CONSIDERATIONS FOR STORAGE OF LIMITED NET EXPLOSIVES QUANTITIES IN MASONRY BUILDINGS

Author : Mr Jon Henderson
Deputy Chief Inspector Explosives (MoD)
UK <Ministry of Defence
Fir 3 A # 4304
MOD Abbeywood, Bristol, BS34 8JH

Traditionally the NATO Quantity Distance (QD) tables have only taken account of Net Explosives Quantities (NEQ) greater than 500 Kg. The decision was made in the 1960s to impose minimum debris distances on external QDs. During the 1990s the UK conducted a series of explosives trials utilising a variety of typical explosives storehouse building types and associated NEQs from 10 to 250 Kg, supplementing the work conducted during the 1980s to establish what the scope of the debris problem was for NEQs below 5600 Kg.

This paper presents an analysis of the available data and considers a variety of methodologies to resolve the small quantity issue and concludes with proposing a set of In habited Building Distances for use with NEQs below 500 Kg. These distances are to be incorporated into JSP 482, the UK MOD Explosives Regulations, and AASTP-1, the NATO Standards for storage of explosives.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE JUL 2010	2. REPORT TYPE N/A	3. DATES COVERED -

4. TITLE AND SUBTITLE Considerations For Storage Of Limited Net Explosives Quantities In Masonry Buildings	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) UK	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002313. Department of Defense Explosives Safety Board Seminar (34th) held in Portland, Oregon on 13-15 July 2010, The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified	SAR	40	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

CONSIDERATIONS FOR STORAGE OF LIMITED NET EXPLOSIVES QUANTITIES IN MASONRY BUILDINGS

Mr Jon Henderson
Deputy Chief Inspector Explosives (MoD)
UK Ministry of Defence

INTRODUCTION

1. Traditionally the NATO Quantity Distance (QD) tables have only taken account of Net Explosives Quantities (NEQ) greater than 500 Kg although this seems to have been as much a historical artefact rather than any specific limitation that was logically imposed. Indeed the origins appear to be mired in early work on igloo type structures which indicated that the hazard from building debris generated in an accidental explosion was a significant problem at Inhabited Building Distances (IBD) particularly at lower NEQs below a few tonnes. No specific data appears to have been examined but the decision was made in the 1960s to impose debris minimum distances on external QDs. These have since been looked at a number of times without any resolution but with a growing recognition that there appeared to be little logic behind standards that imposed the same restrictions on the storage of NEQs from as low as 1 kg as for 500 kg.

2. During the 1990s the UK conducted a series of explosives trials utilising a variety of typical explosives storehouse building types and associated NEQs from 10 to 250 Kg. This was intended to supplement the work conducted during the 1980s to establish what the scope of the debris problem was for NEQs below 5600 Kg. A full list of these trials and their basic test conditions is given at Annex A. It should be noted that all these trials utilised basically a masonry building construction with either brick or concrete walls and concrete or light weight roof, and were generally traversed (barricaded) on two adjacent sides.

3. The data has been used within the UK to underpin new civil sector QDs introduced with the update of the UK Manufacture and Storage of Explosives Regulations in 2005. However these regulations and the associated QDs are only applicable to the commercial sector and there has been a reluctance to introduce these QDs into the UK MoD regulations as they were not deemed to be comprehensive in covering the variety of MoD storage options and they had been developed from a risk perspective rather than the traditional method of considering and simply limiting the consequences. In actual fact these QDs imply an acceptance of a much higher degree of consequence.

4. The data has also been incorporated into the US DoD 6055.9 explosives standards.

5. Several papers have been presented at DDESB and PARARI Seminars reporting the results of the various trials work and attempts at analysing and utilising the resulting data. Most recently debris workshops have been sponsored by AC326 through MSIAC and a TNO paper (Ref 1) presented a potential method of generating QDs for NEQs less than 500 Kg which could be incorporated into AASTP-1.

6. As a comparison the results of all these studies are laid out at Annex B. The table shows the derived IBD for each NEQ quoted.

7. The UK remained unhappy about the way the data was being used and proposed to consider all the available data and to generate definitive QDs for inclusion in AASTP-1 based on the TNO analysis.

8. As a precursor in early 2009 the NATO AC 326 delegates and experts from the UK and US met in Bath, England to consider all the available data, how it had been and should be analysed and laid the ground for the UK expert to generate the necessary advice. As a result the UK have now reconsidered all the original data and reanalysed it according to the procedures laid out below.

DATA ANALYSIS

9. The major problem with analysing any trials debris data is how to assess its lethality from which the appropriate IBDs can be deduced. Throughout NATO the criteria normally associated with consideration of debris hazard for Inhabited Building Distance purposes is to consider that any explosion generated debris with an energy in excess of 80 Joules (The original criterion was 58 ft lb which converts to 78.64 Joules) is potentially fatal and that it should not occur with a density in excess of 1 per 56 square metres as measured on the ground. Although these criteria have been the subject of discussion over the years no better criteria have ever been proposed.

10. There have been various approaches suggested as to how best to represent the "real" hazard from debris. These are detailed in an AC326 WP (Ref 2) which is a copy of the advice from the US (Ref 3). The comments in these two documents have been taken account of in this review of the trials data although it is recognised that there is no one definitive method which can be applied. One of the considerations is the method used for actual pickup of the debris after an explosives trial. In almost all the trials data considered in this review the debris was collated in 10 degree wide 20 m deep sectors. The only exceptions were the earlier of the 1980s trials which were limited generally to 2 degree wide sectors. More recent debris trials (which used NEQs much greater than those under consideration here) have identified debris position by range and bearing thus potentially allowing a study of the effects of different sizes of pickup areas. However to maintain consistency with earlier analyses this data has been reduced to similar sized sectors for the actual analysis.

11. The key issue is how to actually calculate the lethality of the debris generated. The only information available from the trials is the mass and final resting position by sector of the debris. In some trials there is detailed (but limited) information on the variation in mass and actual size of debris pieces collected by sector. In most circumstances only the total number of pieces either within a mass bin or over a certain mass/size are available for each sector.

12. It should be obvious that any piece of debris will have zero residual energy at its final resting position. What is not so obvious is at what range its energy dropped below the defined 80 Joules. What is also not obvious is whether any account needs to be taken of debris that might have passed through the area. This is particularly relevant in circumstances where the debris is expected to be projected horizontally as

the “target” against which the lethality is being measured is a hypothetical standing person. For far field hazard considerations the target is taken as a standing person presenting a target of cross sectional area of some 0.5 sq m to the incoming fragment which is assumed to be falling at or near to the vertical. It should also be noted that Ref 3 indicates quite clearly that the 79 Joules criterion is not a 100% lethality criterion but in reality represents somewhere around a 30% probability of lethality.

13. Currently the accepted method of analysis is to use a trajectory normal approach. Variations of the Trajectory Normal approach have been postulated in the papers referenced at paragraph 10 above. The basic trajectory normal approach assumes that all debris which passes through the target must be taken account of. The proposed Modified Pseudo Trajectory Normal has been applied for all circumstances where there is no barricade or traverse. This essentially means that the debris collected in each sector is modified by the addition of 1/3 of all the debris that was collected in the sectors beyond it. For those circumstances where there is a traverse or barricade only the actual debris pick up data has been used to determine the debris density. This is on the basis that there is essentially no horizontally produced debris and that all debris at a specific range will have impacted the ground surface or near the vertical.

14. All the available data has been plotted and the maximum value for each NEQ tested has been established and the curve plotting solution within MS Excel used to determine a best fit using these maximum values as a bounding option. As a comparison the values derived from the TNO report have also been plotted with an attempted best curve fit solution. For UK purposes a further comparison with the values used by the MSER Regulations are also plotted. And finally the mean and standard deviation for each set of NEQ data has been established and a 90% confidence point established along with the appropriate best curve fit. It should be noted that there are a number of zero values for some of the directions examined in the early SQESH trials and these have been excluded when establishing the mean and standard deviation as it was felt that they skewed the data towards a too low result.

15. These different plots are presented at Annexes C, D and E as follows :

> Annex C1 : Plot of only the traversed/barricaded situations from all trials up to and including NEQs of 500 Kg
> Annex C2 : Plot of only the traversed/barricaded situations from all trials up to and including NEQs of 1800 Kg
> Annex D1 : Plot of only the untraversed/unbarricaded situations from all trials up to and including NEQs of 500 Kg
> Annex D2 : Plot of only the untraversed/unbarricaded situations from all trials up to and including NEQs of 1800 Kg
> Annex E1 : Plot of all the data from all trials up to and including NEQs of 500 Kg
> Annex E2 : Plot of all the data from all trials up to and including NEQs of 1800 Kg

16. It is fairly obvious that the plots all give different solutions, the differences being in some cases very significant. It is interesting to note that the use of the data for MSER and by TNO are not of themselves amenable to simple graphical solutions (certainly not within the limitations of MS Excel at least). In fact, having investigated

several computer based graphical solutions and even the old tried and tested method of hand drawn graphs (even with the aid of a flexicurve) I have essentially come to the conclusion that the inherent variability of the trials data does not lend itself to any easy to understand graphical solution. Or put another way none of the solutions produced an easily predictable result.

17. Annex F tabulates a basic comparison of the various graphical solutions presented in Annexes C to E along with the representative values obtained from the TNO approach, MSER and the AASTP-1 D12 and D13 HD1.1 QDs. The column headed actual max shows the maximum value derived from each set of NEQ trials data.

18. Annex G1 takes this comparison a stage further but does not consider any derived data points above the values obtained for 500 kg NEQ. Each column in the tables presented have been derived as follows :

Table 1 : Traversed

T1(Conf) : The Excel graphical solution from the 90% confidence limits (mean + two standard deviations) for each set of traversed trials data for each NEQ tested up to 500 kg
T2(Conf) : The Excel graphical solution from the 90% confidence limits (mean + two standard deviations) for each set of traversed trials data for each NEQ tested up to 1800 kg
TR Actual(Conf) : The actual 90% confidence limits (mean + two standard deviations) for each set of traversed trials data for each NEQ tested
T3(Max) : The Excel graphical solution from the maximum values for each set of traversed trials data for each NEQ tested up to 500 kg
T4(Max) : The Excel graphical solution from the maximum values for each set of traversed trials data for each NEQ tested up to 1800 kg
Actual Max : The maximum values for each set of traversed trials data for each NEQ tested
All 1(Conf) : The Excel graphical solution from the 90% confidence limits (mean + two standard deviations) for all trials data for each NEQ tested up to 500 kg
All 2(Conf) : The Excel graphical solution from the 90% confidence limits (mean + two standard deviations) for all trials data for each NEQ tested up to 1800 kg
All Actual(Conf) : The actual 90% confidence limits (mean + two standard deviations) for all trials data for each NEQ tested
All 3(Max) : The Excel graphical solution from the maximum values for all trials data for each NEQ tested up to 500 kg
All 4(Max) : The Excel graphical solution from the maximum values for all trials data for each NEQ tested up to 1800 kg
TNO : Data points derived from TNO paper
MSER : Data points derived from MSER
D13 : Values from AASTP-1 HD 1.1 QD Tables
D12 : Values from AASTP-1 HD 1.1 QD Tables

Table 2 : Untraversed

T1(Conf) : The Excel graphical solution from the 90% confidence limits (mean + two standard deviations) for each set of untraversed trials data for each NEQ tested up to 500 kg
T2(Conf) : The Excel graphical solution from the 90% confidence limits (mean + two standard deviations) for each set of untraversed trials data for each NEQ tested up to 1800 kg
TR Actual(Conf) : The actual 90% confidence limits (mean + two standard deviations) for each set of untraversed trials data for each NEQ tested
T3(Max) : The Excel graphical solution from the maximum values for each set of untraversed trials data for each NEQ tested up to 500 kg
T4(Max) : The Excel graphical solution from the maximum values for each set of untraversed trials data for each NEQ tested up to 1800 kg
Actual Max : The maximum values for each set of untraversed trials data for each NEQ tested
All 1(Conf) : The Excel graphical solution from the 90% confidence limits (mean + two standard deviations) for all trials data for each NEQ tested up to 500 kg
All 2(Conf) : The Excel graphical solution from the 90% confidence limits (mean + two standard deviations) for all trials data for each NEQ tested up to 1800 kg
All Actual(Conf) : The actual 90% confidence limits (mean + two standard deviations) for all trials data for each NEQ tested
All 3(Max) : The Excel graphical solution from the maximum values for all trials data for each NEQ tested up to 500 kg
All 4(Max) : The Excel graphical solution from the maximum values for all trials data for each NEQ tested up to 1800 kg
TNO : Data points derived from TNO paper
MSER : Data points derived from MSER
D13 : Values from AASTP-1 HD 1.1 QD Tables
D12 : Values from AASTP-1 HD 1.1 QD Tables

19. Table 3 at Annex G2 shows basically what is considered to be the best (and most defensible solution) depending on whether an all encompassing solution is desired or one that separates out traversed and untraversed circumstances. It should be noted that the option chosen is a value for each NEQ tested that is the actual maximum value of IBD derived from the trial data. Initially chosen was a solution based on the 90% confidence level but after much consideration and discussion within UK it was concluded that this probably did not represent the most appropriate interpretation of the data as it could well be argued that we should use either 95 % or even 99% confidence levels (for comparison these are shown at Annex G2). It is suggested that this approach is more easily understood and probably is not as susceptible as the confidence level approach to significant variation if other trials data becomes available.

20. One difficulty identified is that the value of IBD for an NEQ of 500 kg in untraversed circumstances exceeds the current 400 m minimum debris requirement in AASTP-1. To rectify this it is suggested to simply cap the maximum IBD for 500 kg at 400 m for the generic and untraversed circumstances. The actual value, derived from the trials data, of 437 m in the table at Annex G2 is shown for information.

Small Quantities below 1 Kg

21. All of the preceeding discussion is related to quantities of 1Kg of explosives and greater. Indeed the 10 m distance quoted for 1Kg is a nominal quantity distance requirement to ensure emergency access to the explosives facility since there is no actual trials data for this NEQ. However several UK trials (References 4, 5 and 6) have indicated that it requires in excess of 500 g of HE to demolish a brick walled structure (in the instances trialled with a protective RC roof).

22. Reference 4 is used in the UK as the source of definitive data which allows determination of the recommendations to be applied for NEQs less than 1Kg. These trials utilised buildings with brick wall construction of either 115 mm (nominally 4.5 inches) or 230 mm (nominally 9 inches). They demonstrated that it required some 174g of PE to breach the 115 mm wall and charges up to 230 g failed to breach the 230 mm wall, with the charge in each instance in contact with the wall. In all cases some spalling was evident from the external face (on the other side from the charge position) out to some 5m. When the tests were repeated with a stand-off from the target wall of some 290 mm (nominally 12 inches) charge weights of 231 g for the 115 mm wall and 480 g were sufficient to produce limited spalling from the external face. Charges of 363 g for the 115 mm wall and 933 g for the 230 mm wall were required to produce substantial spalling but neither produced failure of the wall structure.

23. These results coupled with the rather more anecdotal evidence from Refs 5 and 6 clearly indicate that charges of up to 100g of HE will not generate damage or debris outside a brick walled structure if the charge is not in contact with the subject wall. If it is in contact then 50 g HE will generate limited external debris but a nominal 5m separation distance to any exposed site should prevent any significant hazard. Indeed for the practical circumstances a charge of NEQ of 500 g stood off from the wall is unlikely to produce any external effects. It is recognised that the actual stand-off distance is critical in limiting any damage and subsequent hazard.

24. It is therefore recommended that there is no requirement for any external quantity distances from explosive charges with an NEQ no greater than 100g. Such circumstances should still be subject to licensing controls to ensure that the stand-off and NEQ limitations are understood and complied with.

NEQS above 5600 Kg

25. For all values of NEQ from 500 to 5600 kg the recommendations at Annex H essentially caps the IBD at 400 m. Above 5600 kg it is also deemed that the standard HD 1.1 IBD of 22.2 $Q^{1/3}$ will provide the requisite protection from debris effects.

26. This does leave open the problem of debris effects above 500 kg NEQ. All my analysis to date (and mirrored by previous work by Swisdak in US (Ref 7)) strongly suggests that 400 m is not a logical IBD to provide sufficient protection (given current guidelines) from debris from accidental explosions. Debris effects continue to override blast effects up to NEQs of the order of 20,000 kg and this issue needs to be addressed.

27. This is still under investigation and the subject of ongoing discussions with the UK and NATO AC 326 SG5 communities, along with the issue associated with the current debris lethality criteria.

<u>Proposed QDs for NEQs of 500 Kg and less</u>

28. Annex H tabulates the recommended values for traversed (barricaded) and untraversed (unbarricaded) circumstances. Please note that all values have been rounded in accordance with AASTP-1 and JSP 482 guidelines. It is recommended that the proposed quantity-distances tabulated at Annex H should not be interpolated. To ensure this is fully understood the table should be used as in the following example. For an NEQ of 75 Kg the IBD to be used is either 200 m (Traversed/barricaded) or 255 m (Untraversed/unbarricaded). If the available separation distance is 240 m then the allowable NEQ would be 150 Kg (Traversed/barricaded) or 50 Kg (Untraversed/unbarricaded). To allow a measure of refinement in the absence of interpolation values are provided for intermediate NEQs which have not been derived from actual trials at the NEQ quoted. For information purposes these are shown in red in the table at Annex H.

29. This table is still an interim proposal at this point but is currently being used for licensing purposes in UK as it represents a conservative position. Further work still needs to be done on considering whether the correct lethality criteria is being utilised which may result in the distances quoted at Annex H being reduced

References

1. AC326/SG5-SG6 NLD IWP 01-2006 dated January 2006

2. AC/326 D(2008)0006, dated 27 May 2008, 'Measurement And Analysis Of Explosion Produced debris And Fragments following An Accident Or A Test Representative Of An Accident,"

3. DDESB TP 21 dated 22-10-2007

4. Small Quantities Explosives Storage Trial Report, October 1996, ESTC Library number 5121

5. 81 mm Mortar Bomb Trial in Brick Building

6. 2 inch Mortar Bomb Trials in Brick Building

7. Minutes of 30th DoD Explosives Safety Seminar : Swisdak, Michael M., Gould, Michael J. A., and Henderson, Jonathan, "Proposed Inhabited Building Distances Based On Debris For Aboveground Structures"

Annex A

Debris Trials conducted by UK

Test ID	NEQ(Kg)	Explosives	Walls Type	Roof Type	Traverses
Stack Frag 1					
T3	1800	500lb HE Bombs	Brick	R/C	SE/SW
T4	1800	500lb HE Bombs	Brick	R/C	SE/SW
Stack Frag 2					
T5	500	175mm HE Shell	Brick	R/C	SE/SW
T6	500	Comp B	Brick	R/C	SE/SW
T7	500	175mm HE Shell	R/C	R/C	SE/SW
T8	500	Comp B	Brick	Sheet metal	SE/SW
Stack Frag 3					
T9	1800	175mm HE Shell	Brick	R/C	SE/SW/NW
T11	1800	175mm HE Shell	R/C	R/C	SE/SW/NW
T13	500	175mm HE Shell	Brick/Steelcrete	R/C	SE/SW
SQESH 1					
T1	50	Comp B	Brick	Frangible	SE/SW
T2	25	Comp B	Brick	Frangible	SE/SW
T3	50	Comp B	Brick	R/C	SE/SW
T4	25	Comp B	Brick	R/C	SE/SW
T5	25	Comp B	Brick	Frangible	SE/SW
T6	50	Comp B	Brick	Frangible	SE/SW
SQESH 2					
T1	50	Comp B	R Col/Brick	R/C	SE/SW
T2	50	Comp B	Brick	R/C	SE/SW
T3	25	Comp B	R Col/Brick	R/C	SE/SW
T4	25	Comp B	Brick	R/C	SE/SW
T5	10	Comp B	Brick	Frangible	No
T6	10	Comp B	Brick	Frangible	No
SQESH 3					
T2	100	PE4	Brick	Frangible	S/W
T3	100	PE4	Brick	R/C	S/W
T4	250	PE4	R/C	R/C	S/W
T5	100	PE4	R/C	R/C	S/W
T6	250	PE4	Brick	R/C	S/W
DTEO Precursor Tests					
DTEO5	10	PE4	Brick	R/C	No
DTEO4	25	PE4	Brick	R/C	No
DTEO3	10	PE4	Brick	R/C	No
DTEO2	10	PE4	Brick	Steel Panel	No

Annex B

Comparison of Data Use to date

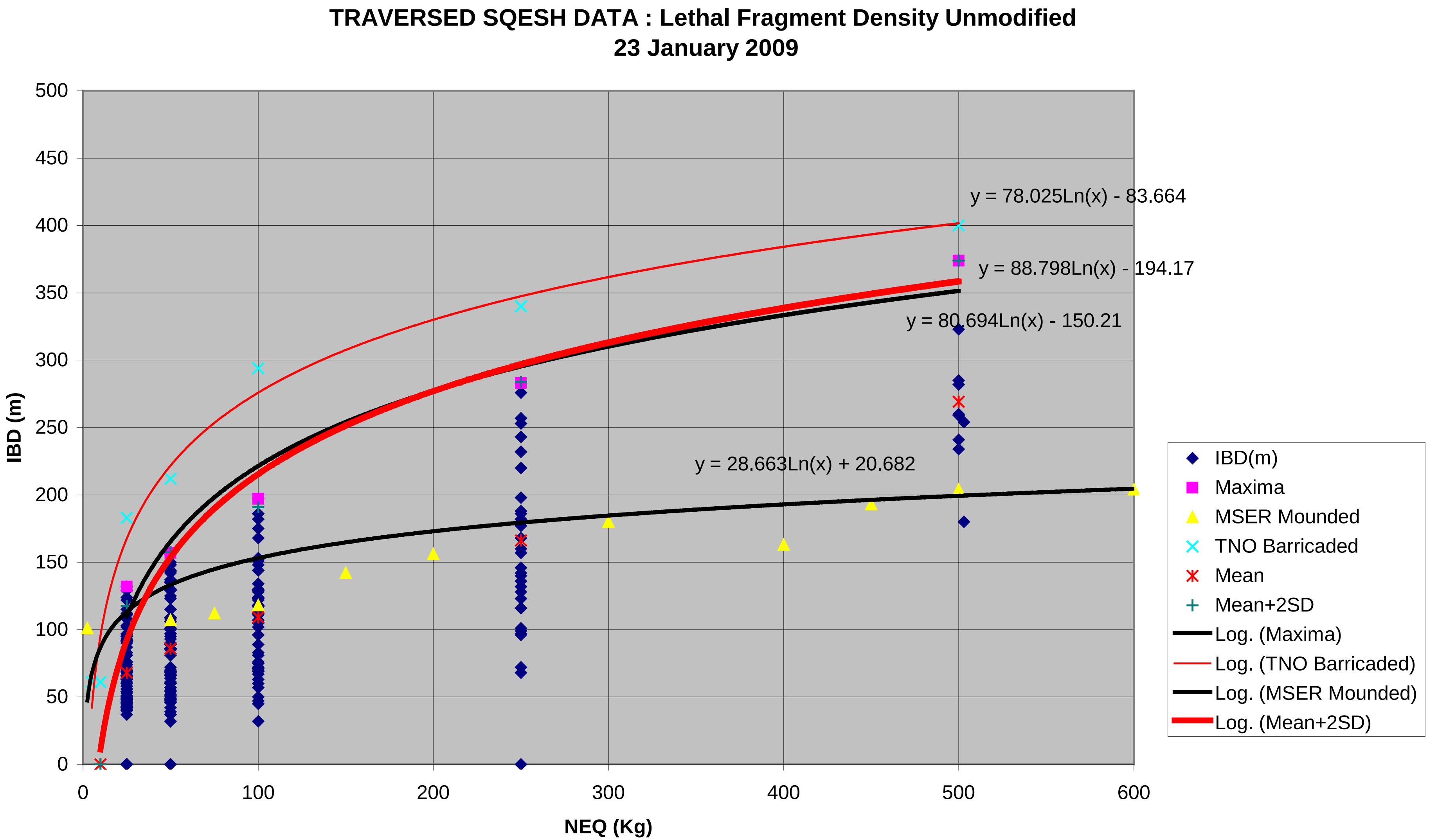
			TNO Analysis			US 6055.9		MSER			
NEQ(Kg)	D13	D12	Unbarr	Barr	B/Conc	Open	Structure	Unmounded Brick	Mounded Brick	Mounded Metal	Unmounded Metal
5	5	38	147	61	94	145	61				
10	7	48	163	61	117	162	61			23	30
25	13	65	183	183	147	184	119	160	107	33	39
50	21	82	212	212	196	201	201	180	112	40	44
100	33	104	294	294	240	283	283	230	142	48	55
250	60	140	340	340	290	381	381	293	180	76	101
500	95	177	400	400	369			355	204	96	138
1000	150	222						398	255	150	168
2000	239	280						442	285	229	229
3000	302	321						449	328	285	285
4000	348	353						454	362	328	328
5000	380	380						495	475	362	362
10000	479	479						550	548	475	475

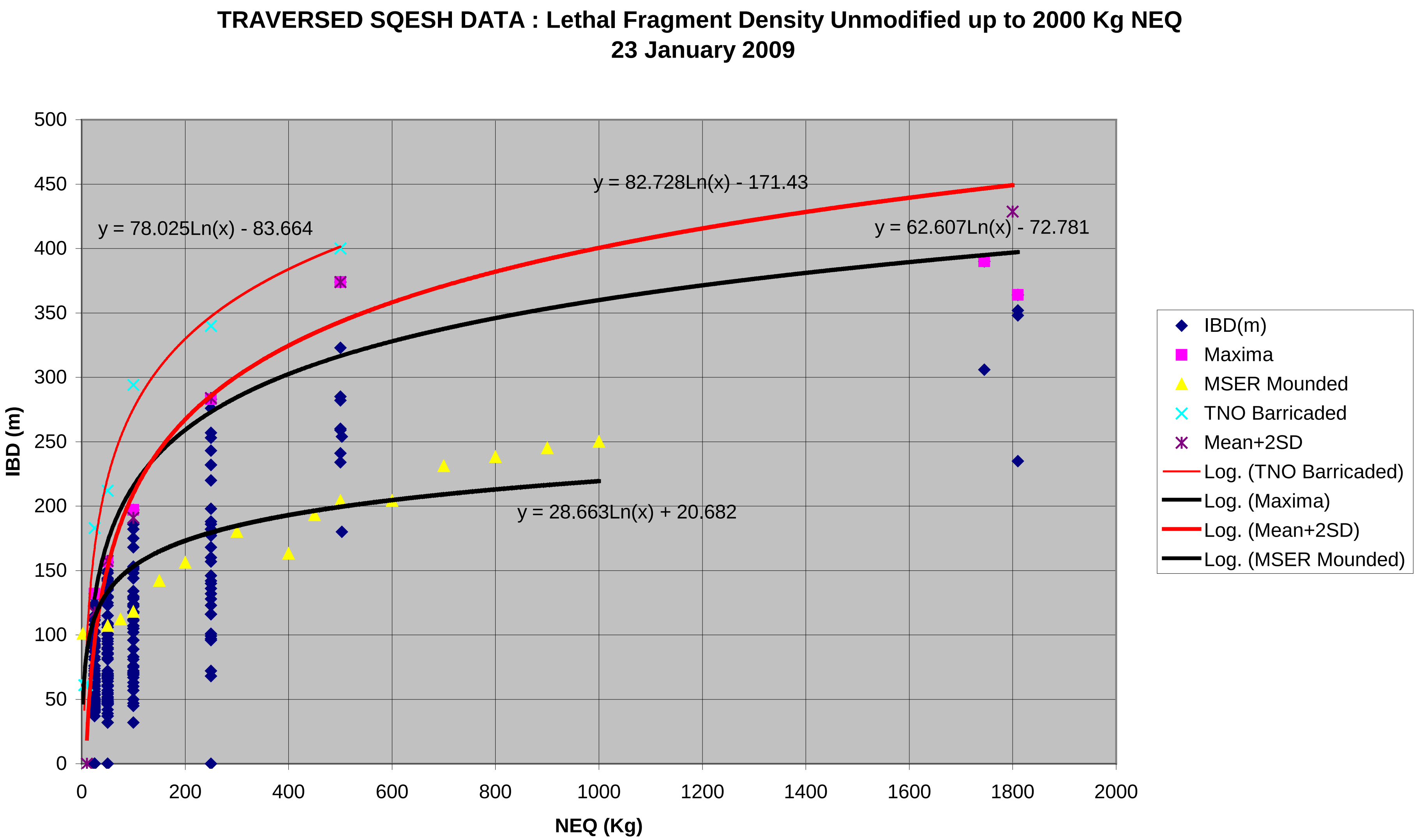
TNO Definitions

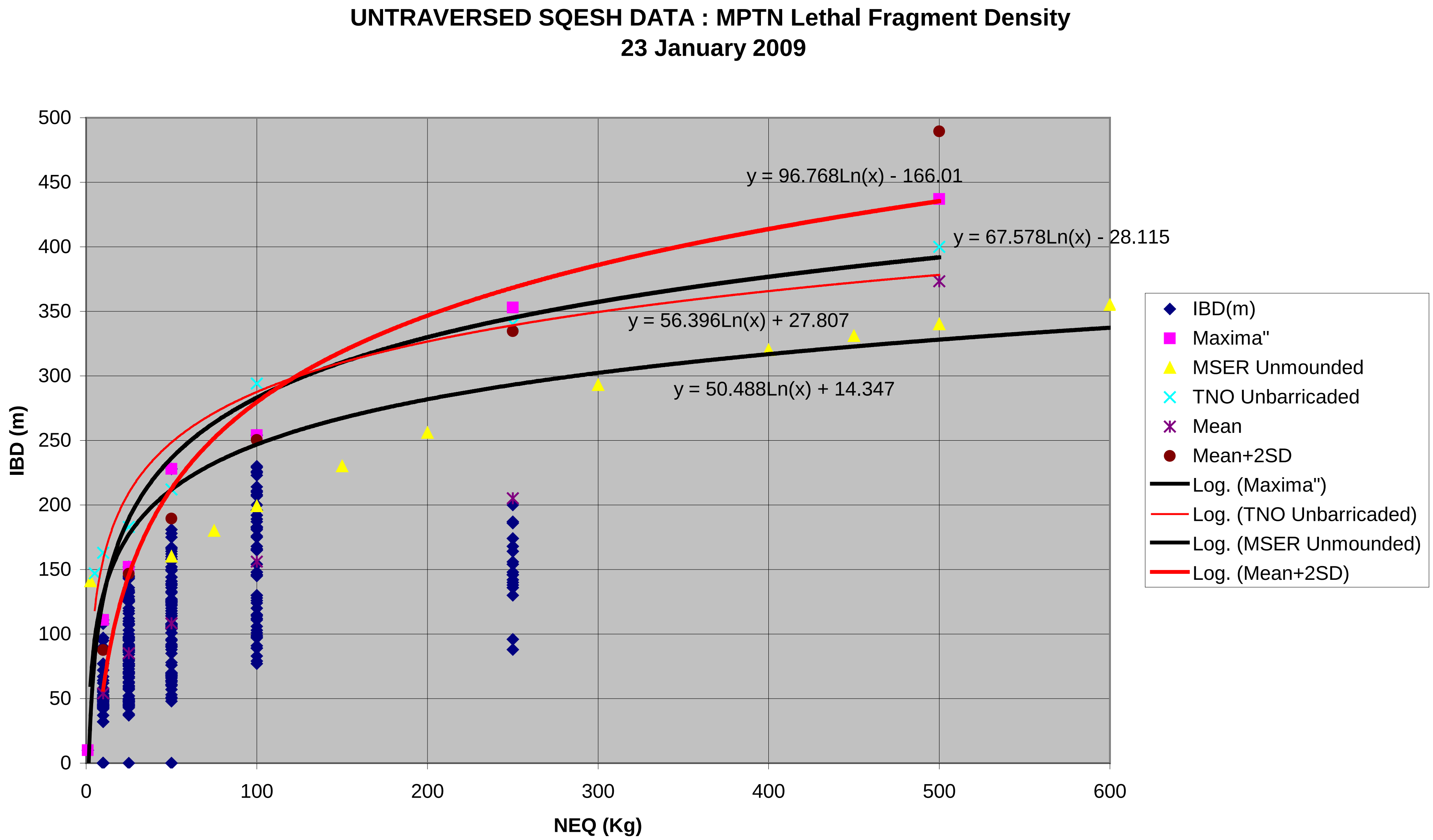
Unbarr : Containers, trucks, vehicles (unbarricaded)
Barr : Open stacks, containers (barricaded)
B/Conc : Structures with brick/concrete walls and RC roof (barricaded/unbarricaded)

US information derived from Table C9T2

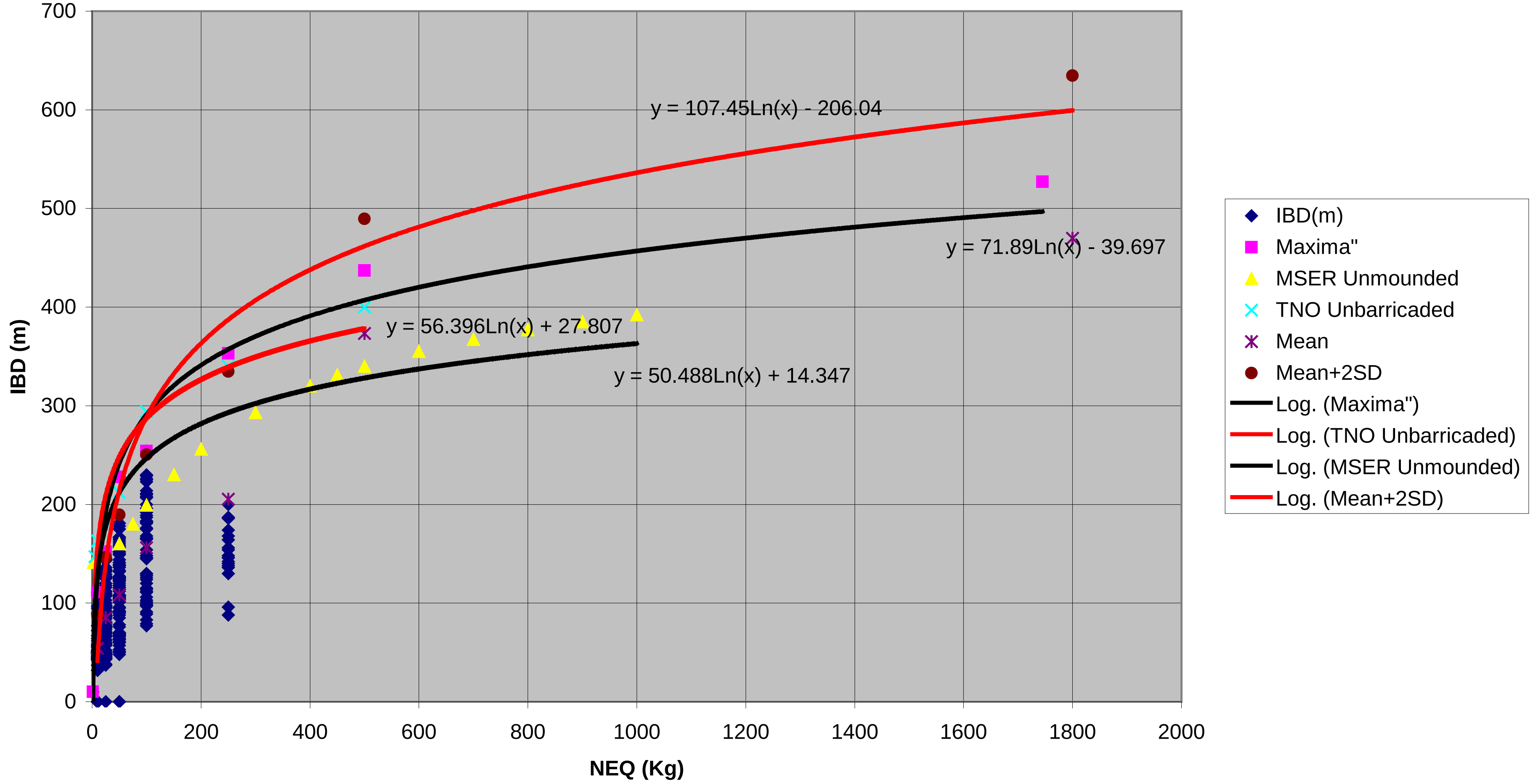
MSER information derived from Approved Code of Practice for MSER 2005


TRAVERSED SQESH DATA : Lethal Fragment Density Unmodified
23 January 2009
y = 78.025Ln(x) - 83.664
y = 88.798Ln(x) - 194.17
y = 80.694Ln(x) - 150.21
y = 28.663Ln(x) + 20.682
IBD (m)
NEQ (Kg)
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500
600
IBD(m)
Maxima
MSER Mounded
TNO Barricaded
Mean
Mean+2SD
Log. (Maxima)
Log. (TNO Barricaded)
Log. (MSER Mounded)
Log. (Mean+2SD)

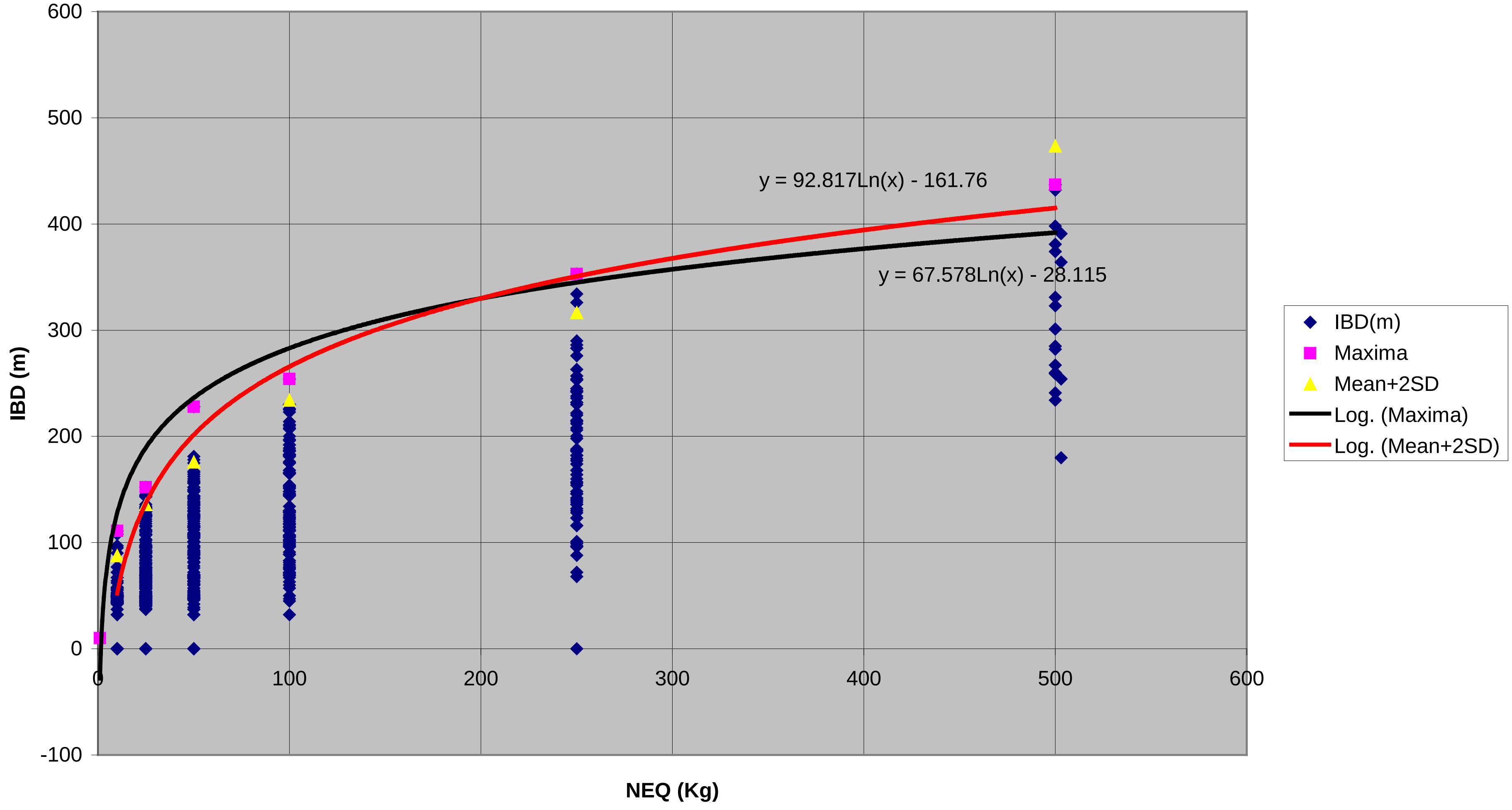

TRAVERSED SQESH DATA : Lethal Fragment Density Unmodified up to 2000 Kg NEQ
23 January 2009
y = 82.728Ln(x) - 171.43
y = 78.025Ln(x) - 83.664
y = 62.607Ln(x) - 72.781
y = 28.663Ln(x) + 20.682
IBD (m)
NEQ (Kg)
0
50
100
150
200
250
300
350
400
450
500
0
200
400
600
800
1000
1200
1400
1600
1800
2000
IBD(m)
Maxima
MSER Mounded
TNO Barricaded
Mean+2SD
Log. (TNO Barricaded)
Log. (Maxima)
Log. (Mean+2SD)
Log. (MSER Mounded)

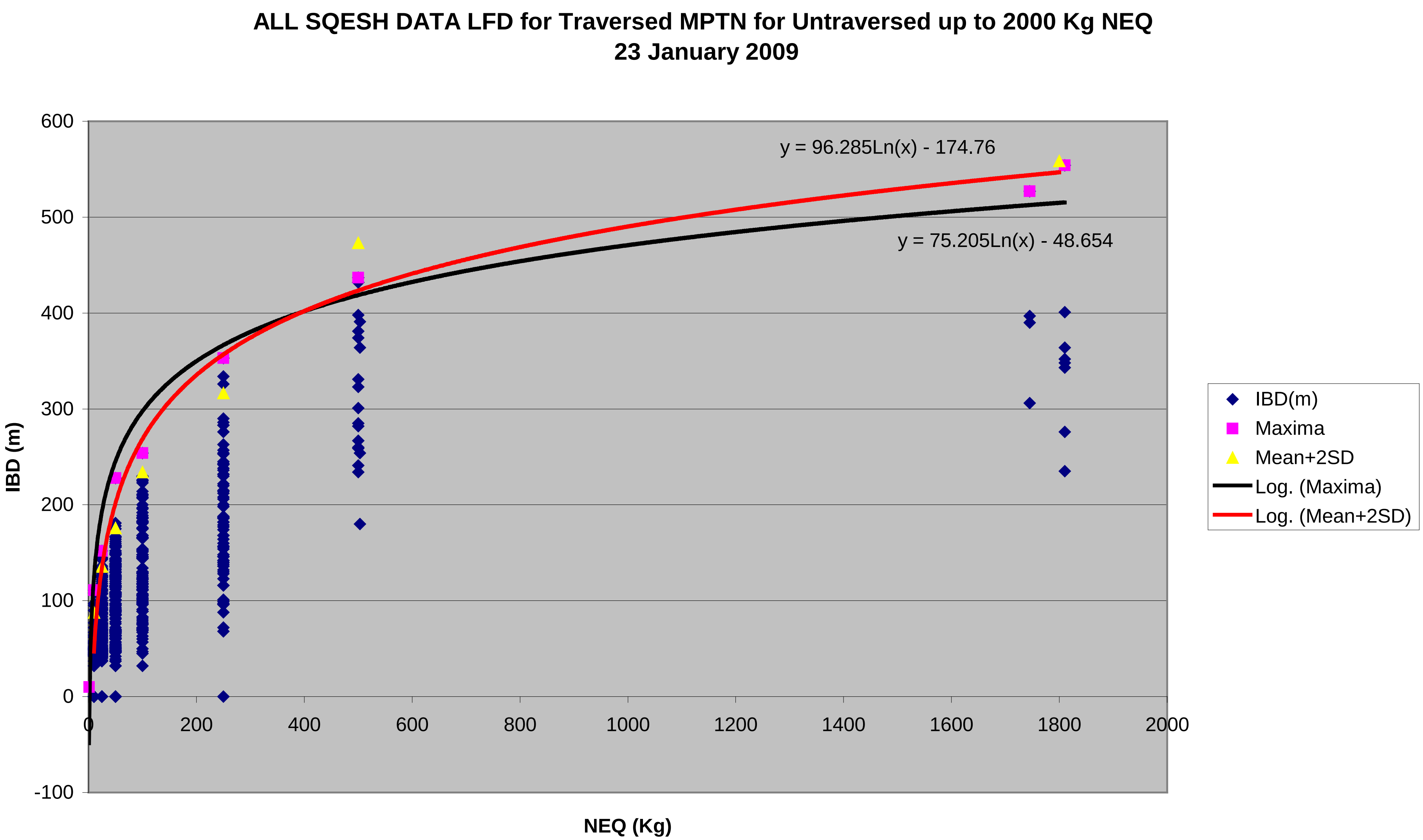

UNTRAVERSED SQESH DATA : MPTN Lethal Fragment Density
23 January 2009
IBD (m)
NEQ (Kg)
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500
600
y = 96.768Ln(x) - 166.01
y = 67.578Ln(x) - 28.115
y = 56.396Ln(x) + 27.807
y = 50.488Ln(x) + 14.347
IBD(m)
Maxima"
MSER Unmounded
TNO Unbarricaded
Mean
Mean+2SD
Log. (Maxima")
Log. (TNO Unbarricaded)
Log. (MSER Unmounded)
Log. (Mean+2SD)

UNTRAVERSED SQESH DATA : MPTN Lethal Fragment Density up to 2000 Kg NEQ
23 January 2009



ALL SQESH DATA LFD for Traversed MPTN for Untraversed





ALL SQESH DATA LFD for Traversed MPTN for Untraversed up to 2000 Kg NEQ
23 January 2009
y = 96.285Ln(x) - 174.76
y = 75.205Ln(x) - 48.654
IBD (m)
600
500
400
300
200
100
0
-100
0
200
400
600
800
1000
1200
1400
1600
1800
2000
NEQ (Kg)
IBD(m)
Maxima
Mean+2SD
Log. (Maxima)
Log. (Mean+2SD)

NEQ	T1(Conf)	T3(Max)	All 1(Conf)	All 3(Max)	TNO	MSER	Actual Max		D13	D12
1	-194.17	-150.21	-161.76	-28.115			6	values in red	2	23
5	-51.2551	-20.338	-12.3768	80.6476	61		27	are interpolated	5	38
10	10.29495	35.5948	51.959041	127.4891	61		53		7	48
25	91.65974	109.534	137.0064	189.4102	183		132		13	65
50	153.2098	165.4668	201.34224	236.2517	212	107	157		21	82
100	214.7599	221.3996	265.67808	283.0932	294		197		33	104
250	296.1247	295.3388	350.72544	345.0143	340		283		60	140
500	357.6748	351.2716	415.06128	391.8558	400	204	374		95	177

NEQ	T2(Conf)	T4(Max)	All 2(Conf)	All 4(Max)	TNO	MSER	Actual Max	D13	D12
1	-171.42	-72.781	-174.76	-48.654			6	2	23
5	-38.2744	27.98108	-19.79527	72.38378	61		27	5	38
10	19.06826	71.37694	46.944406	124.5119	61		53	7	48
25	94.87116	128.7432	135.16946	193.4216	183		132	13	65
50	152.2138	172.139	201.90914	245.5497	212	107	157	21	82
100	209.5565	215.5349	268.64881	297.6778	294		197	33	104
250	285.3594	272.9011	356.87386	366.5875	340		283	60	140
500	342.7021	316.297	423.61354	418.7156	400	204	374	95	177
750	376.2454	341.6819	462.65375	449.2086			377		
1000	400.0448	359.6928	490.35322	470.8437		250	380		
1500	433.5881	385.0778	529.39342	501.3367			386		
1800	448.6712	396.4924	546.94826	515.0482			390		

NEQ	UT1(Conf)	UT3(Max)	All 1(Conf)	All 3(Max)	TNO	MSER	Actual Max	D13	D12
1	-166.01	-28.115	-161.76	-28.115			10	2	23
5	-10.2679	80.6476	-12.3768	80.6476	147		60	5	38
10	56.80655	127.4891	51.959041	127.4891	163		111	7	48
25	145.4742	189.4102	137.0064	189.4102	183		152	13	65
50	212.5486	236.2517	201.34224	236.2517	212	160	228	21	82
100	279.6231	283.0932	265.67808	283.0932	294		254	33	104
250	368.2907	345.0143	350.72544	345.0143	340		353	60	140
500	435.3652	391.8558	415.06128	391.8558	400	340	437	95	177

NEQ	UT2(Conf)	UT4(Max)	All 2(Conf)	All 4(Max)	TNO	MSER	Actual Max	D13	D12
1	-206.04	-39.697	-174.76	-48.654			10	2	23
5	-33.1059	76.00549	-19.79527	72.38378	147		60	5	38
10	41.37277	125.8358	46.944406	124.5119	163		111	7	48
25	139.8282	191.708	135.16946	193.4216	183		152	13	65
50	214.3069	241.5383	201.90914	245.5497	212	160	228	21	82
100	288.7855	291.3687	268.64881	297.6778	294		254	33	104
250	387.241	357.2408	356.87386	366.5875	340		353	60	140
500	461.7196	407.0712	423.61354	418.7156	400	340	437	95	177
750	505.2869	436.2201	462.65375	449.2086			460		
1000	536.1983	456.9015	490.35322	470.8437		392	483		
1500	579.7655	486.0504	529.39342	501.3367			529		
1800	599.356	499.1575	546.94826	515.0482			554		

Annex G1

TABLE 1 : TRAVERSED

NEQ	T1(Conf)	T2(Conf)	TR Actual Conf	T3(Max)	T4(Max)	Actual Max	All 1(Conf)	All 2(Conf)	All Actual Conf	All 3(Max)	All 4(Max)	TNO	MSER	D13	D12
1	-192.39	-170.80	5.00	-150.21	-72.78	6	-161.76	-174.76	9.00	-28.12	-48.65			2	23
5	-50.32	-38.01	25.00	-20.34	27.98	27	-12.38	-19.80	45.00	80.65	72.38	61		5	38
10	10.86	19.19	50.00	35.59	71.38	53	51.96	46.94	87.53	127.49	124.51	61		7	48
25	91.75	94.79	117.50	109.53	128.74	132	137.01	135.17	135.38	189.41	193.42	183		13	65
50	152.93	151.98	157.46	165.47	172.14	157	201.34	201.91	175.60	236.25	245.55	212	107	21	82
100	214.12	209.17	190.90	221.40	215.53	197	265.68	268.65	233.83	283.09	297.68	294		33	104
250	295.00	284.78	283.92	295.34	272.90	283	350.73	356.87	316.40	345.01	366.59	340		60	140
500	356.19	341.97	373.98	351.27	316.30	374	415.06	423.61	473.01	391.86	418.72	400	204	95	177

TABLE 2 : UNTRAVERSED

NEQ	UT1(Conf)	UT2(Conf)	UT Actual Conf	UT3(Max)	UT4(Max)	Actual Max	All 1(Conf)	All 2(Conf)	All Actual Conf	All 3(Max)	All 4(Max)	TNO	MSER	D13	D12
1	-166.01	-206.04	9.00	-28.12	-39.70	10	-161.76	-174.76	9.00	-28.12	-48.65			2	23
5	-10.27	-33.11	45.00	80.65	76.01	60	-12.38	-19.80	45.00	80.65	72.38	147		5	38
10	56.81	41.37	87.53	127.49	125.84	111	51.96	46.94	87.53	127.49	124.51	163		7	48
25	145.47	139.83	146.58	189.41	191.71	152	137.01	135.17	135.38	189.41	193.42	183		13	65
50	212.55	214.31	189.51	236.25	241.54	228	201.34	201.91	175.60	236.25	245.55	212	160	21	82
100	279.62	288.79	250.33	283.09	291.37	254	265.68	268.65	233.83	283.09	297.68	294		33	104
250	368.29	387.24	334.63	345.01	357.24	353	350.73	356.87	316.40	345.01	366.59	340		60	140
500	435.37	461.72	489.51	391.86	407.07	437	415.06	423.61	473.01	391.86	418.72	400	340	95	177
	up to 500kg	up to 1800 kg		up to 500kg	up to 1800 kg		up to 500kg	up to 1800 kg		up to 500kg	up to 1800 kg				

TABLE 3 : PROPOSED SOLUTION

	TRAVERSED				UNTRAVERSED				All Data		
NEQ	90% Confidence	95% Confidence	99% Confidence	Actual Max Traversed	90% Confidence	95% Confidence	99% Confidence	Actual Max Untraversed	90% Confidence	95% Confidence	99% Confidence
1	5.00			6	9.00			10	9.00		
5	25.00			27	45.00			60	45.00		
10	50.00			53	87.53	104.24	120.95	111	87.53	104.24	120.95
25	117.50	142.24	166.97	132	146.58	177.25	207.93	152	135.38	164.58	193.78
50	157.46	193.19	228.93	157	189.51	230.09	270.68	228	175.60	214.21	252.81
100	190.90	231.75	272.60	197	250.33	297.48	344.62	254	233.83	283.78	333.73
250	283.92	342.77	401.63	283	334.63	399.34	464.05	353	316.40	381.06	445.71
500	373.98	426.37	478.76	374	489.51	547.57	605.62	400 (437)	473.01	548.86	624.72

values in red are interpolated

Annex H

PROPOSED SMALL QUANTITY INHABITED BUILDING DISTANCES FOR MASONRY BUILDINGS

NEQ(Kg)	Traversed IBD (m)	Untraversed IBD (m)
< 0.1	0	0
1	6	12
5	28	58
10	54	115
25	135	155
50	160	230
100	200	255
150	230	290
200	260	325
250	285	355
300	305	365
400	340	385
500	375	400

STORAGE OF LIMITED NET EXPLOSIVES QUANTITIES IN MASONRY BUILDINGS

Jon Henderson
Deputy Chief Inspector Explosives (MoD)
UK Ministry of Defence
E-mail : DESWpnseng-DCIE@mod.uk

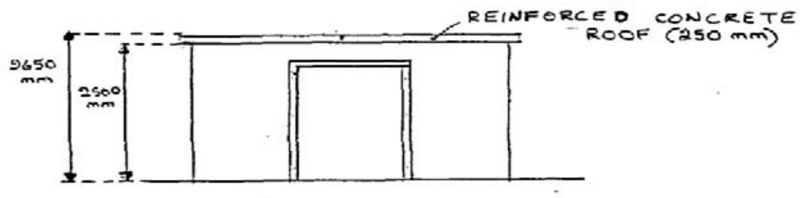
MINISTRY OF DEFENCE

Debris Trials conducted by UK

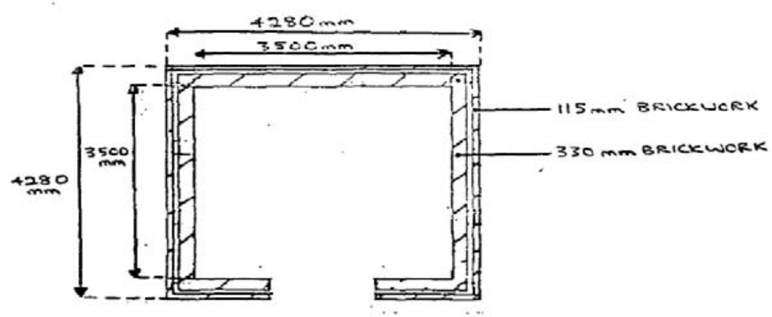
Test ID	NEQ(Kg)	Explosives	Walls Type	Roof Type	Traverses
Stack Frag 1					
T3	1800	500lb HE Bombs	Brick	R/C	SE/SW
T4	1800	500lb HE Bombs	Brick	R/C	SE/SW
Stack Frag 2					
T5	500	175mm HE Shell	Brick	R/C	SE/SW
T6	500	Comp B	Brick	R/C	SE/SW
T7	500	175mm HE Shell	R/C	R/C	SE/SW
T8	500	Comp B	Brick	Sheet metal	SE/SW
Stack Frag 3					
T9	1800	175mm HE Shell	Brick	R/C	SE/SW/NW
T11	1800	175mm HE Shell	R/C	R/C	SE/SW/NW
T13	500	175mm HE Shell	Brick/Steelcrete	R/C	SE/SW
SQESH 1					
T1	50	Comp B	Brick	Frangible	SE/SW
T2	25	Comp B	Brick	Frangible	SE/SW
T3	50	Comp B	Brick	R/C	SE/SW
T4	25	Comp B	Brick	R/C	SE/SW
T5	25	Comp B	Brick	Frangible	SE/SW
T6	50	Comp B	Brick	Frangible	SE/SW
SQESH 2					
T1	50	Comp B	R Col/Brick	R/C	SE/SW
T2	50	Comp B	Brick	R/C	SE/SW
T3	25	Comp B	R Col/Brick	R/C	SE/SW
T4	25	Comp B	Brick	R/C	SE/SW
T5	10	Comp B	Brick	Frangible	No
T6	10	Comp B	Brick	Frangible	No
SQESH 3					
T2	100	PE4	Brick	Frangible	S/W
T3	100	PE4	Brick	R/C	S/W
T4	250	PE4	R/C	R/C	S/W
T5	100	PE4	R/C	R/C	S/W
T6	250	PE4	Brick	R/C	S/W
DTEO Precursor Tests					
DTEO5	10	PE4	Brick	R/C	No
DTEO4	25	PE4	Brick	R/C	No
DTEO3	10	PE4	Brick	R/C	No
DTEO2	10	PE4	Brick	Steel Panel	No

MINISTRY OF DEFENCE

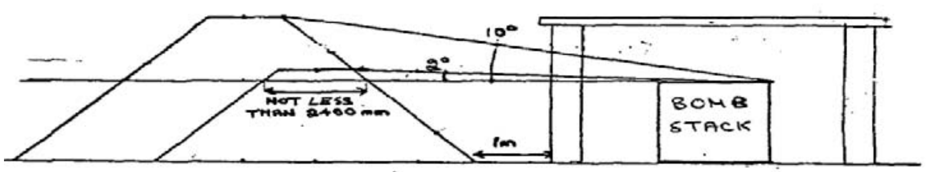
de&s



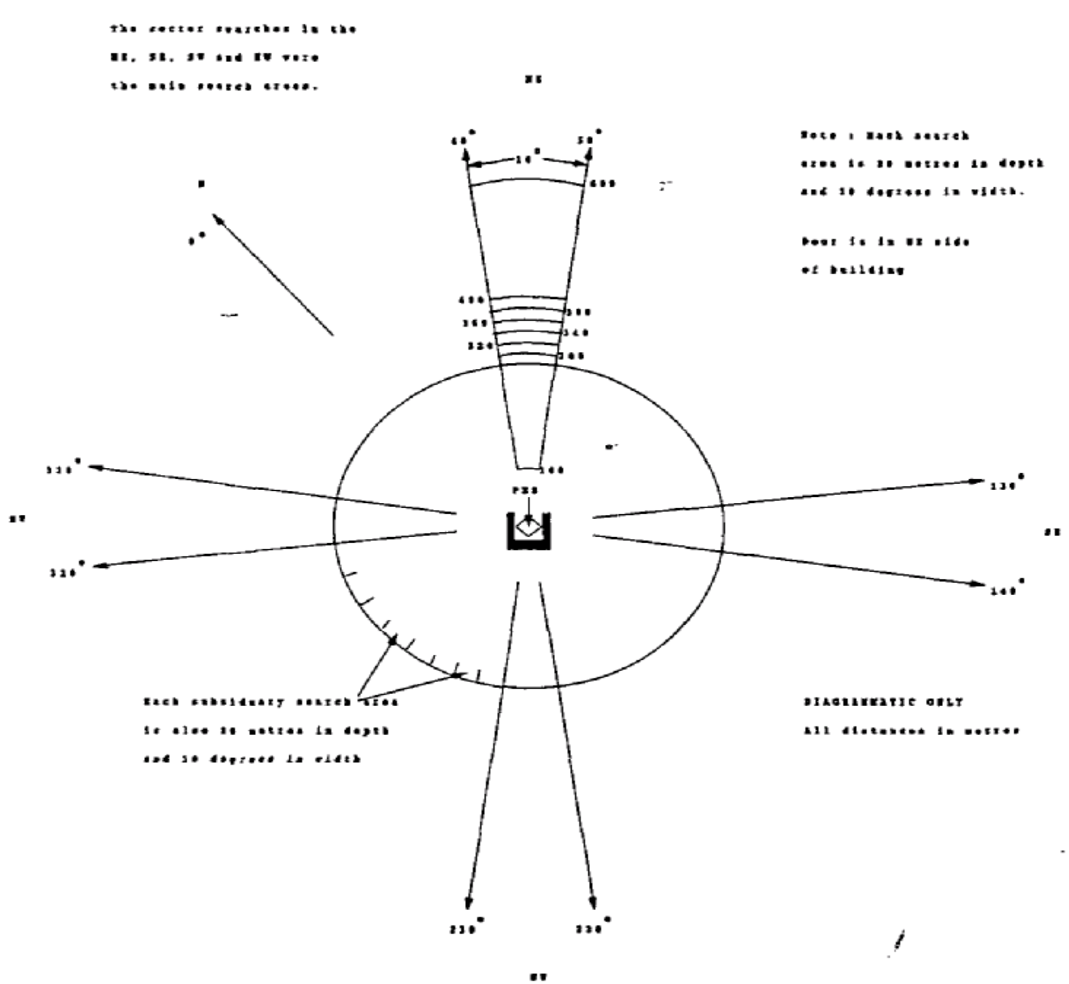
FRONT ELEVATION



PLAN



SEARCH LAYOUT FOR TRIALS



Comparison of Data Use to date

			TNO Analysis			US 6055.9		MSER			
NEQ(Kg)	D13	D12	Unbarr	Barr	B/Conc	Open	Structure	Unmounded Brick	Mounded Brick	Mounded Metal	Unmounded Metal
5	5	38	147	61	94	145	61				
10	7	48	163	61	117	162	61			23	30
25	13	65	183	183	147	184	119	160	107	33	39
50	21	82	212	212	196	201	201	180	112	40	44
100	33	104	294	294	240	283	283	230	142	48	55
250	60	140	340	340	290	381	381	293	180	76	101
500	95	177	400	400	369			355	204	96	138
1000	150	222						398	255	150	168
2000	239	280						442	285	229	229
3000	302	321						449	328	285	285
4000	348	353						454	362	328	328
5000	380	380						495	475	362	362
10000	479	479						550	548	475	475

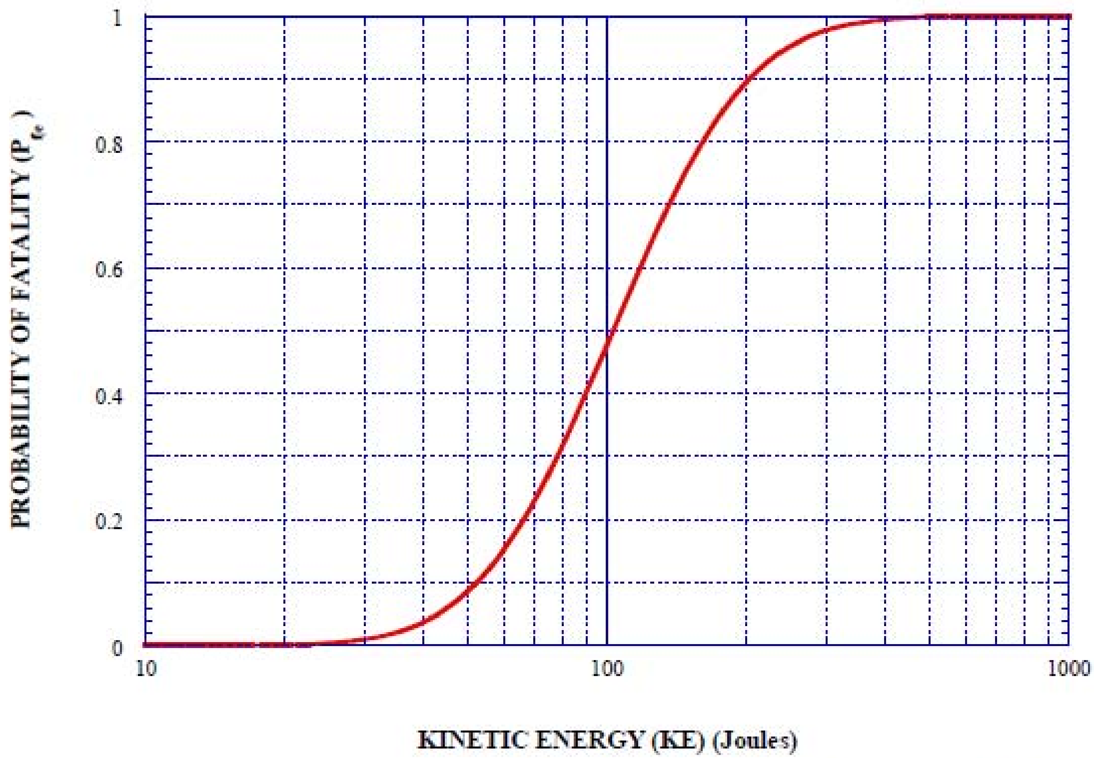
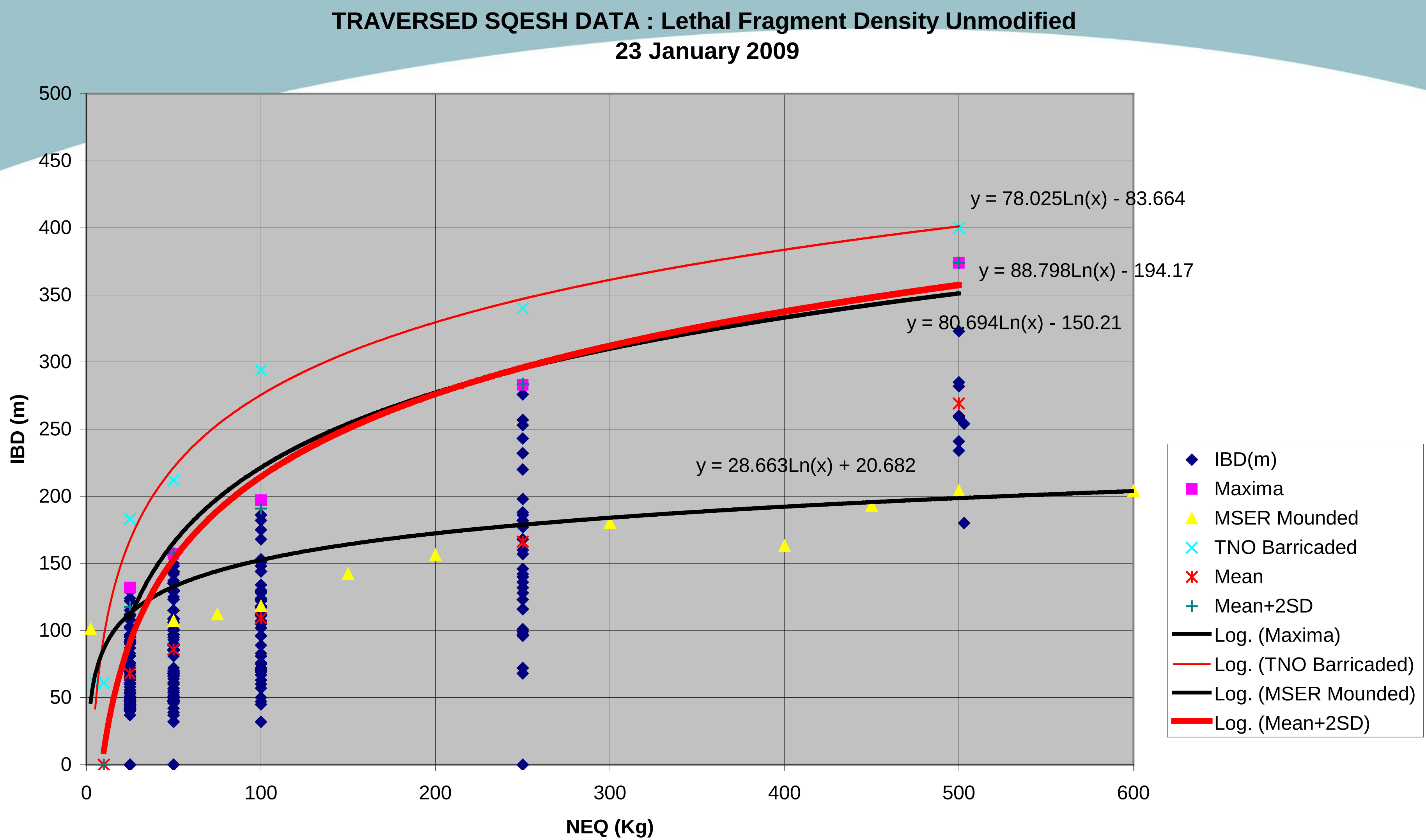


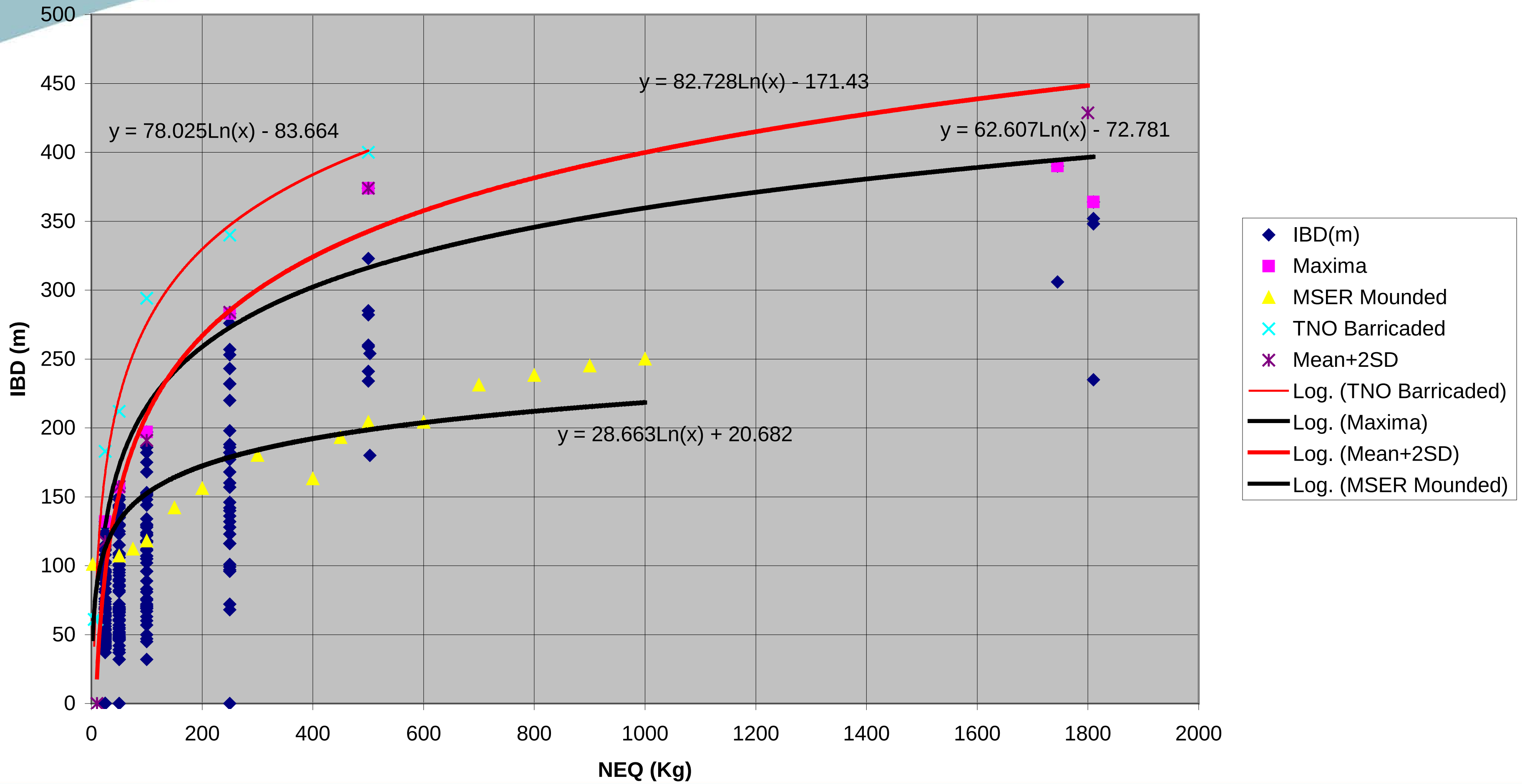
FIGURE 11. KINETIC ENERGY VERSUS PROBABILITY OF FATALITY



MINISTRY OF DEFENCE

de&s

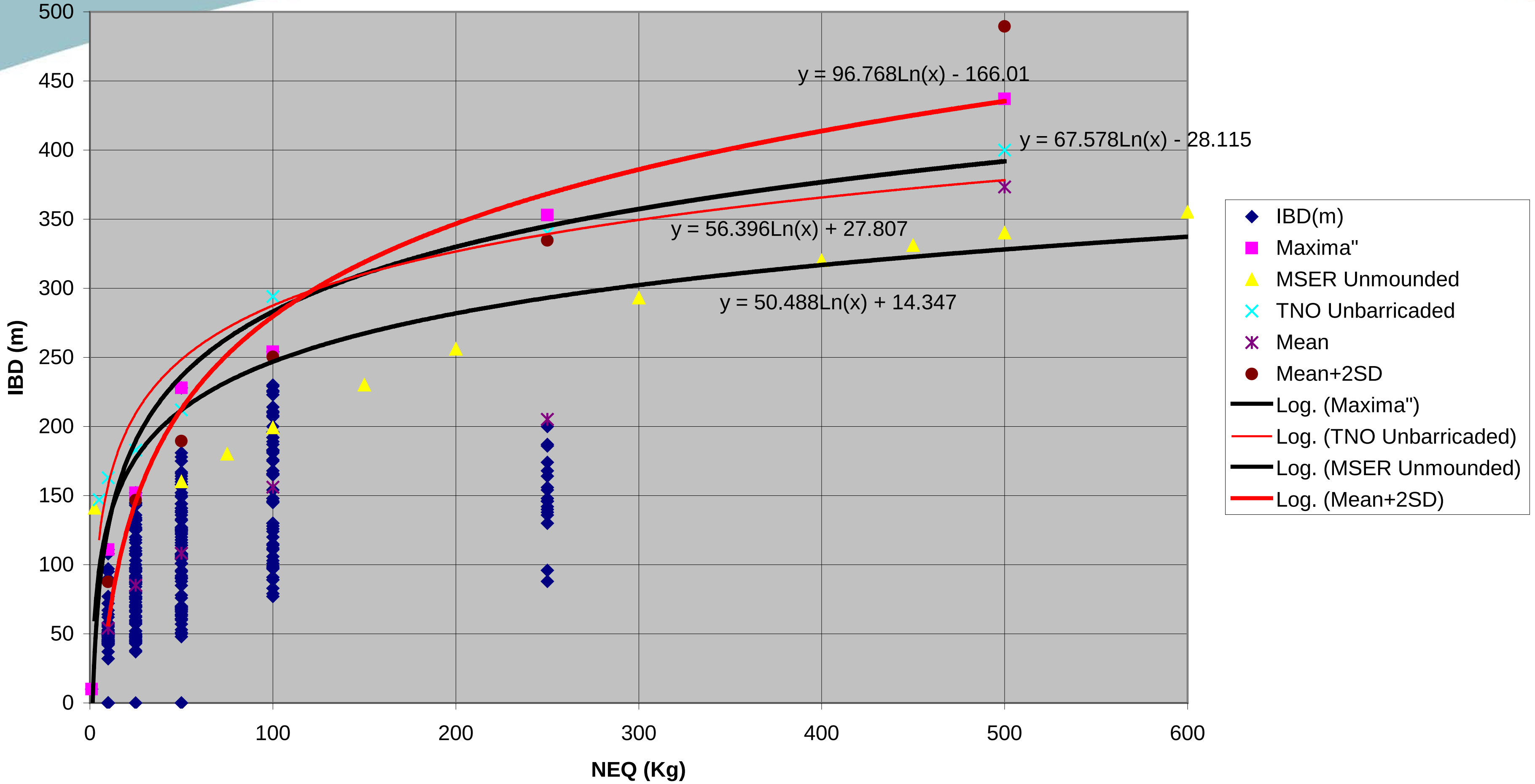
TRAVERSED SQESH DATA : Lethal Fragment Density Unmodified up to 2000 Kg NEQ
23 January 2009



MINISTRY OF DEFENCE

de&s

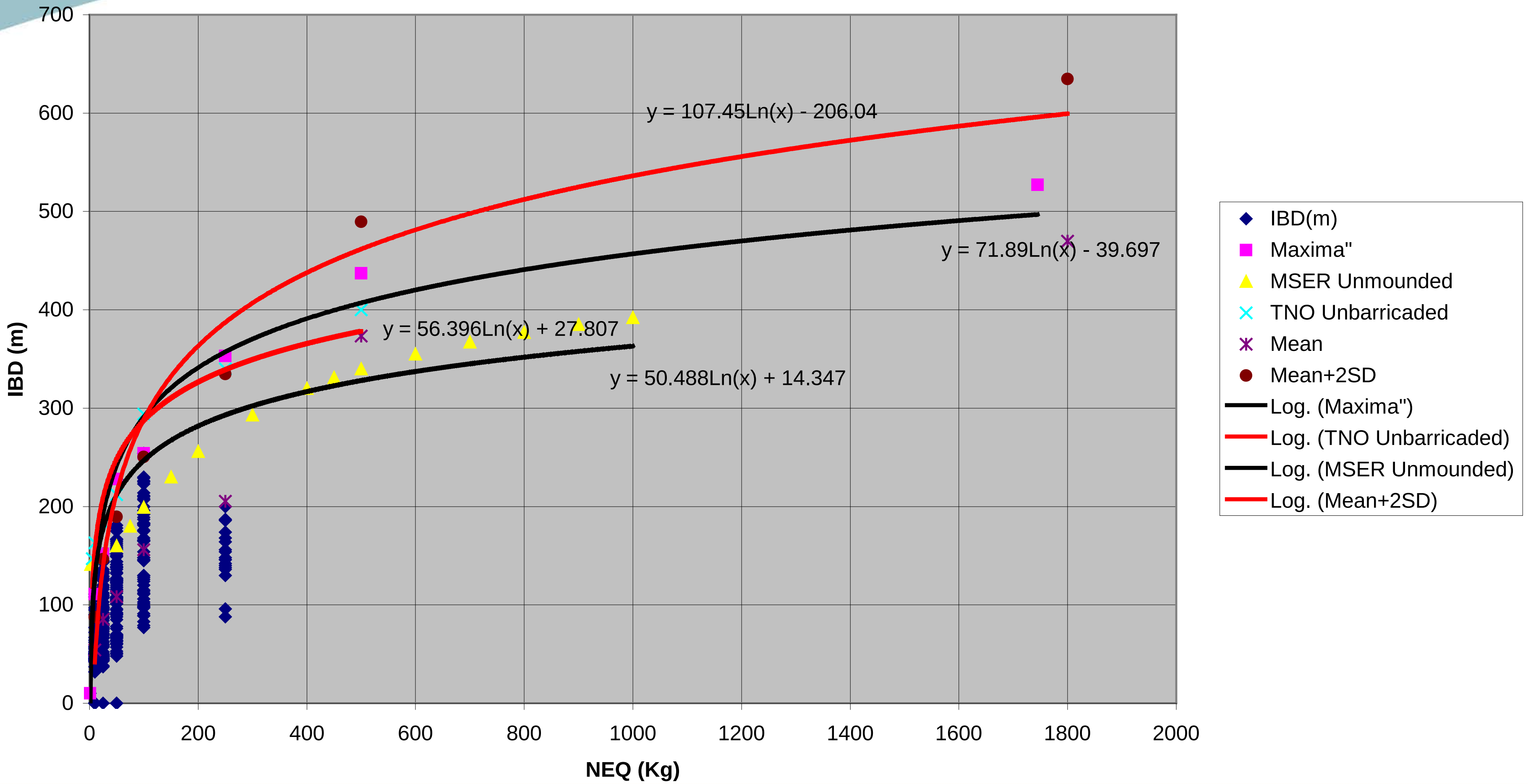
UNTRAVERSED SQESH DATA : MPTN Lethal Fragment Density
23 January 2009



MINISTRY OF DEFENCE

de&s

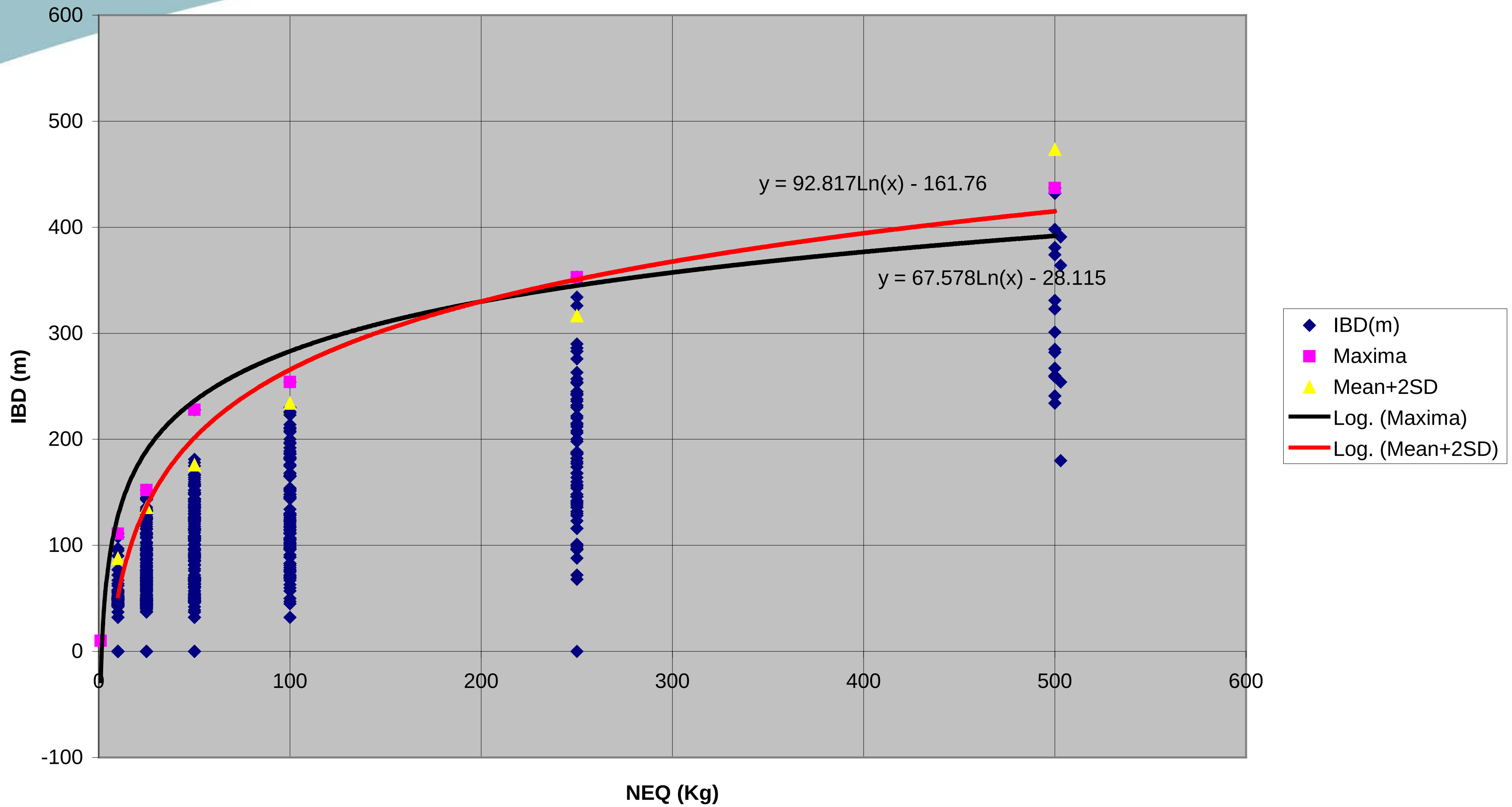
UNTRAVERSED SQESH DATA : MPTN Lethal Fragment Density up to 2000 Kg NEQ
23 January 2009



MINISTRY OF DEFENCE

de&s

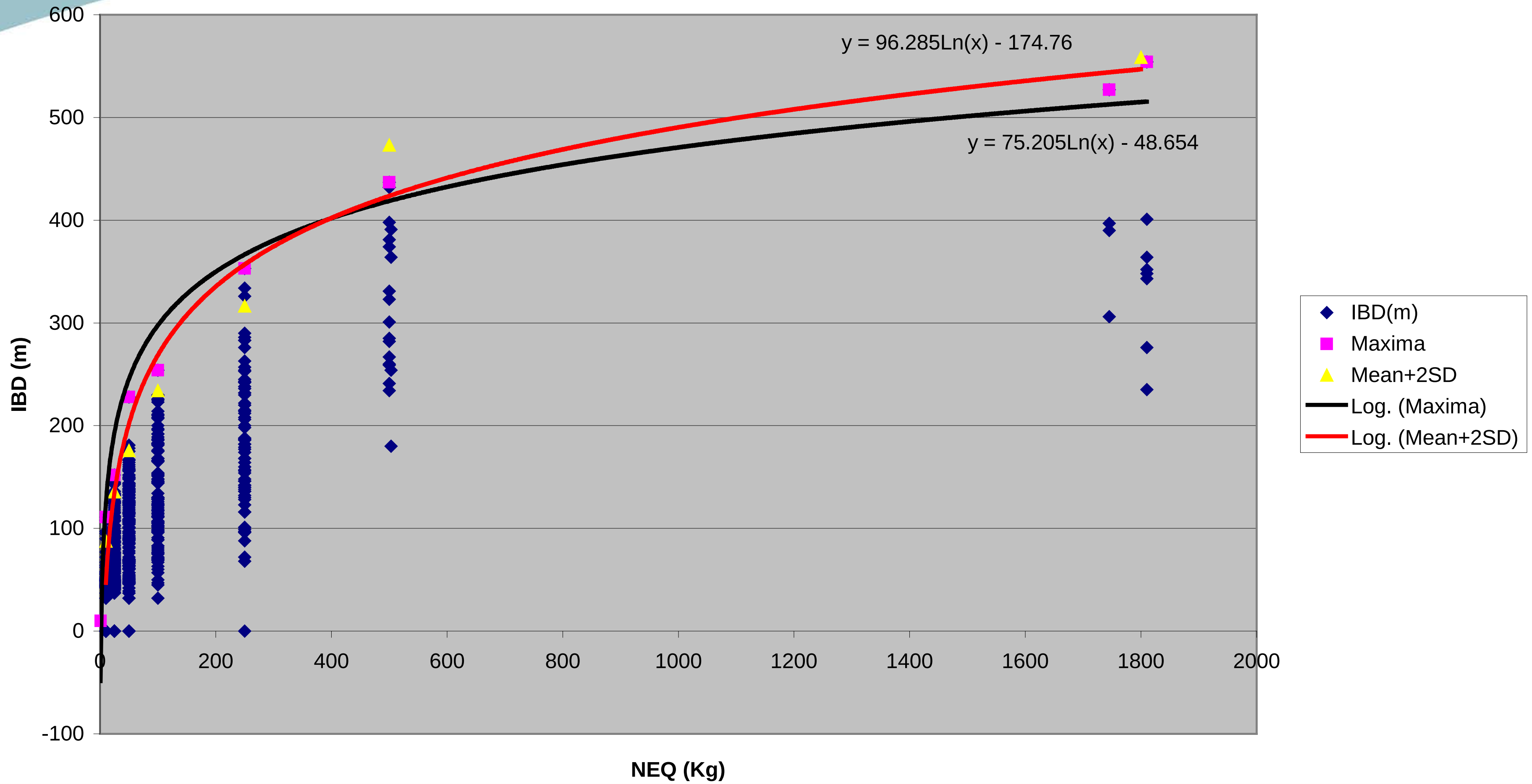
ALL SQESH DATA LFD for Traversed MPTN for Untraversed



MINISTRY OF DEFENCE

de&s

ALL SQESH DATA LFD for Traversed MPTN for Untraversed up to 2000 Kg NEQ
23 January 2009



MINISTRY OF DEFENCE

de&s

NEQ	T1(Conf)	T3(Max)	All 1(Conf)	All 3(Max)	TNO	MSER	Actual Max		D13	D12
1	-194.17	-150.21	-161.76	-28.115			6	values in red	2	23
5	-51.2551	-20.338	-12.3768	80.6476	61		27	are interpolated	5	38
10	10.29495	35.5948	51.959041	127.4891	61		53		7	48
25	91.65974	109.534	137.0064	189.4102	183		132		13	65
50	153.2098	165.4668	201.34224	236.2517	212	107	157		21	82
100	214.7599	221.3996	265.67808	283.0932	294		197		33	104
250	296.1247	295.3388	350.72544	345.0143	340		283		60	140
500	357.6748	351.2716	415.06128	391.8558	400	204	374		95	177

NEQ	T2(Conf)	T4(Max)	All 2(Conf)	All 4(Max)	TNO	MSER	Actual Max	D13	D12
1	-171.42	-72.781	-174.76	-48.654			6	2	23
5	-38.2744	27.98108	-19.79527	72.38378	61		27	5	38
10	19.06826	71.37694	46.944406	124.5119	61		53	7	48
25	94.87116	128.7432	135.16946	193.4216	183		132	13	65
50	152.2138	172.139	201.90914	245.5497	212	107	157	21	82
100	209.5565	215.5349	268.64881	297.6778	294		197	33	104
250	285.3594	272.9011	356.87386	366.5875	340		283	60	140
500	342.7021	316.297	423.61354	418.7156	400	204	374	95	177
750	376.2454	341.6819	462.65375	449.2086			377		
1000	400.0448	359.6928	490.35322	470.8437		250	380		
1500	433.5881	385.0778	529.39342	501.3367			386		
1800	448.6712	396.4924	546.94826	515.0482			390		

NEQ	UT1(Conf)	UT3(Max)	All 1(Conf)	All 3(Max)	TNO	MSER	Actual Max	D13	D12
1	-166.01	-28.115	-161.76	-28.115			10	2	23
5	-10.2679	80.6476	-12.3768	80.6476	147		60	5	38
10	56.80655	127.4891	51.959041	127.4891	163		111	7	48
25	145.4742	189.4102	137.0064	189.4102	183		152	13	65
50	212.5486	236.2517	201.34224	236.2517	212	160	228	21	82
100	279.6231	283.0932	265.67808	283.0932	294		254	33	104
250	368.2907	345.0143	350.72544	345.0143	340		353	60	140
500	435.3652	391.8558	415.06128	391.8558	400	340	437	95	177

NEQ	UT2(Conf)	UT4(Max)	All 2(Conf)	All 4(Max)	TNO	MSER	Actual Max	D13	D12
1	-206.04	-39.697	-174.76	-48.654			10	2	23
5	-33.1059	76.00549	-19.79527	72.38378	147		60	5	38
10	41.37277	125.8358	46.944406	124.5119	163		111	7	48
25	139.8282	191.708	135.16946	193.4216	183		152	13	65
50	214.3069	241.5383	201.90914	245.5497	212	160	228	21	82
100	288.7855	291.3687	268.64881	297.6778	294		254	33	104
250	387.241	357.2408	356.87386	366.5875	340		353	60	140
500	461.7196	407.0712	423.61354	418.7156	400	340	437	95	177
750	505.2869	436.2201	462.65375	449.2086			460		
1000	536.1983	456.9015	490.35322	470.8437		392	483		
1500	579.7655	486.0504	529.39342	501.3367			529		
1800	599.356	499.1575	546.94826	515.0482			554		

TABLE 1 : TRAVERSED

NEQ	T1(Conf)	T2(Conf)	TR Actual Conf	T3(Max)	T4(Max)	Actual Max	All 1(Conf)	All 2(Conf)	All Actual Conf	All 3(Max)	All 4(Max)	TNO	MSER	D13	D12
1	-192.39	-170.80	5.00	-150.21	-72.78	6	-161.76	-174.76	9.00	-28.12	-48.65			2	23
5	-50.32	-38.01	25.00	-20.34	27.98	27	-12.38	-19.80	45.00	80.65	72.38	61		5	38
10	10.86	19.19	50.00	35.59	71.38	53	51.96	46.94	87.53	127.49	124.51	61		7	48
25	91.75	94.79	117.50	109.53	128.74	132	137.01	135.17	135.38	189.41	193.42	183		13	65
50	152.93	151.98	157.46	165.47	172.14	157	201.34	201.91	175.60	236.25	245.55	212	107	21	82
100	214.12	209.17	190.90	221.40	215.53	197	265.68	268.65	233.83	283.09	297.68	294		33	104
250	295.00	284.78	283.92	295.34	272.90	283	350.73	356.87	316.40	345.01	366.59	340		60	140
500	356.19	341.97	373.98	351.27	316.30	374	415.06	423.61	473.01	391.86	418.72	400	204	95	177

TABLE 2 : UNTRAVERSED

NEQ	UT1(Conf)	UT2(Conf)	UT Actual Conf	UT3(Max)	UT4(Max)	Actual Max	All 1(Conf)	All 2(Conf)	All Actual Conf	All 3(Max)	All 4(Max)	TNO	MSER	D13	D12
1	-166.01	-206.04	9.00	-28.12	-39.70	10	-161.76	-174.76	9.00	-28.12	-48.65			2	23
5	-10.27	-33.11	45.00	80.65	76.01	60	-12.38	-19.80	45.00	80.65	72.38	147		5	38
10	56.81	41.37	87.53	127.49	125.84	111	51.96	46.94	87.53	127.49	124.51	163		7	48
25	145.47	139.83	146.58	189.41	191.71	152	137.01	135.17	135.38	189.41	193.42	183		13	65
50	212.55	214.31	189.51	236.25	241.54	228	201.34	201.91	175.60	236.25	245.55	212	160	21	82
100	279.62	288.79	250.33	283.09	291.37	254	265.68	268.65	233.83	283.09	297.68	294		33	104
250	368.29	387.24	334.63	345.01	357.24	353	350.73	356.87	316.40	345.01	366.59	340		60	140
500	435.37	461.72	489.51	391.86	407.07	437	415.06	423.61	473.01	391.86	418.72	400	340	95	177
	up to 500kg	up to 1800 kg		up to 500kg	up to 1800 kg		up to 500kg	up to 1800 kg		up to 500kg	up to 1800 kg				

LE 3 : PROPOSED SOLUTION

	TRAVERSED				UNTRAVERSED				All Data		
)	90% Confidence	95% Confidence	99% Confidence	Actual Max Traversed	90% Confidence	95% Confidence	99% Confidence	Actual Max Untraversed	90% Confidence	95% Confidence	99% Confidence
-	5.00			6	9.00			10	9.00		
;	25.00			27	45.00			60	45.00		
)	50.00			53	87.53	104.24	120.95	111	87.53	104.24	120.95
;	117.50	142.24	166.97	132	146.58	177.25	207.93	152	135.38	164.58	193.78
)	157.46	193.19	228.93	157	189.51	230.09	270.68	228	175.60	214.21	252.81
)	190.90	231.75	272.60	197	250.33	297.48	344.62	254	233.83	283.78	333.73
)	283.92	342.77	401.63	283	334.63	399.34	464.05	353	316.40	381.06	445.71
)	373.98	426.37	478.76	374	489.51	547.57	605.62	400 (437)	473.01	548.86	624.72

values in red are interpolated

For all values of NEQ from 500 to 5600 kg the IBD will also be capped at 400 m.

Above 5600 kg it is deemed that the standard HD 1.1 IBD of 22.2 Q1/3 will provide the requisite protection from debris effects.

PROPOSED SMALL QUANTITY INHABITED BUILDING DISTANCES FOR MASONRY BUILDINGS

NEQ(Kg)	Traversed IBD (m)	Untraversed IBD (m)
< 0.1	0	0
1	6	12
5	28	58
10	54	115
25	135	155
50	160	230
100	200	255
150	230	290
200	260	325
250	285	355
300	305	365
400	340	385
500	375	400

This does leave open the problem of debris effects above 500 kg NEQ.

All my analysis to date strongly suggests that 400 m is not a logical IBD to provide sufficient protection (given current guidelines) from debris from accidental explosions for larger NEQs.

Debris effects continue to override blast effects up to NEQs of the order of 20,000 kg and this issue needs to be addressed.

WATCH THIS SPACE