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AMRISK version 2.0
Documentation of verification tests

HOLM Knut B (ed), ELFVING Carl, BERGLUND Roger, BRYNTSE Anders, ØIOM Hans

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8) ABSTRACT

This report documents the test results for Version 2.0 of the ammunition storage risk analysis tool AMRISK. AMRISK 2.0 contains new models for air blast outside freestanding and earth-covered magazines. In addition the user interface of the program is improved. The verifcation tests show that the new models are implemented correctly. For some cases they produce results considerably different from the results of the old model

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1 INTRODUCTION

In 2001 Norwegian and Swedish Defence entered an agreement on revising and developing AMRISK, a program for quantitative risk analysis of ammunition storages. AMRISK 2.0 is the final stage of the development and the end of the current contract.

The first stage of AMRISK, AMRISK 1.0, is identical to the program AMMORISK as of 30th June 2000. AMMORISK was based on a Swiss risk analysis model and has been used in Norway since 1983. During this period the program has repeatedly been improved and modified.

AMRISK 1.1 is mainly a Windows-version of AMRISK 1.0, which was implemented for MS-DOS. The graphical user interface includes all input and output values, and the storage sites and the exposed objects are displayed in map drawings. The verification of the calculations and functionality of the program is documented in (1).

In AMRISK 1.2 functions for exchanging data with a geographical information system (GIS) are included. Input can be made by point-and-click on maps. User's Guide (2) and Programmer's Manual are integrated in the program as help-files. The program verification is described in (3).

The main distinction between AMRISK version 2.0 and the previous versions is the new models for physical effects. In addition some improvements have been made in the calculation algorithms and the user interface. This includes correction of the errors discovered in the period after AMRISK 1.2.1 was released. This report does not describe pure error recovery without any advances in calculations or user interface. Except for the new models the improvements in AMRISK 2.0 are also implemented in new versions of AMRISK 1.2.

2 AMRISK 2.0

2.1 New models

All the models in AMRISK that estimates physical effects have been evaluated in connection with the program update. The models should give a sufficiently good description of the physical processes. In addition it is considered desirable to use models described in NATO manuals, e.g. (4), especially when consensus to one model is established. For several of the AMRISK models regarded as ready for an update, there are however no alternative models available. Other models are in development and will probably be included in later AMRISK versions.

Ultimately, two new models have been implemented in AMRISK 2.0. These are models for air blast from freestanding and earth-covered magazines.

The new models are based on experimental data that are more comprehensive than the experimental basis of the old models. Moreover the models are implemented in several risk analysis programs and included in NATO documents.

2.1.1 Air blast from freestanding magazines

The lethality from air blast is in AMRISK generally dependent on the peak pressure, *p*, or the dynamic impulse, i_q. This impulse is calculated as

$$i_q = 0.12\, p^{5/3} t_{\mathrm{ip}} \tag{2.1}$$

using the impulsively effective duration t_{ip}, which is proportional to the positive blast wave duration, t_+.

$$t_{\mathrm{ip}} \cong \frac{2}{3} t_+ \tag{2.2}$$

The lethality from dynamic impulse is in AMRISK calculated by the quantity $p^{5/3}t_{\mathrm{ip}}$.

In AMRISK 1.2, the maximum pressure of the air blast from a freestanding (FS) magazine is calculated as (5)

$$p = \exp\left(5.5502 - 2.0975 \ln Z + 1.4819\sqrt{\left(\ln Z - 3.6555\right)^2 + 1.3573}\right) \tag{2.3}$$

where

$$Z = \frac{R}{Q^{1/3}} \tag{2.4}$$

p is given in bars, *R* is the distance in meters from the magazine centre, and *Q* is the charge weight corresponding to metric tons of TNT.

The formula estimating the impulse is

$$\frac{p^{5/3} t_{\mathrm{ip}}}{Q^{1/3}} = \exp\left(4.824 - 0.07626 Z + 0.04984\sqrt{\left(Z - 35.88\right)^2 + 167.8}\right) \tag{2.5}$$

when t_{ip} is given in ms.

The new air blast model employs the simplified Kingery model (6), where the pressure and the positive phase duration are given by the expression

$$y = \exp\left(A + B\ln z + C\left(\ln z\right)^2 + D\left(\ln z\right)^3 + E\left(\ln z\right)^4 + F\left(\ln z\right)^5\right) \quad (2.6)$$

where

$$z = Z/10 \quad (2.7)$$

Thus z is denominated m/kg$^{1/3}$ whereas Z has the denomination m/ton$^{1/3}$. The constants for the pressure are listed below.

Table 2.1 Parameters in Kingery's simplified equation for determining maximum pressure, p/kPa, outside a freestanding magazine

Scaled range, z / $\mathrm{m/kg^{1/3}}$	A	B	C	D	E	F
0.2 – 2.9	7.2106	-2.1069	-0.32290	0.1117	0.06850	0
2.9 – 23.8	7.5938	-3.0523	0.40977	0.0261	-0.01267	0
23.8 – 198.5	6.0536	-1.4066	0	0	0	0

To get values for the lethality also in the extraordinary cases when the scaled distance is less than 0.2 m/kg$^{1/3}$, AMRISK 2.0 sets the distance to 0.2 m/kg$^{1/3}$, which gives the correct lethality 1. However the corresponding pressure value may then be incorrect.

The program code of the model is listed in appendix A. In Figure 2.1 the pressures calculated by AMRISK 1.2 and AMRISK 2.0 are compared.

At small and large distances the pressure values calculated by the new model in AMRISK 2.0 is significantly smaller than the values estimated by AMRISK 1.2. However the smallest distances are rarely relevant.

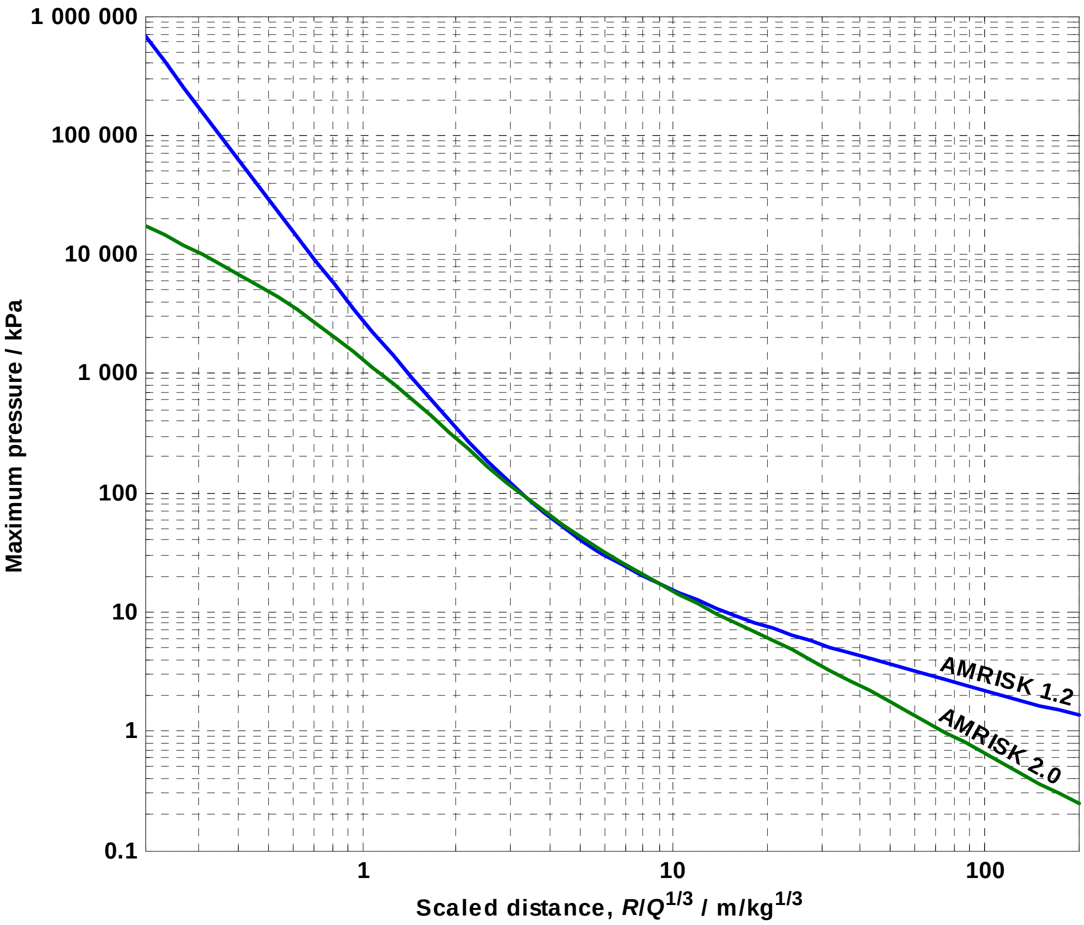

Figure 2.1 Maximum pressure outside a freestanding magazine calculated by AMRISK 2.0 and AMRISK 1.2

Kingery's simplified model does not give the dynamic impulse directly. Therefore AMRISK 2.0 makes use of Kingery's model to estimate the maximum pressure and the duration of the positive pressure wave. Then the dynamic impulse parameter $p^{5/3}t_{ip}$ can be calculated.

For the duration, Kingery's simplified model applies for scaled ranges up to 40 m/kg$^{1/3}$. For larger ranges a power equation adjusted to the upper part of Kingery's curve is employed. This extrapolation may be compared with other models estimating the duration. Kingery's simplified model also gives the shock impulse of the blast wave, and the formula is valid up to 160 m/kg$^{1/3}$. From this it is possible to calculate the duration by assuming a certain shape of the pressure-time curve, for instance a triangular wave where $t_+ = 2I/p$. Figure 2.2 shows duration values from different models.

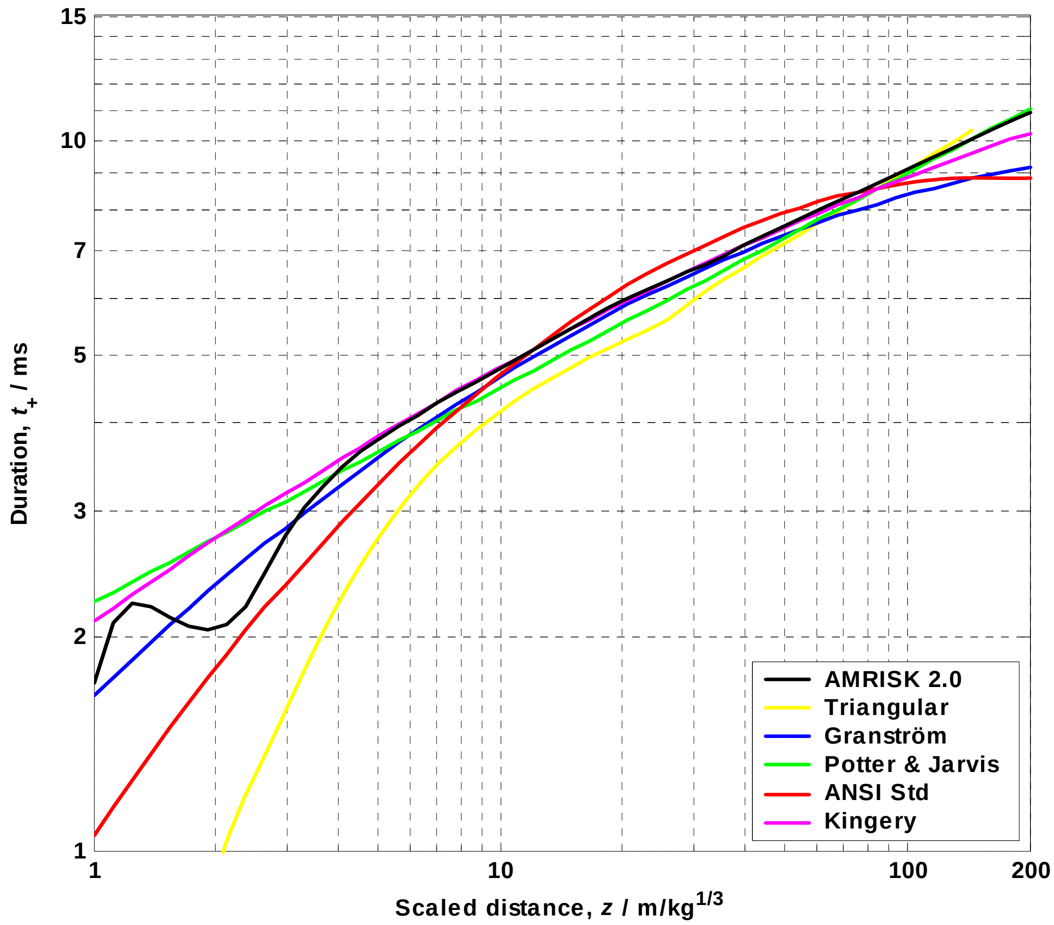

Figure 2.2 *Duration of the blast wave outside a freestanding magazine estimated by AMRISK 2.0, from impulse and pressure (triangular), Granström, Potter & Jarvis, ANSI Standard and Kingery*

This figure shows that the duration given by AMRISK 2.0 is in good accordance with other models, especially at the largest distances where the extrapolation of Kingery's simplified model is used.

The extended version of Kingery's simplified model for the duration has the set of parameters specified in Table 2.2. The resulting dynamic impulse is shown and compared with results form AMRISK 1.2 in Figure 2.3.

Table 2.2 Parameters for determining scaled duration, $t_+/Q^{1/3}/\left(ms/kg^{1/3}\right)$*, outside a free-standing magazine*

Scaled range, z / $\mathrm{m/kg^{1/3}}$	*A*	*B*	*C*	*D*	*E*	*F*
0.2 – 1.02	0.5426	3.2299	-1.5931	-5.9667	-4.0815	-0.9149
1.02 – 2.8	0.5440	2.7082	-9.7354	14.3425	-9.7791	2.8535
2.8 – 40	-2.4608	7.1639	-5.6215	2.2711	-0.44994	0.03486
40 – 200	0.9771	0.2679	0	0	0	0

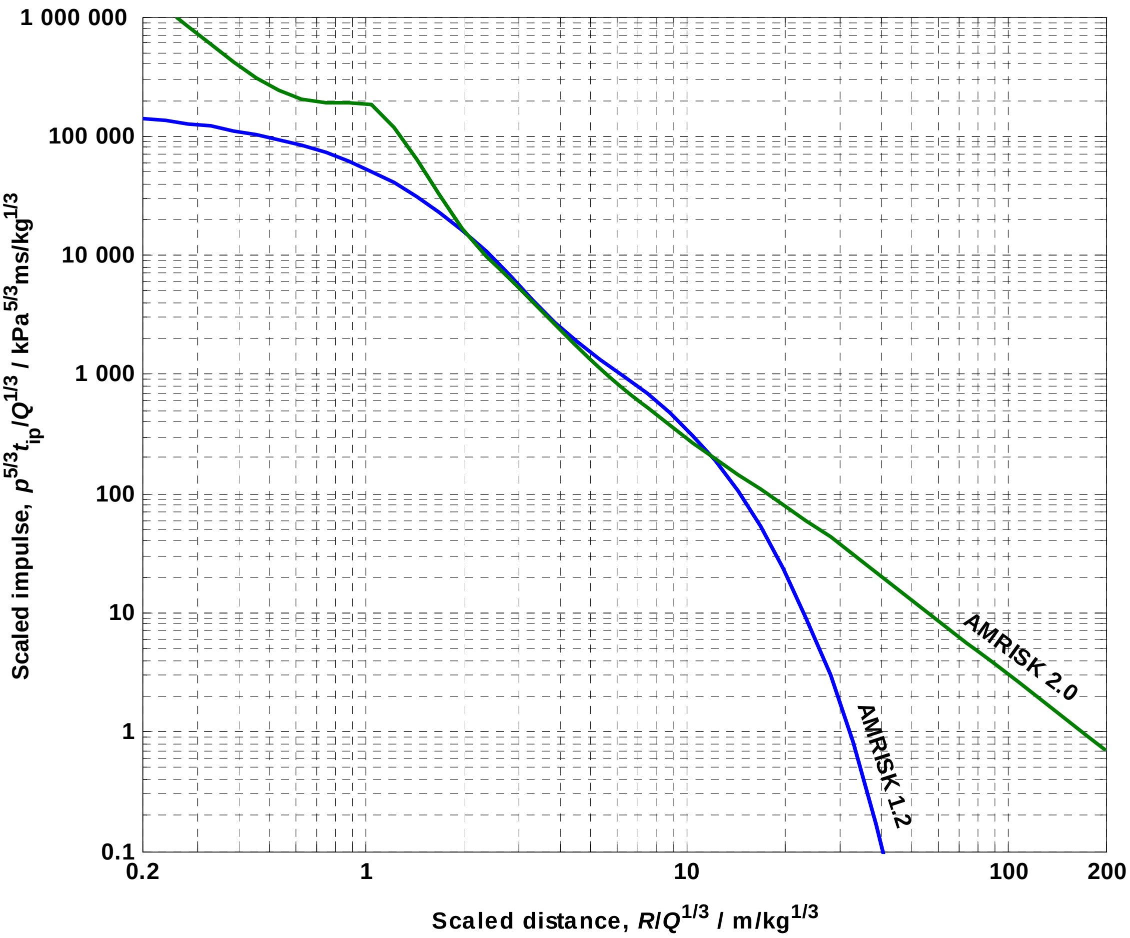

Figure 2.3 Dynamic impulse outside a freestanding magazine calculated by AMRISK 2.0 and AMRISK 1.2

As opposed to the pressure the dynamic impulse estimated by the model in AMRISK 2.0 is for the most part larger than the impulse given by the model in AMRISK 1.2. At large distances the difference is extensive.

2.1.2 Air blast from earth-covered magazines

In AMRISK 1.2 the air blast outside an earth-covered magazine is calculated by the equation (5)

$$p = 47 Z^{-1.293} \tag{2.8}$$

when p is given in bars. The corresponding impulse is

$$\frac{p^{5/3} t_{\text{ip}}}{Q^{1/3}} = 790\, Z^{-1.458} \tag{2.9}$$

AMRISK 2.0 makes use of Kingery's simplified model also for earth-covered magazines. Unlike AMRISK 1.2 the model (7), given by equation (2.6), also consider directional effects. Therefore the model parameters are different for the front, side and rear of the magazine. The front is supposed to be a 120° sector, there are two 75° side sectors and the rear is a 90° sector, see Figure 2.4.

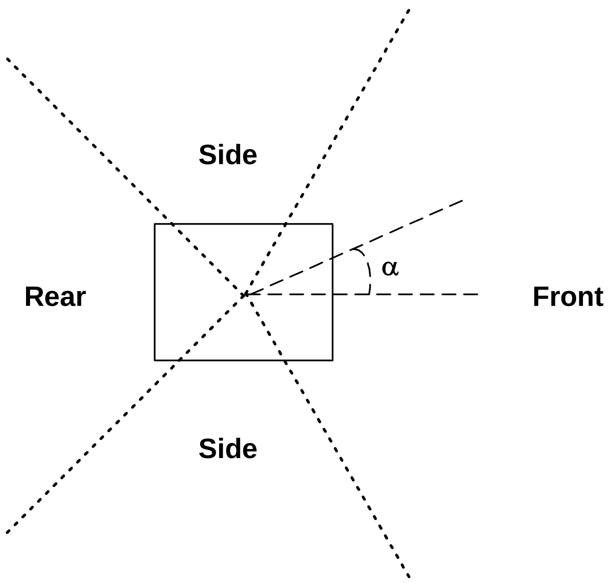

Figure 2.4 Division of the area around an earth-covered magazine according to Kingery's simplified model for estimating blast pressure

Table 2.3 shows the parameters.

Table 2.3 Parameters for determining the maximum pressure, p/kPa, outside an earth-covered magazine, 2 < z < 200

	A	*B*	*C*	*D*	*E*	*F*
Front	7.6032	-2.28717	-0.34671	0.27438	-0.05391	0.00342
Side	5.65556	-1.164	0.031	-0.0849	0.021	-0.00148
Rear	5.55581	-1.47687	0.14494	-0.08519	0.01745	-0.00118

In AMRISK 2.0, Kingery's model with these parameters is used down to $z = 0.7$. The resulting pressure values are shown in Figure 2.5. The figure also shows pressure values calculated by the old model in AMRISK 1.2.

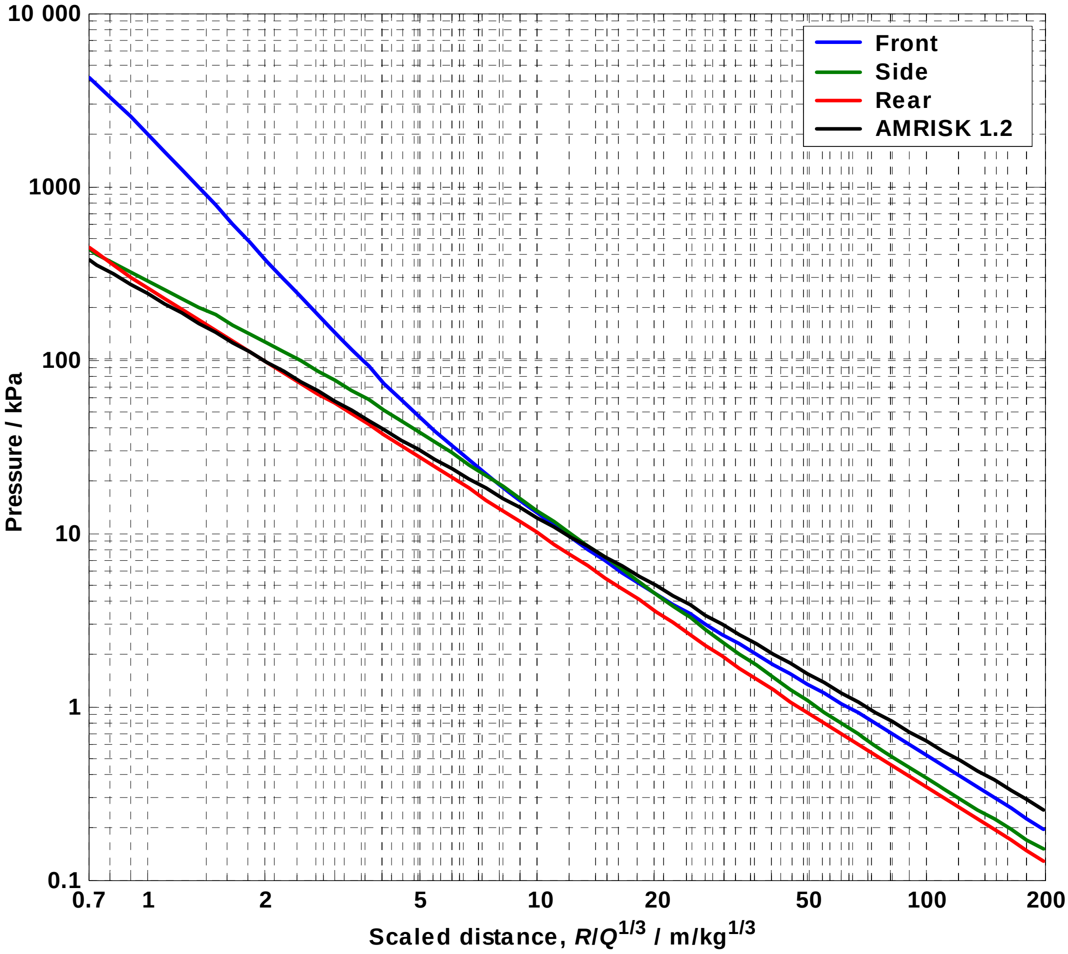

Figure 2.5 Maximum pressure outside an earth-covered magazine calculated by AMRISK 1.2 and at the front, rear and side of an earth-covered magazine calculated by AMRISK 2.0

The new model assumes a larger maximum pressure than the old model in the front and to the side of the magazine for scaled distances less than about 12 $m/kg^{1/3}$. At larger distances the pressure in the new model is reduced relative to the old. At the rear of the magazine the new model gives smaller pressure values at distances larger than 2 $m/kg^{1/3}$, and the difference increases with the distance.

The pressure in the front of the magazine is larger than the pressure to the side and the rear, especially at small distances. An exception to this, which is difficult to give a physical explanation, is at distances between 10 and 20 $m/kg^{1/3}$ where the side pressure is slightly larger.

At scaled distances just above 0.7 m/kg$^{1/3}$ the pressure at the rear of the earth-covered magazine is larger than the pressure at the side. This may indicate that the extrapolation of Kingery's simplified model below 2 m/kg$^{1/3}$ produces some incorrect results. Therefore the results from the new model are examined more closely by comparing them with results from the model in the programs SAFER and BEC (8). Figure 2.6 shows the pressure values.

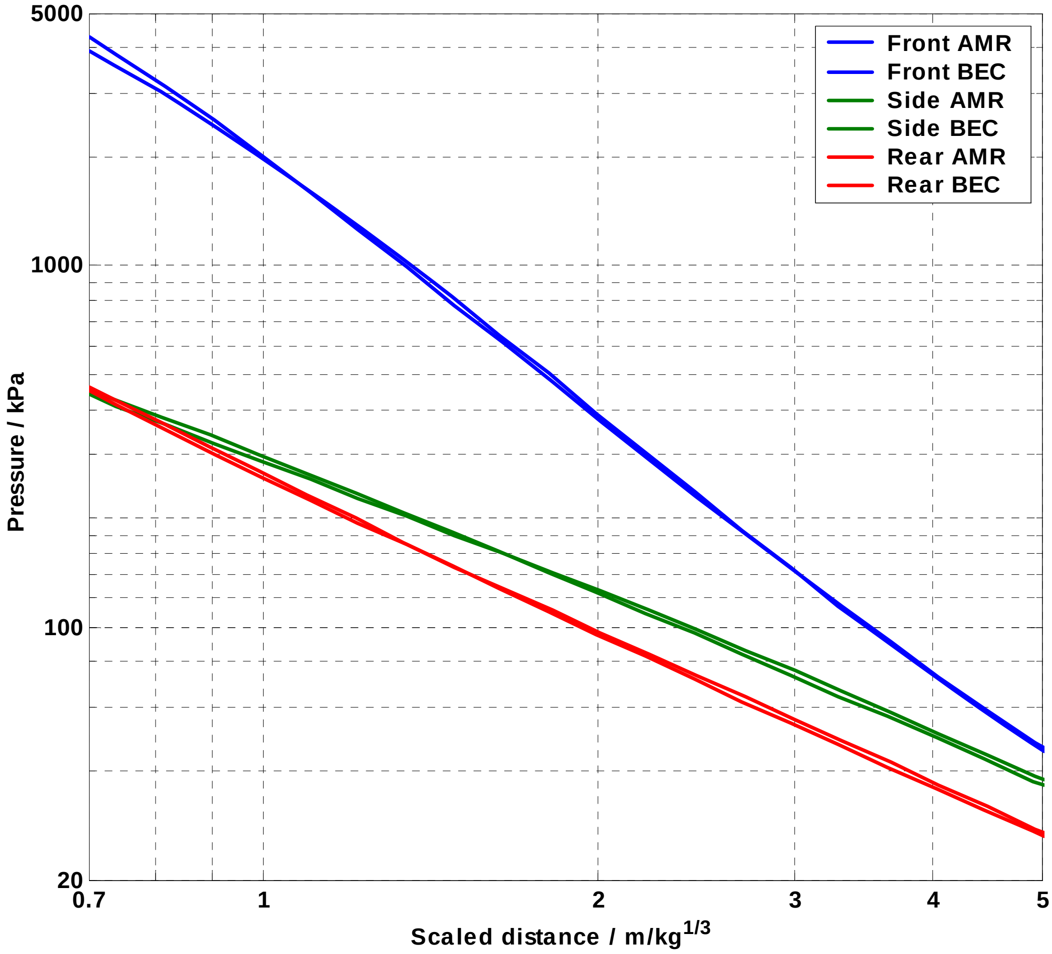

Figure 2.6 Maximum pressure outside an earth-covered magazine calculated by AMRISK 2.0 and BEC

The figure shows that the extension of the model down to 0.7 m/kg$^{1/3}$ gives results in good agreement with the BEC model.

Analogous to the model for freestanding magazines the scaled distance is set to minimum 0.7 m/kg$^{1/3}$ when the pressure outside an earth-covered magazine is determined. At this distance the lethality from pressure at free-field objects at the side and the rear of the magazine is 0.98. For all other objects the lethality is 1. Also here it should be noted that the calculated pressure values at distances less than 0.7 m/kg$^{1/3}$ may not be reliable.

Kingery's model assumes a stepwise angle distribution of the pressure. In reality there is a smooth distribution, and the distribution used in AMRISK 2.0 is the stepwise distribution smoothed by the formula below.

$$p = p_{\text{f/r}} \sqrt{\frac{p_{\text{side}}{}^2 \left(1 + \tan^2 \alpha\right)}{p_{\text{side}}{}^2 + p_{\text{f/r}}{}^2 \tan^2 \alpha}} \qquad (2.10)$$

$$p_{\text{f/r}} = \begin{cases} p_{\text{front}} & 270° \le \alpha \le 90° \\ p_{\text{rear}} & 90° < \alpha < 270° \end{cases}$$

where the angle to the point considered, α, is 0° at the entrance axis (Figure 2.4).[1]

The program code of the model is listed in appendix A. The results produced by the model may be illustrated by an example showing isobars around an earth-covered magazine, see Figure 2.7.

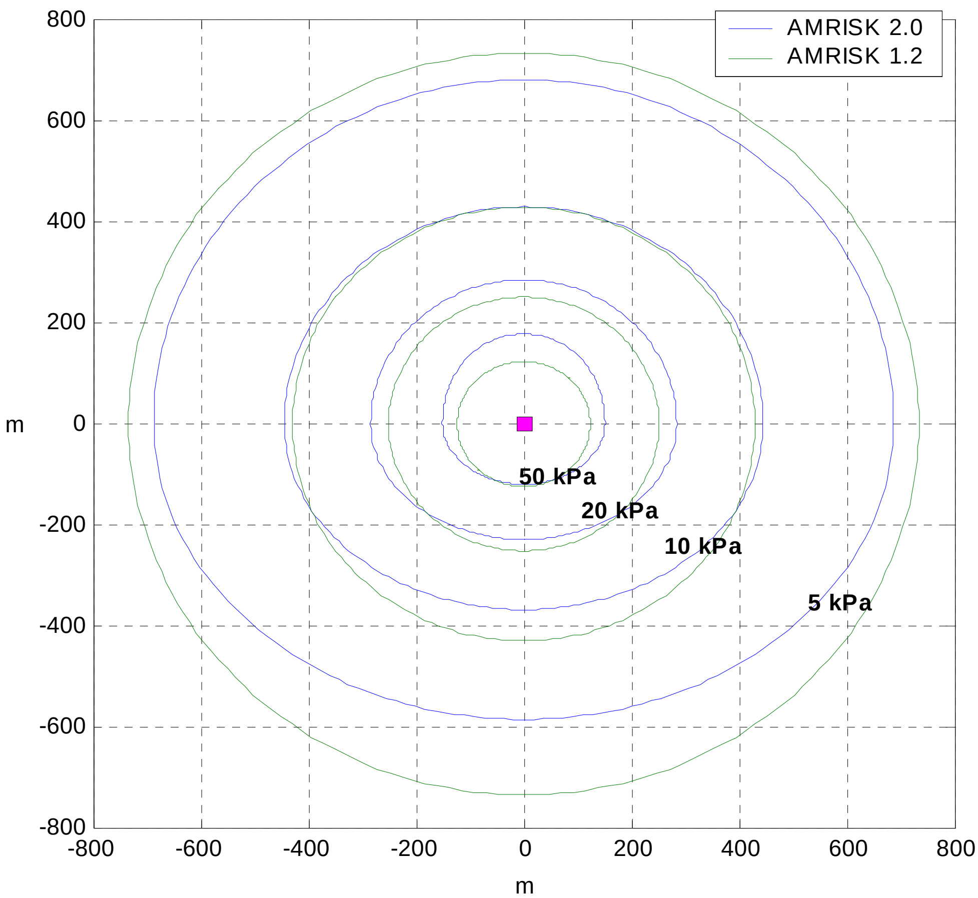

Figure 2.7 Isobars from an explosion of 50 metric tons in an earth-covered magazine with the entrance upwards, calculated by the models in AMRISK 1.2 and AMRISK 2.0

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[1] The access point of aboveground magazines defining the entrance axis is outside the magazine. Thus the angle to the position where the pressure or impulse is calculated is shifted 180° relative to an underground installation where the access point is inside the entrance.

The parameters according to equation (2.6) for estimating the duration of the blast wave outside an earth-covered magazine are listed in Table 2.4 below.

Table 2.4 Parameters for determining scaled duration, $t_+ / Q^{1/3} / \left(ms / kg^{1/3} \right)$*, outside an earth-covered magazine*

	Scaled range, *z* / $m/kg^{1/3}$	*A*	*B*	*C*	*D*	*E*	*F*
Front	0.7 – 2.8	0.386364	0.853478	-0.69357	-2.16149	4.55691	-2.00316
	2.8 – 40	-1.93321	6.16328	-4.9	1.97343	-0.38493	0.029083
	40 – 200	0.460803	0.525296	-0.04567	0	0	0
Side	0.7 – 2.6	0.161349	0.436003	-0.195093	0.657763	0.84928	-1.00476
	2.6 – 40	-0.945587	3.66105	-2.69461	1.09865	-0.225794	0.0183546
	40 – 200	1.00205	0.207429	-0.00055519	0	0	0
Rear	0.43 – 2	0.116706	0.160406	0.600365	1.03725	-0.51708	-0.57615
	2 – 40	-0.37572	2.33924	-1.75688	0.783067	-0.17273	0.014652
	40 – 200	0.334124	0.580877	-0.05944	0	0	0

The coefficients in Table 2.4 are derived from (9) through plotting of the different durations in English units, converting to SI units and then refitting polynomials. The values for *z* over 40 $kg/m^{1/3}$ are found by extrapolating curves that are fitted to duration values for *z* between 15 and 40 $kg/m^{1/3}$, equivalent to the duration outside freestanding magazines.

When the duration is calculated by Kingery's simplified model using the parameters above, the dynamic impulse becomes as Figure 2.8 shows.

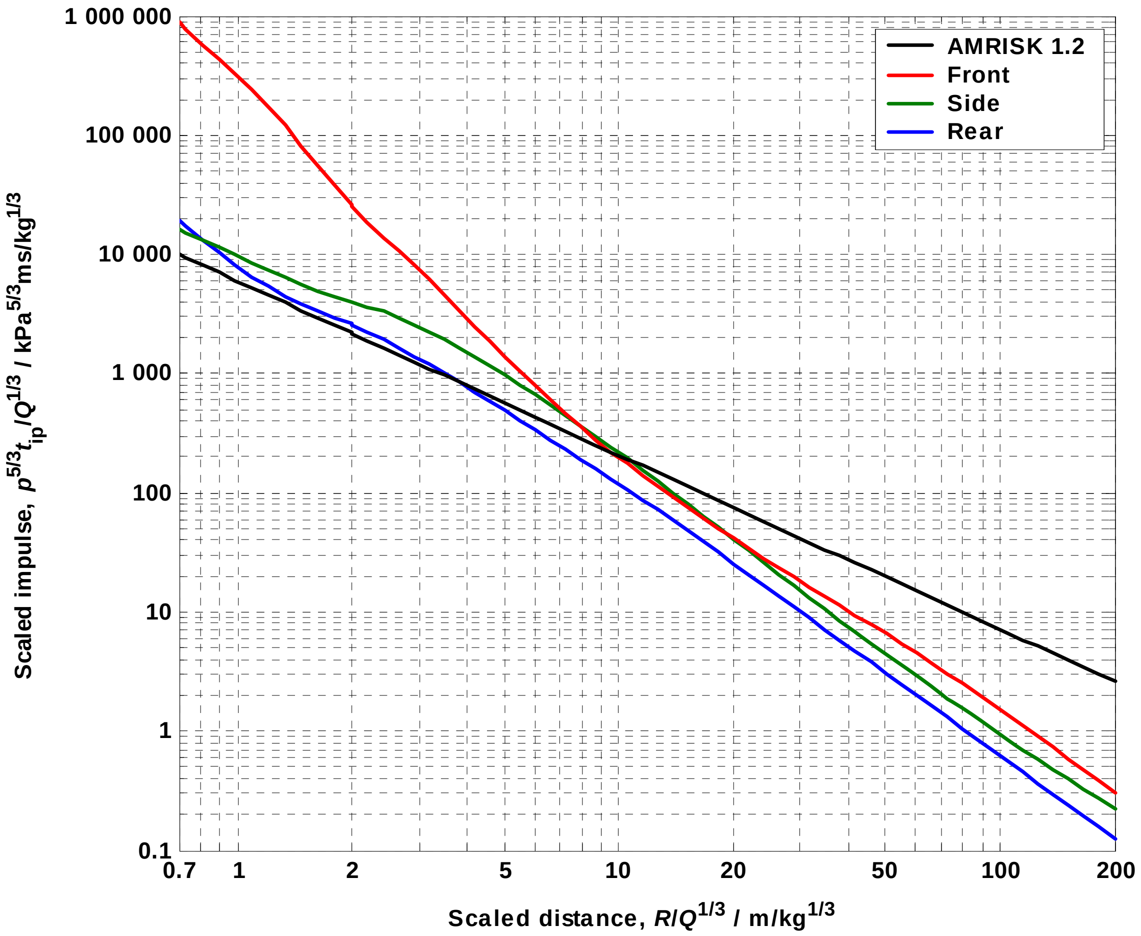

Figure 2.8 Dynamic impulse outside an earth-covered magazine calculated by AMRISK 1.2 and at the front, side and rear calculated by Kingery's simplified method

The relation between the dynamic impulses of the old and the new model follows a similar pattern as the pressure, but the differences are significantly larger.

The angle distribution of the duration is assumed to be identical to the pressure distribution, ref. equation (2.10), resulting in an analogous angle distribution of the impulse. Figure 2.9 shows examples of isoimpulse curves.

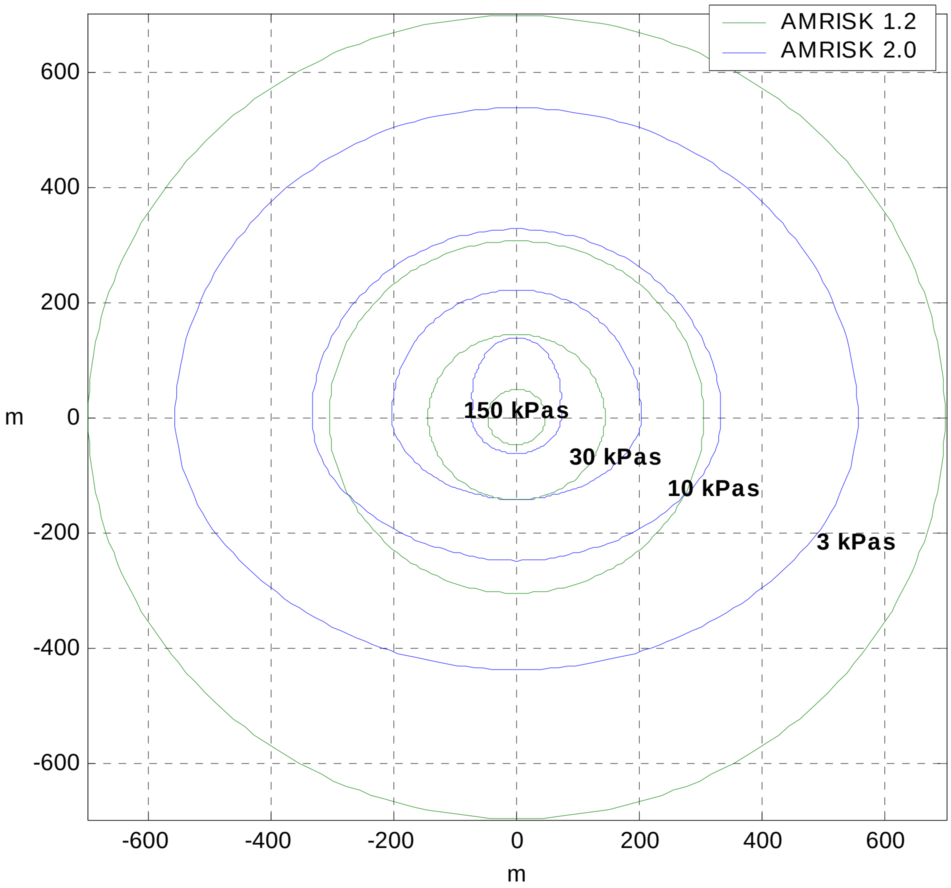

Figure 2.9 Isoimpulse curves from an explosion of 50 metric tons in an earth-covered magazine calculated by the models in AMRISK 1.2 and AMRISK 2.0 (entrance upwards)

2.2 Changes in user interface

Improvement of the user interface of AMRISK has been a continuing process after the completion of AMRISK 1.2. The description below of the main changes does not include the accompanying changes in algorithms and program code.

2.2.1 Calculated values

The window showing calculated values has been extended to include collective risk values for all magazines and exposed objects at the installation.

As opposed to aboveground facilities, the lethality from debris from underground installations uses a specific distance as the effect parameter. In AMRISK 2.0 the description of this parameter under ‘Detailed values’ is changed correspondingly.

In the window showing ‘Detailed values’ a reference to the object considered is now included.

2.2.2 Ammunition gross weight

In AMRISK 1.2 the gross weight of ammunition was automatically calculated as the net explosive weight divided by 0.17 when the information about the storage content was saved. In AMRISK 2.0 the calculation is carried out only when the gross weight is not entered.

2.2.3 Printouts

AMRISK produces a series of printouts containing information about the user input and the calculated results. In AMRISK 2.0 the printouts are given a better and more readable layout. During this process errors have also been corrected.

3 VERIFICATION TESTS

The verification of AMRISK 2.0 is mainly comprised of testing the new models. First of all the values calculated by the new models in AMRISK are controlled by comparing them with calculations made outside AMRISK. In addition it is interesting to compare the results with the corresponding results from AMRISK 1.2.

3.1 Freestanding magazine

The example used for verification of the new air blast model for freestanding magazines consists of a magazine and ten exposed objects at seven different positions, see Figure 3.1.

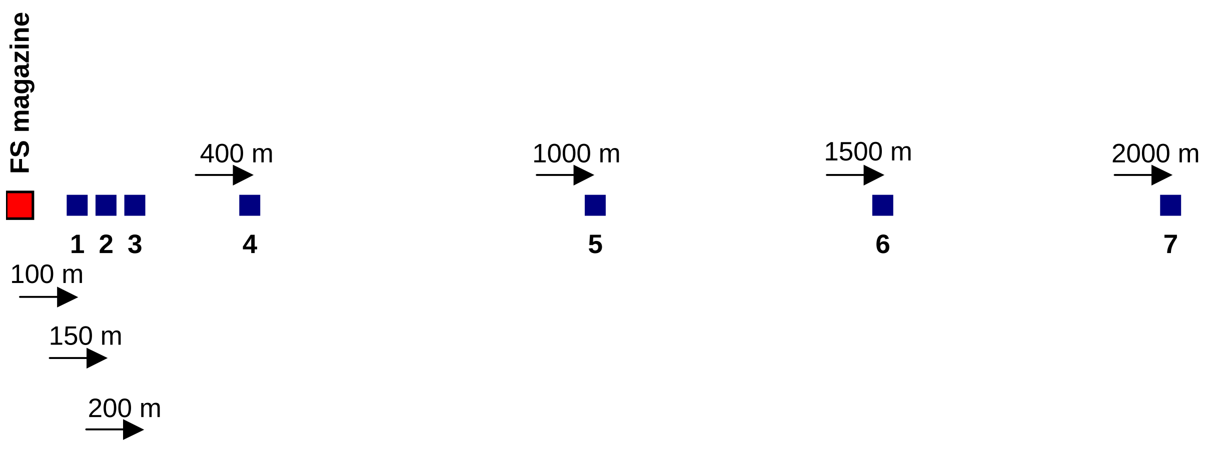

Figure 3.1 Position of freestanding magazine and exposed objects used in verification of air blast model

The magazine contains explosives corresponding to 50 000 kg TNT. The details of the exposed objects are shown below.

Table 3.1 Properties of exposed objects around a freestanding magazine

Pos	Exposed object	Distance/m	z/(m/kg$^{1/3}$)
1	Building (BN)	100	2,71
1	Freefield (FF)	100	2,71
2	Building (BN)	150	4,07
2	Freefield (FF)	150	4,07
3	Building (BN)	200	5,43
3	Freefield (FF)	200	5,43
4	Building (BN)	400	10,86
5	Building (BN)	1000	27,14
6	Building (BN)	1500	40,72
7	Building (BN)	2000	54,29

In Table B.1 the results from AMRISK are compared with results from external calculations. The comparison shows only insignificant differences between AMRISK and the reference values.

In Table B.2 the results from AMRISK 2.0 are compared with results from the air blast model in AMRISK 1.2. The results are reproduced in Figure 3.2 and Figure 3.3. For a more general comparison of pressure and impulse values, see chapter 2.1.1.

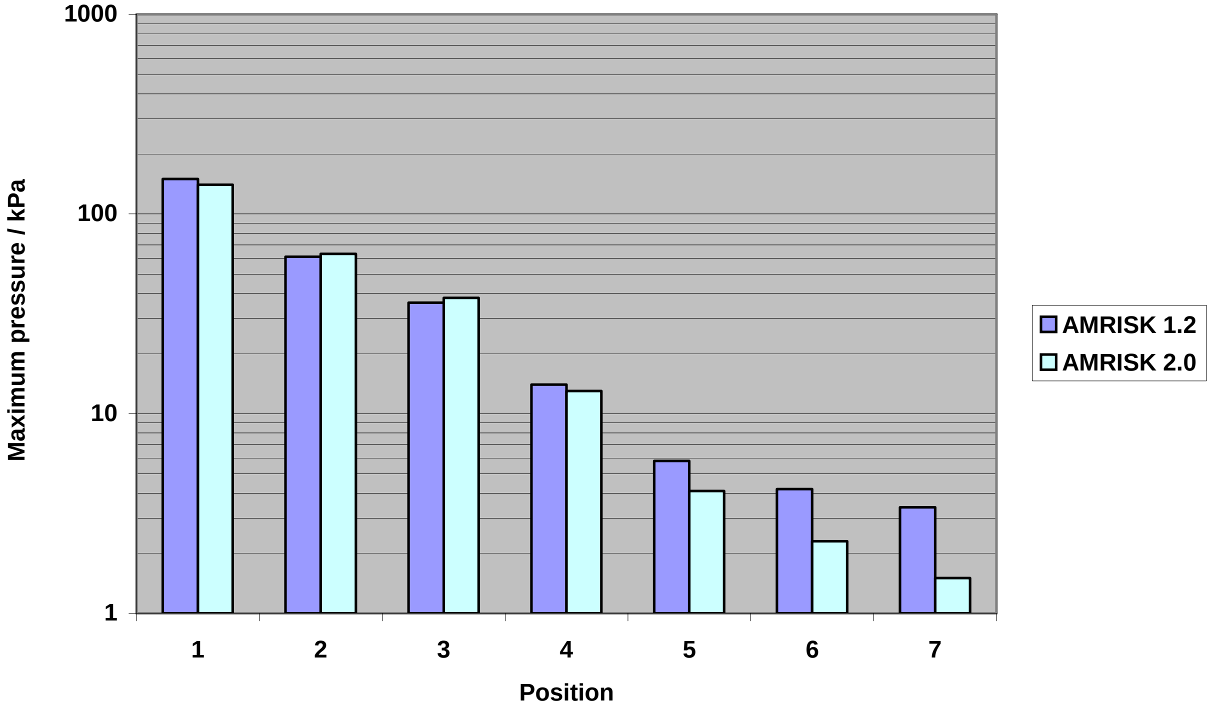

Figure 3.2 Pressure at positions of exposed objects around a freestanding magazine calculated by models in AMRISK 1.2 and AMRISK 2.0

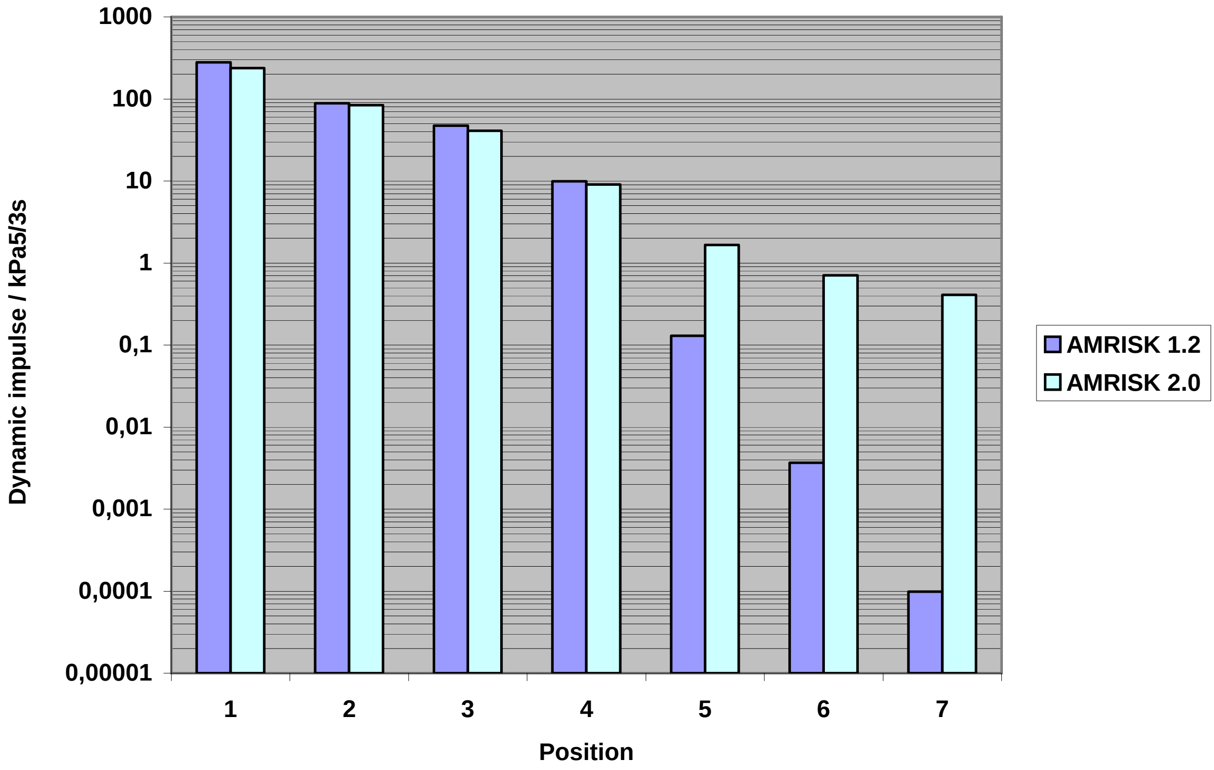

Figure 3.3 Dynamic impulse at positions of exposed objects around a freestanding magazine calculated by models in AMRISK 1.2 and AMRISK 2.0

For scaled distances less than about 10 $m/kg^{1/3}$ (position 1-4) the values of pressure and dynamic impulse from the new and the old model are commensurable. For larger distances the new model's pressure values go down to just above 50 % of the old values. The dynamic impulse is on the other hand estimated to be up to 4000 times larger in the new model compared to the old.

The pressure and the impulse give lethality values as shown in Figure 3.4 (ref. (5)).

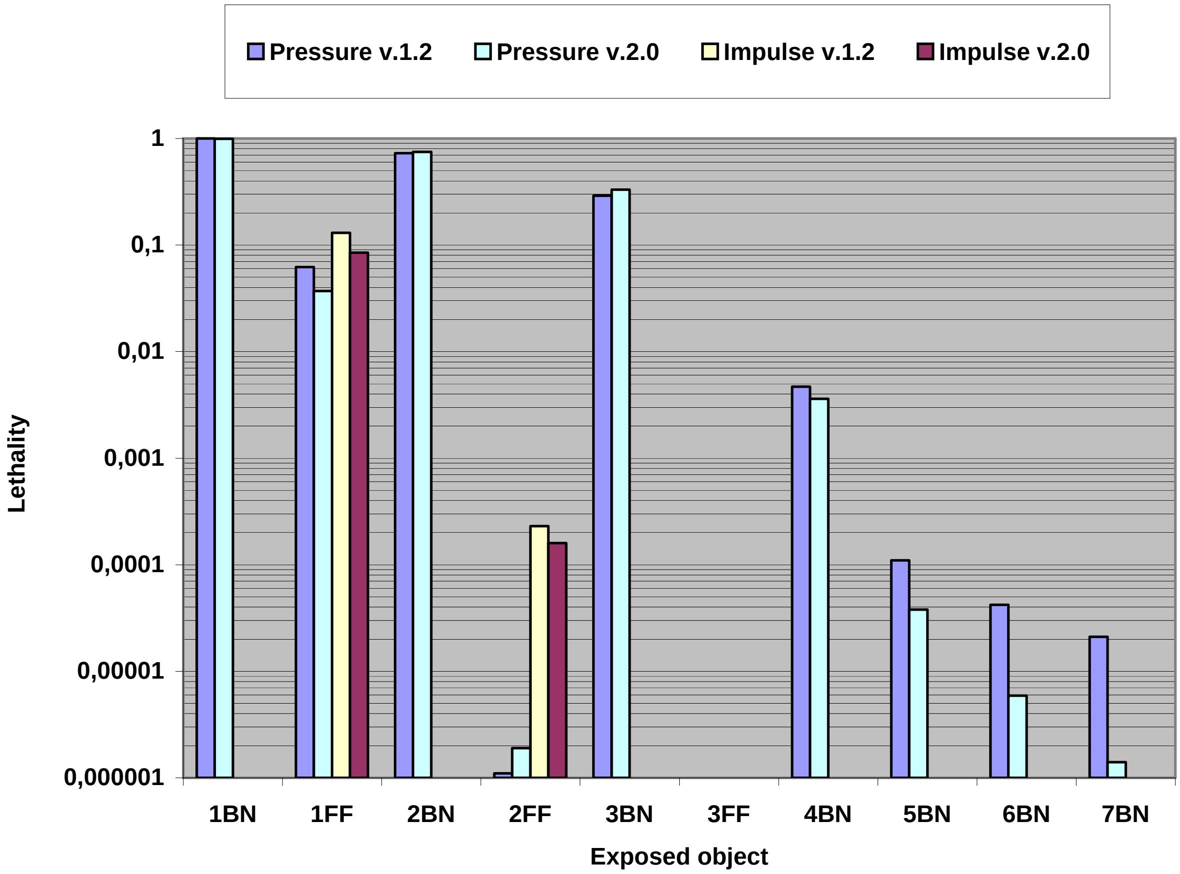

Figure 3.4 Lethality from pressure and dynamic impulse in free field (FF) and normal buildings (BN) around a freestanding magazine calculated by models in AMRISK 1.2 and AMRISK 2.0

Lethality values less than 10^{-6} are not traced here. Note that the dynamic impulse is considered not to cause any lethality to people in buildings. The difference between the lethality values from AMRISK 1.2 and AMRISK 2.0 increases with the distance, and at the object farthest from the magazine the lethality of the new model is 1/15th of the old. For the two free-field objects closest to the magazine the dynamic impulse gives the highest lethality, and the values from AMRISK 2.0 are almost 70 % of those from AMRISK 1.2.

3.2 Earth-covered magazine

The verification of the model for air blast around earth-covered magazines is more comprehensive because it must take into account the directional effects of the model. The exposed objects are the objects used in the verification of the model for freestanding magazines, placed in six directions as Figure 3.5 shows.

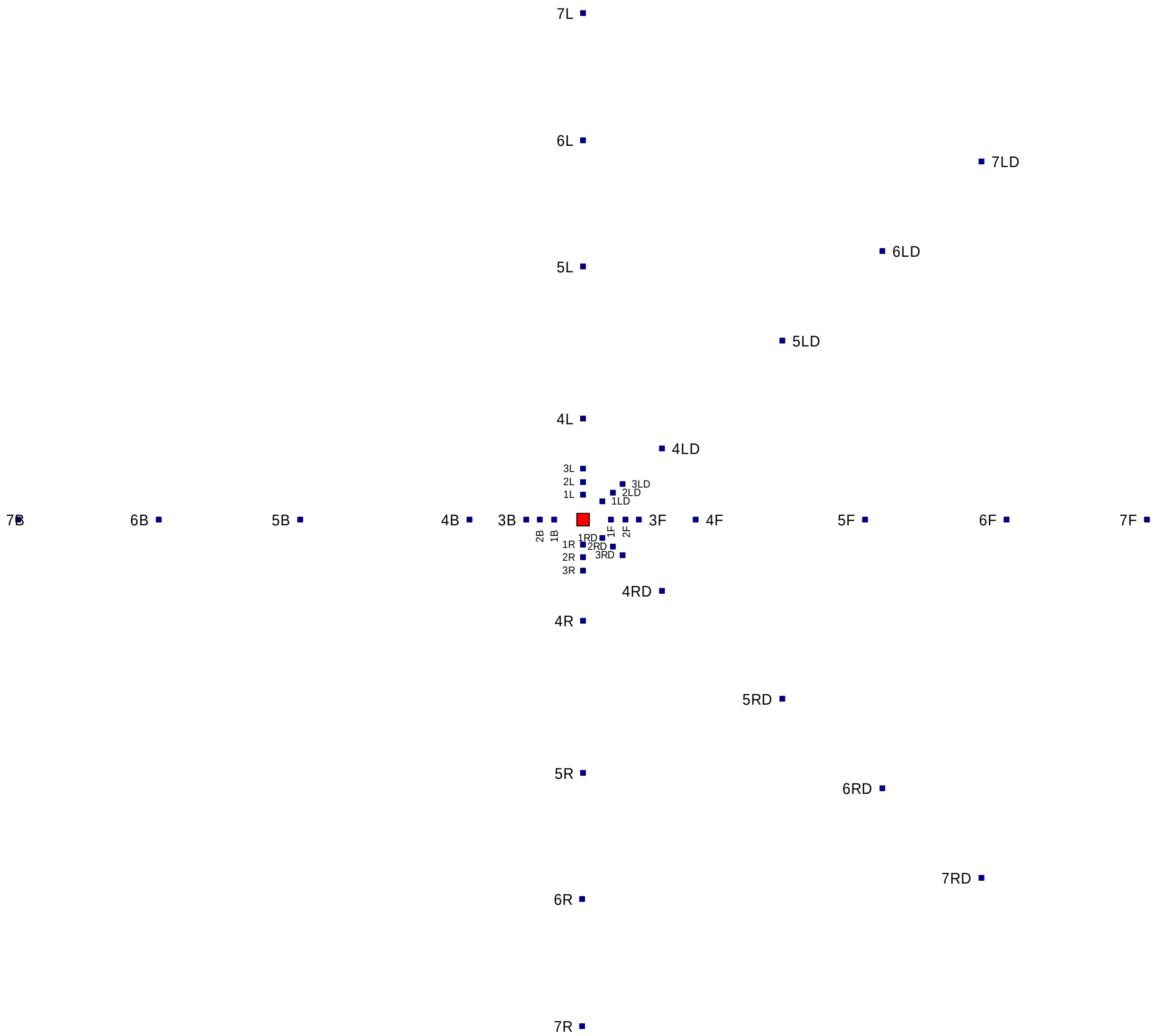

Figure 3.5 Position of exposed objects used in verification of air blast model around an earth-covered magazine

The details of the positions and types of the exposed objects are listed in Table B.3 together with the results from AMRISK 2.0 compared with the external calculation results. The results show that the calculations in AMRISK 2.0 using the new model for air blast around earth-covered magazines produce correct results.

The general tendencies described in chapter 2.1 are reflected in the results from the verification examples listed in Table B.4. Figure 3.6 shows pressure values at the positions of the exposed objects. Note that the values for the objects at left and at the left diagonal are equal to the values at right and at the right diagonal.

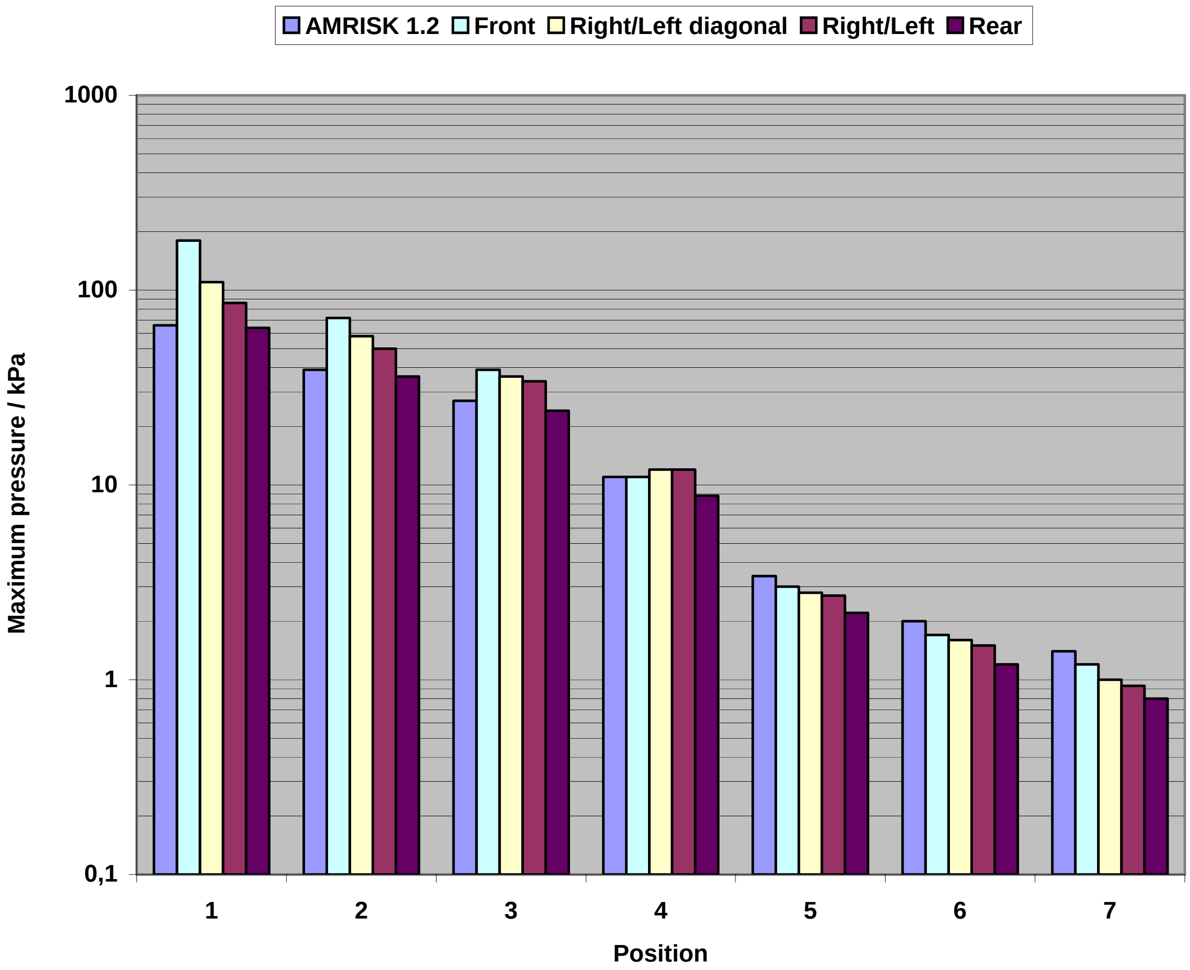

Figure 3.6 Pressure at positions of exposed objects around an earth-covered magazine calculated by models in AMRISK 1.2 and AMRISK 2.0

The pressure calculated by AMRISK 1.2 does not depend on the direction. Except for one distance (position 4) the pressure at the right or left side is smaller than the pressure at the front of the magazine. The pressure at the objects at the right/left diagonal is between the pressure at the front and at the right/left side. Closest to the magazine at position 1 the ratio of the pressures calculated by the new and the old model varies between 270 % and 97%. At the most remote exposed objects the corresponding ratios are between 86 % and 57 %.

The values of the dynamic impulse are shown in Figure 3.7.

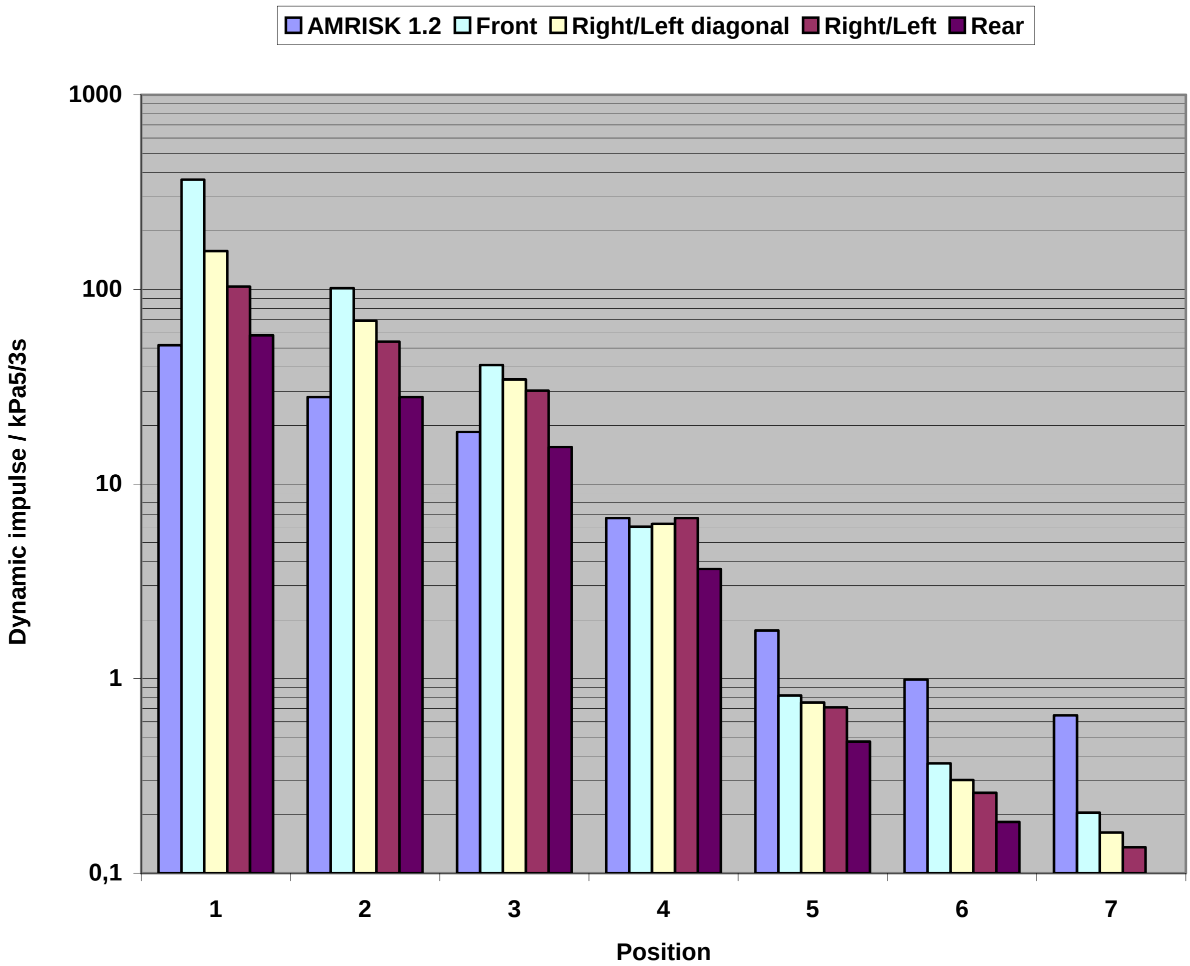

Figure 3.7 Dynamic impulse at positions of exposed objects around an earth-covered magazine calculated by models in AMRISK 1.2 and AMRISK 2.0

At position 4 also the dynamic impulse is larger at the right/left hand side than in the front. Compared to the model in AMRISK 1.2, the new model produces 1.1 to 7 times larger impulse values at the objects closest to the magazine. At the most distant objects the relation is opposite, for instance at position 7 where the values from the new model are between 3.2 and 6.8 times smaller than the impulse from the old model.

Figure 3.7 shows the lethality values resulting from the pressure at the exposed objects.

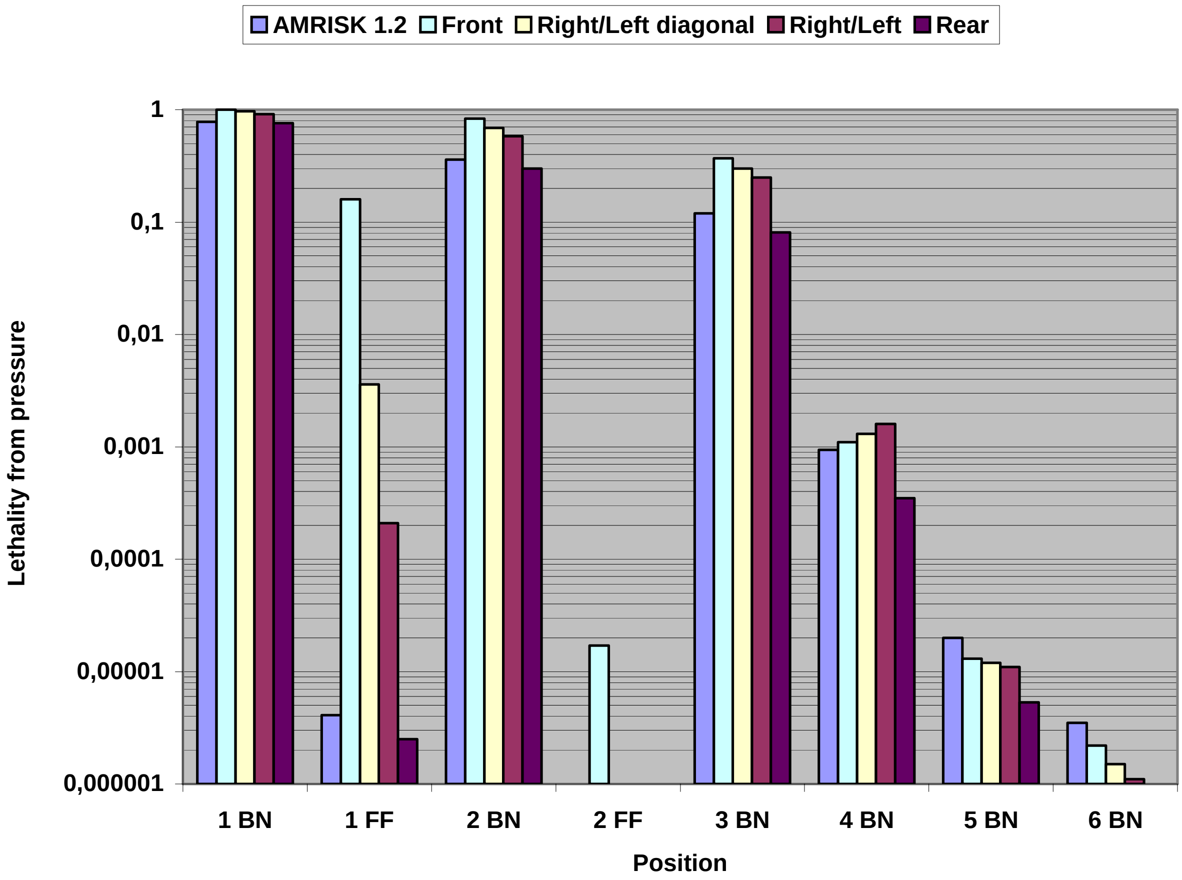

Figure 3.8 *Lethality from pressure in free field (FF) and normal buildings (BN) around an earth-covered magazine calculated by models in AMRISK 1.2 and AMRISK 2.0*

For free field objects at position 1 the direction has a huge influence on the lethality, which varies between $2.5 \cdot 10^{-6}$ and 0.16. For the free field objects at position 2 and 3 the lethalities are insignificant with a possible exception for the object at position 2 in front of the magazine. For the houses (BN) the larger pressure values at the front and side of the magazine at position 2, 3 and 4 result in up to three times larger lethality. However, at position 1 there are only minor differences. At position 5 and 6 the lethality is reduced in all directions by a factor between 1.5 and 5.8 when using the new model. At position 7 the lethality from pressure is insignificant.

The dynamic impulse does not damage persons in buildings. In free field the lethality at position 3 is insignificant, thus only position 1 and 2 are interesting. Figure 3.9 shows the lethality there. For comparison also the lethality from pressure at these positions is drawn.

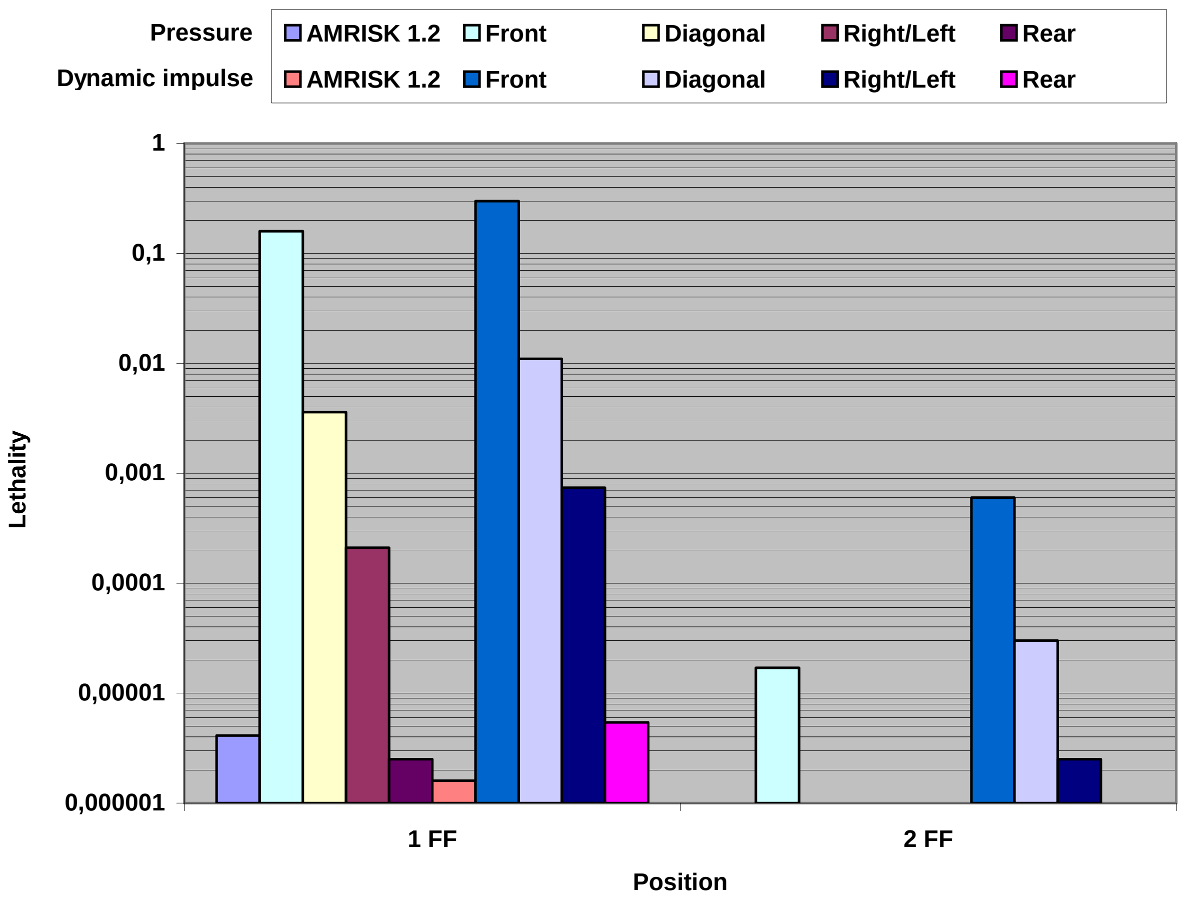

Figure 3.9 Lethality from pressure and dynamic impulse at exposed free field objects around an earth-covered magazine calculated by models in AMRISK 1.2 and AMRISK 2.0

The model in AMRISK 1.2 gives lethality from the impulse only for the position closest to the magazine, and this is about 2.5 times less than the corresponding lethality from pressure. In AMRISK 2.0 the relation is opposite with the lethality from dynamic impulse two to three times larger than the lethality from pressure. Still the relation between the values of lethality from impulse at different directions is similar to that for pressure. At position 2 the dynamic impulse at the front, diagonal and side and the pressure at the front result in lethality above 10^{-6}.

4 CONCLUSION

Version 2.0 of the risk analysis program AMRISK is developed and finished.

In AMRISK 2.0 new models with a better description of the physical effects replace the models used for calculating air blast around freestanding and earth-covered magazines. The models are included in official NATO documents and other risk analysis programs.

The verification tests show that the new models are implemented correctly. In addition the tests show that values of pressure and dynamic impulse calculated by the new models in several cases differ significantly from results produced by the models in the previous release of AMRISK, version 1.2. For earth-covered magazines the directional effects of the new model are considerable.

In the verification example with a freestanding magazine the lethality estimates at buildings more than a few hundred meters from the magazine are significantly smaller when using the model in AMRISK 2.0 compared to AMRISK 1.2. At the earth-covered magazine the difference in lethality between the directions is larger than the difference between the new and the old model.

Besides some error recovery several improvements have been made to the user interface of the program.

APPENDIX

A PROGRAM CODE OF THE NEW MODELS

A.1 FpFSN

```
!     Last change:          AB/FOI    20 June 2005
!AMMORISK------------------------------------------------------------EBP
!     F U N C T I O N   F p F S N
!---------------------------------------------------------------------
!     PURPOSE: Pressure due to airblast for magazines
!
!     DESCRIP-
!        TION: The function FpFSN (replaces FpFS)calculates the airblast
!              pressure for aboveground freestanding magazines for a
!              given distance between magazine and object.
!
!     I/O:     FpFSN  R*4    OUT   Pressure due to airblast (bar)
!              R      R*4    IN    Distance magazine to object (m)
!              Q      R*4    IN    Charge TNT (t)
!
!     COMMON:  None
!
!     CALLS:   Fking (calculates Kingery-Bullmar exp-function)
!
!     REMARKS: Swiss formulas disconnected, replaced by Kingery-Bullmar
!
!
!     HISTORY: Coded on 87 12 01 by EBP
!              Modifisert for AMRISK 1.1a,         HFK-AMK apr-01.
!                 Modified for AMRISK 2.0             FOI jan 2005
!---------------------------------------------------------------------
      FUNCTION FpFSN (R,Q)
!
!-----Type Declarations, parameters & common blocks
!
      IMPLICIT NONE
      REAL FpFSN,R,Q,Z,C(7),C1(7),C2(7),C3(7),Fking!CX constants for Kingery-B.
         DATA C1 /7.2106, -2.1069, -0.32290, 0.1117, 0.0685,0.,0./
         DATA C2 / 7.5938, -3.0523, 0.40977, 0.0261,-0.01267, 0., 0./
         DATA C3 /6.0536,-1.4066, 0., 0., 0., 0., 0./

        Z= R/ MAX(.0001,(Q*1000.)**(1./3.))! Scaled weight in kg
        Z= MAX (0.2,Z)! Kingery formulas not defined for small Z values
!
!-----Input applicable constants for Kingery calc:
!
      IF ( Z.LE.2.9) THEN
      C(1:7)=C1(1:7)
      ELSEIF (Z.GT.2.9.AND.Z.LE.23.8) THEN
      C(1:7)=C2(1:7)
      ELSEIF (Z.GT.23.8) THEN
      C(1:7)=C3(1:7)
      END IF

!-----Pressure due to airblast
!
! Version 1 (disconnected):
!            X = LOG(R/Q**(1./3.))
!            FpFS = EXP(5.5502 -2.0975*X +1.4819*SQRT((X- 3.6555)**2. +1.3573))
!

!---- Calc of pressure, version 2.0(Kingery-Bullmar):
        FpFSN=Fking(Z,C(1),C(2),C(3),C(4),C(5),C(6),C(7))
```

```
       FpFSN=FpFSN/100.! correction kPa -> bar

!-----End of function FpFSN
!
      RETURN
      END
```

A.2 FiFSN

```
!     Last change:                              AB/FOI     20 June 2005
! AMRISK---------------------------------------------------------FLO/AMK C
!      F U N C T I O N   F i F S N                                     C
! -------------------------------------------------------------------C
!      PURPOSE: Momentum due to airblast for magazines                 C
!                                                                      C
!      DESCRIP-                                                        C
!         TION: The function FP53T calculates the physical value       C
!               p^(5/3)* tip for aboveground freestanding, magazines   C
!               for a given distance between a object and the magazine.C
!                                                                      C
!      I/O:     FiFSN   R*4    OUT  Momentum p^(5/3)*tip (bar^(5/3)*ms)C
!               R       R*4    IN   Distance magazine to object (m)    C
!               Q       R*4    IN   Charge TNT (t)                     C
!                                                                      C
!      COMMON:  None                                                   C
!                                                                      C
!      CALLS:   Fking  (calculates Kingery-Bullmar exp-function)
C
!                                                                      C
!      HISTORY: Coded on 87 12 01 by EBP                               C
!               Modified AMRISK                 FLO/AMK may-02.        C
!               Modified for AMRISK ver 2.0     FOI     jan-05         C                      C
! -------------------------------------------------------------------C
!                                                                      C
      FUNCTION FiFSN (R,Q)
!
! -----Type declarations, parameters & common blocks
!
      IMPLICIT NONE
      REAL FiFSN, FpFS, FdFS, R, Q, Z, Fking, &
      C(7),C1(7),C2(7),C3(7), D(7),D1(7),D2(7),D3(7)
!---- Vectors CX and DX contain constants for Kingery calculation
!
       DATA C1 / 7.2106, -2.1069, -0.32290, 0.1117, 0.0685,0.,0./
       DATA C2 / 7.5938,-3.0523, 0.40977, 0.0261,-0.01267, 0., 0./
       DATA C3 /6.0536,-1.4066, 0., 0., 0., 0., 0./
!
       DATA D1 / 0.5426, 3.2299, -1.5931, -5.9667, -4.0815, -0.9149, 0./
       DATA D2 / 0.544, 2.7082, -9.7354, 14.3425, -9.7791, 2.8535, 0./
       DATA D3 /-2.4608, 7.1639, -5.6215, 2.2711, -0.44994, 0.03486, 0./

! -----Calculation of Momentum for Magazines
!
!Disconnected (Version 1 ):
!     X = R / MAX(.0001,Q**(1./3.))
!      FiFS = Q**(1./3.) * EXP(4.824 -.07626*X + .04984*                &
!              SQRT((X -35.88)**2. + 167.8))
!
       Z= R/ MAX(.0001,(Q*1000.)**(1./3.))! Scaled weight in kg
       Z= MAX (0.2,Z)! Kingery formulas not defined for small Z values
!
!------Input Constants for Kingery pressure calculation C(7):

     IF ( Z.LE.2.9) THEN
       C(1:7)=C1(1:7)
     ELSEIF (Z.GT.2.9.AND.Z.LE.23.8) THEN
      C(1:7)=C2(1:7)
     ELSEIF (Z.GT.23.8) THEN
      C(1:7)=C3(1:7)
     END IF
!
!---- Input constants for Kingery duration calculation D(7):
```

```
!
      IF (Z.LE.1.02) THEN
         D(1:7)=D1(1:7)
      ELSEIF (Z.GT.1.02.AND.Z.LE.2.8) THEN
        D(1:7)=D2(1:7)
      ELSEIF (Z.GT.2.8) THEN
        D(1:7)=D3(1:7)
       ENDIF
!
!---- Calculation of pressure (Kingery):

      FpFS=Fking(Z,C(1),C(2),C(3),C(4),C(5),C(6),C(7))

       FpFS=FpFS/100.! correction kPa -> bar
!
!---- Calculation of duration (Kingery):

      FdFS=Fking(Z,D(1),D(2),D(3),D(4),D(5),D(6),D(7))

      FdFS= FdFS*(Q*1000.)**0.33333 !AB korrektion ms/kg^1/3 -> ms
!
!---- Calculation of impulse density from pressure and duration( in bar*ms):
       FiFSN=  0.6666*FdFS*(FpFS**1.6666)
!
! -----End of function FiFSN
!
      RETURN
      END
```

A.3 FpECN

```
!     Last change:  AB   21 June 2005   15:00 pm
!AMRISK------------------------------------------------------- FOI --- C
!     F U N C T I O N   F p E C N                                      C
!----------------------------------------------------------------------C
!     PURPOSE: Pressure due to airblast for magazines                  C
!                                                                      C
!     DESCRIP-                                                         C
!        TION: The function  calculates the airblast pressure for      C
!              earthcovered magazines for a given distance and angle   C
!              between magazine and object.                            C
!                                                                      C
!     I/O:     FpECN  R*4    OUT   Pressure due to airblast (bar)      C
!              R      R*4    IN    Distance magazine to object (m)     C
!              Q      R*4    IN    Charge TNT (t)                      C
!              ang    R*4    IN    Angle (deg)                         C
!                                                                      C
!     COMMON:  None                                                    C
!                                                                      C
!     CALLS:   Fking (Function to calc Kingery-Bulmash exp-function    C
!                                                                      C
!     REMARKS: Kingery formulas.                                       C
!                                                                      C
!     HISTORY: Replaces function FpEC Coded on 87 12 01 by EBP         C
!              Modified for AMRISK ver 2.0,       FOI/AB apr -05       C
!----------------------------------------------------------------------C
!                                                                      C
      FUNCTION FpECN (ang,R,Q)
!
!-----Type Declarations, parameters & common blocks
!
      IMPLICIT NONE
      REAL FpECN, R, Q, ang, angl, Pfront, Pside, Prear, Z, Fking, PI
!
      Z = R/ MAX(.0001,(Q*1000.)**(1./3.))! Scaled weight in kg
       Z= MAX (0.7, Z)! Kingery formulas are not defined for small Z values
!
!-----Prepare angle value for ellipse conditions below
       PI = 3.141592
       angl=ang*PI/180.    ! deg -> rad
       IF(angl.LT.0.)THEN
       angl=angl+(2.*PI)
```

```
       ENDIF
!
!-----Pressure due to airblast (Kingery):
!
       Pfront= Fking( Z ,7.6032,-2.28717,-0.34671,0.27438,-0.05391,0.00342,0.)
       Pside = Fking( Z ,5.65556, -1.164, 0.031, -0.0849, 0.021,  -0.00148,0.)
       Prear = Fking( Z ,5.55581,-1.47687,0.14494,-0.08519,0.01745,-0.00118,0.)
!
!-----Conditions for ellipse:
       IF ((ABS(angl-(PI/2.)).LT.0.00001).OR.(ABS(angl-(3.*PI/2.)).LT.0.00001))THEN
       FpECN = Pside
       GOTO 999  ! Avoid undefined TAN
       ENDIF
!
       IF ( angl.GT.(PI/2.).AND.angl.LT.(3.*PI/2.)) THEN
       FpECN=SQRT((Pside**2.*Pfront**2.*(1.+((TAN(angl))**2.)))/&
       (Pside**2.+(Pfront**2.*((TAN(angl))**2.))))

       ELSEIF ( angl.LT.(PI/2.).OR.angl.GT.(3.*PI/2.)) THEN
       FpECN=SQRT((Pside**2.*Prear**2.*(1.+((TAN(angl))**2.)))/&
       (Pside**2.+(Prear**2.*((TAN(angl))**2.))))
!

       ENDIF
!
999    FpECN = FpECN / 100. ! Convert kPa -> bar
!
!-----End of function FpECN
!
      RETURN
      END
```

A.4 FiECN

```
!     Last change:  AB  20 June 2005
! AMRISK------------------------------------------------------ FOI--- C
!      F U N C T I O N   F i E C N                                    C
! --------------------------------------------------------------------C
!      PURPOSE: Momentum due to airblast for magazines                C
!                                                                     C
!      DESCRIP-                                                       C
!         TION: The function FiECN (replaces FiEC) calculates the     C
!               value p^(5/3)* tip for aboveground earthcovered,      C
!               magazines for a given distance between an object and  C
!               the magazine.                                         C
!                                                                     C
!      I/O:     FiECN   R*4    OUT  Momentum p^(5/3)*tip (bar^(5/3)*ms)C
!               R       R*4    IN   Distance magazine to object (m)   C
!               Q       R*4    IN   Charge TNT (t)                    C
!               ang     R*4    IN   Angle object-magazine's front     C
!      COMMON:  None                                                  C
!                                                                     C
!      CALLS:   Fking (Function to calc Kingery-Bulmash exp-function)  C
!                                                                     C
!      REMARKS: Kingery-Bulmash equations for static pressure and     C
!               pos. duration values derived from BEC 6.1 used        C
!                                                                     C
!      HISTORY: Replaces FP53T Coded on 87 12 01 by EBP               C
!               Modified for AMRISK ver 2.0           AB FOI apr-05   C
! --------------------------------------------------------------------C
!                                                                     C
      FUNCTION FiECN (ang,R,Q)
!
! -----Type declarations, parameters & common blocks
!
      IMPLICIT NONE
      REAL FiECN,R,Q,Z,ang,angl,Pfront,Pside,Prear,Tfront,Tside,Trear,&
           Fking,PI,p,t
!
!
      Z = R/ MAX(.0001,(Q*1000.)**(1./3.))! Scaled weight in kg
       Z= MAX (0.7, Z)! Kingery formulas not defined for small Z values
```

```
!
!-----Prepare angle value for ellipse conditions below
       PI = 3.141592
       angl=ang*PI/180.    ! deg -> rad
       IF(angl.LT.0.)THEN
       angl=angl+(2.*PI)
       ENDIF
!
!-----Pressure due to airblast (Kingery):
!
       Pfront= Fking( Z ,7.6032, -2.28717,-0.34671,0.27438,-0.05391, 0.00342, 0.)
       Pside = Fking( Z ,5.65556, -1.164, 0.031, -0.0849,   0.021,  -0.00148, 0.)
       Prear = Fking( Z ,5.55581, -1.47687,0.14494,-0.08519,0.01745,-0.00118, 0.)

!-----Positive duration due to airblast (derived from BEC 6.1):

       Z= MIN(Z, 200.)! Correction for large Z values

       Tfront= Fking( Z ,0.460803, 0.525296, -0.04567,     0.,0.,0.,0.)
       Tside = Fking( Z ,1.00205,  0.207429, -0.000555187, 0.,0.,0.,0.)
       Trear = Fking( Z ,0.334124, 0.580877, -0.05944,     0.,0.,0.,0.)
!
       IF (Z.LT.40.)THEN
       Tfront=Fking( Z ,-1.93321, 6.16328, -4.9,  1.97343, -0.38493, 0.029083, 0.)
       Tside =Fking( Z ,-0.945587,3.66105,-2.69461,1.09865,-0.225794,0.0183546,0.)
       Trear =Fking( Z ,-0.37572, 2.33924, -1.75688,0.783067,-0.17273,0.014652,0.)
       ENDIF

!----Corrections for small Z values:
!
       IF(Z.LT.2.8)THEN
       Tfront=Fking( Z,0.386364,0.853478,-0.69357,-2.16149,4.55691,-2.00316,0.)
       ENDIF
!
       IF(Z.LT.2.6)THEN
       Tside=Fking( Z, 0.161349,0.436003,-0.195093,0.657763,0.84928,-1.00476,0.)
       ENDIF
!
       IF(Z.LT.2.0)THEN
       Trear=Fking( Z,0.116706,0.160406, 0.600365,1.03725, -0.51708,-0.57615,0.)
       ENDIF
!
!-----Conditions for ellipse

       IF ((ABS(angl-(PI/2.)).LT.0.00001).OR.(ABS(angl-(3.*PI/2.)).LT.0.00001))THEN
       p = Pside
       t = Tside
       GOTO 999  ! Avoid undefined TAN
       ENDIF
!
       IF ( angl.GT.(PI/2.).AND.angl.LT.(3.*PI/2.)) THEN

       p=SQRT((Pside**2.*Pfront**2.*(1.+((TAN(angl))**2.)))/&
              (Pside**2.+(Pfront**2.*((TAN(angl))**2.))))
!
       t=SQRT((Tside**2.*Tfront**2.*(1.+((TAN(angl))**2.)))/&
              (Tside**2.+(Tfront**2.*((TAN(angl))**2.))))
!
!
       ELSEIF( angl.LT.(PI/2.).OR.angl.GT.(3.*PI/2.)) THEN

       p=SQRT((Pside**2.*Prear**2.*(1.+((TAN(angl))**2.)))/&
              (Pside**2.+(Prear**2.*((TAN(angl))**2.))))
!
       t=SQRT((Tside**2.*Trear**2.*(1.+((TAN(angl))**2.)))/&
              (Tside**2.+(Trear**2.*((TAN(angl))**2.))))
!
       ENDIF
!
999    CONTINUE

! -----Calculation of Dynamic impulse from (static) pressure and duration:

      t= t*(Q*1000.)**0.33333 !Correction ms/kg^1/3 -> ms
       p=p/100. !Conversion kPa -> bar before the "5/3-formula"
       FiECN= p**(5./3.)*t*2./3.
```

```
! -----End of function FiECN
!
      RETURN
      END
```

A.5 FKing

```
!     Last change:  AB   20 June 2005   14:00 pm
!AMRISK-----------------------------------------------------------FOI  C
!     F U N C T I O N   F k i n g                                      C
!----------------------------------------------------------------------C
!     PURPOSE: Function for Kingery - Bullmash formulas                C
!                                                                      C
!     DESCRIP-                                                         C
!        TION: The function calculates the exp function used in KingeryC
!              -Bullmash formulas for pressure from magazines.         C
!               7 constants are input (A-G) + the scaled distance (Z)  C
!                                                                      C
!     I/O:     Fking  R*4    OUT   Airblast parameter                  C
!              Z      R*4    IN    Scaled distance (m/kg**1/3)         C
!              A-D    R*4    IN    Input constants                     C
!                                                                      C
!     COMMON:  None                                                    C
!                                                                      C
!     CALLS:   None                                                    C
!                                                                      C
!     REMARKS: Kingery exp formula                                     C
!                                                                      C
!     HISTORY: Coded on 05 04 15 by AB                                 C
!              for        AMRISK ver 2.0,            FOI apr 05.      C
!----------------------------------------------------------------------C
!                                                                      C
      FUNCTION Fking (Z,A,B,C,D,E,F,G)
!
!-----Type Declarations, parameters & common blocks
!
      IMPLICIT NONE
      REAL FKING, Z,A,B,C,D,E,F,G
!
        Fking= EXP(A+(B*LOG(Z))+(C*(LOG(Z))**2)+(D*(LOG(Z))**3)&
              +(E*(LOG(Z))**4)+(F*(LOG(Z))**5)+(G*(LOG(Z))**6))
!
!-----End of function FKING
!
      RETURN
      END
```

B TEST RESULTS FROM AMRISK 2.0

B.1 Air blast around a freestanding magazine

Table B.1 Results from the model for air blast around a freestanding magazine calculated by AMRISK 2.0 and a spreadsheet

Ref	EO	Distance /m	Z /(m/kg$^{1/3}$)	AMRISK 2.0				External verification			
				Pressure /kPa	Lethality from pressure	Dynamic impulse /bar$^{5/3}$ms	Lethality from impulse	Pressure /kPa	Lethality from pressure	Dynamic impulse /bar$^{5/3}$ms	Lethality from impulse
1	House (BN)	100	2.71	140	0.99	110		143.173	0.993	113.4	
1	Freefield (FF)	100	2.71	140	0.037	110	0.085	143.173	0.037	113.4	0.085
2	House (BN)	150	4.07	63	0.75	39		62.742	0.7467	39.6	
2	Freefield (FF)	150	4.07	63	1.9E-06	39	0.00016	62.742	1.9E-06	39.6	0.00018
3	House (BN)	200	5.43	38	0.33	19		37.542	0.3277	18.76	
3	Freefield (FF)	200	5.43	38	0	19	1.4E-07	37.542	0	18.76	1.4E-07
4	House (BN)	400	10.86	13	0.0036	4.2		13.320	0.00361	4.19	
5	House (BN)	1000	27.14	4.1	3.8E-05	0.77		4.097	3.8E-05	0.77	
6	House (BN)	1500	40.72	2.3	5.9E-06	0.33		2.316	5.9E-06	0.33	
7	House (BN)	2000	54.29	1.5	1.4E-06	0.19		1.545	1.4E-06	0.18	

Table B.2 Results from the model for air blast around a freestanding magazine calculated by AMRISK 2.0 and AMRISK 1.2

Ref	**EO**	**Distance /m**	**Z /(m/kg$^{1/3}$)**	**AMRISK 2.0**				**AMRISK 1.2**			
				Pressure /kPa	**Lethality from pressure**	**Dynamic impulse /bar$^{5/3}$ms**	**Lethality from impulse**	**Pressure /kPa**	**Lethality from pressure**	**Dynamic impulse /bar$^{5/3}$ms**	**Lethality from impulse**
1	House (BN)	100	2.71	140	0.99	110		150	1	130	
1	Freefield (FF)	100	2.71	140	0.037	110	0.085	150	0.062	130	0.13
2	House (BN)	150	4.07	63	0.75	39		61	0.73	41	
2	Freefield (FF)	150	4.07	63	1.9E-06	39	0.00016	61	1.1E-06	41	0.00023
3	House (BN)	200	5.43	38	0.33	19		36	0.29	22	
3	Freefield (FF)	200	5.43	38	0	19	1.4E-07	36	0	22	9.6E-7
4	House (BN)	400	10.86	13	0.0036	4.2		14	0.0047	4.6	
5	House (BN)	1000	27.14	4.1	3.8E-05	0.77		5.8	1.1E-04	0.06	
6	House (BN)	1500	40.72	2.3	5.9E-06	0.33		4.2	4.2E-05	0.0017	
7	House (BN)	2000	54.29	1.5	1.4E-06	0.19		3.4	2.1E-05	4.6E-05	

B.2 Air blast around an earth-covered magazine

Table B.3 Results from the model for air blast around an earth-covered magazine calculated by AMRISK 2.0 and a spreadsheet

Ref	EO	Distance /m	Angle /degrees	Z /(m/kg$^{1/3}$)	AMRISK 2.0				External verification			
					Pressure /kPa	Lethality from pressure	Dynamic impulse /bar$^{5/3}$ms	Lethality from impulse	Pressure /kPa	Lethality from pressure	Dynamic impulse /bar$^{5/3}$ms	Lethality from impulse
1L	House (BN)	100	90	2,71	86	0,91	48		86,40	0,912	47,9	
1L	Freefield (FF)	100	90	2,71	86	2,1E-04	48	7,4E-04	86,40	2,1E-04	47,9	7,4E-04
2L	House (BN)	150	90	4,07	50	0,58	25		50,45	0,576	24,7	
2L	Freefield (FF)	150	90	4,07	50	0	25	2,5E-06	50,45	0	24,7	2,5E-06
3L	House (BN)	200	90	5,43	34	0,25	14		33,63	0,247	14,1	
3L	Freefield (FF)	200	90	5,43	34	0	14	0	33,63	0	14,1	0
4L	House (BN)	400	90	10,86	12	0,0016	3,1		11,82	0,0016	3,1	
5L	House (BN)	1000	90	27,14	2,7	1,1E-05	0,33		2,746	1,1E-05	0,329	
6L	House (BN)	1500	90	40,72	1,5	1,1E-06	0,12		1,450	1,1E-06	0,124	
7L	House (BN)	2000	90	54,29	0,93	2,1E-07	0,063		0,9334	2,1E-07	0,0628	
1LD	House (BN)	100	45	2,71	110	0,97	73		110,23	0,970	72,8	
1LD	Freefield (FF)	100	45	2,71	110	0,0036	73	0,011	110,23	0,0036	72,8	0,011
2LD	House (BN)	150	45	4,07	58	0,69	32		58,44	0,695	32,2	
2LD	Freefield (FF)	150	45	4,07	58	5,5E-07	32	3,0E-05	58,44	5,6E-07	32,2	3,0E-05
3LD	House (BN)	200	45	5,43	36	0,3	16		36,21	0,300	16,0	
3LD	Freefield (FF)	200	45	5,43	36	0	16	0	36,21	0	16,0	0
4LD	House (BN)	400	45	10,86	12	0,0013	2,9		11,51	0,00134	2,89	
5LD	House (BN)	1000	45	27,14	2,8	1,2E-05	0,35		2,845	1,2E-05	0,352	

Ref	EO	Distance /m	Angle /degrees	Z /(m/kg$^{1/3}$)	AMRISK 2.0				External verification			
					Pressure /kPa	Lethality from pressure	Dynamic impulse /bar$^{5/3}$ms	Lethality from impulse	Pressure /kPa	Lethality from pressure	Dynamic impulse /bar$^{5/3}$ms	Lethality from impulse
6LD	House (BN)	1500	45	40,72	1,6	1,5E-06	0,14		1,574	1,5E-06	0,143	
7LD	House (BN)	2000	45	54,29	1	3,2E-07	0,075		1,039	3,2E-07	0,0755	
1R	House (BN)	100	270	2,71	86	0,91	48		86,40	0,912	47,9	
1R	Freefield (FF)	100	270	2,71	86	2,1E-04	48	7,4E-04	86,40	2,1E-04	47,9	7,4E-04
2R	House (BN)	150	270	4,07	50	0,58	25		50,45	0,576	24,7	
2R	Freefield (FF)	150	270	4,07	50	0	25	2,5E-06	50,45	0	24,7	2,5E-06
3R	House (BN)	200	270	5,43	34	0,25	14		33,63	0,247	14,1	
3R	Freefield (FF)	200	270	5,43	34	0	14	0	33,63	0	14,1	0
4R	House (BN)	400	270	10,86	12	0,0016	3,1		11,82	0,00161	3,1	
5R	House (BN)	1000	270	27,14	2,7	1,1E-05	0,33		2,746	1,1E-05	0,329	
6R	House (BN)	1500	270	40,72	1,5	1,1E-06	0,12		1,450	1,1E-06	0,124	
7R	House (BN)	2000	270	54,29	0,93	2,1E-07	0,063		0,933	2,1E-07	0,0628	
1RD	House (BN)	100	315	2,71	73	0,84	34		72,64	0,837	34,4	
1RD	Freefield (FF)	100	315	2,71	73	1,9E-05	34	5,5E-05	72,64	1,9E-05	34,4	5,4E-05
2RD	House (BN)	150	315	4,07	42	0,41	17		41,71	0,414	16,8	
2RD	Freefield (FF)	150	315	4,07	42	0	17	0	41,71	0	16,8	0
3RD	House (BN)	200	315	5,43	28	0,14	9,6		27,78	0,136	9,57	
3RD	Freefield (FF)	200	315	5,43	28	0	9,6	0	27,78	0	9,57	0
4RD	House (BN)	400	315	10,86	10	5,0E-04	2,2		9,988	0,00050	2,19	
5RD	House (BN)	1000	315	27,14	2,5	7,2E-06	0,26		2,453	7,2E-06	0,262	
6RD	House (BN)	1500	315	40,72	1,3	8,1E-07	0,1		1,323	8,1E-07	0,101	

Ref	EO	Distance /m	Angle /degrees	Z /(m/kg$^{1/3}$)	AMRISK 2.0				External verification			
					Pressure /kPa	Lethality from pressure	Dynamic impulse /bar$^{5/3}$ms	Lethality from impulse	Pressure /kPa	Lethality from pressure	Dynamic impulse /bar$^{5/3}$ms	Lethality from impulse
7RD	House (BN)	2000	315	54,29	0,86	1,6E-07	0,052		0,8617	1,6E-07	0,0517	
1F	House (BN)	100	0	2,71	180	1	170		180,65	0,998	168	
1F	Freefield (FF)	100	0	2,71	180	0,16	170	0,3	180,65	0,162	168	0,292
2F	House (BN)	150	0	4,07	72	0,83	47		72,03	0,832	46,5	
2F	Freefield (FF)	150	0	4,07	72	1,7E-05	47	6,0E-04	72,03	1,7E-05	46,5	6,0E-04
3F	House (BN)	200	0	5,43	39	0,37	19		39,49	0,368	18,7	
3F	Freefield (FF)	200	0	5,43	39	0	19	1,3E-07	39,49	0	18,7	1,3E-07
4F	House (BN)	400	0	10,86	11	0,0011	2,8		11,23	0,00112	2,75	
5F	House (BN)	1000	0	27,14	3	1,3E-05	0,38		2,956	1,3E-05	0,378	
6F	House (BN)	1500	0	40,72	1,7	2,2E-06	0,17		1,736	2,2E-06	0,170	
7F	House (BN)	2000	0	54,29	1,2	5,5E-07	0,095		1,193	5,5E-07	0,0953	
1B	House (BN)	100	180	2,71	64	0,76	27		63,87	0,759	26,7	
1B	Freefield (FF)	100	180	2,71	64	2,5E-06	27	5,4E-06	63,87	2,5E-06	26,7	5,4E-06
2B	House (BN)	150	180	4,07	36	0,3	13		36,36	0,303	12,6	
2B	Freefield (FF)	150	180	4,07	36	0	13	0	36,36	0	12,6	0
3B	House (BN)	200	180	5,43	24	0,081	7,2		24,20	0,081	7,17	
3B	Freefield (FF)	200	180	5,43	24	0	7,2	0	24,20	0	7,17	0
4B	House (BN)	400	180	10,86	8,8	3,5E-04	1,7		8,811	3,5E-04	1,69	
5B	House (BN)	1000	180	27,14	2,2	5,3E-06	0,22		2,237	5,3E-06	0,216	
6B	House (BN)	1500	180	40,72	1,2	6,0E-07	0,085		1,225	6,0E-07	0,0850	
7B	House (BN)	2000	180	54,29	0,8	1,2E-07	0,044		0,8044	1,2E-07	0,0437	

Table B.4 Results from the model for air blast around an earth-covered magazine calculated by AMRISK 2.0 and AMRISK 1.2

					AMRISK 2.0				AMRISK 1.2			
Ref	**EO**	**Distance /m**	**Angle /degrees**	**Z /(m/kg$^{1/3}$)**	**Pressure /kPa**	**Lethality from pressure**	**Dynamic impulse /bar$^{5/3}$ms**	**Lethality from impulse**	**Pressure /kPa**	**Lethality from pressure**	**Dynamic impulse /bar$^{5/3}$ms**	**Lethality from impulse**
1L	House (BN)	100	90	2,71	86	0,91	48		66	0,78	24	
1L	Freefield (FF)	100	90	2,71	86	2,1E-04	48	7,4E-04	66	4,1E-06	24	1,6E-06
2L	House (BN)	150	90	4,07	50	0,58	25		39	0,36	13	
2L	Freefield (FF)	150	90	4,07	50	0	25	2,5E-06	39	0	13	0
3L	House (BN)	200	90	5,43	34	0,25	14		27	0,12	8,6	
3L	Freefield (FF)	200	90	5,43	34	0	14	0	27	0	8,6	0
4L	House (BN)	400	90	10,86	12	0,0016	3,1		11	9,4E-04	3,1	
5L	House (BN)	1000	90	27,14	2,7	1,1E-05	0,33		3,4	2,0E-05	0,82	
6L	House (BN)	1500	90	40,72	1,5	1,1E-06	0,12		2	3,5E-06	0,46	
7L	House (BN)	2000	90	54,29	0,93	2,1E-07	0,063		1,4	9,1E-07	0,3	
1LD	House (BN)	100	45	2,71	110	0,97	73		66	0,78	24	
1LD	Freefield (FF)	100	45	2,71	110	0,0036	73	0,011	66	4,1E-06	24	1,6E-06
2LD	House (BN)	150	45	4,07	58	0,69	32		39	0,36	13	
2LD	Freefield (FF)	150	45	4,07	58	5,5E-07	32	3,0E-05	39	0	13	0
3LD	House (BN)	200	45	5,43	36	0,3	16		27	0,12	8,6	
3LD	Freefield (FF)	200	45	5,43	36	0	16	0	27	0	8,6	0
4LD	House (BN)	400	45	10,86	12	0,0013	2,9		11	9,4E-04	3,1	
5LD	House (BN)	1000	45	27,14	2,8	1,2E-05	0,35		3,4	2,0E-05	0,82	
6LD	House (BN)	1500	45	40,72	1,6	1,5E-06	0,14		2	3,5E-06	0,46	
7LD	House (BN)	2000	45	54,29	1	3,2E-07	0,075		1,4	9,1E-07	0,3	

Ref	EO	Distance /m	Angle /degrees	Z /(m/kg$^{1/3}$)	AMRISK 2.0				AMRISK 1.2			
					Pressure /kPa	**Lethality from pressure**	**Dynamic impulse /bar$^{5/3}$ms**	**Lethality from impulse**	**Pressure /kPa**	**Lethality from pressure**	**Dynamic impulse /bar$^{5/3}$ms**	**Lethality from impulse**
1R	House (BN)	100	270	2,71	86	0,91	48		66	0,78	24	
1R	Freefield (FF)	100	270	2,71	86	2,1E-04	48	7,4E-04	66	4,1E-06	24	1,6E-06
2R	House (BN)	150	270	4,07	50	0,58	25		39	0,36	13	
2R	Freefield (FF)	150	270	4,07	50	0	25	2,5E-06	39	0	13	0
3R	House (BN)	200	270	5,43	34	0,25	14		27	0,12	8,6	
3R	Freefield (FF)	200	270	5,43	34	0	14	0	27	0	8,6	0
4R	House (BN)	400	270	10,86	12	0,0016	3,1		11	9,4E-04	3,1	
5R	House (BN)	1000	270	27,14	2,7	1,1E-05	0,33		3,4	2,0E-05	0,82	
6R	House (BN)	1500	270	40,72	1,5	1,1E-06	0,12		2	3,5E-06	0,46	
7R	House (BN)	2000	270	54,29	0,93	2,1E-07	0,063		1,4	9,1E-07	0,3	
1RD	House (BN)	100	315	2,71	73	0,84	34		66	0,78	24	
1RD	Freefield (FF)	100	315	2,71	73	1,9E-05	34	5,5E-05	66	4,1E-06	24	1,6E-06
2RD	House (BN)	150	315	4,07	42	0,41	17		39	0,36	13	
2RD	Freefield (FF)	150	315	4,07	42	0	17	0	39	0	13	0
3RD	House (BN)	200	315	5,43	28	0,14	9,6		27	0,12	8,6	
3RD	Freefield (FF)	200	315	5,43	28	0	9,6	0	27	0	8,6	0
4RD	House (BN)	400	315	10,86	10	5,0E-04	2,2		11	9,4E-04	3,1	
5RD	House (BN)	1000	315	27,14	2,5	7,2E-06	0,26		3,4	2,0E-05	0,82	
6RD	House (BN)	1500	315	40,72	1,3	8,1E-07	0,1		2	3,5E-06	0,46	
7RD	House (BN)	2000	315	54,29	0,86	1,6E-07	0,052		1,4	9,1E-07	0,3	
1F	House (BN)	100	0	2,71	180	1	170		66	0,78	24	

Ref	**EO**	**Distance /m**	**Angle /degrees**	**Z /(m/kg$^{1/3}$)**	**AMRISK 2.0**				**AMRISK 1.2**			
					Pressure /kPa	**Lethality from pressure**	**Dynamic impulse /bar$^{5/3}$ms**	**Lethality from impulse**	**Pressure /kPa**	**Lethality from pressure**	**Dynamic impulse /bar$^{5/3}$ms**	**Lethality from impulse**
1F	Freefield (FF)	100	0	2,71	180	0,16	170	0,3	66	4,1E-06	24	1,6E-06
2F	House (BN)	150	0	4,07	72	0,83	47		39	0,36	13	
2F	Freefield (FF)	150	0	4,07	72	1,7E-05	47	6,0E-04	39	0	13	0
3F	House (BN)	200	0	5,43	39	0,37	19		27	0,12	8,6	
3F	Freefield (FF)	200	0	5,43	39	0	19	1,3E-07	27	0	8,6	0
4F	House (BN)	400	0	10,86	11	0,0011	2,8		11	9,4E-04	3,1	
5F	House (BN)	1000	0	27,14	3	1,3E-05	0,38		3,4	2,0E-05	0,82	
6F	House (BN)	1500	0	40,72	1,7	2,2E-06	0,17		2	3,5E-06	0,46	
7F	House (BN)	2000	0	54,29	1,2	5,5E-07	0,095		1,4	9,1E-07	0,3	
1B	House (BN)	100	180	2,71	64	0,76	27		66	0,78	24	
1B	Freefield (FF)	100	180	2,71	64	2,5E-06	27	5,4E-06	66	4,1E-06	24	1,6E-06
2B	House (BN)	150	180	4,07	36	0,3	13		39	0,36	13	
2B	Freefield (FF)	150	180	4,07	36	0	13	0	39	0	13	0
3B	House (BN)	200	180	5,43	24	0,081	7,2		27	0,12	8,6	
3B	Freefield (FF)	200	180	5,43	24	0	7,2	0	27	0	8,6	0
4B	House (BN)	400	180	10,86	8,8	3,5E-04	1,7		11	9,4E-04	3,1	
5B	House (BN)	1000	180	27,14	2,2	5,3E-06	0,22		3,4	2,0E-05	0,82	
6B	House (BN)	1500	180	40,72	1,2	6,0E-07	0,085		2	3,5E-06	0,46	
7B	House (BN)	2000	180	54,29	0,8	1,2E-07	0,044		1,4	9,1E-07	0,3	

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