an EXCEL spreadsheet template. This version, referred to as BECV1, was released in November 1997 and was reported at PARARI 97, the Australian safety seminar[3].

The organization and use of this original version of the EXCEL template was described in detail at that seminar and will not be repeated here. This paper will describe the changes that have been implemented into Version 2.0.

VERSION 2.0 GENERAL INFORMATION

Version 2.0 incorporates several significant improvements into the models. In version 2.0, in addition to open stacks of ammunition, the user can choose earth-covered magazines (front, side, and rear directions) and hardened aircraft shelters (front, side, and rear). In version 1.0, the airblast estimates for all cased weapons were very approximate—simply being based on a Kingery hemispherical TNT curves with a FANO-type correction for the case effect. In the latest version, the airblast estimates for cased weapons are tied to experimental results.

The choice of explosive fills has also been expanded in the new version. The list of potential explosives has been expanded from H-6, Tritonal, Composition B, and TNT to H-6, Tritonal, Composition B, TNT, Composition A3, Composition C4, Explosive D, HBX-1, HBX-3, Minol II, and ANFO.

The ***Back Calculation*** option provided in Version 1.0 has been removed and replaced by a built-in EXCEL tool, the ***Goal Seek*** option under the **Tools Menu**.

Version 2.0 is now available in both English and SI units. The English version is BECVE2; The SI version is BECVM2.

AIRBLAST PARAMETER ALGORITHMS

The combination of **Open Storage** under ***Select Type of Magazin***e and **Bulk/Light Cased** under ***Select Type of Weapon*** leads to the use of the simplified Kingery equations[4] to predict the airblast. The airblast predictions for all other situations are based on these equations as modified by experimental results. These modifications are in the form of algorithms that relate the yield of the weapon at a particular range to an equivalent hemispherical TNT weight. This TNT weight and the hemispherical airblast equations are then used to make the estimates of the airblast parameters.

Built into the BEC are functions which express the yield of each combination of Type of Storage, Type of Weapon, and Type of Explosive in terms of an equivalent hemispherical TNT weight. This equivalent TNT weight is the weight that is used to actually compute the airblast. For example, the actual Net Explosive Weight (NEW) of a MK 82 bomb is 192 pounds of Tritonal. The Equivalent Hemispherical TNT weight varies between 235 pounds and 374 pounds. The effect of this variable yield is to allow the BEC to accurately reproduce the airblast parameters that have been recorded at various distances for the various weapons and storage conditions.

The Earth-Covered Magazine (ECM) airblast is based on a refinement of the data presented in Reference 5. Specifically, the Reference 5 data have been extended to cover much smaller scaled distances. The empirical fits to these data are presented in Table 1.

TABLE 1. AIRBLAST COEFFICIENTS—EARTH-COVERED MAGAZINES

FUNCTION	RANGE	DIRECTION	A	B	C
PRESSURE	Z<=19	Front	3183.8	-2.7054	0.1118
(P)	Z>19		799.43	-2.1850	0.09419
	Z<=14	Side	110.37	-0.9700	-0.08852
	Z>14		70.711	-0.70889	-0.12311
	Z<=14	Rear	144.76	-1.4700	0.01605
	Z>14		89.157	-1.0867	-0.05778
IMPULSE	Z<=15	Front	64.386	-0.6274	-0.1276
($I/W^{1/3}$)	Z>15		54.038	-0.80719	-0.0385
	Z<=15	Side	11.500	0.1772	-0.2067
	Z>15		18.433	-0.19965	-0.13156
	Z<=15	Rear	10.339	-0.07546	-0.1473
	Z>15		10.291	-0.12798	-0.12788

FORM: P (or $I/W^{1/3}$) = $A*Z^{(B+C*ln(Z))}$

Z = Range/Weight $^{1/3}$ (ft/lb$^{1/3}$)

P in psi

W in pounds

I in psi-ms

The Hardened Aircraft Shelter (HAS) airblast is based on a new compilation of all of the available data. These curve fits are presented in Table 2. Similar data for positive impulse does not currently exist.

TABLE 2. AIRBLAST COEFFICIENTS—HARDENED AIRCRAFT SHELTER

FUNCTION	DIRECTION	A	B	C	D
PRESSURE	Front	1831.1	-5.9194	1.9455	-0.2439
(P)	Side	15.7179	0.0963	-0.25163	0.01076
	Rear	24.2617	-1.1910	0.36832	-0.09103

FORM: P = $A*Z^{[B+C*ln(Z)+D*(ln(Z))^2]}$

Z = Range/Weight $^{1/3}$ (ft/lb$^{1/3}$), P in psi, W in pounds

Analysis of the airblast produced by earth-covered magazines has indicated that it is independent of both the type of ammunition and the type of explosive. Rather, it is dependent only upon the total explosive weight. This fact has been implemented into the BEC. The airblast predictions do not change as the type of weapon and/or the type of explosive is changed. The data base for hardened aircraft shelters is much more limited than for earth-covered magazines. However, for purposes of implementation into the BEC, it has been assumed that a HAS will behave in a similar manner to an ECM; therefore, the airblast depends only on the total explosive weight and is independent of the type of ammunition and type of explosive.

VERSION 2.0 CHANGES

There is an English version and a Metric (SI) version available. The user must choose which system of units in which to operate. The basic operation of the BEC is the same in both units. For convenience only, the remainder of the discussion is presented in English units.

In this latest version, there are seven options possible under the heading "***Select Type of Magazin***e." These are: open storage, ECM-Front, ECM-Side, ECM-Rear, HAS-Front, HAS-Side, and HAS-Rear.

There have been several additions and deletions to the "***Select Type of Weapon***" section. When this section is opened, the following options are presented: MK 82 (500 lb Bomb), MK 83 (1000 lb Bomb), MK 84 (2000 lb Bomb), M117 (750 lb Bomb), M107 (155 mm shell), and Bulk/Light Cased. For all of the bombs, the default explosive is TRITONAL. For the M107 projectile, the default explosive is Composition B and for Bulk/Light Cased items the default explosive is TNT. Even though a default explosive is always chosen by the computer, this choice can be over-ridden and any of the explosives listed under the heading "***Select Type of Explosive***" can be chosen at any time. The equivalent weights that are assumed for each of the explosives that are provided in this version of the BEC are shown in Table 3. An energetic material will have several equivalent weights—depending on the airblast parameter upon which the equivalence is determined. Usually, equivalences are reported for peak pressure and positive impulse. Moreover, the equivalence will vary with the range at which it is computed. The values shown in Table 3 are based on peak pressure and are average values. Equivalent weights based on impulse are generally less than those based on peak pressure. Therefore, by using peak pressure values, a degree of conservatism is built into the impulse estimates.

TABLE 3. AVERAGE EQUIVALENT WEIGHTS RELATIVE TO TNT

EXPLOSIVE TYPE	AVERAGE EQUIVALENT WEIGHT (relative to TNT)
TNT	1.00
H-6	1.35
Tritonal	1.07
Composition B	1.11
Composition A3	1.07
Composition C4	1.30
Explosive D	0.92
HBX-1	1.17
HBX-3	1.14
Minol II	1.20
ANFO	0.83

SELECTED AIRBLAST COMPARISONS

Let us consider several examples and compare the airblast predicted by the BEC with the values predicted by empirical curve fits. Consider four situations: (1) Single MK 82 bomb (Tritonal filled) compared with the standard empirical equations, (2) 10 MK 84 bombs (Tritonal filled) compared with the standard empirical equations, (3) 100,000 pounds (NEW) of TNT inside an earth-covered magazine) compared with the empirical equations given in Table 1, and (4) 10,000 pounds NEW inside a hardened aircraft shelter compared with the equations given in Table 2.

MK 82 Bomb. Table 4A presents the comparison for a single Tritonal-filled MK 82 bomb. Shown are BEC predictions for both peak pressure and positive impulse as well as empirically-predicted values. The average difference between the empirical curve fits and the BEC predictions are less than -1% for peak pressure and -15% for positive impulse.

MK 84 Bomb. Table 4B presents the comparison for a 10 Tritonal-filled MK 84 bombs. Shown are BEC predictions for both peak pressure and positive impulse as well as empirically-predicted values. The average difference between the empirical curve fits and the BEC predictions are less than 2% for peak pressure and -10% for positive impulse.

TABLE 4A. SINGLE MK 82 BOMB (TRITONAL FILLED)

RANGE	PRESSURE		IMPULSE	
(feet)	Empirical (psi)	BECV (psi)	Empirical (psi-ms)	BECV (psi-ms)
15	231.6	211.9	233.91	164.02
20	123.3	123.2	174.39	149.35
30	52.72	56.17	115.28	116.23
40	29.63	31.00	85.95	93.63
50	19.25	19.61	68.44	78.07
60	13.67	13.59	56.82	68.00
70	10.30	10.08	48.54	59.93
80	8.11	7.86	42.36	53.38
100	5.49	5.30	33.73	43.47
150	2.80	2.77	22.30	29.01
200	1.79	1.82	16.62	21.37
300	0.98	1.04	10.99	13.63
400	0.66	0.71	8.19	9.81
500	0.49	0.50	6.52	7.59
600	0.39	0.39	5.42	6.28
AVERAGE DIFFERENCE (%)		**-0.67**		**-14.16**

TABLE 4B. TEN MK 84 BOMBS (TRITONAL FILLED)

RANGE	PRESSURE		IMPULSE	
(feet)	Empirical (psi)	BECV (psi)	Empirical (psi-ms)	BECV (psi-ms)
50	288.8	263.8	944.32	550.81
60	192.3	180.8	783.96	594.59
70	137.32	142.73	669.81	585.87
100	64.58	70.66	465.40	470.89
150	28.56	29.91	307.66	340.62
200	16.45	16.39	229.37	267.63
300	7.85	7.43	151.63	188.62
400	4.77	4.48	113.04	142.91
500	3.29	3.13	90.02	113.70
600	2.46	2.37	74.73	93.56
700	1.93	1.89	63.85	79.15
1000	1.13	1.15	44.36	52.95
1500	0.65	0.65	29.33	32.93
2000	0.44	0.43	21.87	23.70
AVERAGE DIFFERENCE (%)		**1.46**		**-8.32**

Earth-Covered Magazine. Table 5 compares the airblast predicted by the BEC with that computed using the equations shown in Table 1. The average differences in peak pressures vary from –5.6% to the front to 2.8% to the rear. The positive impulse differences vary from –17.3% to the front, -4.2% to the side, and –1.6% to the rear.

TABLE 5. EARTH-COVERED MAGAZINE (100,000 LBS NEW OF TNT)

DIRECTION	RANGE	PRESSURE		IMPULSE	
	(feet)	Empirical (psi)	BECV (psi)	Empirical (psi-ms)	BECV (psi-ms)
FRONT	100	426.3	396.6	1712.69	1157.33
	150	155.4	165.6	1201.15	1399.43
	200	77.68	83.29	910.38	1082.42
	300	30.16	30.30	594.28	688.72
	400	15.76	15.19	428.08	500.67
	500	9.65	9.20	327.11	391.15
	600	6.52	6.29	260.10	315.45
	700	4.70	4.64	212.86	260.75
	800	3.56	3.62	178.06	219.81
	1000	2.26	2.45	130.80	163.43
	1500	1.01	1.27	72.28	92.60
	2000	0.59	0.81	46.26	60.75
	AVERAGE DIFFERENCE (%)		**-5.56**		**-17.25**
SIDE	100	49.76	51.96	541.44	362.59
	150	31.32	31.73	494.45	358.12
	200	22.16	22.07	444.88	345.07
	300	13.27	13.03	361.71	327.10
	400	9.06	8.88	299.70	302.18
	500	6.67	6.58	252.99	276.11
	600	5.16	5.13	216.94	251.00
	700	4.14	4.15	188.47	227.65
	800	3.40	3.44	165.52	206.31
	1000	2.44	2.51	131.07	169.54
	1500	1.30	1.38	81.37	105.49
	2000	0.82	0.86	55.67	67.50
	3000	0.42	0.37	30.77	29.40
	AVERAGE DIFFERENCE (%)		**-0.39**		**-4.17**
REAR	100	47.29	49.1	415.25	345.26
	150	26.39	26.5	358.66	300.96
	200	17.50	17.39	313.90	281.55
	300	9.85	9.69	249.58	246.96
	400	6.58	6.48	205.97	217.48
	500	4.81	4.77	174.51	192.31
	600	3.74	3.72	150.75	170.73
	700	3.02	3.02	132.19	152.14
	800	2.51	2.52	117.31	136.05
	1000	1.85	1.85	94.96	109.81
	1500	1.06	1.03	62.30	67.18
	2000	0.72	0.65	44.86	43.09
	3000	0.42	0.32	27.09	23.10
	AVERAGE DIFFERENCE (%)		**2.83**		**-1.58**

<u>Hardened Aircraft Shelter</u>. Table 6 compares the airblast predicted by the BEC with that computed using the equations shown in Table 2. The average differences in peak pressures vary from 3.6% to the front to 1.3% to the rear.

TABLE 6. HARDENED AIRCRAFT SHELTER (10,000 LBS NEW)

DIRECTION	RANGE	PRESSURE		IMPULSE	
	(feet)	Empirical (psi)	BECV (psi)	Empirical* (psi-ms)	BECV (psi-ms)
FRONT	70	17.11	12.22		71.98
	80	12.74	10.47		71.03
	90	10.11	9.27		70.97
	100	8.40	8.01		68.03
	150	4.81	4.85		58.83
	200	3.61	3.86		59.49
	300	2.62	2.78		58.38
	400	2.10	2.06		51.39
	500	1.74	1.62		44.97
	700	1.21	1.18		38.36
	800	1.02	1.04		36.34
	1000	0.71	0.80		29.86
	AVERAGE DIFFERENCE (%)		**3.57**		
SIDE	60	13.48	14.01		69.88
	70	12.63	12.77		74.93
	80	11.85	11.74		79.24
	90	11.13	10.89		82.97
	100	10.47	10.16		86.23
	150	7.95	7.65		97.27
	200	6.29	6.12		102.10
	300	4.30	4.27		101.08
	400	3.18	3.19		93.31
	500	2.47	2.48		83.50
	700	1.64	1.65		64.83
	800	1.38	1.39		57.02
	1000	1.03	1.03		44.59
	1500	0.58	0.56		26.51
	AVERAGE DIFFERENCE (%)		**0.64**		
REAR	60	9.56	9.11		46.48
	70	8.57	8.46		50.34
	80	7.81	7.74		52.52
	90	7.19	7.14		54.28
	100	6.68	6.63		55.68
	150	4.95	4.85		58.81
	200	3.88	3.79		58.15
	300	2.57	2.54		51.76
	400	1.79	1.82		42.69
	500	1.29	1.33		33.30
	700	0.72	0.72		17.81
	800	0.55	0.51		12.34
	AVERAGE DIFFERENCE (%)		**1.31**		

*Data not available

BACK CALCULATIONS

Explosion effects depend upon the inter-relationship of three sets of data: (1) the net explosive weight (NEW), (2) the range, and (3) the type of explosion effect (time of arrival, positive phase duration, etc.). If two of these are known, then the third can be computed. When the NEW and range are known, the BEC computes the effect. It is often useful to reverse this process; i.e., to enter the range and the effect and compute the NEW or to enter the effect and the NEW and compute the range. This reverse process is referred to as back calculation.

When it is planned to use this feature, either the range or the NEW must be entered at the top of the spreadsheet. An arbitrary value for the other input variable must also be used--any number greater than zero. Make the appropriate selections from the other inputs: ***Select Type of Magazine***, ***Select Type of Weapon***, and ***Select Type of Explosive***. When the other inputs are complete, select the ***Goal Seek*** Function under the EXCEL **TOOLS** menu. When this option is selected, the following dialog box is displayed:

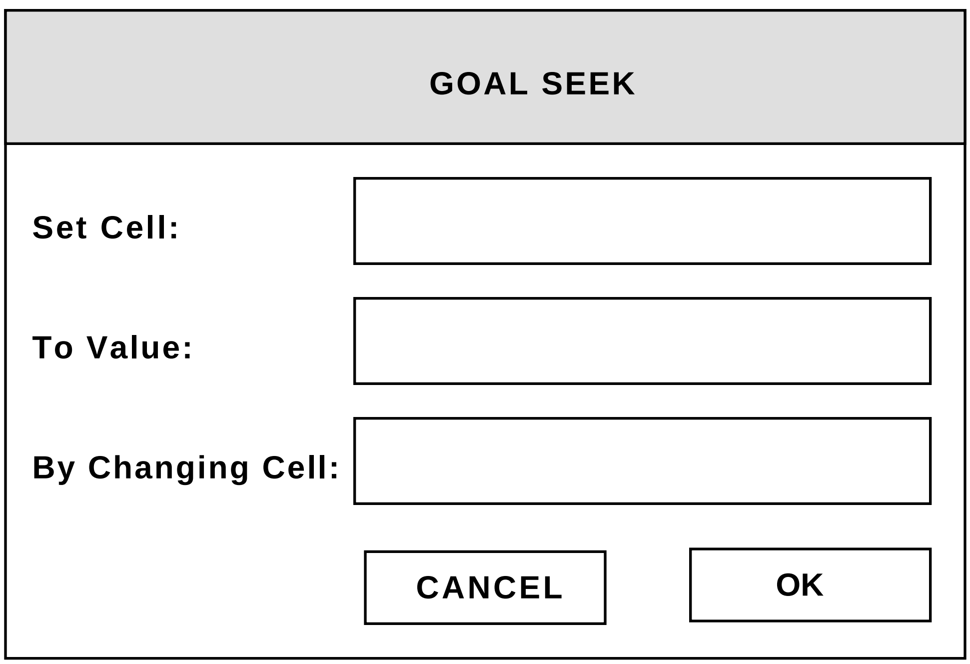

FIGURE 1. DIALOG BOX FOR BACK CALCULATIONS

Enter the Cell Reference of the cell you wish to compute into the ***Set Cell:*** box. Enter the value you wish the cell to obtain in the ***To Value:*** box. Enter the Cell Reference of the Cell you wish to change into the ***By Changing Cell:*** box. The Cell References for each of the parameters of interest are given in Table 7.

TABLE 7. CELL REFERENCES

FUNCTION	CELL REFERENCE
Total NEW or Number of Weapons	G5
Range	H5
Time of Arrival at Range	B20
Overpressure at Range	B22
Reflected Pressure at Range	B24
Positive Phase Duration at Range	B26
Positive Phase Impulse at Range	B29
Reflected Impulse at Range	B32
Shock Front Velocity at Range	B35
Dynamic Overpressure Impulse at Range	B38
Intraline Distance--Barricaded	C41
Intraline Distance--Unbarricaded	B41
Inhabited Building Distance	B43
Public Traffic Route Distance	B45

When you are satisfied with the inputs in the ***Goal Seek*** dialog box, click **OK**. When the Goal Seek process is complete, click **OK** in the new box. The spreadsheet will be displaying all of the selected values. Example 2 (below) illustrates the use of the **Goal Seek** function.

EXAMPLES

The following examples are intended to illustrate some of the features of BECV2.

Example 1.

Statement of problem: A total of 250,000 lbs net explosive weight (NEW) of MK 83 bombs (Tritonal filled) are stacked in an open storage. What are the airblast effects at 2000 ft? At what distance from the stack will undesirable effects result in the event of an accidental explosion?

Inputs:

Type of Magazine	***Open Storage***
Type of Weapon	***MK 83 Bombs***
Type of Explosive	***Tritonal***
Number of Weapons or Total NEW	***Total NEW***
Total NEW (lbs)	***250,000***
Range (ft)	***2,000***

Outputs:

The output (shown below as Figure 2) indicates the effective yield of the 250,000 lbs (NEW) of Tritonal in MK 83 bombs is 267,500 lbs. The equivalent hemispherical weight is 430,748 pounds. The **Explosive Parameters** section of the output gives the airblast effects at 2,000 ft (for example, the over-pressure is 2.02 psi at 2,000 ft). In the **Other Information** section of the output - unbarricaded (K18) and barricaded (K9) intraline distances (ILDs) [1359 ft and 680 ft, respectively], inhabited building distance (IBD) for blast effects only [3776 ft], and public traffic route (PTR) distance for blast effects only [2266 ft] are given. The remainder of the output section supplies the damage effects (undesirable effects) resulting from such a detonation. These include: 50% glass breakage at 1509.8 ft (using an overpressure criterion of 3 psi), Not flyable parked aircraft damage at 2014.7 ft (using an overpressure criterion of 2 psi), Total truck damage from crushing at 440.3 ft (using an overpressure criterion of 30 psi), Threshold for personnel injury (tertiary) for the head at 969.0 ft (using an impulse criterion of 54 psi-ms), and 50% probability of personnel injury (primary) ear damage at 949.4 ft (using an overpressure criterion 6.3 psi).

FIGURE 2A. EXAMPLE 1—INPUTS AND AIRBLAST PARAMETERS

INPUT SECTION:

Select Type of Magazine	Select Type of Weapon	Select Type of Explosive	Select Number of Weapons or Total NEW	Enter Total NEW (lbs)	Enter Range (ft)
Open Storage	MK 83 (1000 lb Bomb)	Tritonal	Total NEW	250,000.0	2,000.0

OUTPUT SECTION:

EXPLOSIVE PARAMETERS

Total NEW (lb)	250,000.0
NEW per weapon (lb)	445
TNT Equivalence	1.07
Equivalent Hemispherical Weight	430,747.6
Effective Yield	267,500.0
(N.B.: Both Weight and Yield are in lbs of TNT)	

AIRBLAST PARAMETERS

Range (feet)	2,000.0
Time of Arrival at Range (msec)	1335.59
Over-Pressure at Range (psi)	2.02
Reflected Press. at Range (psi)	4.26
Positive Phase Duration at Range (msec)	282.7
Positive Phase Impulse at Range (psi-msec)	249.1
Reflected Impulse at Range (psi-msec)	474.1
Shock Front Velocity at Range (kft/sec)	1.179

FIGURE 2B. EXAMPLE 1—INPUTS AND OTHER INFORMATION

INPUT SECTION:

Select Type of Magazine	Select Type of Weapon	Select Type of Explosive	Select Number of Weapons or Total NEW	Enter Total NEW (lbs)	Enter Range (ft)
Open Storage	MK 83 (1000 lb Bomb)	Tritonal	Total NEW	250,000.0	2,000.0

OUTPUT SECTION:

EXPLOSIVE PARAMETERS

Total NEW (lb)	250,000.0
NEW per weapon (lb)	445
TNT Equivalence	1.07
Equivalent Hemispherical Weight	430,747.6
Effective Yield	267,500.0

(N.B.: Both Weight and Yield are in lbs of TNT)

OTHER INFORMATION

Dynamic Overpressure Impulse at Range (psi-msec)	10.1				
	Unbarricaded	Barricaded			
Intraline Distance (ft)	1359	680			
Inhabited Building Distance (ft)	3776	(Blast only)			
Public Traffic Route Distance (ft)	2266	(Blast only)			
	Glass Breakage	Threshold	50%	Total	
Frame House Damage (ft)	9562.2	3757.9	1509.8	1087.8	
criteria (psi)	(0.25)	(0.9)	(3)	(5)	
	Threshold	Not Flyable	Total		
Parked Aircraft Damage (ft)	3454.9	2014.7	1249.3		
criteria (psi)	(1)	(2)	(4)		
Truck Damage	Threshold	Total			
Crushing (ft)	976.5	440.3			
criteria (psi)	(6)	(30)			
Overturning (ft)	777.5	462.7			
criteria (psi-msec)	(90)	(300)			
Personnel Injuries (Tertiary)	Threshold	50%	99%		
Body (ft)	802.6	717.0	673.9		
criteria (psi-ms)	(83.6)	(108.6)	(125.4)		
Head (ft)	969.0	841.0	756.1		
criteria (psi-ms)	(54)	(75)	(96)		
Personnel Injuries (Primary)	Threshold	10%	50%	90%	99%
Lung Damage (ft)	612.5	560.5	519.9	470.4	444.0
criteria (psi)	(14.5)	(17.5)	(20.5)	(25.5)	(29)
Ear Damage (ft)	1764.2	1583.0	949.4	666.7	n/a
criteria (psi)	(2.4)	(2.8)	(6.3)	(12.2)	n/a

Example 2.

Statement of problem: The boundary of an installation (an area that requires Inhabited Building Distance (IBD) level of protection) is 4,000 feet from an aboveground magazine. How many H-6 loaded MK 82 bombs may be stored in the magazine and still achieve equivalent IBD level of protection? What is the equivalent hemispherical TNT weight of the bombs at that distance? What are the other airblast parameters that may be of interest? (Note: Equivalent IBD level of protection corresponds to a pressure level of 0.9 psi for Net Explosive Weights greater than 250,000 pounds).

The **BACK CALCULATION** or **GOAL SEEK** option should be used to solve this problem.

Inputs:

Type of Magazine	***Open Storage***
Type of Weapon	***MK 82 Bombs***
Type of Explosive	***H-6***
Number of Weapons or Total NEW	***Number of Weapons***
Number of Weapons	***10 (arbitrary, such that the Overpressure at Range Cell indicates a number)***
Range (ft)	***4,000***

Select ***Goal Seek*** function under the **TOOLS** menu. When the Goal Seek dialog box appears, enter B22 into ***Set Cell*** box. Enter the value 0.9 into the ***To Value*** box. Enter G5 into the ***By Changing Cell*** box. (Note: This tells the computer that you wish to vary the number of weapons (Cell G5) until the Overpressure at Range (Cell B22) achieves a value of 0.9 psi). Press ***OK***. When the Goal Seek function is completed, press **OK** in the dialog box that appears.

Outputs:

The output (shown below as Figure 3.) indicates that 1,566.2 weapons can be stored and still achieve equivalent IBD blast protection (0.9 psi) at a range of 4,000 feet. This number of weapons is equivalent to 519,235.9 pounds of hemispherical TNT at 4,000 feet. It should be noted, however, that for compliance with the requirements of DoD 6055.9-STD, the actual NEW rather than an effective yield or equivalent hemispherical yield must be used for establishing quantity-distances such as IBD, PTR, and ILD.

FIGURE 3A. EXAMPLE 2—INPUTS AND AIRBLAST PARAMETERS

INPUT SECTION:

Select Type of Magazine	Select Type of Weapon	Select Type of Explosive	Select Number of Weapons or Total NEW	Enter Number of Weapons	Enter Range (ft)
Open Storage	MK82 (500 lb Bomb)	H-6	Number of Weapons	1,566.2	4,000.0

OUTPUT SECTION:

EXPLOSIVE PARAMETERS

Total NEW (lb)	300,716.1
NEW per weapon (lb)	192
TNT Equivalence	1.35
Equivalent Hemispherical Weight	519,235.9
Effective Yield	405,966.8

(N.B.: Both Weight and Yield are in lbs of TNT)

AIRBLAST PARAMETERS

Range (feet)	4,000.0
Time of Arrival at Range (msec)	3028.8
Over-Pressure at Range (psi)	0.9
Reflected Press. at Range (psi)	1.8
Positive Phase Duration at Range (msec)	366.0
Positive Phase Impulse at Range (psi-msec)	144.1
Reflected Impulse at Range (psi-msec)	260.4
Shock Front Velocity at Range (kft/sec)	1.145

FIGURE 3B. EXAMPLE 2—INPUTS AND OTHER INFORMATION

INPUT SECTION:

Select Type of Magazine	Select Type of Weapon	Select Type of Explosive	Select Number of Weapons or Total NEW	Enter Number of Weapons	Enter Range (ft)
Open Storage	MK82 (500 lb Bomb)	H-6	Number of Weapons	1,566.2	4,000.0

OUTPUT SECTION:

EXPLOSIVE PARAMETERS

Total NEW (lb)	300,716.1
NEW per weapon (lb)	192
TNT Equivalence	1.35
Equivalent Hemispherical Weight	519,235.9
Effective Yield	405,966.8

(N.B.: Both Weight and Yield are in lbs of TNT)

OTHER INFORMATION

Dynamic Overpressure Impulse at Range (psi-msec)	2.5				
	Unbarricaded	Barricaded			
Intraline Distance (ft)	1447	723			
Inhabited Building Distance (ft)	4019	(Blast only)			
Public Highway and Passenger Road dist. (ft)	2411	(Blast only)			
	Glass Breakage	Threshold	50%	Total	
Frame House Damage (ft)	10176.7	3999.4	1606.8	1157.7	
criteria (psi)	(0.25)	(0.9)	(3)	(5)	
	Threshold	Not Flyable	Total		
Parked Aircraft Damage (ft)	3676.9	2144.2	1329.5		
criteria (psi)	(1)	(2)	(4)		
Truck Damage	Threshold	Total			
Crushing (ft)	1039.2	468.6			
criteria (psi)	(6)	(30)			
Overturning (ft)	850.0	505.9			
criteria (psi-msec)	(90)	(300)			
Personnel Injuries (Tertiary)	Threshold	50%	99%		
Body (ft)	877.4	783.8	736.7		
criteria (psi-ms)	(83.6)	(108.6)	(125.4)		
Head (ft)	1059.3	919.4	826.6		
criteria (psi-ms)	(54)	(75)	(96)		
Personnel Injuries (Primary)	Threshold	10%	50%	90%	99%
Lung Damage (ft)	651.8	596.5	553.3	500.6	472.5
criteria (psi)	(14.5)	(17.5)	(20.5)	(25.5)	(29)
Ear Damage (ft)	1877.6	1684.7	1010.4	709.5	n/a
criteria (psi)	(2.4)	(2.8)	(6.3)	(12.2)	n/a

HARDWARE/SOFTWARE REQUIREMENTS

The new BEC is written as a Microsoft EXCEL Spreadsheet template. In order to use BECV2, EXCEL (Version 5.0 or higher) must already be installed on your computer. Simply copy BECV2 to your hard drive. To use the program, either double click on the BECV2 filename or launch EXCEL and then use the ***OPEN*** command located in the FILE menu. Because it is written as an EXCEL template, BECV2 will run on any machine that can run EXCEL. Currently, it has been tested on both Macintosh and WINTEL machines. The MAC was using EXCEL Version 5.0 or EXCEL 98 (part of the Microsoft Office 97 suite). The WINTEL machines (using Windows 95) were running EXCEL 97 (part of the Microsoft Office 97 suite) and EXCEL 5.0 (part of Office 95).

When you open a template, EXCEL opens a copy of the template for you to use. Changes you make affect only the copy; the original template is preserved. The copy of the template is a new, unsaved document with a temporary name based on the template name. For example, when you open the Blast Effects Computer template named BECV2.XLT, Microsoft EXCEL gives the copy the temporary name BECV21. When you save or close the copy, the Save As dialog box appears. You can type a new name for the document or accept the temporary name suggested by EXCEL.

When you open the template with EXCEL 97 or EXCEL 98, you will be presented with a dialog box that indicates, ***" The workbook you are opening contains macros …"***. Click on the "**Enable Macros**" button to proceed. You may then be presented with a dialog box concerning Visual Basic. Click **OK** to proceed and open BECV.

REFERENCES

1. Fugelso, L.E., Weiner, L. M., and Schiffman, T. H., "Explosion Effects Computation Aids," Final Report GARD Project No. 1540, June 1972 (AD-903279L).
2. Department of Defense Explosives Safety Board Blast Effects Computer, GPO: 1978 0--266-197.
3. Swisdak, M. M., et. al., "The DDESB Blast Effects Computer—From Circular Slide Rule to EXCEL Spreadsheet," PARARI 97 Australian Safety Seminar, November 1997.
4. Swisdak, M. M., "Simplified Kingery Airblast Calculations," Minutes of the Twenty-Sixth DOD Explosives Safety Seminar, August 1994
5. Swisdak, M. M., "A Reexamination of the Airblast and Debris Produced by Explosions Inside Earth-Covered Igloos," NAVSWC TR 91-102, 28 Jan 1991.

BECv3

“The DDESB Blast Effects Computer—Version 3.0,” Swisdak, Michael M., and Ward, Jerry M., PARARI ’99 Australian Safety Seminar, November 1999.

THE DDESB BLAST EFFECTS COMPUTERS—VERSION 3.0

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ABSTRACT

Version 1.0 of the Department of Defense Explosives Safety Board (DDESB) Blast Effects Computer (BEC) was demonstrated at PARARI 97. This was an EXCEL spreadsheet template that replaced the circular slide rule of the same name. Since that release, significant improvements have been made. These include: the addition of three new types of magazines (Aboveground Structures—Barricades, Aboveground Structures—Unbarricaded, and Ships), algorithms for predicting both dynamic pressure and dynamic pressure impulse, more accurate algorithms for estimating the probability of window breakage, and algorithms for predicting the probability of ear drum rupture and the probability of lethality due to lung damage. This paper will describe the information that went into the construction of these new algorithms. It will then demonstrate the new software.

BACKGROUND

The Department of Defense Explosives Safety Board (DDESB) has had an active role in producing various types of explosion effects computation aids[1]. In 1978, these culminated in the release of a circular slide rule called the "Blast Effects Computer (BEC)[2]." This slide rule was designed to solve problems and provide data related to the expected damage to various potential targets due to blast effects resulting from an explosion of ammunition or explosives stored above ground or in earth-covered magazines.

The algorithms that were developed for the original BEC are described in detail in Reference 1. In 1997, these algorithms were implemented into an EXCEL spreadsheet template. This version, Version 1.0, referred to as BECV1, was released in November 1997 and was reported at PARARI 97[3]. Version 2.0[4] was released in 1998 as BECVE2 and BECVM2. BECVE2 is in English units and BECVM2 is in Metric units. Updated airblast information for earth-covered magazines and hardened aircraft shelters were incorporated into these versions. Also, improved airblast algorithms for MK 82, MK 83, MK 84 and M117 bombs, as well as M107 155-mm projectiles were included.

VERSION 3.0 GENERAL INFORMATION

Version 3 of the Blast Effects Computer is also written as a Microsoft EXCEL spreadsheet template. In order to use Version 3, EXCEL 97 or EXCEL 98 must already be installed on your computer. Simply copy the template to your hard drive. To use the program, either double click on the BECV filename or launch EXCEL and then use the ***OPEN*** command located in the **FILE** menu. Because it is written as an EXCEL template, the Blast Effects Computer will run on any machine that can run EXCEL. At this time, it has been tested on both Macintosh and WINTEL machines.

When you run the template, EXCEL opens a copy of the spreadsheet for you to use. Changes you make affect only the copy; the original template is preserved. The copy of the template is a new, unsaved document with a temporary name based on the template name. For example, when you open the Blast Effects Computer template named BECVE3.xlt, Microsoft EXCEL gives the copy the temporary name BECVE31. When you save or close the copy, the ***Save As*** dialog box appears. You can type a new name for the document, accept the temporary name suggested by EXCEL, or you don't save this copy when you close out.

When you open the template with EXCEL 97 or EXCEL 98, you will be presented with a dialog box that indicates, ***" The workbook you are opening contains macros …"***. Click on the "**Enable Macros**" button to proceed. You may then be presented with a dialog box concerning Visual Basic. Click **OK** to proceed and open BECV.

There are templates available for both English and Metric (SI) units. At the start of the session, the user simply chooses the system of units in which to operate and opens the corresponding template. The basic operation of the BEC is the same in both units. For convenience only, the majority of this discussion is presented in English units.

In this latest version (3.0), three new options have been added under the heading "***Select Potential Explosion Site (PES)***." These are Aboveground Structure—Unbarricaded, Aboveground Structure—Barricaded, and Ship.

New algorithms for the prediction of dynamic pressure and dynamic pressure impulse have been included. Dynamic Pressure was not called out specifically in previous versions and the dynamic pressure impulse algorithm was based on an extrapolation of limited data.

In the previous versions, several damage predictors were grouped into a section called "**OTHER INFORMATION"**. The algorithms for all of these predictors were taken from the original circular slide rule[1]. In the current version, these have been removed and replaced with three predictors: probability of window breakage, probability of eardrum rupture, and probability of lethality due to lung damage.

Additional Potential Explosion Sites. As indicated above, three additional sites have been added. The Aboveground Structures (barricaded and unbarricaded) are based on full-scale UK tests[5] that were conducted in Australia. In these tests, the structures were representative of typical UK designed brick storage buildings. It was the opinion of the authors that, in place of better data, this information could be generalized to represent all aboveground storage sites. If the outputs for barricaded and unbarricaded are compared, it will be seen that the barricade has an apparent effect on the pressures. This is shown in Figure 1. This effect is contrary to the opinion that barricades have no effect on pressure beyond their shadow zone. However, because of the limited data sets used to generate these curves, the differences may be statistically insignificant.

The "Ship" site is based on airblast data generated on the United States Marine Corps (USMC) Maritime Prepositioning Ship (MPS) test.[6,7] This test, with a net explosive weight of over 500,000 pounds was a full scale event that included ordnance stored in ISO-containers, shipboard storage arrangements, as well as the ship hull and decking.

Dynamic Pressure and Dynamic Pressure Impulse. Previous versions of the blast effects computer did not contain an explicit algorithm for predicting dynamic pressure; however, they did contain a simplistic algorithm for predicting dynamic pressure impulse. Models have been developed for the Defense Threat Reduction Agency (formerly the Defense Nuclear Agency) that predict the pressure-time waveforms for ANFO and TNT surface burst detonations[8, 9]. These models were used in conjunction with the CONWEP computer code[10] to develop estimates for the dynamic pressure and dynamic pressure impulse as a function of range and charge weight. These data form the basis of the new algorithms included in this version of the computer. A comparison of the dynamic pressure impulse predicted by the new algorithm and that predicted by Version 2.0 is presented as Table 1.

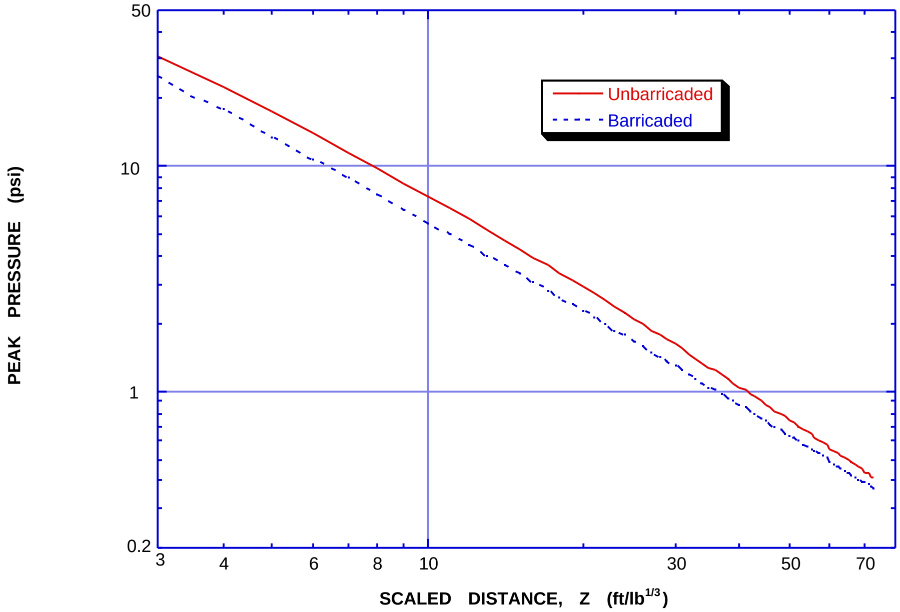

FIGURE 1. PREDICTED AIRBLAST—BARRICADED/UNBARRICADED ABOVEGROUND STRUCTURE

TABLE 1. COMPARISON OF SCALED DYNAMIC PRESSURE IMPULSE ALGORITHMS

SCALED DISTANCE	SCALED DYNAMIC PRESSURE IMPULSE		SCALED DISTANCE	SCALED DYNAMIC PRESSURE IMPULSE	
	NEW	OLD		NEW	OLD
($ft/lb^{1/3}$)	($psi\text{-}ms/lb^{1/3}$)	($psi\text{-}ms/lb^{1/3}$)	($ft/lb^{1/3}$)	($psi\text{-}ms/lb^{1/3}$)	($psi\text{-}ms/lb^{1/3}$)
2	36.7	53.3	12	0.79	0.82
3	14.7	20.8	15	0.47	0.50
4	10.3	10.7	17	0.36	0.37
5	7.7	6.4	20	0.25	0.26
6	5	4.2	30	0.10	0.10
7	3.3	2.9	50	0.034	0.030
8	2.3	2.1	70	0.016	0.014
9	1.6	1.6	100	0.006	0.006
10	1.2	1.3			

Probability of Window Breakage. Window breakage probabilities are estimated for six different combinations of glass size and type using the GLASSC[11] model developed by ACTA, Inc. In this model, the probability estimates are based on the stress capacity distribution for glass samples taken from the Vandenberg AFB, California area.

Measurements of glass stress capacity show a significant variation due to geographical location. For example, the measured mean stress capacity is about 15% higher for window glass taken from communities surrounding Vandenberg AFB compared to those around Cape Canaveral Air Station, Florida. This difference produces about a 10% change in the predicted probability of breakage results[12].

Probability of Eardrum Rupture. Two estimates for the probability of eardrum rupture are presented. The first of these was developed and published by Mercx[13, 14]; the second was published by Eisenberg et. al.[15], based on work by Fugelso[1]. Both estimates utilize PROBIT functions, which relate the probability to the incident pressure.

$$P_r = -12.6 + 1.524*\ln(P_s) \qquad \text{Mercx}$$

$$P_r = -15.6 + 1.93*\ln(P_s) \qquad \text{Eisenberg}$$

where P_s is the incident pressure in Pascals and P_r is the PROBIT function. The Blast Effects Computer relates the PROBIT function to percent probability through an algorithm that was developed for the DoD Explosives Safety Board Risked-based Explosives Safety Criteria Working Group[16].

These two functions result in significantly different probabilities. Work is currently ongoing in NATO, which may resolve this issue. However, until it is, it is left to the user to decide which probability is the more appropriate.

Probability of Lethality Due To Lung Damage. The probability of lethality due to lung damage is also based on a PROBIT function developed by Mercx[13, 14]. This function relates the lethality probability to a combination of the incident pressure and impulse, the ambient atmospheric pressure, and an assumed mass of the human body. For this application, standard atmospheric pressure was assumed to be 100 kPa (14.5 psi); the mass of the human being was assumed to be 70 kg. (154 pounds). With these assumptions, the PROBIT function becomes

$$P_r = 5.00 - 5.74*\ln(S)$$

$$S = (4.2/P_{sc}) + (1.3/I_{sc})$$

$$P_{sc} = P_s/P_0 = 0.01*P_s$$

$$I_{sc} = I_s/(m^{1/3}*P_0^{1/2}) = 0.7673*I_s$$

where:

P_{sc}	Scaled Pressure
I_{sc}	Scaled Impulse
P_s	Side-on or incident overpressure in kPa
I_s	Side-on or incident impulse in kPa-s
m	Mass of human being (70 kg assumed)
P_0	atmospheric pressure (100 kPa assumed)

PROCEDURE FOR ADDING A PES

As indicated above, three new Potential Explosion Sites were added to this version of the Blast Effects Computer. Because other sites may be added in the future, it was felt that it would be instructive to go through the process and procedures necessary to accomplish this.

The Blast Effects Computer uses the equations for a hemispherical TNT surface burst to generate the various airblast parameters. This means that the effective yield of each PES relative to a hemispherical TNT surface burst must be computed as a function of scaled distance. This effective yield is then used in conjunction with the TNT curves to generate the appropriate airblast parameters. Therefore, when adding another PES, the information which must be computed is the effective yield of the new site relative to hemispherical TNT. This is analogous to determining the equivalent weight[17, 18] of the site.

- For the new site, compute equations for the pressure-scaled distance relationships (note: this should be for sea level conditions); subscript ***s*** refers to the new site
  - Z_s = function (P_s)
  - P_s = function (Z_s)
- For the scaled distance range determined above, compute equations for the pressure-scaled distance relationships for hemispherical, surface burst TNT; subscript ***t*** refers to TNT
  - Z_t = function (P_t)
  - P_t = function (Z_t)
- Compute the equivalent yield for the new site as a function of the pressure level, using the definition of equivalent weight.

  Scaled Effective Yield, $Y_{scaled} = [(Z_s/Z_t)_{pressure=constant}]^3$

- Construct a curve of Effective Yield versus scaled distance for the new site

  $Y_{effective}$ = function (Z_s)

It is this function that defines the new site for the Blast Effects Computer.

As an example of this procedure, let us work through the steps that were necessary before the new “***Ship***” site could be added to the Blast Effects Computer.

Reference 6 gives the equation of the pressure-distance curve for the MPS test:

$$P = \exp(25.51412 - 5.28634*(\ln(R)) + 0.26197*(\ln(R))^2),$$

Where P is overpressure in psi and R is range in feet. The NEW for the event was 523,790 pounds. The next step is to perform a curve fit to obtain Z as a function of P. This is shown in Figure 2

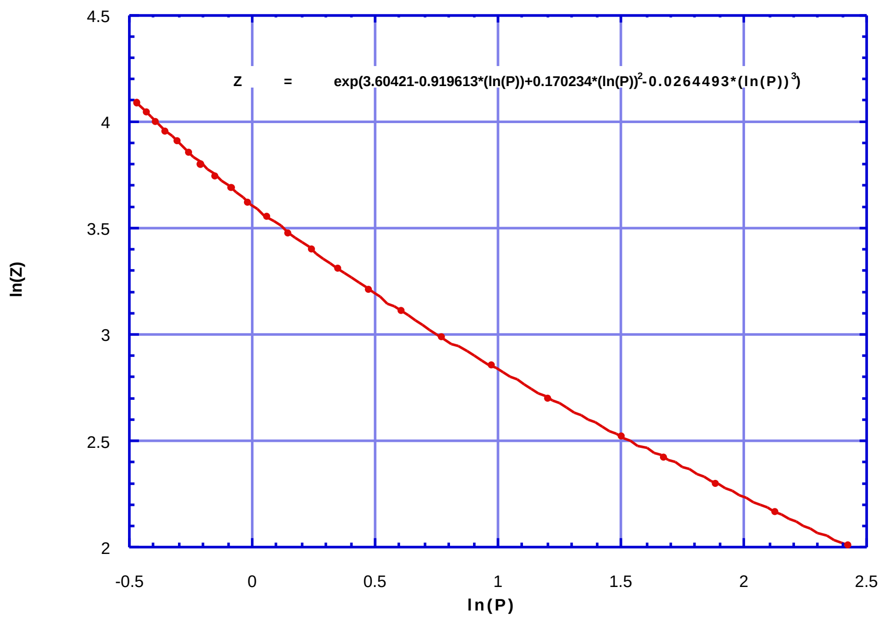

FIGURE 2. MPS CURVE FIT

Surface Burst, hemispherical TNT over the same nominal pressure range has the form:

$$Z_t = \exp(3.81-0.82465*(\ln(P)) + 0.085399*(\ln(P))^2 - 0.0062199*(\ln(P))^3)$$

Using these equations, a table of scaled yield versus pressure and scaled distance can be computed. This is shown in Table 2.

TABLE 2. YIELD CALCULATION—SHIP PES

PRESSURE (psi)	Z_s ($ft/lb^{1/3}$)	Z_t ($ft/lb^{1/3}$)	SCALED YIELD	PRESSURE (psi)	Z_s ($ft/lb^{1/3}$)	Z_t ($ft/lb^{1/3}$)	SCALED YIELD
10	7.90	9.86	0.514	4	13.28	16.68	0.504
9.5	8.12	10.13	0.516	3.5	14.40	18.15	0.499
9	8.37	10.43	0.518	3	15.87	20.06	0.495
8.5	8.64	10.75	0.519	2.5	17.89	22.68	0.491
8	8.94	11.12	0.519	2	20.90	26.51	0.490
7.5	9.26	11.52	0.520	1.5	25.99	32.76	0.499
7	9.63	11.98	0.519	1	36.75	45.15	0.539
6.5	10.03	12.49	0.518	0.9	40.57	49.30	0.557
6	10.49	13.08	0.517	0.8	45.52	54.51	0.582
5.5	11.03	13.76	0.515	0.7	52.20	61.27	0.618
5	11.64	14.56	0.512	0.6	61.68	70.41	0.672
4.5	12.38	15.51	0.508	0.5	76.11	83.49	0.758

An effective yield curve as a function of scaled distance for the "Ship" PES is shown in Figure 3.

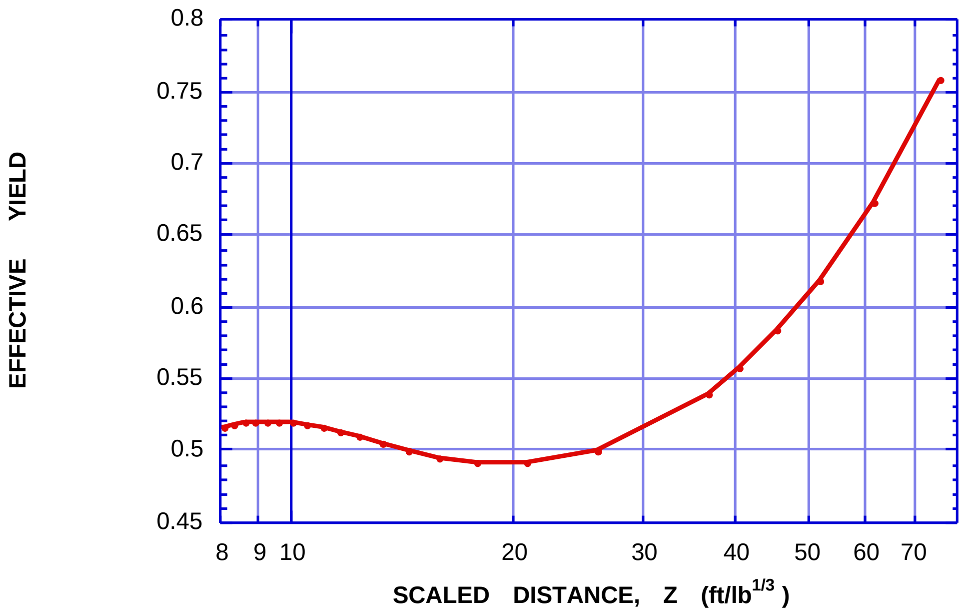

FIGURE 3 MPS EFFECTIVE YIELD

The algorithm that is included in the Blast Effects Computer is summarized as follows for the "Ship" PES:

$Z \leq 9$ $Y=0.52*W$
$Z > 74$ $Y=0.76* W$
$9 < Z \leq 74$

$$Y=\exp(-13.7765 + 20.0853*X - 11.8223*X^2 + 3.34422*X^3 - 0.458199*X^4 + 0.024806*X^5) * W$$

Where

Z is scaled distance (range divided by cube root of charge weight, W)
W is Net Explosive Weight in pounds
X is ln(Z).

The upper limit ($Z > 74$, $Y=0.76* W$) represents an arbitrary choice of the authors. There were no data available beyond this scaled distance, yet a value was required for the computer. At a scaled distance of 74 $ft/lb^{1/3}$, the incident overpressure is approximately 0.5 psi (well beyond inhabited building distance).

USING THE COMPUTER

The following steps should be followed to use the computer.

- Select either English or Metric version
- Launch the appropriate version of the BEC—either by double clicking on the template icon or by starting EXCEL and using the ***open*** command (under the **File** menu)
- Use the ***Select Type of PES*** menu to choose the appropriate PES
- Use the ***Select Type of Weapon*** menu to choose the appropriate type of weapon
- Use the ***Select Type of Explosive*** menu to change the default explosive type
- Choose either a **Total NEW** or **Number of Weapons** under the ***Select Number of Weapons or Total NEW*** menu.
- Enter either the **Total NEW** or the **Number of Weapons** as required in the next box
- Enter the range of interest

Once these inputs are completed, the results are immediately available in the output section.

Once you have selected a PES, weapon type, and explosive type, the explosion effects are dependent upon the inter-relationship of three sets of data: the Net Explosive Weight (or Number of Weapons), the selected range, and the type of explosion effect (time of arrival, peak pressure, probability of fatality due to lung rupture, etc.). If two of these are known, then the third can be computed. When the NEW and range are known, the BEC computes the effect. This is the procedure described above. However, it is sometimes useful to reverse the process; i.e., to enter the effect and either the range or NEW/Number of Weapons and compute the other variable. This reverse process is referred to as "Back Calculation."

When it is planned to use this feature, either the range or the NEW must be entered at the top of the spreadsheet. An arbitrary value for the other input variable must also be used--any number greater than zero. Make the appropriate selections from the other inputs: ***Select Potential Explosion Site***, ***Select Type of Weapon***, and ***Select Type of Explosive***. When the other inputs are complete, select the ***Goal Seek*** Function under the EXCEL **TOOLS** menu. When this option is selected, the following dialog box (Figure 4) is displayed:

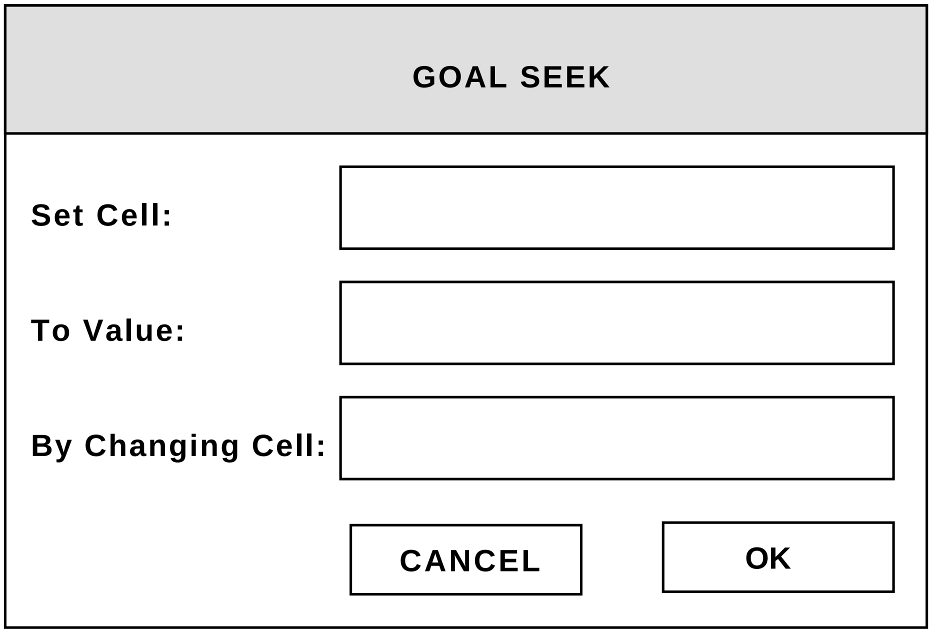

FIGURE 4. GOAL SEEK DIALOG BOX

Enter the Cell Reference of the cell you wish to compute into the ***Set Cell:*** box. Enter the value you wish the cell to obtain in the ***To Value:*** box. Enter the Cell Reference of the Cell you wish to change into the ***By Changing Cell:*** box. The Cell Reference can be set by first placing the cursor in the appropriate ***GOAL SEEK*** dialog box then clicking on the cell of choice in the BEC.

SAMPLE PROBLEM

The following examples are intended to illustrate some of the features of this version of the Blast Effects Computer.

Example 1.

Forty tonnes of MK 82 bombs (Tritonal filled) are detonated inside a barricaded, aboveground structure. What are the airblast effects at 500 meters? At what range is there a 10% probability of eardrum rupture using the Mercx algorithm?

Choose the Metric (SI) version of the BEC

Inputs:

Type of PES	**Aboveground Structure—Barricaded**
Type of Weapon	**MK 82**
Type of Explosive	**Tritonal**
Number of Weapons	
Or Total NEW	**Total NEW**
Total NEW (kg)	**40,000**
Range (m)	**500**

Outputs:

Figure 5A (below) shows the input and the airblast parameters for this problem. At a range of 500 meters, the incident pressure is expected to be 6.8 kPa with a duration of 157.6 ms. All of the other airblast parameters are also shown in this Figure.

INPUT SECTION: **Metric Version: Units of kg, m, kilopascals, pascal-seconds, msec**

Select Type of Magazine	Select Type of Weapon	Select Type of Explosive	Select Number of Weapons or Total NEW	Enter Total NEW (kg)	Enter Range (m)
AGS--Barricaded	MK82 (500 lb Bomb)	Tritonal	Total NEW	40,000.0	500.0

OUTPUT SECTION:

EXPLOSIVE PARAMETERS

Total NEW (kg)	40,000.0
NEW per weapon (kg)	87.090
TNT Equivalence	1.07
Equivalent Hemispherical Weight (kg)	19,955.2
Effective Yield (kg)	42,800.0
(N.B.: Both Weight and Yield are in kg of TNT)	

AIRBLAST PARAMETERS

Range (m)	500.0
Time of Arrival at Range (msec)	1228.80
Over-Pressure at Range (kPa)	6.76
Reflected Press. at Range (kPa)	13.81
Positive Phase Duration at Range (msec)	157.6
Positive Phase Impulse at Range (Pa-sec)	466.5
Reflected Impulse at Range (Pa-sec)	847.2
Dynamic Overpressure at Range (kPa)	0.2
Dynamic Overpressure Impulse at Range (Kpa-sec)	9.6
Shock Front Velocity at Range (km/sec)	0.350

FIGURE 5A. EXAMPLE 1—INPUTS AND AIRBLAST PARAMETERS

Figure 5B presents the window breakage probabilities as well as the eardrum rupture and lung damage fatality probabilities for the selected input conditions.

INPUT SECTION:	Metric Version: Units of kg, m, kilopascals, pascal-seconds, msec				
Select Type of Magazine	Select Type of Weapon	Select Type of Explosive	Select Number of Weapons or Total NEW	Enter Total NEW (kg)	Enter Range (m)
AGS--Barricaded	MK82 (500 lb Bomb)	Tritonal	Total NEW	40,000.0	500.0

OUTPUT SECTION:

EXPLOSIVE PARAMETERS

Total NEW (kg)	40,000.0
NEW per weapon (kg)	87.090
TNT Equivalence	1.07
Equivalent Hemispherical Weight (kg)	19,955.2
Effective Yield (kg)	42,800.0
(N.B.: Both Weight and Yield are in kg of TNT)	

OTHER INFORMATION

Probability of Window Breakage (percent) at Range (note: dimensions are cm)	Area = 0.186 m^2 30.5 x 61.0 x 0.020 Float annealed	**68.8**	Area = 1.626 m^2 152.4 x 106.7 x 0.559 Plate annealed	**100.0**
	Area = 0.372 m^2 61.0 x 61.0 x0.020 Float annealed	**100.0**	Area = 2.787 m^2 182.9 x 152.4 x 0.559 Plate annealed	**100.0**
	Area = 0.975 m^2 106.7 x 61.0 x 0.305 Float annealed	**100.0**	Area = 4.645 m^2 304.8 x 152.4 x 0.762 Plate annealed	**100.0**

Probability of Eardrum Rupture	**0.0**	(Mercx)
(percent) at Range	**0.0**	(Eisenberg)
Probability of lethality due to lung damage (percent) at Range	**0.0**	

FIGURE 5B. INPUTS AND OTHER INFORMATION

As can be seen, at the 500-meter range, there is a high probability that windows will be broken. However, there is a negligible probability of either eardrum rupture or lethality due to lung damage.

The second portion of the problem was to determine the range at which there was a 10% probability of eardrum rupture using the Mercx algorithm. This can be accomplished using the same input conditions and then choosing the ***GOAL SEEK*** option under the **Tools** menu. When the ***GOAL SEEK*** dialog appears, set up the problem as follows:

Set Cell:	\$B\$59 (Mercx eardrum rupture probability)
To Value:	10
By Changing Cell:	\$H\$5 (range)

The answer is 118.7 meters. This can be seen in Figures 5C and 5D, which give the outputs for this problem.

INPUT SECTION:	Metric Version: Units of kg, m, kilopascals, pascal-seconds, msec				
Select Type of Magazine	**Select Type of Weapon**	**Select Type of Explosive**	**Select Number of Weapons or Total NEW**	**Enter Total NEW (kg)**	**Enter Range (m)**
AGS--Barricaded	MK82 (500 lb Bomb)	Tritonal	Total NEW	40,000.0	118.7

OUTPUT SECTION:

EXPLOSIVE PARAMETERS

Total NEW (kg)	40,000.0
NEW per weapon (kg)	87.090
TNT Equivalence	1.07
Equivalent Hemispherical Weight (kg)	14,704.7
Effective Yield (kg)	42,800.0

(N.B.: Both Weight and Yield are in kg of TNT)

AIRBLAST PARAMETERS

Range (m)	118.7
Time of Arrival at Range (msec)	192.26
Over-Pressure at Range (kPa)	45.69
Reflected Press. at Range (kPa)	107.68
Positive Phase Duration at Range (msec)	91.7
Positive Phase Impulse at Range (Pa-sec)	1495.1
Reflected Impulse at Range (Pa-sec)	3186.6
Dynamic Overpressure at Range (kPa)	7.2
Dynamic Overpressure Impulse at Range (Kpa-sec)	166.0
Shock Front Velocity at Range (km/sec)	0.401

FIGURE 5C. RESULTS OF GOAL SEEK OPTION—INPUTS/AIRBLAST PARAMETERS

INPUT SECTION:	Metric Version: Units of kg, m, kilopascals, pascal-seconds, msec				
Select Type of Magazine	**Select Type of Weapon**	**Select Type of Explosive**	**Select Number of Weapons or Total NEW**	**Enter Total NEW (kg)**	**Enter Range (m)**
AGS--Barricaded	MK82 (500 lb Bomb)	Tritonal	Total NEW	40,000.0	118.7

OUTPUT SECTION:

EXPLOSIVE PARAMETERS

Total NEW (kg)	40,000.0
NEW per weapon (kg)	87.090
TNT Equivalence	1.07
Equivalent Hemispherical Weight (kg)	14,704.7
Effective Yield (kg)	42,800.0
(N.B.: Both Weight and Yield are in kg of TNT)	

OTHER INFORMATION

Probability of Window Breakage (percent) at Range (note: dimensions are cm)	Area = 0.186 m^2 30.5 x 61.0 x 0.020 Float annealed	**100.0**	Area = 1.626 m^2 152.4 x 106.7 x 0.559 Plate annealed	**100.0**
	Area = 0.372 m^2 61.0 x 61.0 x0.020 Float annealed	**100.0**	Area = 2.787 m^2 182.9 x 152.4 x 0.559 Plate annealed	**100.0**
	Area = 0.975 m^2 106.7 x 61.0 x 0.305 Float annealed	**100.0**	Area = 4.645 m^2 304.8 x 152.4 x 0.762 Plate annealed	**100.0**

Probability of Eardrum Rupture	**10.0**	(Mercx)
(percent) at Range	**52.9**	(Eisenberg)

Probability of lethality due to lung damage (percent) at Range	**0.0**

FIGURE 5D. RESULTS OF GOAL SEEK OPTION—INPUTS AND OTHER INFORMATION

As can be seen in Figure 5d, the eardrum rupture probability is now 10%, using the Mercx algorithm (Note: the Eisenberg algorithm predicts a 52.9% probability of eardrum rupture for these same conditions). As can be seen in the input section, the range has been adjusted to a value of 118.7 meters to achieve this result.

SUMMARY

The latest version of the DDESB Blast Effects Computer has been presented. The significant differences between Version 3.0 and previous versions have been discussed. In addition, some of the procedures for adding new PESs have been discussed. Finally, a sample problem that demonstrates some of the uses of the calculator is presented.

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