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TECHNICAL MEMORANDUM 2034

ZONE

A COMPUTER PROGRAM

FOR

REDUCING TEST ARENA DATA TO ZONE DATA

FOR

FRAGMENTING WARHEADS
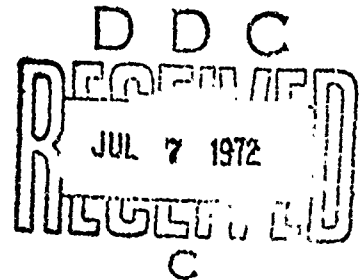
EDWARD B. LACHER

MARCH 1972

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PICATINNY ARSENAL

DOVER, NEW JERSEY

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1 ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Picatinny Arsenal	UNCLASSIFIED
Dover, New Jersey 07801	2b. GROUP

3. REPORT TITLE

ZONE A COMPUTER PROGRAM FOR REDUCING TEST ARENA DATA TO ZONE DATA, FOR FRAGMENTING WARHEADS.

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*

Edward B. Lacher

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NC. OF REFS
March 1974	48	1

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	Technical Memorandum 2034
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

This report describes the the computer program ZONE, whose purpose is to convert input data, obtained by firing a fragmenting warhead in a test arena, into a quantitative description of distribution of the concentrations and velocities of the fragments by angular zone. Because all fragments are assumed to have the same weight, test procedure is greatly simplified in that there is no need to recover any fragments, but instead, only target panel coverings and filmed records of fragment hits need be examined to obtain the raw data. The report includes a description of the arena and methods for collecting the data, a description of the method of calculation, an input guide for using ZONE, and a sample case.

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fragmenting Warhead						
Test Arena						
Zone Data						

Technical Memorandum 2034

ZONE

A COMPUTER PROGRAM FOR REDUCING TEST ARENA

DATA TO ZONE DATA, FOR FRAGMENTING WARHEADS

by

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March 1972

Approved for public release; distribution unlimited

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INTRODUCTION

A number of computer programs for analyzing effectiveness of fragmenting warheads are currently in use. Many of these require a description of the fragmentation pattern and distribution of velocities of fragments by angular zone, as measured with respect to the warhead. The raw data upon which this information is to be based can be obtained by firing the warhead in a test arena consisting of halves of two (nearly) cylindrical surfaces, one made up of (flat) "distribution panels" to gather fragment density data and one made up of "velocity panels" used for recording fragment velocity data. Because all fragments are assumed to have equal weights, the data consists of observable fragment holes in the (distribution) panels as well as films of fragments penetrating through the (velocity) panels of the arena. The computer program ZONE has been developed in order to provide a convenient means of converting this raw data into the required quantitative description of the density and velocity distributions of the fragments by angular zone.

Use of ZONE and the methods described in this report enables one to conveniently record the results of the test firing on data cards without the need of recovering any fragments, and it provides a systematic approach to obtaining a description of the warhead's fragmentation pattern by angular zone. This can be easily done for arbitrary arrangements of the zones without the need of any fragment data modification whatsoever, and with only a very slight change in program input. In contrast to other programs of its type, ZONE allows one to collect the data using rectangular panels but processes it to obtain an accurate picture of the fragment pattern by conical zone through its use of steradian measure.

The first two sections of this report describe the test arena (and actual test) and the method of calculation used by ZONE. The description of the arena is a general one and is not intended to be highly detailed because the methods of setting up the arena and obtaining the data are basically standard; more comprehensive descriptions of these procedures can be found elsewhere.

The final two sections of the report describe the computer program ZONE (including an input guide and output guide) and a sample case.

1.0 DESCRIPTION OF THE TEST ARENA

A top view of the test arena is illustrated in figure 1. The dimensions given in the figures are those used in the accompanying sample case (see Sec. 2.0); neither the test nor the computer program require that these same dimensions be used.

The warhead is placed in the center of the arena, which is also the center of the two semi-circular cylindrical surfaces, one consisting of "distribution panels" (also called "density panels") and one consisting of "velocity panels" (for obtaining velocity information). These will now be described individually.

1.1 Distribution Panels

The distribution panels are usually made of rectangular pieces of 1/2 inch plywood on which a grid is drawn dividing the panels into sub-panels or targets. After the warhead has been fired, the fragment holes in each sub-panel are counted and recorded. The horizontal indexing system for identifying the sub-panels is indicated in fig. 1 (also in fig. 2) which shows the distribution panels as viewed from inside the arena. The letters H (Horizontal) and V (Vertical) are used to label the sub-panels; for example, the sub-panel containing the asterisk in fig. 2 would be referred to as sub-panel V-7, H-4 or as the (7,4)th sub-panel.

Once the number of panels is decided, one can choose a radius so that these panels will very nearly fit along a semi-circle with this radius. The "effective radius" R of the arena is then computed as

$$R = \frac{NW}{\pi} = \frac{\text{Half circumference of arena}}{\pi} \quad (1)$$

where N is the number of distribuiton panels horizontally, and W is the width of each panel.[1] That is, since the panel width is small compared to the radius of the arena, one can approximate the circumference of the (half) arena by NW.[2] The two ends of each panel should be placed at this distance R from the burst point (measured on the ground); this also ensures proper angular placement of the panels. Although the plywood panels are flat rather than curved and the ends of the sub-panels will not generally lie exactly on the circumference of the semi-circle (unless the sub-panels and panels are identical), they will adequately approximate a semi-circle of radius R.

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[1] The program actually uses $N_S W_S$ instead of NW, where N_S and W_S are the corresponding quantities for sub-panels; however, it is obvious that $N_S W_S$=NW.

[2] The actual radius of a semi-circle on which the ends of each panel would lie exactly is given by (cont. ⊷)

1.2 Velocity Panels

The velocity panels are made of aluminum (with black backing) attached around the edges to a plywood frame. These panels are also considered to be divided into a grid of sub-panels which are numbered as in fig. 1. Just before the warhead is detonated, a number of long duration flash bulbs are set off and the cameras pick up the light coming through the holes made by the fragments as they penetrate the aluminum. Each hit is read off the film and the location and frame number of the hit are noted. The location is again described by the horizontal and vertical indices of the sub-panels, which are now formed by putting a grid over the developed film rather than by drawing them on the panels as was done for the distribution panels. This data together with the camera speeds and drag information allows one to compute the average velocity of fragments.

The radius of the velocity panel half of the arena is computed in a fashion analagous to that of the distribution panel half.

It is critically important that the warhead lie parallel to and above the center line of the arena and that it have zero degree azimuth and elevation angles. This is because the zones are defined relative to the direction the shell is pointing, which is assumed to be parallel to the center line of the arena.

(cont.)

$$R = \frac{W}{2 \sin\left(\frac{\pi}{2N}\right)} \qquad (2)$$

The difference in results from using (1) in place of (2) is generally negligible (and for reasons of practicality it is usually sufficient for the arena to be set up with a radius within two inches of the value calculated using (1)).

2.0 METHOD OF CALCULATION

The purpose of ZONE is to obtain estimates of the number and velocity of fragments by angular zone, from the input data gathered at the test arena. The program is divided into two major sections, one for density calculations and one for velocity calculations. Each of these will be considered separately.

2.1 Density Calculations

Aside from the basic dimensions of the arena, the data necessary for the computation of densities are the number of fragment hits counted for each distribution sub-panel. These densities to be calculated are called "fragment densities"; they are measured in units of number of fragments per steradian and they provide a description of the distribution of the fragments from the warhead throughout the arena. They should not be confused with the "density of a fragment" which might be measured in grains per cubic centimeter and is a characteristic of the fragment rather than of the fragmenting warhead.

The program, assuming that each panel is divided into an integral number of sub-panels and that these lie on the perimeter of the arena, computes the coordinates of the four corners and the center of each sub-panel. Using these, it then calculates the steradians (area on the unit sphere) of each target or sub-panel and which zone it is in.[3] The angles defining the zones are inputs to the program, and may be changed from run to run.

The program repeats the above for each sub-panel, keeping track of the total fragments in each zone and total steradians of the targets in the zones. After going through all the sub-panel data the program computes fragment density (fragments/ steradian) for each zone, and under the assumption that the . fragment distribution is uniform _within_ any one zone, multiplies this by the total steradians in the zone to obtain the total predicted number of fragments for each zone.

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[3] A zone is defined as the region of space between two cones having the same axis and vertex, described by an upper and a lower angle. A point is in a particular zone if the angle between the vector from the burst point to that point and the vector from the burst point through the nose of the shell lies between the upper and lower angles of the zone. The program assigns all the hits in any one sub-panel to that zone which contains the center of the sub-panel. This method greatly simplifies the calculations without significant loss of accuracy.

2.2 Velocity Calculations

The purpose of these calculations is to convert the fragment data from the velocity sub-panels into a breakup of average velocity by zone. As mentioned previously, the data is obtained from high speed films of the actual test, from which frame numbers corresponding to each hit are recorded and are inputted to the program along with camera speeds (in frames per second). Since there will usually be four cameras filming the test, four camera speeds must be inputted together with the number of horizontal sub-panels each one filmed.

As was the case for density calculations, the data is collected by sub-panel; here however, for input purposes sub-panels with no hits should be omitted. The program computes average velocities for each fragment by using the following relations:

$$T= \frac{\text{Frame Number}}{\text{Camera Speed}} \tag{3}$$

$$\overline{V}= \frac{D}{T} \tag{4}$$

where T = time required for fragments to hit the velocity panels
D = distance from the burst point to the center of the sub-panel
$\overline{V}$ = average velocity of a fragment in travelling distance D.

The initial velocity of a fragment at the burst point immediately after detonation is computed using the formula

$$V = \overline{V} \left[\frac{e^{\alpha D} - 1}{D} \right] \tag{5}$$

The quantity α (in units of ft^{-1}) is a drag factor which is a slowly varying function of velocity and also depends on the fragment shape and weight. The formula for alpha is

$$\alpha = C_D \, \rho \, k \, m^{-1/3} \tag{6}$$

where
C_D = drag coefficient (dimensionless)
ρ = density of air (lb/ft^3)
k = shape factor (ft^2-grains $^{1/3}$/lb)
m = fragment weight (grains)

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ρ (RHO) is assumed to have a value of .0765 (density of air at 15°C) and is included in a DATA statement in the program. Values of m (GRAINS), C_D (CD) and k (SHAPE) are inputs to be chosen by the user. A set of typical values is m = 30.0 , C_D = .55 and k = .462, which yields a value of α = .006239. Values for C_D and k can be found in reference 1. Capitalized names in parentheses above are the FORTRAN names of the variables preceding them. In the program, α is called ALPH and the term in square brackets in (5) is called FCTR.

The program stores the number of fragments, the sums of the average and initial velocities, and the sum of the squares of the initial velocities for each zone, from which it computes an "average average" velocity (AVERAGE VBAR), an average inital velocity, and a standard deviation (for initial velocities only) for each zone. These are calculated as:

$$\text{AVERAGE VBAR FOR Ith zone} = \frac{1}{N(I)} \sum \overline{V}_{IJ} \tag{7}$$

$$\text{AVERAGE INIT. VEL. for Ith zone} = \frac{1}{N(I)} \sum V^{\circ}_{IJ} \tag{8}$$

$$\text{STD DEV for Ith zone} = \left\{ \frac{1}{N(I)-1} \left[\sum (V^{\circ}_{IJ})^2 - \frac{1}{N(I)} \left(\sum V^{\circ}_{IJ} \right)^2 \right] \right\}^{\frac{1}{2}} \tag{9}$$

where

$\overline{V}_{IJ}$ = average velocity for the Jth fragment in the Ith zone,

V°_{IJ} = initial velocity for the Jth fragment in the Ith zone.

$N(I)$ = number of fragments in the Ith zone.

All summations are on J, from J = 1 to J = N(I).

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3.0 COMPUTER PROGRAM

ZONE is a computer program written in FORTRAN for use on CDC 6000 series computers; it can easily be modified for use on other computers. The next sections contain some notes on the program, descriptions of the input and output, and a source listing.

3.1 Program Notes

1. Present limits in the program are 35 zones (36 zone angles), 16 sub-panels vertically, and 90 sub-panels horizontally. These can be increased by varying dimensions at the beginning of the main routine and possibly varying some output formats.

2. The inputs NDENS and NVEL indicate to the program which calculations are to be performed, and the variable NLEFT will adjust the results to correspond to the direction the warhead is facing (fig. 1 corresponds to NLEFT = 1). This does not affect the numbering of the sub-panels, but it does reverse the positions of the zones, since they are measured relative to the direction the warhead is facing.

3. The coordinate system used to locate the corners of the sub-panels is left-handed with origin at the burst point, y-axis perpendicular to the ground and pointing up, and x-axis along the warhead axis pointing towards the far edge of the last panel.

4. The velocity section of the program resembles the density section in that some quantities occur in both sections which may have different values in the two sections. In these cases the suffix "2" is appended to their FORTRAN names in the velocity section. For example, whereas R represents the radius of the density half of the arena, R2 represents the radius of the velocity half.

5. If one is mainly interested in zones totalling less than 180°, say from 60° to 120°, it is advisable to include two extra zones, from 0° to 60°, and from 120° to 180°, to account for the remainder of the fragments. If this is not done, fragments not in the 60° - 120° range will not be printed in the summary and no count or record of them will be outputted.

6. The purpose of SUBROUTINE PROJ is to compute the area of a sub-panel in steradians (using the coordinates of its four corners) and to compute what zone the sub-panel is in (using the coordinates of its center).

3.2 Input Guide

The following is a list of input cards necessary to run
ZONE. The input data is divided into three groups of cards I,
II and III, and card sets in these groups are A, B, C....
The user has the option of selecting density and/or velocity
calculations as indicated to the program by the values of NDENS
and NVEL. These values govern which groups of cards are necessary
for the run. A table showing which inputs are required for
the different calculations follows the description of the input
cards.

Contents, Description	Format

I.   GENERAL INPUTS

  A. (TITLE(M), M=1, 8)　　　　　　　　　　　　(8A10)

    TITLE is any (80 character max.) title to be printed
    at the top of each page of output.

  B. NDENS,NVEL,NLEFT,NSET,BRSTH　　　　(4I3,F8.2)

$$NDENS = \begin{cases} 0 & \text{Do } \underline{\text{not}} \text{ calculate densities} \\ 1 & \text{Calculate densities} \end{cases}$$

$$NVEL = \begin{cases} 0 & \text{Do } \underline{\text{not}} \text{ calculate velocities} \\ 1 & \text{Calculate velocities} \end{cases}$$

$$NLEFT = \begin{cases} 0 & \text{If warhead is facing last panels} \\ 1 & \text{If warhead is facing first panels (as in fig. 1)} \end{cases}$$

    NSET = Number of zones
    BRSTH = Burst height (ft)

  C. (CØNA(K), K=1, NSET1)　　　　　　　　(8F10.3)

    These are the cone angles (in degrees) describing the zones.
    The zones are assumed to be contiguous, so that the number
    of angles required will be one more than the number of
    zones.

II. DENSITY CALCULATION INPUTS

  A. BASE, WTHSP, HTSP　　　　　　　　　　(4F10.1)

    BASE = distance above ground of bottom of density panels (ft)
    WTHSP = width of density sub-panels (ft)
    HTSP = height of density sub-panels (ft)

B. NV,NH   (2I3)

These are the numbers of density sub-panels, vertically and horizontally respectively.

C. ((N(I,J),   I=1,NV),J=1,NH)   (26I3)

$N(I,J)$ is the number of fragments in the (I,J)th sub-panel, read in one (vertical) column at a time. Each new column must begin on a new card.

III. VELOCITY CALCULATION INPUTS

A. BASE2, WTHSP2,HTSP2,GRAINS, CD, SHAPE   (6F10.1)
The first three of these are the same as in II-A, except they are for velocity sub-panels.

GRAINS = weight of fragment (grains)
CD   = drag coefficient (dimensionless)
SHAPE   = shape factor ($ft^2 - grains^{1/3}/lb$)

B. NV2, NH2   (2I3)

These are the same as in II-B, except they are for velocity sub-panels.

C. (FSD(M), KL(M)), M=1,4)   (4(F10.1,I5))

FSD(M) = camera speed (frames/sec) of camera M
KL(M)   = number of sub-panels (horizontally) filmed by camera M.

D. I, J, NN, (KF(M), M=1,NN)   (3I3,1X14I5/(16I5))

I = index of sub-panel, vertical direction (V)
J = index of sub-panel, horizontal direction (H)
NN = number of fragments in (I,J)th sub-panel.
KF(M) = frame number of Mth fragment in (I,J)th sub-panel.

Ordering of fragments within a sub-panel is arbitrary, as is the ordering of the input cards in III-D. A sub-panel with no fragment hits should not be inputted. If there are more than 14 frame numbers to be included for any sub-panel, the additional frame numbers must be included in succeeding cards using (16I5) format.

The program may be run for the density half of the arena, the velocity half, or for both halves. The input variables NDENS and NVEL in I-A indicate to the program which calculations are desired. The table below indicates the inputs necessary in the three cases:

NDENS	NVEL	Necessary Input Data
1	0	I, II
0	1	I, III
1	1	I, II, III

Type I data is always required and the input cards are ordered as they appear each letter (e.g., III-B, III-C) indicating at least one new card.

3.3 Input Data Forms

Convenient forms for reporting the data to the program user have been prepared and are illustrated in the following three pages. It is a simple matter to punch the input data in the correct format once the data has been entered on these forms correctly.

Form 1 contains the title or description of the round, the burst height, and the necessary test arena data for the distribution and velocity sub-panels. It also contains the camera speeds of the four cameras and the corresponding indices of the sub-panels they film. A "REMARKS" section has been included for any other pertinent information about the test.

Form 2 is used to record the number of fragment hits for each distribution sub-panel, and as indicated above, H represents the horizontal index of the sub-panel and V the vertical index. The H numbering goes from left to right and the V goes from bottom to top so that the panels appear on this form as they are in the arena. This data corresponds to data set II-C above.

Form 3 is used to record the film data from the velocity panels. The vertical index of the sub-panel is entered in the first column (labelled V), the horizontal index is entered in the second column (labelled H), and the number of fragments hitting a particular sub-panel is entered in the third column. The frame numbers of each fragment are recorded in the remaining space. If there is not enough space on one line for all the frame numbers, succeeding lines can be used. Sub-panels with no hits should <u>not</u> be recorded. The data on Form 3 corresponds to data set III-D.

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FORM NO. 1

Title or Description of Round   _____

Burst Height   _____

Density Data Included?   YES   NO   (Circle One)

Dimensions of Distribution Sub-Panels: , Width_____

                                          Height_____

Number of Distribution Sub-Panels: Horizontally_____

                                          Vertically_____

Distance Above Ground of Bottom
  of Panel   _____

Velocity Data Included?   YES   NO   (Circle One)

Dimensions of Velocity Sub-Panels: Width_____

                                          Height_____

Number of Velocity Sub-Panels: Horizontally_____

                                          Vertically_____

Distance Above Ground of Bottom
  of Panel   _____

	Camera Speed (Frames/Sec)	No. of Horizontal Indices Covered
Camera 1		
Camera 2		
Camera 3		
Camera 4		

REMARKS:

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FORM NO. 2 – DISTRIBUTION SUB-PANELS

Number of Fragments

H →→	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
V-8																											
V-7																											
V-6																											
V-5																											
V-4																											
V-3																											
V-2																											
V-1																											

H →	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
V-8																											
V-7																											
V-6																											
V-5																											
V-4																											
V-3																											
V-2																											
V-1																											

FORM NO. 3 – VELOCITY SUB-PANELS

V	H	NO. HITS	FRAME NUMBERS OF HITS	V	H	NO. HITS	FRAME NUMBERS OF HITS

3.4 Output Guide

The first page of the density output contains a listing of the dimensions of the distribution sub-panels, including all the information about these found on Form 1. It also contains a list of the inputted zone angles.

The next page(s) contains a listing of the number of fragments by sub-panel, 40 lines per page, and corresponds to the data entered on form 2.

The final density page contains a summary of the results by zone, including definitions of zones by angles, fragments counted, density of fragments per steradian, and predicted number of fragments computed using the method of Section 2.1. The "TOTAL NUMBER FRAGMENTS PREDICTED" at the bottom of this page is simply the sum of the predicted numbers for each zone.

The first page of the velocity output contains a listing of the dimensions of the velocity sub-panels (including all the information about them found on form 1), the drag information, the camera speeds and the inputted zone angles.

The next page(s) contains a listing of the number of fragments by sub-panel (40 lines per page) which corresponds to the data entered in the "V", "H" and "NO. HITS" columns on Form 3.

The final density output page contains a summary of the results by zone, including definitions of zones by angles and fragments counted per zone. The column labelled "AVERAGE VBAR" is an "average average" velocity for each zone, since the velocities being averaged are already average velocities over the distance from the burst point to the velocity panels. The "AVERAGE INIT. VEL." and the "STD. DEV. INIT. VEL." for each zone are computed as explained in Section 2.2.

If the program reads any frame numbers equal to zero, it will print out the vertical and horizontal indices of the sub-panel and the number of the fragment. For example, if the message

$$I=3 \qquad J=6 \qquad M=7$$

appeared, it would indicate that the 7th frame number for sub-panel V-3, H-6 was equal to zero. This usually means that the number of fragments for this sub-panel punched on the input card (type III-D) was greater than it should have been. This message allows one to locate certain incorrectly punched input cards.

4.0 SAMPLE CASE

The arena used in the sample case is shown in fig. 1;
it is set up so that the panels are centered about a height of
10 ft., corresponding to the burst height. The distribution
panels are 16 ft. high and 4 ft. wide, and the bottom panels
are 2 ft. off the ground. There are 27 of these panels,
each divided into sixteen 2' x 2' sub-panels, so that there
are 54 sub-panels horizontally and 8 sub-panels vertically.
Using equation (1) the radius of this half of the arena is
R = 34.3775.

The velocity panels are 8 ft. high and 4 ft. wide, and
the bottom panels are 6 ft. off the ground. There are 17
of these panels each divided into thirty-two 1' x 1' sub-
panels, so that there are 68 sub-panels horizontally and 8 sub-
panels vertically. Using equation (1) the radius of this half
of the arena is R = 21.6451.

For the sample case, the values of m, C_D, and k mentioned
in 2.2 are used, resulting in the value α = .006239.

Cameras 1, 3, and 4 filmed four panels each and camera
2 filmed five panels. This is reflected in the entries on form
no. 1 which lists the number of sub-panels horizontally that
each camera filmed.

The sample case is further described by the data on
completed forms 1, 2 and 3 which follow in 4.1; these are
simply a tabulation of the fragment hits and camera results
from an arena as illustrated in fig. 1. A list of the input
deck, card by card, is given in 4.2, and the output from this
same sample case is provided in 4.3.

4.1 <u>Completed Input Forms for Sample Case</u>

FORM NO. 1

Title or Description of Round   Sample case

Burst Height   10.0′

Density Data Included?   (YES)   NO   (Circle One)

Dimensions of Distribution Sub-Panels: Width   2.′

                                       Height   2.0′

Number of Distribution Sub-Panels: Horizontally   54

                                       Vertically   8

Distance Above Ground of Bottom
   of Panel   2.0′

Velocity Data Included?   (YES)   NO   (Circle One)

Dimensions of Velocity Sub-Panels: Width   1.0′

                                       Height   1.0′

Number of Velocity Sub-Panels: Horizontally   68

                                       Vertically   8

Distance Above Ground of Bottom
   of Panel   6.0′

	Camera Speed (Frames/Sec)	No. of Horizontal Indices Covered
Camera 1	14000.	16
Camera 2	13772.	20
Camera 3	14381.	16
Camera 4	12666.	16

REMARKS: $m = 30$ grains $C_D = .55$ $k = .462 \frac{ft^2-gr^{1/3}}{lb}$

               Warhead facing left (as in fig. 1)

FORM NO. 2 - DISTRIBUTION SUB-PANELS

Number of Fragments

H →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
V-8	1										1	1	1	1	1								1			3	10
V-7			1								1	2						1					2			2	5
V-6											1	1	1			2							1		1	4	7
V-5	1		1	2	1						1		1	1	2	2				2		1	1			4	6
V-4				1							1		1		2	2				1	1	1		1	1	3	5
V-3			1								1	2	2		2	1		1			2		1			4	8
V-2				1									1		1	1				1		1	2			7	11
V-1	1		1								2						1	1		1	1	1			1	2	6

H →	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
V-8	7	2		1	1	2			2			1												1					
V-7	7	2		2	2	2	2		1						1										1				
V-6	2	2		2	3	1	1	1	1	1		2																1	
V-5	7	1		2	2	3	1	1	2	1		1		1											2	1			
V-4	6	2		2	3	3	1		2			1				1													
V-3	5	1		2	3	2	1	1	1	1		2			1														
V-2	2	4		1	3	2	1		3		1												2		1				1
V-1	4	2		2	2	2	2					1			1		1						1						

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FORM NO. 3 - VELOCITY SUB-PANELS

V	H	NO. HITS	FRAME NUMBERS OF HITS	V	H	NO. HITS	FRAME NUMBERS OF HITS
1	1	1	64	5	14	1	132
1	14	1	130	5	16	2	127, 131
1	15	1	126	6	2	1	35
2	1	1	64	6	3	1	65
2	2	2	129, 147	6	4	2	69, 96
2	4	1	79	6	15	3	122, 123, 124
2	5	1	160	7	1	1	42
2	7	1	103	7	2	1	64
2	8	1	92	7	3	1	76
2	15	2	130, 166	7	6	2	127, 173
2	16	1	130	7	15	1	127
3	1	1	36	8	2	1	73
3	2	1	38	8	4	1	57
3	5	1	153	8	6	2	138, 166
3	15	3	127, 128, 135	8	15	1	140
4	2	2	59, 60	8	16	1	125
4	3	1	51	1	17	1	120
4	4	2	51, 127	1	22	2	91, 119
4	5	1	176	1	23	1	30
4	6	1	140	1	27	1	76
4	9	1	153	1	29	1	76
4	15	2	128, 131	2	22	1	115
4	16	1	130	2	23	2	75, 91
5	2	3	60, 68, 58	2	26	1	87
5	5	2	124, 128	2	27	3	63, 74, 98

FORM NO. 3 - VELOCITY SUB-PANELS

V	H	NO. HITS	FRAME NUMBERS OF HITS	V	H	NO. HITS	FRAME NUMBERS OF HITS
2	29	2	76, 98	6	26	1	75
3	17	2	117, 133	6	27	1	98
3	19	2	117, 117	6	28	2	65, 113
3	22	2	78, 87	6	29	2	74, 102
3	23	1	86	7	17	2	114, 126
3	25	1	22	7	22	1	115
3	26	3	75, 76, 119	7	23	2	79, 124
3	27	2	74, 98	7	24	1	119
3	30	1	72	7	26	1	76
4	18	1	111	7	27	1	120
4	19	2	117, 132	7	30	1	74
4	22	1	75	8	17	1	113
4	23	1	115	8	22	1	120
4	26	2	85, 101	8	25	1	84
4	27	1	101	8	26	1	74
5	18	3	119, 138, 142	8	27	1	70
5	23	2	79, 115	8	30	1	71
5	24	1	79	8	31	1	74
5	26	2	74, 75	8	32	2	63, 79
5	30	1	73	8	33	3	63, 65, 65
5	18	1	99	8	34	2	63, 65
6	20	1	117	8	35	2	63, 64
6	21	3	75, 77, 80	8	36	1	65
6	22	1	117	7	32	2	69, 73
6	23	2	78, 85	7	33	2	62, 67

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FORM NO. 3 - VELOCITY SUB-PANELS

V	H	NO. HITS	FRAME NUMBERS OF HITS	V	H	NO. HITS	FRAME NUMBERS OF HITS
7	35	3	62,62,65	2	34	1	63
6	31	3	70,76,91	2	35	4	62,62,63,63
6	32	1	35	2	36	1	63
6	33	3	67,67,77	1	32	2	71,76
6	34	2	61,68	1	33	1	69
6	35	4	62,63,68,68	1	34	1	63
5	31	2	72,90	1	36	1	76
5	32	2	70,74	1	38	3	59,70,71
5	33	2	62,65	1	39	3	74
5	34	1	61	1	41	1	76
5	35	3	62,62,71	1	43	1	78
4	31	1	74	1	46	1	88
4	32	1	72	1	51	1	85
4	33	4	62,63,65,68	2	37	1	71
4	35	5	61,63,63,65,68	2	38	2	69,69
4	36	2	62,68	2	40	1	75
3	31	1	73	2	43	1	88
3	32	3	70,72,73	2	44	1	78
3	33	3	62,68,71	2	46	1	90
3	34	1	58	2	52	1	90
3	35	1	62	3	37	1	72
3	36	2	74,74	2	38	2	69,73
2	31	1	76		39	2	76,74
2	32	2	69,72		40	2	66,75
2	33	1	63		41	1	75

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FORM NO. 3 - VELOCITY SUB-PANELS

V	H	NO. HITS	FRAME NUMBERS OF HITS	V	H	NO. HITS	FRAME NUMBERS OF HITS
3	42	1	76	6	50	1	85
3	43	1	78	6	52	1	91
3	46	2	3?,88	7	37	3	58,62,71
3	51	1	87	7	38	3	60,61,73
4	37	5	68,71,72,73,74	7	39	2	72,74
4	38	2	56,69	7	40	1	73
4	39	3	56,61,73	7	42	2	75,76
4	40	1	61	7	43	1	86
4	43	1	86	7	44	1	79
4	45	1	79	7	46	1	91
4	50	1	90	7	50	1	91
4	51	1	86	8	37	2	71,71
5	37	3	58,72,72	8	38	3	62,65,72
5	38	1	66	8	39	1	74
5	40	1	75	8	41	1	75
5	42	2	76,79	8	45	1	90
5	45	1	82	8	46	1	82
5	46	1	28	8	49	1	86
5	47	1	88	8	50	1	85
5	48	1	83	8	54	1	83
6	37	4	71,71,73,74	7		2	82,86
6	38	1	68	7			61,61
6	39	1	74	7			60
6	41	1	71	7		1	63
6	47	1	71	7	65	1	35

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FORM NO. 3 - VELOCITY SUB-PANELS

V	H	NO. HITS	FRAME NUMBERS OF HITS	V	H	NO. HITS	FRAME NUMBERS OF HITS
6	55	1	88	3	67	3	27, 33, 33
6	59	1	42	3	68	3	27, 27, 30
6	60	2	87, 87	2	53	1	83
6	62	2	48, 60	2	54	1	79
6	63	3	58, 58, 60	2	59	1	78
6	64	1	58	2	60	1	96
6	66	2	27, 34	2	62	1	48
6	68	1	80	2	64	1	4 x
5	53	1	79	2	65	1	27
5	60	2	8, 64	2	66	2	30, 25
5	63	2	61, 70	2	67	2	30, 25
5	64	1	35	2	68	5	30, 31, 31, 31, 31
5	65	1	34	1	62	1	60
5	66	3	27, 27, 34	1	63	1	60
5	67	1	27	1	60	1	61
4	53	1	79	1	66	1	34
4	54	1	89	1	67	2	30, 33
4	60	1	76	1	68	1	31
4	63	1	53				
4	65	2	35, 35				
4	66	1	35				
4	67	1	27				
4	68	3	23, 23, 23				
3	59	1	87				
3	61	1	58				

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4.2 Input Cards for Sample Case

The following pages contain a listing of the actual data cards used for the sample case. The numbers in the far left column are card numbers; they are listed here for easier reference and should not be considered part of the actual data punched on the cards which begins to the right of the line.

SAMPLE CASE FOR ZONE

		0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.
		80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.
		160.	170.0	180.0					
		2.0	2.0	2.0					

1									
2		1	1						
3									
4									
5									
6									
7	8	54							
8	1								
9									
10	1		1						
11		1	1						
12		1	2						
13		1							
14									
15				1					
16									
17									
18	2	2	1	1	1	1			
19		1	1	1	2				
20		1	2	1	1				
21			1	1					
22		1	2	2	2	1			
23	1	1	2	2					
24	1								
25	1	1	1		1				
26									
27	1	1	2						
28	1	2	1						
29	1	1	1						
30	2	2	1	1	2	1			
31	1	1	1						
32	1	1	1	1	1				
33	2	4	4	4	2	3			
34	5	11	6	7	5	10			
35	4	2	6	7	7	7			
36	2	4	2	2	2	2			
37	2	3	3	2	2	1			
38	2	2	5	3	3	2			
39	2	1	1	1	1				
40		1	1	1					

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121	4	6	1	140		
122	4	9	1	153		
123	4	15	2	162	131	
124	4	16	1	132		
125	5	2	1	40	68	
126	5	5	2	124	128	68
127	5	14	1	132		
128	5	16	2	127	131	
129	6	3	1	35		
130	6	4	1	55		
131	6	4	2	67	96	
132	6	15	3	122	123	124
133	7	1	1	42		
134	7	2	1	64		
135	7	3	1	76		
136	7	6	2	127	173	
137	7	15	1	127		
138	8	2	1	73		
139	8	4	1	57		
140	8	6	2	136	166	
141	8	15	1	140		
142	8	16	1	123		
143	1	17	1	120		
144	1	22	2	91	119	
145	1	23	1	30		
146	1	27	1	76		
147	1	29	1	76		
148	2	22	1	115		
149	2	23	2	75	91	
150	2	26	1	87		
151	2	27	3	63	93	98
152	2	29	2	76	93	
153	3	17	2	117	133	
154	3	19	2	117	117	
155	3	22	2	78	87	
156	3	23	1	86		
157	3	25	1	82		
158	3	26	3	72	76	112
159	3	27	2	74	94	
160	3	30	1	72		

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161	4	18	1	111	
162	4	19	2	117	132
163	4	22	1	75	
164	4	23	1	115	
165	4	26	2	85	101
166	4	27	1	101	
167	5	18	3	119	138 142
168	5	23	2	79	115
169	5	24	1	79	
170	5	26	2	74	13
171	5	30	1	73	
172	6	18	1	77	
173	6	20	1	117	
174	6	21	3	72	71 80
175	6	22	1	117	
176	6	23	2	73	85
177	6	26	1	75	
178	5	27	1	70	
179	5	28	2	65	113
180	7	17	1	74	102
181	7	26	2	114	12
182	7	23	2	112	124
183	7	24	2	112	
184	7	26	1	70	
185	7	27	1	120	
186	7	30	1	74	
187	8	17	1	113	
188	8	22	1	120	
189	8	25	1	74	
190	8	26	1	70	
191	8	27	1	91	
192	8	30	1	74	
193	8	31	2	59	72 68
194	7	33	3	23	73
195	7	34	2	60	69
196	7	35	2	60	64
197	7	36	1	60	
198	7	12	2	72	13

201	7 53	2	52	67			
202	7 35	3	52	62	52		
203	31	3	70	76	91		
204	5 36	1	82				
205	6 33	3	67	67	77		
206	6 34	2	61	68			
207	6 35	4	62	63	68	68	
208	5 31	2	72	90			
209	32	2	71	74			
210	33	2	62	65			
211	34	1	61				
212	5 30	3	62	62	71		
213	4 31	1	74				
214	4 32	1	76				
215	4 33	4	63	63	65	68	
216	4 35	5	91	83	63	65	58
217	4 35	2	62	68			
218	3 31	1	73	72	73		
219	3 32	3	70	72	71		
220	3 33	3	62	68			
221	3 34	1	58				
222	3 35	2	62	62			
223	3 30	2	74	74			
224	2 31	1	76	76			
225	2 32	2	69	72			
226	2 33	1	63				
227	2 34	1	63				
228	2 35	4	62	62	63	63	
229	2 36	1	63				
230	1 32	2	71	76			
231	1 33	1	63				
232	1 34	1	63				
233	1 36	1	76				
234	8 37	2	71	71			
235	8 38	3	62	65	72		
236	8 39	1	74				
237	8 41	1	75				
238	7 44	1	79				
239	7 42	2	75	76			
240	7 43	1	85				

241	7	40	1	73				
242	7	39	2	72	74			
243	7	38	3	60	61	73		
244	7	37	3	58	62	71		
245	6	39	1	74				
246	6	41	1	11				
247	6	37	4	71	71	73	74	
248	5	32	1	68				
249	5	42	2	76	79			
250	5	40	1	75				
251	5	38	1	66				
252	5	37	3	53	72	72		
253	4	43	1	46				
254	4	40	1	61				
255	4	39	3	56	61	73		
256	4	38	2	56	62			
257	4	37	2	68	71	72	73	74
258	3	43	1	75				
259	3	42	1	76				
260	3	41	1	75				
261	3	40	2	66	75			
262	1	39	2	76	74			
263	3	38	2	69	73			
264	3	37	1	72				
265	2	37	1	71				
266	1	36	3	59	70	71		
267	2	35	2	57	67			
268	1	39	1	74				
269	2	40	2	72				
270	1	41	1	75				
271	1	43	1	78				
272	2	43	1	85				
273	2	44	1	78				
274	1	58	1	31				
275	1	57	2	30	53			
276	1	65	1	34				
277	1	64	1	61				
278	2	58	5	30	31	31	31	31
279	1	52	1	54				
280	1	23	1	24				

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4.3 Output from Sample Case

SAMPLE CASE FOR ZONE

----- DENSITY PANELS

NO. SUB-PANELS, HORIZONTALLY = 54
NO. SUB-PANELS, VERTICALLY = 8

ADJUSTED RADIUS = 34.3775
HEIGHT = 16.00
DIST. ABOVE GROUND = 2.00
BURST HEIGHT = 10.00

TARGET OR SUB-PANEL WIDTH = 2.00
TARGET OR SUB-PANEL HEIGHT = 2.00

ZONE ANGLES

0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0
160.0	170.0	180.0

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SAMPLE CASE FOR ZONE

FRAGMENTS BY SUB-PANEL - FOR DENSITY CALCULATIONS

HORIZ	SUB-PANEL (VERTICALLY)							
	1	2	3	4	5	6	7	8
1	1	0	0	1	0	0	0	1
2	0	0	0	0	0	0	0	0
3	1	1	0	1	0	0	1	0
4	0	0	0	1	2	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	1	0	0	0	0	1
10	2	2	1	1	1	1	1	1
11	0	1	2	0	0	1	2	1
12	3	0	0	0	1	0	0	1
13	0	0	1	1	1	1	0	1
14	0	1	2	2	2	0	0	1
15	1	0	2	0	2	2	1	0
16	1	0	1	0	0	0	0	0
17	0	0	0	1	0	0	1	0
18	1	1	0	0	0	0	0	0
19	1	0	0	0	0	0	0	0
20	1	0	2	1	2	0	2	0
21	0	2	1	0	0	1	0	1
22	0	0	1	1	1	0	0	0
23	1	0	1	0	0	1	0	0
24	2	2	4	3	3	4	2	3
25	6	7	8	5	6	7	5	7
26	4	11	5	6	7	2	7	10
27	2	4	1	2	1	2	2	2
28	2	3	3	3	2	3	2	1
29	2	2	2	5	3	1	2	2
30	0	1	1	1	1	1	1	0
31	0	0	0	0	0	1	0	2
32	0	3	1	2	2	1	0	0
33	0	0	0	0	1	1	0	1
34	1	1	1	1	1	1	0	0
35	0	0	0	0	0	0	0	0
36	1	1	2	1	1	2	0	2
37	0	0	0	0	3	3	0	1
38	0	0	0	0	3	3	0	0
39	1	1	0	1	1	0	1	0
40	1		0	0		0		0

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FRAGMENTS BY SUB-PANEL - FOR DENSITY CALCULATIONS

HORIZ	SUB-PANEL (VERTICALLY)
	1	2	3	4	5	6	7	8
41	0	0	1	0	0	0	0	0
42	1	0	1	0	0	0	0	0
43	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0
47	0	2	0	0	0	0	0	0
48	1	0	0	0	0	0	0	1
49	0	1	0	0	1	0	1	0
50	0	0	0	0	0	0	0	0
51	0	0	0	0	0	1	0	0
52	0	0	0	0	0	1	0	0
53	0	0	1	0	0	0	0	0
54	0	1	1	0	0	0	0	0

SAMPLE CASE FOR ZONE

------DENSITY INFORMATION------

ZONE	LOWER ANGLE	UPPER ANGLE	FRAGMENTS COUNTED	DENSITY	PRED. NO. FRAGMENTS
1	0.0	10.0	2	3.4	3.6
2	10.0	20.0	9	98.0	27.8
3	20.0	30.0	0	0.0	0.0
4	30.0	40.0	14	163.7	102.9
5	40.0	50.0	16	202.2	156.6
6	50.0	60.0	12	151.6	136.0
7	60.0	70.0	9	113.7	112.9
8	70.0	80.0	13	164.3	173.8
9	80.0	90.0	90	1137.3	1240.8
10	90.0	100.0	75	947.7	1034.0
11	100.0	110.0	30	379.1	401.
12	110.0	120.0	16	202.2	200.7
13	120.0	130.0	9	113.7	102.0
14	130.0	140.0	6	75.8	
15	140.0	150.0	0	0.0	0.0
16	150.0	160.0	4	46.7	21.6
17	160.0	170.0	3	32.7	9.3
18	170.0	180.0	2	37.4	3.6

.... TOTAL NO. FRAGMENTS PREDICTED = 3785.3

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SAMPLE CASE FOR ZONE

VELOCITY PANELS

NO. SUB-PANELS, HORIZONTALLY = 68
NO. SUB-PANELS, VERTICALLY = 8

ADJUSTED RADIUS = 21.6451
HEIGHT = 8.00
DIST. ABOVE GROUND = 6.00
BURST HEIGHT = 10.00

TARGET OR SUB-PANEL WIDTH = 1.00
TARGET OR SUB-PANEL HEIGHT = 1.00

FRAGMENT WEIGHT (GRAINS) = 30.0
DRAG COEF. = .5500
SHAPE FACTOR = .4620

CAMERA SPEEDS (FRAMES/SEC)

. 14000.0   13772.0   14381.0   ·12666.0

ZONE ANGLES

0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0
160.0	170.0	180.0					

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FRAGMENTS BY SUB-PANEL - FOR VELOCITY CALCULATIONS

HORIZ	SUB-PANEL (VERTICALLY)							
	1	2	3	4	5	6	7	8
1	1	1	1	0	0	0	1	0
2	0	2	1	2	3	1	1	1
3	0	0	0	1	0	1	0	0
4	0	1	1	2	2	2	1	1
5	0	1	1	1	0	0	0	0
6	0	0	0	1	0	0	2	2
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	1	1	0	0	0
12	1	0	0	0	0	0	1	1
13	1	0	0	0	1	0	2	1
14	0	0	0	0	0	0	0	0
15	1	0	2	2	2	3	2	0
16	0	2	2	0	0	0	0	0
17	2	0	0	0	1	1	1	1
18	1	0	1	0	0	0	1	1
19	0	0	1	0	3	3	0	0
20	0	0	1	2	0	2	2	0
21	0	0	2	1	1	0	1	0
22	2	2	1	0	0	1	0	1
23	1	0	0	0	2	1	2	0
24	0	0	1	0	1	0	1	0
25	0	1	1	0	0	1	0	1
26	0	2	1	2	2	2	1	1
27	1	0	3	1	1	0	0	1
28	0	1	3	0	0	1	1	2
29	1	2	0	0	1	2	0	3
30	0	0	1	1	2	3	2	2
31	0	1	1	4	2	1	3	2
32	1	1	3	5	3	3	3	1
33	0	4	1	2	0	0	0	0
34	1	1	2	5	3	4	3	2
35	0	1	1	2	0	0	0	2
36	1	1	2	5	3	4	3	1
37	0	0	1	2	1	1	3	2
38	3	2	2	2	3	1	3	3
39	1	0	2	3	1	1	2	1
40	0	0	2	1	0	0	1	0

SAMPLE CASE FOR ZONE

FRAGMENTS BY SUB-PANEL - FOR VELOCITY CALCULATIONS

HORIZ	1	2	3	4	5	6	7	8
				SUB-PANEL (VERTICALLY)				
41	1	0	1	0	0	1	0	1
42	0	1	1	0	2	0	2	0
43	0	1	1	1	0	0	1	0
44	0	0	0	1	0	0	0	0
45	1	1	2	0	1	1	1	1
46	0	0	0	0	1	0	0	0
47	0	0	0	0	0	0	0	1
48	0	0	0	0	0	1	0	0
49	0	1	1	1	0	0	0	0
50	1	0	0	1	0	1	1	1
51	0	1	0	1	0	0	0	0
52	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	1
54	0	0	0	0	1	1	2	0
55	0	0	0	0	0	0	0	0
56	0	0	0	0	0	2	0	0
57	0	1	0	1	0	0	0	0
58	1	1	1	0	2	1	2	0
59	1	0	0	1	0	2	1	0
60	0	1	1	0	1	3	1	0
61	1	0	0	1	2	1	1	1
62	0	1	0	0	1	0	1	0
63	1	1	0	1	2	1	0	0
64	1	1	0	0	1	2	0	0
65	0	2	2	2	1	0	0	0
66	1	1	1	1	3	0	0	0
67	2	2	3	3	1	1	0	0
68	1	5	3	3	0	0	0	0

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SAMPLE CASE FOR ZONE

-----VELOCITY INFORMATION-----

| ZONE	LOWER ANGLE	UPPER ANGLE	FRAGMENTS COUNTED	AVERAGE VBAR	AVERAGE INIT. VEL.	STD. DEV. INIT. VEL.
1	0.0	10.0	19	5441.7	5828.4	2199.4
2	10.0	20.0	16	2842.6	3045.3	1150.2
3	20.0	30.0	2	2647.7	2836.1	1011.4
4	30.0	40.0	15	2331.3	2497.3	170.0
5	40.0	50.0	20	2460.5	2635.5	226.0
6	50.0	60.0	24	3274.7	3507.8	644.0
7	60.0	70.0	15	3591.7	3847.2	566.3
8	70.0	80.0	21	3597.3	3853.7	715.8
9	80.0	90.0	51	4348.3	4658.0	432.4
10	90.0	100.0	65	4615.0	4943.6	363.2
11	100.0	110.0	25	4322.2	4712.3	479.7
12	110.0	120.0	10	3808.3	4079.7	224.2
13	120.0	130.0	11	3689.3	3952.2	287.4
14	130.0	140.0	12	3530.6	3781.9	133.5
15	140.0	150.0	6	3268.8	3501.9	170.6
16	150.0	160.0	10	3622.6	3879.9	758.6
17	160.0	170.0	24	5716.4	6124.2	1958.2
18	170.0	180.0	31	9094.9	9741.3	1719.9

TEST ARENA
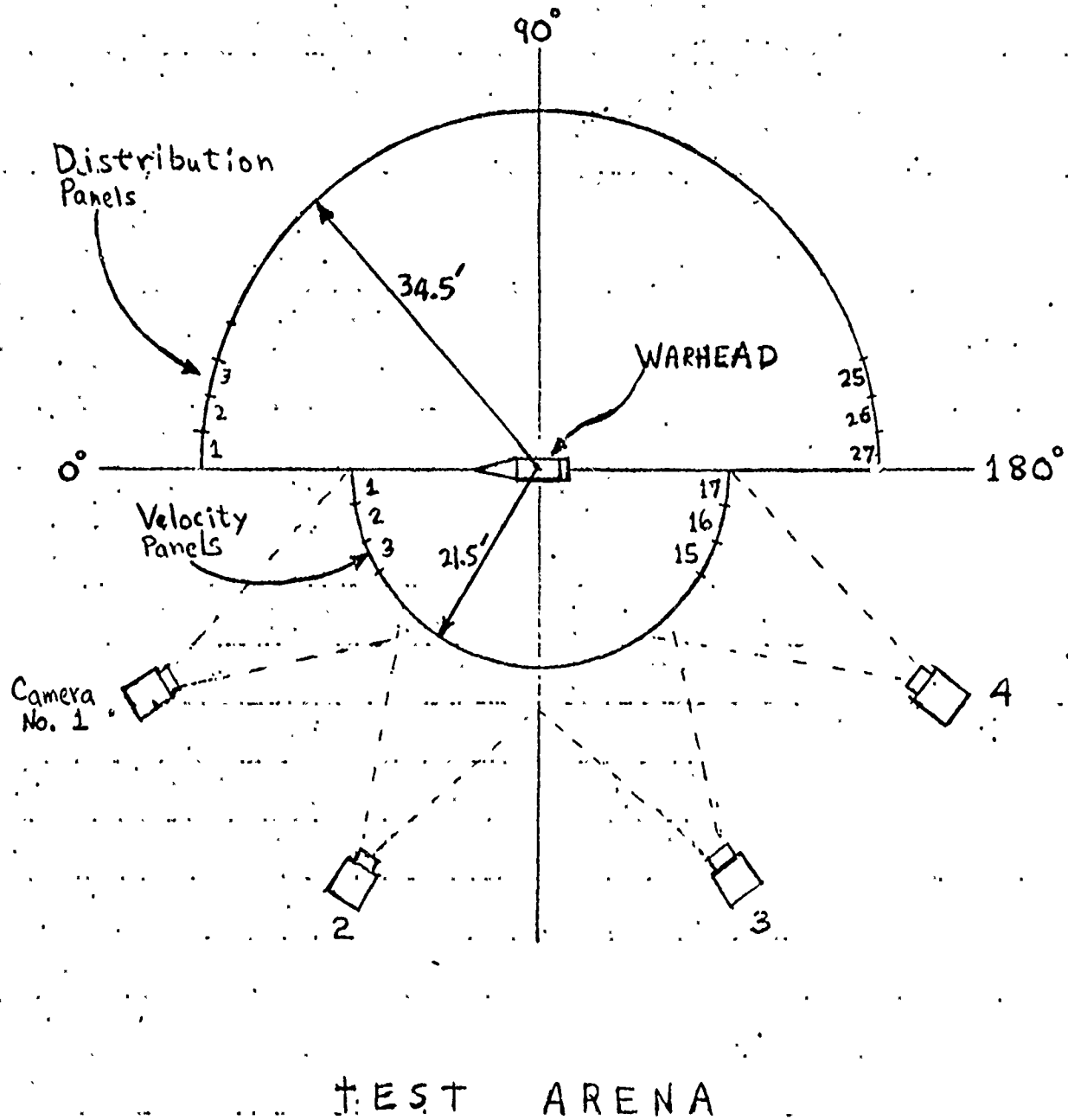
Fig. 1
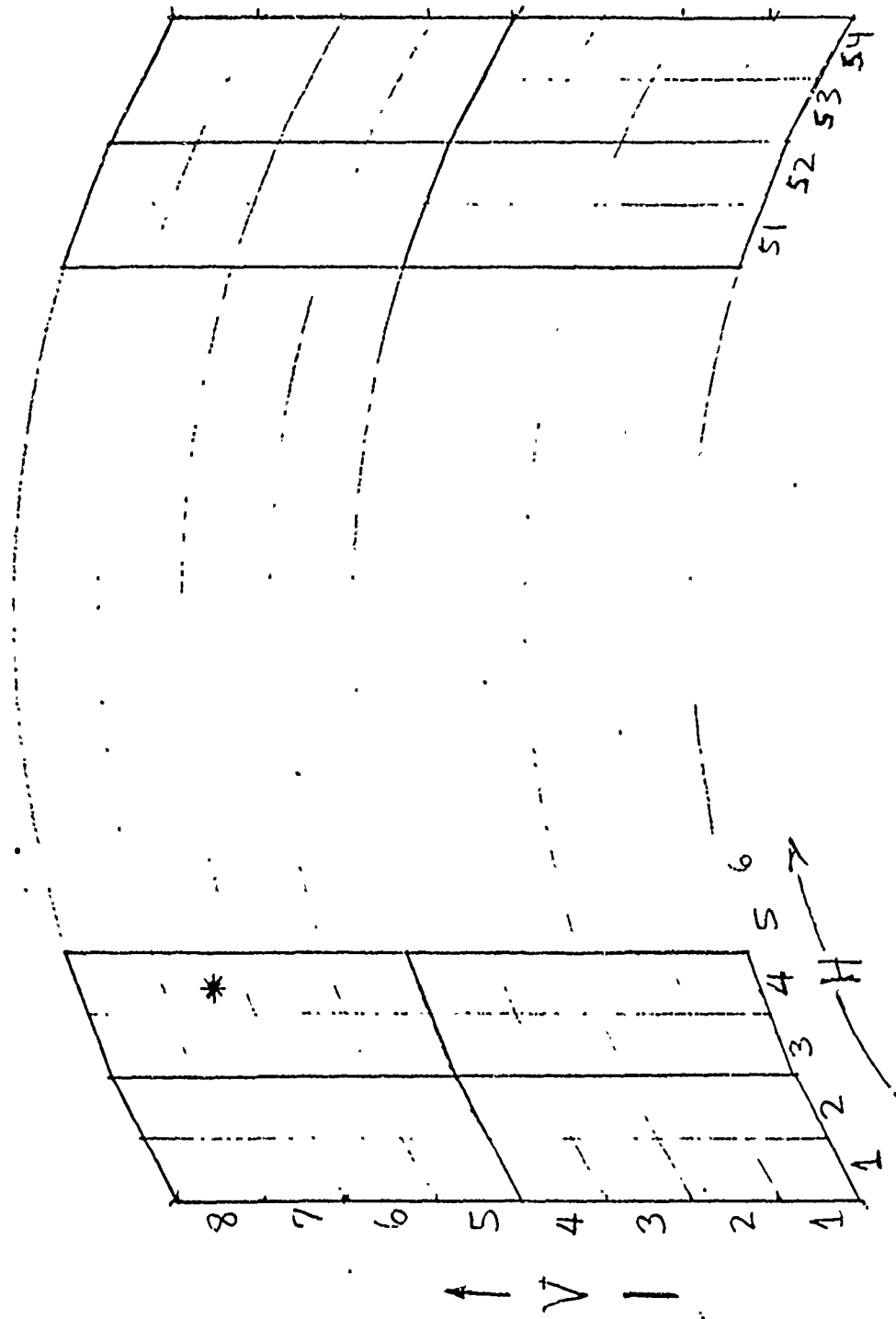
Fragment Distribution Grid and Indexing Notation

Fig. 2

REFERENCE

Dunn and Porter, "Air Drag Measurements of Fragments," BRL MR915, August 1955.