NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.
TECHNICAL MEMORANDUM 1404
A DIGITAL COMPUTER PROGRAM
FOR
HIRSCHFELDER INTERIOR BALLISTICS
FORREST L. McMAMINS
ACMS 5523.11.565

COPY 39 OF 51
APRIL 1964

PICATINNY ARSENAL
DOVER, NEW JERSEY
The findings in this report are not to be construed as an official Department of the Army Position.

DISPOSITION
Destroy this report when it is no longer needed.
Do not return.

DDC AVAILABILITY NOTICE
Qualified requesters may obtain copies of this report from DDC.
TECHNICAL MEMORANDUM 1404

A DIGITAL COMPUTER PROGRAM
FOR
HIRSCHFELDER INTERIOR BALLISTICS

BY

FORREST L. McMAINS

AMCMS 5523.11.565
APRIL 1964

REVIEWED BY: A. BERMAN
Chief, Special
Ammunition &
Analysis Section

APPROVED BY: E. H. BUCHANAN
Chief, Artillery
Ammunition Laboratory

AMMUNITION ENGINEERING DIRECTORATE
PICATINNY ARSENAL
DOVER, NEW JERSEY
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>1</td>
</tr>
<tr>
<td>CONCLUSIONS</td>
<td>1</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>2</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td></td>
</tr>
<tr>
<td>Part I - Input and Output Formats</td>
<td>4</td>
</tr>
<tr>
<td>Part II - Numerical Calculations</td>
<td>7</td>
</tr>
<tr>
<td>Part III - Program Logic</td>
<td>10</td>
</tr>
<tr>
<td>Part IV - Examples</td>
<td>11</td>
</tr>
<tr>
<td>REFERENCE</td>
<td>15</td>
</tr>
<tr>
<td>APPENDICES</td>
<td></td>
</tr>
<tr>
<td>A. Tables</td>
<td>16</td>
</tr>
<tr>
<td>B. Program Output for Cases 1-4</td>
<td>18</td>
</tr>
<tr>
<td>C. Fortran Program for Interior Ballistics</td>
<td>22</td>
</tr>
<tr>
<td>ABSTRACT DATA</td>
<td>30</td>
</tr>
<tr>
<td>TABLE OF DISTRIBUTION</td>
<td>31</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENT

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\(^3\).
Spaces 19-24 are reserved for the propellant co-volume in in\(^3\)/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 $\Phi$ and $\Xi$; 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.

$\phi$, $P_p$, $E_m$, $\alpha$, $\Xi$ are referred to as "PHI," "PP\phi," "XIM," "GAMMA" and "\XiS" 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 $P_{\text{MAX}}$ denote the maximum pressure in psi.
Let $P_{\text{OPR}}$ denote the operating pressure in psi.
Let $B$ denote the burning constant in $(\text{in/sec})/\text{psi}$.
Let $C$ denote the charge in lbs.
Let $W_{\text{EB}}$ denote the web in inches.
Let $\Delta$ denote the loading density in gms/cc.
Let $V_m$ denote the velocity in ft/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 lbs/$\text{in}^3$.
Let $k$ denote the propellant covolume in $\text{in}^3/\text{lb}$.
Let $F$ denote the propellant force in ft-lbs/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:

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

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

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

are derived. Therefore, if $n$ $\phi$'s are chosen, $\phi_1, \ldots, \phi_n$ (as in Case 1)
and C is not given, each of the n $\Delta$'s are calculable:

$$\Delta i = \frac{1}{\rho_0 + \frac{a}{\phi_1}}$$

and hence $C_i = \Delta i \cdot V_c, i = 1, \ldots, n$

Let A denote the bore area of the projectile.

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

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

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

Let $P_{pi}^0 = a_0 \text{PMAX} \left( \frac{M + \frac{3}{2}}{M + \frac{Cl}{2}} \right)$

$\text{PMAX} = 1.15 \text{POPR}$

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

Let $m_i = \frac{L02(m + \frac{3}{1})}{32.175}$

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

$$\sqrt{\left(1 - \phi_i \cdot C_m^{0.3} \cdot \frac{2CiF}{0.3m'_i} \right), \text{ i = 1, \ldots, n}}$$

Consider the case (Case 3) when C and $V_m$ are given. Here $C_i = C$ for each i and $\phi_i, P_{pi}^0, Z_i, \phi_i$ and $m'_i$ all have the single values $\phi, P_{pi}^0, Z, \phi$, and $m'$ respectively.
Therefore, since $V_m = \sqrt{(1 - \varphi m^{0.3}) \frac{2CF}{0.3m'}}$

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

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

$\varphi = (\frac{CF}{0.15m'} - V_m^2) \frac{0.15m'}{\varphi m^{0.3} CF}$

$\varphi = (1 - \frac{0.15m' V_m^2}{CF}) \varphi m^{0.3}$

Knowing $\varphi$ and $\phi$, $P_{p^o}$ is obtainable from Tables 6 or 10.

From $P_{p^o} = a^o \frac{M + \frac{c}{2}}{M + \frac{c}{3}}$

we find $P_{M^X} = \frac{P_{p^o}}{a^o} \left[ \frac{M + \frac{c}{2}}{M + \frac{c}{3}} \right]$

Knowing $P_{p^o}$ and $\phi$, $Z$ is obtainable from Table 4 or 6

Let $\varphi m^{0.3} = S$

Let $(1 - 0.1485 Z) / \varphi = T_s$

Let $(1 - 0.242 Z) / \varphi = T_m$

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

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

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

$WEB = (B/A) \sqrt{\frac{CFm' Z}{1.369}}$
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°/2,000 where Pp° = 2,000, 4,000, 6,000, ..., 90,000, 95,000, 100,000. J = 20φ where φ = 0.05, 0.10, ..., 0.95, 1.0.

Linear interpolations were made within these tables when φ and -z are known and Pp° is to be found. No attempt was made to interpolate between the φ's; instead, the tabular φ closest to the calculated φ has been selected.
PART IV -- EXAMPLES

90mm, Gun, M41

1. Gun constants
   Projectile weight M ----------------------- 12.65 lbs.
   Chamber volume Vc ----------------------- 300 in.³
   Propellant Type ------------------------ M17 (M.P.)
   Total Travel L -------------------------- 155 in.

2. Case 4
   Given: Charge C ------------------------ 8.58 lbs.
   Maximum Pressure PMAX ----------------- 50,500 psi
   Velocity Vm -------------------------- 4,000 f/s
   Web ---------------------------------- 0.052 in.

\[ \Delta = \frac{c}{V_c} = \frac{8.58}{300} = 0.0286 \]

\[ \phi = \frac{a}{\Delta} \cdot \frac{1}{P} = \frac{12.92}{0.0286 - 0.0603} = \frac{12.92}{0.0286 - 0.0603} \]

\[ = \frac{12.92}{0.7028} \approx 0.70 \]

(Where a and \( \phi \) are found in Table 2 (9) of Appendix A).

\[ P_p^o = a^o PMAX \left[ \frac{C}{M + 3} \right] = \left( \frac{8.58}{3} \right) \left[ \frac{12.65 + 8.58}{12.65 + 2} \right] \]

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

\[ = (42975.5)(0.915584) = 39347.697 \]

(Where \( a^o \) is also found in Table 2).
\( \xi = 1.763 \) by Table 8 in Reference 1.

\[
m' = \frac{1.02(M + 3.1)}{32.174} = \frac{1.02 \cdot (12.65 + 3.1)}{32.174} = \frac{1.02 \cdot 15.41777}{32.174} = \frac{15.7261}{32.174} = 0.48878
\]

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

Since \( \text{Web} = (B/A) \sqrt{\frac{C F m' \xi}{1.369}} \)

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

\[0.5127 = B \sqrt{\frac{2681157.356}{1.369}}\]

\[0.5118 = B \sqrt{\frac{1637.424}{1.17}}\]

\[0.598806 = 1637.424 B\]

\[B = 0.0003657\]

3. Case 2

Given: Charge \( C \) --------- 8.58 lbs.

Maximum Pressure \( P_{\text{MAX}} \) --------- 50,500 psi

\[\Delta = 0.0286, \phi = 0.70; P_{p} = 39347.697\]

\[\gamma = 1.410 \text{ by Table 10 in Hirschfelder}\]

\[A = 9.8607\]

\[X = \frac{V_c + A \cdot L}{V_c} = \frac{300 + (9.8607)(155)}{300} = \frac{1828.4085}{300} = 6.0947\]
\[ \dot{\mathcal{E}}_m = \frac{(12.92)(0.0286)}{6.0947 - (29.50)(0.0286)} \]

\[ = \frac{0.3695}{6.0947 - 0.8437} = \frac{0.3695}{5.251} = 0.07037 \]

\[ S = \dot{\mathcal{E}}_m^0.3 = 0.451 \]

\[ V_m = \sqrt[3]{(1 - \dot{\mathcal{E}}_m^0.3) \frac{2CF}{0.3m^3}} \]

\[ = \sqrt[3]{(1 - (1.410)(0.451)) \cdot \frac{2(8.58)(364000)}{(0.3)(0.48878)}} \]

\[ = \sqrt[3]{(1 - 0.6359) \cdot \frac{6246240}{0.14669}} \]

\[ = \sqrt[3]{\frac{2274255.984}{0.14669}} \]

\[ = \frac{1508.4577}{0.383} = 3938.532 \]

\[ T_m = \frac{1 - 0.242 Z}{\dot{\mathcal{E}}} = \frac{1 - (0.242)(1.763)}{1.410} = \frac{0.57393}{1.410} = 0.407 \]

Since \( S = 0.451 > 0.407 = T_m \), burning is taking place outside the weapon.

To attain optimum conditions, new and smaller \( v \)'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
\[ \delta = \left(1 - \frac{0.15m' V_m^2}{CF} \right) / 2m^{0.3} \]

\[ 1 - \frac{(0.15)(0.48878)(4000)^2}{(8.58)(364,000)} = \frac{0.451}{1173072} \]
\[ 1 - \frac{3123120}{0.451} = 1 - 0.37561 = 0.62439 = 1.384 \]

Since \( \phi = 0.70 \), \( P_{p0} = 41561.1367 \) by Table 10 in Reference 1.
Therefore, \( Z = 1.693 \)

\[ \frac{P_{p0}}{a_0} \left[ M + \frac{c}{2} \right]^{\frac{1}{M + 3}} \]
\[ = \left( \frac{41561.1367}{0.851} \right) \left( \frac{12.65 + \frac{8.58}{2}}{12.65 + \frac{8.58}{3}} \right) \]
\[ = \left( \frac{41561.1367}{0.851} \right) \left( \frac{16.94}{15.51} \right) \]
\[ = (41561.1367)(1.2834) \]
\[ = 53340.792 \text{ psi} \]

\( Z = 1.693 \) by Table 8 in the reference.
Therefore, \( \text{Web} = \frac{0.0003657}{9.8607} \cdot \sqrt{\frac{(8.58)(364000)(0.48878)(1.693)}{1.369}} \)
\[ = \frac{0.0003657}{9.8607} \cdot \sqrt{258439597.29} \]
\[ = \frac{(0.0003657)(16076.0566)}{11.537} \]
\[ = 0.05879 \]
\[ \frac{11.537}{11.537} \]
\[ = 0.005096 \]
REFERENCE

APPENDIX A

TABLES
<table>
<thead>
<tr>
<th>Propellant</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>1</td>
</tr>
<tr>
<td>M2</td>
<td>2</td>
</tr>
<tr>
<td>M5</td>
<td>5</td>
</tr>
<tr>
<td>M6</td>
<td>6</td>
</tr>
<tr>
<td>M9</td>
<td>9</td>
</tr>
<tr>
<td>M10</td>
<td>10</td>
</tr>
<tr>
<td>M14</td>
<td>14</td>
</tr>
<tr>
<td>M15</td>
<td>15</td>
</tr>
<tr>
<td>M17</td>
<td>17</td>
</tr>
<tr>
<td>T25</td>
<td>25</td>
</tr>
<tr>
<td>T28</td>
<td>28</td>
</tr>
<tr>
<td>T34</td>
<td>34</td>
</tr>
<tr>
<td>T36</td>
<td>36</td>
</tr>
</tbody>
</table>

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 $a^0$ represent the propellant "$a$" constants; $\rho$ represents the propellant density in lbs/in$^3$, $\kappa$ represents propellant covolume in in$^3$/lbs, and $F$ represents the propellant force in ft. lbs/lbs.

<table>
<thead>
<tr>
<th>Propellant</th>
<th>$a$</th>
<th>$a^0$</th>
<th>$\rho$</th>
<th>$\kappa$</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>12.92</td>
<td>1.015</td>
<td>0.0567</td>
<td>30.57</td>
<td>305,000</td>
</tr>
<tr>
<td>M2</td>
<td>11.16</td>
<td>0.743</td>
<td>0.0597</td>
<td>27.91</td>
<td>360,000</td>
</tr>
<tr>
<td>M5</td>
<td>10.74</td>
<td>0.725</td>
<td>0.0596</td>
<td>27.52</td>
<td>355,000</td>
</tr>
<tr>
<td>M6</td>
<td>12.41</td>
<td>0.938</td>
<td>0.0571</td>
<td>29.92</td>
<td>317,000</td>
</tr>
<tr>
<td>M9</td>
<td>9.02</td>
<td>0.566</td>
<td>0.659</td>
<td>25.97</td>
<td>382,000</td>
</tr>
<tr>
<td>M10</td>
<td>11.15</td>
<td>0.788</td>
<td>0.0602</td>
<td>27.76</td>
<td>339,000</td>
</tr>
<tr>
<td>M14</td>
<td>12.36</td>
<td>0.906</td>
<td>0.058</td>
<td>29.54</td>
<td>327,000</td>
</tr>
<tr>
<td>M15</td>
<td>14.50</td>
<td>1.034</td>
<td>0.06</td>
<td>31.17</td>
<td>336,000</td>
</tr>
<tr>
<td>M17</td>
<td>12.92</td>
<td>0.851</td>
<td>0.0603</td>
<td>29.50</td>
<td>364,000</td>
</tr>
<tr>
<td>T25</td>
<td>11.57</td>
<td>0.786</td>
<td>0.0585</td>
<td>28.66</td>
<td>353,000</td>
</tr>
<tr>
<td>T28</td>
<td>11.68</td>
<td>0.786</td>
<td>0.0585</td>
<td>28.77</td>
<td>356,000</td>
</tr>
<tr>
<td>T34</td>
<td>14.07</td>
<td>1.007</td>
<td>0.0596</td>
<td>30.85</td>
<td>335,000</td>
</tr>
<tr>
<td>T36</td>
<td>12.59</td>
<td>0.828</td>
<td>0.06</td>
<td>29.26</td>
<td>364,000</td>
</tr>
</tbody>
</table>

-17-
APPENDIX B

PROGRAM OUTPUT FOR CASES 1-4
INPUT

CASE = 1
PRÆPELLANT CODE = 17
CODE FORM FUNCTION = 2
WEAPøN W' (MM) = 90.000
PRÆJ. WT. PJW (LBS.) = 12.6500
CHAMBER VOLUME V'C (C.IN) = 300.0000
TRAVEL TRAV (IN) = 155.0000
MAX PRESSURE PMAX (PSI) = 50500.0000
OPERATING PRESSURE P0PR (PSI) = 43913.0435
PRÆP. G0VOLUME ETA (C.IN/LBS) = 29.5000
PRÆP. DENSITY RHO (LBS/C.IN) = 0.0603
PRÆP. FORCE F (FT.LBS/LBS) = 364000.0000
PRÆP. CONSTANTS A0 A0 = 12.9200 0.8510
BURN CONSTANT B = 0.00036573
BORE AREA = 9.8607

OUTPUT

PHI  L. DENSITY  CHARGE  PPÆ  XIM  GAMMA  ZS  VELOCITY  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  0.39799377
0.700  0.029  8.56  39353.5654  0.070 1.410  1.763  3937.836  0.451  0.407  0.051929250

THE POINT OF OPTIMUM 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
### INPUT

CASE = 2  
PRØPELLANT CODE = .17  
CODE FORM FUNCTION = 2  
WEAPON W (MM) = 90.0000  
PRØJ.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 PØPR (PSI) = 43913.0435  
PRØP. COVOLUME ETA (C.IN/LBS) = 29.5000  
PRØP. DENSITY RHØ (LBS/C.IN) = 0.0603  
PRØP. FORÇE F (FT-LBS/LBS) = 364000.0000  
PRØP. CONSTANS A,AB, = 12.9200 0.8510  
BURN.CONSTANT B = 0.00036573  
BORE AREA = 9.8607

### OUTPUT

<table>
<thead>
<tr>
<th>PHI</th>
<th>L.DENSITY</th>
<th>CHARGE</th>
<th>PPØ</th>
<th>XIM</th>
<th>GAMMA</th>
<th>ZS</th>
<th>VELOCITY</th>
<th>S</th>
<th>T</th>
<th>WEB</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.70</td>
<td>0.029</td>
<td>8.58</td>
<td>39347.6973</td>
<td>0.070</td>
<td>1.410</td>
<td>1.763</td>
<td>3938.532</td>
<td>0.451</td>
<td>0.407</td>
<td>0.051998682</td>
</tr>
<tr>
<td>0.65</td>
<td>0.027</td>
<td>8.25</td>
<td>39453.5811</td>
<td>0.067</td>
<td>1.405</td>
<td>1.646</td>
<td>3930.916</td>
<td>0.445</td>
<td>0.428</td>
<td>0.049098566</td>
</tr>
<tr>
<td>0.60</td>
<td>0.026</td>
<td>7.89</td>
<td>39569.4810</td>
<td>0.064</td>
<td>1.404</td>
<td>1.531</td>
<td>3910.559</td>
<td>0.438</td>
<td>0.448</td>
<td>0.046135731</td>
</tr>
</tbody>
</table>

**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
INPUT

CASE = 3
PROPellant Code = 17
Code Form Function = Z
WEAP2 W (MM) = 90.0000
PR0J.WT. PJW (LBS.) = 12.6500
CHAMBER VOLUME VC (C.IN) = 300.0000
TRAVEL TRAV (IN) = 155.0000
CHARGE CH11 (LBS) = 8.5800
VELOCITY VM11 (F/S) = 4000.0000
PROP. CVOLUME ETA (C.IN/LBS) = 29.5000
PROP. DENSITY RH0 (LBS/C.IN) = 0.0603
PROP. FORCE F (FT.LBS/LBS) = 364000.0000
PROP. CONSTANTS A, A0, = 12.9200
BURN. CONSTANT B = 0.00036673
Bore Area = 9.8607

OUTPUT

PHI L DENSITY CHARGE PP0 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
INPUT

CASE = 4
PROPELLANT CODE = 17
CODE FORM FUNCTION = 2
WEAPON W (MM) = 90.0000
PROP.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
PROP. GVOLUME ETA (C.IN/LBS) = 29.5000
PROP. DENSITY RH (LBS/C.IN) = 0.0603
PROP. FORCE F (FT.LBS/LBS) = 364000.0000
PROP. CONSTANTS A,AB, = 12.9200
BORE AREA = 9.8607

OUTPUT

PHI L.DENSITY CHARGE PP0 XIM GAMMA ZS VELOCITY S T B

0.703 0.029 8.58 39347.6973 0.070 1.410 1.763 4000.0000 0.451 0.407 0.000365734

THE POINT OF OPTIMUM EFFICIENCY IS WHEN S AND T ARE EQUAL
APPENDIX C

FORTRAN PROGRAM FOR INTERIOR BALLISTICS
FORTRAN PROGRAM FOR HIRSCHFELDER INTERIOR BALLISTIC CALCULATIONS

DIMENSION A(25,55), B(25,55), C(25,55), D(25,55), PH(15), DELTA(15), CH(15), P0
1 P(15), XIM(15), ZS(15), GAMMA(15), H(15), VM(15), S(15), T(15), WEB(15), E(25, 55), F(25, 55), AB(50), ABV(50)

READ INPUT TAPE 2,2,(A(1,J),J=1,14),(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=6,31),(A(7,J),J=7,38),(A(8,J),J=8,47),
1 (A(9,J),J=9,47),(A(10,J),J=10,47), 3A(12,J),J=11,47),(A(13,J),J=12,47),4A(14,J),J=13,47),
1 (A(15,J),J=14,47),(A(16,J),J=15,47),(A(17,J),J=16,47),(A(18,J),J=17,47),(A(19,J)
1 ,J=18,47),(A(20,J),J=19,47),1B(1,J),I=1,5)
2 FORMAT(24F3.2/(24F3.2))

READ INPUT TAPE 2,3,(C(1,J),J=1,14),(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=6,31),(C(7,J),J=7,38),(C(8,J)
1 ,J=8,47),(C(9,J),J=9,47),(C(10,J),J=10,47),3C(12,J),J=11,47),(C(13,J)
1 ,J=12,47),(C(14,J),J=13,47),(C(15,J),J=14,47),(C(16,J),J=15,47),(C(17,J)
1 ,J=16,47),(C(18,J),J=17,47),(C(19,J),J=18,47),(C(20,J),J=19,47),1D(1)
1 ,I=1,5)
3 FORMAT(25F3.2/(24F3.2))

READ INPUT TAPE 2,8,(E(1,J),J=1,17),(E(2,J),J=2,15),(E(3,J),J=3,25)
1 ,E(4,J),J=4,15),(E(5,J),J=5,46),(E(6,J),J=6,47),(E(7,J),J=7,47),
2 E(8,J),J=8,47),(E(9,J),J=9,47),(E(10,J),J=10,47),(E(11,J),J=11,47),
1 (E(12,J),J=12,47),(E(13,J),J=13,47),(E(14,J),J=14,47),(E(15,J)
1 ,J=15,47),(E(16,J),J=16,47),(E(17,J),J=17,47),(E(18,J),J=18,47),
1 (E(19,J),J=19,47),(E(20,J),J=20,47)
8 FORMAT(24F3.2/(24F3.2))

READ INPUT TAPE 2,8,(F(1,J),J=1,17),(F(2,J),J=2,15),(F(3,J),J=3,25)
1 ,F(4,J),J=4,35),(F(5,J),J=5,46),(F(6,J),J=6,47),(F(7,J),J=7,47),
2 F(8,J),J=8,47),(F(9,J),J=9,47),(F(10,J),J=10,47),(F(11,J),J=11,47),
1 (F(12,J),J=12,47),(F(13,J),J=13,47),(F(14,J),J=14,47),(F(15,J)
1 ,J=15,47),(F(16,J),J=16,47),(F(17,J),J=17,47),(F(18,J),J=18,47),
1 (F(19,J),J=19,47),(F(20,J),J=20,47)
9 FORMAT(25F3.2/(24F3.2))

1 READ INPUT TAPE 2,4,KASE,KOde,M,W, PJW, VC, TRAV, PMAX, CH(1), VM(1), W
1 ED(1), Y, (PH(H1),I=1,N)
4 FORMAT(2,1X,3F6.0, F8.8, 5F2.2)
3P=PR=PMAX/1.15
500 CONTINUE
60 IF(KOde=99)60,61,60
61 READ INPUT TAPE 2,62,V,Ao,RHo, ETA, U
62 FORMAT(5F6.0)
64 V=12.92
66 Ao=1.015
67 RHo=0.0567
68 ETA=30.57
70 U=305000.

-22-
FORDRAN PROGRAM FOR HIRSCHFELDER INTERIOR BALLISTIC CALCULATIONS

63 IF (KODE = 2) 65, 66, 65
66 V = 11.16
A0 = 0.743
RH0 = 0.0597
ETA = 27.91
U = 360000.
65 IF (KODE = 1) 67, 68, 67
68 V = 10.74
A0 = 0.725
RH0 = 0.0596
ETA = 27.52
U = 355000.
67 IF (KODE = 3) 69, 70, 69
69 V = 12.41
A0 = 0.938
RH0 = 0.0571
ETA = 29.92
U = 317000.
70 IF (KODE = 4) 71, 72, 71
71 V = 9.02
A0 = 0.566
RH0 = 0.6590
ETA = 25.97
U = 382000.
72 IF (KODE = 5) 73, 74, 73
73 V = 11.15
A0 = 0.788
RH0 = 0.0602
ETA = 27.76
U = 339000.
74 IF (KODE = 6) 75, 76, 75
75 V = 12.36
A0 = 0.906
RH0 = 0.0582
ETA = 29.54
U = 327000.
76 IF (KODE = 7) 77, 78, 77
77 V = 14.50
A0 = 1.034
RH0 = 0.0600
ETA = 31.17
U = 336000.
78 IF (KODE = 8) 79, 80, 79
79 V = 12.92
A0 = 0.851
RH0 = 0.0603
ETA = 29.50
U = 364000.
80 IF (KODE = 9) 81, 82, 81
81 V = 11.57
A0 = 0.786
RH0 = 0.0585
ETA = 28.66
U = 353000.
82 IF (KODE = 10) 83, 84, 83
83 V = 11.68

Page 2
FORTRAN PROGRAM FOR HIRSCHFELDER INTERIOR BALLISTIC CALCULATIONS

A0 = 0.786
RH0 = 0.0585
ETA = 28.77
U = 356000.
83 IF(K0DE=34)85,86,85
86 V = 14.07
A0 = 1.007
RH0 = 0.0596
ETA = 30.85
U = 335000.
85 IF(K0DE=36)300,89,300
88 V = 12.59
A0 = 0.828
RH0 = 0.060
ETA = 29.26
U = 364500.
300 STEV0 = 0.0
IF(KASE-1)1100,31,100
100 IF(KASE-2)1102,103,102
103 N=1
   I=1
   DELTA(1)=CH(1)/VC
   PH(1)=V/((1./DELTA(1))-(1./RH0))
   G0 T0 106
102 IF(KASE=3)1104,105,600
600 I=2
   DELTA(I)=CH(1)/VC
   PH(I)=V/((1./DELTA(I))-(1./RH0))
   CH(2)=CH(1)
   WEB(2)=WEB(1)
   VM(2)=VM(1)
   G0 T0 106
105 DELTA(1)= CH(1)/VC
   PH(1)=V/((1./DELTA(1))-(1./RH0))
   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
   12=0
   D0 120 I=1,20
   IF(L=1)120,140,120
140 I2=1
120 CONTINUE
   IF(I2)122,121,122
121 WRITE OUTPUT TAPE 3,123,KASE,PH(1)
123 FORMAT(1H1,10X,7A CASE 13,63H TYPE PROBLEM HAS BEEN REJECTED HERE
   1 BECAUSE CALCULATED PHI IS F10.4,38H FOR WHICH THE TABLES ARE NOT
   ADEQUATE)
   G0 T0 40
122 IF(M=1)108,108,107
107 D0 109 I=1,47
   ABV(I) = ABSF(C(I,1) - GAMMA(1))

-24-
109 CONTINUE
   VAL = ABV(I)
   D0 129 I=1,47
      VAL = MIN1F(VAI,ABV(I))
   129 CONTINUE
   D0 110 I=1,47
      IF(ABV(I) - VAL) 110,112,110
   112 K = I
      TK = K
   110 CONTINUE
      IF(GAMMA(I) - C(L,K))113,114
   113 R=(C(L,K)-GAMMA(I))/(C(L,K)-C(L,K+1)) + TK
      G0 T0 116
   114 R=TK
      S0 T0 116
   115 R=(C(L,K-1)-GAMMA(I))/(C(L,K-1)-C(L,K))+TK-1.
      J=R
   117 Z=J
   118 ZS(1)=A(L,J)-(ABSF(R-Z)*ABSF(A(L,J)-A(L,J+1)))
      T1(1)=1. - 242*ZS(1)/GAMMA(1)
   151 WEB(1)=Y/SQRTF((1.369*AREA**2)/(CH(1)*U*H(1)*ZS(1)))
      PMAX=(POP(1)/A0)*(1.+(CH(1)*(6.*PJW+2.*CH(1))))
      G0 T0 137
   108 D0 130 I=1,47
      ABV(I)=ABSF(F(L,I)-GAMMA(I))
   130 CONTINUE
      VAL=ABV(I)
   131 CONTINUE
      D0 131 I=1,47
      VAL=MIN1F(VAI,ABV(I))
   131 CONTINUE
      D0 132 I=1,47
      IF(ABV(I)-VAL)132,133,132
   132 CONTINUE
      IF(GAMMA(I)-F(L,K))150,134,135
   150 R=(F(L,K)-GAMMA(I))/(F(L,K)-F(L,K+1))+TK
      G0 T0 136
   134 R=TK
      G0 T0 136
   135 R=(F(L,K-1)-GAMMA(I))/(F(L,K-1)-F(L,K))+TK-1.
      J=R
   137 WRITE OUTPUT TAPE 3,138,KASE,KODE,M,W,PJW,VC,TRAV,CH(1),VM(1),ETA,
      RH0,U,V,A0,Y,AREA
   138 FORMAT(1HI,5X,9HI N P U T//5X,7HCASE = 11/5X,18HPR0PELLANT C0DE =
      1 12/5X,21HC0DE F0RM FUNCTION = 11,6H, 7/5X,16HWEAP0N W (MM) = F
      212.4/5X,22HPR0J.WT. PJW (LBS.) = F12.4/5X,27HCHAMBER VOLUME VC (C.
      3IN) = F12.4/5X,19HTRAVEL TRAV (IN) = F12.4/5X,21HC0ARGE CH(1) (LBS.
      4) = F12.4/5X,23HVEL0CITY VM(1) (F/S) = F12.4,10H
      /5X,32HP
FORIRAN PROGRAM FOR HIRSCHFELDER INTERIOR BALLISTIC CALCULATIONS

SR0P, COVOLUME ETA (C,IN/LBS) = F12.4/5X,31HPROP, DENSITY RH0 (LBS/6C.IN) = F12.4/5X,29HPROP, FORCE F (FT.LBS/LBS) = F12.4/5X,24HPROP.
7. CONSTANTS A,AA0 = F12.4,5X,F12.4,5X,16HBURN,CONSTANT B = F12.8/5X,12HBØRE AREA = F12.4,

N=1
WRITE OUTPUT TAPE 3,89,(PHI(1),DELTA(1),CH(1),PP0(1),XIM(1),GAMMA(1),ZS(1),PMAX,S(1),T(1),WEB(1),E(1),N=1)
89 FORMAT(1X//5OX,11H0,UTPUT//102H,PHI,L.DENSITY,CHARGE)
1 PP0 XIM GAMMA ZS PRESSURE S T
3,1X,F123,1X,F8.3,1X,F8.3,1X,F123,2))
G0 T0 40
153 WRITE OUTPUT TAPE 3,155,KASE,KODE,M,W,PP0,VC,TRAV,PMAX,P0PR,CH(1),
1VM(1),WEB(1),ETA,RH0,U,V,A0,AREA
155 FORMAT(1H1,50X,9PH1N P U T //5X,7HCASE = .11/5X,18HPROPPELLANT CODE =
1 1 I2/5X,21HCØDE FØRM FUNCTION = I1,6H
/5X,16WEAP0N W (MM) = F
212.4/5X,22HPØJ,T. PW (LBS) = F12.4/5X,27HCAMBER VOLUME VC (C.
3IN) = F12.4/5X,19HTRAVEL TRAV (IN) = F12.4/5X,26HMÄX PRESSURE PMAX
4 (PSI) = F12.4/5X,32HP0PR (PSI) = F12.4/5X,15HC
5HARGE (LBS) = F12.4/5X,17HEL0CITY (F/S) = F12.4/5X,6HEW = F12.4,
654H
/5X,32HP
7R0P, COVOLUME ETA (C,IN/LBS) = F12.4/5X,31HPROP, DENSITY RH0 (LBS/8C.IN) = F12.4/5X,29HPROP, FORCE F (FT.LBS/LBS) = F12.4/5X,24HPROP.
9 CONSTANTS A,AA0 = F12.4,5X,F12.4,5X,12HBØRE AREA = F12.4,

N=1
WRITE OUTPUT TAPE 3,700,PH(2),DELTA(2),CH(1),P0P(2),XIM(2),GAMMA(2
1),ZS(2),VM(1),WEB(1),ETA,RH0,U,V,A0,AREA
700 FORMAT(1X//5OX,11H0,UTPUT//102H,PHI,L.DENSITY,CHARGE)
1 PP0 XIM GAMMA ZS VELOCITY S T
3,1X,F123,1X,F8.3,1X,F8.3,1X,F123,9))
WRITE OUTPUT TAPE 3,156
156 FORMAT(1X//3OX,57HTHE POINT 0F ØPTIMUM EFFICIENCY IS WHEN S AND T
1AIRE EQUAL)
104 G0 T0 40
31 D0 5 I = 1,N
1 DELTA(I) = 1./(5*PH(1))*1./RH0
1 CH(I) = VC*DELTA(I)
106 P0P(I) = PMAX*A0*(((PW + CH(I))/3.)/(PW + CH(I))/2.))
1 AREA = ((W/25.4)**2)*3.1416/4.)
1 X = (VC*(AREA/TRAV))//VC
1 XIM(I) = VM*DELTA(I)/(X*(ETA*DELTA(I)))
1 Q = (PH(1)*100.)/5.
1 Q = Q+0.4
1 R = P0P(I)/2000.
1 R = R+(1.//10.**7))
1 L = Q
1 J = R
1 Z = J
1 IF(M-I)**11,11,10
1 GAMMA(I) = F(L,J)-ABS((P0P(I)/2000.-Z)*ABS(F[L,J]-F[L,J+1]))
1 H(I) = 0.317*(PW+1.3226*CH(I)))
1 VM(I) = SQRTF((1.-GAMMA(I)*(XIM(I)**0.3))*((2.*CH(I)*U)/(0.3*H(I))))
1 S(I) = XIM(I)**0.3
1 T(I) = (1.41485*ZS(I))/*GAMMA(I)

Page 5

-26-
FORTRAN PROGRAM FOR HIRSCHFELDER INTERIOR BALLISTIC CALCULATIONS

162 \( Y = \text{WEB}(1) * \text{SQRTF}(0.99 * \text{AREA}**2) / (\text{CH}(1) * \text{U} * \text{H}(1) * \text{ZS}(1)) \)

\text{G0 TO 153}

10 \( \text{ZS}(1) = A(L,J) - (\text{ABSF}((P0P(I)/2000.0) - Z) * \text{ABSF}(C(L,J) - C(L,J+1))) \)

\( H(I) = 0.317 * (\text{PWW} .5 + 3.226 * \text{CH}(1)) \)

\( \text{VM}(I) = \text{SQRTF}(1 - \text{GAMMA}(I) * (XIM(I) * 0.3)) \)

\( \text{S}(I) = XIM(I) * 0.3 \)

\( \text{T}(I) = (1 - 0.242 * \text{ZS}(I)) / \text{GAMMA}(I) \)

\( \text{WEB}(I) = Y / \text{SQRTF}(1.369 * \text{AREA}**2) / (\text{CH}(1) * \text{U} * \text{H}(1) * \text{ZS}(1)) \)

IF(KASE-4) 5,152,152

152 \( Y = \text{WEB}(1) * \text{SQRTF}(1.369 * \text{AREA}**2) / (\text{CH}(1) * \text{U} * \text{H}(1) * \text{ZS}(1)) \)

\text{G0 TO 153}

5 CONTINUE

IF(STEV0)201,200,201

WRITE OUTPUT TAPE 3,6,\text{KASE, KODE, M, W, PJW, VC, TRAV, PMAX, P0PR, ETA, RH0, U, V, A0, Y, AREA}

F12.4/5X,201,200,201

WRITE OUTPUT TAPE 3,6,\text{PHI, DELTA(I), CH(I), P0P(I), XIM(I), GAMMA(I), ZS(I), VM(I), S(I), T(I), WEB(I), I=1,N)

F12.4/5X,18HWEAP0N W (MM) = F12.4/5X,16HAREA

12/5X,22HPROJECT W (MM) = F12.4/5X,19HTRAVEL TRAV (IN) = F12.4/5X,26HMAX PRESSURE PMA

4 (PSI) = F12.4/5X,32HP0PR (PSI) = F12.4/5X,32HCHAMBER VOLUME VC (C.3IN)

5R0P. DENSITY RH0 (LBS/6C.IN) = F12.4/,5X429HPR0P. 70F.F. F12.4/5X,24HPR0P.

WRITE OUTPUT TAPE 3,7 THE POINT OF OPTIMUM EFFICIENCY IS WHEN S AND T ARE EQUAL.

IF(STEV0)40,32,40

32 N4 = 2

N5 = 1

D0 30 I=1,N

IF(S(I)-T(I))29,27,25

25 AB(I) = 100.

N5 = 2

G0 TO 30

27 WRITE OUTPUT TAPE 3,28,PHI(I),S(I)

28 F0RMAT(1X/30X,6HPHI = F12.3,15H SINCE S = T = F12.4)

N4 = 1

G0 TO 30

29 AB(I) = ABSF(S(I) - T(I))

Page 6

VALUE=AB(I)

G0 TO(40,35),N4

35 D0 23 I=1,N

VALUE=MINIF(VALUE,AB(I))

23 CONTINUE

K=10
FORTRAN PROGRAM FOR HIRSCHFELDER INTERIOR BALLISTIC CALCULATIONS

DO 24, 1 = 1, N
   IF(AB(I) - VALUE) 24, 26, 24
26 K = I
24 CONTINUE
   IF(K - 10) 950, 951, 951
951 WRITE OUTPUT TAPE 3, 952, PH(I), S(I), T(I)
952 FORMAT(1X//20X, 22H TRUE 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
   N = 1
   STEV0 = 2.0
   GO TO 31
970 N = 1
   STEV0 = 2.0
   GO TO 31
950 IF(STEV0) 900, 905, 900
900 IF(K - 2) 201, 201, 902
905 WRITE OUTPUT TAPE 3, 33, PH(K), S(K), T(K)
33 FORMAT(1X//20X, 25H TRUE PHI IS GREATER THAN F12.4, 11H WHERE S = F12
   1, 4H AND T = F12.4//)
902 IF(PH(K) - 1.0) 41, 40, 40
   41 IF(PH(K) - PH(1)) 44, 43, 43
   42 IF(PH(1) - 0.95) 51, 51, 51
51 PH(1) = 1.0
   N = 1
   GO TO 48
50 IF(PH(1) - 0.90) 53, 52, 52
52 PH(1) = 0.95
   PH(2) = 1.0
   N = 2
   GO TO 48
53 PH(1) = PH(1) + 0.05
   PH(2) = PH(1) + 0.05
   N = 3
   GO TO 48
43 IF(PH(K) - 0.95) 44, 45, 45
45 PH(1) = PH(K) + 0.05
   N = 1
   GO TO 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
   GO TO 48
46 PH(1) = PH(K) + 0.05
   PH(2) = PH(1) + 0.05
   PH(3) = PH(2) + 0.05
   N = 3
48 STEV0 = 1.0
   GO TO 31
201 WRITE OUTPUT TAPE 3, 202, (PH(I), DELTA(I), CH(I), P0P(I), XIM(I), GAMMA(I),
   11I, ZS(I), VM(I), S(I), T(I), WEB(I), I = 1, N)
   IF(STEV0 - 1.) 40, 920, 960
960 IF(S(1) - T(1)) 44, 27, 961
920 DO 921 I = 1, N
   -28-
FØRTRAN PROGRAM FØR HIRSCHFELDER INTERIØR BALLISTIC CALCULATIONS

IF(S(11)-T(11))921,921,922
922 N5=2
921 CONTINUE
   IF(N5-2)32,40,40
40 GO TO 1
   END(1,1,0,0,0,0,1,1,0,0,0,0,0,0,0)
ABSTRACT DATA
A DIGITAL COMPUTER PROGRAM FOR HIRSCHFELDER INTERIOR BALLISTICS

Forrest L. McMains


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.
UNCLASSIFIED

1. Digital Computer Program — Programming (Computers)
2. Ballistics — Interior

I. McMain, Forrest L.

UNTERMS
Digital computer
Input format
Output format
Interior ballistic calculations
Hirschfelder System
Velocity
Web
Propellant codes
McMain, F. L.

UNCLASSIFIED

1. Digital Computer Program — Programming (Computers)
2. Ballistics — Interior

I. McMain, Forrest L.

UNTERMS
Digital computer
Input format
Output format
Interior ballistic calculations
Hirschfelder System
Velocity
Web
Propellant codes
McMain, F. L.

UNCLASSIFIED
Accession No. AD
Picatinny Arsenal, Dover, New Jersey

A DIGITAL COMPUTER PROGRAM FOR HIRSCHFELDER INTERIOR BALLISTICS
Forrest L. McMain

Technical Memorandum 1404, April 1964, 31 pp., tables. Unclassified report from the Artillery Ammunition Laboratory, Ammunition Engineering Directorate.

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.
<table>
<thead>
<tr>
<th>Copy Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
</tbody>
</table>

### TABLE OF DISTRIBUTION

1. **Commanding General**  
   U. S. Army Materiel Command  
   Washington, D.C.  
   ATTN: AMCRD-RD

2. **Commanding General**  
   U. S. Army Munitions Command  
   Dover, New Jersey  
   ATTN: SMSMU-AA

3. **Commanding Officer**  
   Picatinny Arsenal  
   Dover, New Jersey  
   ATTN: SMUPA-VA6
   SMUPA-DX1
   SMUPA-DR3
   SMUPA-VC4

4. **Commanding Officer**  
   Harry Diamond Laboratories  
   Washington, D.C.  
   ATTN: Library, Bldg. 92

5. **Commandant**  
   U. S. Army Ordnance Center and School  
   Aberdeen Proving Ground, Maryland  
   ATTN: AISO-SL

6. **Commanding Officer**  
   Ammunition Procurement and Supply Agency  
   Joliet, Illinois  
   ATTN: SMUAP-AE

7. **Commanding Officer**  
   U. S. Army Engineer Research & Development Laboratories  
   Fort Belvoir, Virginia  
   ATTN: STINFO Branch

8. **Defense Documentation Center**  
   Cameron Station  
   Alexandria, Virginia