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VISCOUS MODELING OF THE INTERIOR ROLLISTIC CYCLE (H)
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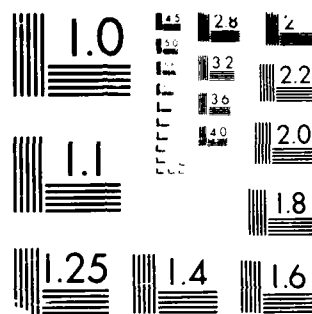
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Fraunhofer-Institut für Kurzzeltdynamik
Ernst-Mach-Institut
Abteilung für Ballistik

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VISCOUS MODELING OF THE INTERIOR BALLISTIC CYCLE

R. Heiser

CONTRACTOR:

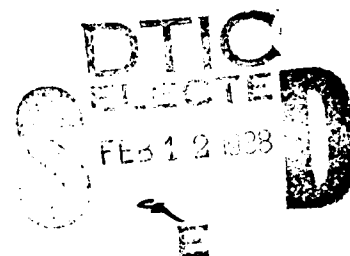
FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG e.V.,
ATTN: CONTRACTS DEPARTMENT, LEONRODSTRASSE 54,
D-8000 MÜNCHEN 19, FEDERAL REPUBLIC OF GERMANY

CONTRACT No. DAJA 45-86-C-0031

First Periodic Report

April 1987 - May 1987

June - September 1987



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1. This contract has been started on April 1, 1987. In time EMI-AFB succeeded in hiring Dr. Jürgen Garloff as a Research Associate who will work on this contract by a full time job. He has a very good background in numerical mathematics above all in solving particular sets of linear equations as they are found, for example, in computational fluid dynamics by applying implicit finite difference methods. Since he was never involved in ballistic problems he has been mainly busy with becoming familiar with the objective of the contract during this period. This concerned the physical subject as well as its way of mathematical approach.
2. The latest version of the DELTA code as it existed at the BRL at the end of 1984 was successfully installed on the EMI-AFB computer. This means that we abandoned the CDC Update format and made this modified version operational on our VAX computer. As no significant modifications of this code had been reported to us since 1984, we assume that this code version is the newest one with respect to the physical modeling and its numerical solution of the viscous modeling of the interior ballistic flow.
3. One of the first objectives of the contract is dealing with the turbulent modeling of the interior ballistic flow. Therefore, I visited a lecture course on Modeling of Turbulence at the von Karman Institute for Fluid Dynamics at Rhode-Saint-Genèse, Belgium. This course gave an overview on the state-of-the-art in the mathematical modeling of turbulent flows.

Weil am Rhein, 26 May 1987

R. Heier

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Fraunhofer-Institut für Kurzzeitdynamik
Ernst-Mach-Institut
Abteilung für Ballistik



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Second Periodic Report

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The latest version of the DELTA code as it was installed on the EMI-AFB VAX computer was used to run several test cases for the laminar type of flow. The results agreed with those computed at the Ballistic Research Laboratory such that we assumed that the installation of DELTA was successful. Thereafter the investigations of the turbulent flow have been started. In a first step the implementation of algebraic mixing length turbulence models was resumed. Two different algebraic turbulence models were considered and incorporated into the DELTA code, e.g., the Cebeci-Smith-Mosinski Model and the Baldwin-Lomax Model. To display the results obtained, comprehensive graphics software was developed.

During the second period two meetings took place:

- On June 1, 1987, R. Heiser visited the Department of Mechanical Engineering of the Imperial College of Science and Technology, London, UK, to discuss with J. H. Whitelaw and his co-workers how they can support our modeling efforts by experiments with their gun simulators.
- J. Garloff visited the Ballistic Research Laboratory, Aberdeen Proving Ground, MD, on September 3 and 4, 1987, to report the progress made by our ongoing activities.

Numerical Results

At present, two algebraic turbulence models are considered and coded in DELTA: the Cebeci-Smith-Mosinski Model and the Baldwin-Lomax Model. Computational results were obtained for the so-called Lagrange gun, i.e., the simulation of a pure gas expansion flow behind a projectile inside of a constant cross-section tube. The tube is closed at one end by a stationary surface, and at the other end by a movable flat based projectile. The initial states of the gas are uniform and quiescent. The numerical results enclosed refer to a 20-mm caliber tube assuming an initial pressure of 300 MPa and an initial temperature of 3000 K. Figures 1 to 12 show the axial and radial flow velocity,

temperature, and pressure computed by using the Baldwin-Lomax Model at the time steps 100, 200, and 300. In comparison, the application of the Cebeci-Smith-Mosinski Model results in stronger oscillations in the computed quantities especially for high numbers of time steps. Special emphasis was put on the computation of the boundary layer. Figures Nos. 13 to 15 show the growing of the boundary layer thickness and the boundary layer displacement thickness for time steps 100, 200, and 300 computed by using the Baldwin-Lomax Model. The boundary layer thickness and boundary layer displacement thickness computed by using the Cebeci-Smith-Mosinski Model coincide in general after about 250 time steps. However, this model gives again oscillations in both quantities.

We have also simulated the transition of laminar to turbulent flow. Our computations show that there is no significant difference to the results obtained under the assumption of a purely turbulent flow.

The oscillations obtained by using both algebraic turbulence models are not satisfactory since in the laminar case no oscillations were observed. Therefore, we are going to incorporate into the code a nonalgebraic turbulence model, e.g., the $k-\epsilon$ -Model (see Section on future work).

Up to now our Institute does not have available the graphics software for running the pre- and post-processors of DELTA. To display the numerical results, software for 2-D and 3-D plots was developed. Also a plot of the projectile velocity history is now available, see Figure 16.

Future Work

We have just obtained a series of experimental data on boundary layers measured by J. H. Whitelaw and his co-workers [1,2]. These results have been obtained by experiments with low pressure gun simulators. We will run the DELTA code for computing the flow in the simulator and compare the results with the experimental data.

At present, nonalgebraic turbulence models, e.g., the k- ϵ -Model are considered and will be coded. To treat also heat transfer, J. Garloff will attend a lecture series entitled "Numerical Methods of Fluid Dynamics and Heat Transfer" to be held at the University of Erlangen-Nürnberg, FRG, at the end of October 1987. In this course, one main objective will be the presentation and demonstration of various codes for the computation of turbulence and heat transfer problems.

We did not succeed so far to find a black box solver suitable for our purposes. Available codes considered so far suffer from being presently designed only for incompressible flows (e.g., MODULEF, Multigrid Solvers) or their conversion to our system would require extensive time, effort, and a commitment of programmer assistance for successful transfer (this applies to the codes from Lawrence Livermore National Laboratory).

W. Schönauer from the University of Karlsruhe, FRG, is designing a code named FIDISOL for treating also problems of compressible unsteady flows at high Reynolds numbers. But his work is still under development and the code can not be expected to be available for us before 1/2 to 1 year.

References

- [1] Bicen, A.F., Khezzar, L., Whitelaw, J.H., "Subsonic Single-Phase Flow in a Gun Simulator", Imperial College of Science and Technology, Mechanical Engineering Department, London, UK, Rep. FS/86/03, April 1986
- [2] Bicen, A.F., Khezzar, L., Whitelaw, J.H., "Subsonic Single- and Two-Phase Flow Characteristics of a Gun Simulator", Imperial College of Science and Technology, Mechanical Engineering Department, London, UK, Rep. FS/86/43, Sept. 1986

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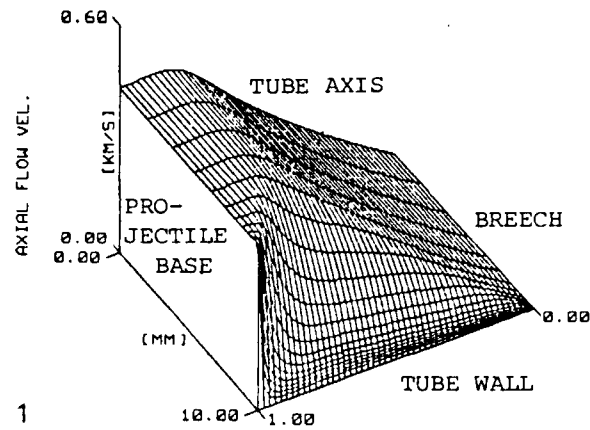


Figure 1

TIME-STEP = 200 TIME = 2.000 (MS)
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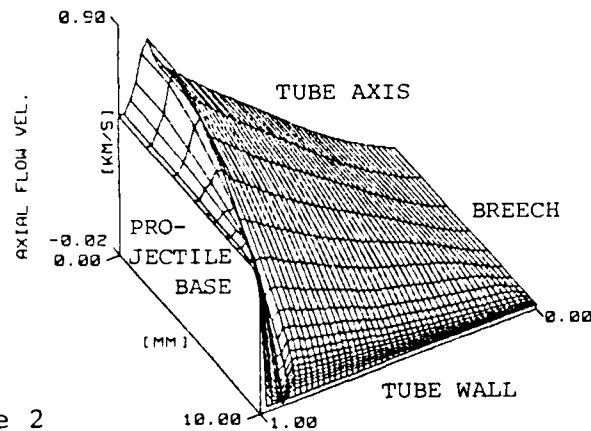


Figure 2

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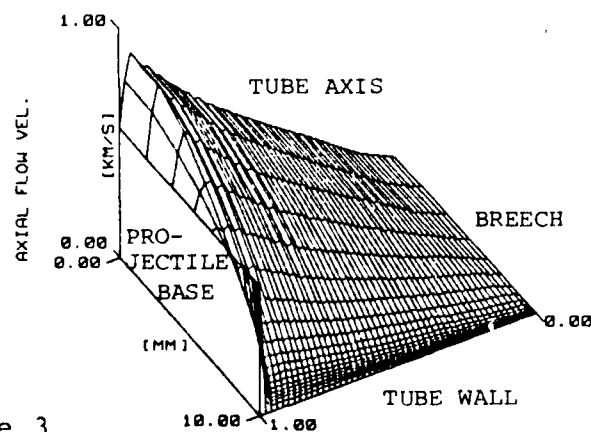


Figure 3

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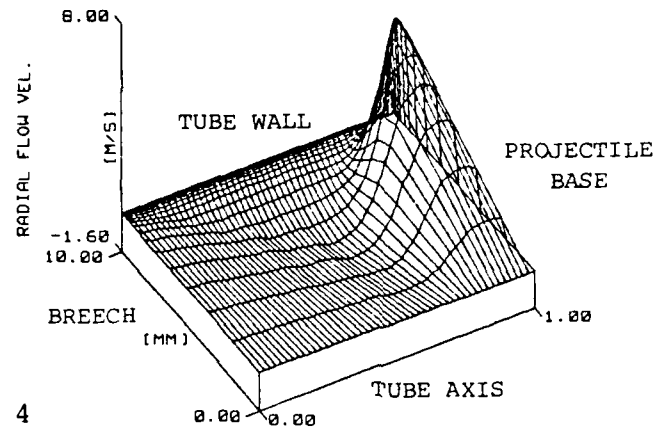


Figure 4

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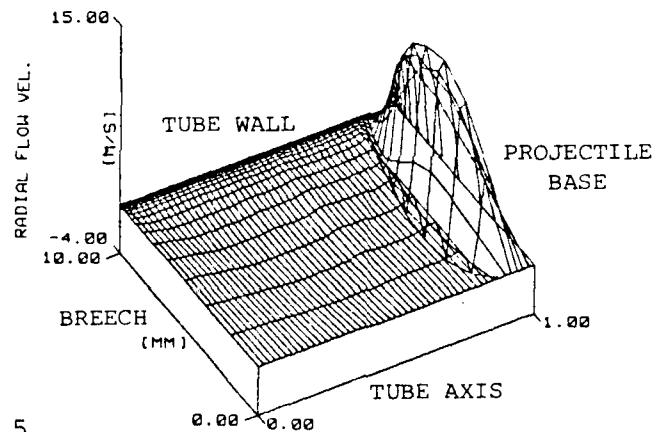


Figure 5

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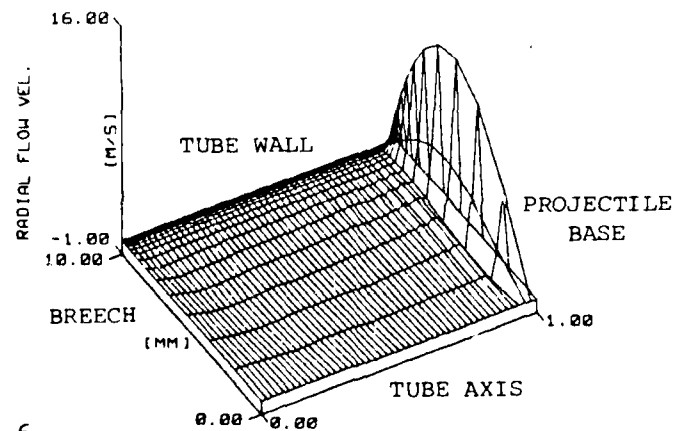


Figure 6

TIME-STEP = 100 TIME = 1.000 (MS)
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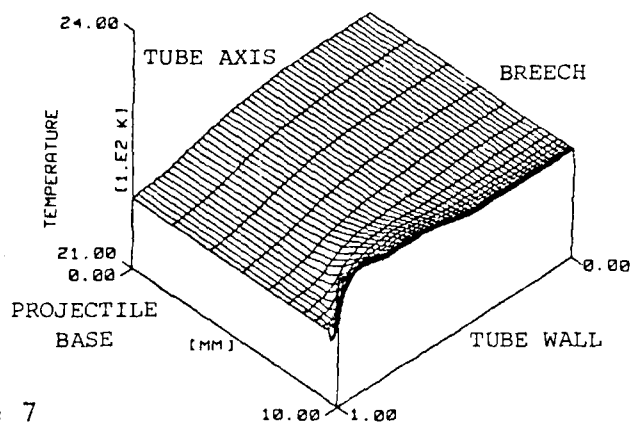


Figure 7

TIME-STEP = 200 TIME = 2.000 (MS)
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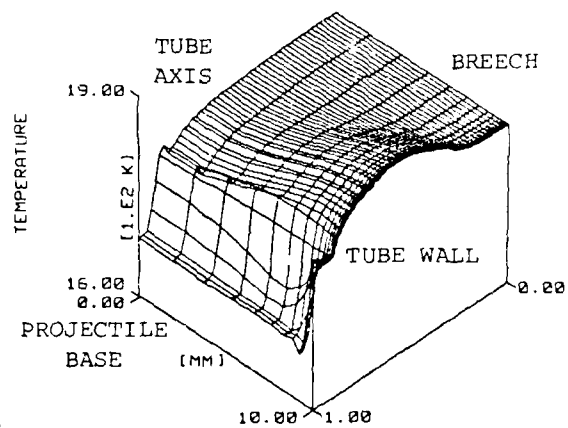


Figure 8

TIME-STEP = 300 TIME = 3.000 (MS)
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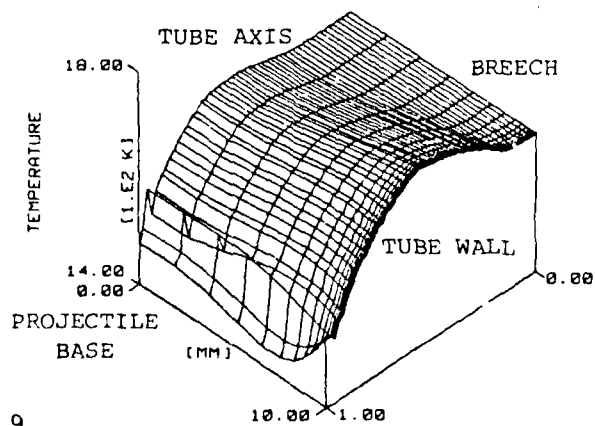


Figure 9

TIME-STEP = 100 TIME = 1.000 [MS]
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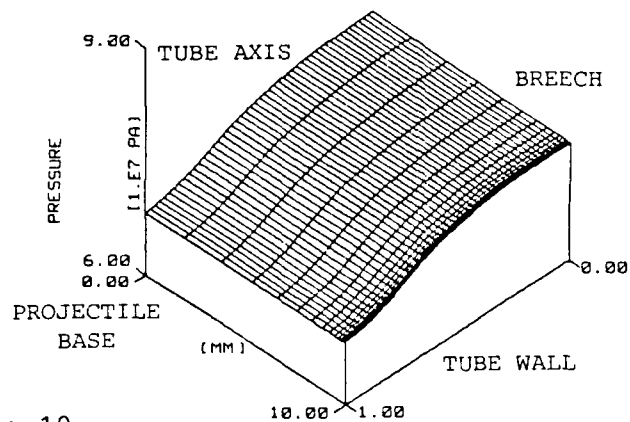


Figure 10

TIME-STEP = 200 TIME = 2.000 [MS]
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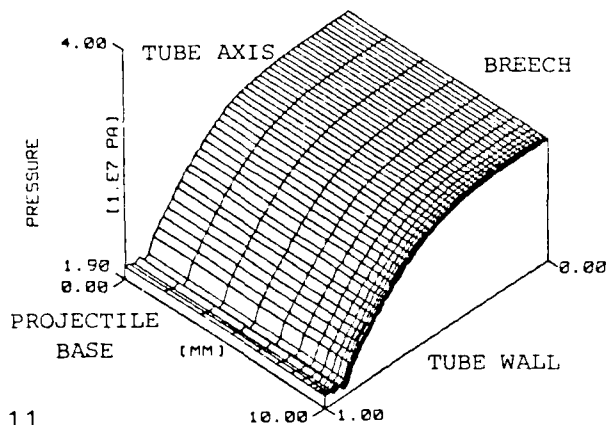


Figure 11

TIME-STEP = 300 TIME = 3.000 [MS]
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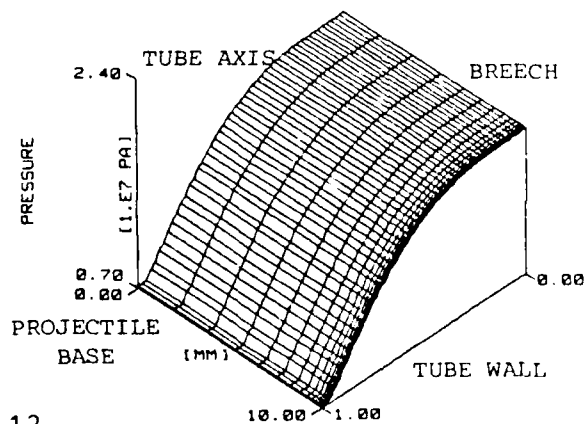


Figure 12

TIME-STEP = 100 TIME = 1.000 (MS)
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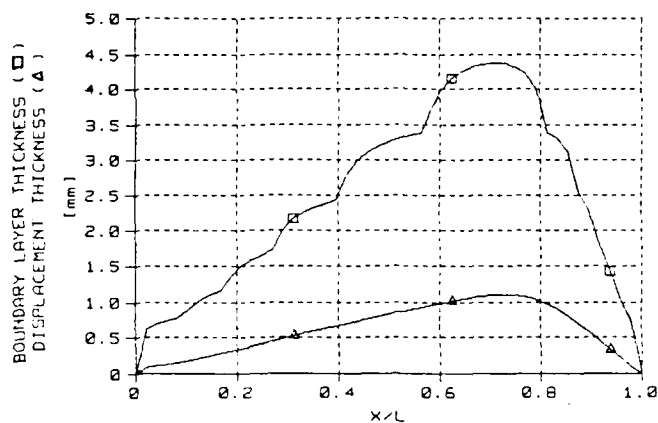


Figure 13

TIME-STEP = 200 TIME = 2.000 (MS)
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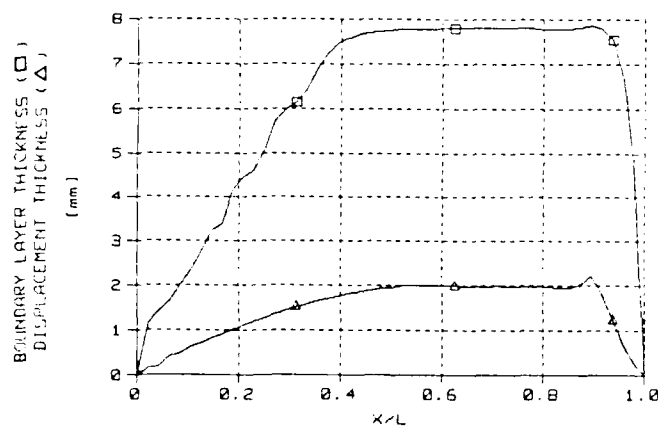


Figure 14

TIME-STEP = 300 TIME = 3.000 (MS)
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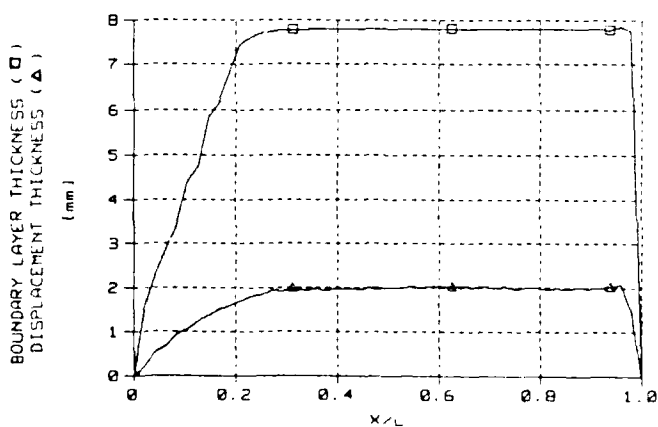


Figure 15

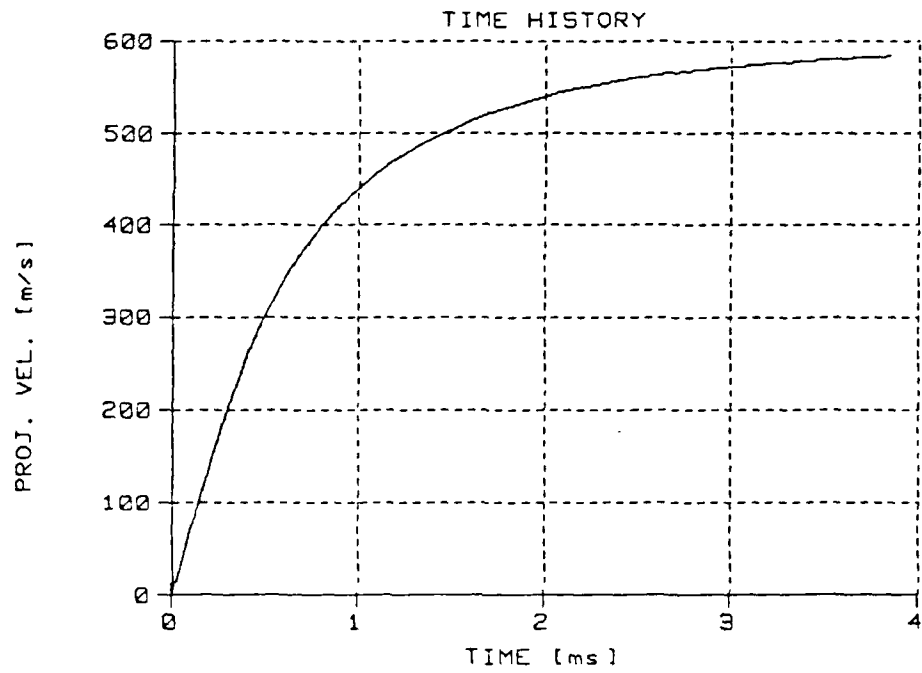


Figure 16

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