AD-A202 409

BRL-MR-3726

MEMORANDUM REPORT BRL-MR-3726

BRL

1938 – Serving the Army for Fifty Years – 1988

ANALYSIS OF SHOCKS BY NUMERICAL SOLUTION OF DUHAMEL'S INTEGRAL

CALEDONIA L. HENRY

CEMBER 1988

APPROVED FOR [illegible] EASE; DISTRIBUTION UNLIMITED.

U.S. AR[illegible]ORATORY COMMAND

BALLISTIC [illegible]SEARCH LABORATORY

ABERDEEN P[illegible]G GROUND, MARYLAND

DESTRUCTION NOTICE

Destroy this report when it is no longer needed. DO NOT return it to the originator.

Additional copies of this report may be obtained from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22151.

The findings of 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 indorsement of any commercial product.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) BRL-MR-3726	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USA Ballistic Research Laboratory	6b. OFFICE SYMBOL *(If applicable)* SLCBR-IB
7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS *(City, State, and ZIP Code)* Aberdeen Proving Ground, MD 21005-5066	7b. ADDRESS *(City, State, and ZIP Code)*
8a. NAME OF FUNDING / SPONSORING ORGANIZATION	8b. OFFICE SYMBOL *(If applicable)*
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS *(City, State, and ZIP Code)*	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
1L1621618	AH80		

11. TITLE *(Include Security Classification)*

Analysis of Shocks By Numerical Solution of Duhamel's Integral

12. PERSONAL AUTHOR(S)

Caledonia L. Henry

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(Year, Month, Day)*	15. PAGE COUNT
MR	FROM 10/85 TO 09/87		

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
FIELD	GROUP	SUB-GROUP	
13	06		

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

The Duhamel's integral computer code was developed to analytically test instrumentation and structures for survivability and reliability in gun launch environments and to assess the damage to the human ear due to non-classical pressure pulses and to determine the shock survivability of proposed structural designs. The shock spectra determined from Duhamel's integral for the test and environmental pulses forms a basis for comparison of the severity of the environment. The program has been installed on several machines, including mainframe computers, mini-computers and microcomputers in both BASIC and FORTRAN languages.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Caledonia L. Henry	22b. TELEPHONE *(Include Area Code)* (301) 278-6127 — 22c. OFFICE SYMBOL SLCBR-IB-W

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS
(cont.)

I. INTRODUCTION

Some of the ongoing concerns of the Weapon Dynamics and Accuracy Branch (WDAB) of the Interior Ballistics Division (IBD) of the Ballistic Research Laboratory (BRL) are

(1) To realistically test instrumentation and structures for survivability and reliability in gun launch environments,

(2) To assess the damage to the human ear due to nonclassical pressure pulses such as those generated by multiple sources in confined volumes,

(3) To establish economic screening and quality assurance procedures for shock testing production items and

(4) To assess the shock survivability of proposed structural designs.

Two approaches that can be made to these problems are

(1) To empirically duplicate exactly the shock environment by duplicating the pulse shape, force amplitude and time duration and

(2) To empirically duplicate the severity of the environment by dissimilar pulses whose severity has been analytically determined to be relatively the same in the frequency response regime of the test item.

The latter method has been used successfully by scientists at BRL since the late sixties for various projects. This technique is dependent on the ability to determine the shock spectra from Duhamel's integral for the test and environmental pulses, thus forming a basis for comparison of severity. The main advantage of the approach is that it permits greater latitude in test facilities and provides a means of comparing different testing systems. It also provides the designer with information concerning the severity of the environment and its effect upon the structure's components.

Justification for the method is proven by consideration of several aspects of the behavior of structures. First, all structural systems are complex oscillators and they have responses in specific frequency regimes unique to the particular systems. Therefore, tests to determine survivability need only reflect the energy and momentum existing in the frequency regimes of interest.

Secondly, the relative response of the structure is deterministic and repeatable for any given pulse shape.

Thirdly, the response of the structure can be described by two spectra: the first being the primary spectrum showing the forced vibration response during the time duration of the pulse; the second being the residual spectrum showing the free vibration response after the pulse.

II. BASIC EQUATION FOR DUHAMEL'S INTEGRAL

The spectra are obtained by calculating the response of systems with discrete frequencies using the Duhamel integral over a time period three times the pulse duration. The integral in the form used is shown in Eq. (1).

$$A_r = \left[x_0 \omega_n^2 - \frac{1}{\omega_n} \int_0^s A(t_v) \sin(\omega_n t_v)\, dt_v \right] \cos(\omega_n s)$$

$$+ \left[\dot{x}_0 \omega_n + \frac{1}{\omega_n} \int_0^s A(t_v) \cos(\omega_n t_v)\, dt_v \right] \sin(\omega_n s) \tag{1}$$

where A_r = response acceleration

x_0 = initial displacement of the system

$\dot{x}_0$ = initial velocity of the system

ω_n = natural frequency of the system

$A(t_v)$ = instantaneous acceleration of the pulse at time t_v

t_v = time of observation

s = period of the system of frequency ω_n.

A numerical approach was necessary because the parameter that describes the motion ($A(t_v)$) is generally an unknown function that is approximated by a set of ordered pairs taken from a digitized set of experimental firing data.

If we assume that the pulse starts with zero displacement and velocity, then Eq. (1) can be simplified to that shown in Eq. (2).

$$A_r = \frac{\sin(\omega_n s)}{\omega_n} \int_0^s A(t_v) \cos(\omega_n t_v)\, dt_v - \frac{\cos(\omega_n s)}{\omega_n} \int_0^s A(t_v) \sin(\omega_n t_v)\, dt_v \tag{2}$$

Since the sum of the integral equals the integral of the sum, Eq. (2) can be expanded so that we do not integrate from zero for each point of the time history. The natural frequency ω_n of the system in Eq. (3) is replaced by the damped frequency ω_δ. This damped frequency is calculated by multiplying the natural frequency by $\sqrt{1-\delta^2}$, where δ is the damping factor. The expanded Eq. (2) with the damped frequency is shown in Eq. (3).

$$A_{r_{s+1}} = \frac{1}{\omega_\delta} \left[sin\,(\omega_{\delta_{i+1}}) \left\{ \int_{s_0}^{s_i} A\,(t_v)\, cos\,(\omega_\delta\, t_v)\, dt_v + \int_{s_i}^{s_{i+1}} A\,(t_v) \cos(\omega_\delta\, t_v)\, dt_v \right\} \right.$$

$$\left. - \cos(\omega_{\delta_{i+1}}) \left\{ \int_{s_0}^{s_i} A\,(t_v) \sin(\omega_\delta\, t_v)\, dt_v + \int_{s_i}^{s_{i+1}} A\,(t_v) \sin(\omega_\delta\, t_v)\, dt_v \right\} \right] \quad (3)$$

Because it is not necessary to integrate from zero for each point of time history, Eq. (3) provides considerable savings in central processing unit (cpu) time. Hence, Eq. (3) was used in the program instead of Eq. (2). This equation produces the primary system response for a given frequency.

A damping coefficient, which takes into account the viscous loss due to velocity in the system, has been incorporated into Eq. (3). This coefficient was determined from Eq. (4).

$$Damp_p = e^{(-\delta\omega_n s)} \quad (4)$$

where $Damp_p$ = damping coefficient for primary system response

δ = damping factor

ω_n = natural frequency of the system

s = period of the system of frequency ω_n.

The residual system response is obtained analytically from Eq. (5).

$$R_t = Ar_z\, cos\,(\omega_\delta(t - z)) + A\,'r_z\, \sin(\omega_\delta(t - z)) \quad (5)$$

where R_t = residual response acceleration at time z

Ar_z = response acceleration at time z

$A\,'r_z$ = response velocity at time z

t = time after pulse ends

ω_δ = damped frequency of the system

z = pulse duration.

As in the primary system response, the natural frequency in Eq. (5) has been replaced by a damped frequency. Eq. (6) shows the resulting formulation.

$$R'_t = Ar_z\, e^{(-\delta\omega_\delta(t-z))} \cos(\omega_\delta(t-z)) + \frac{A'r_z\, e^{(-\delta\omega_\delta(t-z))}}{\omega_\delta} \sin(\omega_\delta(t-z)) \tag{6}$$

Where the definitions of all variables are the same as those previously listed in Eqs. (4) and (5).

III. THE COMPUTER PROGRAM

The BRL mainframe computer during the past few years has been a Control Data Corporation (CDC) CYBER 7600(MFZ). The two front-end machines were a CYBER 750(MFA) and an 825(MFB). Two new BRL supercomputers, the CRAY XMP/48 and the CRAY 2 have been installed at the BRL site. There are various minicomputers and microcomputers within the divisions of BRL. The IBD has several Hewlett-Packard (HP) microcomputers, namely the HP9845C, the HP9836C and the HP9000. Also, within the IBD is an HP1000F minicomputer.

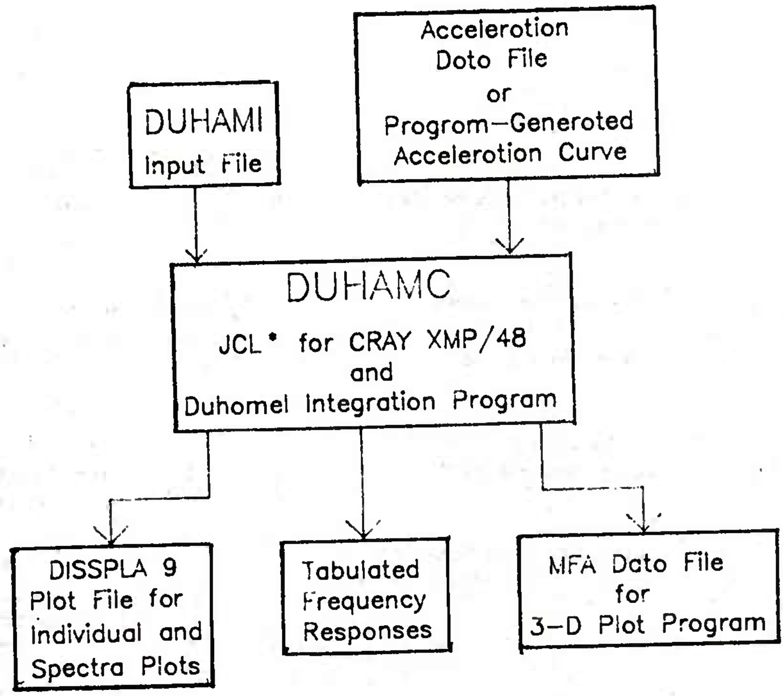
A computer program was written to numerically evaluate Duhamel's integral. The numerical integration scheme used in this program is Simpson's integration. The reciprocal of a given frequency is used as the period of the function. Additionally, the step size for Simpson's integration is less than one-eighth the period to attain reasonable accuracy using this numerical integration scheme. This step size scheme was selected so that the program would use fewer calculations in the lower frequencies.

The natural frequency ω of the system, given by $\omega = 2\pi f$ where f is the inputted frequency (in Hertz), is an integral part of the function being integrated as illustrated in Eqs. (1) through (6).

The Duhamel integral is currently coded in both FORTRAN and BASIC programming languages and has been run on the Hewlett-Packard (HP) 9845C, 9836C, CYBER 750, 825 and 7600 and the CRAY XMP/48. The code can also be used on the HP1000, HP9000 and other machines which support FORTRAN and/or BASIC. The FORTRAN version is currently being prepared, along with its job control language, to be run on the CRAY 2 machine.

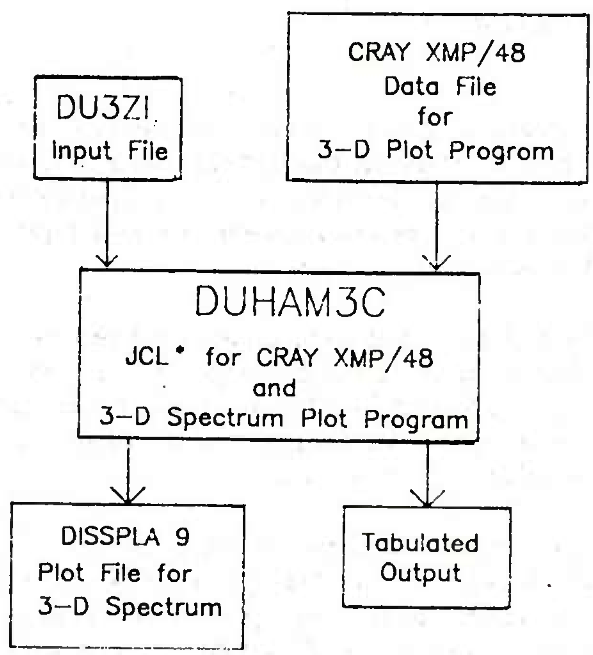
The program is fully documented and is generic for both damped and undamped systems. The FORTRAN code along with its associated job control language for CRAY XMP/48 is listed in Appendix A.

The functions and interrelationships of files run on CRAY XMP/48 are found in Figures 1 and 2. Figure 3 is a general flow diagram of the basic program.



* Job Control Language

Figure 1. CRAY XMP/48 Integration Program Sequence



* Job Control Language

Figure 2. CRAY XMP/48 3-D Plot Program Sequence

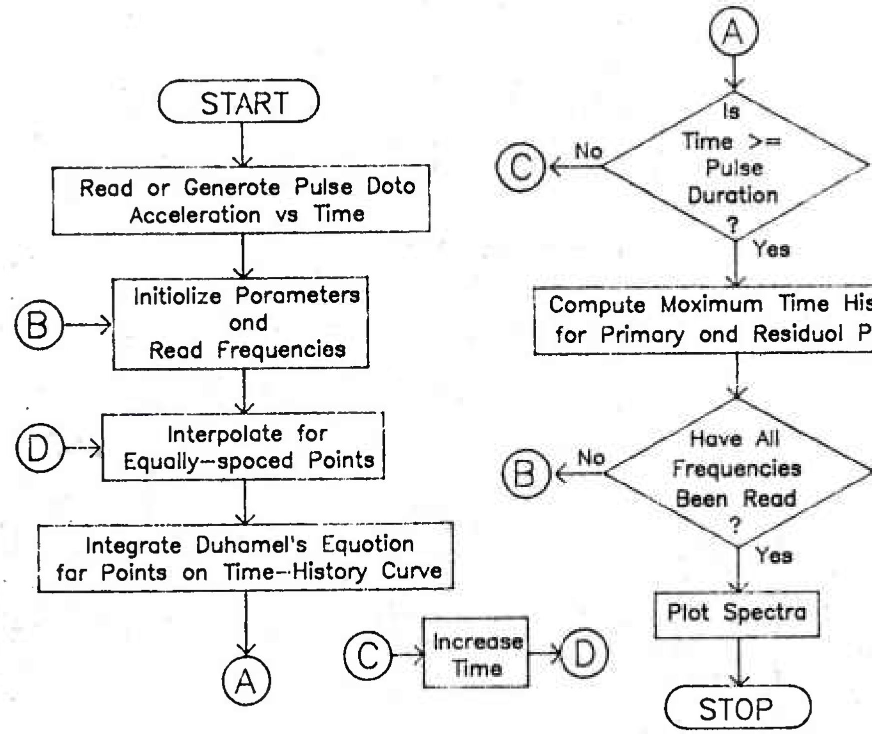


Figure 3. General Flow Diagram of the Basic Integration Program

A. Input to the Computer Program

The first step in establishing test criteria is to obtain response spectra of the shock pulse representing the environment. Thus far, the half-sine pulse, test machine pulses, interior ballistic pulses, idealized free-space blast, modified free-space blast and measured confined blast pulses have been used as representations of the environment. Figures 4 through 8 are examples of these different types of shock pulses.

These types of shock pulses are used as input to the program. Figure 4, a half-sine pulse, is an example of a code-generated curve which was generated in the Duhamel code. The idealized free-space blast and modified blast pulses, Figures 5 and 6, are curves that were generated in an auxiliary program for utilization in the Duhamel code. Figures 7 and 8 are examples of actual experimental data curves taken from firing data.

The amplitude of the input data curves is normalized to one, thus eliminating the need for dimensions. The frequency axis is normalized by multiplying the frequency by the pulse duration. This yields cycles. Depending on the program option selected, the frequency characteristics can be inputted from the keyboard, read from the data statement within the program or included as a part of the input file. The frequency range is generally between .1 and 10000 cycles. The damping characteristics are inputted from the keyboard or from a data file and range from zero to one. Figure 9 is an example of input data. Table 1 defines the input variables and lists the formats.

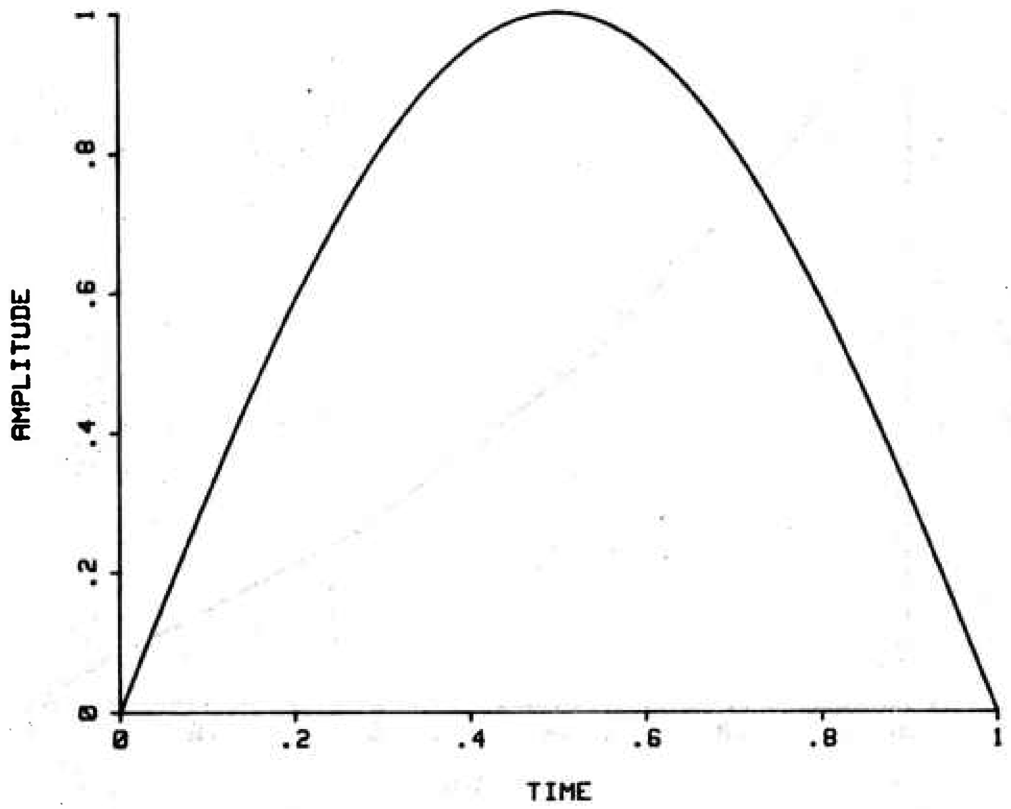


Figure 4. Program Input - Half-Sine Pulse

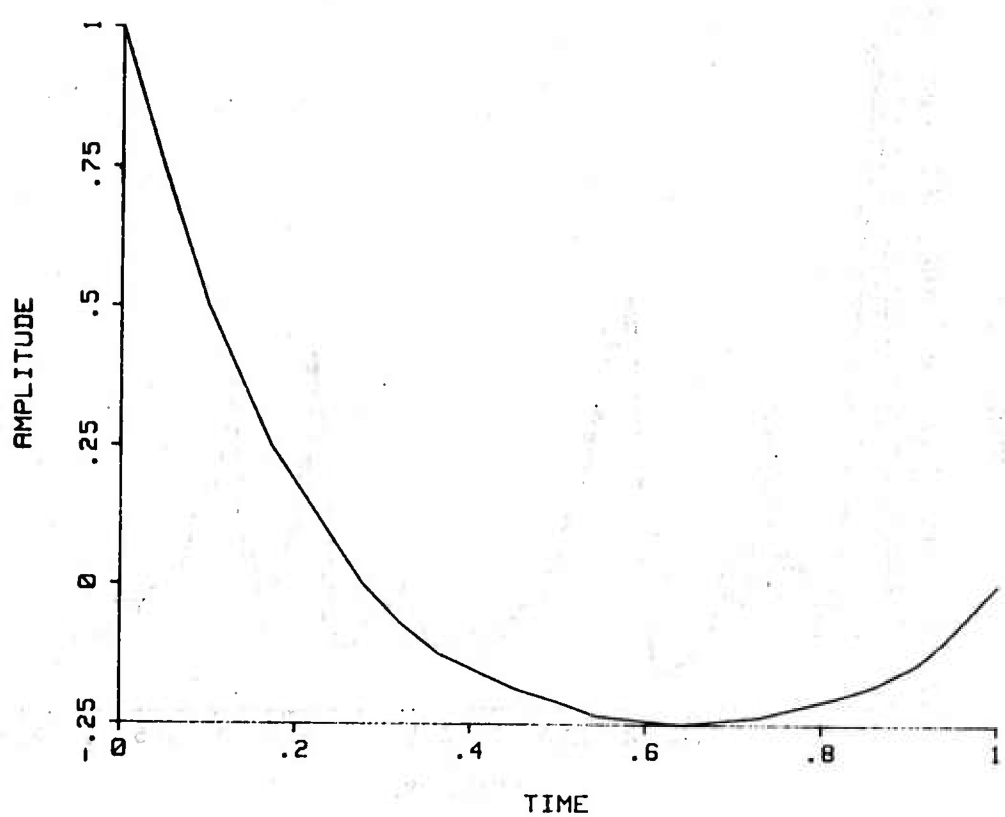


Figure 5. Program Input - Idealized Free-Space Blast Pulse

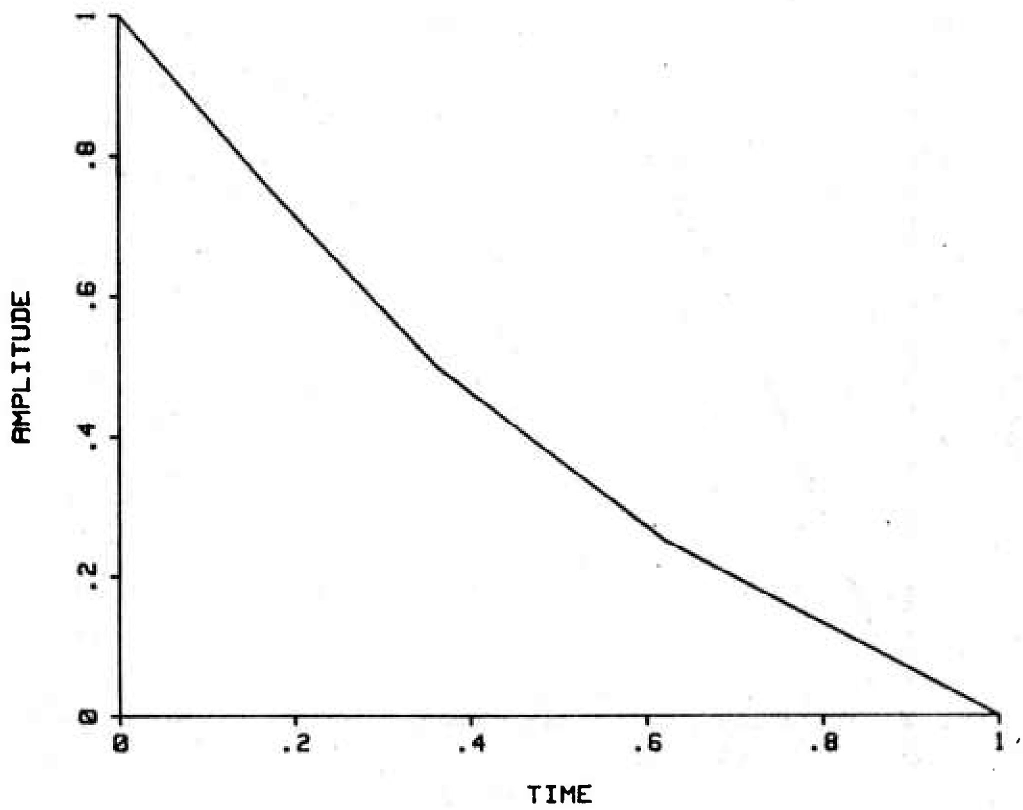


Figure 6. Program Input - Modified Blast Pulse (Positive Portion)

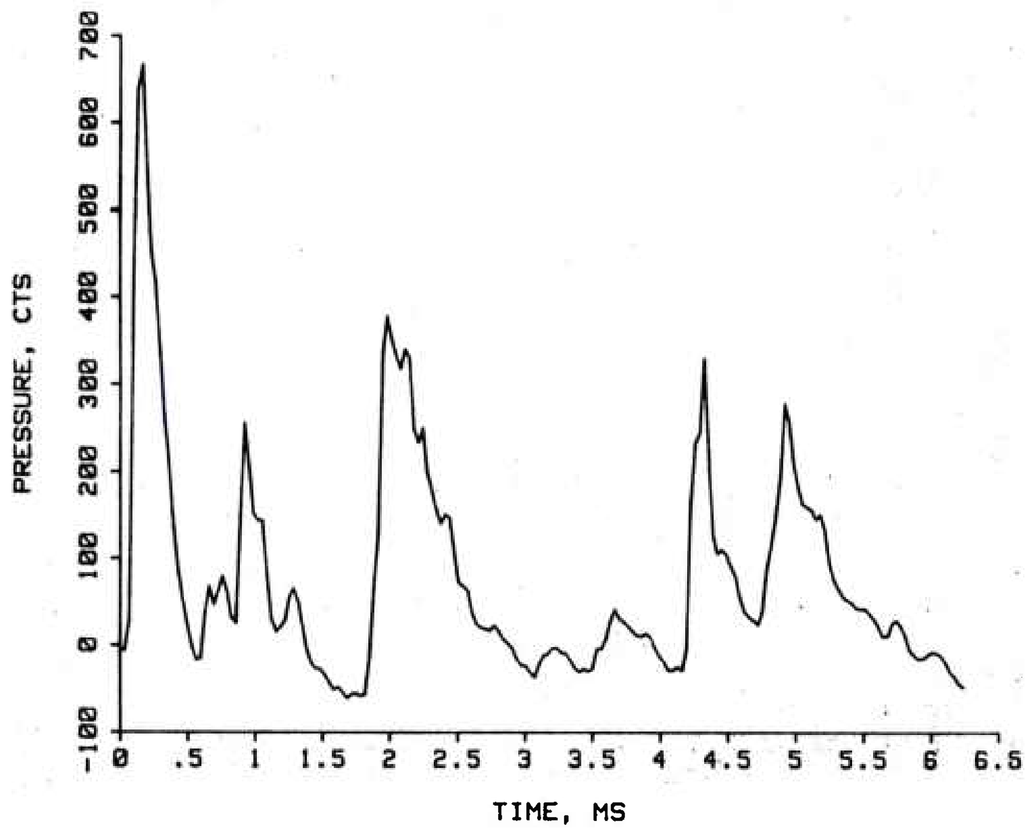


Figure 7. Program Input - Pressure Pulse Tera Socorro ID 24

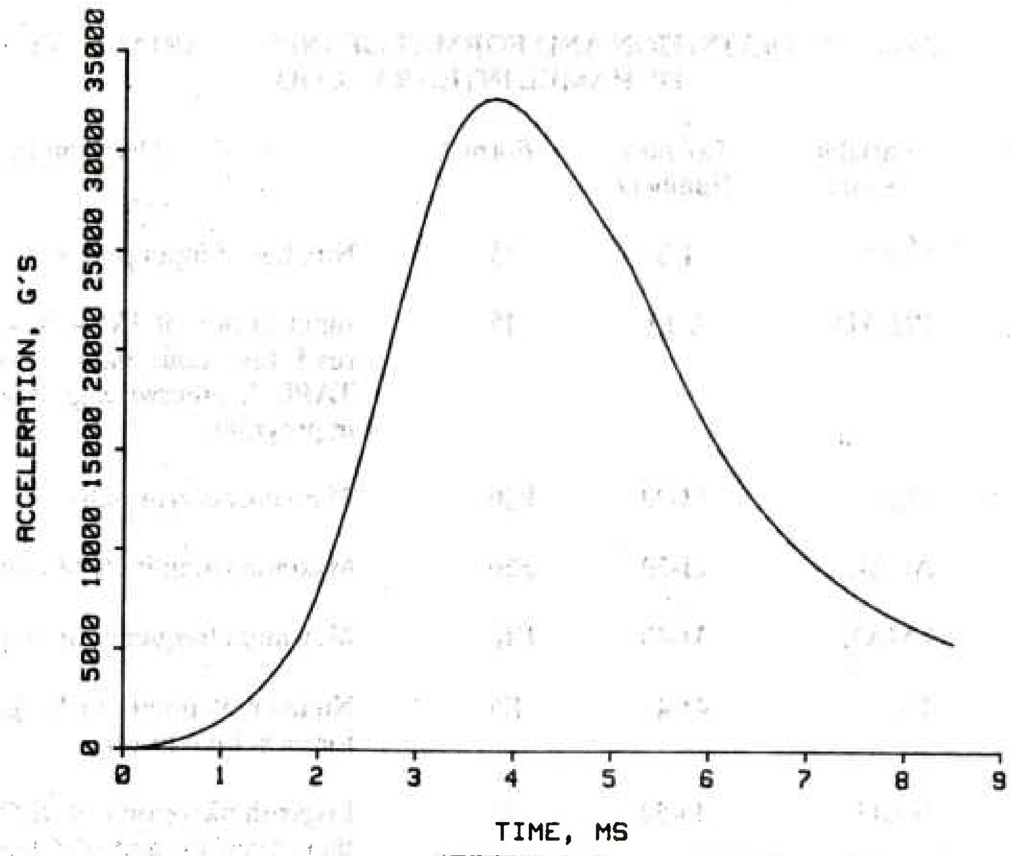


Figure 8. Program Input - Acceleration Pulse 105-mm Gun M68 M456A2

Card Number	Data
1	201 0 3.14159 1.0 10000. 100. 0 1 1 1 0
2	105MM GUN, M68 M456A2
3	ACC-TIME HISTORY OF M456A2
4	TIME, MSEC ACCELERATION, G'S
7a	.000
10	SHOCK SPECTRA M456A2
11	FRQ * PULSE DURATION STATIC ACCELERATION
12	.1 10000.0 1000. 0.0 5.0 1.

Figure 9. Sample FORTRAN Card Image Input For Duhamel Integral Code

TABLE 1. DEFINITION AND FORMAT OF INPUT VARIABLES TO DUHAMEL INTEGRAL CODE

Record Number	Variable Name	Column Numbers	Format	Description
1	NOC	1-5	I5	Number of input points.
	IREAD	6-10	I5	Input option, if IREAD = 1, then read the input data curves from TAPE 1, otherwise, generate curve in program.
	TCAL	11-20	F10	Time duration of pulse.
	ACAL	21-30	F10	Maximum amplitude of input pulse.
	FMAX	31-40	F10	Maximum frequency times pulse duration.
	TS	41-45	F5	Number of points to be generated for each time history.
	ILOG	46-50	I5	Logarithmic option, if ILOG = 1, then calculate and plot logarithmic values of frequency.
	IRES	51-55	I5	Residual option, if IRES = 1, then plot only residual spectrum.
	IFREQ	56-60	I5	Frequency option, if IFREQ = 1, then convert frequency times pulse duration to frequency.
	ISPEC	61-65	I5	Spectra option, if ISPEC = 1, then plot both primary and residual spectra.
	I3D	66-70	I5	3-D option, if I3D = 1, then plot a 3-D spectra surface.
	IPLOR	71-72	I2	Plot option, if IPLOR = 1, then plot the original input pulse, unnormalized.
	IPLNO	73-74	I2	Plot option, if IPLNO = 1, then plot the original input pulse, normalized.

TABLE 1. DEFINITION AND FORMAT OF INPUT VARIABLES TO DUHAMEL INTEGRAL CODE(cont.)

Record Number	Variable Name	Column Numbers	Format	Description
2	PGTIT	1-80	10A8	Page title to be printed on tabulated output.
3	TIT4	1-80	10A8	Plot title for unnormalized input pulse.
4	LXNAME	1-24	3A8	Label for x axis for plot of unnormalized input pulse.
	LYNAME	25-48	3A8	Label for y axis for plot of unnormalized input pulse.
5	TIT4	1-80	10A8	Plot title for normalized pulse.
6	LXNAME	1-24	3A8	Label for x axis for plot of normalized input pulse.
	LYNAME	25-48	3A8	Label for y axis for plot of normalized input pulse.
7	FT	1-10	F10	Frequency times pulse duration.
	DAMP	11-20	F10	Damping characteristic.
	IPLOT	21-25	I5	Plot option, if IPLOT = 1, then plot the time history of the individual frequency.
7a	DAMP	1-10	F10	If a spectra is being plotted, then the damping characteristic is the only variable on Input Card 7 that needs to be read. It only needs to be read once, not for each frequency.
8	TIT4	1-80	10A8	Plot title for plot of time history of an individual frequency.
9	LXNAME	1-24	3A8	Label for x axis for plot of time history of an individual frequency.

TABLE 1. DEFINITION AND FORMAT OF INPUT VARIABLES TO DUHAMEL INTEGRAL CODE(cont.)

Record Number	Variable Name	Column Numbers	Format	Description
9	LYNAME	25-48	3A8	Label for y axis for plot of time history of an individual frequency.
10	TIT4	1-80	10A8	Plot title for plot of residual and/or primary spectra.
11	LXNAME	1-24	3A8	Label for x axis for plot of residual and/or primary spectra.
	LYNAME	25-48	3A8	Label for y axis for plot of residual and/or primary spectra.
12	XORIG	1-10	E10.3	Minimum x-scale value for plot of residual and/or primary spectra.
	XMAX	11-20	E10.3	Maximum x-scale value for plot of residual and/or primary spectra.
	XSTP	21-30	E10.3	Data units per x-scale plot inch for plot of residual and/or primary spectra.
	YORIG	31-40	E10.3	Minimum y-scale value for plot of residual and/or primary spectra.
	YMAX	41-50	E10.3	Maximum y-scale value for plot of residual and/or primary spectra.
	YSTP	51-60	E10.3	Data units per y-scale plot inch for plot of residual and/or primary spectra.

B. Output From the Computer Program

Two spectra are obtained as output from the Duhamel code.

The primary spectrum which is the maximum positive or negative relative acceleration achieved during the pulse.

The residual spectrum which is the maximum positive or negative relative acceleration achieved after the pulse.

Both spectra are plotted versus frequency.

The tabulated output of the Duhamel code includes the input in its original form, the input in its normalized form and the individual responses for the selected frequencies.

The plotted output is a choice of any or all of the following:

(a) the input curve in original form,
(b) the input curve in normalized form,
(c) individual frequency response,
(d) a spectra of the primary and residual system responses to the given frequencies, and/or
(e) a three-dimensional mapping of the primary and residual system responses showing relative acceleration, time and frequencies.

C. Plot Routines

On the Hewlett-Packard machines, there is a separate plot routine for each of the plot options. The data are stored on disc and then read in by the selected plot program. In the case of the 3-D option, on all of the machines, the data must be stored for each system response individually. The data are then read by the 3-D routine, geometrically rotated and subsequently plotted. The rotation is done to provide an optimum view of each of the individual system responses. The FORTRAN code for the 3-D plot and the associated job control language for the CRAY XMP/48 are listed in Appendix B. Figure 10 is an example of actual input data while Table 2 provides a listing, including descriptions and formats, of the input variables for the 3-D spectra plot.

On the Hewlett-Packard machines, the HP graphics routines are used, while on the CRAY XMP/48, the graphics are done using the commercial plotting package DISSPLA. Version 9 of DISSPLA is now resident on the CRAY XMP/48. The plots created using DISSPLA can be displayed on a terminal screen, plotted on a printer attached to an interactive terminal and/or transferred to the CALCOMP plotter at the BRL central computer site for hardcopy.

Card Number	Data
1	50 2
2	105MM GUN, M68 M456A2
3	0. 2.5 .3125 -4. 1.5 .9167

Figure 10. Sample FORTRAN Card Image Input for Duhamel 3-D Spectra Plot

Table 2. DEFINITION AND FORMAT OF INPUT VARIABLES FOR DUHAMEL 3-D SPECTRA PLOT

Record Number	Variable Name	Column Numbers	Format	Description
1	NFILES	1-5	I5	Number of response files to be plotted.
	MAXT	6-10	I5	Maximum time of response plot. 1 = Primary response only 2 = Primary and partial residual responses 3 = Primary and full residual responses
2	TIT4	1-80	10A8	Plot title
3	XORIG	1-10	E10.3	Minimum x-scale value
	XMAX	11-20	E10.3	Maximum x-scale value
	XSTP	21-30	E10.3	Data units per x-scale plot inch
	YORIG	31-40	E10.3	Minimum y-scale value
	YMAX	41-50	E10.3	Maximum y-scale value
	YSTP	51-60	E10.3	Data units per y-scale plot inch

Figures 11, 12 and 13 show the response of systems with 30 cycles normalized frequency and .05 damping to the pulses in Figures 5 through 7, respectively. Figures 11 through 13 are individual system responses versus time for a single frequency. Figure 14 is an overlay of Figures 11, 12 and 13.

Figure 15 is the response spectra of systems with .1 to 10000 cycles normalized frequencies and .05 damping applied to the half-sine pulse, Figure 6. Figures 16 through 20 are response spectra of systems with .1 to 10000 cycles normalized frequencies and no damping applied to Figures 4 through 8, respectively. Figures 11 through 14 show both primary and residual response spectra versus frequency plotted on a semi-log plot.

In actuality, these represent normalized response curves where the abscissa is frequency times pulse duration (cycles) and the ordinate is in relative acceleration (dimensionless).

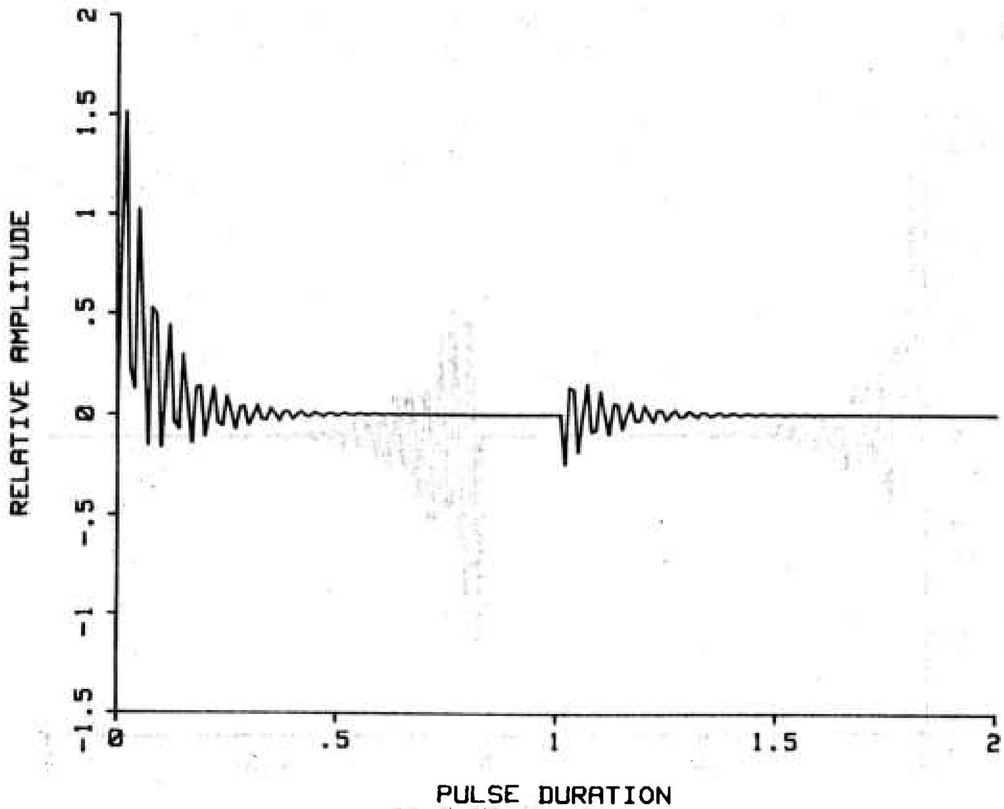


Figure 11. Response Curve (Frequency = 30, Damping = .05) Idealized Free-Space Blast Pulse

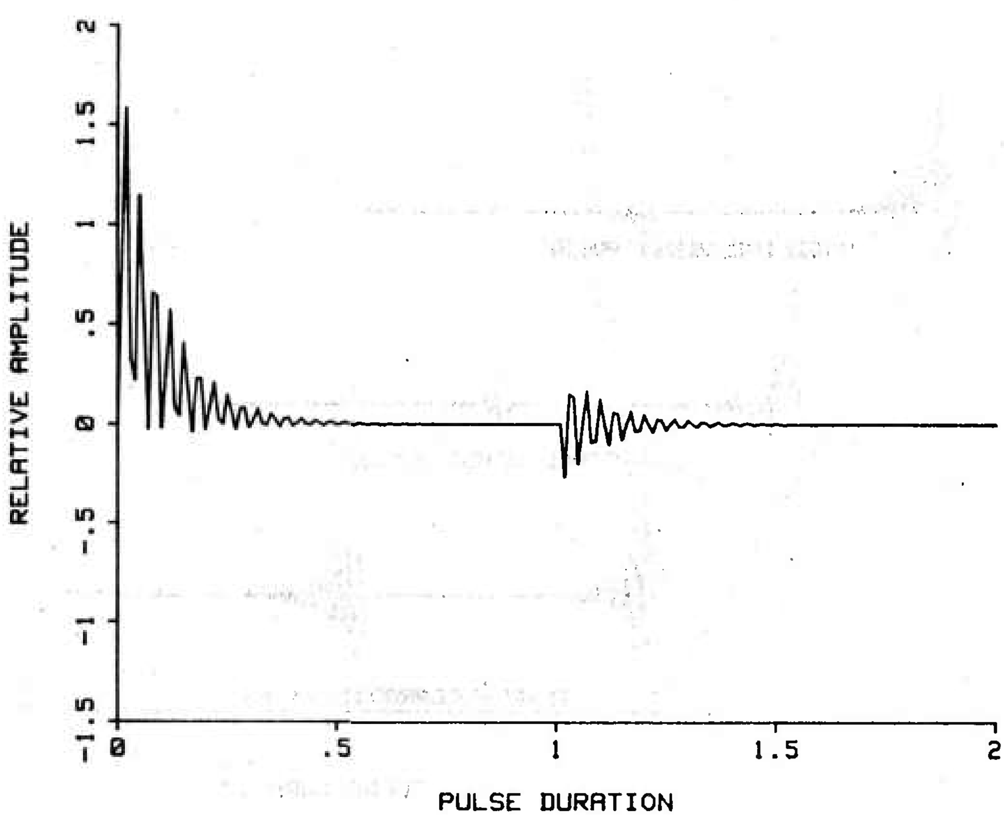


Figure 12. Response Curve (Frequency = 30, Damping = .05) Modified Blast Pulse (Positive Portion)

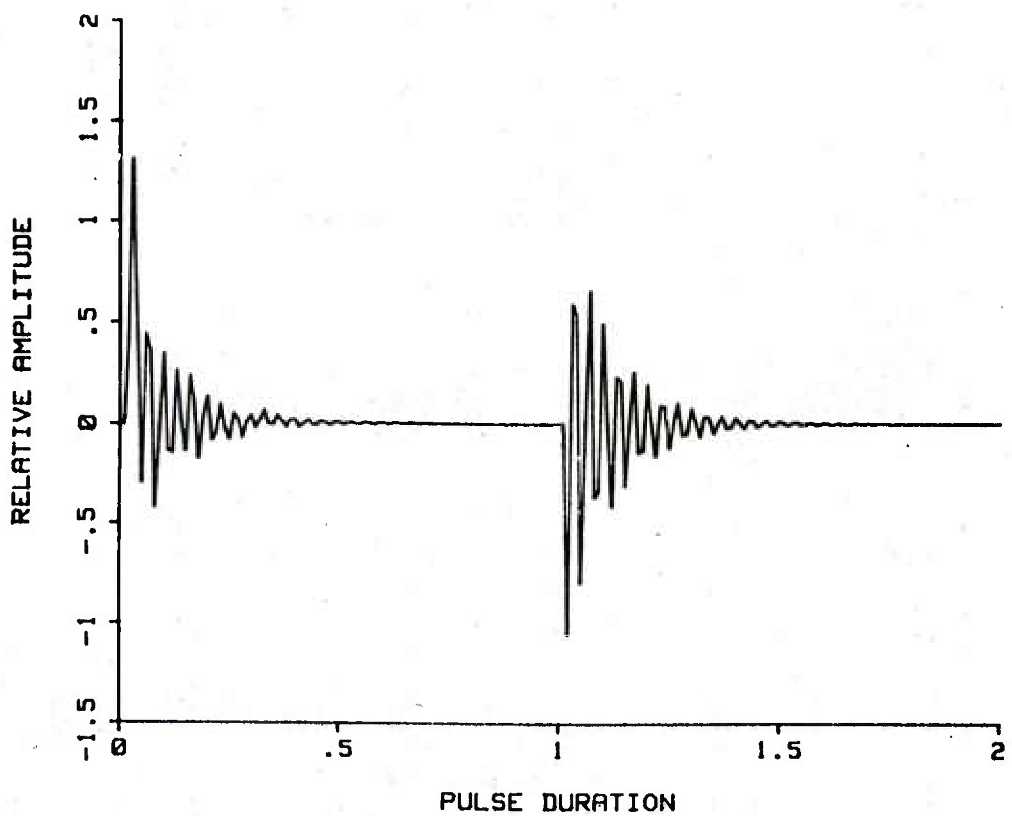


Figure 13. Response Curve (Frequency = 30, Damping = .05) Pressure Pulse
Tera Socorro ID 24

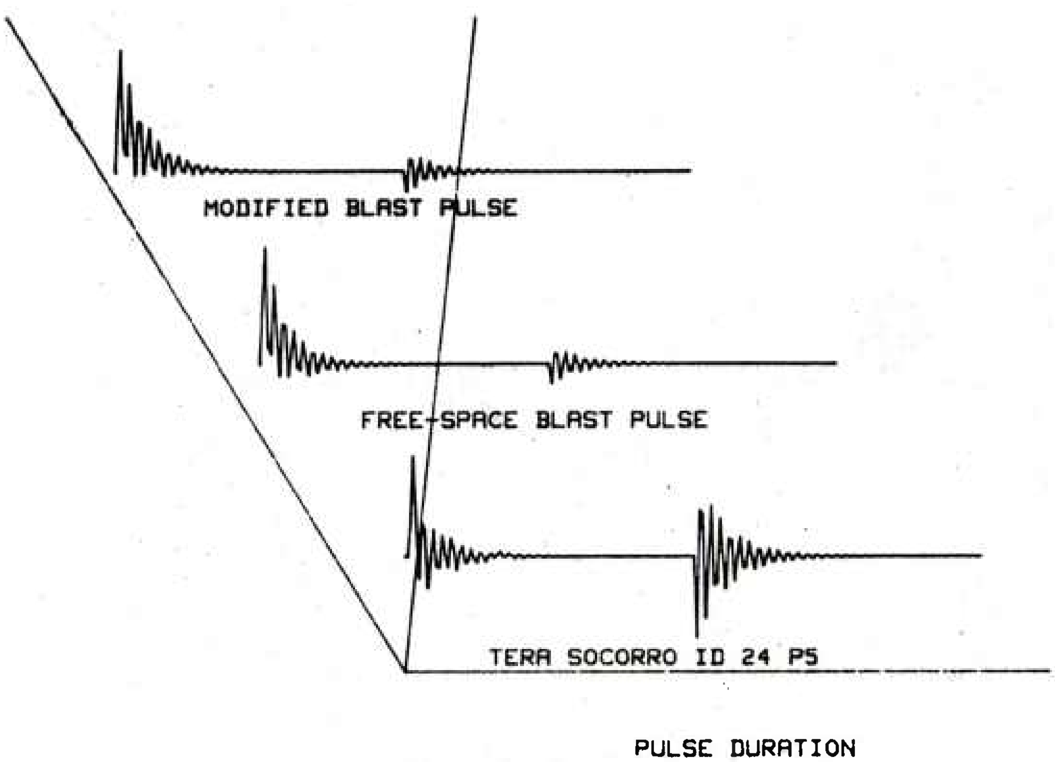


Figure 14. Comparison Response Curves (Frequency = 30, Damping = .05)

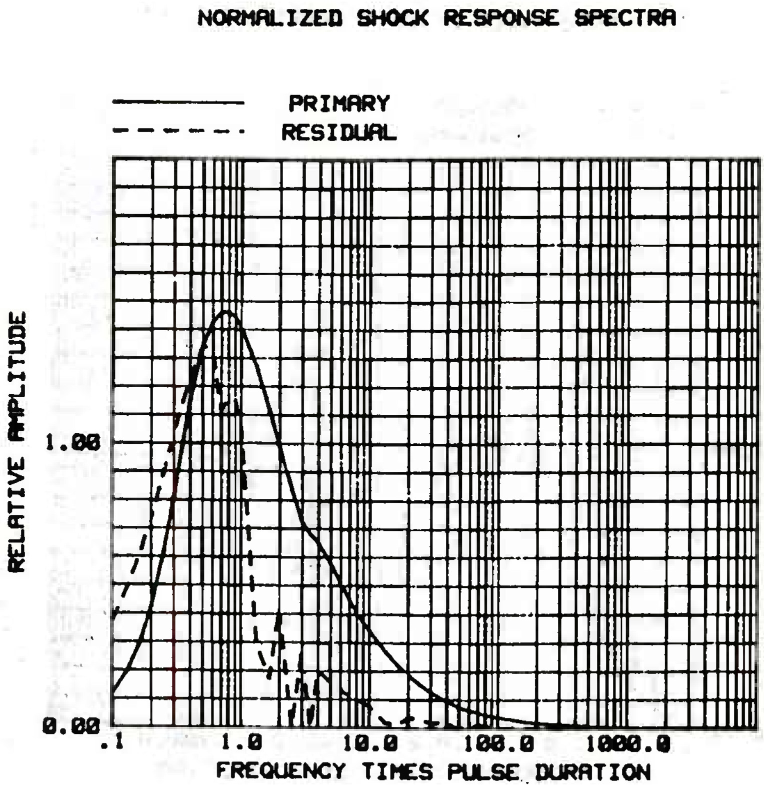


Figure 15. Normalized Shock Response Spectra - Half-Sine Pulse (Damping = .05)

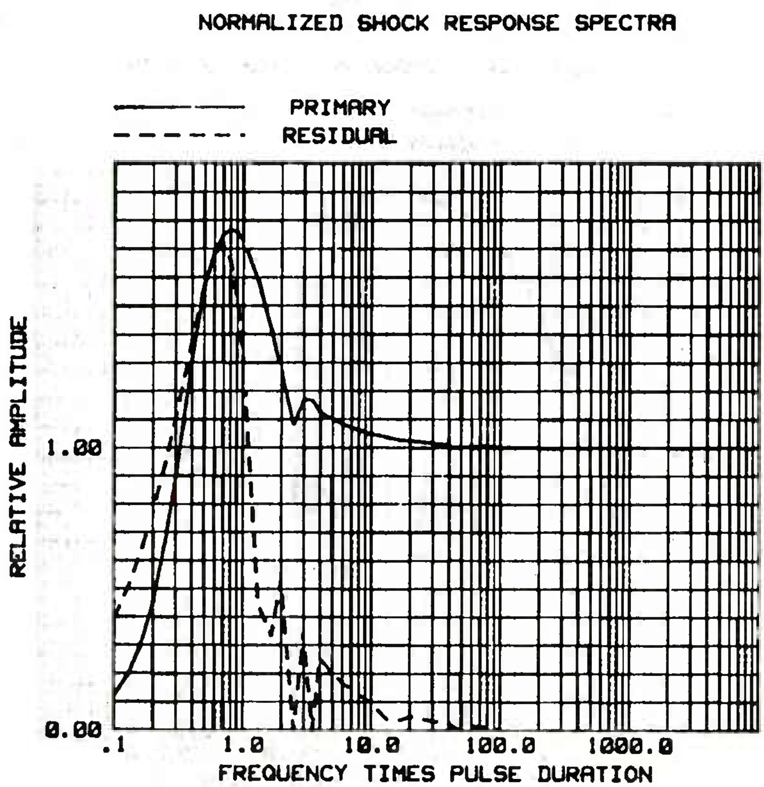


Figure 16. Normalized Shock Response Spectra - Half-Sine Pulse (Undamped)

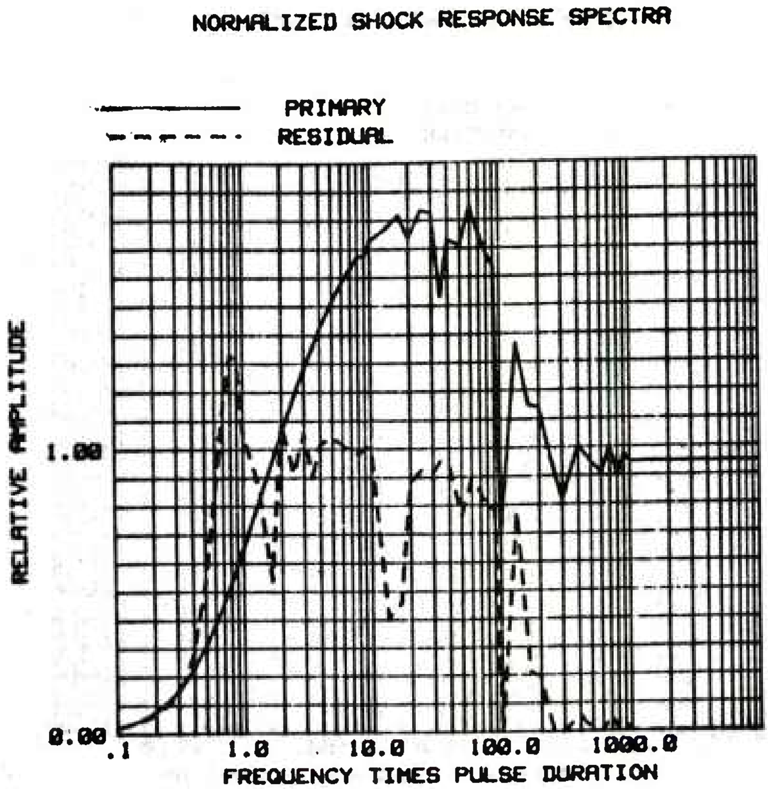


Figure 17. Normalized Shock Response Spectra - Idealized Free-Space Blast Pulse

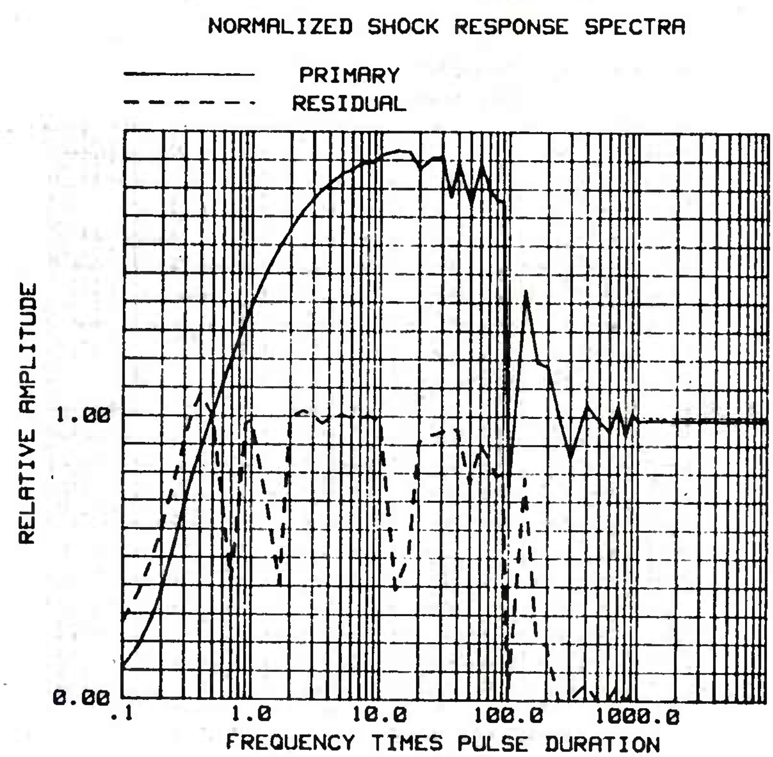


Figure 18. Normalized Shock Response Spectra - Modified Blast Pulse (Positive Portion)

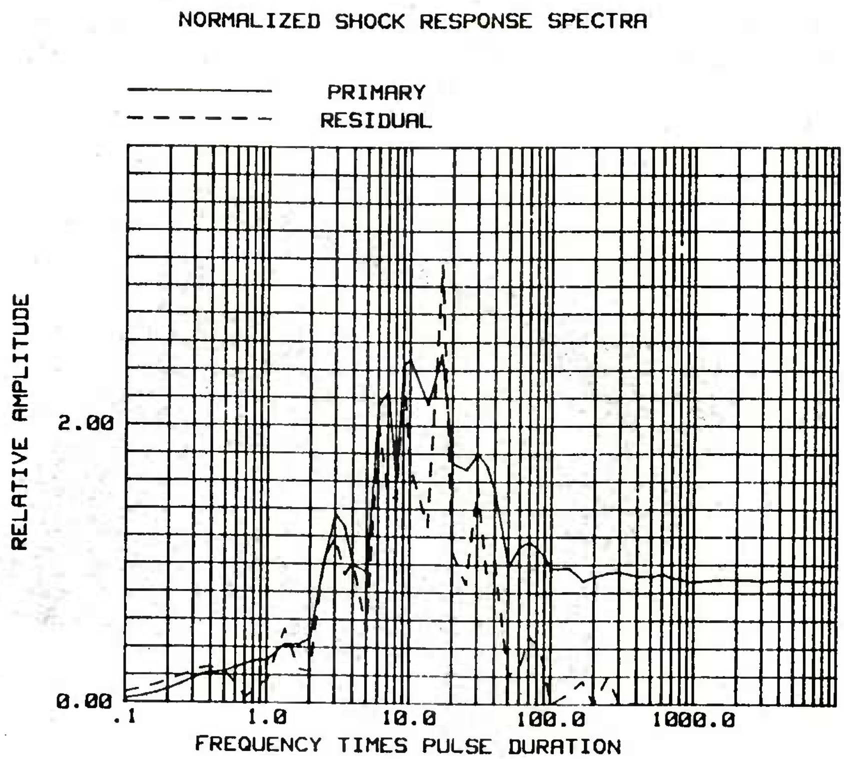


Figure 19. Normalized Shock Response Spectra - Pressure Pulse
Tera Socorro ID 24

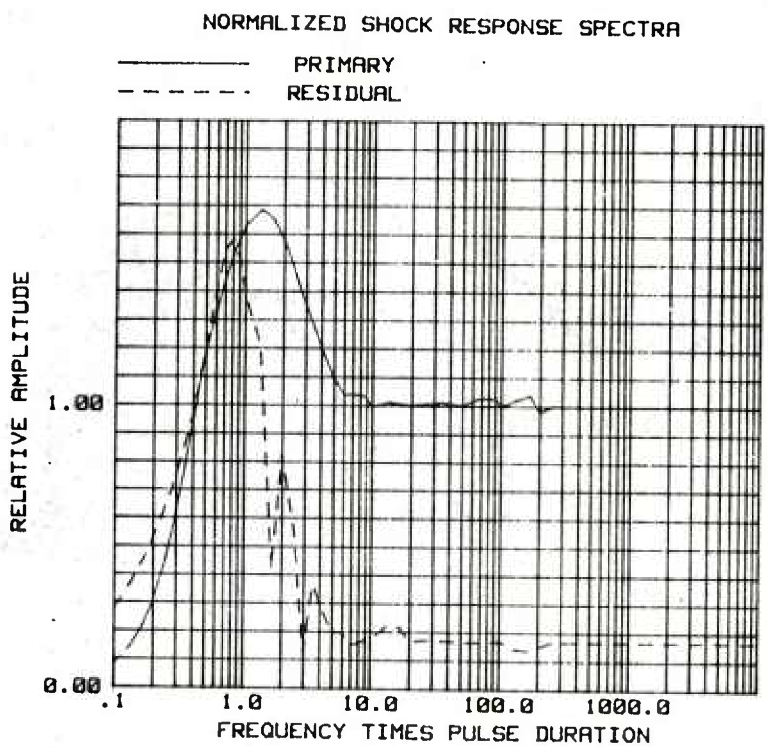


Figure 20. Normalized Shock Response Spectra - Acceleration Pulse
105-mm Gun M68 M456A2

Figures 21 through 26 are 3-D mappings of the response spectra shown in Figures 15 through 20, respectively. The three dimensions are relative acceleration, time and frequency.

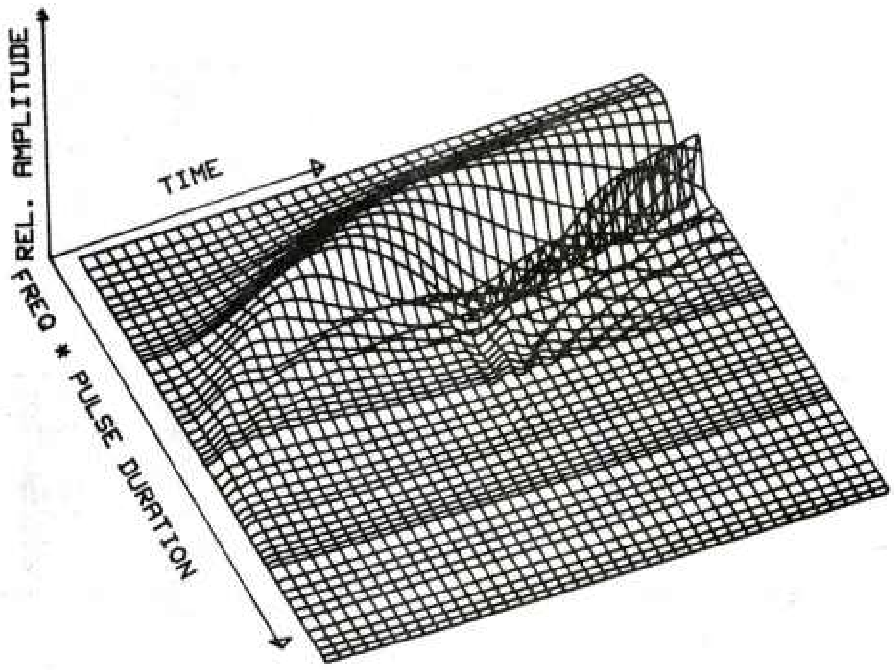


Figure 21. 3-D Shock Response - Half-Sine Pulse (Damping = .05)

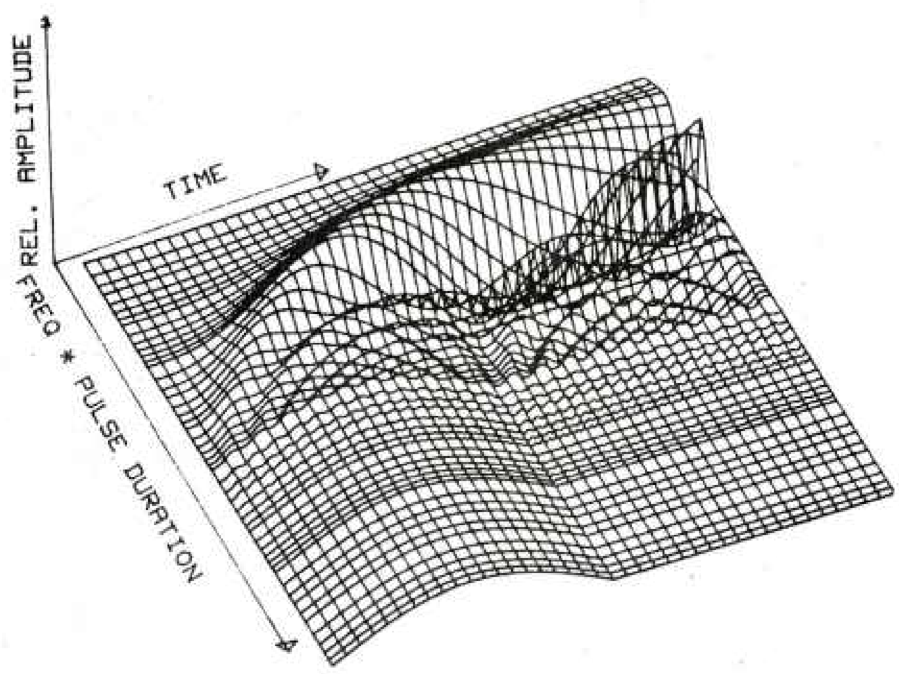


Figure 22. 3-D Shock Response - Half-Sine Pulse (Undamped)

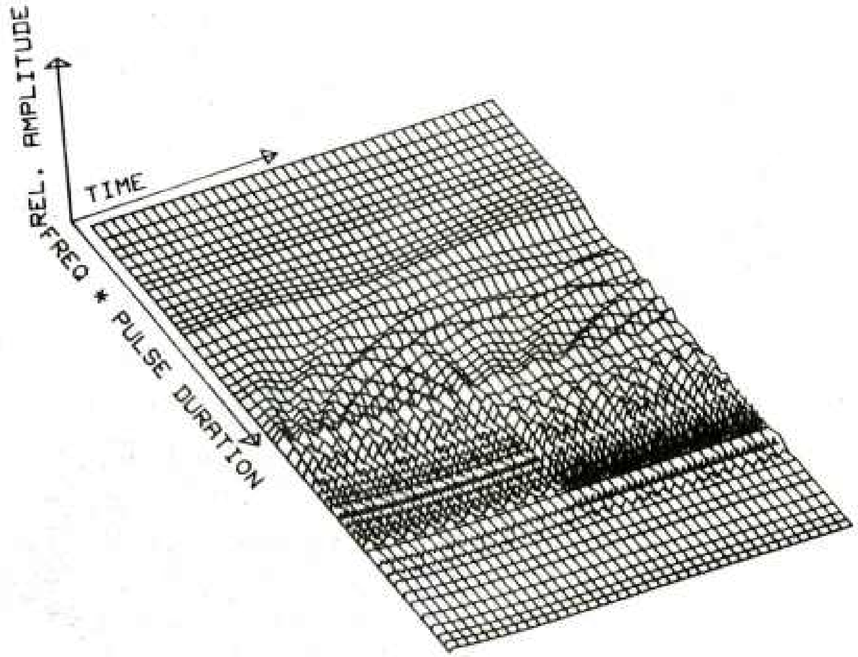


Figure 23. 3-D Shock Response - Idealized Free-Space Blast Pulse

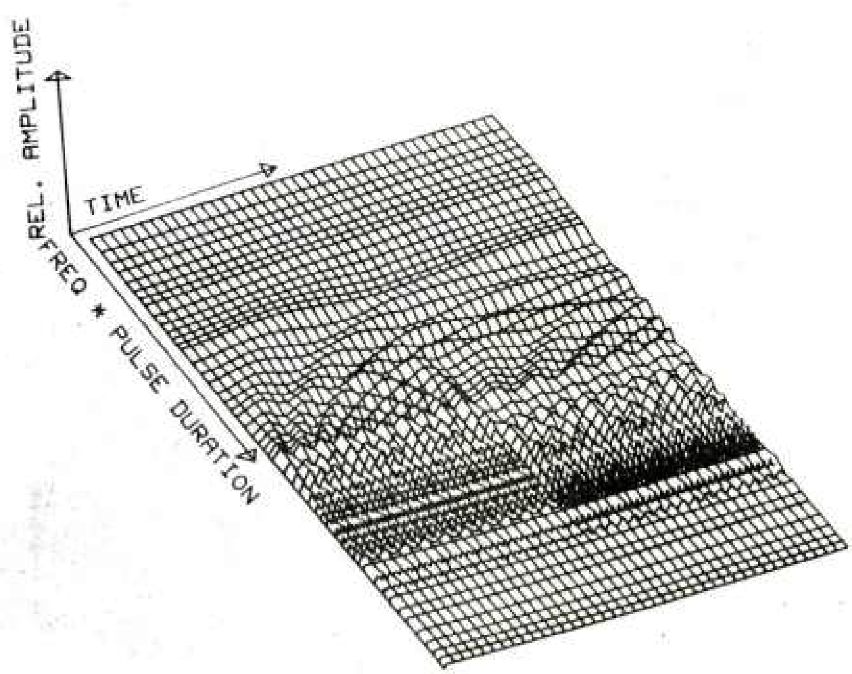


Figure 24. 3-D Shock Response - Modified Blast Pulse (Positive Portion)

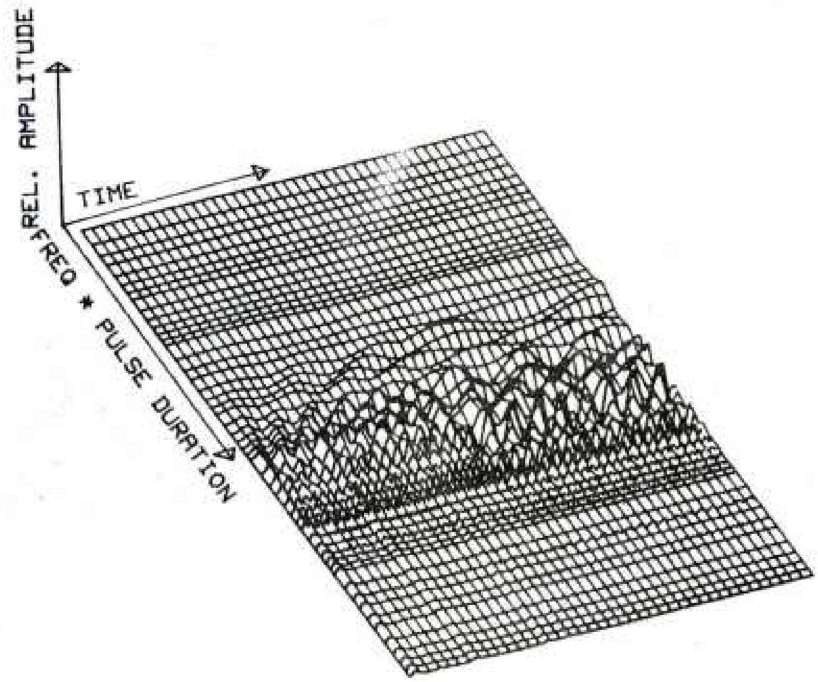


Figure 25. 3-D Shock Response - Pressure Pulse Tera Socorro ID 24

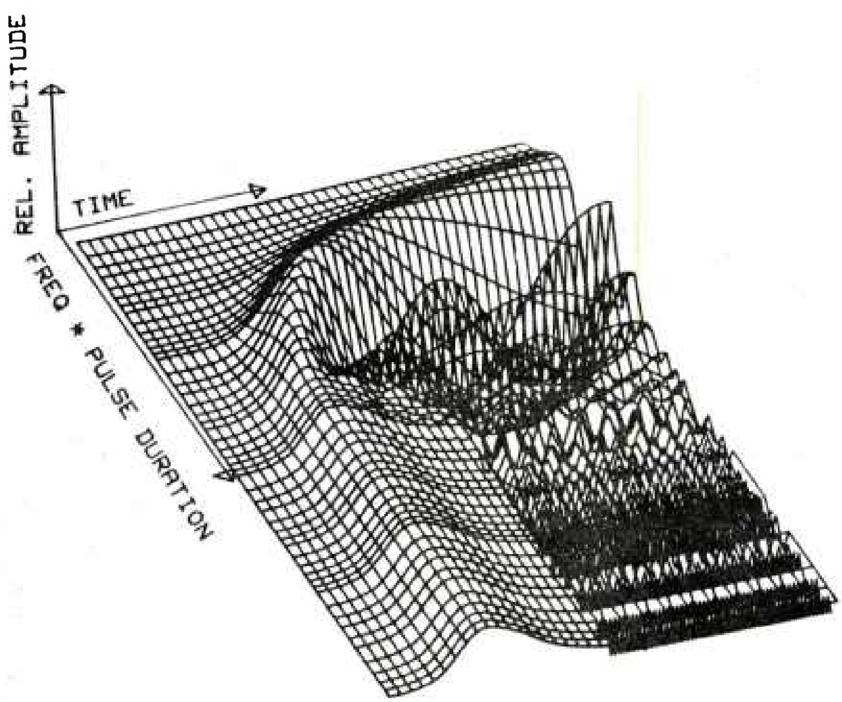


Figure 26. 3-D Shock Response - Acceleration Pulse 105-mm Gun M68 M456A2

IV. SUMMARY

The Duhamel's integral computer code was developed to analyze the transient response of test instrumentation and structures and to assess damage to the human ear caused by nonclassical pressure pulses. The code has been used to assess the relative severity of laboratory test environments with respect to gun environments. The program has been installed on a mainframe, a front-end machine and several microcomputers in BASIC and FORTRAN programming languages so as to make it more accessible to the user.

The Duhamel's integral package is now being run on the CRAY 2 supercomputer which, along with the CRAY XMP/48, has replaced the CYBER 7600 at the BRL. This code will be incorporated into the general structural and analysis scheme of the IBD. In addition, the program will be extended to compound response descriptions which include more than one frequency and other nonlinear forms, such as hardening and softening stiffness systems.

APPENDIX A

LISTING OF FORTRAN PROGRAM TO INTEGRATE DUHAMEL'S INTEGRAL ALONG WITH ASSOCIATED JOB CONTROL LANGUAGE FOR CRAY XMP/48

APPENDIX A

LISTING OF FORTRAN PROGRAMS TO INTEGRATE DUHAMEL'S INTEGRAL ALONG WITH ASSOCIATED JOB CONTROL LANGUAGE FOR CRAY XMP/48

I. Job Control Language for CRAY XMP/48

JOB,JN=*jobname*,T=150,MFL=350000.
ACCOUNT,AC=*accountnumber*,US=*username*,UPW=*userpassword*.
ACCESS,DN=DISLIB,PDN=DISLIB,ID=DISSPLA,OWN=SYSTEM.
ACCESS,DN=DVSD,PDN=DVSD,ID=DISSPLA,OWN=SYSTEM.
ACCESS,DN=INTLIB,PDN=INTLIB,ID=DISSPLA,OWN=SYSTEM.
FETCH,DN=*infile*,TEXT='CHARGE,*acctno*, *pn*.GET, *infile*=*infile*.CTASK.'.

where *infile* = name of input file which contains program options and plot titles
pn = first two letters of the account number

ASSIGN,DN=*infile*,A=FT03.
FETCH,DN=*acfile*,TEXT='CHARGE,*acctno*, *pn*.GET,*acfile*=*acfile*.CTASK.'.

where *acfile* = name of permanent file residing on front end which contains data to be used as shock pulse

ASSIGN,DN=*acfile*,A=FT01.
ASSIGN,DN=TAPE2,A=FT02.
CFT.
SEGLDR,CMD='LIB=DISLIB,INTLIB',GO.
DISPOSE,DN=META,DC=ST,DF=BB,^
TEXT='CHARGE=*acctno*, *pn*.CTASK.REPLACE,META=*pfn*.'.

where *pfn* = name of output file in which the DISSPLA plot file is stored on the front end.

DISPOSE,DN=TAPE2,DC=ST,DF=BB,^
TEXT='CHARGE=*acctno*, *pn*.CTASK.REPLACE,TAPE2=*3dfile*.'.

where *3dfile* = name of output file that will contain data to be used in calculations for 3-D plot.

II. Listing of FORTRAN File

```
      PROGRAM SPECTRM(INPUT,OUTPUT,TAPE1,TAPE5,TAPE6=OUTPUT,
     *META,TAPE10=OUTPUT,TAPE2)
C     THIS PROGRAM NUMERICALLY INTEGRATES DUHAMEL'S INTEGRAL TO
C     OBTAIN A PRIMARY AND RESIDUAL SHOCK SPECTRA.  THE INPUT
C     CONSISTS OF A SET OF ORDERED PAIRS THAT DESCRIBE THE
C     ACCELERATION OF A SYSTEM AND A SET OF FREQUENCIES OVER
C     WHICH THE SYSTEM IS TO BE EVALUATED. THIS PROGRAM WILL ALSO
C     PLOT THE PRIMARY AND RESIDUAL SHOCK TIME HISTORY OF A GIVEN
C      FREQUENCY.
C
      DIMENSION RMAX(500),FWN(500),FR(500),MSAVE(75),XPLT(7000)
      DIMENSION PFT(200),PXP(200),PXR(200),PGTIT(10),YPLT(7000)
      DIMENSION XA(3500),XB(3500),TA(3500),TB(3500),TIT4(4)
      DIMENSION U(210),A(210),V(1040),VP(1040),DUM(1),FTR(61)
      REAL NX, NXP, MAXP, MAXR
C
      DATA PI2,PI/6.283185307,3.14159265358/
C
C     FREQUENCY INPUT DATA
C
      DATA FTR/.1,.133,.167,.2,.25,.3,.35,.4,.5,.6,.7,.8,.9,1.,1.333,
     *1.667,2.,2.5,3.,3.5,4.,5.,6.,7.,8.,9.,10.,13.333,16.667,20.,25.,
     *30.,35.,40.,50.,60.,70.,80.,90.,100.,133.333,166.667,200.,250.,
     *300.,400.,500.,600.,700.,800.,900.,1000.,2000.,3000.,4000.,5000.,
     *6000.,7000.,8000.,9000.,10000./
C
C
      CALL COMPRS
      CALL SETDEV(10,6)
C
C     ACCELERATION AND TIME ARE NORMALIZED.
C
C     NOC = NO. OF INPUT POINTS.
C     IF IREAD = 1, THEN READ INPUT DATA FROM TAPE1
C                   OTHERWISE, GENERATE DATA IN PROGRAM.
C     TCAL = TIME DURATION OF PULSE
C     ACAL = MAXIMUM ACCELERATION OF PULSE
C     FMAX = MAXIMUM FREQUENCY TIMES PULSE DURATION
C     TS = THE NUMBER OF POINTS GENERATED FOR EACH TIME HISTORY.
C     IF ILOG = 1, CALCULATE AND PLOT LOG VALUES OF FREQUENCY
C     IF IRES = 1, PLOT ONLY RESIDUAL SPECTRUM
C     IF IFREQ = 1, CONVERT FREQUENCY TIMES PULSE
C                   DURATION TO FREQUENCY.
C     IF ISPEC = 1, PLOT PRIMARY AND RESIDUAL SPECTRA
C     IF I3D = 1, PLOT A 3-D SPECTRUM SURFACE.
C     IF IPLOR = 1, PLOT THE ORIGINAL PULSE, UNNORMALIZED.
C     IF IPLNO = 1, PLOT THE ORIGINAL PULSE, NORMALIZED.
```

```
C
C         SET UP PLOT VARIABLES
C
          ISC=0
          ITYPE=0
          N4=0
          ICOLOR=0
          NCURV=1
C
C         READ AND PRINT PROGRAM CONTROL VARIABLES
C
10        READ(5,1000) NOC,IREAD,TCAL,ACAL,FMAX,TS,ILOG,IRES,
         *IFREQ,ISPEC,I3D,IPLOR,IPLNO
          IF(EOF(5).EQ.0.) GO TO 20
          CALL DONEPL
          STOP
20        WRITE(6,1000) NOC,IREAD,TCAL,ACAL,FMAX,TS,ILOG,IRES,
         *IFREQ,ISPEC,I3D,IPLOR,IPLNO
C
C         READ IN TITLE AND SET UP OTHER PLOT VARIABLES
C
          READ(5,1100) PGTIT
          WRITE(6,1200) PGTIT
          IF(IFREQ.EQ.1) FMAX=FMAX/TCAL
C
C         DO-LOOP TO READ AND NORMALIZE ORDERED PAIRS (U,A)
C
          IF(IREAD.NE.1) GO TO 30
          READ(1,1600) (U(I),A(I),I=1,NOC)
          GO TO 50
30        TIME=0.
          DO 40 I=1,NOC
          ACC=SIN(TIME)
          U(I)=TIME
          A(I)=ACC
          TIME=TIME+PI/(NOC-1)
40        CONTINUE
50        WRITE(6,1300)
          WRITE(6,1400)
          WRITE(6,1500) (U(I),A(I),I=1,NOC)
C
C         PLOT ORIGINAL INPUT PULSE
C
          IF(IPLOR.NE.1) GO TO 60
          READ(5,1100) TIT4
          LST=1
          LSP=NOC
          CALL DATA4(NCURV,U,A,DUM,NOC,ISC,ITYPE,LST,LSP,TIT4,
         *ICOLOR)
          TIME=0.
```

```
C
C        NORMALIZE INPUT PULSE
C
60       DO 70 I=1,NOC
         U(I)=U(I)/TCAL
         A(I)=A(I)/ACAL
         UMAX=U(I)
70       CONTINUE
C
C        PRINT NORMALIZED ACCELERATION PULSE
C
         WRITE(6,1700)
         WRITE(6,1300)
         WRITE(6,1500) (U(I),A(I),I=1,NOC)
C
C        PLOT PULSE CURVE
C
         IF(IPLNO.NE.1) GO TO 80
         READ(5,1100) TIT4
         LST=1
         LSP=NOC
         NCURV=1
         CALL DATA4(NCURV,U,A,DUM,NOC,ISC,ITYPE,LST,LSP,TIT4,
        *ICOLOR)
C
C        TIME AND ACCELERATION MUST START AT 0.
C
80       A(1)=0.
         U(1)=0.
C
C        S = RANGE OVER WHICH DUHAMEL'S INTEGRAL IS INTEGRATED
C        TO OBTAIN A POINT OF TIME HISTORY FOR PRIMARY SHOCK
C        SPECTRUM. PRIMARY SHOCK SPECTRUM IS GENERATED AS XA VS S.
C
         S=0
C
C        T IS USED TO GENERATE EQUALLY SPACED POINTS FOR
C        SIMPSON'S INTEGRATION
C
         T=0
C
C        DS DETERMINES THE NO. OF POINTS GENERATED FOR EACH
C        TIME HISTORY.
C
         DS=(UMAX-U(1))/TS
C
C        NP = NO. OF FREQUENCIES USED
C
         NP=1
C
```

```
C         FT IS FREQUENCY TIMES THE PULSE DURATION. F IS FREQUENCY      SPEC 148
C         AND IS EQUAL TO FT SINCE TIME HAS BEEN NORMALIZED.            SPEC 149
C         IF IPLOT EQUALS 1, PLOT TIME HISTORY OF FREQUENCY             SPEC 150
C                                                                       SPEC 151
90        IF(IRES.EQ.1.OR.ISPEC.EQ.1.OR.I3D.EQ.1) GO TO 92              SPEC 152
          READ(5,1800) FT,DAMP,IPLOT                                    SPEC 153
          WRITE(6,1800) FT,DAMP,IPLOT                                   SPEC 154
          GO TO 94                                                      SPEC 155
92        FT=FTR(NP)                                                    SPEC 156
          IF(NP.EQ.1) READ(5,1800) DAMP                                 SPEC 157
94        F0=FT                                                         SPEC 158
          FT=FT*SQRT(1.-DAMP**2)                                        SPEC 159
          F=FT/UMAX                                                     SPEC 160
C                                                                       SPEC 161
C         X1 AND X2 ARE RUNNING VALUES OF INTEGRATION AND ARE           SPEC 162
C         SET TO 0 WHEN A NEW FREQUENCY IS READ.                        SPEC 163
C                                                                       SPEC 164
          X1=0.                                                         SPEC 165
          X2=0.                                                         SPEC 166
          I=1                                                           SPEC 167
          K=1                                                           SPEC 168
          L=1                                                           SPEC 169
          M=1                                                           SPEC 170
C                                                                       SPEC 171
C         H IS STEP SIZE FOR SIMPSON'S INTEGRATION                      SPEC 172
C                                                                       SPEC 173
          H=DS/8.                                                       SPEC 174
C                                                                       SPEC 175
C         P = PERIOD OF FUNCTION.                                       SPEC 176
C                                                                       SPEC 177
          P=1./F                                                        SPEC 178
C                                                                       SPEC 179
C         H MUST BE LESS THAN 1/8 THE PERIOD FOR REASONABLE             SPEC 180
C         ACCURACY USING SIMPSON'S INTEGRATION.                         SPEC 181
C                                                                       SPEC 182
100       IF(H.LT.(1./8.)*P) GO TO 110                                  SPEC 183
          H=H/2.                                                        SPEC 184
          GO TO 100                                                     SPEC 185
110       H3=H/3.                                                       SPEC 186
C                                                                       SPEC 187
C         SWS = SIN(WS) AND CWS = COS(WS).                              SPEC 188
C                                                                       SPEC 189
          W=PI2*F                                                       SPEC 190
          WD=PI2*F0                                                     SPEC 191
120       WS=W*S                                                        SPEC 192
          CWS=COS(WS)                                                   SPEC 193
          SWS=SIN(WS)                                                   SPEC 194
C                                                                       SPEC 195
C         U AND A ARE UPDATED FOR PROPER LINEAR INTERPOLATION.          SPEC 196
C                                                                       SPEC 197
```

```
130       IF(T.GE.U(I).AND.T.LE.U(I+1)) GO TO 150                        SPEC 198
          IF(T.LT.UMAX) GO TO 140                                        SPEC 199
C                                                                        SPEC 200
C         T IS SET TO TMAX TO CORRECT POSSIBLE ACCUMULATIVE ERRORS       SPEC 201
C                                                                        SPEC 202
          T=UMAX                                                         SPEC 203
          GO TO 150                                                      SPEC 204
140       I=I+1                                                          SPEC 205
          GO TO 130                                                      SPEC 206
C                                                                        SPEC 207
C         Y IS THE LINEAR INTERPOLATION F(T). HENCE THE NEW              SPEC 208
C         SET OF EQUALLY SPACED ORDERED PAIRS ARE (T,Y)                  SPEC 209
C                                                                        SPEC 210
150       Y=(T-U(I))*(A(I+1)-A(I))/(U(I+1)-U(I))+A(I)                    SPEC 211
C                                                                        SPEC 212
C         WT = 2*PI*F*T  SWT = SIN(WT).   CWT = COS(WT).                 SPEC 213
C                                                                        SPEC 214
          WT =W*T                                                        SPEC 215
          SWT=SIN(WT)                                                    SPEC 216
          CWT=COS(WT)                                                    SPEC 217
C                                                                        SPEC 218
C         THIS SECTION APPLIES SIMPSON'S INTEGRATION FORMULA TO          SPEC 219
C         ORDERED PAIRS (T,V) AND (T,VP) AND STORES THE RESULTS          SPEC 220
C         IN X AND XP RESPECTIVELY. V AND VP ARE PARTS OF                SPEC 221
C         DUHAMEL'S INTEGRAL THAT ARE TO BE INTEGRATED.                  SPEC 222
C                                                                        SPEC 223
          V(K)=Y*SWT                                                     SPEC 224
          VP(K)=Y*CWT                                                    SPEC 225
          T=T+H                                                          SPEC 226
          IF(T.LT.0..OR.T.GT.UMAX+H) GO TO 300                           SPEC 227
C                                                                        SPEC 228
C         T HAS A TOLERANCE H/2 TO ASSURE THAT LAST POINT IS USED.       SPEC 229
C                                                                        SPEC 230
          IF(T.GT.S+H/2.) GO TO 160                                      SPEC 231
          K=K+1                                                          SPEC 232
          GO TO 110                                                      SPEC 233
C                                                                        SPEC 234
160       OD=0.                                                          SPEC 235
          EV=0.                                                          SPEC 236
          DO 170 J=2,K,2                                                 SPEC 237
          OD=OD+V(J)                                                     SPEC 238
170       EV=EV+V(J+1)                                                   SPEC 239
          EV=EV-V(K)                                                     SPEC 240
          X=H3*(V(1)+V(K)+4.*OD+2.*EV)                                   SPEC 241
          OD=0.                                                          SPEC 242
          EV=0.                                                          SPEC 243
          DO 180 J=2,K,2                                                 SPEC 244
          OD=OD+VP(J)                                                    SPEC 245
180       EV=EV+VP(J+1)                                                  SPEC 246
          EV=EV-VP(K)                                                    SPEC 247
```

```
      XP=H3*(VP(1)+VP*(K)+4.*OD+2.*EV)
C
C     X1 AND X2 SUM TERMS SO THAT WE ARE INTEGRATING OVER
C     THE RANGE 0. TO S.
C
      X1=X1+X
      X2=X2+XP
C
C     NX IS THE INTEGRAL OF DUHAMEL'S EQUATION FOR THE
C     RANGE 0. TO S.
C
      NX=EXP(-DAMP*S*WD)*W*(SWS*X2-CWS*X1)
      IF (ABS(NX).LT..1E-06) NX=0
C
C     (T,NX) IS A POINT ON THE TIME HISTORY CURVE.
C
C     WHEN S .LT. UMAX THE PROGRAM INCREASES S BY DS AND
C     DECREASES T BY H. IT THEN RETURNS TO LOCATION 120
C     AND BEGINS TO INTEGRATE THE NEXT AREA.
C
      IF (S.EQ.0.) GO TO 190
      I=I-1
190   T=T-H
      IF(IRES.EQ.1) GO TO 200
C
C     TA STORES T
C
      TA(L)=T
C
C     XA STORES NX
C
      XA(L)=NX
      XPLT(M)=T
      YPLT(M)=NX
      L=L+1
      M=M+1
200   K=1
      IF ((S-UMAX).GE.-.1E-10)GO TO 210
      S=S+DS
      GO TO 120
C
C     NXP IS THE DERIVATIVE OF THE TIME HISTORY AT UMAX.
C
210   ST=W*(T-S)
      SWST=SIN(ST)
      CWST=COS(ST)
      TT=T-S
      NXP=EXP(-DAMP*WD*TT)*W*W*(X1*SWST+X2*CWST)
     * +EXP(-DAMP*WD*TT)*W*(DAMP*WD)*(-X2*SWST+X1*CWST)
C
```

```
C      XMAX IS THE MAXIMUM VALUE OF THE RESIDUAL SPECTRUM
C
       XMAX=SQRT(NX*NX+NXP*NXP/W/W)
C
       L=1
220    ST=WD*(T-S)
       SWST=SIN(ST)
       CWST=COS(ST)
       TT=T-S
C
C      (TB,XB) ARE ORDERED PAIRS FOR THE RESIDUAL TIME HISTORY
C
       XB(L)=EXP(-DAMP*WD*TT)*(NXP*SWST/WD+NX*CWST)
       TB(L)=T
       XPLT(M)=T
       YPLT(M)=XB(L)
       M=M+1
       L=L+1
       IF(T.GE.3.*UMAX) GO TO 230
       T=T+DS
       GO TO 220
230    M=M-1
       IF(IPLOT.NE.1) GO TO 240
       READ(5,1100) TIT4
C
C      PLOT TIME HISTORY OF INDIVIDUAL FREQUENCY
C
       LST=1
       LSP=M
       CALL DATA4(NCURV,XPLT,YPLT,DUM,M,ISC,ITYPE,LST,LSP,
      * TIT4,ICOLOR)
C
C      THIS SECTION FINDS MAGNITUDE OF PRIMARY TIME HISTORY
C      (MAXP) AND MAGNITUDE OF RESIDUAL TIME HISTORY (MAXR)
C
240    MAXP=XA(1)
       MAXR=XB(1)
       DO 250 I=1,L
       IF(XA(I).LE.MAXP) GO TO 250
       MAXP=XA(I)
250    CONTINUE
       DO 260 I=1,L
       IF(XB(I).LE.MAXR) GO TO 260
       MAXR=XB(I)
260    CONTINUE
C
C      THIS SECTION STORES DATA FOR 3-D PLOT
C
       MSAVE(NP)=M
       IF(NP.EQ.1.AND.I3D.EQ.1) WRITE(2)DS
```

```
      IF (I3D.EQ.1) WRITE(2) M,(XPLT(I),I=1,M),(YPLT(I),I=1,M)
C
      IF(IFREQ.EQ.1) F=(F*UMAX)/TCAL
C
C     THIS SECTION CONVERTS FREQUENCY TIMES PULSE
C     DURATION(FT) TO FREQUENCY, IF DESIRED, AND CONVERTS
C     FT TO LOG10 SCALE, IF DESIRED, AND STORES IT
C     ALONG WITH MAXR AND XMAX FOR PLOTTING.
C
      IF(IFREQ.EQ.1) FT=FT/TCAL
      IF(ILOG.NE.1) PFT(NP)=FT
      IF(ILOG.EQ.1) PFT(NP)=ALOG10(FT)
      RMAX(NP)=MAXR
      FR(NP)=F
      FWN(NP)=F0/TCAL
      PXP(NP)=MAXP
      PXR(NP)=MAXR
      NP=NP+1
C
C     AFTER THE CODE COMPUTES THE SPECTRUM FOR FMAX, IT
C     GOES TO THE PLOT SUBROUTINE. OTHERWISE, IT RESETS T,
C     I, AND S AND RETURNS TO LOCATION 90.
C
      IF(F0.GE.FMAX)  GO TO 270
      T=0
      I=1
      S=0
      GO TO 90
C
C     NP IS NO. OF FREQUENCIES USED. IT IS RESTRICTED TO
C     200 DUE TO DIMENSION STATEMENT
C
270   NP=NP-1
C
C     PLOT PRIMARY AND RESIDUAL SPECTRA
C
      IF(ISPEC.NE.1) GO TO 280
      READ(5,1100) TIT4
      ITYPE=1
      LST=1
      LSP=NP
      NCURV=2
      ISC=1
      IF(ISPEC.EQ.1)CALL DATA4(NCURV,PFT,PXP,PXR,NP,ISC,
     *ITYPE,LST,LSP,TIT4,ICOLOR)
      IF(IRES.EQ.1) NCURV=1
      IF(IRES.EQ.1) CALL DATA4(NCURV,PFT,PXR,DUM,NP,ISC,
     *ITYPE,LST,LSP,TIT4,ICOLOR)
      ITYPE=0
      ISC=0
```

```
C
C         PRINT HEADINGS AND DATA
C
280       WRITE(6,1200) PGTIT
          WRITE(6,1900)
          WRITE(6,2000)
          IF(IFREQ.EQ.1) WRITE(6,2100)
          IF(IFREQ.NE.1) WRITE(6,2200)
          WRITE(6,2500) (FR(I),PXP(I),RMAX(I),FWN(I),I=1,NP)
          WRITE(6,2300) NP
          REWIND 2
          DO 290 I=1,1000
          V(I)=0.0
          VP(I)=0.
290       CONTINUE
          GO TO 10
300       WRITE(6,2400) T
          STOP
1000      FORMAT(2I5,3F10.3,F5.0,5I5,3I2)
1100      FORMAT(10A8)
1200      FORMAT(1H1,10A8,/)
1300      FORMAT(1H0,4(6X,'TIME',7X,'ACCELERATION',1X))
1400      FORMAT(1H ,4(6X,4HMSEC,11X,3HG'S,6X)/)
1500      FORMAT(8(1X,F14.5))
1600      FORMAT(8F10.3)
1700      FORMAT(1H1,'NORMALIZED INPUT DATA'/)
1800      FORMAT(2F10.3,I5)
1900      FORMAT('   PRIMARY AND RESIDUAL SPECTRA OF
         *ACCELERATION PULSE',//)
2000      FORMAT('   FREQUENCY',5X,'   RELATIVE
         *  ACCELERATION ACTUAL')
2100      FORMAT('       KHZ',13X,'PRIMARY    RESIDUAL
         *FREQUENCY')
2200      FORMAT(' X PULSE DURATION',5X,' PRIMARY
         *  RESIDUAL FREQUENCY')
2300      FORMAT('0NFILES = ',I5)
2400      FORMAT('0T<0 OR >  UMAX+H, T=',F10.3)
2500      FORMAT(F12.3,5X,3F12.5)
          END
C
C
C
          SUBROUTINE DATA4(NCURV,Z1,Z2,Z3,NPLT,ISC,ITYPE,LST,
         *LSP,TITLE,ICOLOR)
C
C         THIS SUBROUTINE SETS UP DATA AND LABELS FOR PLOT
C
          DIMENSION Z1(NPLT),Z2(NPLT),X(1000),Y1(1000),DUM(1),
         *Y2(1000),Z3(NPLT),LXNAME(3),LYNAME(3),TITLE(4)
          DUM(1)=1.E100
```

```
C
C        STORE DATA TO BE PLOTTED IN APPROPRIATE ARRAYS AND
C        COUNT DATA POINTS
C
         J=0
         DO 100 L=LST,LSP
         J=J+1
         X(J)=Z1(L)
         Y1(J)=Z2(L)
         Y2(J)=Z3(L)
100      CONTINUE
         IF(NCURV.LT.2) Y2(1)=DUM(1)
C
C        PRINT PLOT LIMITS
C
         WRITE(6,2) LST,LSP,X(1),X(J)
C
C        READ AND PRINT PLOT LABELS
C
         READ(5,3) LXNAME,LYNAME
         WRITE(6,3) LXNAME,LYNAME
C
C        CALL PLOT SUBROUTINE
C
         CALL DISS4(X,Y1,Y2,J,TITLE,ISC,ITYPE,LXNAME,LYNAME,
        *ICOLOR)
         RETURN
1        FORMAT(2F10.0)
2        FORMAT(' PLOT LIMITS - ',2I5,2F10.4)
3        FORMAT(10A8)
         END
C
C
         SUBROUTINE DISS4(X,Y1,Y2,NPT,TITLE,ISC,ITYPE,LXNAME,
        *LYNAME,ICOLOR)
C
C        THIS SUBROUTINE CREATES A DISSPLA 9 PLOT FILE
C
C
C        ISC=0 SELF-SCALE
C           =1 READ IN XORIG, XMAX, XSTP, YORIG, YMAX, YSTP
C
C        ITYPE=0 NORMAL PLOT
C             =1 X-LOG AXIS
C
C        ICOLOR=0 BLACK/WHITE
C              =1 COLOR
C
         DIMENSION X(NPT),Y1(NPT),Y2(NPT),RAT(10),LXNAME(3),
        * LYNAME(3),TITLE(4)
```

```fortran
C
C         DETERMINE PLOT SCALES
C
          IF(ISC.NE.0)GO TO 300
          XORIG=X(1)
          XSTP='SCALE'
          XMAX=X(NPT)
          YORIG=1.E100
          YSTP='SCALE'
          YMAX=-1.E100
          DO 200 I=1,NPT
          IF(Y1(I).LT.YMAX)GO TO 100
          YMAX=Y1(I)
100       IF(Y1(I).GT.YORIG)GO TO 200
          YORIG=Y1(I)
200       CONTINUE
          GO TO 400
300       READ(5,1)XORIG,XMAX,XSTP,YORIG,YMAX,YSTP
400       IF(ISC.EQ.1)WRITE(6,2)XORIG,XSTP,XMAX,YORIG,YSTP,YMAX
          IF(ISC.EQ.0)WRITE(6,2)XORIG,XMAX,YORIG,YMAX
          JJ=JJ+1
C
C         SET UP GRID
C
          CALL BASALF('STANDARD')
          CALL MIXALF('SPECIAL')
          CALL PHYSOR(1.5,1.)
          CALL PAGE(11.,8.5)
          CALL SETCLR('BLACK')
          XSIZE=8.0
          YSIZE=6.0
          CALL AREA2D(XSIZE,YSIZE)
C
C          LABEL PLOTS
C
          CALL HEIGHT(.25)
          CALL HEADIN(TITLE,32,1.1,1)
          CALL XNAME(LXNAME,24)
          CALL YNAME(LYNAME,24)
C
C         SET PLOT SCALES FOR LOG PLOT
C
          IF(ITYPE.NE.1) GO TO 500
          ICY=ALOG10(X(NPT))-ALOG10(X(1))+.5
          XCY=XSIZE/FLOAT(ICY)
          IF(ITYPE.EQ.1.AND.ISC.EQ.0)YSTP=(YMAX-YORIG)/YSIZE
          WRITE(6,3) XCY,YSTP,ICY
C
C         DRAW GRID
C
```

```
500   IF(ITYPE.EQ.0)CALL GRAF(XORIG,XSTP,XMAX,YORIG,
     *YSTP,YMAX)
      IF(ITYPE.EQ.1)CALL XLOG(XORIG,XCY,YORIG,YSTP)
      IMARK=0
      IF(ICOLOR.EQ.1)CALL SETCLR('BLUE')
C
C     PLOT DATA
C
      CALL CURVE(X,Y1,NPT,IMARK)
      IF(ICOLOR.EQ.1)CALL SETCLR('RED')
      TL=.5
      NMRK=10
      RAT(1)=2.
      RAT(2)=1.
      IF(ICOLOR.EQ.0)CALL MRSCOD(TL,NMRK,RAT)
      IF(Y2(1).NE.1.E100.AND.ITYPE.EQ.0)
     *CALL CURVE(X,Y2,NPT,IMARK)
      IF(Y2(1).NE.1.E100.AND.ITYPE.EQ.1)
     *CALL CURVE(X,Y2,NPT,IMARK)
      CALL RESET('DASH')
      CALL ENDPL(JJ)
      RETURN
1     FORMAT(6E10.3)
2     FORMAT(' PLOT SCALES - ',6E13.5)
3     FORMAT(' XCYCLE, YSTP, ICY =',2E13.5,I10)
      END
```

APPENDIX B

LISTING OF FORTRAN PROGRAM TO CREATE 3-D SHOCK RESPONSE PLOT ALONG WITH ASSOCIATED JOB CONTROL LANGUAGE FOR CRAY XMP/48

APPENDIX B

LISTING OF FORTRAN PROGRAM TO CREATE 3-D SHOCK RESPONSE PLOT ALONG WITH ASSOCIATED JOB CONTROL LANGUAGE FOR CRAY XMP/48

I. Job Control Language for CRAY XMP/48

JOB,JN=*jobname*,T=150,MFL=350000.
ACCOUNT,AC=*accountnumber*,US=*username*,UPW=*userpassword.*
ACCESS,DN=DISLIB,PDN=DISLIB,ID=DISSPLA,OWN=SYSTEM.
ACCESS,DN=DVSD,PDN=DVSD,ID=DISSPLA,OWN=SYSTEM.
ACCESS,DN=INTLIB,PDN=INTLIB,ID=DISSPLA,OWN=SYSTEM.
FETCH,DN=*3dfile*,TEXT='CHARGE,*acctno*, *pn*.GET, *3dfile*=*3dfile*.CTASK.',DF=BB.

where *3dfile* = name of input file which contains data for calculations for 3-D plot
pn = first two letters of account number

ASSIGN,DN=3dfile,A=FT01.
FETCH,DN=*infile*,TEXT='CHARGE,*acctno*, *pn*.GET, *infile*=*infile*.CTASK.'.

where *infile* = name of input file which contains program options and plot titles
pn = first two letters of the account number

ASSIGN,DN=*infile*,A=FT05.
CFT.
SEGLDR,CMD='LIB=DISLIB,INTLIB',GO.
DISPOSE,DN=META,DC=ST,DF=BB,^
TEXT='CHARGE=*acctno*, *pn*.CTASK.REPLACE,META=*pl3file*.'.

where *pl3file* = name of output file in which the DISSPLA plot file for 3-D plot is stored on the front end.

II. Listing of FORTRAN File

```
      PROGRAM DUHM3D(INPUT,OUTPUT,TAPE1,TAPE5,
     * TAPE6=OUTPUT,META,TAPE10=OUTPUT,TAPE2)
C
C     THIS PROGRAM READS FREQUENCY RESPONSE DATA AND
C     CREATES A 3-D SURFACE PLOT
C
C     THIS PROGRAM USES A DATA FILE CREATED BY A
C     DUHAMEL INTEGRAL PROGRAM AS INPUT
```

```
C
      DIMENSION TX(65),TY(65),TX1(65),TY1(65)
      DIMENSION TX2(65),TY2(65),TX3(65),TY3(65),TX4(65),TY4(65)
      DIMENSION OFF(50),OFFX(50),PARRAY(1500,4),RES(1500,4),
     * T1(4,4),XPT(1500),YPT(1500),TIT4(4),XPLT(1500),YPLT(1500),
     * T2(4,4)
C
      DATA OFF/1.,1.33,1.67,2.,2.5,3.,3.5,4.,5.,6.,7.,8.,9.,10.,13.3,
     *16.7,20.,25.,30.,35.,40.,50.,60.,70.,80.,90.,100.,133.33,166.67,
     *200.,250.,300.,350.,400.,500.,600.,700.,800.,900.,1000.,1333.3,
     *1666.67,2000.,2500.,3000.,4000.,5000.,6000.,7000.,8000./
C
C     INITIALIZE DISSPLA
C
      CALL COMPRS
      CALL SETDEV(10,6)
C
      ISC=1.
      ICOLOR=1
      IEP=1
C
C     NFILES(I5) = NUMBER OF FREQUENCY RESPONSE CURVES
C     MAXT  (I5) = MAXIMUM TIME OF RESPONSE PLOT
C          MAXT = 1, PRIMARY RESPONSE CURVE
C          MAXT = 2, PRIMARY RESPONSE PLUS PARTIAL RESIDUAL
C          MAXT = 3, PRIMARY RESPONSE PLUS FULL RESIDUAL
C
      READ(5,1000) NFILES,MAXT
      NF=NFILES
C
C     DS = TIME STEP READ FROM DATA FILE
C
      READ(1) DS
      WRITE(6,5000) DS
C
C     CALCULATE NUMBER AND INTERVAL OF TIME CURVES
C     TO BE PLOTTED
C
      K=(MAXT/DS)+1
      A=MAXT
      B=AMOD(A,DS)
      IF(B.GE..0)K=K+1
      KD=K/4
      J1=4
      J=MOD(K,J1)
      IF(J.GT.0)KD=KD+1
      KS=K/100
      J1=100
      J=MOD(K,J1)
      IF(J.GT.0)KS=KS+1
```

```
      KD2=2*KD                                                          DU3D  59
      KD3=3*KD                                                          DU3D  60
      KP=0                                                              DU3D  61
      WRITE(6,6000) KD,KS,K                                             DU3D  62
      IPSAVE=10000                                                      DU3D  63
C                                                                       DU3D  64
C     READ DATA AND STORE IN SEPARATE ARRAYS TO CREATE                  DU3D  65
C     DATA CURVES AT SPECIFIC TIME INTERVALS                            DU3D  66
C                                                                       DU3D  67
      DO 80 J=1,KD,KS                                                   DU3D  68
      IS=0                                                              DU3D  69
      DO 60 I=1,NF                                                      DU3D  70
      IS=IS+1                                                           DU3D  71
      IF(J.GT.1.AND.I.EQ.1) READ(1) DS                                  DU3D  72
      READ(1) M,(XPLT(N),N=1,M),(YPLT(N),N=1,M)                         DU3D  73
      IF(I.EQ.1.AND.J.EQ.1)WRITE(6,4000) (XPLT(N),N=1,M),(YPLT(N),N=1,M) DU3D  74
      IF(J.EQ.1.AND.I.EQ.1) GO TO 30                                    DU3D  75
10    IF((J+KD2).GT.IPSAVE) KP=1                                        DU3D  76
      TX(I)=XPLT(J)                                                     DU3D  77
      TY(I)=YPLT(J)                                                     DU3D  78
      TX1(I)=XPLT(J+KD)                                                 DU3D  79
      TY1(I)=YPLT(J+KD)                                                 DU3D  80
      TX2(I)=XPLT(J+KD2+KP)                                             DU3D  81
      TY2(I)=YPLT(J+KD2+KP)                                             DU3D  82
      TX3(I)=XPLT(J+KD3+KP)                                             DU3D  83
      TY3(I)=YPLT(J+KD3+KP)                                             DU3D  84
      IF((J+KS).GT.KD.AND.J.NE.KD) GO TO 20                             DU3D  85
      GO TO 60                                                          DU3D  86
20    IF(I.EQ.1) IEND=1                                                 DU3D  87
      TX4(I)=XPLT(K)                                                    DU3D  88
      TY4(I)=YPLT(K)                                                    DU3D  89
      GO TO 60                                                          DU3D  90
30    K1=1                                                              DU3D  91
      DO 40 IP=1,M                                                      DU3D  92
      IF((XPLT(IP+1)-XPLT(IP)).LT..001) IPSAVE=IP                       DU3D  93
      IF(ABS(MAXT-XPLT(IP)).LT..0001) GO TO 50                          DU3D  94
      K1=K1+1                                                           DU3D  95
40    CONTINUE                                                          DU3D  96
50    K=K1                                                              DU3D  97
      GO TO 10                                                          DU3D  98
60    CONTINUE                                                          DU3D  99
      REWIND 1                                                          DU3D 100
C                                                                       DU3D 101
C     STORE NEWLY CREATED DATA CURVES                                   DU3D 102
C                                                                       DU3D 103
      WRITE(2) IS,(TX(N),N=1,IS),(TY(N),N=1,IS)                         DU3D 104
      NFILES=NFILES+1                                                   DU3D 105
      WRITE(2) (TX1(N),N=1,IS),(TY1(N),N=1,IS)                          DU3D 106
      NFILES=NFILES+1                                                   DU3D 107
      WRITE(2) (TX2(N),N=1,IS),(TY2(N),N=1,IS)                          DU3D 108
```

```
      NFILES=NFILES+1
      WRITE(2) (TX3(N),N=1,IS),(TY3(N),N=1,IS)
      NFILES=NFILES+1
      WRITE(6,4000) (TX(N),N=1,8),(TY(N),N=1,8)
      IF (IEND.NE.1) GO TO 70
      WRITE(2) (TX4(N),N=1,IS),(TY4(N),N=1,IS)
      NFILES=NFILES+1
70    WRITE(6,2000) J
      IF (IEND.EQ.1) WRITE(6,3000)
80    CONTINUE
      REWIND 2
C
C     GENERATE OFFSET FACTORS FOR PLOTTING
C
      RMS=(ALOG10(OFF(NF))-ALOG10(OFF(1)))/(NF*.01)
      DO 90 I=1,NF
      OFFX(I)=(ALOG10(OFF(NF))-ALOG10(OFF(I))-NF*.01*RMS)/(-RMS)
90    CONTINUE
C
C     SET UP ARRAYS FOR CURVE ROTATION
C
      AX=1HY
      ANG=53
      CALL ROT1 (ANG,AX,T1)
      AX=1HX
      ANG=67
      CALL ROT1 (ANG,AX,T2)
C
C     READ DATA FROM FILES
C
      IMAXC=NFILES
      DO 180 II=1,NFILES
      J1=4
      J=MOD((II-NF),J1)
      MM=1
      IF(II.GT.NF) GO TO 100
      IF(II.EQ.1) READ(1) DS
      READ(1) M,(XPLT(I),I=1,M),(YPLT(I),I=1,M)
      GO TO 120
100   IF(J.EQ.1.AND.II.NE.NFILES)GO TO 110
      READ(2) (XPLT(I),I=1,M),(YPLT(I),I=1,M)
      GO TO 120
110   READ(2) M,(XPLT(I),I=1,M),(YPLT(I),I=1,M)
C
C     ROTATE DATA
C
120   DO 130 JJ=1,M
      PARRAY(MM,2)=YPLT(JJ)
      PARRAY(MM,1)=XPLT(JJ)
      PARRAY(MM,3)=0.
```

```
      PARRAY(MM,4)=1.
      MM=MM+1
      IF(II.GT.NF) GO TO 130
      IF(XPLT(JJ).GE.MAXT) GO TO 140
130   CONTINUE
140   MM=MM-1
      IA=MM
      IM=1500
      JM=4
      KM=4
      NM=1500
      CALL MATMPY(PARRAY,T1,RES,IA,JM,KM,IM,JM,NM)
      CALL MATMPY(RES,T2,PARRAY,IA,JM,KM,IM,JM,NM)
C
C     OFFSET DATA FOR PLOTTING
C
      DO 170 JJ=1,MM
      IF(II.LE.NF) GO TO 150
      OFFSETX=OFFX(JJ)
      OFFSET=OFF(JJ)
      IF(IEND.EQ.1.AND.II.EQ.NFILES.AND.JJ.EQ.MM)OFFSET=OFF(50)
      GO TO 160
150   OFFSETX=OFFX(II)
      OFFSET=OFF(II)
160   XPT(JJ)=PARRAY(JJ,1)+OFFSETX
      YPT(JJ)=PARRAY(JJ,2)-ALOG10(OFFSET)
170   CONTINUE
C
C     READ PLOT TITLE AND CALL PLOT ROUTINE
C
      IF(IEP.EQ.1) READ(5,7000) TIT4
      LST=1
      LSP=MM
      NPLT=1500
      CALL DATA4(XPT,YPT,NPLT,ISC,LST,LSP,TIT4,ICOLOR,IEP,IMAXC)
      IEP=IEP+1
180   CONTINUE
      CALL DONEPL
1000  FORMAT(2I5)
2000  FORMAT(' CYCLE NO. ',I5,' HAS BEEN STORED')
3000  FORMAT(' FINAL FILE HAS BEEN STORED')
4000  FORMAT(8F12.5)
5000  FORMAT('0DS= ',F30.20)
6000  FORMAT(' KD KS K ',3I10)
7000  FORMAT(10A8)
      STOP
      END

C
      SUBROUTINE ROT1(ANG,AX,T)
```

```
C                                                                    ROT1   2
C       THIS SUBROUTINE CREATES A MATRIX FOR ROTATION OF DATA        ROT1   3
C                                                                    ROT1   4
C                                                                    ROT1   5
        DIMENSION T(4,4)                                             ROT1   6
C                                                                    ROT1   7
C       CONVERT DEGREES TO RADIANS                                   ROT1   8
C                                                                    ROT1   9
        ANG=ANG*.01745329                                            ROT1  10
C                                                                    ROT1  11
C       ZEROING OUT THE T ARRAY                                      ROT1  12
C                                                                    ROT1  13
        DO 100 I=1,4                                                 ROT1  14
        DO 100 J=1,4                                                 ROT1  15
        T(I,J)=0.0                                                   ROT1  16
100     CONTINUE                                                     ROT1  17
        IF(AX.EQ.1HY) GO TO 200                                      ROT1  18
        IF(AX.EQ.1HZ) GO TO 300                                      ROT1  19
C                                                                    ROT1  20
C       X-AXIS ARRAY                                                 ROT1  21
C                                                                    ROT1  22
        T(2,3)=SIN(ANG)                                              ROT1  23
        T(2,2)=COS(ANG)                                              ROT1  24
        T(3,2)=-T(2,3)                                               ROT1  25
        T(3,3)=T(2,2)                                                ROT1  26
        T(1,1)=1.                                                    ROT1  27
        GO TO 400                                                    ROT1  28
C                                                                    ROT1  29
C       Y-AXIS ARRAY                                                 ROT1  30
C                                                                    ROT1  31
200     T(3,1)=SIN(ANG)                                              ROT1  32
        T(1,1)=COS(ANG)                                              ROT1  33
        T(1,3)=-T(3,1)                                               ROT1  34
        T(3,3)=T(1,1)                                                ROT1  35
        T(2,2)=1.                                                    ROT1  36
        GO TO 400                                                    ROT1  37
C                                                                    ROT1  38
C       Z-AXIS ARRAY                                                 ROT1  39
C                                                                    ROT1  40
300     T(1,3)=SIN(ANG)                                              ROT1  41
        T(1,1)=COS(ANG)                                              ROT1  42
        T(2,1)=-T(1,3)                                               ROT1  43
        T(2,2)=T(1,1)                                                ROT1  44
        T(3,3)=1.                                                    ROT1  45
400     RETURN                                                       ROT1  46
        END                                                          ROT1  47

C
        SUBROUTINE DATA4(Z1,Z2,NPLT,ISC,LST,LSP,TITLE,ICOLOR,        DAT4   1
       *IEP,IMAXC)                                                   DAT4   2
```

```
C
C         THIS SUBROUTINE SETS UP DATA FOR PLOTTING
C         AND CREATES A 3-D DISSPLA 9 PLOT FILE
C
          DIMENSION Z1(NPLT),Z2(NPLT),X(1000),Y1(1000),TITLE(4)
C
C         ISC=0 SELF-SCALE
C            =1 READ IN XORIG, XMAX, XSTP, YORIG, YMAX, YSTP
C
C         ICOLOR=0 BLACK/WHITE
C               =1 COLOR
C
C
C         STORE DATA TO BE PLOTTED IN APPROPRIATE ARRAYS AND
C         COUNT DATA POINTS
C
          J=0
          DO 10 L=LST,LSP
          J=J+1
          X(J)=Z1(L)
          Y1(J)=Z2(L)
10        CONTINUE
C
C         PRINT PLOT LIMITS
C
          WRITE(6,3000)LST,LSP,X(1),X(J)
          NPT=J
          IF(IEP.GT.1) GO TO 60
C
C         DETERMINE PLOT SCALES
C
          IF(ISC.NE.0)GO TO 40
          XORIG=X(1)
          XSTP='SCALE'
          XMAX=X(NPT)
          YORIG=1.E100
          YSTP='SCALE'
          YMAX=-1.E100
          DO 30 I=1,NPT
          IF(Y1(I).LT.YMAX)GO TO 20
          YMAX=Y1(I)
20        IF(Y1(I).GT.YORIG)GO TO 30
          YORIG=Y1(I)
30        CONTINUE
          GO TO 50
40        READ(5,1000)XORIG,XMAX,XSTP,YORIG,YMAX,YSTP
50        IF(ISC.EQ.1)WRITE(6,2000)XORIG,XSTP,XMAX,YORIG,YSTP,YMAX
          IF(ISC.EQ.0)WRITE(6,2000)XORIG,XMAX,YORIG,YMAX
          JJ=JJ+1
C
```

```
C          SET UP PLOTTING AREA                                         DAT4 53
C                                                                       DAT4 54
           CALL PHYSOR(1.5,1.)                                          DAT4 55
           CALL NOBRDR                                                  DAT4 56
           CALL PAGE(11.,8.5)                                           DAT4 57
           CALL SETCLR('BLACK')                                         DAT4 58
           XSIZE=9.0                                                    DAT4 59
           YSIZE=6.0                                                    DAT4 60
           CALL AREA2D(XSIZE,YSIZE)                                     DAT4 61
C                                                                       DAT4 62
C          PLOT TITLE                                                   DAT4 63
C                                                                       DAT4 64
           CALL HEIGHT(.25)                                             DAT4 65
           CALL HEADIN(TITLE,32,1.1,1)                                  DAT4 66
           CALL GRAF(XORIG,XSTP,XMAX,YORIG,YSTP,YMAX)                   DAT4 67
           IMARK=0                                                      DAT4 68
           IF(ICOLOR.EQ.1)CALL SETCLR('BLUE')                           DAT4 69
C                                                                       DAT4 70
C          PLOT DATA                                                    DAT4 71
C                                                                       DAT4 72
60         CALL CURVE(X,Y1,NPT,IMARK)                                   DAT4 73
           IF(IMAXC.EQ.IEP) CALL ENDPL(JJ)                              DAT4 74
           RETURN                                                       DAT4 75
1000       FORMAT(6E10.3)                                               DAT4 76
2000       FORMAT(' PLOT SCALES - ',6E13.5)                             DAT4 77
3000       FORMAT(' PLOT LIMITS - ',2I5,2F10.4)                         DAT4 78
           END                                                          DAT4 79
C
           SUBROUTINE MATMPY (A,B,C,I,J,K,L,M,N)                        MATMPY  1
C                                                                       MATMPY  2
C          A(I,J) B(J,K) ARE ACTUAL DIMENSIONS WITHIN                   MATMPY  3
C          MAX DIMENSIONS OF A(L,) B(M,) C(N,)                          MATMPY  4
C          REST OF RESULT C IS NOT SET TO ZERO                          MATMPY  5
C                                                                       MATMPY  6
           DIMENSION A(L,J),B(M,K),C(N,K)                               MATMPY  7
           DO 2 I2=1,K                                                  MATMPY  8
           DO 2 I1=1,I                                                  MATMPY  9
           C(I1,I2)=0.                                                  MATMPY 10
           DO 2 I3=1,J                                                  MATMPY 11
2          C(I1,I2)=C(I1,I2)+A(I1,13)*B(I3,I2)                          MATMPY 12
           RETURN                                                       MATMPY 13
           END                                                          MATMPY 14
```

DISTRIBUTION LIST

No. of Copies	Organization
12	Administrator Defense Technical Info Center ATTN: DTIC-DDA Cameron Station Alexandria, VA 22304-6145
1	Commander USA Concepts Analysis Agency ATTN: D. Hardison 8120 Woodmont Avenue Bethesda, MD 20014-2797
1	HQDA (SARD-TR) Washington, DC 20310
1	Commander US Army Laboratory Command ATTN: AMSLC-TD Adelphi, MD 20783-1145
1	HQDA, SARDA Washington, DC 20310-2500
1	Commander US Army War College ATTN: Library-FF229 Carlisle Barracks, PA 17013
1	US Army Ballistic Missile Defense Systems Command Advanced Technology Center P. O. Box 1500 Huntsville, AL 35807-3801
1	Commander US Army Watervliet Arsenal ATTN: SARWV-RD, R. Thierry Watervliet, NY 12189-5001
1	Chairman DOD Explosives Safety Board Room 856-C Hoffman Bldg. 1 2461 Eisenhower Avenue Alexandria, VA 22331-9999

No. of Copies	Organization
1	Commander US Army Materiel Command ATTN: AMCDRA-ST 5001 Eisenhower Avenue Alexandria, VA 22333-5001
1	Commander US Army Materiel Command ATTN: AMCDE-DW 5001 Eisenhower Avenue Alexandria, VA 22333-5001
5	Project Manager Cannon Artillery Weapons Systems, ARDEC, AMCCOM ATTN: AMCPM-CW, F. Menke AMCPM-CWW AMCPM-CWS, M. Fisette AMCPM-CWA, R. DeKleine H. Hassmann Dover, NJ 07801-5001
2	Project Manager Munitions Production Base Modernization and Expansion ATTN: AMCPM-PBM, A. Siklosi AMCPM-PBM-E, L. Laibson Dover, NJ 07801-5001
3	Project Manager Tank Main Armrment Systems ATTN: AMCPM-TMA, K. Russell AMCPM-TMA-105 AMCPM-TMA-120 Dover, NJ 07801-5001
1	Commander Armament R&D Center US Army AMCCOM ATTN: SMCAR-MSI Picatinny Arsenal, NJ 07806-5000
1	Commander US Army Materiel Command ATTN: AMCPM-GCM-WF 5001 Eisenhower Avenue Alexandria, VA 22333-5001

DISTRIBUTION LIST

No. of Copies	Organization
4	Commander Benet Weapons Laboratory Armament R&D Center US Army AMCCOM ATTN: SMCAR-LCB-TL SMCAR-LCB, E. Hyland R. Hassenbein SMCAR-LCB-I, D. Spring Watervliet, NY 12189-5001
4	Commander US Army Armament Munitions and Chemical Command ATTN: SMCAR-ESP-L Rock Island, IL 61299
1	Commander US Army Aviation Systems Command ATTN: AMSAV-DACL 4300 Goodfellow Blvd. St. Louis, MO 63120-1702
1	HQDA DAMA-ART-M Washington, DC 20310-2500
1	Director US Army Aviation Research and Technology Activity Ames Research Center Moffett Field, CA 94305-1099
1	Commander US Army Harry Diamond Lab ATTN: DELHD-TA-L 2800 Powder Mill Road Adelphi, MD 20783-1145
1	Commander US Army Missile and Space Intelligence Center ATTN: AIAMS-YDL Redstone Arsenal, AL 35898-5500
20	Commander Armament R&D Center US Army AMCCOM ATTN: SMCAR-TSS SMCAR-TDC SMCAR-LC, LTC N. Baron SMCAR-LCA, A. Beardell D. Downs S. Einstein S. Westley S. Bernstein C. Roller J. Rutkowski SMCAR-LCE SMCAR-LCM-E, S. Kaplowitz SMCAR-LCS SMCAR-LCU-CT, E. Barrieres R. Davitt SMCAR-LCU-CV, C. Mandala SMCAR-LCW-A, M. Salsbury SMCAR-SCA, L. Stiefel B. Brodman Picatinny Arsenal, NJ 07806-5000
1	Commander US Army TSARCOM 4300 Goodfellow Blvd. St. Louis, MO 63120-1702
1	Commander US Army Communications Electronics Command ATTN: AMSEL-ED Ft. Monmouth, NJ 07703-5301
1	Commander ERADCOM Technical Library ATTN: DELSD-L (Reports Section) Fort Monmouth, NJ 07703-5301
1	Commander US Army Missile Command ATTN: AMSMI-AS Redstone Arsenal, AL 35898-5000

DISTRIBUTION LIST

No. of Copies	Organization
1	Commander US Army Missile Command ATTN: AMSMI-RD Redstone Arsenal, AL 35898-5500
1	Commandant US Army Aviation School ATTN: Aviation Agency Fort Rucker, AL 36360
1	Commander US Army Tank Automotive Command ATTN: AMSTA-DI AMSTA-CG Warren, MI 48090
1	Project Manager Improved TOW Vehicle ATTN: AMCPM-ITV US Army Tank Automotive Command Warren, MI 48397-5000
2	Program Manager M1 Abrams Tank System ATTN: AMCPM-GMC-SA, T. Dean Warren, MI 48092-2498
1	Project Manager Fighting Vehicle Systems ATTN: AMCPM-FVS Warren, MI 48092-2498
1	Commandant US Army Infantry School ATTN: ATSH-CD-CSO-OR Fort Benning, GA 31905
1	Office of Naval Research ATTN: Code 473, R.S. Miller 800 N. Quincy Street Arlington, VA 22217-9999

No. of Copies	Organization
1	President US Army Armor & Engineer Board ATTN: ATZK-AD-S Fort Knox, KY 40121-5200
1	Project Manager M-60 Tank Development ATTN: AMCPM-M60TD Warren, MI 48092-2498
1	Director US Army TRADOC Analysis Command ATTN: ATAA-SL White Sands Missile Range, NM 88002
1	Commander US Army Training & Doctrine Command ATTN: ATCD-MA/Maj Williams Fort Monroe, VA 23651
4	Commander US Army Materials and Mechanics Research Center ATTN: Director (3 cys) AMXMR-ATL, Tech Library Watertown, MA 02172
4	Commander US Army Research Office ATTN: Tech Library (1 cy) Technical Director Engineering Division Metallurgy & Materials Division P. O. Box 12211 Research Triangle Park, NC 27709-2211
1	Commander US Army Belvoir Research & Development Center ATTN: STRBE-WC Fort Belvoir, VA 22060-5606

DISTRIBUTION LIST

No. of Copies	Organization
1	Commandant US Army Command and General Staff College Fort Leavenworth, KS 66027
1	Commandant US Army Special Warfare School ATTN: Rev & Tng Lit Div Fort Bragg, NC 28307
3	Commander Radford Army Ammunition Plant ATTN: SMCRA-QA/HI LIB Radford, VA 24141-0298
1	Commander US Army Foreign Science and Technology Center ATTN: AMXST-MC-3 220 Seventh Street, NE Charlottesville, VA 22901-5396
1	Commander Naval Research Lab Tech Library Washington, DC 20375
5	Commander Naval Surface Weapons Center ATTN: Code G33, J.L. East W. Burrell J. Johndrow Code G23, D. McClure Code DX-21 Tech Lib Dahlgren, VA 22448-5000
2	Commander US Naval Surface Weapons Center ATTN: J.P. Consaga C. Gotzmer Indian Head, MD 20640-5000
1	Commander US Army Logistics Mgmt Ctr Defense Logistics Studies Fort Lee, VA 23801
1	President US Army Artillery Board Fort Sill, OK 73503-5600
3	Commandant US Army Armor School ATTN: ATZK-CD-MS M. Falkovitch Armor Agency Fort Knox, KY 40121-5215
2	Commander Naval Sea Systems Command ATTN: SEA 62R SEA 64 Washington, DC 20362-5101
1	Commander Naval Air Systems Command ATTN: AIR-954-Tech Lib Washington, DC 20360
1	Assistant Secretary of the Navy (R, E, and S) ATTN: R. Reichenbach Room 5E787 Pentagon Bldg. Washington, DC 20350
2	Commandant US Army Field Artillery Center and School ATTN: ATSF-CO-MW, B. Willis Fort Sill, OK 73503-5600
1	Commander US Army Development and Employment Agency ATTN: MODE-TED-SAB Fort Lewis, WA 98433-5099

DISTRIBUTION LIST

No. of Copies	Organization
4	Commander Naval Surface Weapons Center ATTN: S. Jacobs/Code 240 Code 730 K. Kim/Code R-13 R. Bernecker Silver Springs, MD 20903-5000
2	Commanding Officer Naval Underwater Center Energy Conversion Dept. ATTN: Code 5B331, R.S. Lazar Tech Library Newport, RI 02840
4	Commander Naval Weapons Center ATTN: Code 388, R.L.Derr C.F. Price T. Boggs Info. Sci. Div. China Lake, CA 93555-6001
2	Superintendent Naval Postgraduate School Department of Mechanical Engineering Monterey, CA 9343-5100
1	AFWL/SUL Kirtland AFB, NM 87117
1	NASA/Lyndon B. Johnson Space Center ATTN: NHS-22, Library Section Houston, TX 77054
1	AFELM, The Rand Corporation 1700 Main Street Santa Monica, CA 90401-3297
1	General Applied Sciences Lab ATTN: J. Erdos 77 Raynor Avenue Ronkonkama, NY 11779-6649

No. of Copies	Organization
6	Commander Naval Ordnance Station ATTN: P.L. Stang J. Birkett L. Torreyson T.C. Smith D. Brooks Tech Library Indian Head, MD 20640-5000
1	AFSC/SDOA Andrews AFB, MD 20334
1	AFRPL/DY, Stop 24 ATTN: J. Levine/DYCR R. Corley/DYC D. Williams/DYCC Edwards AFB, CA 93523-5000
1	AFRPL/TSTL (Tech Library) Stop 24 Edwards AFB, CA 93523-5000
1	AFATL/DLYV Eglin AFB, FL 32542-5000
1	AFATL/DLXP Eglin AFB, FL 32542-5000
1	AFATL/DLJE Eglin AFB, FL 32542-5000
1	Air Force Armament Lab ATTN: AFATL/DLODL Eglin AFB, FL 32542-5000
1	Program Manager AFOSR Directorate of Aerospace Sciences ATTN: L.H. Caveny Bolling AFB, DC 20332-0001
2	Calspan Corporation ATTN: C. Morphy P. O. Box 400 Buffalo, NY 14225-0400

DISTRIBUTION LIST

No. of Copies	Organization
1	AAI Corporation ATTN: J. Hebert J. Frankle P. O. Box 6767 Baltimore, MD 21204
1	Hercules, Inc Allegheny Ballistics Laboratory ATTN: R. B. Miller P. O. Box 210 Cumberland, MD 21501-0210
1	Aerojet Ordnance Company ATTN: D. Thatcher 2521 Michelle Drive Tustin, CA 92680-7014
1	Aerojet Solid Propulsion Co. ATTN: P. Micheli Sacramento, CA 95813
1	Atlantic Research Corporation ATTN: M. K. King 5390 Cherokee Avenue Alexandria, VA 22312-2302
1	Honeywell, Inc. - MN64 2200 Defense Systems Division ATTN: C. Hargreaves 6110 Blue Circle Drive Minnetonka, MN 55436
1	Lawrence Livermore National Laboratory ATTN: L-355 A. Buckingham M. Finger P. O. Box 808 Livermore, CA 94550-0622
1	Lawrence Livermore National Laboratory ATTN: L-324 M. Constantino P. O. Box 808 Livermore, CA 94550-0622
10	Central Intelligence Agency Office of Central Reference Dissemination Branch Room GE-47 HQS Washington, DC 20505
1	General Electric Company Armament Systems Dept. ATTN: M. J. Bulman, Room 1311 128 Lakeside Avenue Burlington, VT 05401-4985
1	IITRI ATTN: M. J. Klein 10 W. 35th Street Chicago, IL 60616-3799
1	Hercules, Inc. Bacchus Works ATTN: K. P. McCarty P. O. Box 98 Magna, UT 84044-0098
1	Hercules, Inc. Radford Army Ammunition Plant ATTN: J. Pierce Radford, VA 24141-0299
1	AVCO Everett Rsch Lab ATTN: D. Stickler 2385 Revere Beach Parkway Everett, MA 02149-5936
1	Princeton Combustion Research Lab., Inc. ATTN: M. Summerfield 475 US Highway One Monmouth Junction, NJ 08852-9650
2	Rockwell International Rocketdyne Division ATTN: BA08 J.E. Flanagan J. Gray 6633 Canoga Avenue Canoga Park, CA 91303-2703

DISTRIBUTION LIST

No. of Copies	Organization
1	Olin Corporation Badger Army Ammunition Plant ATTN: R.J. Thiede Baraboo, WI 53913
1	Olin Corporation Smokeless Powder Operations ATTN: D.C. Mann P. O. Box 222 St. Marks, FL 32355-0222
1	Paul Gough Associates, Inc. ATTN: P. S. Gough P. O. Box 1614 1048 South St. Portsmouth, NH 03801-1614
1	Physics International Company ATTN: Library H. Wayne Wampler 2700 Merced Street San Leandro, CA 94577-5602
2	United Technologies Chemical Systems Division ATTN: R. Brown Tech Library P. O. Box 358 Sunnyvale, CA 94086-9998
1	Universal Propulsion Company ATTN: H. J. McSpadden Black Canyon Stage 1 Box 1140 Phoenix, AZ 85029
1	Battelle Memorial Institute ATTN: Tech Library 505 King Avenue Columbus, OH 43201-2693
1	Towson State University Department of Mathematics ATTN: Miss Margaret Zipp Towson, MD 21204

No. of Copies	Organization
1	Science Applications, Inc. ATTN: R.B. Edelman 23146 Cumorah Crest Drive Woodland Hills, CA 91364-3710
3	Thiokol Corporation Huntsville Division ATTN: D. Flanigan R. Glick Tech Library Huntsville, AL 35807
1	Scientific Research Associates, Inc. ATTN: H. McDonald P. O. Box 498 Glastonbury, CT 06033-0498
1	Veritay Technology, Inc ATTN: E. Fisher 4845 Millersport Hwy. P. O. Box 305 East Amherst, NY 14051-0305
2	Thiokol Corporation Elkton Division ATTN: R. Biddle Tech Library P. O. Box 241 Elkton, MD 21921-0241
1	BLM Applied Mechanics Consultants ATTN: Dr. A. Boresi 3310 Willett Drive Laramie, WY 82070
1	S & D Dynamics, Inc. ATTN: Dr. M. Soifer Suite 210 Deerfield Beach, FL 33442
1	Southwest Research Institute ATTN: P. Cox 8500 Culebra Road San Antonio, TX 78228

DISTRIBUTION LIST

No. of Copies	Organization
2	University of Delaware Department of Mathematics Department of Mechanical Engineering Newark, DE 19711
1	Brigham Young University Dept. of Chemical Engineering ATTN: M. Beckstead Provo, UT 84601
1	California Institute of Technology 204 Karman Lab Main Stop 301-46 ATTN: F.E.C. Culick 1201 E. California Street Pasadena, CA 91109
1	California Institute of Technology Jet Propulsion Laboratory ATTN: L.D. Strand 4800 Oak Grove Drive Pasadena, CA 91109-8099
1	University of Illinois Dept of Mech/Indust Eng ATTN: H. Krier 144 MEB; 1206 N. Green St. Urbana, IL 61801-2978
1	University of Illinois Department of Mathematics ATTN: Dr. Evelyn Frank Urbana, IL 61801
1	University of Southern California Mechanical Engineering Dept ATTN: OHE200, M. Gerstein Los Angeles, CA 90089-5199
2	University of Utah Dept. of Chemical Engineering ATTN: A. Baer G. Flandro Salt Lake City, UT 84112-1194
1	Stanford University Stanford Linear Accelerator Center ATTN: Eric Grosse, Numerical Analysis Consultant ALAC, P. O. Box 4349 Stanford, CA 94305
1	University of Massachusetts Dept. of Mechanical Engineering ATTN: K. Jakus Amherst, MA 01002-0014
1	University of Minnesota Dept. of Mechanical Engineering ATTN: E. Fletcher Minneapolis, MN 55414-3368
1	Case Western Reserve University Division of Aerospace Sciences ATTN: J. Tien Cleveland, OH 44135
1	Georgia Institute of Technology School of Aerospace Engineering ATTN: B.T. Zinn E. Price W. C. Strahle Atlanta, GA 30332
1	Institute of Gas Technology ATTN: D. Gidaspow 3424 S. State Street Chicago, IL 60616-3896
1	Johns Hopkins University Applied Physics Laboratory Chemical Propulsion Information Agency ATTN: T. Christian Johns Hopkins Road Laurel, MD 20707-0690

DISTRIBUTION LIST

No. of Copies	Organization
3	University of Wisconsin-Madison Mathematics Research Center ATTN: Dr. John Nohel Dr. Carl de Boor Dr. George Box 610 Walnut Street Madison, WI 53706
1	University of Kentucky Department of Computer Science ATTN: Prof. H.C. Thacher, Jr. 915 Patterson Office Tower Lexington, KY 40506
1	Virginia Commonwealth Univ. Department of Mathematical Sciences ATTN: Mr. V. Benokraitis 901 W. Franklin Richmond, VA 23284
1	Virginia Polytechnic Institute Dept. of Aerospace Engineering ATTN: Prof. G. Inger Blacksburg, VA 24061
1	Washington State University Dept. of Mechanical Engineering ATTN: C.T. Crowe Pullman, WA 99163-5201
1	Rensselaer Polytechnic Institute Department of Mathematics Troy, NY 12181
1	Rutgers University Dept. of Mechanical and Aerospace Engineering ATTN: S. Temkin University Heights Campus New Brunswick, NJ 08903

No. of Copies	Organization
1	Massachusetts Institute of Technology Dept. of Mechanical Engineering ATTN: T. Toong 77 Massachusetts Ave. Cambridge, MA 02139-4307
1	G. M. Faeth Pennsylvania State University Applied Research Laboratory University Park, PA 16802-7501
1	Pennsylvania State University Dept. of Mechanical Engineering ATTN: K. Kuo University Park, PA 16802-7501
1	Purdue University School of Mechanical Engineering ATTN: J. R. Osborn TSPC Chaffee Hall West Lafayette, IN 47907-1199
1	SRI International Propulsion Sciences Division ATTN: Tech Library 333 Ravenswood Ave. Menlo Park, CA 94025-3493
1	Stevens Institute of Technology Davidson Laboratory ATTN: R. McAlevy, III Castle Point Station Hoboken, NJ 07030-5907

DISTRIBUTION LIST

Aberdeen Proving Ground

Director, USAMSAA
ATTN: AMXSY-D
AMXSY-MP, H. Cohen

Commander, USATECOM
ATTN: AMSTE-TO-F

Commander, USACSTA
ATTN: STECS-CC-P

Commander, CRDC, AMCCOM
ATTN: SMCCR-RSP-A
SMCCR-MU
SMCCR-SPS-IL

TRADOC Liaison Office
Ryan Building