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AUTHORITY

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THEORETICAL CALCULATIONS OF THE
PHENOMENOLOGY OF HE DETONATIONS

Volume II

William A. Whitaker, Captain, USAF
Edmund A. Nawrocki, Captain, USAF
Charles E. Needham
William W. Troutman

TECHNICAL REPORT NO. AFWL-TR-66-141, Vol. II

November 1966

AIR FORCE WEAPONS LABORATORY
Research and Technology Division
Air Force Systems Command
Kirtland Air Force Base
New Mexico

Best Available Copy
THEORETICAL CALCULATIONS OF THE PHENOMENOLOGY OF HE DETONATIONS

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FOREWORD

This research was performed under Program Element 7.60.08.01.D, Project 5710, Subtask 1.027, and was funded by the Defense Atomic Support Agency (DASA).

Inclusive dates of research were 1 September 1965 to 1 June 1966. The report was submitted 27 October 1966 by the Project Officer, Capt William A. Whitaker (WLRTH).

This report has been reviewed and is approved.

WILLIAM A. WHITAKER
Captain, USAF
Project Officer

RALPH H. PENNINGTON
Colonel, USAF
Chief, Theoretical Branch

CLAUDE K. STAMBAUGH
Colonel, USAF
Chief, Research Division
ABSTRACT

The phenomenology of two atmospheric high-explosive detonations were calculated theoretically. The first was a 20-short-ton spherical charge of TNT (loading density--1.56 gms/cc). The second was a methane-oxygen mixture (mole ratio 1 to 1.5) contained in a 55-ft-radius balloon. Both detonations took place at an altitude of 670 meters (ambient pressure 13.6 psi) with a reflecting surface 85 feet below burst point. The calculations, taken out to 300 milliseconds after detonations, were performed by using SAP, a one-dimensional Lagrangian hydrodynamic code and SHELL-OIL, a two-dimensional pure Eulerian hydrodynamic code. Volume II of this report contains the details of the results in graphical form. Included are pressure and density contours, velocity vector plots, and wave forms for 19 test stations.
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</table>
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SECTION I

INTRODUCTION

Volume II is divided into three sections, the last two of which are, in turn, divided into three parts.

Section II contains plots of the TNT calculations. Part 1 consists of profiles of the thermodynamic variables at selected times as calculated by SAP. Part 2 consists of pressure and density contours and velocity vectors at selected times as calculated by SHELL-OIL. Part 3 consists of traces of overpressure, dynamic pressure impulse, radial velocity and axial velocity as a function of time at the various test stations; again, the results of SHELL-OIL.

Section III contains plots of the methane calculation. The format of this section is the same as in Section II: first, SAP profiles; second, SHELL-OIL contours and velocity vectors; third, SHELL-OIL tracings at the test stations.

The output contained in this volume is small compared to that available. More detailed, or additional output, in graphical form is available upon request to AFWL (WLRT8).
Table I

POSITION OF TEST STATIONS

<table>
<thead>
<tr>
<th>Test Stations</th>
<th>Range</th>
<th>Altitude</th>
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</thead>
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<tr>
<td></td>
<td>Meters</td>
<td>(Feet)</td>
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<tr>
<td>1</td>
<td>0</td>
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</tr>
<tr>
<td>2</td>
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<tr>
<td>3</td>
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<tr>
<td>4</td>
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<td>5</td>
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<td>6</td>
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<td>0</td>
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<tr>
<td>7</td>
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<td>0</td>
</tr>
<tr>
<td>8</td>
<td>78.0 (256)</td>
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<td>10</td>
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<td>11</td>
<td>38.0 (125)</td>
<td>2.8 (9)</td>
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<td>12</td>
<td>50.0 (164)</td>
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<td>13</td>
<td>38.0 (125)</td>
<td>7.6 (25)</td>
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<tr>
<td>14</td>
<td>50.0 (164)</td>
<td>7.6 (25)</td>
</tr>
<tr>
<td>15</td>
<td>63.8 (209)</td>
<td>7.6 (25)</td>
</tr>
<tr>
<td>16</td>
<td>50.0 (164)</td>
<td>15.2 (50)</td>
</tr>
<tr>
<td>17</td>
<td>63.8 (209)</td>
<td>18.0 (59)</td>
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<td>18</td>
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<td>15.2 (50)</td>
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<tr>
<td>19</td>
<td>78.0 (256)</td>
<td>22.8 (75)</td>
</tr>
</tbody>
</table>
SECTION II

THE TNT CALCULATION

SAP Profiles

This part contains profiles of pressure, density, and velocity as calculated by SAP for the TNT detonation scaled to 20 short tons. There are plots for 25 different times.

The first plot contains the profiles describing the flow field behind the detonation front in the TNT. Also shown on this plot, as indicated by the symbols, is the similarity solution for the detonation wave, obtained using the LSZK equation of state for TNT. Agreement between the SAP "burn" calculation, which provides a nonself-similar solution, and the similarity solution is excellent.

Succeeding plots show the convergence of the rarefaction wave on the origin, the formation and expansion of the free-air shock, and the formation and motion of secondary shocks.
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SHELL Contours and Velocity Vectors

This part contains pressure and density contours and velocity vector plots of the results of the SHELL-OIL calculation of the TNT detonation (20 short-tons). There are plots for 8 different times.

The first plot shows the reflection of the free-air shock at the ground. Subsequent plots show the formation and movement of the triple point and mach stem. The heavy black line on each plot shows the location of the massless trace particles that represent the TNT-air interface at that time.

The numbers along the top of each plot represent the horizontal index of each cell of the mesh used in the calculation. The numbers along the right edge of the plot refer to vertical indices. The number associated with each contour line represents a value for that line appearing in the upper right hand corner of each contour plot. The velocity vector scale is similarly given in the upper right hand corner of each velocity vector plot.
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AFWL SHELL OIL CALC. OF 20 TONS TNT ON 85 FT. TOWER, P0=13.6
TIME: 61.4 SEC  CYCLE: 61  PROBLEM: 201.406
AFWL SHELL OIL CALC. OF 20 TONS TNT ON 85 FT. TOWER PO=3.46
TIME 0.19 SEC  CYCLE 111  PROBLEM 201.004
REAL SHELL OIL CALC. OF 20 TONS TNT ON 85 FT TOWER: P0=1316
TIME: 0.42 SEC  CYCLE 283  PROBLEM 201.008
AFW SHELL OIL CALC. OF 20 TONS TNT ON 85 FT. TOWER PO=136
TIME 056 SEC CYCLE 328 PROBLEM 201004
AFWH SHELL OIL CALC. OF 20 TONS TNT ON 85 FT. TOWER PO=13.6
TIME  .056 SEC   CYCLE 32B   PROBLEM 201.009
AFW, SHELL OIL, CALC. OF 20 TONS TNT ON 85 FT. TOWER P0 = 13.6
TIME: 300 SEC  CYCLE: .748  PROBLEM: 20, 000
AFWI SHELL OIL CALC. OF 20 TONS TNT ON 65 FT. TOWER P0=13.6
TIME .300 SEC CYCLE 248. PROBLEM 201.000
SHELL Tracings

This part contains the tracings recorded at each test station of overpressure, dynamic pressure overpressure impulse, dynamic pressure impulse and velocity resulting from the TNT detonation. These are SHELL-OIL results.

Table 1 gives the location of each test station.
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VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME: STATION NUMBER 9
HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER 2

TIME (SEC.)

0.040 6 0.080 0.120 0.160 0.200 0.240 0.280 0.320 0.360 0.400 0.440
OVER PRESSURE IMPULSE VS TIME. STATION NUMBER 10.
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SECTION III
THE METHANE CALCULATION

SAP Profiles

This part contains profiles of pressure, density and velocity as calculated by SAP for the methane detonation. This charge, a 1.5 to 1 molar mixture of oxygen and methane, was initially contained in a balloon of 55 ft radius. There are plots for 16 different times.

The first plot contains the profiles describing the flow field behind the detonation front in the methane. Unlike the TNT detonation ambient pressure (13.6 psi) is not negligible; therefore the similarity solution differs from the SAP calculation by approximately 5 percent as can be seen in the first figure. The similarity solution for the methane detonation using the following parameters: detonation velocity, $2.7522 \times 10^5$ cm/sec; loading density, $1.07197 \times 10^{-3}$ gm/cm$^3$; gamma = 1.2136.

Succeeding plots show the convergence of the rarefaction wave on the origin, the formation and expansion of the free-air shock, and the formation and motion of secondary shocks.
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SHEE-L Contours and Velocity Vectors

This part contains pressure and density contours and velocity vector plots of the results of the SHEE-L-OIL calculation of the Methane detonation. There are plots for eight different times.

The first plot shows the reflection of the free-air shock at the ground. Subsequent plots show the formation and movement of the triple point and mach stem. The heavy black line on each plot shows the location of the massless trace particles which represent the methane-air interface at that time.

The numbers along the top of each plot represent the horizontal index of each cell of the mesh used in the calculation. The numbers along the right edge of the plot refer to vertical indices. The number associated with each contour line represents a value for that line appearing in the upper right-hand corner of each contour plot. The velocity vector scale is similarly given in the upper right-hand corner of each velocity vector plot.
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AFHL SHELL OIL CALCULATIONS OF 110 FT. METHANE BALLOON AT 85 FT.

TIME 0.026 SEC  CYCLE 181  PROBLEM EOL.004  /9

207
APRIL SHELL OIL CALCULATIONS OF 110 FT - METHANE BALLOON AT 85 FT.

TIME  .026 SEG  CYCLE 151  PROBLEM 201.05N

208
SHELL Tracings

This part contains the tracings recorded at each test station of overpressure, dynamic pressure overpressure impulse, dynamic pressure impulse and velocity resulting from the methane detonation. These are SHELL-OIL results.

Table I gives the location of each test station.
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OVERRIDE PRESSURE VS TIME STATION NUMBER 1
OVER PRESSURE VS TEMP: STATION (RUGER. 2)
HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER 3
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THEORETICAL CALCULATIONS OF THE PHENOMENOLOGY OF HE DETONATIONS

1. September 1965 to 1 June 1966

Whitaker, William A., Capt, USAF; Nawrocki, Edmund A., Capt, USAF; Needham, Charles E.; Troutman, William W.

November 1966

AFWL-TR-66-141, Vol. II

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13. ABSTRACT

The phenomenology of two atmospheric high-explosive detonations were calculated theoretically. The first was a 20-short-ton spherical charge of TNT (loading density--1.56 gms/cc). The second was a methane-oxygen mixture (mole ratio 1 to 1.5) contained in a 55-ft-radius balloon. Both detonations took place at an altitude of 670 meters (ambient pressure 13.6 psi) with a reflecting surface 85 feet below burst point. The calculations, taken out to 300 milliseconds after detonations, were performed by using SAP, a one-dimensional Lagrangian hydrodynamic code and SHELL-OIL, a two-dimensional pure Eulerian hydrodynamic code. Volume II of this report contains the details of the results in graphical form. Included are pressure and density contours, velocity vector plots, and wave forms for 19 test stations.
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DEPARTMENT OF THE AIR FORCE
AF Weapons Laboratory, RTD (AFSC)
Kirtland Air Force Base, New Mexico 87117

12 April 1967

ERRATA

AFWl-TR-66-141,
Volume II


1. Replace pages 5 through 29 with the attached pages 5 through 29.

2. The units for the values appearing in the contour scales in Sections II and III are: grams/cm$^3$ for the density contours and dynes/cm$^2$ for the pressure contours.

AUTHORITY:
EDWARD A. NAWROCKI
Capt, USAF
4 April 1967

C. W. HAIG
Chief, Reports and Data Branch
Technical Information Division