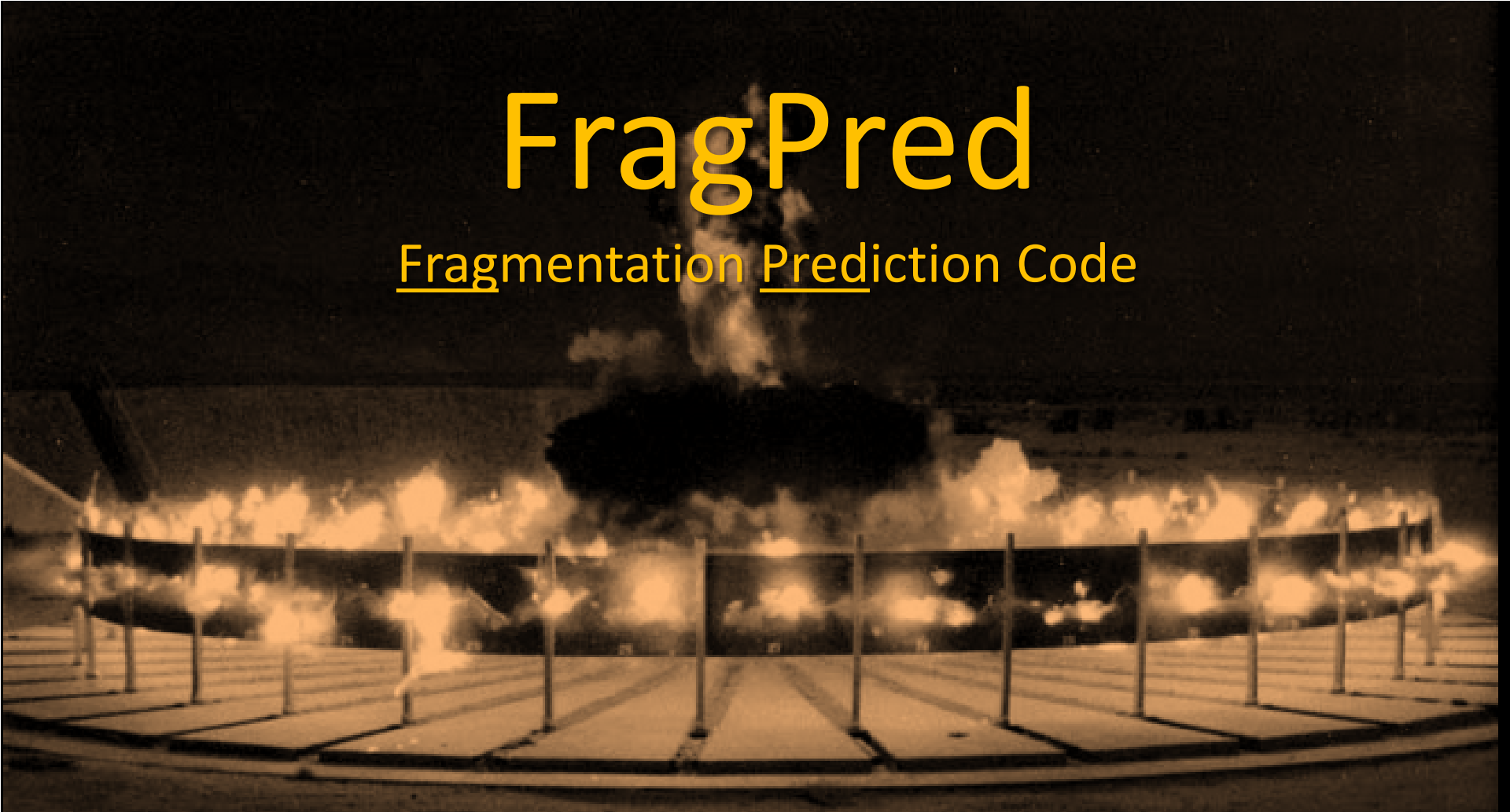
FragPred

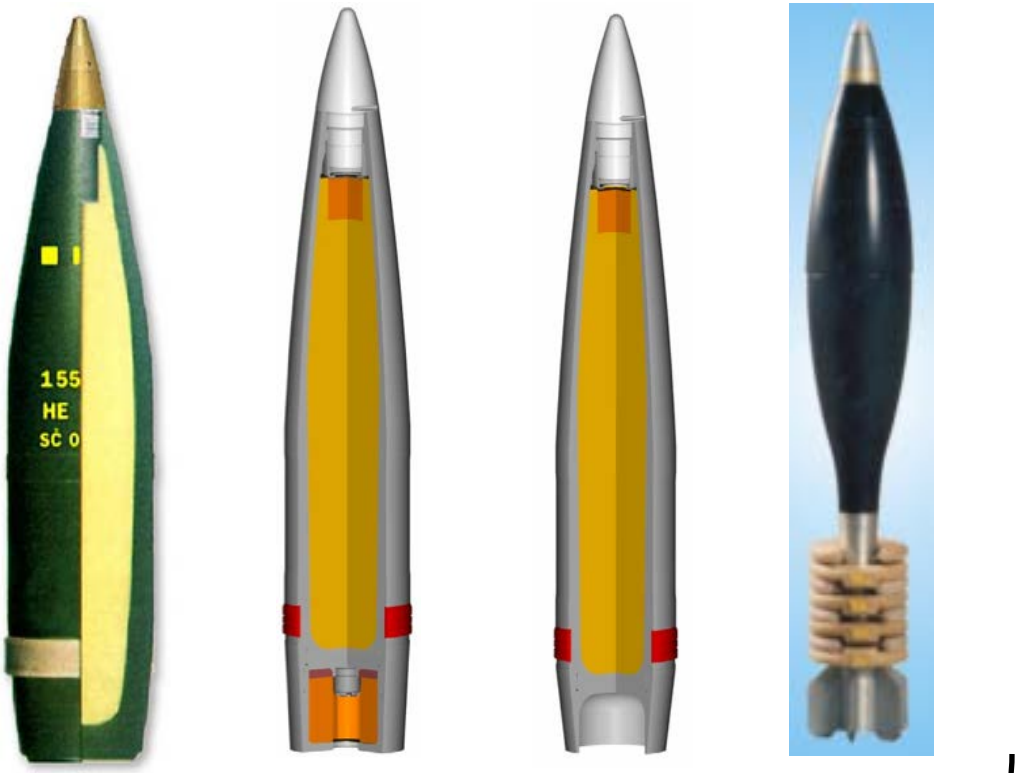
Fragmentation Prediction Code



Numerical method for prediction:

- ***Number, mass, velocity and space distribution of naturally fragmented weapon fragments,***
- ***Arena and Pit results***

Warheads which Can Be Considered by the Program



Classical artillery projectiles (all callibers)

Artillery rocket warhead

Naturally fragmenting warheads

Method

- A two dimension space, time dependent, fluid dynamic computer code.
- Metal casing is treated as sets of mass points of which motion is found along with the gas flow.
- The gas dynamics following detonation of the explosive is Lagrangian, with provision for slippage along the metal boundary.
- A conventional Lagrangian scheme with artificial viscosity is used for the interior gas dynamics.
- Gas grid points are made to slide along the metal boundary.
- The program, written in FORTRAN 90, is simple and quick to run.

Capability

- Calculation of number of fragments produced by the detonation of the high explosive (HE) warhead.
- Calculation of distributions, of fragment's mass, linear and angular velocity in the polar zones surrounding the projectile.
- Prediction of parameters of the effective lethal area of naturally fragmenting warheads.
- Program has a clear GUI for entering and manipulating with data, and for controlling the execution.
- The results of calculation are printed in files and plotted on graphs.

Purpose

- Simple, fast and reliable, prediction of lethal area parameters.
- Preliminary warhead design.
- Analysis of the influence of various design parameters on the warhead efficiency:
  - warhead caliber and length,
  - explosive charge characteristics,
  - casing thickness,
  - target characteristics, etc.
- Simulation of Arena and Pit tests and thus avoids the need for expensive model fabrication or the tedious collection of fragments from.

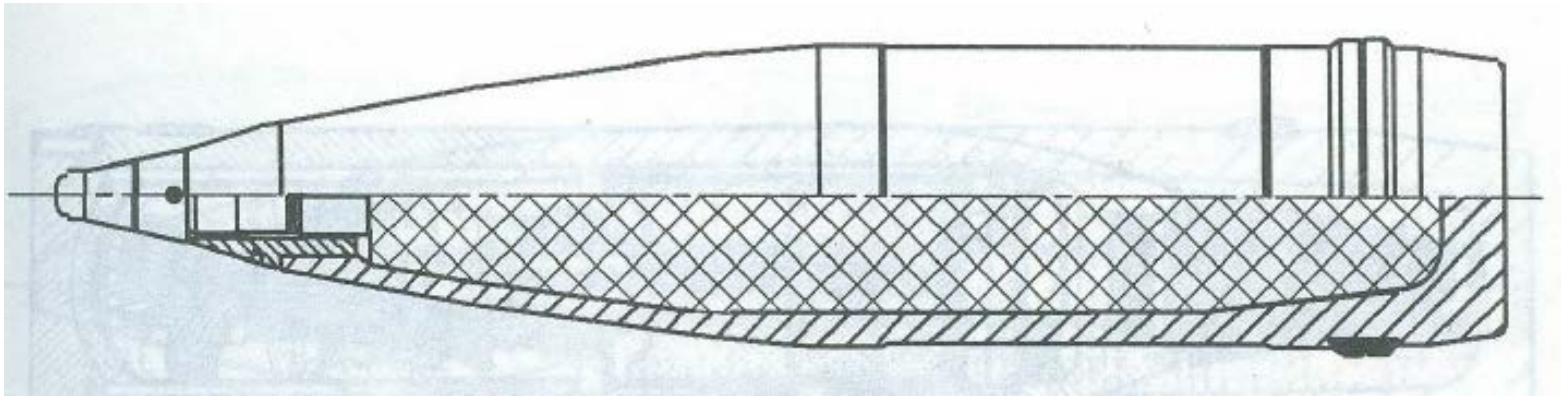
Limitations

The current version of the Program requires some empirically determined constants:

- **The values of JWL Equation of state of product of detonation. In current version the constants are determined upon the fitting the results of Cylinder test, and they are stored in the Program as optional values.**
- **Casing material is defined only by density.**
- **Detonation always starts on the warhead “nose side”.**
- **Application on naturally fragmented warheads only, but the Program can be extended to account for premade fragmented warheads.**
- **Number of discretization zones in longitudinal direction is limited to 24.**

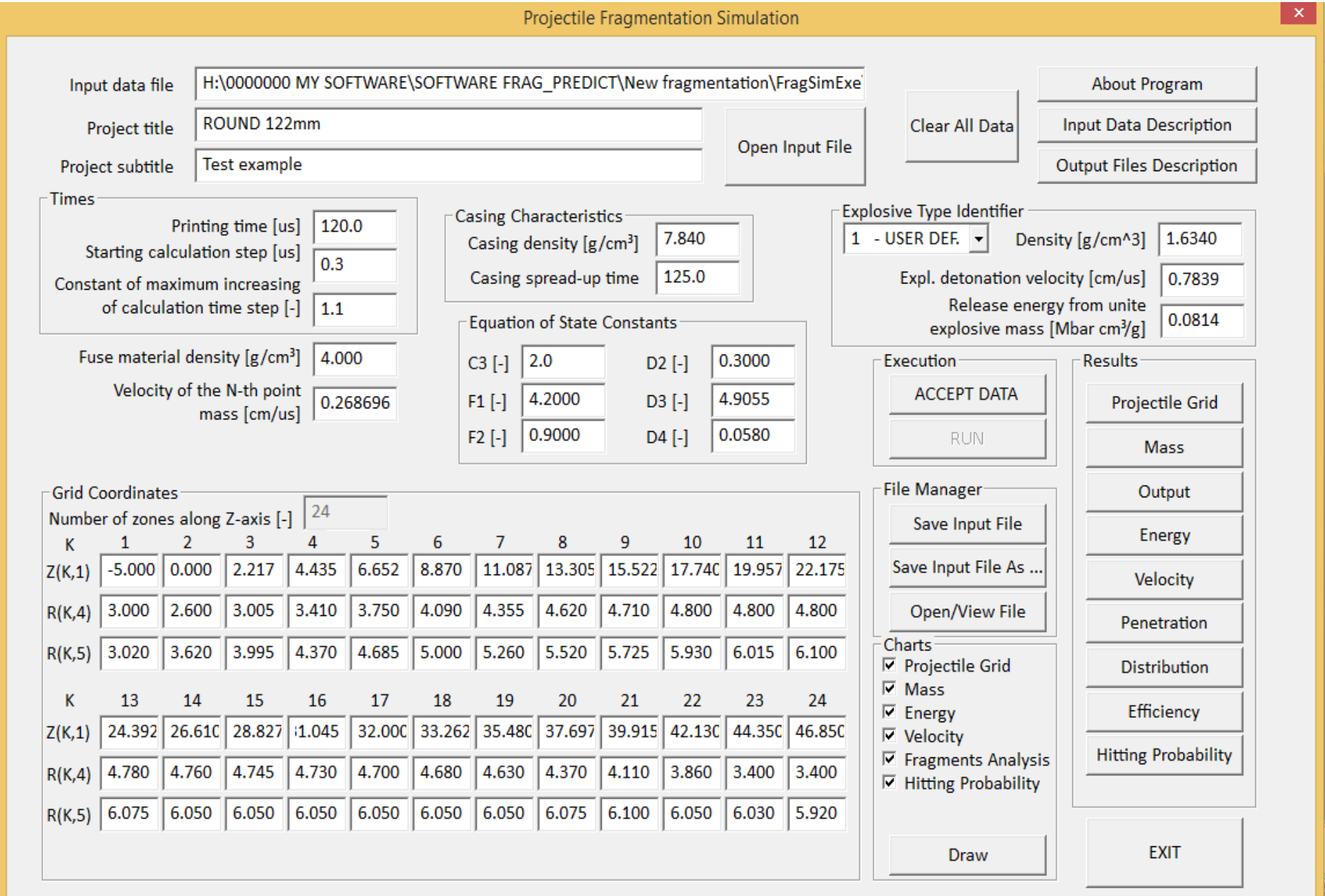
Comparison with Experiments

Example:
Artillery projectile 122 mm M76



Next diagrams show comparison of the FragPred calculation with results of experiments for the arena radius 10.5, 14.0, 17.5 and 21 m

Main menu


Projectile Fragmentation Simulation
Input data file
H:\0000000 MY SOFTWARE\SOFTWARE FRAG_PREDICT\New fragmentation\FragSimExe
Project title
ROUND 122mm
Project subtitle
Test example
Open Input File
Clear All Data
About Program
Input Data Description
Output Files Description
Times
Printing time [us] 120.0
Starting calculation step [us] 0.3
Constant of maximum increasing of calculation time step [-] 1.1
Fuse material density [g/cm3] 4.000
Velocity of the N-th point mass [cm/us] 0.268696
Casing Characteristics
Casing density [g/cm3] 7.840
Casing spread-up time 125.0
Equation of State Constants
C3 [-] 2.0
F1 [-] 4.2000
F2 [-] 0.9000
D2 [-] 0.3000
D3 [-] 4.9055
D4 [-] 0.0580
Explosive Type Identifier
1 - USER DEF.
Density [g/cm^3] 1.6340
Expl. detonation velocity [cm/us] 0.7839
Release energy from unite explosive mass [Mbar cm3/g] 0.0814
Execution
ACCEPT DATA
RUN
Results
Projectile Grid
Mass
Output
Energy
Velocity
Penetration
Distribution
Efficiency
Hitting Probability
Grid Coordinates
Number of zones along Z-axis [-] 24
K 1 2 3 4 5 6 7 8 9 10 11 12
Z(K,1) -5.000 0.000 2.217 4.435 6.652 8.870 11.087 13.305 15.522 17.740 19.957 22.175
R(K,4) 3.000 2.600 3.005 3.410 3.750 4.090 4.355 4.620 4.710 4.800 4.800 4.800
R(K,5) 3.020 3.620 3.995 4.370 4.685 5.000 5.260 5.520 5.725 5.930 6.015 6.100
K 13 14 15 16 17 18 19 20 21 22 23 24
Z(K,1) 24.392 26.610 28.827 31.045 32.000 33.262 35.480 37.697 39.915 42.130 44.350 46.850
R(K,4) 4.780 4.760 4.745 4.730 4.700 4.680 4.630 4.370 4.110 3.860 3.400 3.400
R(K,5) 6.075 6.050 6.050 6.050 6.050 6.050 6.050 6.075 6.100 6.050 6.030 5.920
File Manager
Save Input File
Save Input File As ...
Open/View File
Charts
Projectile Grid
Mass
Energy
Velocity
Fragments Analysis
Hitting Probability
Draw
EXIT

Input data: Grid Coordinates

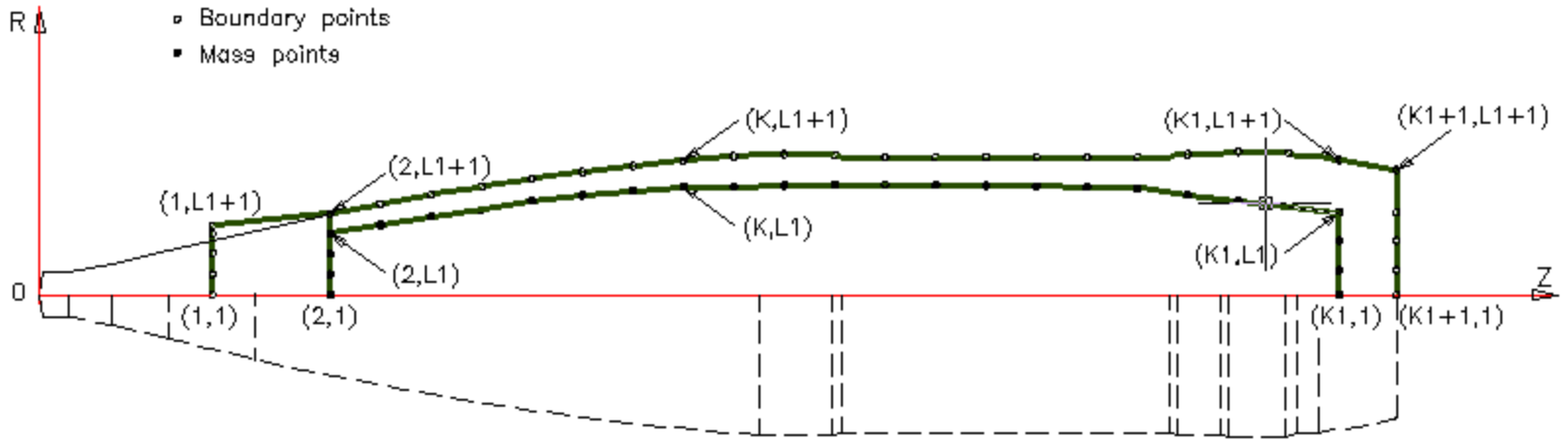
Grid Coordinates

Number of zones along Z-axis [-] 24

K	1	2	3	4	5	6	7	8	9	10	11	12
Z	-5.000	0.000	2.217	4.435	6.652	8.870	11.087	13.305	15.522	17.740	19.957	22.175
Ri	3.000	2.600	3.005	3.410	3.750	4.090	4.355	4.620	4.710	4.800	4.800	4.800
Ro	3.020	3.620	3.995	4.370	4.685	5.000	5.260	5.520	5.725	5.930	6.015	6.100

K	13	14	15	16	17	18	19	20	21	22	23	24
Z	24.392	26.610	28.827	31.045	32.000	33.262	35.480	37.697	39.915	42.130	44.350	46.850
Ri	4.780	4.760	4.745	4.730	4.700	4.680	4.630	4.370	4.110	3.860	3.400	3.400
Ro	6.075	6.050	6.050	6.050	6.050	6.050	6.050	6.075	6.100	6.050	6.030	5.920

Sketch of projectile grid oordinates

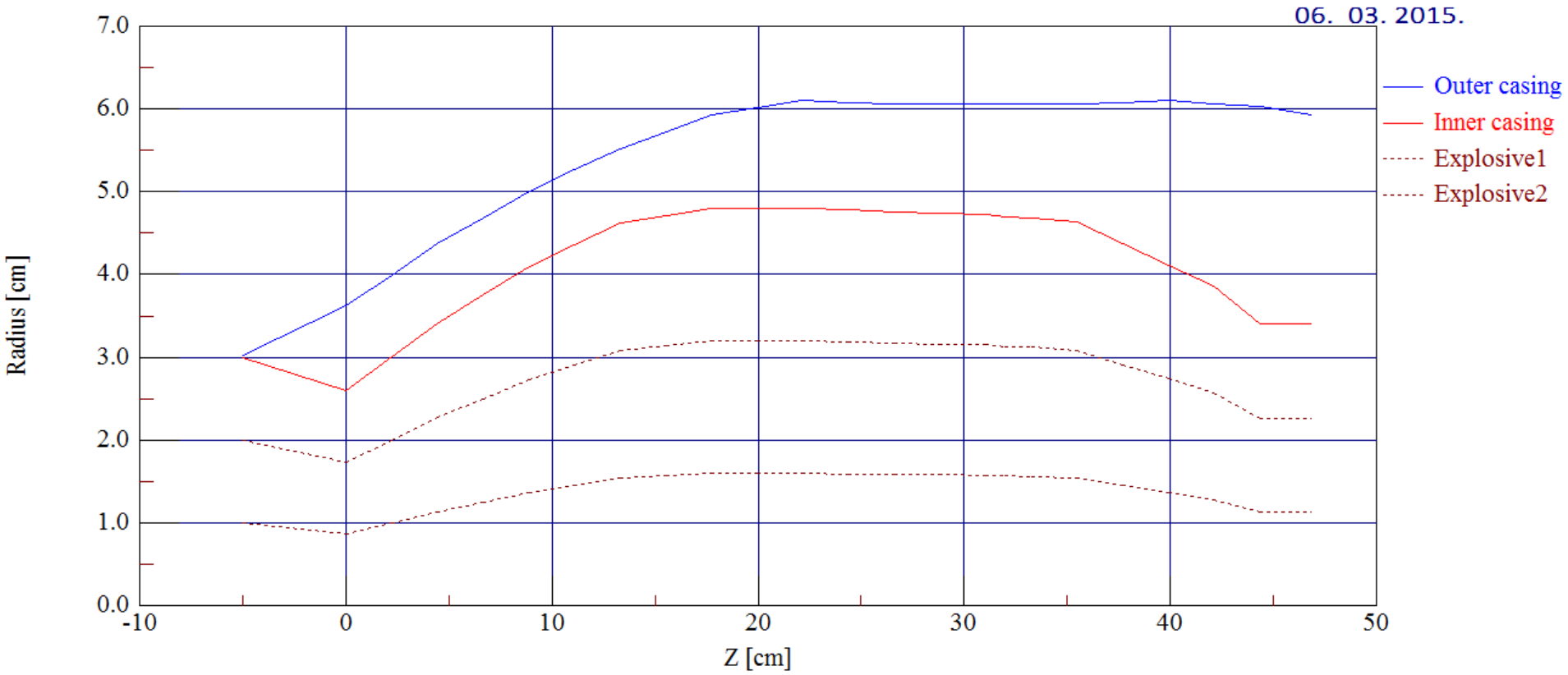


Charts
- [x] Projectile Grid
- [ ] Mass
- [ ] Energy
- [ ] Velocity
- [ ] Fragments Analysis
- [ ] Hitting Probability

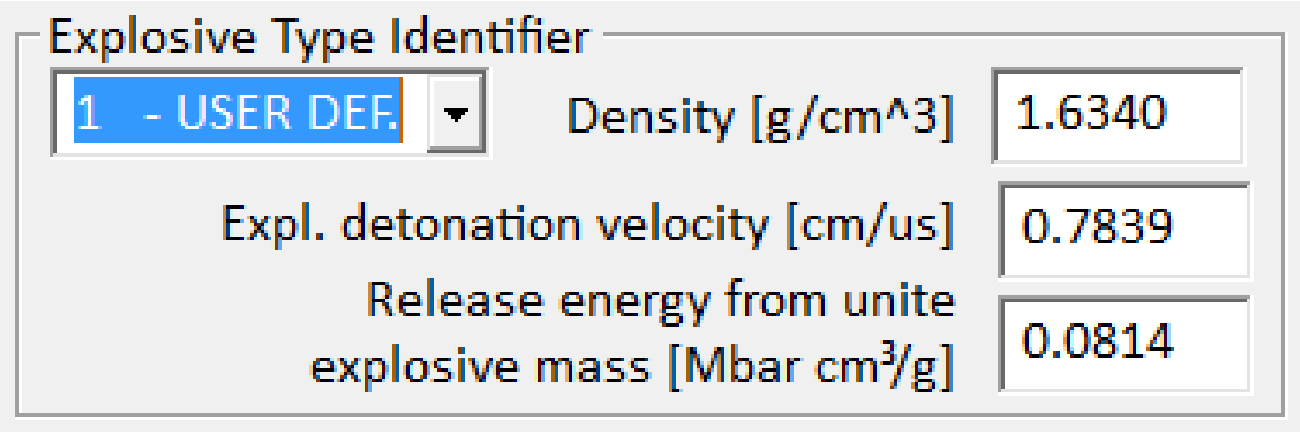
Draw

The Starting Grid Lines

Sketch of starting grid lines produced by program



Explosive Parameters Input



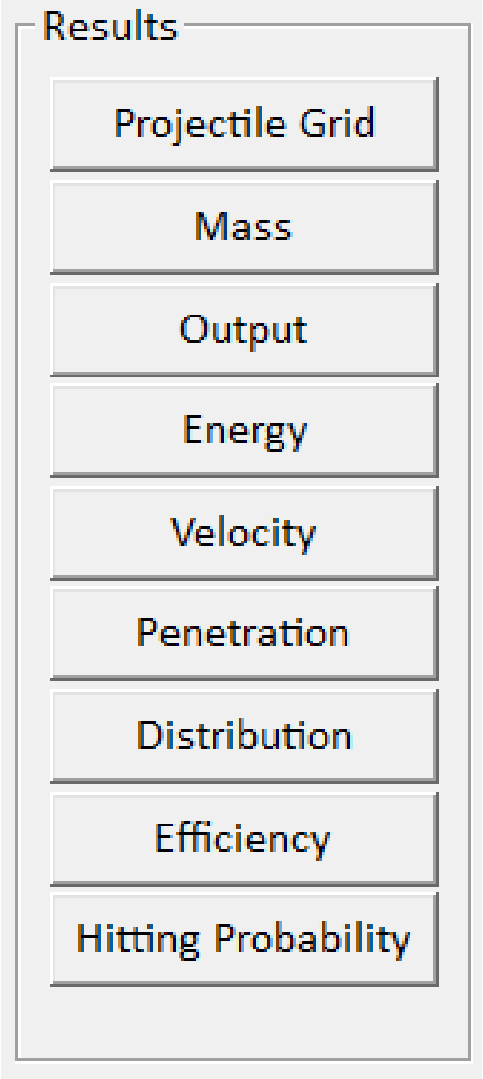
Six predefined explosive plus one user defined

NEXPL #	EXPLOSIVE	DENSITY r (g/cm³)	DETONAT. RATE D (cm/ms)	RELEASING ENERGY E1 (Mbar cm³/cm³)
1	USER DEF.	1.634	0.7839	0.0814
2	TNT	1.54	0.67	0.0703
3	COMP B	1.634	0.7839	0.0814
4	HEXOGEN - RDX	1.76	0.875	0.0994
5	OCTOL (70 30)	1.8	0.8377	0.0837
6	OCTOL (75 25)	1.81	0.8643	0.0867
7	OCTOGEN - HMX	1.9	0.91	0.1177

Results

- Sketch (drawing) of projectile
- Files and diagrams with calculated jet parameters
- Files and diagrams with calculated fragmentation parameters

Output Files



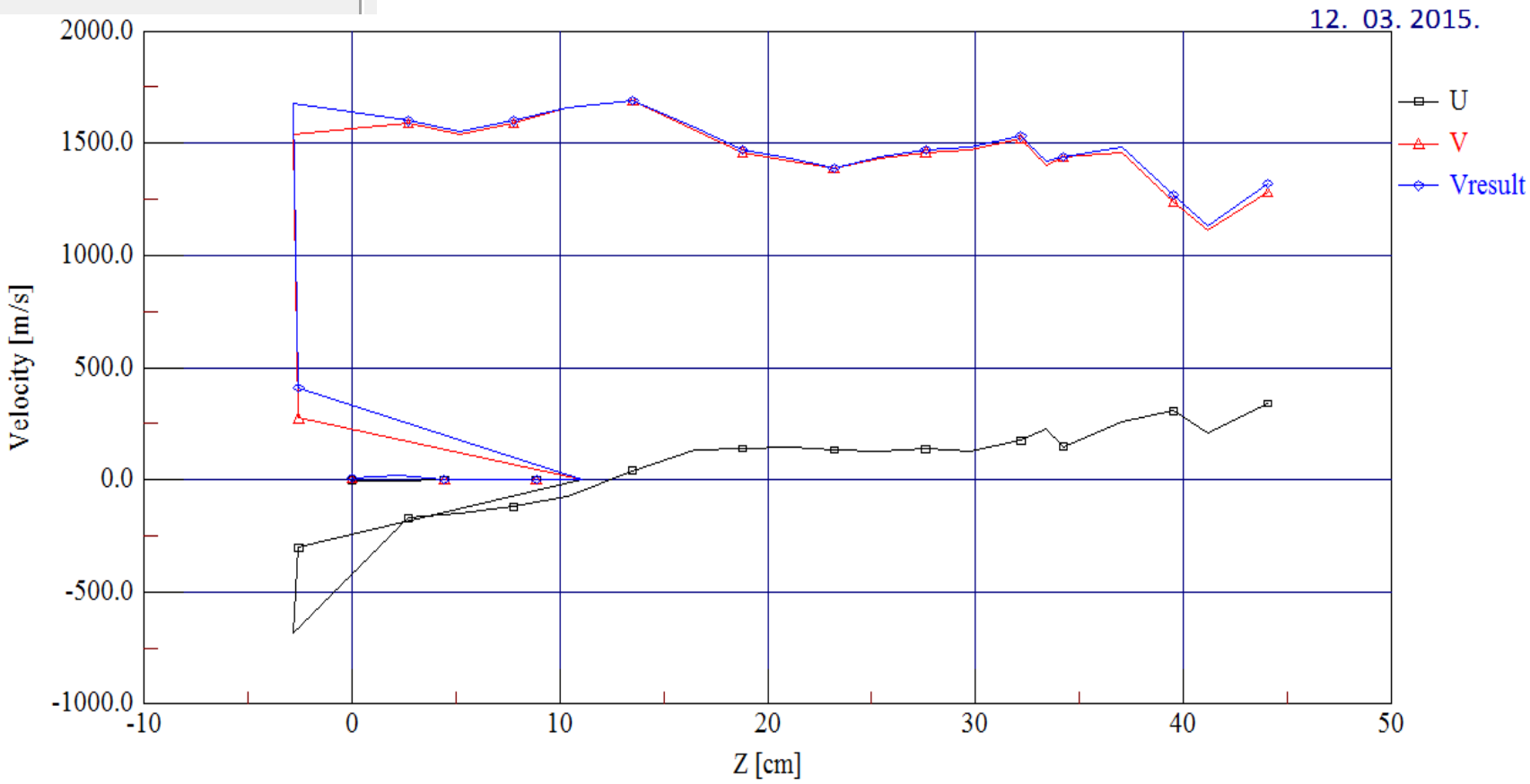
Output Files – Cont.

FILE NAME	DESCRIPTION
Output.txt	Input data and various calculated quantities
Grid.txt	Coordinates of grid points
Mass.txt	Casing and explosive cell and total mass. Mass ratio and crushing casing parameter
Energy.txt	Kinetic and internal energy of product of detonation, kinetic energy of metal casing and total energy on calculacion cycle N
Velocity.txt	Coordinates and velocity components of grid points
Penetration.txt	Number of penetrations through arena panels placed around warhead
Distribution.txt	Fragments distribution according to the mass group and the number in the polar zones
Efficiency.txt	The efficiency coefficient A_E [$m^{2]}$] for Alpha=30, 45, 60 degrees
Hitting prob.txt	Hitting probability of the recumbent or standing man target
Final.txt	Coordinates and velocity components of grid points and cell mass

Charts
- [ ] Projectile Grid
- [ ] Mass
- [ ] Energy
- [x] Velocity
- [ ] Fragments Analysis
- [ ] Hitting Probability

Distribution of Fragments

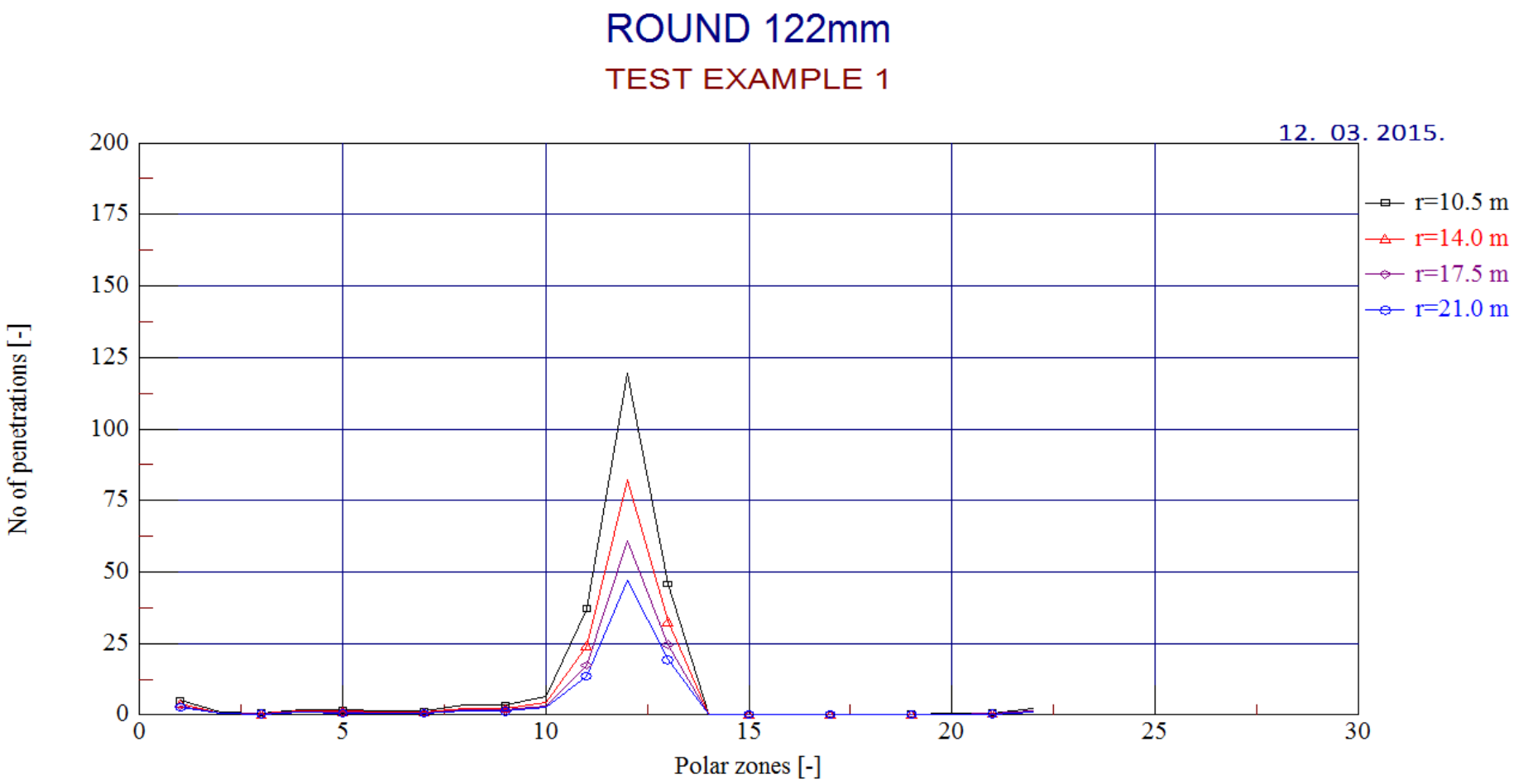
Fragments velocity components



Charts
- [ ] Projectile Grid
- [ ] Mass
- [ ] Energy
- [ ] Velocity
- [x] Fragments Analysis

Distribution of Fragments

Number of fragments in polar zones



Charts
- [ ] Projectile Grid
- [ ] Mass
- [ ] Energy
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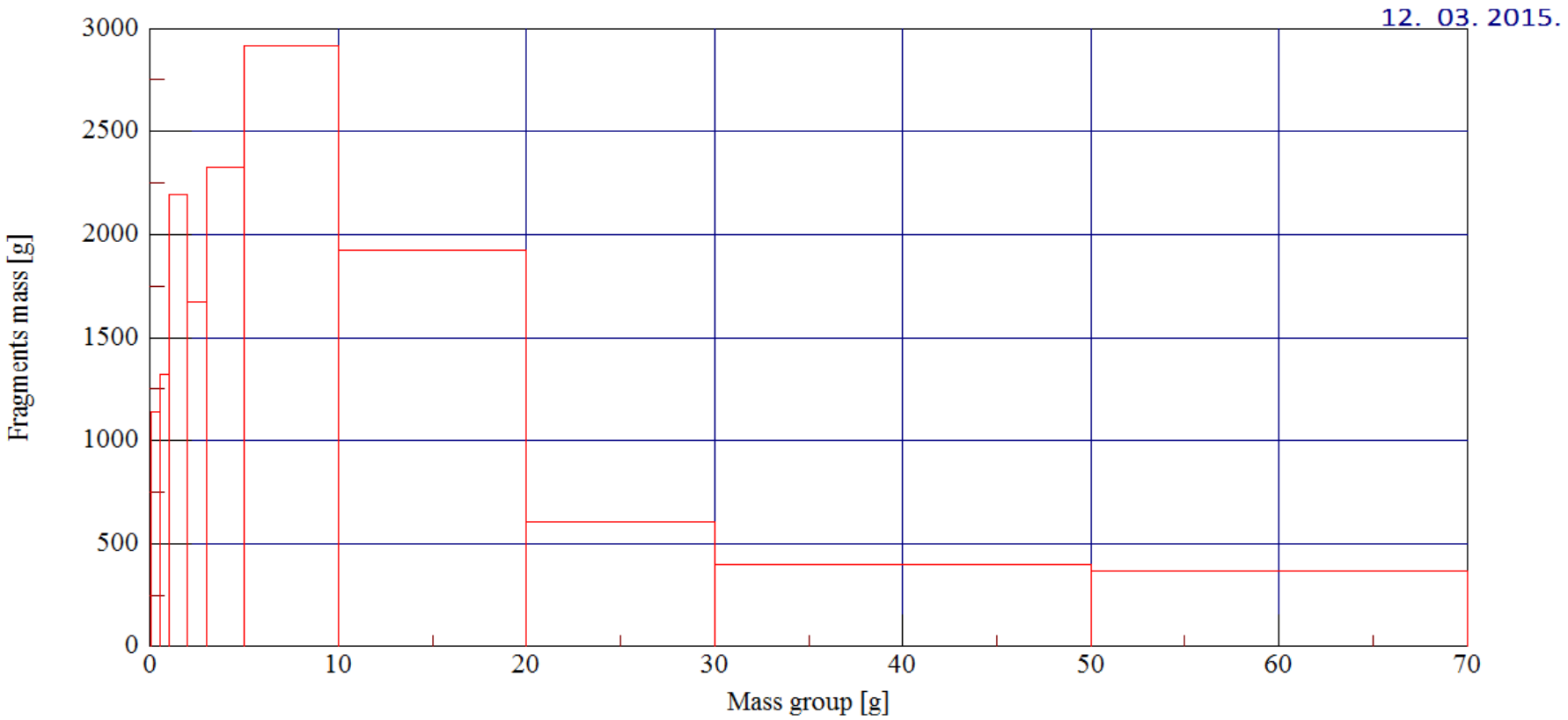
- [x] Fragments Analysis
- [ ] Hitting Probability

Distribution of Fragments

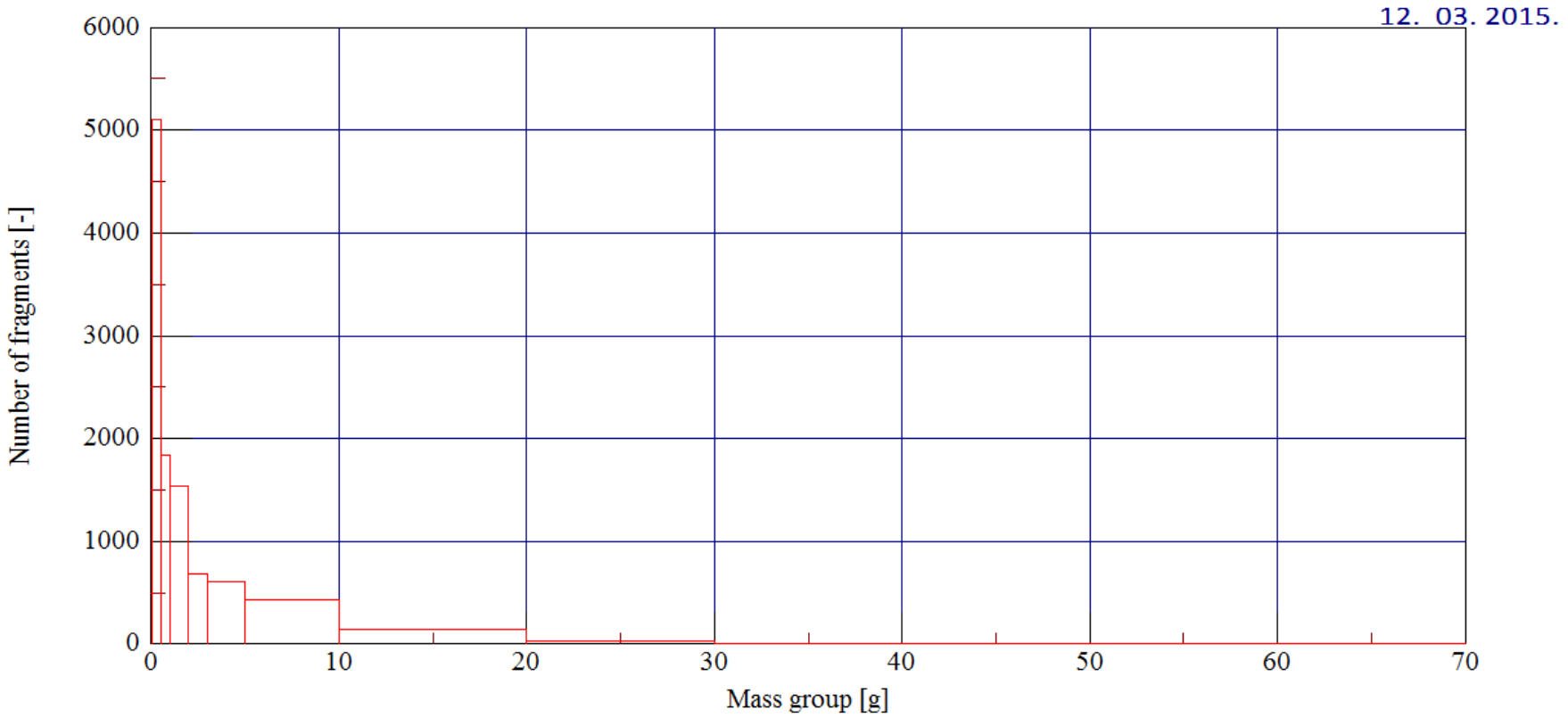
Distribution of fragments mass in mass groups



Charts
- [ ] Projectile Grid
- [ ] Mass
- [ ] Energy
- [ ] Velocity
- [x] Fragments Analysis
- [ ] Hitting Probability

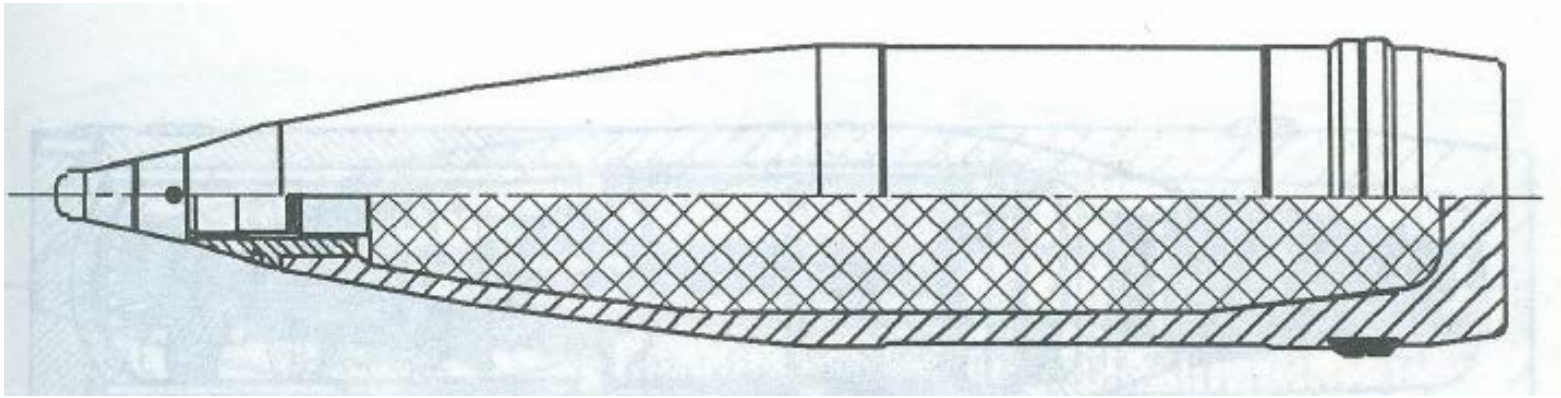
Distribution of Fragments

Distribution of number of fragments in mass groups



Comparison with Experiments

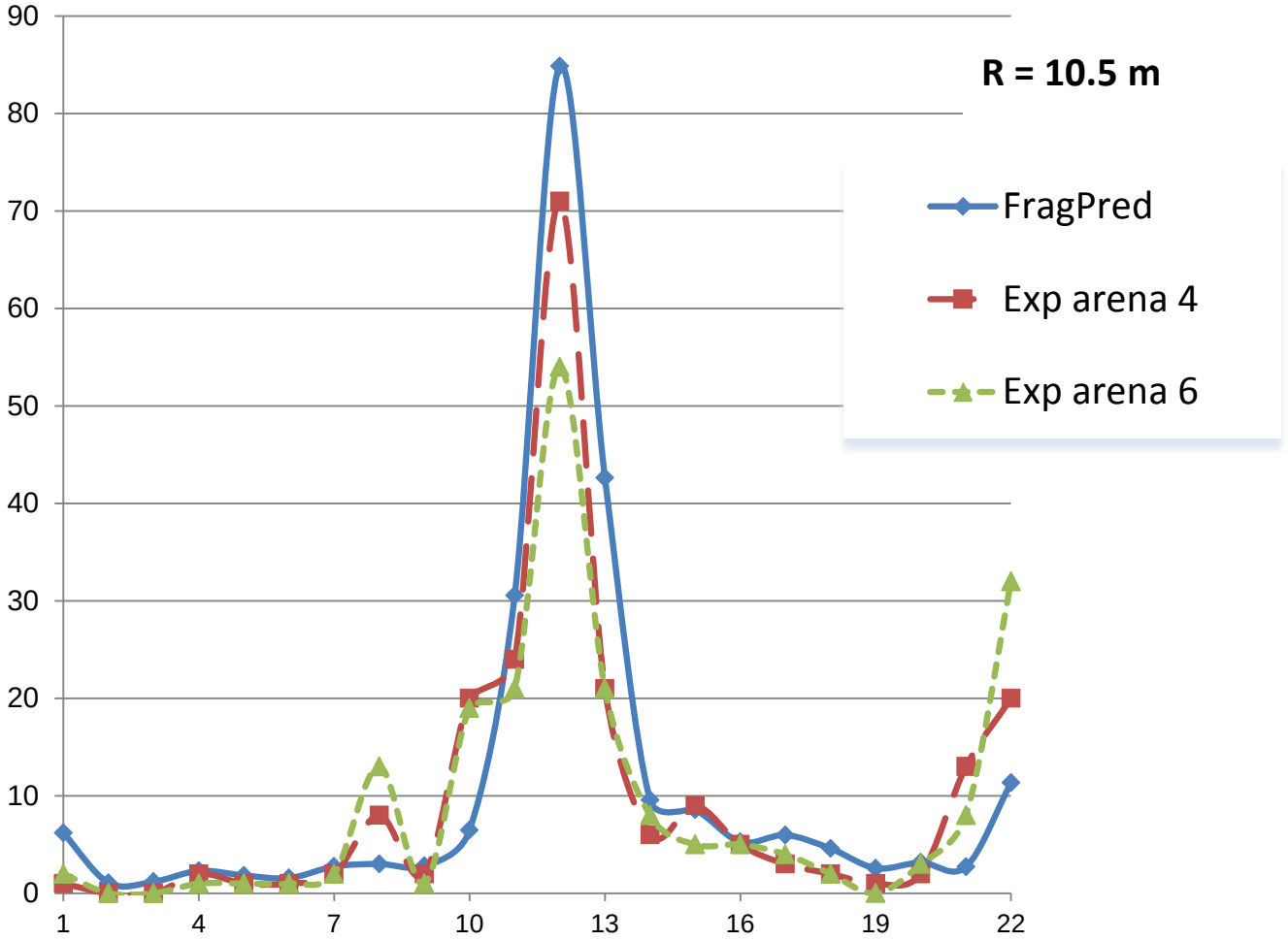
Example:
Artillery projectile 122 mm M76



Next diagrams show comparison of the FragPred calculation with results of experiments for the arena radius 10.5, 14.0, 17.5 and 21 m

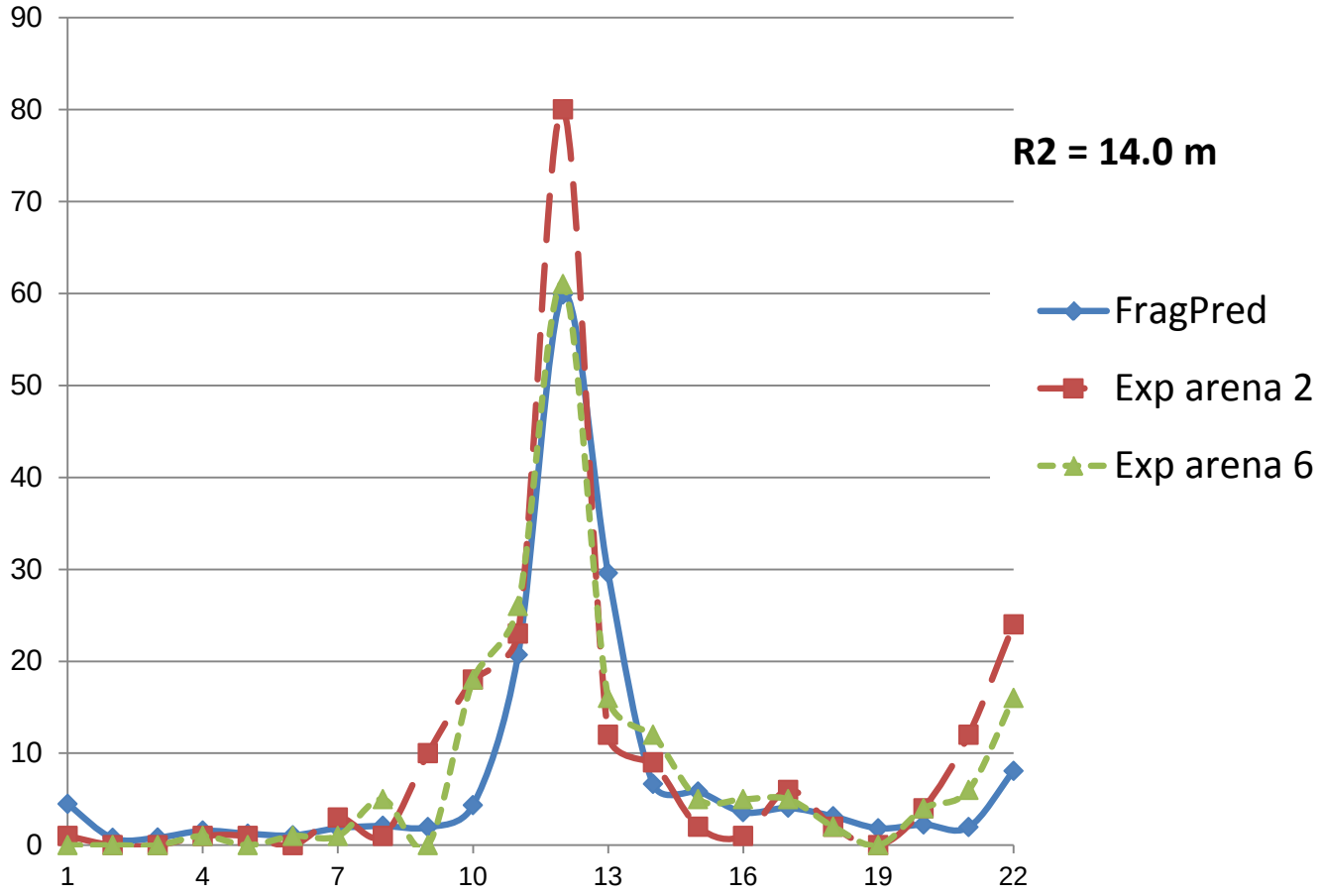
The Distribution of the Number of Penetrations Through the Panels in Arena Test

Semicircular Sector on 10.5 m from the Center



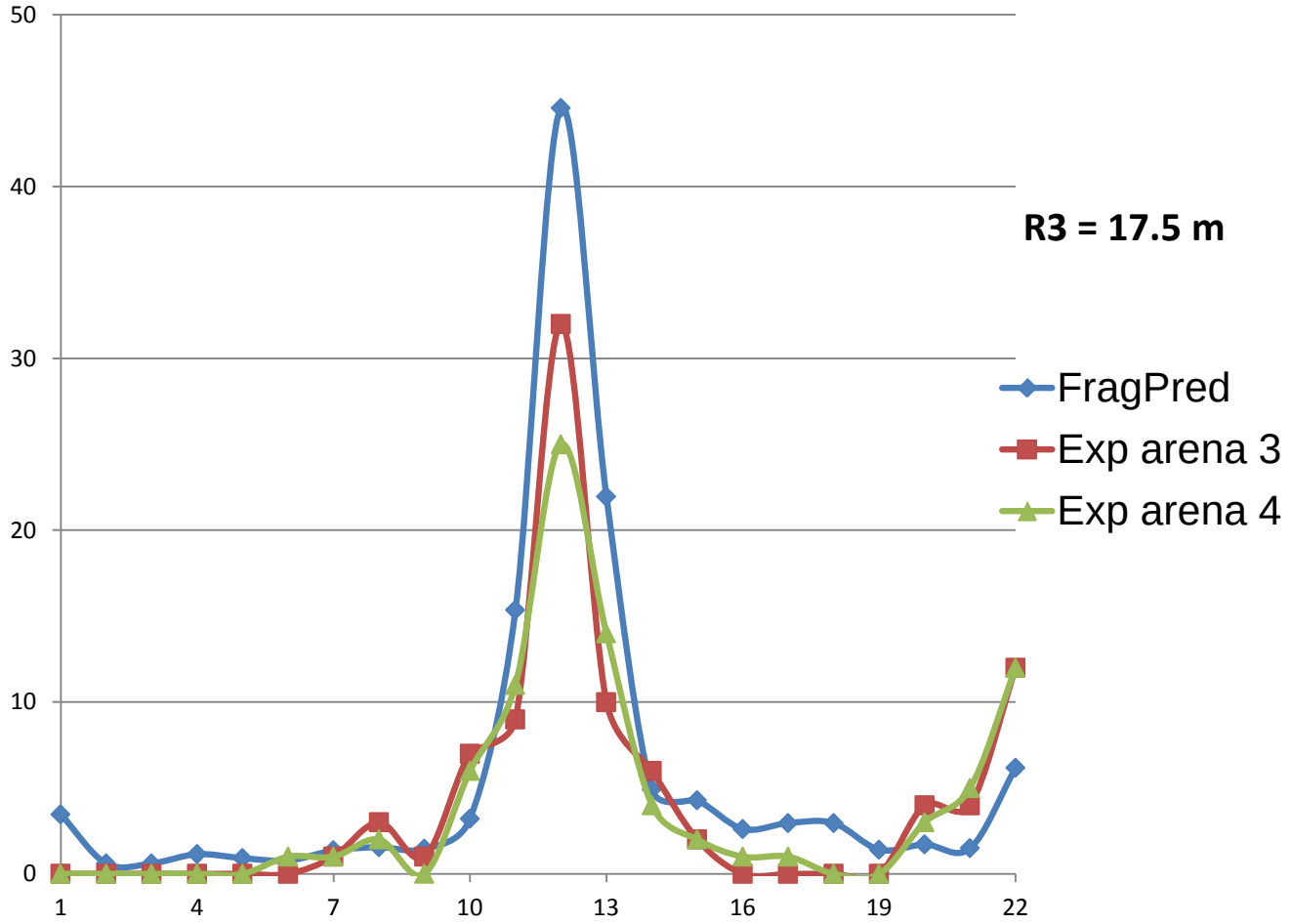
The Distribution of the Number of Penetrations Through the Panels in Arena Test

Semicircular Sector on 14.0 m from the Center



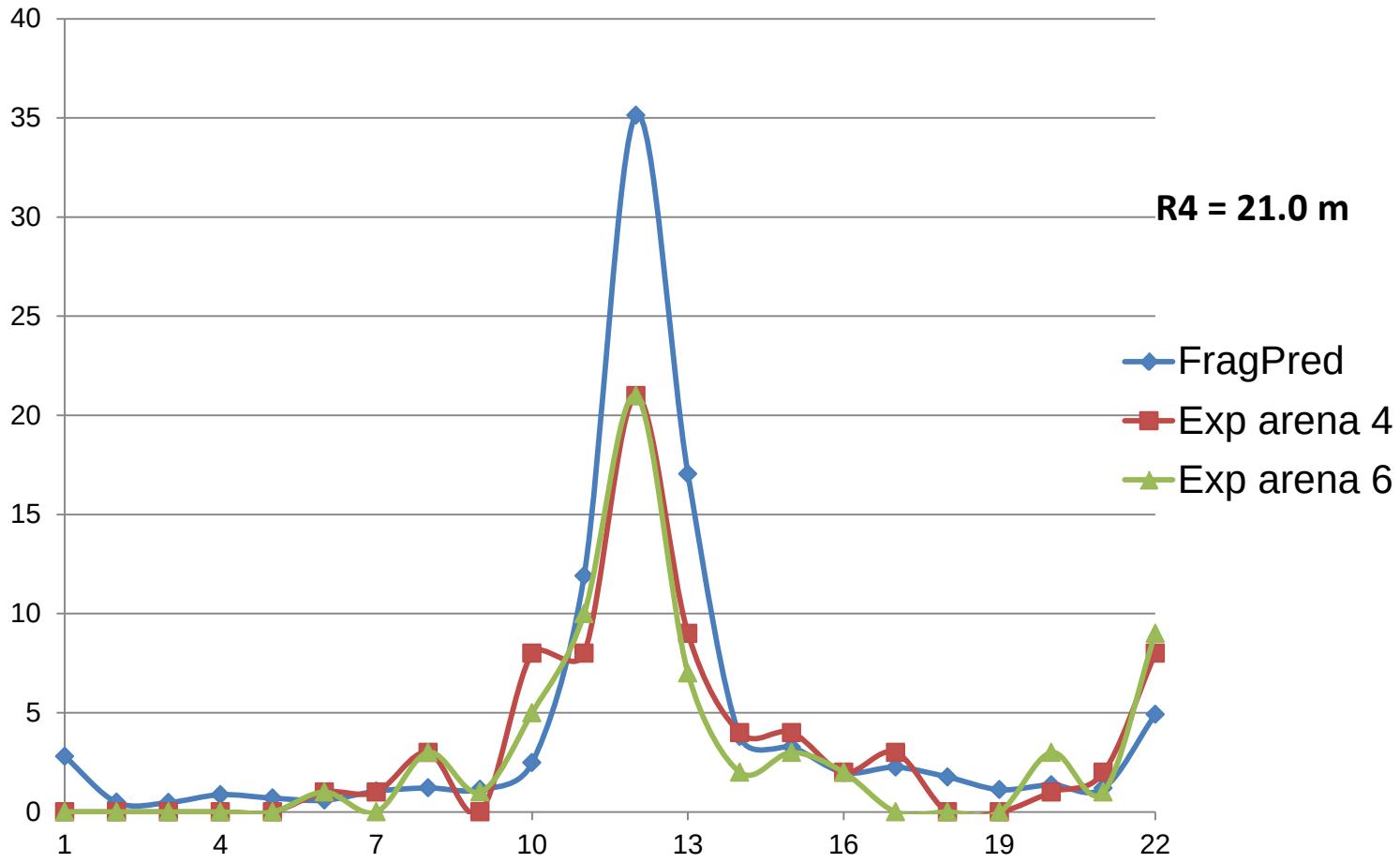
The Distribution of the Number of Penetrations Through the Panels in Arena Test

Semicircular Sector on 17.5 m from the Center



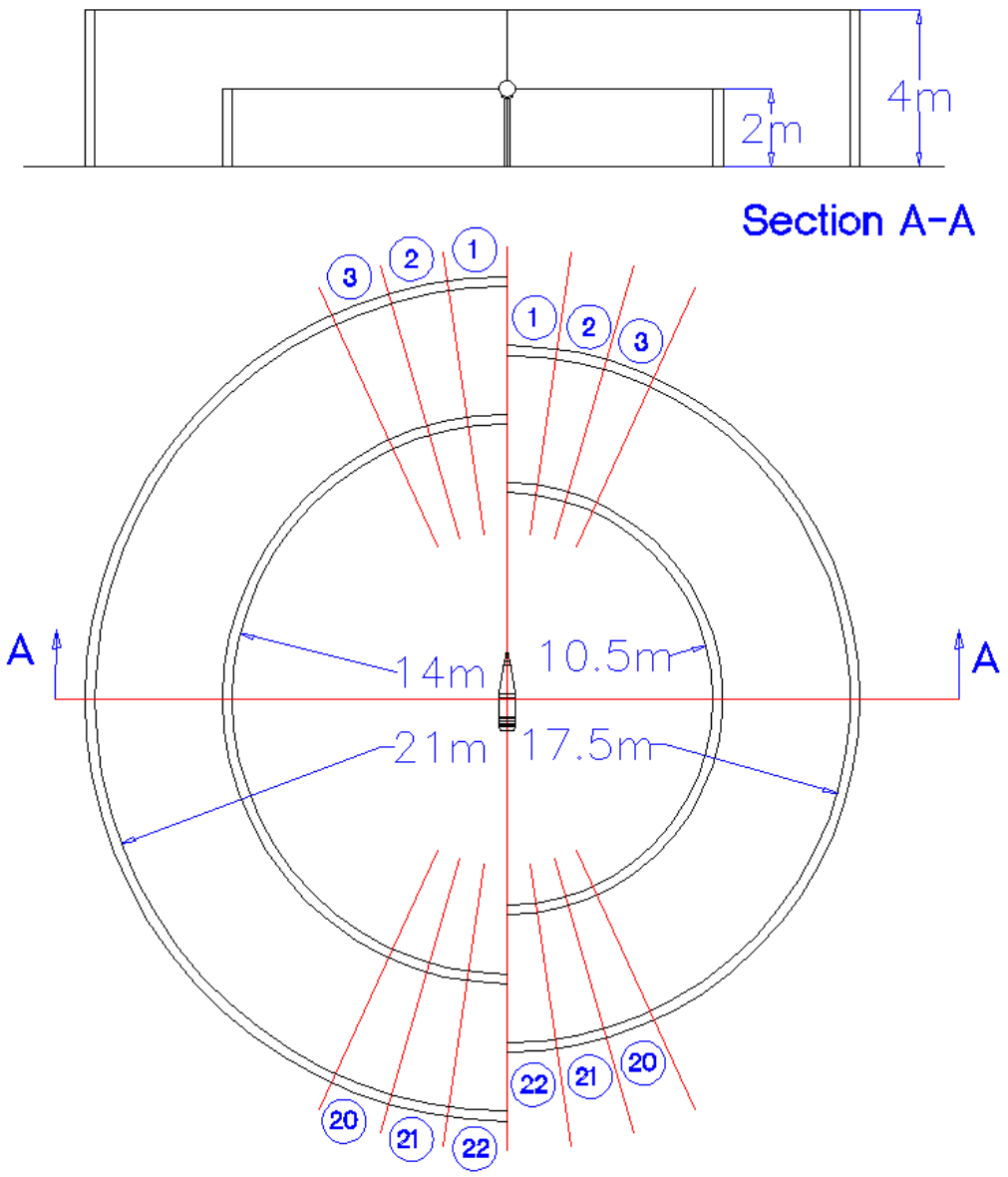
The Distribution of the Number of Penetrations Through the Panels in Arena Test

Semicircular Sector on 21.0 m from the Center



Arena set-up

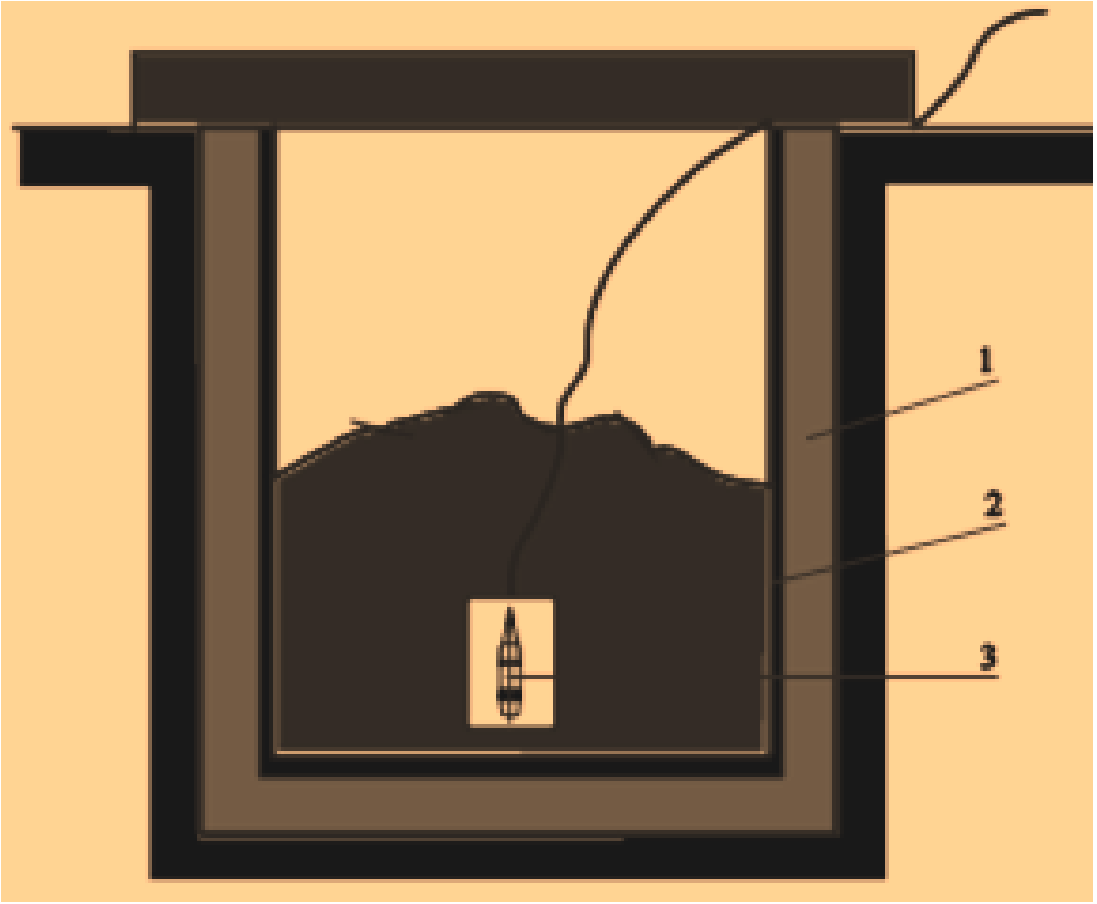
Schematic of French & Serbian standard Arena setup used for testing.



Comparison between calculated and experimentally obtained values of coefficient of efficiency A_E

Height of explosion h = 0 m. The recumbent figure of a man.	Angle of fall (degree)		
	30	45	60
Predicting A_E [m^2]	268.44	306.66	385.28
Experimental values of A_E [m^2]	258.78	306.83	395.56

Sand Pit Instalation



Testing projectile in a sand pit:

1 - cylindrical concrete pit;
2 - metal liner;
3 - projectile

Comparison of Results of Fragmentation - Sand Pit Test -

Results at a distance R = 100 cal. (12.2 m)

Characteristics	From FragPred	From Sand Pit
Mass of efficient fragment (E_k = 100 J)	0.3127	0.3113
Number of projectile fragments N_{ef} (-)	5746	6645

The difference in the number of N_{ef} results from the 6.7% lost fragments in the pit. This lost mass is distributed across all mass groups. But these are by nature very small (inefficient fragments) and can be omitted from the calculation.