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TECHNICAL MEMORANDUM 1404

A DIGITAL COMPUTER PROGRAM  
FOR  
HIRSCHFELDER INTERIOR BALLISTICS

FORREST L. McMAINS

ACMS 5523.11.565

COPY 39 OF 51

APRIL 1964

PICATINNY ARSENAL  
DOVER, NEW JERSEY

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BY

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The author is grateful to Sidney Bernstein and Stuart Levy of the Artillery Ammunition Laboratory for originating the idea of writing the program and supplying the data to test it.

### ABSTRACT

A digital computer program was written which will perform interior ballistic calculations on an IBM 709 or IBM 7090. A brief description is given as well as an outline of the method of analysis which this program uses. Examples are presented and both input and output formats are discussed.

### CONCLUSIONS

It is not the purpose of this report to evaluate or verify the accuracy of the Hirschfelder System on Interior Ballistics. Its only purpose is to describe a digital computer program which will perform the Hirschfelder calculations.

The reader will note that the results of the hand calculations given in Part IV correspond exactly to the computer results given in Appendix B.

## INTRODUCTION

This report describes a digital computer program for performing the interior ballistic calculations of J. O. Hirschfelder.

The Hirschfelder System was developed between 1942 and 1945 and makes these basic assumptions:

1. A "first-degree burning law" is used in finding solutions to the fundamental ballistic equations.
2. The powder gas is distributed according to Kent's solution of the problem of the motion of the powder gas.
3. The heat lost to the bore up to any instant is proportional to the square of the velocity.
4. The friction of the projectile is taken as equivalent to a resisting pressure on the base of the projectile which is equal to a constant fraction of the average pressure.

This report's findings are divided into four parts:

The first part discusses the input and output formats.

The second part is devoted to a study of the basic equations used in the program. (It is assumed that the calculations found in Part II will be used in conjunction with Reference 1.)

The third part is a brief presentation of program logic.

In Part IV an example is given in which Cases 2, 3 and 4 are presented.

The program will solve four different types of problems (cases). In Case 1, various  $\phi$ 's are given along with maximum pressure and the computer will find velocity and web. In Case 2, charge and maximum pressure are given and web and velocity are found. In Case 3, charge and velocity are given and web and maximum pressure are found. In Case 4, charge, velocity and web are given and the burning constant is found.

The appendices include tables giving propellant codes and constants, the program output for the example given in Part IV and also the complete Fortran Program.

The reference used is a revision and consolidation of seven progress reports on interior ballistics written by J. O. Hirschfelder and others of the staff of the Geophysical Laboratory, Carnegie Institution of Washington (Reference 1).

## DISCUSSION

### PART I - INPUT AND OUTPUT FORMATS

#### Input Format

The first 104 data cards will be the same for any group of runs. These cards incorporate constant tabular values (Part III of this report).

Following this set of cards, any number of runs may be included provided each run is in correct sequence. For each run, the following format is used.

#### Card 1

Space 1 is reserved for a numerical code giving the type of problem to be solved. "1" means that maximum pressure and parameters  $\phi$ 's are given and web and velocity are to be found. "2" means that charge and pressure are given and web and velocity are to be found. "3" means that charge and velocity are given and maximum pressure and web are to be found. "4" means that charge, velocity and web are given and the burning constant is to be found.

Spaces 2 and 3 are reserved for a numerical code which denotes the propellant to be used in accordance with Table 1. The propellant constants are (given in Table 2) automatically selected from the memory of the machine. If no propellant code is specified or if it is given as "99," these constants must be given as part of the data, appearing on Card 2 below.

Space 4 is reserved for the code form function. A "1" denotes a propellant of single perforation. A "2" denotes a multiperforated propellant (for example, seven-perforated grains).

Space 5 is reserved for the number N of  $\phi$ 's used. Since the maximum number of  $\phi$ 's used is five,  $0 < N \leq 5$ , Space 6 is left blank and Spaces 7-12 are reserved for the weapon in millimeters.

Spaces 13-18 are reserved for the projectile weight in pounds.

Spaces 19-24 are reserved for the chamber volume in cubic inches.

Spaces 25-30 are reserved for the travel in inches.

Spaces 31-36 are reserved for the maximum pressure in psi.

Spaces 37-42 are reserved for the charge in pounds.

Spaces 43-48 are reserved for the muzzle velocity in ft/sec.

Spaces 49-54 are reserved for the web in inches.

Spaces 55-62 are reserved for the burning constant.

Spaces 63-64, 65-66, 67-68, 69-70, 71-72 are reserved for the values of  $\phi$ 's.

Card 2 (This card is only required if no propellant code -  
Spaces 2 and 3 above - is given or is given as "99.")

Spaces 1-6 are reserved for the propellant constant  $a$ .

Spaces 7-12 are reserved for the propellant constant  $a^0$ .

Spaces 13-18 are reserved for the propellant density in lbs/in<sup>3</sup>.

Spaces 19-24 are reserved for the propellant co-volume in in<sup>3</sup>/lbs.

Spaces 25-30 are reserved for the propellant force in ft-lbs/lb.

Most of these values must be punched on the card with a decimal point. The exceptions are:

The codes: Spaces 1-4.

The burning constant which may be given to eight significant digits.

The  $\phi$ 's less than unity. The values for  $\phi$  are 0.05, 0.10, 0.05, ..., 0.95, 1.00 and are punched as 05, 10, 15, ..., 95, 1.

### Output Format

The output will list all input data as well as the calculated loading densities, tabular values  $\delta$  and  $z$ ; velocities, pressures, web or burning constants depending on the problem being solved. If the problem is of Type 1 or 2 and the  $\phi$ 's given as input do not result in optimum efficiency, consecutive  $\phi$ 's are tried in an effort to improve the results.

$\phi$ ,  $P_p$ ,  $E_m$ ,  $\delta$ ,  $z$  are referred to as "PHI," "PP $\phi$ ," "XIM," "GAMMA" and "ZS" respectively.

An example of this program's output is in Appendix B.

## PART II - NUMERICAL CALCULATIONS

Let W denote the weapon (caliber) in millimeters.

Let M denote the projectile weight in lbs.

Let  $V_c$  denote the chamber volume in  $\text{in}^3$ .

Let L denote the length of travel in  $\text{in}^3$ .

Let PMAX denote the maximum pressure in psi.

Let POPR denote the operating pressure in psi.

Let B denote the burning constant in  $(\text{in}/\text{sec})/\text{psi}$ .

Let C denote the charge in lbs.

Let WEB denote the web in inches.

Let  $\Delta$  denote the loading density in  $\text{gms}/\text{cc}$ .

Let  $V_m$  denote the velocity in  $\text{ft}/\text{sec}$ .

The following are constant for the propellant. Their values are given in Table 2 of Appendix A.

Let a and  $a^0$  denote the two "propellant constants" in  $\text{in}^3/\text{lb}$ .

Let  $\rho$  denote the propellant density in  $\text{lbs}/\text{in}^3$ .

Let  $\eta$  denote the propellant covolume in  $\text{in}^3/\text{lb}$ .

Let F denote the propellant force in  $\text{ft}\text{-lbs}/\text{lb}$ .

If C is given (Cases 2, 3 and 4),  $\Delta$  (the loading density) is obtainable:  
 $\Delta = C/V_c$

To facilitate the calculations, the parameter  $\phi$  is used and is equal to the value:  $a / (\frac{1}{\Delta} - \frac{1}{\rho})$

From  $\phi = a / (\frac{1}{\Delta} - \frac{1}{\rho})$ , the equalities

$$\phi \left( \frac{1}{\Delta} - \frac{1}{\rho} \right) = a$$

$$\frac{1}{\Delta} - \frac{1}{\rho} = \frac{a}{\phi}$$

$$\frac{1}{\Delta} = \frac{1}{\rho} + \frac{a}{\phi}$$

$$\Delta = 1 / \left( \frac{1}{\rho} + \frac{a}{\phi} \right)$$

are derived. Therefore, if n  $\phi$ 's are chosen,  $\phi_1, \dots, \phi_n$  (as in Case 1)

and C is not given, each of the n  $\Delta$ 's are calculable:

$$\Delta_i = 1 / \left( \frac{1}{\rho} + \frac{a}{\phi_i} \right)$$

and hence  $C_i = \Delta_i \cdot V_c, i = 1, \dots, n$

Let A denote the bore area of the projectile.

$$A = \left( \frac{w}{25.4} \cdot \frac{1}{2} \right)^2 \cdot \pi$$

Let  $X = (V_c + A \cdot L) / V_c$

Let  $\xi_m = (a \Delta) / (X - \eta \Delta)$

Let  $P_{pi}^0 = a^0 P_{MAX} \left( \frac{M + \frac{C_i}{3}}{M + \frac{C_i}{2}} \right)$  where

$P_{MAX} = 1.15 \text{ POPR}$

Knowing the value of  $\phi_i$  and  $P_{pi}^0$ , the values of  $Z_i$  and  $\delta_i$  for each  $i$  are now obtainable from Tables 4, 6, 8 and 10 in Reference 1. Tables 4 and 6 give  $Z_i$  and  $\delta_i$ , respectively, for single-perforated propellants. Table 8 and 10 give  $Z_i$ , and  $\delta_i$ , respectively, for seven-perforated propellants.

$$\text{Let } m_i' = \frac{102(m + \frac{C_i}{3.1})}{32.175}$$

The velocity  $V_{m_i}$  is then equal to the value

$$\sqrt{(1 - \delta_i \xi_m^{0.3}) \frac{2C_i F}{0.3m_i'}}, \quad i = 1, \dots, n$$

Consider the case (Case 3) when C and  $V_m$  are given. Here  $C_i = C$  for each  $i$  and  $\phi_i, P_{pi}^0, Z_i, \delta_i$  and  $m_i'$  all have the single values  $\phi, P_p^0, Z, \delta$ ; and  $m'$  respectively.

Therefore, since  $V_m = \sqrt{(1 - \delta \xi_m^{0.3}) \frac{2CF}{0.3m'}}$

$$V_m^2 = (1 - \delta \xi_m^{0.3}) \frac{2CF}{0.3m'}$$

$$(\delta \xi_m^{0.3}) \frac{2CF}{0.3m'} = \frac{2CF}{0.3m'} - V_m^2$$

$$\delta = \left( \frac{CF}{0.15m'} - V_m^2 \right) \frac{0.15m'}{\xi_m^{0.13} \cdot CF}$$

$$\delta = \left( 1 - \frac{0.15m' V_m^2}{CF} \right) / \xi_m^{0.3}$$

Knowing  $\delta$  and  $\phi$ ,  $P_p^0$  is obtainable from Tables 6 or 10.

$$\text{From } P_p^0 = a^0 \text{ PMAX} \left[ \frac{M + \frac{c}{3}}{M + 2} \right]$$

$$\text{we find } \text{PMAX} = \frac{P_p^0}{a^0} \left[ \frac{M + 2}{M + 3} \right]$$

Knowing  $P_p^0$  and  $\phi$ ,  $Z$  is obtainable from Table 4 or 6

$$\text{Let } \xi_m^{0.3} = S$$

$$\text{Let } (1 - 0.1485 Z) / \delta = T_s$$

$$\text{Let } (1 - 0.242 Z) / \delta = T_m$$

When a single-perforated propellant is used,  $T_s$  is calculated and the point of optimum efficiency is when  $S$  and  $T_s$  are equal. In this case

$$\text{WEB} = (B/A) \sqrt{\frac{CFm'Z}{0.99}}$$

However, when a multiperforated propellant is used,  $T_m$  is calculated and the point of optimum efficiency is when  $S$  and  $T_m$  are equal. In this case

$$\text{WEB} = (B/A) \sqrt{\frac{CFm'Z}{1.369}}$$

### PART III - PROGRAM LOGIC

Tables 8, 10, 4 and 6 of Reference 1 appear in the first 104 data cards. As  $I = 1, 20$  and  $J = 1, 47$ ; Cards 1-24 give  $A(I, J)$ , the values in Table 8. Cards 25-48 give  $C(I, J)$ , the values in Table 10. Cards 49-76 give  $E(I, J)$ , the values in Table 4 and Cards 77-104 give  $F(I, J)$ , the values in Table 6.  $I = Pp^0/2,000$  where  $Pp^0 = 2,000, 4,000, 6,000, \dots, 90,000, 95,000, 100,000$ .  $J = 20\phi$  where  $\phi = 0.05, 0.10, \dots, 0.95, 1.0$ .

Linear interpolations were made within these tables when  $\delta$  and  $Z$  are known and  $Pp^0$  is to be found. No attempt was made to interpolate between the  $\phi$ 's; instead, the tabular  $\phi$  closest to the calculated  $\phi$  has been selected.

PART IV -- EXAMPLES

90mm, Gun, M41

1. Gun constants

Projectile weight M ----- 12.65 lbs.  
 Chamber volume Vc ----- 300 in.<sup>3</sup>  
 Propellant Type ----- M17 (M.P.)  
 Total Travel L ----- 155 in.

2. Case 4

Given: Charge C ----- 8.58 lbs.  
 Maximum Pressure P<sub>MAX</sub> ----- 50,500 psi  
 Velocity V<sub>m</sub> ----- 4,000 f/s  
 Web ----- 0.052 in.

$$\Delta = \frac{c}{V_c} = \frac{8.58}{300} = 0.0286$$

$$\phi = \frac{a}{\frac{1}{\Delta} - \frac{1}{P}} = \frac{12.92}{\frac{1}{0.0286} - \frac{1}{0.0603}} = \frac{12.92}{34.965 - 16.5837}$$

$$= \frac{12.92}{18.38126}$$

$$= 0.70289 \approx 0.70$$

(where a and  $\rho$  are found in Table 2 (9) of Appendix A).

$$P_p^0 = a^0 P_{MAX} \left[ \frac{M + \frac{c}{3}}{M + \frac{c}{2}} \right] = (0.851)(50,500) \left[ \frac{12.65 + \frac{8.58}{3}}{12.65 + \frac{8.58}{2}} \right]$$

$$= (42975.5) \cdot \left[ \frac{15.51}{16.94} \right]$$

$$= (42975.5)(0.915584) = 39347.697$$

(where a<sup>0</sup> is also found in Table 2).

$z = 1.763$  by Table 8 in Reference 1.

$$m' = \frac{1.02(M + \frac{c}{3.1})}{32.174} = \frac{1.02 \cdot (12.65 + \frac{8.58}{3.1})}{32.174}$$

$$= \frac{1.02(15.41777)}{32.174} = \frac{15.7261}{32.174}$$

$$= 0.48878$$

$$A = (\frac{90}{25.4} \cdot 0.5)^2 (3.1416) = (1.772)^2 (3.1416) = 9.8607$$

Since Web  $\approx (B/A) \sqrt{\frac{CFm'z}{1.369}}$

$$0.052 = \frac{B}{9.8607} \cdot \sqrt{\frac{(8.58)(364,000)(0.48878)(1.763)}{1.369}}$$

$$0.5127 = B \cdot \sqrt{\frac{2681157.356}{1.369}}$$

$$0.5118 = B \cdot \left( \frac{1637.424}{1.17} \right)$$

$$0.598806 = 1637.424 B$$

$$B = 0.0003657$$

### 3. Case 2

Given: Charge C ----- 8.58 lbs.  
Maximum Pressure P<sub>MAX</sub> ----- 50,500 psi

$$\Delta = 0.0286, \phi = 0.70; Pp^0 = 39347.697$$

$\delta = 1.410$  by Table 10 in Hirschfelder

$$A = 9.8607$$

$$X = \frac{V_c + A \cdot L}{V_c} = \frac{300 + (9.8607)(155)}{300} = \frac{1828.4085}{300}$$

$$= 6.0947$$

$$\begin{aligned}
 E_m &= \frac{(12.92)(0.0286)}{6.0947 - (29.50)(0.0286)} \\
 &= \frac{0.3695}{6.0947 - 0.8437} = \frac{0.3695}{5.251} = 0.07037
 \end{aligned}$$

$$S = E_m^{0.3} = 0.451$$

$$\begin{aligned}
 V_m &= \sqrt{(1 - \delta E_m^{0.3}) \frac{2CF}{0.3m^2}} \\
 &= \sqrt{(1 - (1.410)(0.451)) \cdot \frac{2(8.58)(364000)}{(0.3)(0.48878)}} \\
 &= \sqrt{(1 - 0.6359) \cdot \left(\frac{6246240}{0.14669}\right)} \\
 &= \sqrt{\frac{2274255.984}{0.14669}} \\
 &= \frac{1508.4577}{0.383} = 3938.532
 \end{aligned}$$

$$T_m = \frac{1 - 0.242 Z}{\delta} = \frac{1 - (0.242)(1.763)}{1.410} = \frac{0.57393}{1.410} = 0.407$$

Since  $S = 0.451 > 0.407 = T_m$ , burning is taking place outside the weapon. To attain optimum conditions, new and smaller  $\phi$ 's (and hence new charges) may be chosen in an effort to minimize  $|S - T_m|$ . This was done on the computer and the results are in Appendix B for Cases 1 and 2.

It is obvious that the web, calculated with  $B = 0.0003657$ , will be 0.052 since the equation for web was used in Case 4 to find B.

#### 4. Case 3

Given: Charge C ----- 8.58 lbs.  
Velocity  $V_m$  ----- 4,000 f/s

$$\delta = \left(1 - \frac{0.15m' Vm^2}{CF}\right) / \epsilon_m^{0.3}$$

$$= \frac{1 - \frac{(0.15)(0.48878)(4000)^2}{(8.58)(364,000)}}{0.451}$$

$$= \frac{1 - \frac{1173072}{3123120}}{0.451} = \frac{1 - 0.37561}{0.451} = \frac{0.62439}{0.451} = 1.384$$

Since  $\phi = 0.70$ ,  $Pp^o = 41561.1367$  by Table 10 in Reference 1.  
Therefore,  $Z = 1.693$

$$\begin{aligned} P_{MAX} &= \frac{Pp^o}{a^o} \left[ \frac{M + \frac{2}{c}}{M + \frac{3}{c}} \right] \\ &= \left( \frac{41561.1367}{0.851} \right) \left( \frac{12.65 + \frac{8.58}{2}}{12.65 + \frac{8.58}{3}} \right) \\ &= \left( \frac{41561.1367}{0.851} \right) \left( \frac{16.94}{15.51} \right) \\ &= (41561.1367)(1.2834) \\ &= 53340.792 \text{ psi} \end{aligned}$$

$Z = 1.693$  by Table 8 in the reference.

$$\begin{aligned} \text{Therefore, Web} &= \frac{0.0003657}{9.8607} \cdot \sqrt{\frac{(8.58)(364000)(0.48878)(1.693)}{1.369}} \\ &= \frac{0.0003657}{9.8607} \cdot \frac{\sqrt{258439597.29}}{1.17} \\ &= \frac{(0.0003657)(16076.0566)}{11.537} \\ &= \frac{0.05879}{11.537} \\ &= 0.005096 \end{aligned}$$

REFERENCE

1. C. F. Curtiss and J. W. Wrench Jr., Interior Ballistics: A Consolidation and Revision of Previous Reports, Interior Ballistics I to VII, Inclusive, July 1945, Geophysical Laboratory, Carnegie Institution of Washington, NDRC Report No. A-397, OSRD Report No. 6468.

APPENDICES

APPENDIX A

TABLES

TABLE 1  
PROPELLANT CODES

<u>Propellant</u>	<u>Code</u>
M1	1
M2	2
M5	5
M6	6
M9	9
M10	10
M14	14
M15	15
M17	17
T25	25
T28	28
T34	34
T36	36

In order for the propellant constants to be read in as part of the input (data Card 2), the code is "99."

TABLE 2

PROPELLANT CONSTANTS

In the following table,  $a$  and  $a^{\circ}$  represent the propellant "a" - constants;  $\rho$  represents the propellant density in  $\text{lbs}/\text{in}^3$ ,  $\mathcal{V}$  represents propellant covolume in  $\text{in}^3/\text{lbs.}$ , and  $F$  represents the propellant force in  $\text{ft. lbs}/\text{lbs.}$

Propellant	$a$	$a^{\circ}$	$\rho$	$\mathcal{V}$	$F$
M1	12.92	1.015	0.0567	30.57	305,000
M2	11.16	0.743	0.0597	27.91	360,000
M5	10.74	0.725	0.0596	27.52	355,000
M6	12.41	0.938	0.0571	29.92	317,000
M9	9.02	0.566	0.659	25.97	382,000
M10	11.15	0.788	0.0602	27.76	339,000
M14	12.36	0.906	0.058	29.54	327,000
M15	14.50	1.034	0.06	31.17	336,000
M17	12.92	0.851	0.0603	29.50	364,000
T25	11.57	0.786	0.0585	28.66	353,000
T28	11.68	0.786	0.0585	28.77	356,000
T34	14.07	1.007	0.0596	30.85	335,000
T36	12.59	0.828	0.06	29.26	364,000

APPENDIX B  
PROGRAM OUTPUT FOR CASES 1-4

I N P U T

CASE = 1  
 PROPELLANT CODE = 17  
 CODE FORM FUNCTION = 2  
 WEAPON W (MM) = 90.0000  
 PRØJ.WT. PJW (LBS.) = 12.6500  
 CHAMBER VØLUME VC (C.IN) = 300.0000  
 TRAVEL TRAV (IN) = 155.0000  
 MAX PRESSURE PMAX (PSI) = 50500.0000  
 ØPERATING PRESSURE PØPR (PSI) = 43913.0435  
 PRØP. CØVØLUME ETA (C.IN/LBS) = 29.5000  
 PRØP. DENSITY RHØ (LBS/C.IN) = 0.0603  
 PRØP. FØRCE F (FT.LBS/LBS) = 364000.0000  
 PRØP. CØNSTANTS A, AØ, = 12.9200  
 BURN.CØNSTANT B = 0.00036573  
 BØRE AREA = 9.8607  
 0.8510

Ø U T P U T

PHI	L.DENSITY	CHARGE	PPØ	XIM	GAMMA	ZS	VELØCITY	S	T	WEB
0.050	0.004	1.09	42383.3135	0.008	-0.	-0.	2534.419	0.234	0.	0.
0.300	0.017	5.03	40600.0542	0.039	1.527	0.758	3383.761	0.377	0.535	0.025117025
0.500	0.024	7.07	39846.1870	0.056	1.422	1.294	3808.135	0.422	0.483	0.039799377
0.700	0.029	8.56	39353.5654	0.070	1.410	1.763	3937.836	0.451	0.407	0.051929250

THE PØINT ØF ØPTIMUM EFFICIENCY IS WHEN S AND T ARE EQUAL

TRUE PHI IS GREATER THAN 0.5000 WHERE S = 0.4221 AND T = 0.4832

0.55	0.025	7.49	39704.6367	0.060	1.413	1.407	3861.345	0.430	0.467	0.042898998
0.60	0.026	7.87	39576.5127	0.064	1.404	1.531	3909.213	0.438	0.448	0.046060152
0.65	0.027	8.23	39459.9917	0.067	1.405	1.646	3929.880	0.445	0.428	0.049026169

I N P U T

CASE = 2  
 PROPELLANT CODE = 17  
 CODE FORM FUNCTION = 2  
 WEAPON W (MM) = 90.0000  
 PROJ.WT. PJW (LBS.) = 12.6500  
 CHAMBER VOLUME VC (C.IN) = 300.0000  
 TRAVEL TRAV (IN) = 155.0000  
 MAX PRESSURE PMAX (PSI) = 50500.0000  
 OPERATING PRESSURE POPR (PSI) = 43913.0435  
 PROJ. CUVOLUME ETA (C-IN/LBS) = 29.5000  
 PROJ. DENSITY RH0 (LBS/C.IN) = 0.0603  
 PROJ. FORCE F (FT-LBS/LBS) = 364000.0000  
 PROJ. CONSTANTS A, A0, = 12.9200  
 BURN-CONSTANT B = 0.00036573  
 BORE AREA = 9.8607  
 0.8510

O U T P U T

PHI	L.DENSITY	CHARGE	PP0	XIM	GAMMA	ZS	VELOCITY	S	T	WEB
0.70	0.029	8.58	39347.6973	0.070	1.410	1.763	3938.532	0.451	0.407	0.051998682
THE POINT OF OPTIMUM EFFICIENCY IS WHEN S AND T ARE EQUAL										
TRUE PHI IS LESS THAN 0.7029 WHERE S = 0.4510 AND T = 0.4067										
0.65	0.027	8.25	39453.5811	0.067	1.405	1.646	3930.916	0.445	0.428	0.049098566
0.60	0.026	7.89	39569.4810	0.064	1.404	1.531	3910.559	0.438	0.448	0.046135731

I N P U T

CASE = 3  
 PROPELLANT CODE = 17  
 CODE FORM FUNCTION = 2  
 WEAPON W (MM) = 90.0000  
 PROJ. WT. PJM (LBS.) = 12.6500  
 CHAMBER VOLUME VC (C.IN) = 300.0000  
 TRAVEL TRAV (IN) = 155.0000  
 CHARGE CH(1) (LBS) = 8.5800  
 VELOCITY VM(1) (F/S) = 4000.0000  
 PROJ. CAVOLUME ETA (C.IN/LBS) = 29.5000  
 PROJ. DENSITY RH0 (LBS/C.IN) = 0.0603  
 PROJ. FORCE F (FT.LBS/LBS) = 364000.0000  
 PROJ. CONSTANT A, A0, = 12.9200  
 PROJ. CONSTANT B = 0.00036573  
 BORE AREA = 9.8607  
 0.8510

O U T P U T

PHI	L-DENSITY	CHARGE	PPØ	XIM	GAMMA	ZS	PRESSURE	S	T	WEB
0.703	0.029	8.58	41561.1367	0.070	1.384	1.693	53340.792	0.451	0.426	0.050960869

I N P U T

CASE = 4  
 PROPELLANT CODE = 17  
 CODE FORM FUNCTION = 2  
 WEAPON W (MM) = 90.0000  
 PROJ.WT. PJW (LBS.) = 12.6500  
 CHAMBER VOLUME VC (C.IN) = 300.0000  
 TRAVEL TRAV (IN) = 155.0000  
 MAX PRESSURE PMAX (PSI) = 50500.0000  
 OPERATING PRESSURE POPR (PSI) = 43913.0435  
 CHARGE (LBS) = 8.5800  
 VELOCITY (F/S) = 4000.0000  
 WEB = 0.0520  
 PRØP. CØVØLUME ETA (C.IN/LBS) = 29.5000  
 PRØP. DENSITY RHØ (LBS/C.IN) = 0.0603  
 PRØP. FØRCE F (FT.LBS/LBS) = 364000.0000  
 PRØP. CØNSTANTS A, AØ, = 12.9200  
 BØRE AREA = 9.8607  
 0.8510

Ø U T P U T

PHI	L.DENSITY	CHARGE	PPØ	XIM	GAMMA	ZS	VELOCITY	S	T	B
0.703	0.029	8.58	39347.6973	0.070	1.410	1.763	4000.000	0.451	0.407	0.000365734

THE POINT OF ØPTIMUM EFFICIENCY IS WHEN S AND T ARE EQUAL

APPENDIX C

FORTRAN PROGRAM FOR INTERIOR BALLISTICS

FØRTRAN PRØGRAM FØR HIRSCHFELDER INTERIØR BALLISTIC CALCULATIØNS

DIMENSION A(25,55),B(25),C(25,55),D(25),PH(15),DELTA(15),CH(15),PØ  
 1P(15),XIM(15),ZS(15),GAMMA(15),H(15),VM(15),S(15),T(15),WEB(15),E(

225,55),F(25,55),AB(50),ABV(50)  
 READ INPUT TAPE 2,2,(A(1,J),J=1,4),(A(2,J),J=2,8),(A(3,J),J=3,13),  
 1(A(4,J),J=4,19),(A(5,J),J=5,24),(A(6,J),J=5,31),(A(7,J),J=6,38),(A  
 2(8,J),J=7,45),(A(9,J),J=8,47),(A(10,J),J=9,47),(A(11,J),J=10,47),(  
 3A(12,J),J=11,47),(A(13,J),J=12,47),(A(14,J),J=13,47),(A(15,J),J=14  
 4,47),(A(16,J),J=15,47),(A(17,J),J=16,47),(A(18,J),J=17,47),(A(19,J  
 5),J=18,47),(A(20,J),J=19,47),(B(I),I=1,5)

2 FØRMAT(24F3.2/(24F3.2))

READ INPUT TAPE 2,3,(C(1,J),J=1,4),(C(2,J),J=2,8),(C(3,J),J=3,13),  
 1(C(4,J),J=4,19),(C(5,J),J=5,24),(C(6,J),J=5,31),(C(7,J),J=6,38),(C  
 2(8,J),J=7,45),(C(9,J),J=8,47),(C(10,J),J=9,47),(C(11,J),J=10,47),(  
 3C(12,J),J=11,47),(C(13,J),J=12,47),(C(14,J),J=13,47),(C(15,J),J=14  
 4,47),(C(16,J),J=15,47),(C(17,J),J=16,47),(C(18,J),J=17,47),(C(19,J  
 5),J=18,47),(C(20,J),J=19,47),(D(I),I=1,5)

3 FØRMAT(24F3.2/(24F3.2))

READ INPUT TAPE 2,8,(E(1,J),J=1,7),(E(2,J),J=2,15),(E(3,J),J=3,25)  
 1,(E(4,J),J=4,35),(E(5,J),J=4,46),(E(6,J),J=5,47),(E(7,J),J=6,47),(  
 2E(8,J),J=7,47),(E(9,J),J=8,47),(E(10,J),J=9,47),(E(11,J),J=10,47),  
 3(E(12,J),J=11,47),(E(13,J),J=12,47),(E(14,J),J=13,47),(E(15,J),J=1  
 44,47),(E(16,J),J=15,47),(E(17,J),J=17,47),(E(18,J),J=18,47),(E(19,  
 5J),J=19,47),(E(20,J),J=20,47)

8 FØRMAT(24F3.2/(24F3.2))

READ INPUT TAPE 2,8,(F(1,J),J=1,7),(F(2,J),J=2,15),(F(3,J),J=3,25)  
 1,(F(4,J),J=4,35),(F(5,J),J=4,46),(F(6,J),J=5,47),(F(7,J),J=6,47),(  
 2F(8,J),J=7,47),(F(9,J),J=8,47),(F(10,J),J=9,47),(F(11,J),J=10,47),  
 3(F(12,J),J=11,47),(F(13,J),J=12,47),(F(14,J),J=13,47),(F(15,J),J=1  
 44,47),(F(16,J),J=15,47),(F(17,J),J=17,47),(F(18,J),J=18,47),(F(19,  
 5J),J=19,47),(F(20,J),J=20,47)

9 FØRMAT(24F3.2/(24F3.2))

1 READ INPUT TAPE 2,4,KASE,KØDE,M,N,W,PJW,VC,TRAV,PMAX,CH(1),VM(1),W  
 1EB(1),Y,(PH(I),I=1,N)

4 FØRMAT(I1,I2,2I1,1X,ØF6.0,F8.8,5F2.2)

PØPR=PMAX/1.15

DØ 500 I=1,20

A(I,46)=A(I,47)

A(I,47)=A(I,50)

C(I,46)=C(I,47)

C(I,47)=C(I,50)

E(I,46)=E(I,47)

E(I,47)=E(I,50)

F(I,46)=F(I,47)

F(I,47)=F(I,50)

500 CØNTINUE

IF(KØDE-99)60,61,60

61 READ INPUT TAPE 2,62,V,AØ,RHØ,ETA,U

62 FØRMAT(5F6.0)

GØ IØ 300

60 IF(KØDE-1)61,64,63

64 V=12.92

AØ=1.015

RHØ=0.0567

ETA=30.57

U=305000.

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FØRTRAN PRØGRAM FØR HIRSCHFELDER INTERIØR BALLISTIC CALCULATIØNS

63 IF(KØDE-2)65,66,65

66 V=11.16  
 AØ=0.743  
 RHØ= 0.0597  
 ETA= 27.91  
 U= 360000.

65 IF(KØDE-5)67,68,67

68 V=10.74  
 AØ=0.725  
 RHØ = 0.0596  
 ETA = 27.52  
 U = 355000.

67 IF(KØDE-6)69,70,69

70 V=12.41  
 AØ = 0.938  
 RHØ = 0.0571  
 ETA = 29.92  
 U = 317000.

69 IF(KØDE-9)71,72,71

72 V= 9.02  
 AØ = 0.566  
 RHØ = 0.6590  
 ETA = 25.97  
 U = 382000.

71 IF(KØDE - 10)73,74,73

74 V= 11.15  
 AØ = 0.788  
 RHØ = 0.0602  
 ETA = 27.76  
 U = 339000.

73 IF(KØDE-14)75,76,75

76 V = 12.36  
 AØ = 0.906  
 RHØ = 0.0582  
 ETA = 29.54  
 U = 327000.

75 IF(KØDE-15)77,78,77

78 V = 14.50  
 AØ = 1.034  
 RHØ = 0.0600  
 ETA = 31.17  
 U = 336000.

77 IF(KØDE-17)79,80,79

80 V= 12.92  
 AØ = 0.851  
 RHØ = 0.0603  
 ETA = 29.50  
 U = 364000.

79 IF(KØDE-25)81,82,81

82 V = 11.57  
 AØ = 0.786  
 RHØ = 0.0585  
 ETA = 28.66  
 U = 353000.

81 IF(KØDE-28)83,84,83

84 V = 11.68

FØRTRAN PRØGRAM FØR HIRSCHFELDER INTERIØR BALLISTIC CALCULATIØNS

```

AØ = 0.786
RHØ = 0.0585
ETA = 28.77
U = 356000.
83 IF(KØDE-34)85,86,85
86 V = 14.07
AØ = 1.007
RHØ = 0.0596
ETA = 30.85
U = 335000.
85 IF(KØDE-36)300,88,300
88 V = 12.59
AØ = 0.828
RHØ = 0.060
ETA = 29.26
U = 364500.
300 STEVØ = 0.0
IF(KASE-1)100,31,100
100 IF(KASE-2)102,103,102
103 N=1
I=1
DELTA(1)=CH(1)/VC
PH(1)=V/((1./DELTA(1))-(1./RHØ))
GØ TØ 106
102 IF(KASE-3)104,105,600
600 I=2
DELTA(I)=CH(I)/VC
PH(I)=V/((1./DELTA(I))-(1./RHØ))
CH(2)=CH(1)
WEB(2)=WEB(1)
VM(2)=VM(1)
GØ TØ 106
105 DELTA(1)= CH(1)/VC
PH(1)=V/((1./DELTA(1))-(1./RHØ))
AREA = ((W/25.4)**2)*(3.1416/4.)
X = (VC + (AREA*TRAV))/VC
XIM(1) = (V*DELTA(1))/(X-(ETA*DELTA(1)))
S(1) = XIM(1)**0.3
H(1) = .0317*(PJW+(.3226*CH(1)))
GAMMA(1) = (1.-((.15*H(1))*(VM(1)**2))/(CH(1)*U))/S(1)
Q = (PH(1)*20.) + 0.4
L=Q
I2=0
DØ 120 I=1,20
IF(L-I)120,140,120
140 I2=I
120 CØNTINUE
IF(I2)122,121,122
121 WRITE ØUTPUT TAPE 3,123,KASE,PH(1)
123 FØRMAT(1H1,10X,7HA CASE I3,63H TYPE PRØBLEM HAS BEEN REJECTED HERE
1 BECAUSE CALCULATED PHI IS F10.4,38H FØR WHICH THE TABLES ARE NØT
2ADEQUATE)
GØ TØ 40
122 IF(M-1)108,108,107
107 DØ 109 I=1,47
ABV(I) = ABSF(C(L,I) - GAMMA(1))

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FØRTRAN PRØGRAM FØR HIRSCHFELDER INTERIØR BALLISTIC CALCULATIØNS

```

109 CØNTINUE
    VAL = ABV(1)
    DØ 129 I=1,47
    VAL = MINIF(VAL,ABV(I))
129 CØNTINUE
    DØ 110 I=1,47
    IF(ABV(I) - VAL) 110,112,110
112 K = I
    TK = K
110 CØNTINUE
    IF(GAMMA(1) - C(L,K))113,114,115
113 R=(C(L,K)-GAMMA(1))/(C(L,K)-C(L,K+1))+TK
    GØ TØ 116
114 R=TK
    GØ TØ 116
115 R=(C(L,K-1)-GAMMA(1))/(C(L,K-1)-C(L,K))+TK-1.
116 PØP(1)=R*2000.
    J=R
    Z=J
    ZS(1) = A(L,J)-(ABSF(R-Z)*ABSF(A(L,J) - A(L,J+1)))
    T(1)=(1.-.242*ZS(1))/GAMMA(1)
151 WEB(1)=Y/SQRTF((1.369*AREA**2)/(CH(1)*U*H(1)*ZS(1)))
    PMAX=(PØP(1)/AØ)*(1.+(CH(1)/(6.*PJW+2.*CH(1))))
    GØ TØ 137
108 DØ 130 I=1,47
    ABV(I)=ABSF(F(L,I)-GAMMA(1))
130 CØNTINUE
    VAL=ABV(1)
    DØ 131 I=1,47
    VAL=MINIF(VAL,ABV(I))
131 CØNTINUE
    DØ 132 I=1,47
    IF(ABV(I)-VAL) 132,133,132
133 K=I
    TK=K
132 CØNTINUE
    IF(GAMMA(1)-F(L,K))150,134,135
150 R=(F(L,K)-GAMMA(1))/(F(L,K)-F(L,K+1))+TK
    GØ TØ 136
134 R=TK
    GØ TØ 136
135 R=(F(L,K-1)-GAMMA(1))/(F(L,K-1)-F(L,K))+TK-1.
136 PØP(1)=R*2000.
    J=R
    Z=J
    ZS(1)=E(L,J)-(ABSF(R-Z)*ABSF(E(L,J)-E(L,J+1)))
    T(1)=(1.-.1485*ZS(1))/GAMMA(1)
161 WEB(1)=Y/SQRTF((0.990*AREA**2)/(CH(1)*U*H(1)*ZS(1)))
    PMAX=(PØP(1)/AØ)*(1.+(CH(1)/(6.*PJW+2.*CH(1))))
137 WRITE ØUTPUT TAPE 3,138,KASE,KØDE,M,W,PJW,VC,TRAV,CH(1),VM(1),ETA,
    1RHØ,U,V,AØ,Y,AREA
138 FØRMAT(1H1,5ØX,9HI N P U T//5X,7HCASE = 11/5X,18HPRØPELLANT CØDE =
    1 I2/5X,21HCØDE FØRM FUNCTIØN = 11,6H /5X,16HWEAPØN W (MM) = F
    212.4/5X,22HPRØJ.WT. PJW (LBS.) = F12.4/5X,27HCHAMBER VØLUME VC (C.
    3IN) = F12.4/5X,19HTRAVEL TRAV (IN) = F12.4/5X,21HCHARGE CH(1) (LBS.
    4) = F12.4/5X,23HVELØCITY VM(1) (F/S) = F12.4,1ØH /5X,32HP

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FØRTRAN PRØGRAM FØR HIRSCHFELDER INTERIØR BALLISTIC CALCULATIØNS

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5RØP. CØVØLUME ETA (C.IN/LBS) = F12.4/5X,31HPRØP. DENSITY RHØ (LBS/
6C.IN) = F12.4/5X,29HPRØP. FØRCE F (FT.LBS/LBS) = F12.4/5X,24HPRØP.
7 CØNSTANTS A,AØ, = F12.4,5X,F12.4/5X,18HBURN.CØNSTANT B = F12.8/5X
8,12HBØRE AREA = F12.4)
N=1
WRITE ØUTPUT TAPE 3,89,(PH(I),DELTA(I),CH(I),PØP(I),XIM(I),GAMMA(I
1),ZS(I),PMAx,S(I),T(I),WEB(I),I=1,N)
89 FØRMAT(1X//50X,11HØ U T P U T//102H      PHI      L.DENSITY      CHARGE
1  PPØ      XIM      GAMMA      ZS      PRESSURE      S      T
2  WEB///(1X,F8.2,1X,F8.3,1X,F10.2,1X,F12.4,1X,F8.3,1X,F6.3,1X,F6.3
3,1X,F12.3,1X,F8.3,1X,F8.3,1X,F8.3,1X,F12.9))
GØ TØ 40
153 WRITE ØUTPUT TAPE 3,155,KASE,KØDE,M,W,PJW,VC,TRAV,PMAx,PØPR,CH(1),
1VM(1),WEB(1),ETA,RHØ,U,V,AØ,AREA
155 FØRMAT(11H,50X,9HI N P U T//5X,7HCASE = I1/5X,18HPRØPELLANT CØDE =
1 I2/5X,21HCØDE FØRM FUNCTIØN = I1,6H      /5X,16HWEAPØN W (MM) = F
212.4/5X,22HPRØJ.WT. PJW (LBS.) = F12.4/5X,27HCHAMBER VØLUME VC (C.
3IN) = F12.4/5X,19HTRAVEL TRAV (IN) = F12.4/5X,26HMAX PRESSURE PMAx
4 (PSI) = F12.4/5X,32HØPERATING PRESSURE PØPR (PSI) = F12.4/5X,15HC
5HARGE (LBS) = F12.4/5X,17HVELØCITY (F/S) = F12.4/5X,6HWEB = F12.4,
654H      /5X,32HP
7RØP. CØVØLUME ETA (C.IN/LBS) = F12.4/5X,31HPRØP. DENSITY RHØ (LBS/
8C.IN) = F12.4/5X,29HPRØP. FØRCE F (FT.LBS/LBS) = F12.4/5X,24HPRØP.
9 CØNSTANTS A,AØ, = F12.4,5X,F12.4/5X,12HBØRE AREA = F12.4)
N=1
WRITE ØUTPUT TAPE 3,700,PH(2),DELTA(2),CH(1),PØP(2),XIM(2),GAMMA(2
1),ZS(2),VM(1),S(2),T(2),Y
700 FØRMAT(1X//50X,11HØ U T P U T//102H      PHI      L.DENSITY      CHARGE
1  PPØ      XIM      GAMMA      ZS      VELØCITY      S      T
2  B///(1X,F8.2,1X,F8.3,1X,F10.2,1X,F12.4,1X,F8.3,1X,F6.3,1X,F6.3
3,1X,F12.3,1X,F8.3,1X,F8.3,1X,F12.9))
WRITE ØUTPUT TAPE 3,156
156 FØRMAT(1X//30X,57HTHE PØINT ØF ØPTIMUM EFFICIENCY IS WHEN S AND T
1ARE EQUAL)
104 GØ TØ 40
31 DØ 5 I = 1,N
DELTA(I) = 1./((V/PH(I))+(1./RHØ))
CH(I)=VC*DELTA(I)
106 PØP(I)= PMAx*AØ*((PJW +CH(I)/3.)/(PJW +CH(I)/2.))
AREA =((W/25.4)**2)*(3.1416/4.)
X =(VC+(AREA*TRAV))/VC
XIM(I)=(V*DELTA(I))/(X-(ETA*DELTA(I)))
Q=(PH(I)*100.)/5.
Q=Q+0.4
R= PØP(I)/2000.
R=R+(1./(10.**7))
L=Q
J=R
Z=J
IF(M-1)11,11,10
11 ZS(I)=E(L,J)-(ABSF((PØP(I)/2000.)-Z)*ABSF(E(L,J)-E(L,J+1)))
GAMMA(I)=F(L,J)-(ABSF((PØP(I)/2000.)-Z)*ABSF(F(L,J)-F(L,J+1)))
H(I)=.0317*(PJW +(.3226*CH(I)))
VM(I)=SQRTF((1.-GAMMA(I)*(XIM(I)**0.3))*((2.*CH(I)*U)/(0.3*H(I))))
S(I)=XIM(I)**0.3
T(I)=(1.-(.1485*ZS(I)))/GAMMA(I)

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FØRTRAN PRØGRAM FØR HIRSCHFELDER INTERIØR BALLISTIC CALCULATIØNS

```

WEB(I)=Y/SQRTF((0.990*AREA**2)/(CH(I)*U*H(I)*ZS(I)))
IF(KASE-4) 5,162,162
162 Y = WEB(1)*SQRTF((0.99*AREA**2)/(CH(1)*U*H(1)*ZS(1)))
GØ TØ 153
10 ZS(I)=A(L,J)-(ABSF((PØP(I)/2000.)-Z)*ABSF(A(L,J)-A(L,J+1)))
GAMMA(I)=C(L,J)-(ABSF((PØP(I)/2000.)-Z)*ABSF(C(L,J)-C(L,J+1)))
H(I)=.0317*(P.JW.+(.3226*CH(I)))
VM(I)=SQRTF((1.-GAMMA(I)*(XIM(I)**0.3))*((2.*CH(I)*U)/(0.3*H(I))))
S(I)=XIM(I)**0.3
T(I)=(1.-(.242*ZS(I)))/GAMMA(I)
WEB(I)=Y/SQRTF((1.369*AREA**2)/(CH(I)*U*H(I)*ZS(I)))
IF(KASE-4) 5,152,152
152 Y = WEB(1)*SQRTF((1.369*AREA**2)/(CH(1)*U*H(1)*ZS(1)))
GØ TØ 153
5 CØNTINUE
IF(STEVØ)201,200,201
200 WRITE ØUTPUT TAPE 3,6,KASE,KØDE,M,W,PJW,VC,TRAV,PMAX,PØPR,ETA,RHØ,
1U,V,AØ,Y,AREA
6 FØRMAT(1H1,50X,9HI N P U I//5X,7HCASE = 11/5X,18HPRØPELLANT CØDE =
1 12/5X,21HCØDE FØRM FUNCTIØN = 11,6H /5X,16HWEAPON W (MM) = F
212.4/5X,22HPRØJ.WT. PJW (LBS.) = F12.4/5X,27HCHAMBER VØLUME VC (C.
3IN) = F12.4/5X,19HTRAVEL TRAV (IN) = F12.4/5X,26HMAX PRESSURE PMAX
4 (PSI) = F12.4/5X,32HØPERATING PRESSURE PØPR (PSI) = F12.4/5X,32HP
5RØP. CØVØLUME ETA (C.IN/LBS) = F12.4/5X,31HPRØP. DENSITY RHØ (LBS/
6C.IN) = F12.4/5X,29HPRØP. FØRCE F (FT.LBS/LBS) = F12.4/5X,24HPRØP.
7 CØNSTANTS A,AØ, = F12.4,5X,F12.4/5X,18HBURN.CØNSTANT B = F12.8/5X
8,12HBØRE AREA = F12.4)
WRITE ØUTPUT TAPE 3,20,(PH(I),DELTA(I),CH(I),PØP(I),XIM(I),GAMMA(I
1),ZS(I),VM(I),S(I),T(I),WEB(I),I=1,N)
20 FØRMAT(1X//50X,11HØ U T P U T//102H PHI L.DENSITY CHARGE
1 PPØ XIM GAMMA ZS VELØCITY S T
2 WEB//(1X,F8.2,1X,F8.3,1X,F10.2,1X,F12.4,1X,F8.3,1X,F6.3,1X,F6.3
3,1X,F12.3,1X,F8.3,1X,F8.3,1X,F12.9))
WRITE ØUTPUT TAPE 3,7
7 FØRMAT(1X//30X,57HTHE PØINT ØF ØPTIMUM EFFICIENCY IS WHEN S AND T
1ARE EQUAL)
IF(STEVØ)40,32,40
32 N4=2
N5=1
DØ 30 I=1,N
IF(S(I)-T(I))29,27,25
25 AB(I)=100.
N5=2
GØ TØ 30
27 WRITE ØUTPUT TAPE 3,28,PH(I),S(I)
28 FØRMAT(1X//30X,6HPHI = F12.3,15H SINCE S = T = F12.4)
N4 = 1
GØ TØ 30
29 AB(I) = ABSE(S(I) - T(I))
VALUE=AB(1)
30 CØNTINUE
GØ TØ(40,35),N4
35 DØ 23 I=1,N
VALUE=MINIF(VALUE,AB(I))
23 CØNTINUE
K=10

```

FØRTRAN PRØGRAM FØR HIRSCHFELDER INTERIØR BALLISTIC CALCULATIØNS

```

DØ 24 I=1,N
IF(AB(I)-VALUE)24,26,24
26 K=I
24 CØNTINUE
IF(K-10)950,951,951
951 WRITE ØUTPUT TAPE 3,952,PH(1),S(1),T(1)
952 FØRMAT(1X//20X,22HTRUE PHI IS LESS THAN F12.4,11H WHERE S = F12.4,
1,9H AND T = F12.4//)
961 PH(1) = PH(1) - 0.05
IF(PH(1)-0.05)40,970,970
970 N=1
STEVO=2.0
GØ TØ 31
950 IF(STEVO)900,905,900
900 IF(K-2)201,201,902
905 WRITE ØUTPUT TAPE 3,33,PH(K),S(K),T(K)
33 FØRMAT(1X//20X,25HTRUE PHI IS GREATER THAN F12.4,11H WHERE S = F12
1.4,9H AND T = F12.4//)
902 IF(PH(K)-1.0)41,40,40
41 IF(PH(K)-PH(1))40,42,43
42 IF(PH(1)-0.95)50,51,51
51 PH(1) = 1.0
N=1
GØ TØ 48
50 IF(PH(1)-0.90)53,52,52
52 PH(1)=0.95
PH(2)=1.0
N=2
GØ TØ 48
53 PH(1) = PH(1) + 0.05
PH(2)=PH(1) + 0.05
PH(3) = PH(2) +0.05
N= 3
GØ TØ 48
43 IF(PH(K)-0.95)44,45,45
45 PH(1) = PH(K) + 0.05
N=1
GØ TØ 48
44 IF(PH(K) - 0.90)46,47,47
47 PH(1) = PH(K) + 0.05
PH(2) = PH(1) + 0.1
N=2
GØ TØ 48
46 PH(1) = PH(K) + 0.05
PH(2) = PH(1) + 0.05
PH(3) = PH(2) + 0.05
N= 3
48 STEVO = 1.0
GØ TØ 31
201 WRITE ØUTPUT TAPE 3,202,(PH(I),DELTA(I),CH(I),PØP(I),XIM(I),GAMMA(
I),ZS(I),VM(I),S(I),T(I),WEB(I),I=1,N)
202 FØRMAT(1X//(1X,F8.2,1X,F8.3,1X,F10.2,1X,F12.4,1X,F8.3,1X,F6.3,1X,F
16.3,1X,F12.3,1X,F8.3,1X,F8.3,1X,F12.9))
IF(STEVO-1.)40,920,960
960 IF(S(1)-T(1))40,27,961
920 DØ 921 I=1,N

```

FØRTRAN PRØGRAM FØR HIRSCHFELDER INTERIØR BALLISTIC CALCULATIØNS

```
IF(S(I)-T(I))921,921,922.....  
922 N5=2  
921 CØNTINUE  
IF(N5-2)32,40,40  
40 GØ TØ 1  
END(1,1,0,0,0,0,1,1,0,0,0,0,0,0)
```

ABSTRACT DATA

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Accession No. \_\_\_\_\_ AD \_\_\_\_\_

Picatinny Arsenal, Dover, New Jersey

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Forrest L. McMains

Technical Memorandum 1404, April 1964, 31 pp,  
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A Digital Computer  
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Hirschfelder Interior  
Ballistics

UNITERMS

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Input format  
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