DRAG COEFFICIENT MEASUREMENTS FOR TYPICAL BOMB AND PROJECTILE FRAGMENTS

By

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ABSTRACT

The FRAGHAZ computer program has been developed to predict the hazardous regions due to fragments produced by an accidential explosion of stored ammunition. Determination of these hazardous regions is based on computer simulations of fragment trajectories. Currently, the fragment drag coefficients used in the program are extrapolations of subsonic drag coefficients out to transonic and supersonic speed regimes. Errors in the Mach number effects of these fragments can influence the predicted range characteristics. This paper describes a series of wind tunnel and air gun tests conducted to measure the drag coefficients of representative bomb and projectile fragnments over the entire Mach number range experienced in flight. Comparative trajectories are made to illustrate the differences between using the original and current drag coefficient data for the FRAGHAZ program.

ACKNOWLEDGEMENT

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NOMENCLATURE

C_D	Drag coefficient - D/qS	V	Velocity
S	Reference Area	o	Air Density
D	Drag force	R_e	Reynolds number - Vd/υ
E	Flight path angle (to ground)	d	Reference length
q	Dynamic pressure - $\rho V^2/2$	υ	Air kinematic viscosity

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INTRODUCTION

The FRAGHAZ computer program (Ref 1) has been developed to predict the hazardous regions due to fragments produced by an accidental explosion of stored ammunition. Determination of these hazardous regions is based on computer simulations of fragment trajectories. The trajectory calculations are a function of the drag coefficients derived from representative bomb and artillery projectile fragments. These drag coefficients depend on the fragment shape and the Mach number at which they fly through the air. Currently, the fragment drag coefficients are established by extrapolating measured subsonic drag coefficients out to transonic and supersonic speed regimes. Errors in the Mach number effects of these fragments could influence the predicted range characteristics.

This paper describes the initial results of wind tunnel and air gun tests to measure the drag coefficients of representative bomb and projectile fragments over the entire Mach number range experienced in flight. These data are used to compute comparative trajectories to illustrate the differences between using the original and current drag coefficient data for the FRAGHAZ program.

BACKGROUND

The FRAGHAZ program computes the trajectories of nominal fragment configurations using experimentally determined initial velocities and experimentally determined drag characteristics. A large number of parameters defining the physical conditions of the fragments and the initial blast effects can be simulated. Resulting fragment trajectories are computed using a Monte Carlo statistical technique and danger regions determined for any prescribed hazard constraints. The drag coefficients used in the FragHaz program are functions of the fragment shape and the Mach number at which they fly through the air. Initial fragment velocities depend on their size and weight, but are on the order of 5000 ft/sec (Mach 4.5).

The current version of the FRAGHAZ program uses an empirical method to define the drag coefficient for a particular class of fragments. This approach is based on a drag coeffient value for the fragment determined during previous experiments in a vertical wind tunnel. A particular fragment was placed in the test section of the tunnel and the upward directed air stream was adjusted until the fragment freely floated. The fragment thus assumed the same flight attitude to the free stream that it would have under free flight conditions. The tunnel velocity represented the fragment's terminal velocity and this value, along with the known fragment weight and size, allowed the drag coefficient to be computed. This method provided the experimental drag coefficient value for the actual flight attitude, but for a very low Mach number (on the order of Mach 0.1). This procedure was repeated for a large number of fragments and the data analyzed to develop a general empirical method to determine the drag coefficient for any fragment over the entire Mach number range of interest. Using the single subsonic data point as a reference, the drag coefficient was estimated at specific Mach number "anchor points" to generate the general Mach number effects. This procedure is illustrated in Fig 1.

The goal of the current study was to experimentally determine the drag coefficient as a function of Mach number over the entire anticipated Mach number range. These data could then be compared to the previous empirical method to validate or improve the FRAGHAZ program.

FRAGMENT CONFIGURATIONS

The original fragment analysis considered a total of 96 representative fragments composed of half artillery projectile and half bomb type fragments. From these, 10 projectile and 10 bomb fragments were selected for analysis under this effort. These were chosen to represent various size, shape and texture characteristics. Since these fragments are part of a set of standard fragments which are being retained for future reference, it was not desirable to alter these fragments for wind tunnel mounting nor risk the chance of loosing them during air gun firing. This problem was solved by making multiple duplicates of each fragment. A rubber based molding apparatus was constructed which allowed duplicate fragments to be molded out of CERABEND metal which is a low melting temperature alloy used by pipe fitters. Several different fragments could be made from a single mold as shown in Fig 2. The resulting fragments had the same size, shape and effective weight of the original and could be easily made by the dozens. Fig 3 contains an actual and a duplicate fragment.

WIND TUNNEL TESTS

Initially, a series of wind tunnel tests was conducted to measure the drag coefficients of selected fragments for validation of the FRAGHAZ program as well as to provide a comparative basis for the air gun tests. The full scale, duplicate fragment model was mounted to a sting type strut in a broadside orientation to the free stream air flow direction which is the attitude at which it is expected to have in free flight. An internal strain gage balance was located inside the strut to measure the drag force. The model was first tested in the ARCA Br 6 X 6-Inch Supersonic Wind Tunnel over a Mach number range from Mach 1.5 to Mach 4 (Ref 2). The same arrangement was then employed for tests in the ARCA Br 20 X 20-Inch Transonic Wind Tunnel for speeds of Mach .45 through Mach 1.2. Figs 4 and 5 show the model installed in the supersonic and transonic wind tunnels, respectively. A 1-Inch sphere model was tested using the same experimental setup to validate the experimental arrangement. The resulting data are shown in Fig 6 compared with data from other sources. Fig 7 summarizes the drag coefficient as a function of Mach number for a nominal fragment as determined from these tunnel tests.

The supersonic wind tunnel has the capability of operating at fixed Mach numbers like conventional facilities. However, its assymetrical nozzle block can be pneumatically shifted with time allowing the Mach number to be varied during a single test run. This permits supersonic data to be obtained in a relatively short time. Fig 8 compares drag data for the nominal fragment using these two tunnel testing techniques.

AIR GUN TESTS

A series of tests were conducted where the fragment was fired from the ARCA Br, 6-Inch spinning barrel air gun illustrated in Fig 9. A special sabot design was employed to launch the fragments from the 6 inch diameter gun as shown in Fig 10. Upon exiting the barrel, the two piece, polyethylene sabot separated from the fragment allowing the fragment to fly down range. Barrel spin provided a means of rapidly separating the sabot pieces and having them travel laterally away from the fragment flight path. The small amount of spin also reduced lateral dispersion of the fragment keeping it flying along its original heading. A ground based, doppler radar system tracked the fragment velocity as a function of time. From the deceleration data and the known fragment weight and size, the drag coefficient could be obtained over the flight Mach number achieved. This approach has the advantages over wind tunnel testing in that it obtains data over a large Mach number range very quickly and allows the fragment to assume its natural flight orientation.

Initially, air gun tests have been completed with a spherical projectile in order to evolve and validate the testing technique. Fig 11 shows data for a 1-Inch diameter sphere which was tested from the air gun and illustrates the complex interaction between Reynolds number and Mach number characteristic of a sphere. Only a few air gun tests have been completed with a fragment and these have been limited to transonic and subsonic velocities. Data for the nominal fragment are shown in Fig 12.

VELOCITY CALCULATIONS

Fig 13 summarizes the drag coefficient data obtained from this study with that generated by the current FRAGHAZ methodology for the nominal fragment. Note that the newer data possesses a slightly lower transonic drag coefficient and a slightly higher supersonic drag coefficient compared to the original data. The resulting velocity decay for these sets of data are contained in Fig 14 for a typical initial blast condition. The associated velocity with range for these same conditions are shown in Fig 15. Finally, the resulting trajectory is contained in Fig 16. Note, that the newer data results in about a 5% increase in range compared to the older data. These data also include the results using the subsonic drag coefficient value only. This latter result indicates a 20% increase in range over the original FRAGHAZ approach. Even though the bulk of the flight is subsonic, the higher Mach number effects have an appreciable influence on the trajectory.

CONCLUSIONS

1. The use of duplicate fragments molded from CERABEND metal provides a large number of identical fragments for testing purposes.

2. The results of conventional wind tunnel tests have shown good agreement with the current FRAGHAZ fragment drag coefficient estimating technique.

3. Initial air gun firings of duplicate fragments have demonstrated the use of the special sabot and radar tracking methodology but have been limited to transonic and subsonic velocities.

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2. Miller, M. C., "Experimental Aerodynamic Facilities of the Aerodynamics Research and Concepts Assistance Section", CSL Special Report, ARCSL-SP-83007, February 1983.

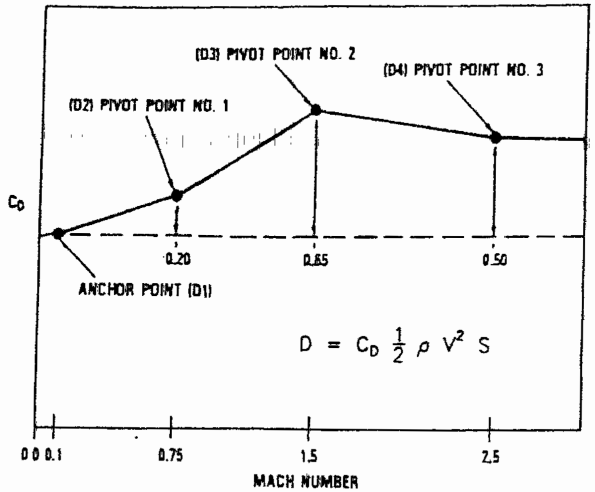

Fig 1. FRAGHAZ Coefficient Method

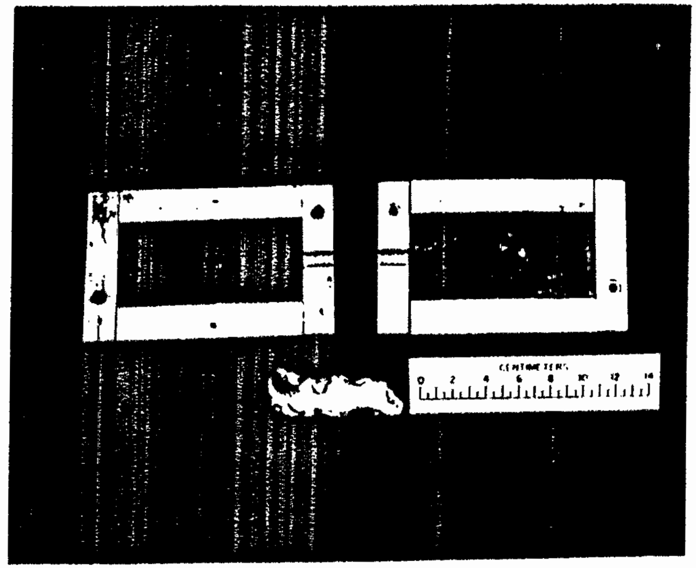

Fig 2. Duplicate Fragment Mold

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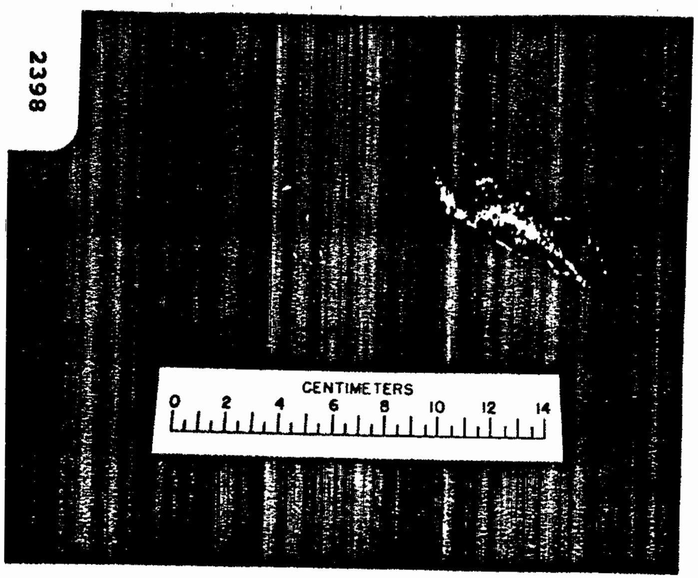

Fig 3. Duplicate and Actual Fragment

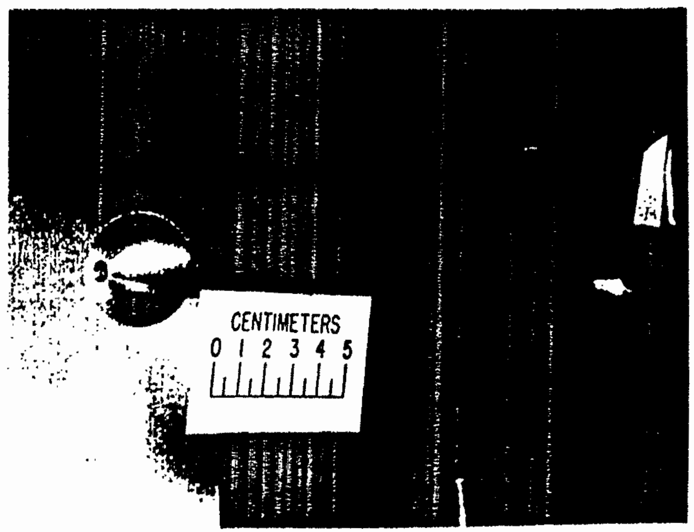

Fig 4. Model Installed in Supersonic Wind Tunnel

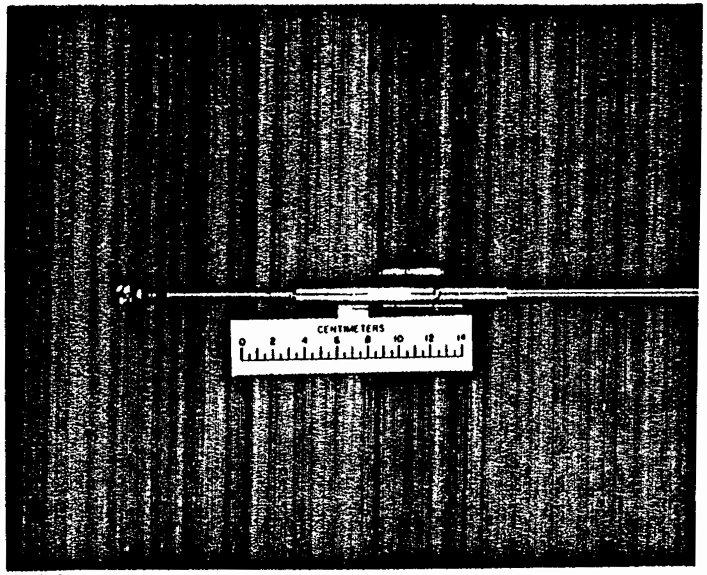

Fig 5. Model Installed in Transonic Wind Tunnel

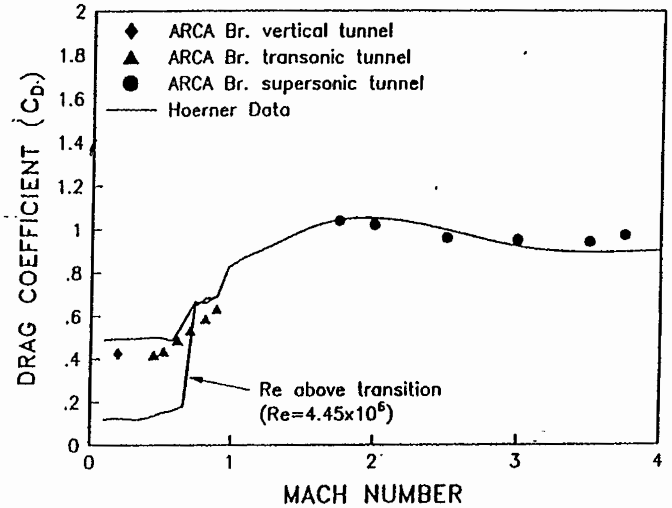

Fig 6. Wind Tunnel Data for Sphere

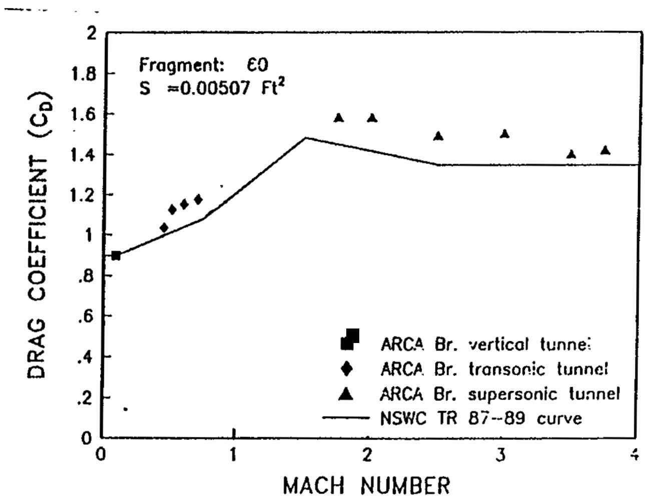

Fig 7. Wind Tunnel Data for Fragment

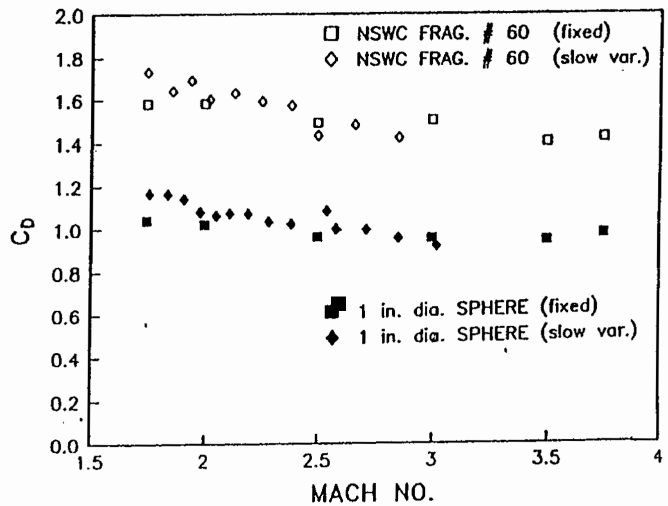

Fig 8. Variable Versus Fixed Mach Number Data

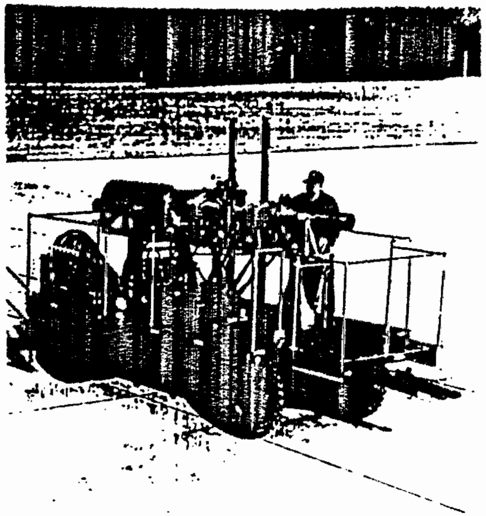

Fig 9. Spinning Barrel Air Gun

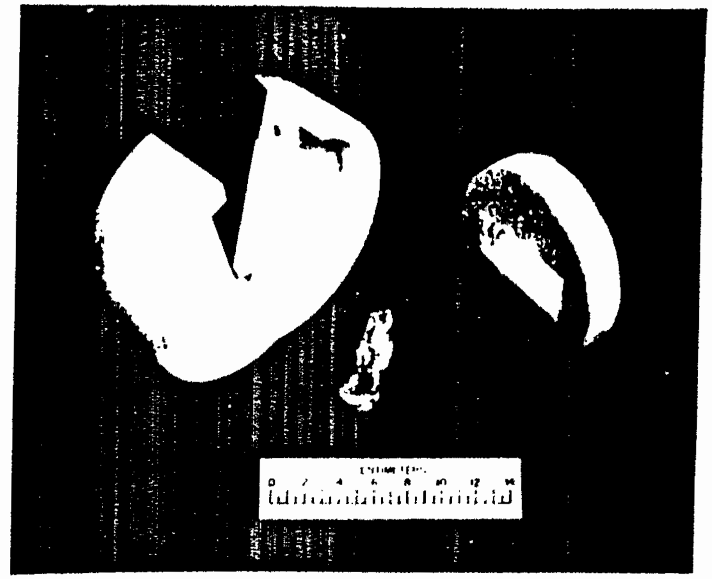

Fig 10. Fragment Sabot

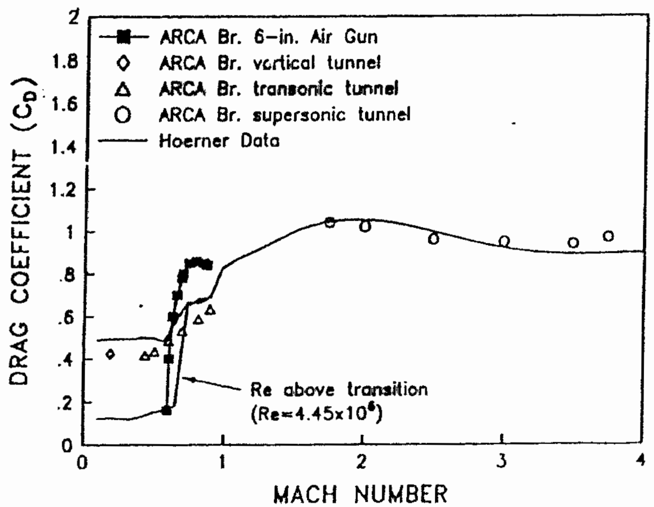

Fig 11. Air Gun Test Data for Sphere

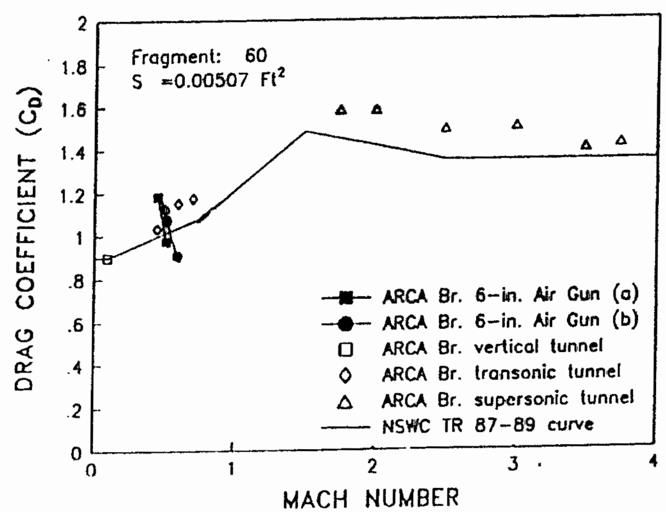

Fig 12. Air Gun Test Data for Fragment

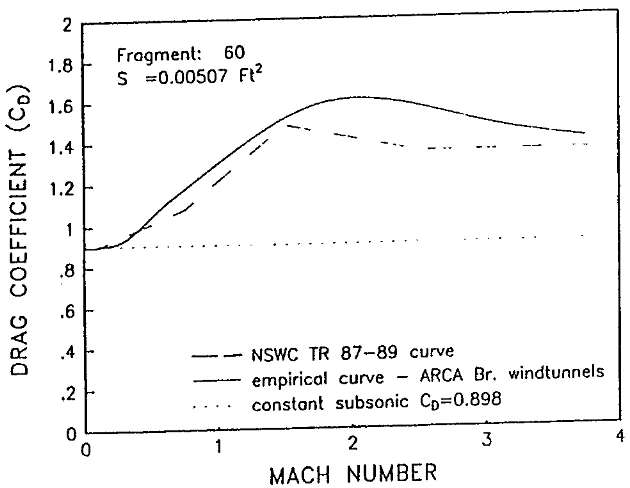

Fig 13. Comparison of FRAGHAZ and Test Data

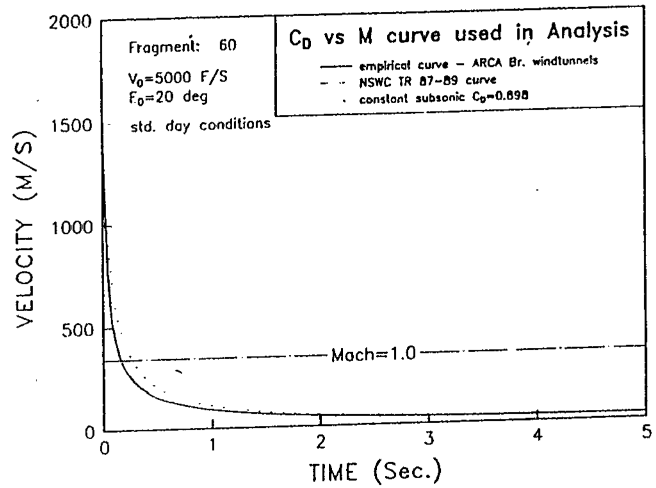

Fig 14. Computed Velocity Decay With Time

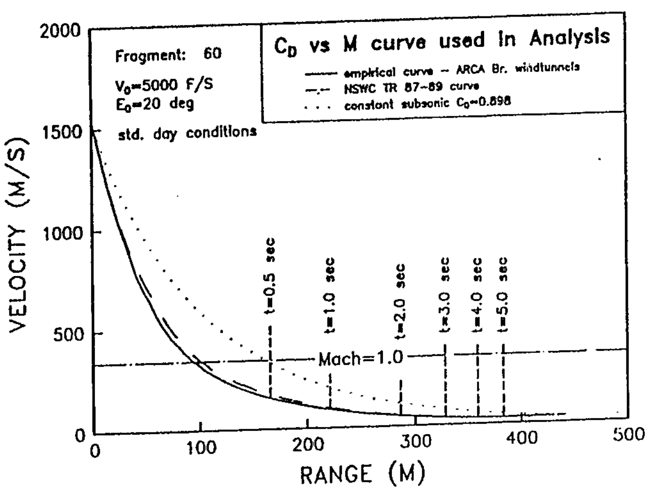

Fig 15. Computed Velocity Decay With Range

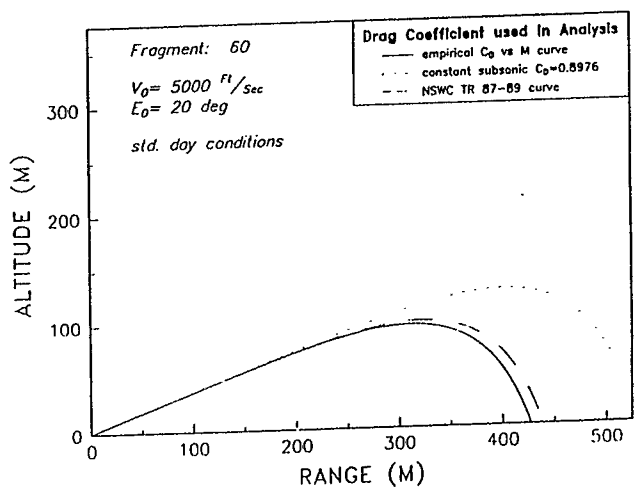

Fig 16. Computed Trajectories