

AD A102770

LEVEL 11

12
75

AD

TECHNICAL REPORT ARBRL-TR-02330

A METHOD FOR REDUCING DATA FROM
RADIOGRAPHS OF SHAPED-CHARGE JETS

H. John Blische
Brian M. Simmons

June 1981

DTIC
AUG 13 1981
C



US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

DTIC FILE COPY

Approved for public release; distribution unlimited.

81 8 13 005

Destroy this report when it is no longer needed.
Do not return it to the originator.

Secondary distribution of this report by originating
or sponsoring activity is prohibited.

Additional copies of this report may be obtained
from the National Technical Information Service,
U.S. Department of Commerce, Springfield, Virginia
22161.

The findings in this report are not to be construed as
an official Department of the Army position, unless
so designated by other authorized documents.

*The use of trade names or manufacturers' names in this report
does not constitute endorsement of any commercial product.*

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TECHNICAL REPORT ARBRL-TR-02330	2. GOVT ACCESSION NO. AD-A102	3. RECIPIENT'S CATALOG NUMBER 770
4. TITLE (and Subtitle) A METHOD FOR REDUCING DATA FROM RADIOGRAPHS OF SHAPED-CHARGE JETS.		5. TYPE OF REPORT & PERIOD COVERED Final
7. AUTHOR(s) H. John Blische Brian M. Simmons		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Ballistic Research Laboratory ATTN: DRDAR-BLT) Aberdeen Proving Ground, MD 21005		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Armament Research and Development Command U.S. Army Ballistic Research Laboratory (ATTN: DRDAR-BL) Aberdeen Proving Ground, MD 21005		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L162618AH80
14. MONITORING AGENCY NAME & ADDRESS (If different from Controlling Office)		12. REPORT DATE JUN 1981
		13. NUMBER OF PAGES 45
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release, distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Shaped-Charge Jet Radiograph Data Reduction		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (hib) This report is a users' guide intended for those involved in reducing data from radiographs of shaped-charge jets. The procedure for setting-up and reading radiographs is listed step-by-step. A computer code listing and description of the calculations are included. Jet particle velocities, break-up time, kinetic energies, lengths, diameters, length-to-diameter ratios, masses, momentums, and jet virtual origin are all included in the code.		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

	Page
I. INTRODUCTION	5
II. COMPUTATIONS AND EQUATIONS	5
III. SUMMARY.	10
APPENDICES	
A. Procedures for Preparing and Reading Radiographs . .	11
B. Input to the Program	17
C. Program Listing.	21
D. Alphabetical Listing of Program Variable Names . . .	29
E. Output from a Sample Run	33
DISTRIBUTION LIST.	45

Accession For	
HTIS GR121	☒
DSIC TAB	☐
Unannounced	☐
Justification	
By _____	
Distribution/ _____	
Availability Codes _____	
Dist	Special
A	

I. INTRODUCTION

With measurements taken directly from flash radiographs of shaped-charge jets before and after breakup, quantitative information describing particulated jet characteristics can be derived. The measurements are used to calculate such properties as particle length, diameter, velocity, mass and break-up time. It is, however, a very tedious and time consuming operation to take the measurements by hand and subsequently perform the calculations at one's desk. To alleviate much of this work, a method using digitizing equipment and a computer program has been developed and is the subject of this report. This method has proven to be very useful, especially in projects involving many rounds and requiring short turn-around time for measurements and computations.^{1,2} The equations used in the computations will be discussed in the next section. Appendices for film reading procedures and for the computer program operation are included.

II. COMPUTATIONS AND EQUATIONS

The program was designed to calculate as many quantities as possible with the data extracted from radiographs. This includes individual particles as well as the whole jet measurements. Since this report is intended as a user's guide, the calculations will be described briefly. All computations are tabulated in the output with proper headings. A typical output is shown in Appendix E.

All radiographs contain slightly magnified images of the particles of a shaped-charge jet. The positions of the particles are likewise altered from their true positions relative to the base of the shaped-charge liner. This difference is taken into account by the magnification factor, M , which is determined by the ratio of the distance, a , from the face of the x-ray tube to the jet path, to the distance, b , from the tube face to the film, as depicted in Figure 1. Thus, $M = a/b$. This factor is used in determining particle lengths, diameters, and positions. To calculate lengths and diameters, the measurements taken from the particle images on film are simply multiplied by the magnification factor.

To calculate change in position the magnification factor is used in the determination of a particle's true position during a given flash. Two cases must be considered regarding the film location in

¹R. L. Jameson, and H. J. Blische, "A Study of a Light Anti-tank Weapon," report in preparation.

²D. Dorfman, and S. K. Golaski, "Electro Formed Shaped Charge Liner Evaluation," report in preparation. Martin Marietta Corp. Contract #DAAK 11-77-0088.

the determination of position. Refer to Figure 1 for the locations of the terms involved. Note that on all films the distance, p, from the fiducial to the particle is positive below the fiducial and negative above.

Case I: Film numbers 1 and 2.

$$s = F - [(f-p) M] ,$$

where s is the true position, F is the distance from the shaped-charge liner base to the x-ray tube focal level, f is the location of the y fiducial relative to the focal level, p is the point on the particle measured from f, and M is the magnification factor.

Case II: Film numbers 3 and 4

$$s = F + [(f+p) M] .$$

Once the positions have been determined for all flashes, velocity is calculated by

$$v = \frac{s_b - s_a}{T_b - T_a} ,$$

where $s_b - s_a$ is the distance of jet travel between the earlier (a) and later (b) flashes, and $T_b - T_a$ is the change in time between the flashes.

Break-up time is determined by the equation developed by Simon.³

$$t_b = \frac{\sum_{i=1}^n \ell_i}{v_1 - v_n}$$

where ℓ_i is the individual particle length, v_1 is the velocity of the first particle and v_n is the velocity of the nth particle.

³J. Simon, "The Effect of Explosive Detonation Characteristics on Shaped Charge Performance," BRL Memorandum Report 2414 (1974). (AD #B000337L).

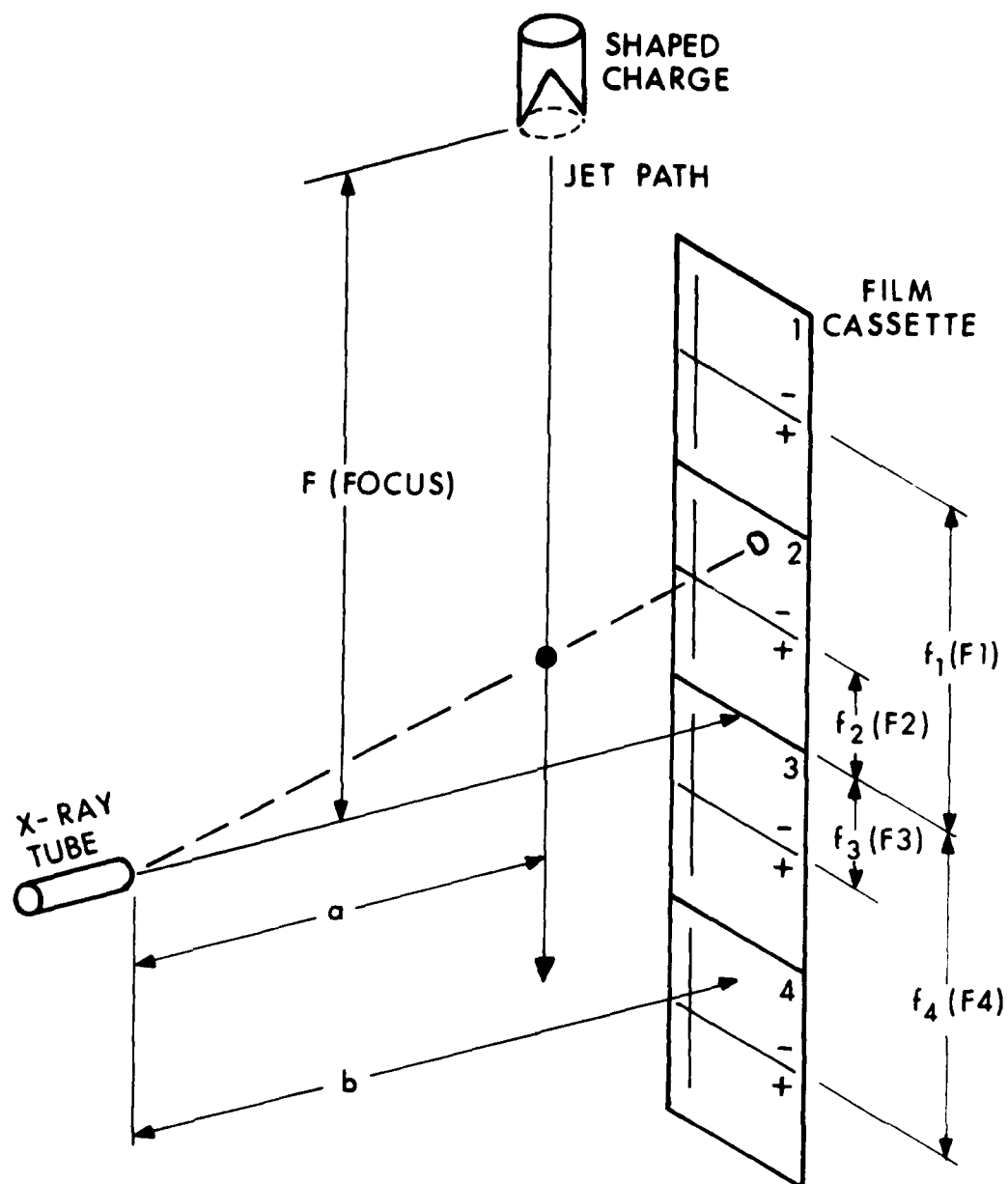


Figure 1. Typical Flash X-ray Set-Up Showing Relative Positions of the Apparatus

Mass calculations involve the equation for the volume of a truncated cone. As described in Appendix A, points located around the film image of a particle outline a pair of trapezoids. This is also shown in Figure 2. The program interprets the coordinates of the points as measurements for truncated cones and applies the equation for mass, m , where

$$m = \rho \frac{\pi}{3} [H_1(R_1^2 + R_1R_2 + R_2^2) + H_2(R_2^2 + R_2R_3 + R_3^2)] .$$

Here, ρ is the density of the shaped-charge liner material, H_1 and H_2 are the heights of the truncated cones, and R_1 , R_2 and R_3 are the radii.

Momentum (mv) and kinetic energy ($\frac{1}{2} mv^2$) are finally calculated using velocity and mass previously computed.

The virtual origin of the shaped-charge jet is found by fitting a least-squares line through the particle velocity/particle position data for each flash. Theoretically, the position of the virtual origin corresponds to a particle velocity of zero.⁴

Tabulations of the above mentioned quantities are performed and listed in the output as averages. However, for the purpose of trouble-shooting, and to gain insight into the accuracy of the average computed quantities, velocities between the flashes and masses for each flash are also listed.

⁴R. DiPersio, J. Simon and A. B. Merendino, "Penetration of Shaped-Charge Jets Into Metallic Targets," BRL Report 1296 (1965). (AD #476717).

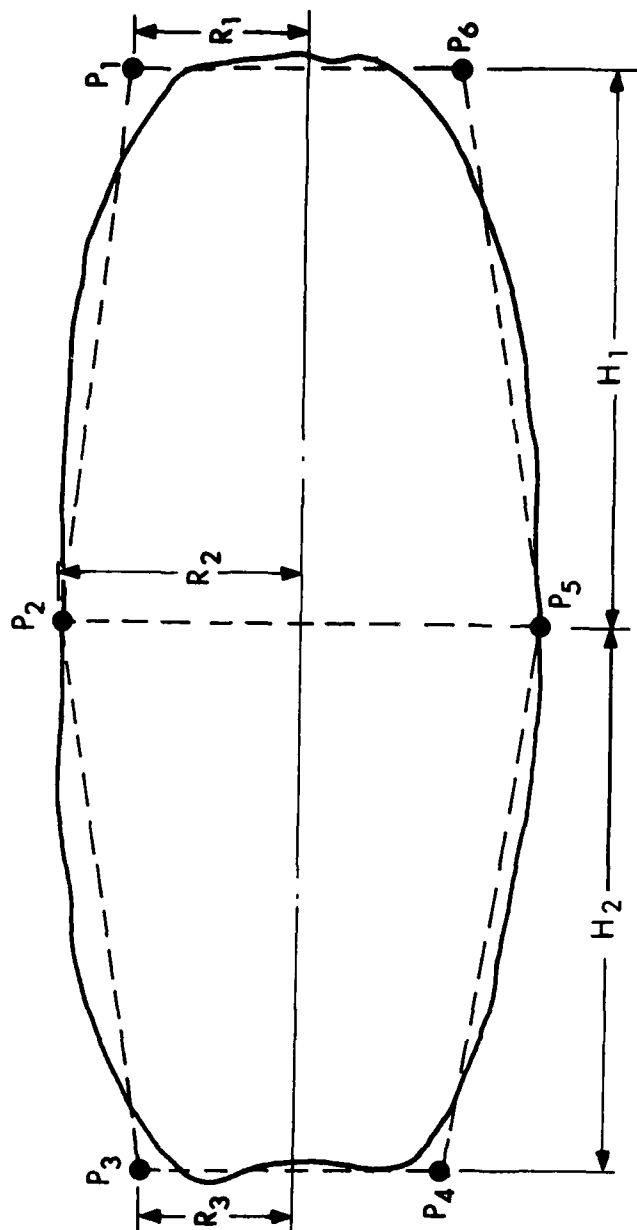


Figure 2. Particle Shape Approximation.. Dashed lines outline two trapezoids that are interpreted as truncated cones in the program.

III. SUMMARY

As indicated earlier, this method quickly yields valuable information necessary for the evaluation of shaped charge designs. A large number of radiographs can be data reduced in a few days, whereas the same number would take months if reduced by hand. This has the advantage of giving the shaped charge investigator more flexibility by allowing more time to assess designs and make decisions.

For accuracy considerations, comparisons of some measurements were made with other findings, and an error estimate of one measurement was performed. Velocity, length, diameter and break-up time calculations for the round in Appendix E were compared to data of several similar rounds as reported by Majerus⁵. The quantities in Appendix E were found to be within the range of Majerus' data. There is a problem, however, with particle mass calculations. An error estimate for the mass of a selected particle revealed that the measurement could be incorrect by approximately 60%. Several factors are involved in this large error including magnification measurements, digitizing equipment accuracy, image clarity and coordinate point locations. Referring back to Figure 2, note that the group of points surrounding the particle does not represent a contour mapping of the particle shape but approximates two truncated cone geometries. This is where the largest part of the error occurs. Ideally, a much larger number of digitized points would give a better approximation of shape, but the equipment currently in use limits the number to six. One solution would be the use of a digitizer with a rapid and continuous mode point reader connected to a tape or disc data storage device. This would enable the operator to trace the image of a particle and produce a closer geometric approximation. The computer program could subsequently be modified to compute mass more accurately.

⁵J. N. Majerus, "A Model for Studying the Influence of Guidance Packages Upon Shaped Charge Warhead Performance," *BSI Report* (1976). (AD#B015299L).

APPENDIX A
PROCEDURES FOR PREPARING AND READING RADIOGRAPHS

The standard BRL flash radiographic test site contains holders for film cassettes, each cassette containing either three or four films. As a rule the films bear the flash number and the film number.

After developing the films, they are arranged according to their positions in the cassettes. The jet particles are then numbered starting with the jet tip and working back, with each particle having the same designated number for every flash.

Once the particles are identified, a set of six points, outlining a pair of trapezoids, is obtained for each particle. When measurements are taken of these points, the configuration will be interpreted as a pair of truncated cones in order to calculate mass. Figure A-1 describes the preparation of the jet particle images.

The film reading machine that is presently used for this procedure is the Data Reducer 099, manufactured by the Telecomputing Corp. Signals are sent from the 099 to a digitizer, developed for BRL by Mr. Donald F. Merritt. The digitizer then transmits this information, in the form of data units per inch, to a MAI Equipment Corp. 523 Gang Summary Unit which punches the data onto computer cards.

The following procedures will enable the user to operate the film reading equipment:

1. Insert the wired circuit board labeled "JET", label down, into the connection frame of the Gang Summary Unit.
2. Load the Gang Summary Unit feeder with blank computer cards.
3. Turn all three machines on, in any order.
4. Beginning with the first flash, place the film containing the jet tip onto the lighted reading surface of the 099. Arrange the film so that the jet is aligned horizontally on the lighted surface. The horizontal fiducial should run parallel to a line marked across the lighted surface as indicated in Figure 2. This is the x-direction. The vertical fiducial will indicate the y - direction.
5. By adjusting the large wheels located on either side of the console, place the cursor cross-hairs on the intersection of the x and y fiducials and press the button marked " ϕ " on the right of the console. This will assign (0,0) to the x/y intersection.
6. Located at the bottom-center of the digitizer console is a set of twelve registers with star-wheel adjustments. Reading from left to right, enter the round number in the first five registers, film number in the seventh and flash number in the eleventh.

7. The frame count windows in the center of the digitizer console should read zero in all units. If not, press the reset buttons until all units are zeroed.

8. Position the other switches and registers on the digitizer console as indicated in Table A-1.

9. With the cursor at (0,0), press the foot switch repeatedly until the number "1" appears in the frame count window. This will zero-out the memory in the card punch machine.

10. To read a particle place the cursor on each point, beginning with p_1 (Figure A-1), and press the foot switch for reading at each point. Repeat this step for every particle on the film.

Table A-1. Positions of Switches and Other Adjustments on the Electronic Digitizer

<u>SWITCH</u>	<u>POSITION</u>
Multiplier (x and y)	4
Direction (x)	Down
Direction (y)	Down
Normal/Test (x)	Normal
Normal/Test (y)	Normal
Printer (paper tape)	User's choice
Punch	on
Skip/Print Constants	Print (on)
Frame Count Advance	6

11. Repeat steps 4 through 10 for each film.

12. Change registers seven, film number, and eleven, flash number, when the film is changed.

13. After the particles are read for all flashes, sort the cards out by "reading the holes" in columns 77 through 80, and remove only the card for each particle that has punched holes for a "+" character over column 76. This will be the sixth (last) card for the particle.

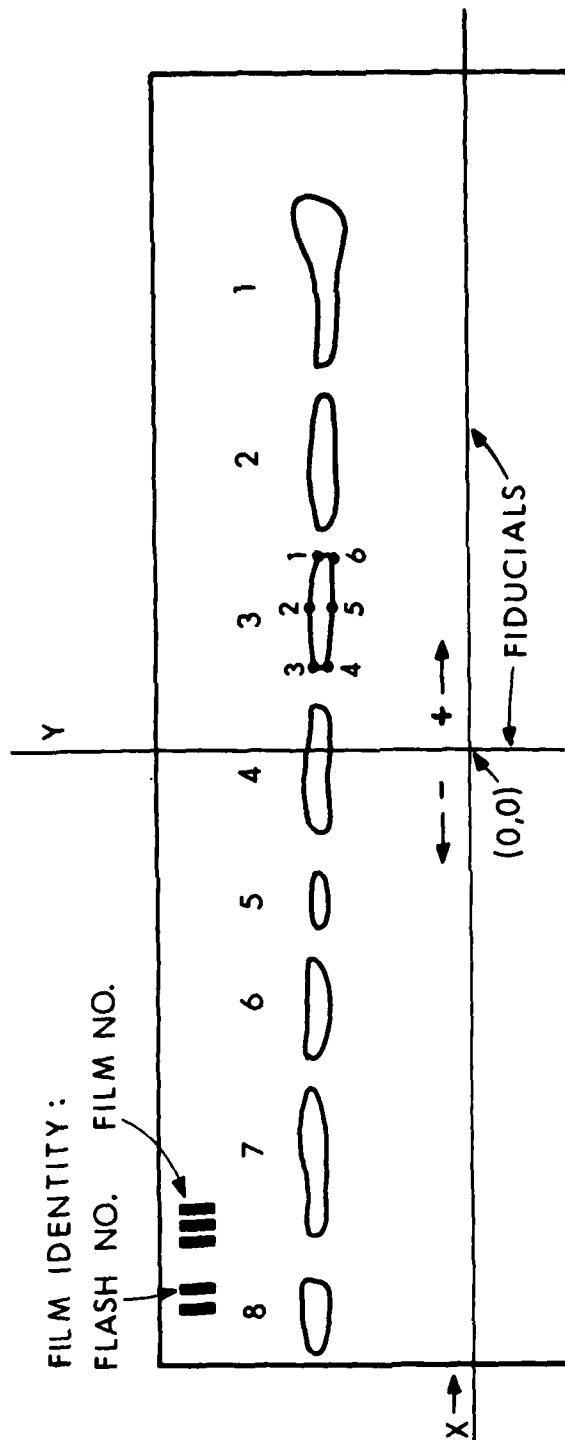


Figure A-1. Typical Radiograph of a Shaped-Charge Jet Mounted on Film Reading Device and Showing the Sequence for Reading a Particle

APPENDIX B
INPUT TO THE PROGRAM

Card 1:

Columns 1-5: ICASES - Number of rounds to be run.

6-10: LCL - Option for printing out the shaped-charge liner density. Enter 1 if print out is not desired. Otherwise, leave blank.

Card 2: Case Identifier and some constants.

Columns 1-5: NROUND - Round Number
6-10: NPART - Number of jet particles
11-15: NFLASH - Number of flashes
16-20: RHO - Shaped-charge liner density
21-30: XMAG1 - Magnification factor for first flash
31-40: XMAG2 - Magnification factor for second flash
41-50: XMAG3 - Magnification factor for third flash
51-60: Flash 1 - Delay time for first flash
61-70: Flash 2 - Delay time for second flash
71-80: Flash 3 - Delay time for third flash.

Card 3: More constants.

Columns 1-10: FOCUS 1 - Distance from the shaped-charge liner base to the focal level of the first x-ray tube.
11-20: FOCUS 2 - Distance from the shaped-charge liner base to the focal level of the second x-ray tube.
21-30: FOCUS 3 - Distance from the shaped-charge liner base to the focal level of the third x-ray tube.
31-40: F1A } Distances of film "y" fiducials to the
41-50: F2A } focal level of Flash A. Digit is film
51-60: F3A } number and letter (A, B or C) is flash.
61-70: F4A } This also applies for Card 4 constants.

Card 4: More constants for fiducial measurements.

Columns 1-10: F1B
11-20: F2B
21-30: F3B
31-40: F4B
41-50: F1C
51-60: F2C
61-70: F3C
71-80: F4C

Card 5: First particle card. All particle cards are identical in format. x and y coordinates are data units/inch in integer form.

Columns 1-5: IX(1) - x coordinate of p_1
6-10: IY(1) - y coordinate of p_1
11-15: IX(2) - x coordinate of p_2
16-20: IY(2) - y coordinate of p_2
21-25: IX(3) - x coordinate of p_3
26-30: IY(3) - y coordinate of p_3
31-35: IX(4) - x coordinate of p_4
36-40: IY(4) - y coordinate of p_4
41-45: IX(5) - x coordinate of p_5
46-50: IY(5) - y coordinate of p_5
51-55: IX(6) - x coordinate of p_6
56-60: IY(6) - y coordinate of p_6

65: L - Flash number (1,2 or 3)

70: IFILM - Film number

71-75: IROUND - Round number

77-80: IPART - Particle number

APPENDIX C
PROGRAM LISTING

The program is written in FORTRAN IV and is currently on file in the BRL Control Data Corporation's CYBER 170/7600 system.

1	PROGRAM MAIN(INPUT,OUTPUT,TAPES=INPUT,TAPE=OUTPUT)	MAIN	2
	DIMENSION S1(100),S2(100),S3(100),VOL(100),XL(100),DIA(100),	MAIN	3
	IV1(100),V2(100),V3(100),VEL(100),XMASS(100),XKE(100),SUMKE(100),	MAIN	4
	2FLOC(100),XXL(100),SUML(100),IX(6),IY(6),ZX(6),ZY(6),	MAIN	5
5	3HPEAK(100),SUMHAS(100),B(10000),DA(3),DB(3),XMAG(3)	MAIN	6
	DIMENSION AA(2,3),CC(2),PR(500),AF(500),SIG(2),TY(2)	COFMA	1
	DIMENSION SA(10),SB(10),SC(10),SD(10),SE(10),SF(10),SL1(10),	MAIN	7
	1SL2(10),SL3(10),ST(10),L1(100),L2(100),L3(100)	MAIN	8
	DIMENSION P(100),TOTP(100),SUMDIA(100),SUMLEN(100),XDIA(100),DELV(	MAIN	9
10	100),SDELV(100),SUMDEL(100)	MAIN	10
	DIMENSION XVOL(3,100)	MAIN	11
	DIMENSION AZ(100,100)	COFMA	1
	DATA SA(1),SA(2),SA(3)/10HVELOCITY (,10MM/MICROSEC,3MC)/	MAIN	12
	DATA SB(1),SB(2),SB(3)/10HCUMULATIVE,10H MASS (GRA,4HMS)/	MAIN	13
15	DATA SC(1),SC(2),SC(3),SC(4)/10HPOSITION A,10HLONG JET L,10HLENGTH	MAIN	14
	1(MM),1H)/	MAIN	15
	DATA SD(1),SD(2),SD(3)/10HCUMULATIVE,10H R.E. (JCH,5HLES)/	MAIN	16
	DATA SE(1),SE(2),SE(3),SE(4)/10HDISTANCE P,10HROM CHARGE,10H BASE	MAIN	17
	1(MM),1H)/	MAIN	18
20	DATA SF(1),SF(2),SF(3)/10HWEAK-UP T,10HIME (MICRO,5HSEC)/	MAIN	19
	DATA SL1(1)/8HFLASH 1)/	MAIN	20
	DATA SL2(1)/8HFLASH 2)/	MAIN	21
	DATA SL3(1)/8HFLASH 3)/	MAIN	22
24	1 FORMAT(3I5,F5,2,6F10,5)	MAIN	23
	2 FORMAT(7F10,5)	MAIN	24
	6 FORMAT(6F10,5)	MAIN	25
	21 FORMAT(2I5)	MAIN	26
	30 FORMAT(12I5,2X,11,2X,3I5)	MAIN	27
	HEAD(5,21) ICASES,LCL	MAIN	28
30	IF(EOF(5)) 23,23	MAIN	29
	23 DO 500 IJ=1,ICASF5	MAIN	30
	22 READ(5,1)NFOUND,NPAHT,NFLASH,RHO,(XMAG(I),I=1,3),FLASH1,FLASH2,	MAIN	31
	1FLASH3	MAIN	32
	IF(EOF(5)) 24,24	MAIN	33
35	24 ENCODE(21,20,ST(1)) NROUND	MAIN	34
	20 FORMAT(10HROUND NUMB,4MER ,15,2H)	MAIN	35
	HEAD(5,2) FOCUS1,FOCUS2,FOCUS3,F1A,F2A,F3A,F4A	MAIN	36
	IF(EOF(5)) 25,25	MAIN	37
	25 READ(5,6) F1B,F2B,F3B,F4B,F1C,F2C,F3C,F4C	MAIN	38
40	IF(EOF(5)) 26,26	MAIN	39
	26 RORRHO	MAIN	40
	IF(LCL,NE,1) GO TO 29	MAIN	41
	RHO=0.	MAIN	42
		MAIN	43
45	C	MAIN	44
	C	MAIN	45
	ROUND INFORMATION CARD NEXT	MAIN	46
	24 PRINT 5	MAIN	47
	WRITE 3, NROUND,RHO,(XMAG(N),N=1,3),FOCUS1,FOCUS2,FOCUS3,FLASH1,FL	MAIN	48
	1ASH2,FLASH3	MAIN	49
50	3 FORMAT(////,20X,'ROUND NUMBER ',15,/,20X,'LINE DENSITY (GM/CC)-	MAIN	50
	1 ',F6,1,/,20X,'MAGNIFICATION FACTOR=',3F9,5,/,20X,'DISTANCE FROM L	MAIN	51
	21H BASE TO FOCAL POINT(MM)',/,25X,'FLASH 1= ',F6,1,/,25X,'FLASH	MAIN	52
	32= ',F6,1,/,25X,'FLASH 3= ',F6,1,/,20X,'DELAY TIMES (MICROSEC)',/,	MAIN	53
	425X,'FLASH 1= ',F6,1,/,25X,'FLASH 2= ',F6,1,/,25X,'FLASH 3= ',F6,1	MAIN	54
	4)	MAIN	55
55	RHO=FO	MAIN	56
	PRINT 5	MAIN	57
	5 FORMAT(1H1:	MAIN	58

	PRINT *	MAIN	57
	4 FORMAT(21X,'PARTICLE AVG. VELOCITY TOTAL JET BREAK-UP',/,2	CORRA	58
60	12X,'NUMBER',/,2X,'(MM/MICROSEC)',/,3X,'LENGTH(MM)',/,3X,'(MICROSEC)',/,)	CORRA	59
	P1=3.14159	MAIN	60
	00 150 I=1,NFLASH	MAIN	61
	00 149 J=1,NPANT	MAIN	62
65	READ(5,30) (IX(K),IY(K),K=1,6),L,IFILM,IROUND,IPANT	MAIN	63
	IF(EGF(5)) 32,32	MAIN	64
	32 DO 35 M=1,6	MAIN	65
	ZX(M)=FLOAT(IX(M))/15.5906	MAIN	66
	35 ZY(M)=FLOAT(IY(M))/15.5906	MAIN	67
	IF(ZX(1).EQ.ZX(2)) GO TO 40	MAIN	68
70	R1=.5*SQRT((ZX(1)-ZX(4))**2+(ZY(1)-ZY(6))**2)*XMAG(I)	MAIN	69
	R2=.5*SQRT((ZX(2)-ZX(5))**2+(ZY(2)-ZY(5))**2)*XMAG(I)	MAIN	70
	R3=.5*SQRT((ZX(3)-ZX(4))**2+(ZY(3)-ZY(4))**2)*XMAG(I)	MAIN	71
	P1X=(ZX(1)+ZX(4))/2.	MAIN	72
75	P1Y=(ZY(1)+ZY(4))/2.	MAIN	73
	P2X=(ZX(3)+ZX(4))/2.	MAIN	74
	P2Y=(ZY(3)+ZY(4))/2.	MAIN	75
	P3X=(ZX(2)+ZX(5))/2.	MAIN	76
	AZ(I,J)=(ZY(2)+ZY(5))/2.	CORRA	77
	P3Y=(ZY(2)+ZY(5))/2.	MAIN	78
80	XM1=SQRT((P1X-P3X)**2+(P1Y-P3Y)**2)*XMAG(I)	MAIN	79
	XM2=SQRT((P3X-P2X)**2+(P3Y-P2Y)**2)*XMAG(I)	MAIN	80
	P1Z=P1X	MAIN	81
	P1X=P2X	MAIN	82
85	GO TO 45	MAIN	83
	40 P1X=ZX(1)	MAIN	84
	45 IF(L.EQ.2) GO TO 55	MAIN	85
	IF(L.EQ.3) GO TO 65	MAIN	86
	IF(IFILM.EQ.2) GO TO 47	MAIN	87
	IF(IFILM.EQ.3) GO TO 48	MAIN	88
90	IF(IFILM.EQ.4) GO TO 49	MAIN	89
	S1(J)=FOCUS1-(F1A-P1X)*XMAG(I)	MAIN	90
	GO TO 15	MAIN	91
	47 S1(J)=FOCUS1-(F2A-P1X)*XMAG(I)	MAIN	92
	GO TO 15	MAIN	93
95	48 S1(J)=FOCUS1-(F3A-P1X)*XMAG(I)	MAIN	94
	GO TO 15	MAIN	95
	49 S1(J)=FOCUS1-(F4A-P1X)*XMAG(I)	MAIN	96
	15 IF(ZX(1).EQ.ZX(2)) GO TO 50	MAIN	97
100	L1(J)=0	MAIN	98
	GO TO 75	MAIN	99
	50 L1(J)=1	MAIN	100
	GO TO 40	MAIN	101
	55 IF(IFILM.EQ.2) GO TO 57	MAIN	102
	IF(IFILM.EQ.3) GO TO 58	MAIN	103
105	IF(IFILM.EQ.4) GO TO 59	MAIN	104
	S2(J)=FOCUS2-(F1B-P1X)*XMAG(I)	MAIN	105
	GO TO 16	MAIN	106
	57 S2(J)=FOCUS2-(F2B-P1X)*XMAG(I)	MAIN	107
	GO TO 16	MAIN	108
110	58 S2(J)=FOCUS2-(F3B-P1X)*XMAG(I)	MAIN	109
	GO TO 16	MAIN	110
	59 S2(J)=FOCUS2-(F4B-P1X)*XMAG(I)	MAIN	111
	16 V1(J)=(S2(J)-S1(J))/(FLASH2-FLASH1)	MAIN	112
	IF(ZX(1).EQ.ZX(2)) GO TO 60	MAIN	

115	L2(J)=0	MAIN	113
	GOTO 75	MAIN	114
	60 L2(J)=1	MAIN	115
	GOTO 80	MAIN	116
	65 IF (NFLASH.EQ.2) GOTO 80	MAIN	117
120	IF (IFILM.EQ.2) GO TO 67	MAIN	118
	IF (IFILM.EQ.3) GO TO 68	MAIN	119
	IF (IFILM.EQ.4) GO TO 69	MAIN	120
	S3(J)=FOCUS3-(F1C-P1X)*XMAG(I)	MAIN	121
	GO TO 17	MAIN	122
125	67 S3(J)=FOCUS3-(F2C-P1X)*XMAG(I)	MAIN	123
	GO TO 17	MAIN	124
	68 S3(J)=FOCUS3-(F3C-P1X)*XMAG(I)	MAIN	125
	GO TO 17	MAIN	126
	69 S3(J)=FOCUS3-(F4C-P1X)*XMAG(I)	MAIN	127
130	17 V2(J)=(S3(J)-S2(J))/(FLASH3-FLASH2)	MAIN	128
	V3(J)=(S3(J)-S1(J))/(FLASH3-FLASH1)	MAIN	129
	IF (ZX(1).EQ.ZX(2)) GO TO 70	MAIN	130
	L3(J)=0	MAIN	131
	GOTO 75	MAIN	132
135	70 L3(J)=1	MAIN	133
	GOTO 80	MAIN	134
	75 VOL(J)=VOL(J)+(PI*XM1/3.*(M1**2*R1*R2+P2**2)+PI*XM2/3.*(M2**2+M2*	MAIN	135
	R3+R3**2))	MAIN	136
	M1=PI*Z	MAIN	137
140	XVOL(I,J)=PI*XM1/3.*(R1**2+R1*R2+R2**2)+PI*XM2/3.*(M2**2+M2*R3	MAIN	138
	+R3**2)	MAIN	139
	XVOL(I,J)=XVOL(I,J)*.001*RH0	MAIN	140
	XL(J)=XL(J)+SQRT((P1X-P2X)**2+(P1Y-P2Y)**2)*XMAG(I)	MAIN	141
	OIA(J)=OIA(J)+2.*R2	MAIN	142
145	80 CONTINUE	MAIN	143
	IF (I.LT.NFLASH) GOTO 149	MAIN	144
	IF (NFLASH.EQ.2) GOTO 85	MAIN	145
	IF (L1(J).EQ.1.AND.L2(J).EQ.1.AND.L3(J).EQ.1) GO TO 149	MAIN	146
	IF (L1(J).EQ.0.AND.L2(J).EQ.0.AND.L3(J).EQ.0) GO TO 90	MAIN	147
150	IF (L2(J).EQ.1.AND.L3(J).EQ.1) GO TO 95	MAIN	148
	IF (L1(J).EQ.1.AND.L3(J).EQ.1) GO TO 95	MAIN	149
	IF (L1(J).EQ.0.AND.L2(J).EQ.1) GO TO 95	MAIN	150
	IF (L2(J).EQ.0.AND.L3(J).EQ.0) GO TO 100	MAIN	151
	IF (L1(J).EQ.0.AND.L3(J).EQ.0) GO TO 100	MAIN	152
155	IF (L1(J).EQ.0.AND.L2(J).EQ.0) GO TO 100	MAIN	153
	IF (L1(J).EQ.1.AND.L2(J).EQ.1) GO TO 149	MAIN	154
	IF (L1(J).EQ.0.AND.L2(J).EQ.0) GO TO 100	MAIN	155
	IF (L1(J).EQ.0.AND.L2(J).EQ.0) GO TO 95	MAIN	156
160	90 XMASS(J)=VOL(J)*.001/3.*RH0	MAIN	157
	XL(J)=XL(J)/3.	MAIN	158
	OIA(J)=OIA(J)/3.	MAIN	159
	GOTO 149	MAIN	160
	95 XMASS(J)=VOL(J)*.001*RH0	MAIN	161
	GOTO 149	MAIN	162
165	130 XMASS(J)=VOL(J)*.001/2.*RH0	MAIN	163
	XL(J)=XL(J)/2.	MAIN	164
	OIA(J)=OIA(J)/2.	MAIN	165
170	149 CONTINUE	MAIN	166
	150 CONTINUE	MAIN	167
	GO 170 N=1,NPAHT	MAIN	168
	IF (NFLASH.EQ.2) GOTO 155	MAIN	169

	VEL(N)=(V1(N)+V2(N)+V3(N))/3*.1	MAIN	170
	GOTO 160	MAIN	171
175	155 VFL(N)=V1(N)*.1	MAIN	172
	160 SUML(N)=XL(N)+SUML(N-1)	MAIN	173
	SUMMAS(N)=XMASS(N)+SUMMAS(N-1)	MAIN	174
	ELOD(N)=XL(N)/DIA(N)	MAIN	175
	VEL(N)=VEL(N)*10.	MAIN	176
180	XKE(N)=.5*XMASS(N)*.001*(VEL(N)*1000.)*.2	MAIN	177
	SUMKE(N)=XKE(N)+SUMKE(N-1)	MAIN	178
	P(N)=VEL(N)*XMASS(N)	MAIN	179
	TOTF(N)=P(N)+TOTF(N-1)	MAIN	180
	SUMDIA(N)=SUMDIA(N-1)+DIA(N)	MAIN	181
185	IF(N.EQ.1)GOTO 165	MAIN	182
	HREAK(N)=SUML(N)/(VEL(1)-VEL(N))	MAIN	183
	GOTO 170	MAIN	184
	165 HREAK(1)=0.0	MAIN	185
	170 PRINT 171, N, VEL(N), SUML(N), HREAK(N)	MAIN	186
190	171 FORMAT(23X, I2, 10X, F6.3, 9X, F6.2, 7X, F6.1)	CORWA	4
	PRINT 52	MAIN	188
	52 FORMAT(1M1, 20X, 'PARTICLE', 4X, 'VELOCITY1', 6X, 'VELOCITY2', 6X,	CORWA	5
	1, 'VELOCITY3', 6X, 'NUMBER', 3X, ' (MM/MICROSEC)', 2X, ' (MM/MICROSEC)',	CORWA	6
	22X, ' (MM/MICROSEC)', /)	CORWA	7
195	DO 172 J=1, NPART	MAIN	190
	172 PRINT 173, J, V1(J), V2(J), V3(J)	MAIN	191
	173 FORMAT(23X, I2, 9X, F6.3, 9X, F6.3, 9X, F6.3)	CORWA	8
	PRINT 175	MAIN	193
200	175 FORMAT(1M1, 20X, 'PARTICLE LENGTH DIA. L/D MASS TOTAL J	MAIN	194
	1ET', 22X, 'NUMBER', 5X, ' (MM)', 4X, ' (MM)', 9X, ' (GRAMS)', 2X, ' MASS (GRAMS	CORWA	9
	21, /)	CORWA	10
	DO 176 I=1, NPART	MAIN	197
	176 PRINT 177, I, XL(I), DIA(I), ELOD(I), AMASS(I), SUMMAS(I)	MAIN	198
	177 FORMAT(23X, I2, 8X, F4.1, 4X, F4.1, 2X, F4.1, 4X, F5.2, 5X, F4.2)	CORWA	11
	PRINT 603	MAIN	200
205	603 FORMAT(1M1, 20X, 'PARTICLE', 4X, 'MASS1', 9X, 'MASS2', 9X, 'MASS3', 6X, 'MASS4',	CORWA	12
	1, 'NUMBER', 4X, ' (GRAMS)', 7X, ' (GRAMS)', 7X, ' (GRAMS)', /)	CORWA	13
	DO 600 J=1, NPART	MAIN	202
	I=1	CORWA	14
210	600 PRINT 602, J, XVOL(I, J), XVOL(I+1, J), XVOL(I+2, J)	CORWA	15
	602 FORMAT(23X, I2, 6X, F8.4, 6X, F8.4, 6X, F8.4)	CORWA	16
	PRINT 180	MAIN	206
	180 FORMAT(1M1, 20X, 'PARTICLE K.E. TOTAL JET [DISTANCE FROM CM	MAIN	207
	LARGE BASE', 22X, 'NUMBER', 4X, ' (JCOULES)', 3X, 'KE (JCOULES)', 2X, 'FLASH	CORWA	17
215	21, 2X, 'FLASH 2', 2X, 'FLASH 3', /)	CORWA	18
	DO 181 I=1, NPART	MAIN	210
	181 PRINT 182, I, XKE(I), SUMKE(I), S1(I), S2(I), S3(I)	MAIN	211
	182 FORMAT(23X, I2, 7X, F8.0, 4X, F8.0, 4X, F5.0, 4X, F5.0, 4X, F5.0)	CORWA	19
	PRINT 183	MAIN	213
220	183 FORMAT(1M1, 20X, 'PARTICLE', 4X, 'MOMENTUM', 4X, 'TOTAL JET', 6X, 'NUMBER	CORWA	20
	1ET', 4X, ' (KG-M/SEC)', 3X, 'MOMENTUM', /)	CORWA	21
	DO 185 I=1, NPART	MAIN	216
	185 PRINT 186, I, P(I), TOTF(I)	MAIN	217
	186 FORMAT(23X, I2, 9X, F6.2, 7X, F6.2)	CORWA	22
	PRINT 33	CORWA	3
225	33 FORMAT(1M1, 21X, 'PARTICLE', 8X, 'DEVIANCE FROM PATH (MM)', 6X, 'FLASH 1	CORWA	4
	1, 'NUMBER', 6X, 'FLASH 2 FLASH 3', /)	CORWA	5
	DO 800 JUJ=1, NPART	CORWA	6
	WRITE (6, 36) JUJ, AZ(1, JUJ), AZ(2, JUJ), AZ(3, JUJ)	CORWA	7

230	36 FORMAT(24X,12.8X,F8.3,3X,F8.3,3X,F8.3)	CORWA	8
	400 CONTINUE	CORWA	9
	DO 192 N=2,NPART	MAIN	219
	SUMLEN(N)=SUMLEN(N-1)+XL(N)	MAIN	220
	XDIA(N)=XDIA(N-1)+DIA(N)	MAIN	221
	IF(N.EQ.2) GO TO 191	MAIN	222
235	DELV(N)=VEL(N-1)-VEL(N)	MAIN	223
	GO TO 192	MAIN	224
	191 DELV(N)=VEL(1)-VEL(N)	MAIN	225
	192 SDELV(N)=SDELV(N-1)+DELV(N)	MAIN	226
	DO 195 J=3,NPART	MAIN	227
240	195 SUMDEL(J)=DELV(J)+SUMDEL(J-1)	MAIN	228
	AVL1=SUMLEN(NPART)/FLOAT(NPART)	MAIN	229
	AVL2=SUMLEN(NPART)/FLOAT(NPART-1)	MAIN	230
	AVD1=SUMDIA(NPART)/FLOAT(NPART)	MAIN	231
	AVD2=XDIA(NPART)/FLOAT(NPART-1)	MAIN	232
245	ADELV1=SDELV(NPART)/FLOAT(NPART-1)	MAIN	233
	ADELV2=SUMDEL(NPART)/FLOAT(NPART-2)	MAIN	234
	PRINT 200, AVL1,AVL2,AVD1,AVD2,ADELV1,ADELV2	MAIN	235
	200 FORMAT(1H1,////,47X,'WITH JET TIP #/O TIP',/,20X,'AVERAGE PART	MAIN	236
	ICLE LENGTH',7X,F6.2,7X,F6.2,/,20X,'AVERAGE PARTICLE DIAMETER',6A,	MAIN	237
250	2F5.2,8X,F5.2,/,20X,'AVERAGE CHANGE IN VELOCITY',6X,F4.2,9X,F4.2)	MAIN	238
	PRINT 505	MAIN	239
	NRA=2	CORWA	23
	NN=1	CORWA	24
	IC=0	CORWA	25
255	CALL POLYLS(VEL,S1,NPART,AA,NRA,NN,CC,HR,AF,ERMS,SIG,TT,DET,IC)	CORWA	26
	WRITE(6,41) CC(1)	CORWA	27
	41 FORMAT(20X,' VIRTUAL ORIGIN FOR FLASH 1',F12.6)	CORWA	28
	CALL POLYLS(VEL,S2,NPART,AA,NRA,NN,CC,HR,AF,ERMS,SIG,TT,DET,IC)	CORWA	29
	WRITE(6,42) CC(1)	CORWA	30
260	42 FORMAT(20X,' VIRTUAL ORIGIN FOR FLASH 2',F12.6)	CORWA	31
	IF(L.LT.3) GO TO 515	CORWA	32
	CALL POLYLS(VEL,S3,NPART,AA,NRA,NN,CC,HR,AF,ERMS,SIG,TT,DET,IC)	CORWA	33
	WRITE(6,43) CC(1)	CORWA	34
	43 FORMAT(20X,' VIRTUAL ORIGIN FOR FLASH 3',F12.6)	CORWA	35
265	515 CONTINUE	CORWA	36
	505 FORMAT(1H1)	MAIN	240
	DO 510 JN= 1,NPART	MAIN	241
	VEL(JN)=0.	MAIN	242
	XL(JN)=0.	MAIN	243
270	510 DIA(JN)=0.	MAIN	244
	500 CONTINUE	MAIN	245
	STOP	MAIN	246
	END	MAIN	247

APPENDIX D
ALPHABETICAL LISTING OF PROGRAM VARIABLE NAMES

ADELV1: Average change in velocity between particles.
 ADELV2: Average change in velocity between particles, excluding the jet tip.
 AVD1: Average diameter of all particles.
 AVD2: Average diameter of particles, excluding the jet tip.
 BREAK: Break-up time.
 DELVA: Change in velocity between particles.
 DIA: Diameter of a particle.
 ELOD: Length-to-diameter ratio of a particle.
 L1, L2, L3: Flags for flashes 1, 2 and 3 used for determining the average length, diameter and mass of a particle.
 P: Momentum of a particle.
 P1X, P2X, P3X: Computed x coordinates of points between p_1 and p_6 , p_3 and p_4 , and p_2 and p_5 , respectively.
 P1Y, P2Y, P3Y: Computed y coordinates of points between p_1 and p_6 , p_3 and p_4 , and p_2 and p_5 , respectively.
 R1: Radius of the front end of a particle.
 R2: Radius of the mid-section of a particle.
 R3: Radius of the back end of a particle.
 S1: Computed distance from the shaped-charge liner base to the back end of a particle for the first flash.
 S2: Computed distance from the shaped-charge liner base to the back end of a particle for the second flash.
 S3: Computed distance from the shaped-charge liner base to the back end of a particle for the third flash.
 SDELV: Summation of the changes in velocities between particles, used in the calculation of average change in velocity.

SUMDEL: Summation of the changes in velocities between particles excluding the jet tip.

SUMDIA: Summation of the diameters of all particles, used to compute average diameter.

SUMKE: Summation of all particle kinetic energies.

SUML: Summation of the lengths of all particles.

SUMLEN: Summation of the lengths of particles excluding the jet tip.

SUMMAS: Summation of the masses of all particles.

TOTP: Summation of the momentums of all particles.

V1: Velocity computed between the first and second flashes.

V2: Velocity computed between the second and third flashes.

V3: Velocity computed between the first and third flashes.

VEL: Average velocity of V1, V2 and V3.

VOL: Summation of the volumes of a particle over all flashes.

XDIA: Summation of all particle diameters excluding the jet tip.

XH1: Height of the truncated cone on the front end of a particle.

XH2: Height of the truncated cone on the back end of a particle.

XKE: Kinetic energy of a particle.

XL: Length of a particle averaged over all flashes.

XMASS: Mass of a particle averaged over all flashes.

XVOL: Mass of a particle for a particular flash.

ZX: X coordinate converted from data units/inch to millimeters.

ZY: Y coordinates converted from data units/inch to millimeters.

APPENDIX E
OUTPUT FROM A SAMPLE RUN

ROUND NUMBER 2203

LINER DENSITY(GM/CC)- 8.9

MAGNIFICATION FACTOR- .92000 .92000 .92000

DISTANCE FROM LINER BASE TO FOCAL POINT(MM)

FLASH 1- 914.4

FLASH 2- 914.4

FLASH 3- 914.4

DELAY TIMES (MICROSEC)

FLASH 1- 161.9

FLASH 2- 183.1

FLASH 3- 202.9

PARTICLE NUMBER	AVG. VELOCITY (MM/MICROSEC)	TOTAL JET LENGTH(MM)	BREAK-UP (MICROSEC)
1	7.741	30.93	0.0
2	7.549	42.00	214.8
3	7.476	54.87	207.1
4	7.371	77.95	210.4
5	7.123	87.68	141.9
6	7.046	97.79	140.7
7	6.918	107.25	130.3
8	6.899	110.82	131.6
9	6.863	116.90	133.2
10	6.776	131.93	136.8
11	6.625	144.04	129.0
12	6.614	149.58	132.7
13	6.501	163.09	131.5
14	6.323	178.85	126.1
15	6.291	184.00	126.4
16	6.188	188.02	121.0
17	6.163	193.36	122.5
18	6.124	201.88	124.8
19	5.951	214.28	119.7
20	5.898	226.25	122.6
21	5.772	243.74	123.6
22	5.613	262.23	123.6
23	5.432	278.11	120.3
24	5.295	288.03	117.6
25	5.247	298.54	119.7
26	5.160	310.01	120.5
27	5.075	321.11	120.5
28	4.944	331.04	118.4
29	4.842	350.73	121.0
30	4.674	368.56	120.7
31	4.588	376.67	119.5
32	4.501	394.92	121.7
33	4.414	407.47	122.7
34	4.213	430.33	122.7
35	4.088	441.84	120.9
36	4.046	454.14	122.9
37	3.879	473.40	122.9
38	3.629	494.02	122.9
39	3.555	510.84	122.9
40	3.333	538.79	122.9
41	3.177	554.78	121.6
42	3.066	574.32	122.9
43	2.822	595.34	121.0

PARTICLE NUMBER	VELOCITY1 (MM/MICROSEC)	VELOCITY2 (MM/MICROSEC)	VELOCITY3 (MM/MICROSEC)
1	7.773	7.709	7.742
2	7.573	7.525	7.550
3	7.483	7.469	7.476
4	7.586	7.150	7.376
5	7.244	6.999	7.126
6	7.163	6.926	7.049
7	7.048	6.785	6.921
8	7.009	6.786	6.901
9	6.987	6.737	6.866
10	6.886	6.664	6.779
11	6.728	6.519	6.627
12	6.580	6.649	6.613
13	6.555	6.445	6.502
14	6.370	6.275	6.324
15	6.325	6.256	6.292
16	6.239	6.135	6.189
17	6.206	6.119	6.164
18	6.178	6.068	6.125
19	6.014	5.888	5.943
20	5.950	5.846	5.900
21	5.849	5.692	5.774
22	5.699	5.524	5.615
23	5.532	5.330	5.435
24	5.362	5.226	5.297
25	5.307	5.186	5.248
26	5.227	5.108	5.170
27	5.123	5.026	5.076
28	5.020	4.867	4.948
29	5.823	3.839	4.885
30	4.797	4.548	4.677
31	4.694	4.479	4.541
32	4.621	4.378	4.503
33	4.509	4.317	4.416
34	4.330	4.093	4.216
35	4.209	3.964	4.040
36	4.175	3.915	4.049
37	3.979	3.776	3.881
38	3.787	3.468	3.633
39	3.699	3.408	3.559
40	3.457	3.205	3.235
41	3.305	3.046	3.180
42	3.253	2.876	3.071
43	2.953	2.688	2.825

PARTICLE NUMBER	LENGTH (MM)	DIA. (MM)	L/D	MASS (GRAMS)	TOTAL JET MASS (GRAMS)
1	30.9	4.8	6.4	3.70	3.70
2	11.1	2.5	4.4	.29	3.99
3	12.9	2.9	4.5	.41	4.40
4	23.1	2.8	8.3	.73	5.14
5	9.7	2.9	3.4	.30	5.44
6	10.1	2.7	3.7	.31	5.75
7	9.5	2.3	4.1	.23	5.97
8	3.6	2.0	1.8	.07	6.04
9	6.1	2.4	2.6	.14	6.18
10	15.0	2.6	5.8	.48	6.66
11	12.1	2.4	5.0	.30	6.97
12	5.5	2.5	2.2	.15	7.12
13	13.5	2.9	4.7	.42	7.54
14	15.8	2.5	6.3	.43	7.97
15	5.1	2.2	2.3	.11	8.07
16	4.0	2.1	1.9	.07	8.14
17	5.3	2.5	2.1	.13	8.28
18	6.5	2.8	3.1	.25	8.52
19	12.4	2.8	4.4	.40	8.93
20	12.0	2.3	5.3	.27	9.19
21	17.5	2.3	7.7	.42	9.61
22	18.5	2.6	7.1	.50	10.10
23	15.9	2.6	6.0	.44	10.55
24	9.9	2.8	3.5	.31	10.86
25	10.5	2.7	3.9	.31	11.17
26	11.5	2.6	4.5	.31	11.48
27	11.1	3.0	3.7	.34	11.82
28	9.9	2.9	3.5	.32	12.20
29	19.7	2.9	6.9	.66	12.87
30	17.8	2.8	6.3	.65	13.42
31	8.1	2.9	2.8	.25	13.66
32	18.3	2.6	7.0	.51	14.17
33	12.5	3.1	4.0	.47	14.64
34	22.9	2.8	8.1	.73	15.37
35	11.5	2.9	4.0	.39	15.76
36	12.3	3.2	3.9	.46	16.22
37	19.3	3.0	6.4	.78	17.00
38	20.6	3.6	5.8	.96	17.96
39	16.8	3.0	5.6	.68	18.61
40	27.4	3.5	8.0	1.49	20.11
41	16.0	3.6	4.5	.73	20.84
42	19.5	4.0	4.9	1.10	21.94
43	21.0	3.9	5.3	1.24	23.18

PARTICLE NUMBER	MASS1 (GRAMS)	MASS2 (GRAMS)	MASS3 (GRAMS)
1	3.2790	3.7919	4.0380
2	.2431	.3145	.3044
3	.3305	.5462	.3644
4	.7037	0.0000	.7587
5	.2584	.3559	.2993
6	.2835	.3017	.3442
7	.1980	.2552	.2219
8	.0553	.0600	.0804
9	.1137	.1287	.1890
10	.4704	.4470	.5257
11	.2633	.3399	.3070
12	.1232	.1771	0.0000
13	.3949	.4784	.3792
14	.4385	.4003	.4510
15	.0947	.0979	.1233
16	.0725	.0615	.0746
17	.0923	.1691	.1431
18	.2072	.3005	.2321
19	.2944	.5067	.4109
20	.2320	.3066	.2623
21	.2949	.4622	.4899
22	.4570	.4864	.5437
23	.4447	.3612	.5205
24	.3100	.3123	.3067
25	.2868	.3094	.3429
26	.3022	.3063	.3340
27	.4153	.3907	.3757
28	.3499	.3318	.2924
29	.6938	0.0000	.6331
30	.6149	.5427	.4927
31	.3094	.1883	.2465
32	.7093	.3562	.4584
33	.4304	.5044	0.0000
34	.7279	.6439	.6305
35	.3945	.3630	.4038
36	.4736	.5001	.3942
37	.9466	.6912	.7134
38	1.2210	.9140	.7421
39	.5911	.4527	.9220
40	1.6889	1.5423	1.1957
41	.7484	.6758	.7803
42	1.2289	1.1217	.9580
43	1.3572	1.1849	1.1808

PARTICLE NUMBER	K.E. (JOULES)	TOTAL JET KE (JOULES)	DISTANCE FROM CHARGE BASE (MM)		
			FLASH 1	FLASH 2	FLASH 3
1	110950.	110950.	1005.	1170.	1323.
2	8188.	119138.	980.	1140.	1249.
3	11561.	130699.	964.	1123.	1271.
4	19862.	150560.	930.	1091.	1233.
5	7726.	158286.	915.	1069.	1207.
6	7690.	165976.	902.	1054.	1191.
7	5384.	171360.	888.	1038.	1172.
8	1552.	172912.	884.	1032.	1167.
9	3387.	176299.	876.	1025.	1158.
10	11045.	187345.	859.	1005.	1137.
11	6657.	194002.	841.	983.	1112.
12	3245.	197286.	831.	970.	1102.
13	8821.	206108.	816.	955.	1083.
14	8594.	214702.	794.	929.	1043.
15	2083.	216785.	788.	922.	1046.
16	1331.	218117.	782.	914.	1036.
17	2560.	220677.	776.	907.	1028.
18	4624.	225300.	766.	897.	1017.
19	7154.	232455.	744.	878.	993.
20	4644.	237099.	736.	862.	978.
21	6924.	244023.	715.	839.	952.
22	7807.	251830.	689.	810.	920.
23	6524.	258354.	669.	788.	892.
24	4341.	262695.	655.	768.	872.
25	4309.	267004.	645.	757.	860.
26	4196.	271200.	633.	743.	845.
27	5073.	276273.	621.	729.	829.
28	3969.	280242.	608.	714.	811.
29	7777.	288020.	587.	710.	788.
30	6009.	294029.	566.	688.	758.
31	2611.	296640.	557.	657.	746.
32	5145.	301784.	538.	636.	723.
33	4554.	306338.	523.	619.	704.
34	6515.	312853.	500.	602.	673.
35	3234.	316087.	488.	577.	655.
36	3733.	319820.	475.	562.	641.
37	5895.	325715.	452.	537.	611.
38	6315.	332030.	425.	508.	574.
39	4141.	336172.	409.	487.	555.
40	8287.	344459.	381.	454.	518.
41	3709.	348167.	366.	438.	498.
42	5182.	353344.	345.	414.	471.
43	4942.	358292.	323.	388.	435.

PARTICLE NUMBER	MOMENTUM (KG-M/SEC)	TOTAL JET MOMENTUM
1	28.67	28.67
2	2.17	30.83
3	3.09	33.93
4	5.39	39.32
5	2.17	41.49
6	2.18	43.67
7	1.56	45.23
8	.45	45.68
9	.99	46.66
10	3.26	49.92
11	2.01	51.93
12	.99	52.92
13	2.71	55.64
14	2.72	58.36
15	.66	59.02
16	.43	59.45
17	.83	60.28
18	1.51	61.79
19	2.40	64.20
20	1.57	65.77
21	2.40	68.17
22	2.78	70.95
23	2.40	73.35
24	1.64	74.99
25	1.64	76.64
26	1.62	78.26
27	2.00	80.26
28	1.61	81.86
29	3.21	85.08
30	2.57	87.65
31	1.14	88.79
32	2.29	91.07
33	2.06	93.13
34	3.04	96.23
35	1.58	97.81
36	1.84	99.65
37	3.04	102.69
38	3.48	106.17
39	2.33	108.50
40	4.97	113.48
41	2.33	115.81
42	3.38	119.19
43	3.50	122.69

	WITH JET TIP	W/O TIP
AVERAGE PARTICLE LENGTH (mm)	13.85	13.44
AVERAGE PARTICLE DIAMETER (mm)	2.84	2.79
AVERAGE CHANGE IN VELOCITY (mm/μsec)	0.12	0.12

VIRTUAL ORIGIN FOR FLASH 1= -85.114956 MM
VIRTUAL ORIGIN FOR FLASH 2= -81.133748 MM
VIRTUAL ORIGIN FOR FLASH 3= -85.896955 MM

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
12	Commander Defense Technical Info Center ATTN: DDC-DDA Cameron Station Alexandria, VA 22314	1	Commander US Army Communications Rsch and Development Command ATTN: DRDCO-PPA-SA Fort Monmouth, NJ 07703
1	Commander US Army Materiel Development and Readiness Command ATTN: DRCDMD-ST 5001 Eisenhower Avenue Alexandria, VA 22333	1	Commander US Army Electronics Research and Development Command Technical Support Activity ATTN: DELSD-L Fort Monmouth, NJ 07703
2	Commander US Army Armament Research and Development Command ATTN: DRDAR-TSS (2 cys) Dover, NJ 07801	2	Commander US Army Missile Command ATTN: DRSMI-R DRSMI-YDL Redstone Arsenal, AL 35809
1	Commander US Army Armament Materiel Readiness Command ATTN: DRSAR-LEP-L, Tech Lib Rock Island, IL 61299	1	Commander US Army Tank Automotive Rsch and Development Command ATTN: DRDTA-UL Warren, MI 48090
1	Director US Army ARRADCOM Benet Weapons Laboratory ATTN: DRDAR-LCB-TL Watervliet, NY 12189	1	Director US Army TRADOC Systems Analysis Activity ATTN: ATAA-SL, Tech Lib White Sands Missile Range NM 88002
1	Commander US Army Aviation Research and Development Command ATTN: DRSAV-E P. O. Box 209 St. Louis, MO 61366	1	AFELM, The Rand Corporation ATTN: Library-D 1700 Main Street Santa Monica, CA 90406
1	Director US Army Air Mobility Research and Development Laboratory Ames Research Center Moffett Field, CA 94035	<u>Aberdeen Proving Ground</u> Dir, USAMSAA ATTN: DRXSY-D DRXSY-MP, H. Cohen Cdr, USATECOM ATTN: DRSTE-TO-F Dir, USA CSL Bldg. E3516, EA ATTN: DRDAR-CLB-PA	

USER EVALUATION OF REPORT

Please take a few minutes to answer the questions below; tear out this sheet, fold as indicated, staple or tape closed, and place in the mail. Your comments will provide us with information for improving future reports.

1. BRL Report Number _____

2. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

3. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.) _____

4. Has the information in this report led to any quantitative savings as far as man-hours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

5. General Comments (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.) _____

6. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name: _____

Telephone Number: _____

Organization Address: _____

----- FOLD HERE -----

Director
US Army Ballistic Research Laboratory
Aberdeen Proving Ground, MD 21005

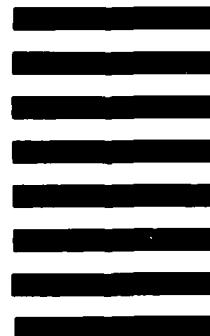


NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, \$300

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO 12062 WASHINGTON, DC
POSTAGE WILL BE PAID BY DEPARTMENT OF THE ARMY

Director
US Army Ballistic Research Laboratory
ATTN: DRDAR-TSB
Aberdeen Proving Ground, MD 21005



----- FOLD HERE -----