

**STRUCTURED ADAPTIVE GRID GENERATION
USING ALGEBRAIC METHODS**

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by

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ABSTRACT

The accuracy of the numerical algorithm depends not only on the formal order of approximation but also on the distribution of grid points in the computational domain. Grid adaptation is a procedure which allows optimal grid redistribution as the solution progresses. It offers the prospect of accurate flow field simulations without the use of excessively time, computationally expensive, grid.

Grid adaptive schemes are divided into two basic categories: differential and algebraic. The differential method is based on a variational approach where a function which contains a measure of grid smoothness, orthogonality and volume variation is minimized by using a variational principle. This approach provides a solid mathematical basis for the adaptive method, but the Euler-Lagrange equations must be solved in addition to the original governing equations. On the other hand, the algebraic method requires much less computational effort, but the grid may not be smooth. The algebraic techniques are based on devising an algorithm where the grid movement is governed by estimates of the local error in the numerical solution. This is achieved by requiring the points in the large error regions to attract other points and points in the low error region to repel other points.

The development of a fast, efficient, and robust algebraic adaptive algorithm for structured flow simulation applications is presented. This development is accomplished in a three step process. The first step is to define an adaptive weighting mesh (distribution mesh) [1][2] on the basis of the equidistribution law applied to the flow field solution. The second, and probably the most crucial step, is to redistribute grid points in the computational domain according to the aforementioned weighting mesh. The third and the last step is to reevaluate the flow property by an appropriate search/interpolate scheme at the new grid locations.

The adaptive weighting mesh provides the information on the desired concentration of points to the grid redistribution scheme. The evaluation of the weighting mesh is accomplished by utilizing the weight function representing the solution variation and the equidistribution law [3]. The selection of the weight function plays a key role in grid adaptation [4]. A new weight function utilizing a properly weighted boolean sum of various flowfield characteristics is defined. The redistribution scheme is developed utilizing Non-Uniform Rational B-Splines (NURBS) representation [5]. The application of NURBS representation results in a well distributed smooth grid by maintaining the fidelity of the geometry associated with boundary curves. Several algebraic methods are applied to smooth and/or nearly orthogonalize the grid lines. Elliptic solver is utilized to smooth the grid lines if there are grid crossing.

Various computational examples of practical interest are presented to demonstrate the success of these methods. (1) Single wedge case. (2) Cylinder case. (3) Airfoil NACA 0012 case. (4) Viscous missile case. (5) Slot cooled seeker window case. (6) Moving shock in converge inlet case. (7) 3-D single wedge case. (8) 3-D viscous cone case. (9) 3-D f15 body and wing case. (10) 3-D helicopter propeller shock prediction case. In case (1),(2),(4),(5),(6),(7),(8),and(9), PARC2D and PARC3D [6] are used as the flow simulation code. In case (3), UBI [7] is used as the flow simulation code, and compare to Peter M. Goorjian's solution [8]. In case (10), MSUTC [9] is used as the flow simulation code.

MISSISSIPPI STATE UNIVERSITY / National Science Foundation

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WHY?

More Accurate Simulated Solution

HOW?

- 1. Add More Grid Points**
- 2. Move Grid Points**



TWO CATEGORIES OF ADAPTIVE GRID SYSTEM

. Differential Method

- . Slow
- . Smooth
- . Orthogonal

. Algebraic Method

- . Fast
- . Unsmooth
- . Unorthogonal



• Weight function

$$W = \{ 1 + [\sum_{j=1}^N \lambda_j (a_j q_j \oplus \beta_j k_j)] wtf \} \text{ disf}$$

$$\sum_{j=1}^N \lambda_j = 1, \quad 0 \leq a_j \leq 1, \quad 0 \leq \beta_j \leq 1$$

where $W = W_s$ or W_r (In ξ or η Direction)

$q = q_s$ or q_r (Gradient)

$k = k_s$ or k_r (Curvature)

$wtf =$ weight factor

$disf =$ distribution factor

$$a_j q_j \oplus \beta_j k_j = a_j q_j + \beta_j k_j - (a_j + \beta_j - 1) q_j k_j$$

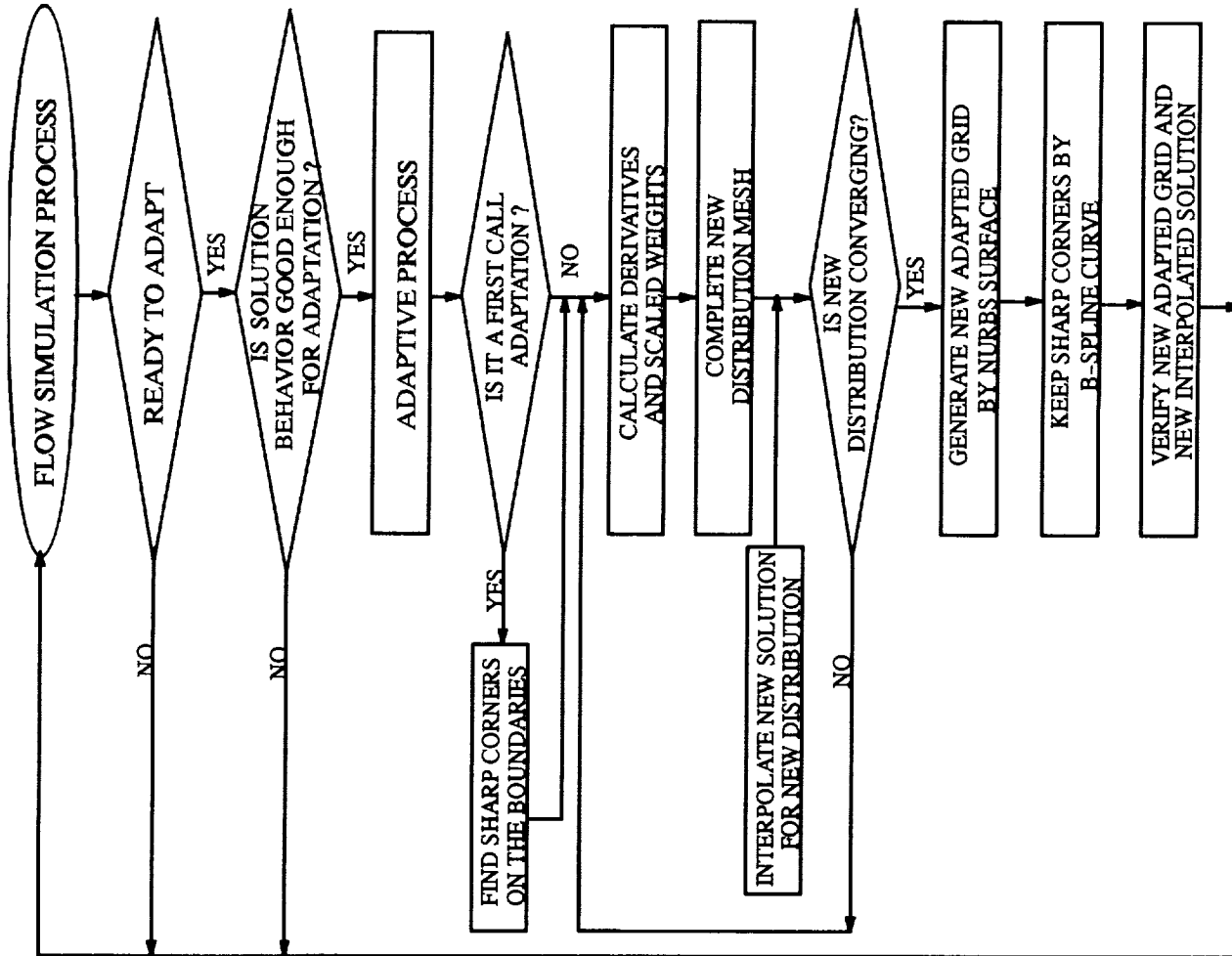


Figure 1.
Algorithm for Algebraic Adaptive Grid Generation System

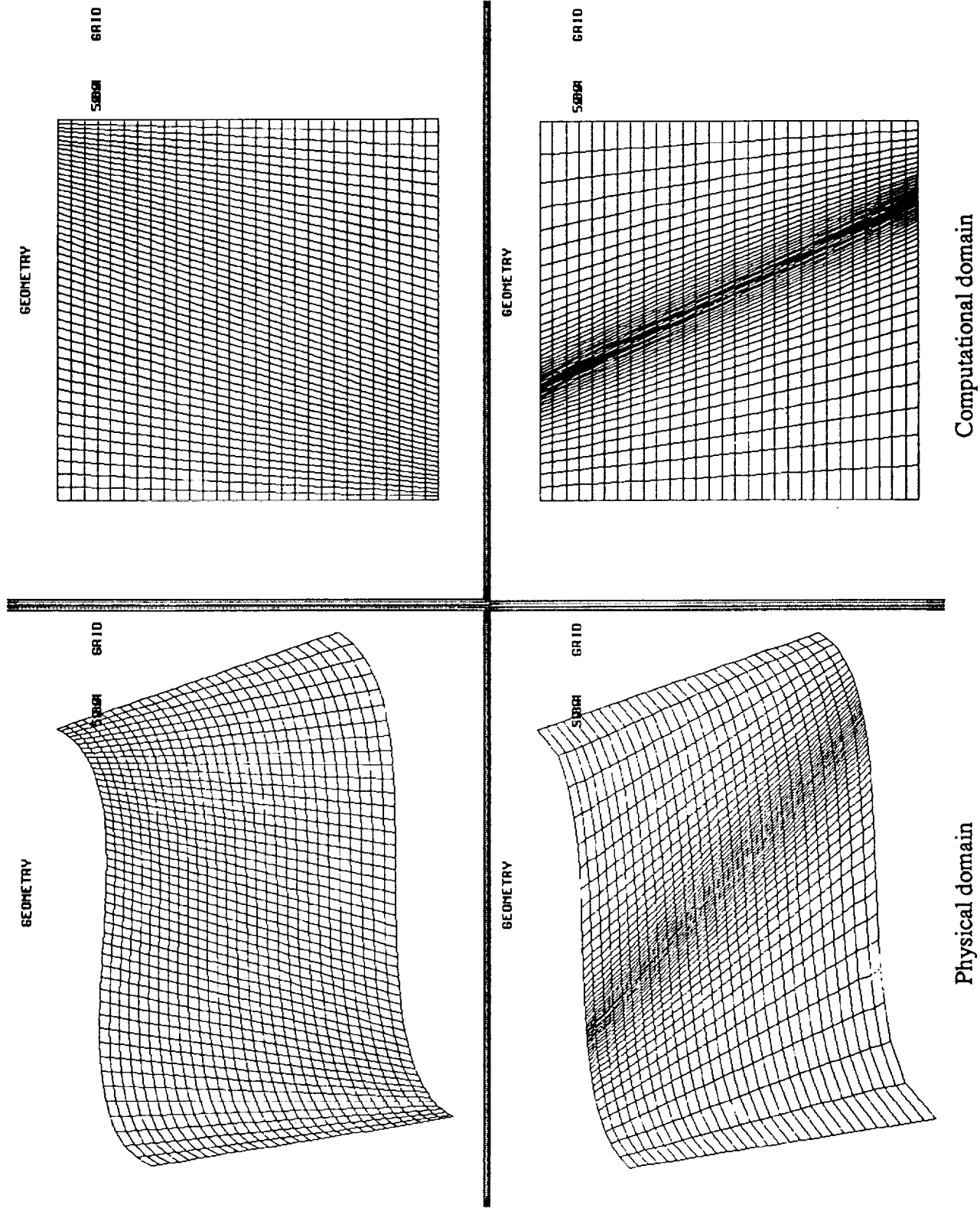


Figure 1.
Use NURBS surface to generate smooth grid.

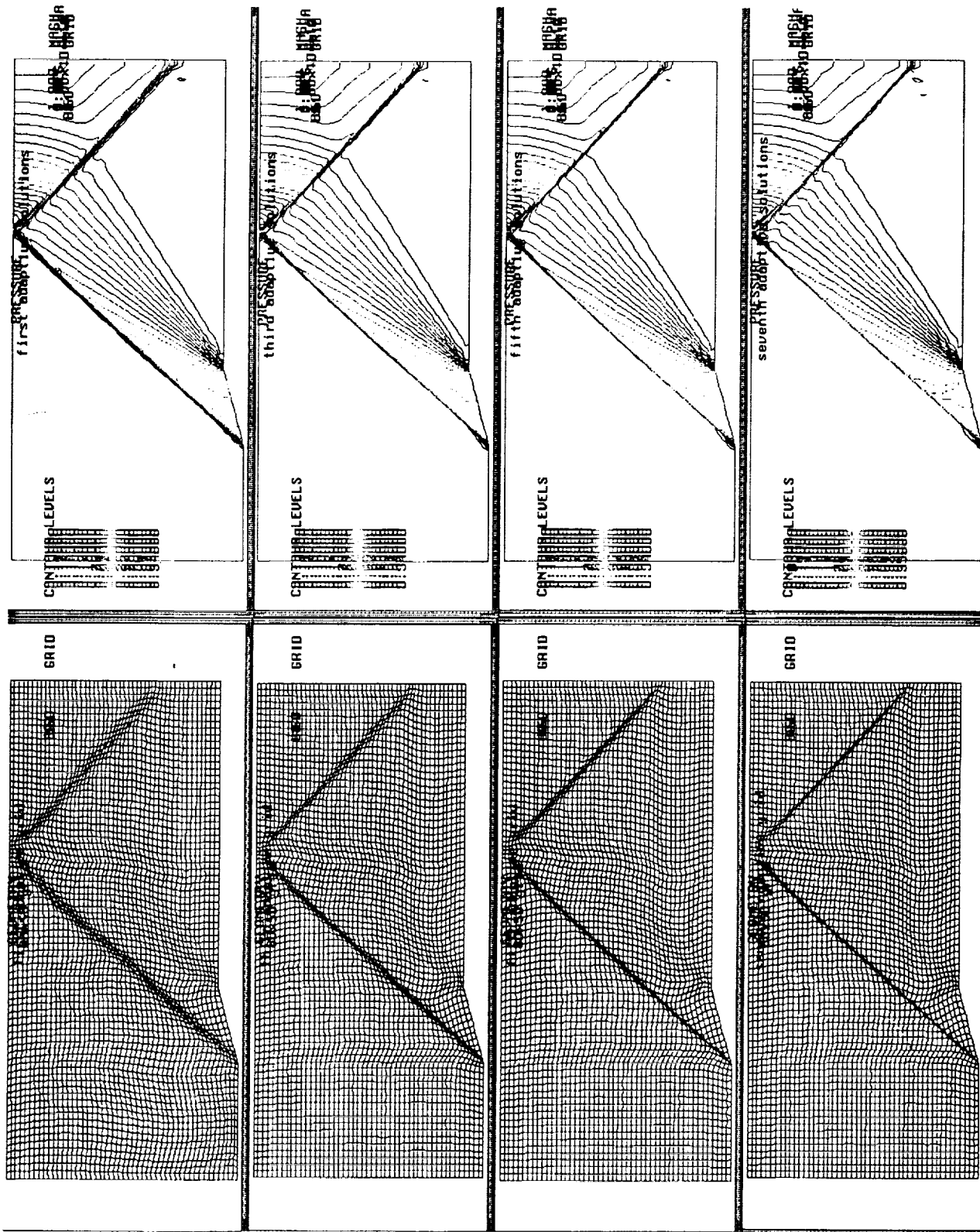
Single Wedge Case

Grid Size : 80 X 50

Mach = 1.9

Flow Solver Applied : PARC2D





Pressure contours

Grids

Figure 3.

Single wedge grid adaptation process.

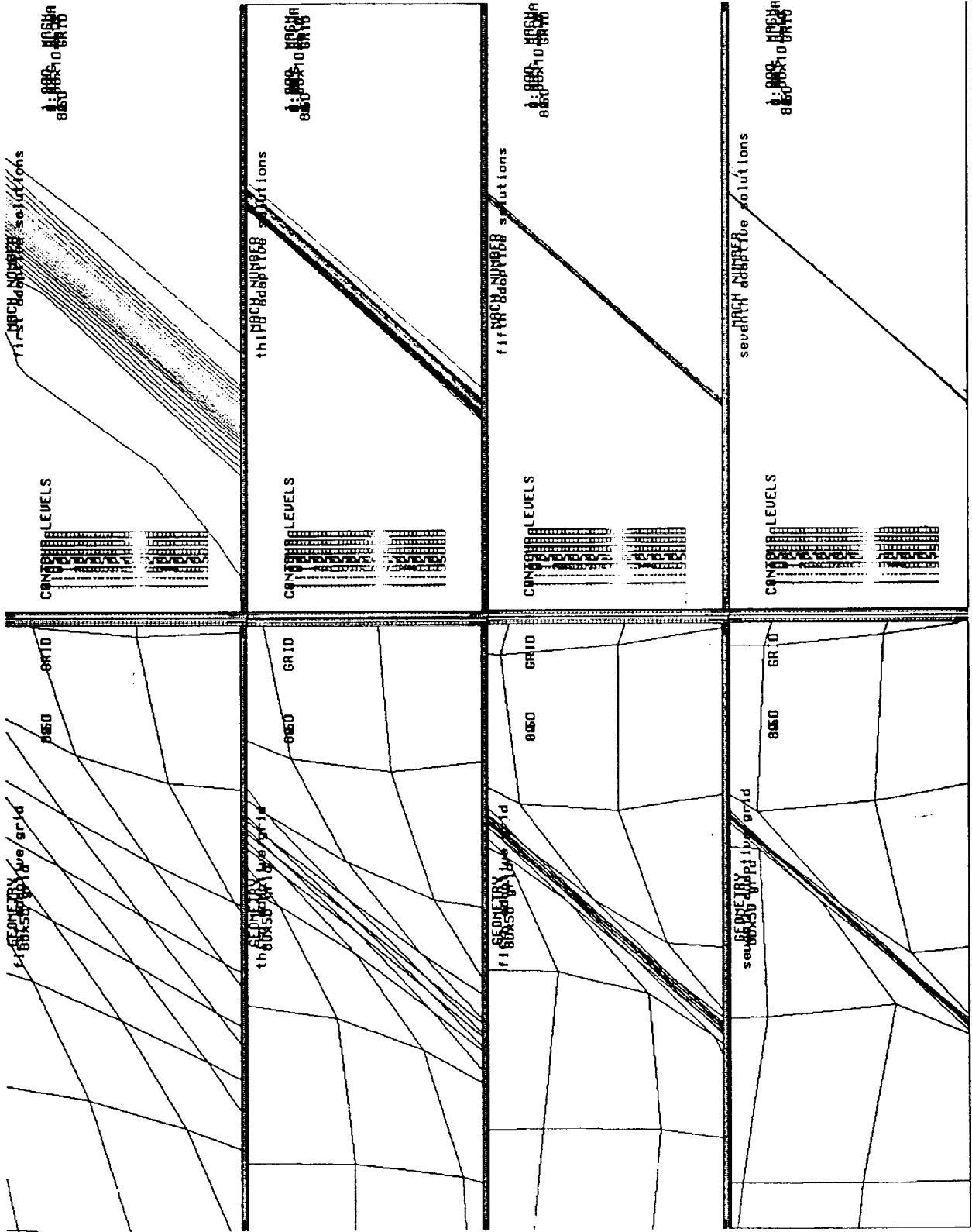


Figure 4.

Single wedge, closer Mach number contour look near shock region.

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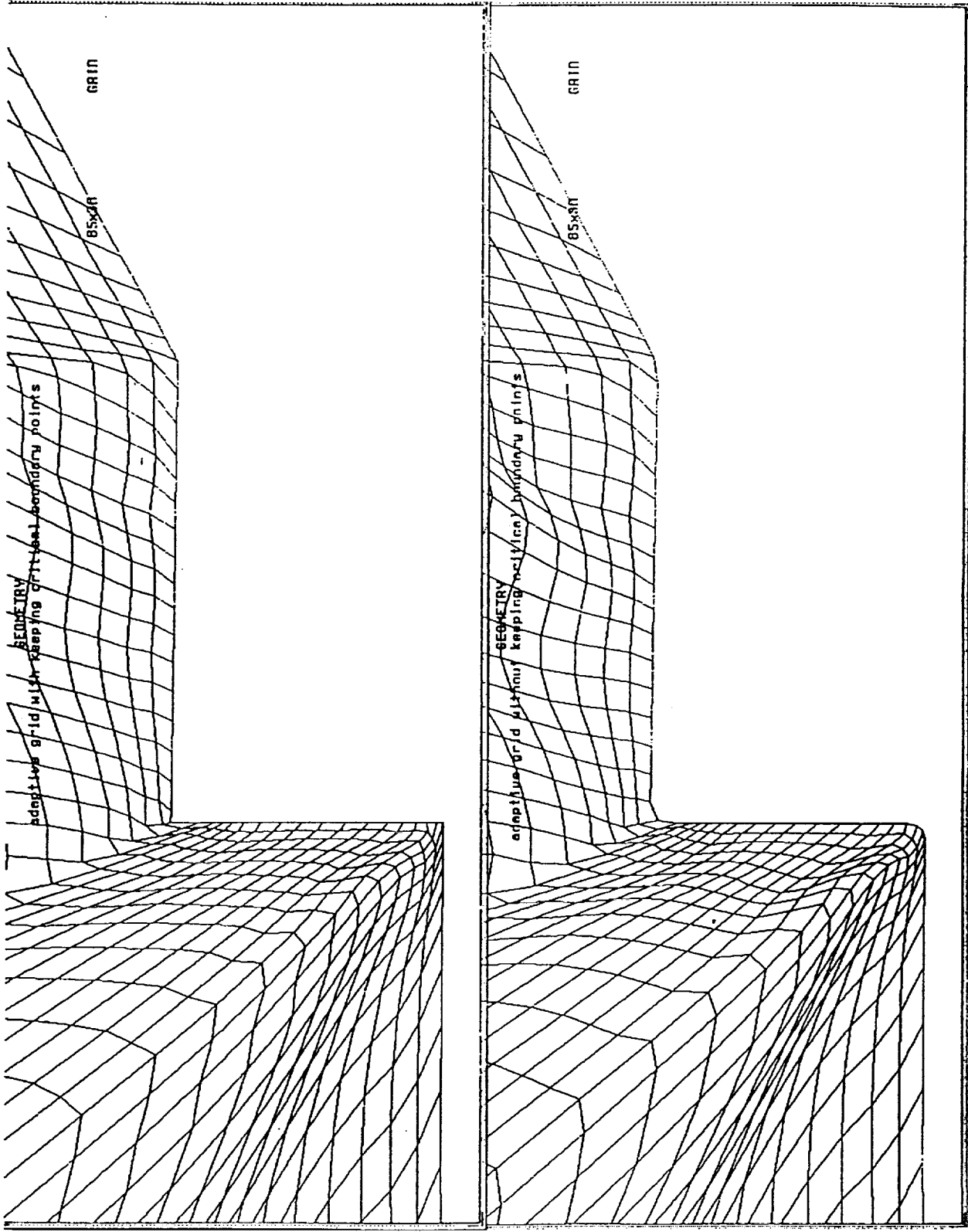


Figure 5.
Use B-Spline curve to keep sharp corners.

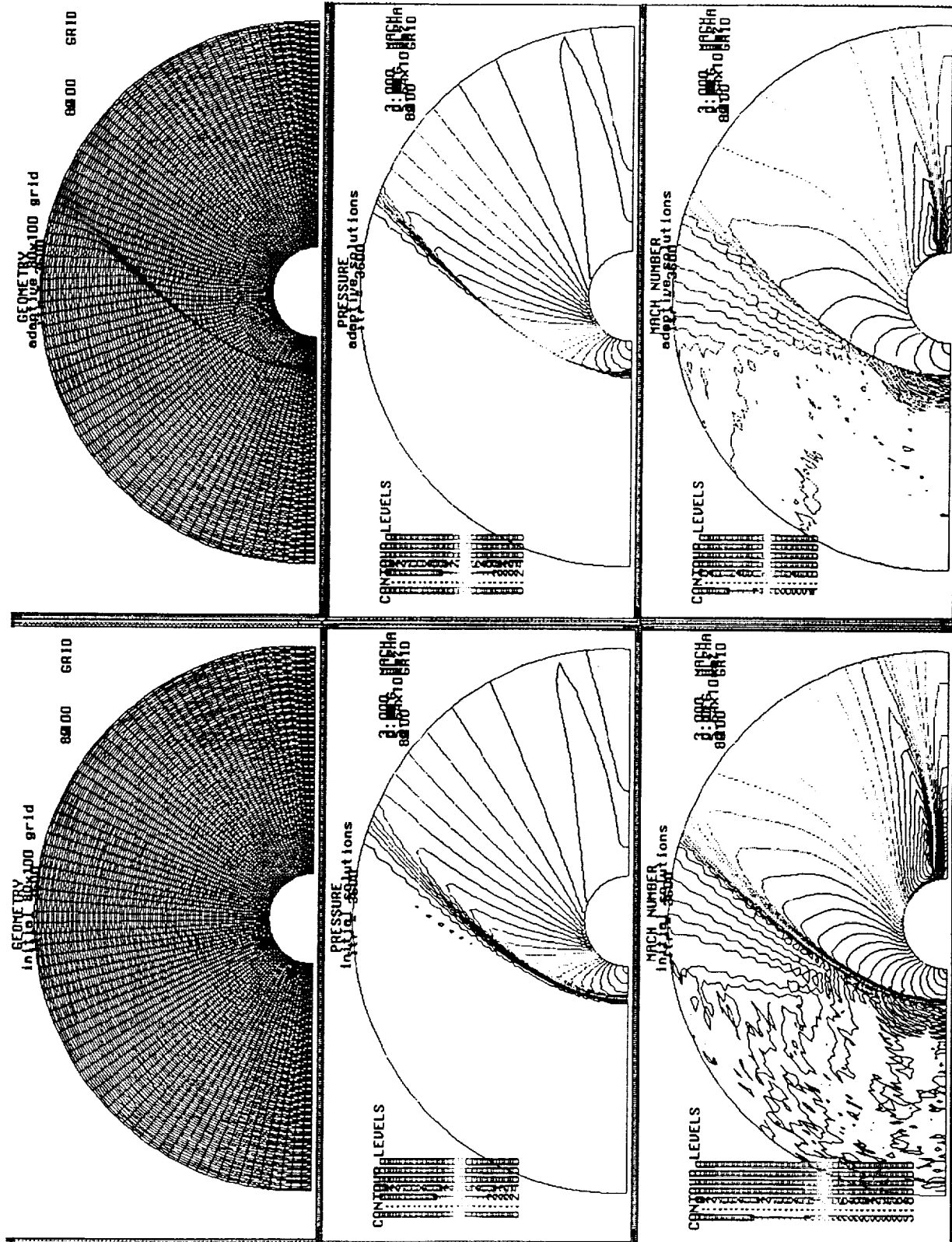
Cylinder Case

Grid Size : 80 X 100

Mach = 3.0

Flow Solver Applied : PARC2D





Initial grid simulation

Adaptive grid simulation

Figure 6.

Flow around cylinder initial/adaptive cases.

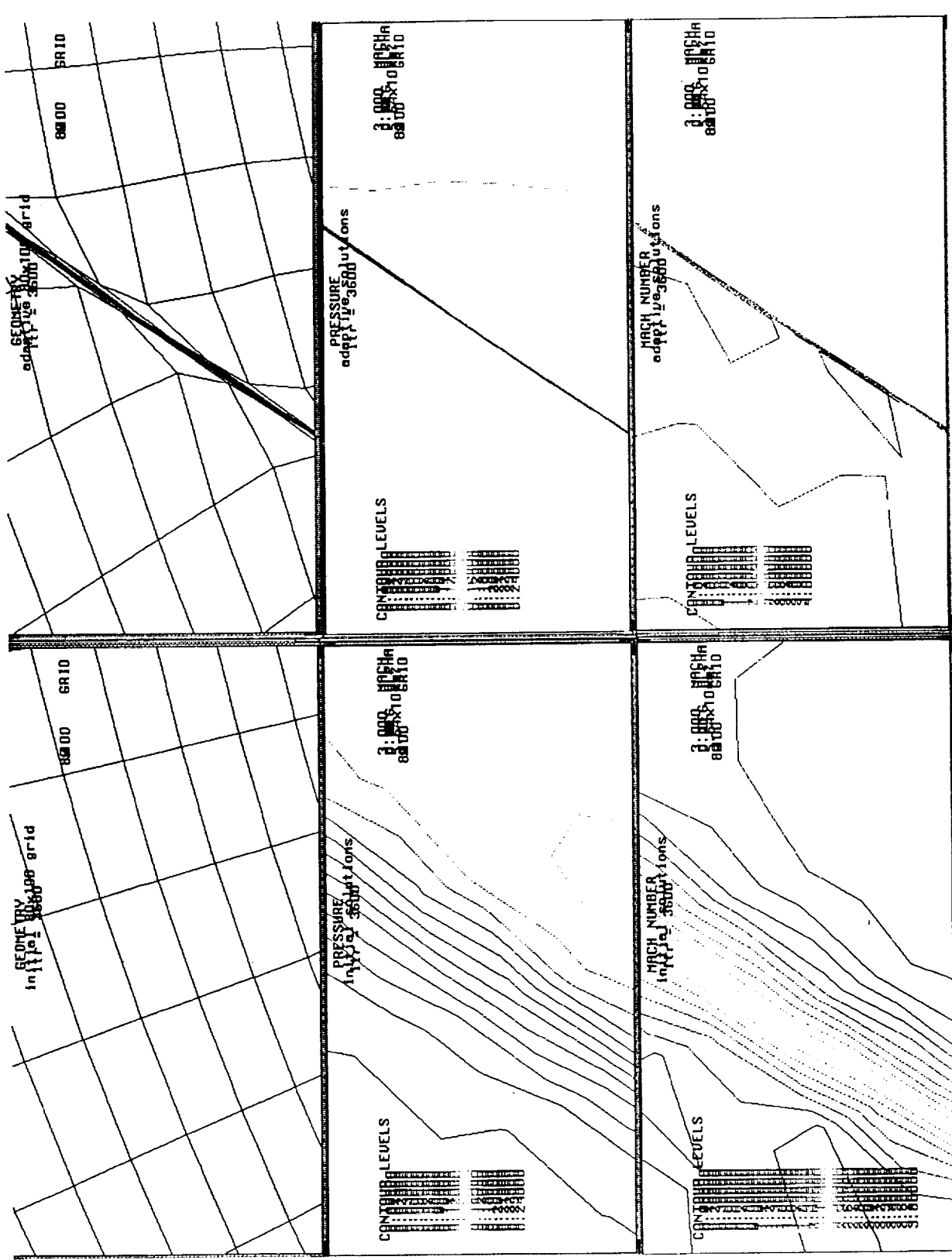


Figure 7.
Flow around cylinder, closer look near shock region.

Airfoil NACA0012 Case

Grid Size : 120 X 100

Mach = 0.8, $\alpha = 1.25$

Flow Solver Applied : UBI



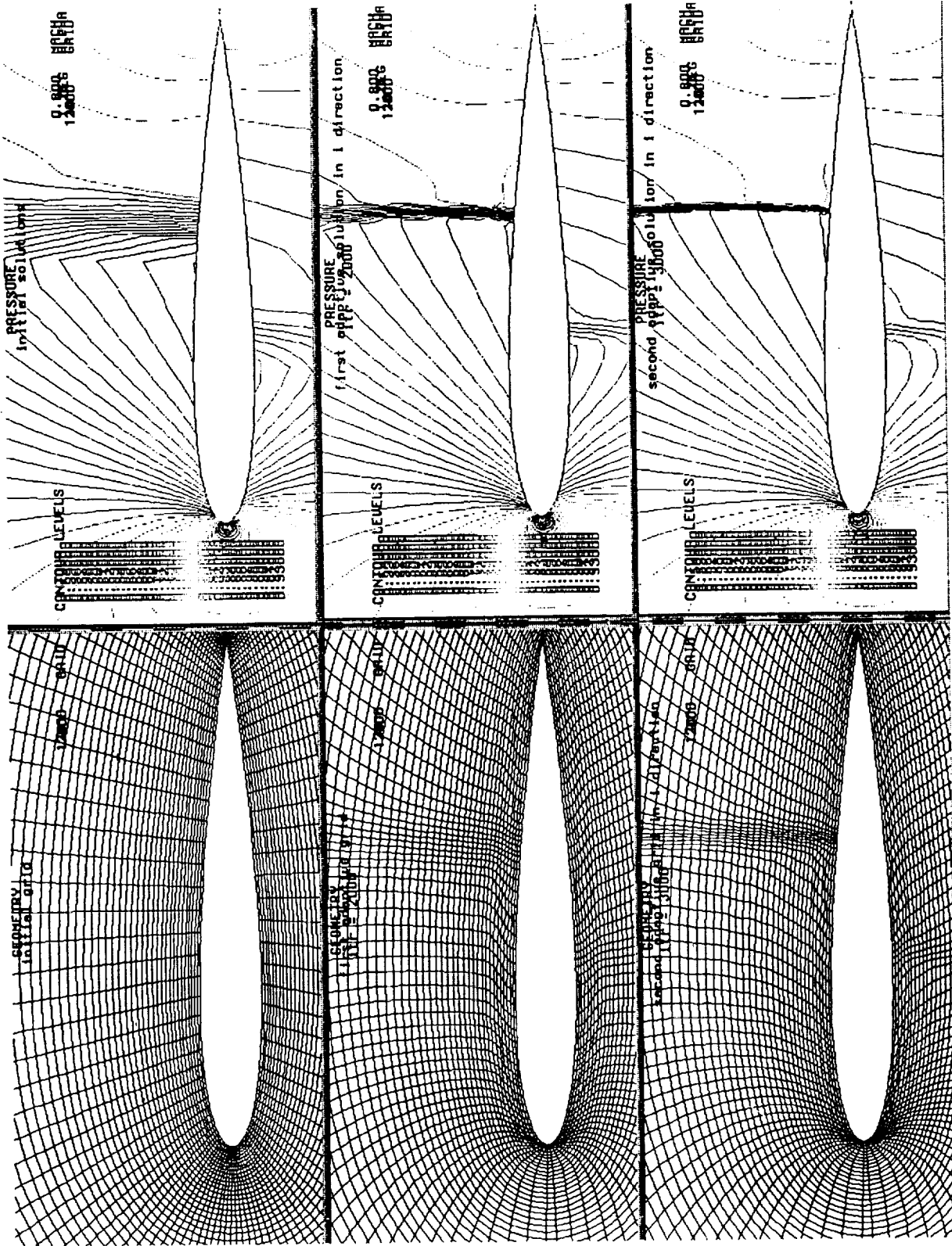


Figure 8.

Airfoil NACA0012 case non-adaptive/adaptive grid/solution,

Mach = 0.8, $\alpha = 1.25$.

Inviscid Pressure coefficients for NACA 0012

Mach=0.8, alpha=1.25, itr=3000, 120x100 Grid, idirection

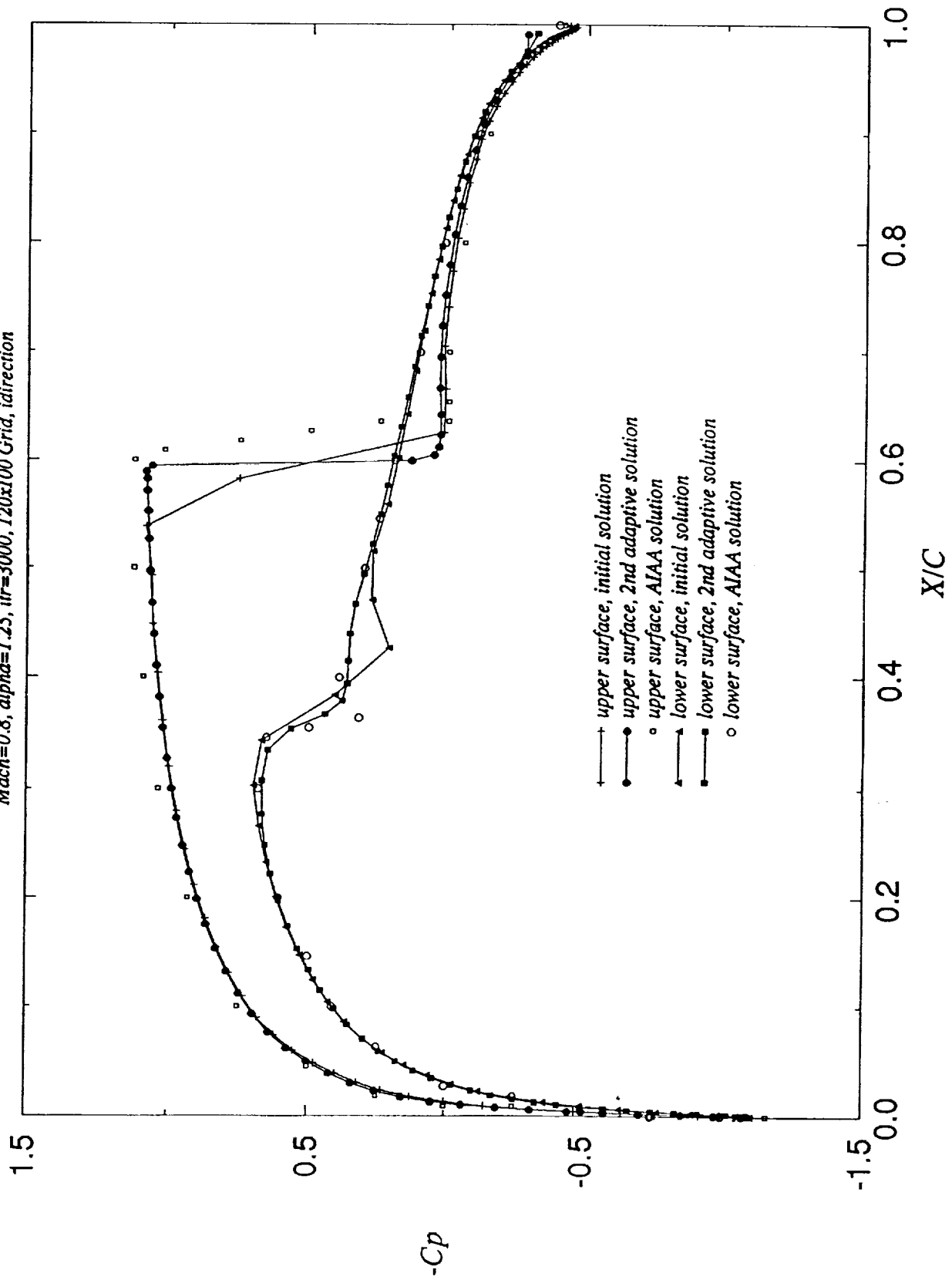


Figure 9.

Airfoil NACA0012 case Cp vs x/c plot, Mach = 0.8, $\alpha = 1.25$.

Viscous Missile Case

Grid Size : 105 X 50

Mach = 3.0, Re = 4.9558×10^6

Flow Solver Applied : PARC2D



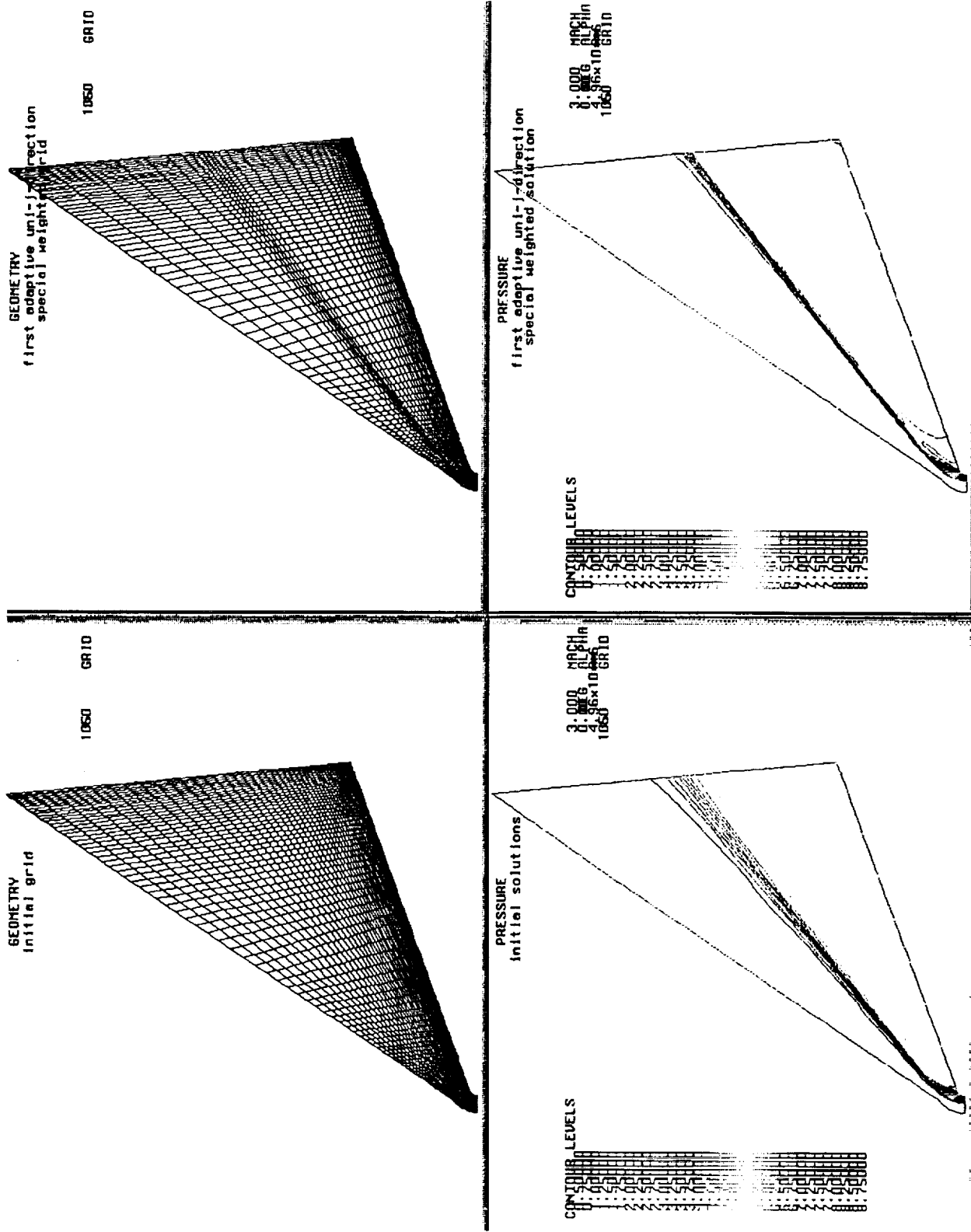


Figure 10.

Viscous missile case, whole field view.

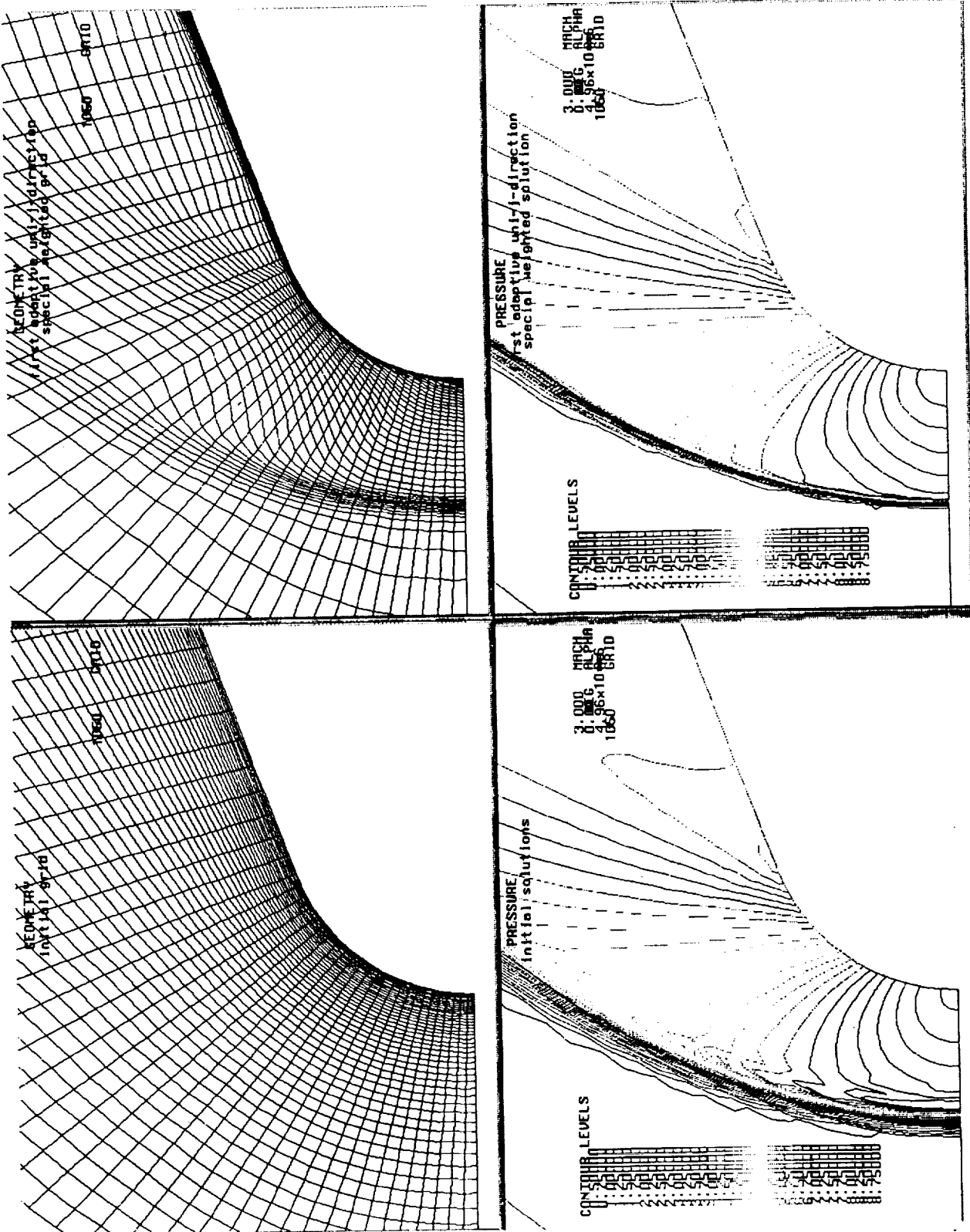


Figure 11. Viscous missile case, bow shock in front of leading edge.

Slot Cooled Seeker Window

Grid Size : 381 X 109

Mach = 5.0, Re = 3.141×10^5

Flow Solver Applied : PARC2D



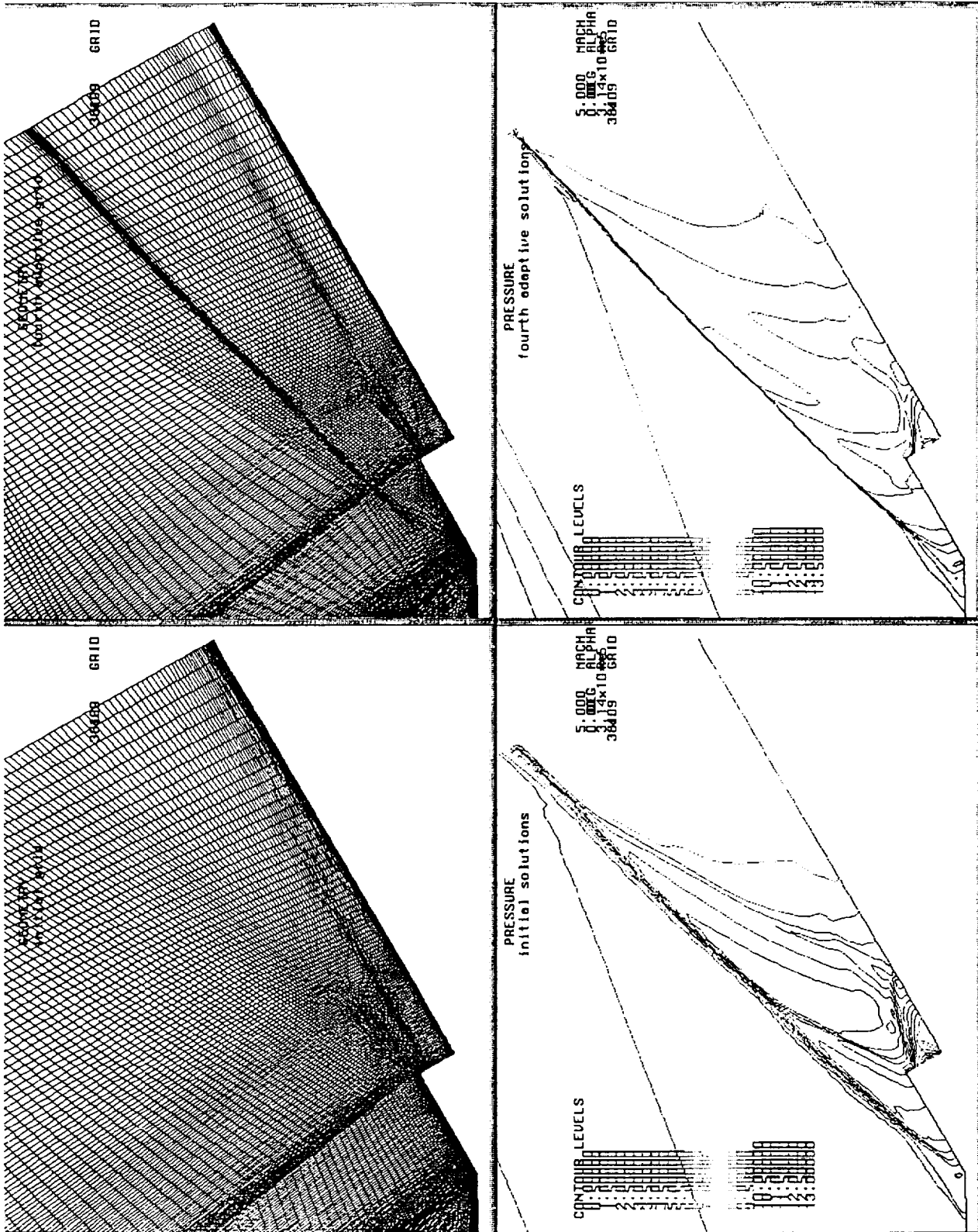


Figure 12.
Slot cooled seeker window case, oblique shock above deflection corner.

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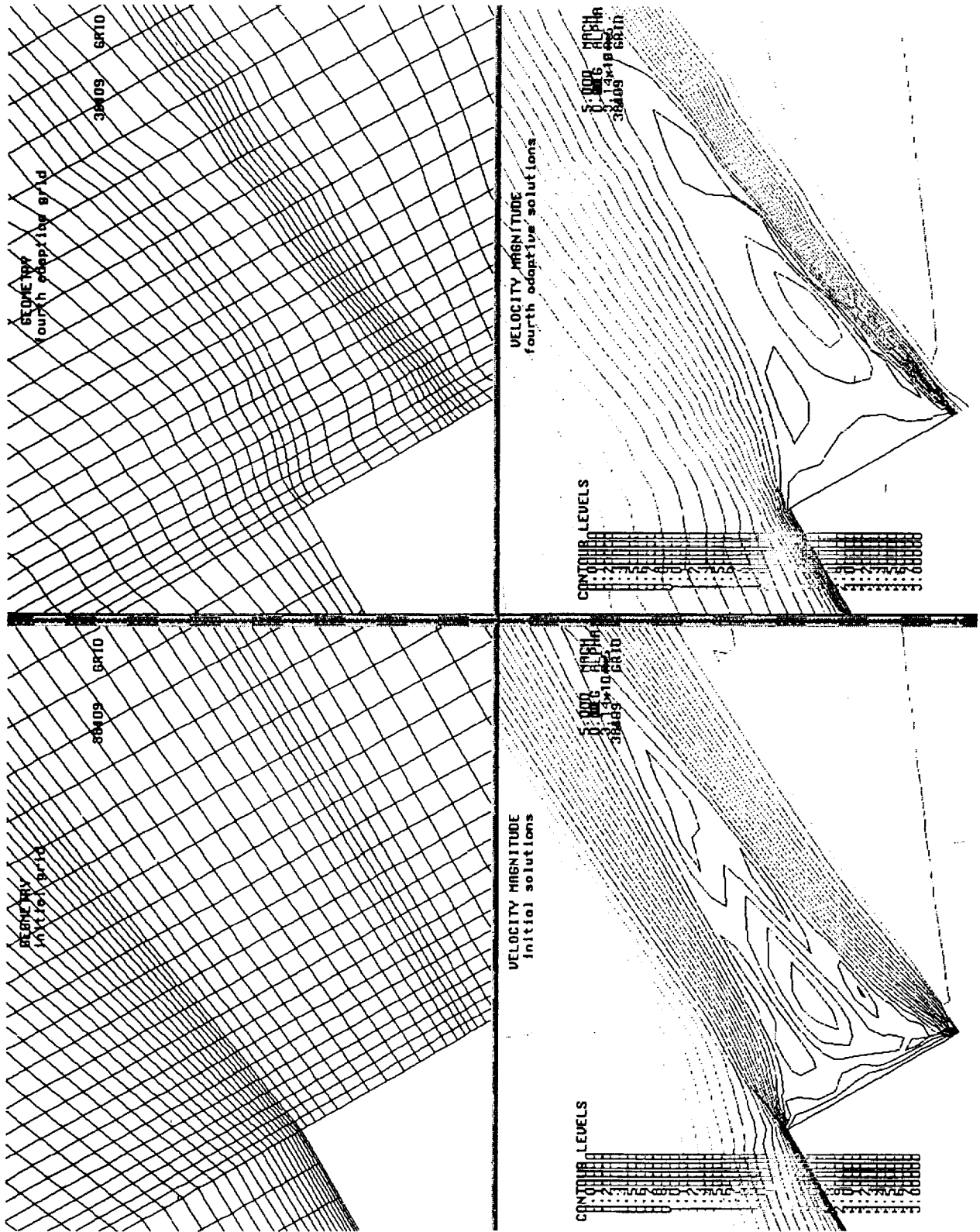


Figure 13. Slot cooled seeker window case, velocity contour near interceptor.

Moving Shock in Converge Inlet

Grid Size : 200 X 40

Mach = 3.0

Flow Solver Applied : PARC2D



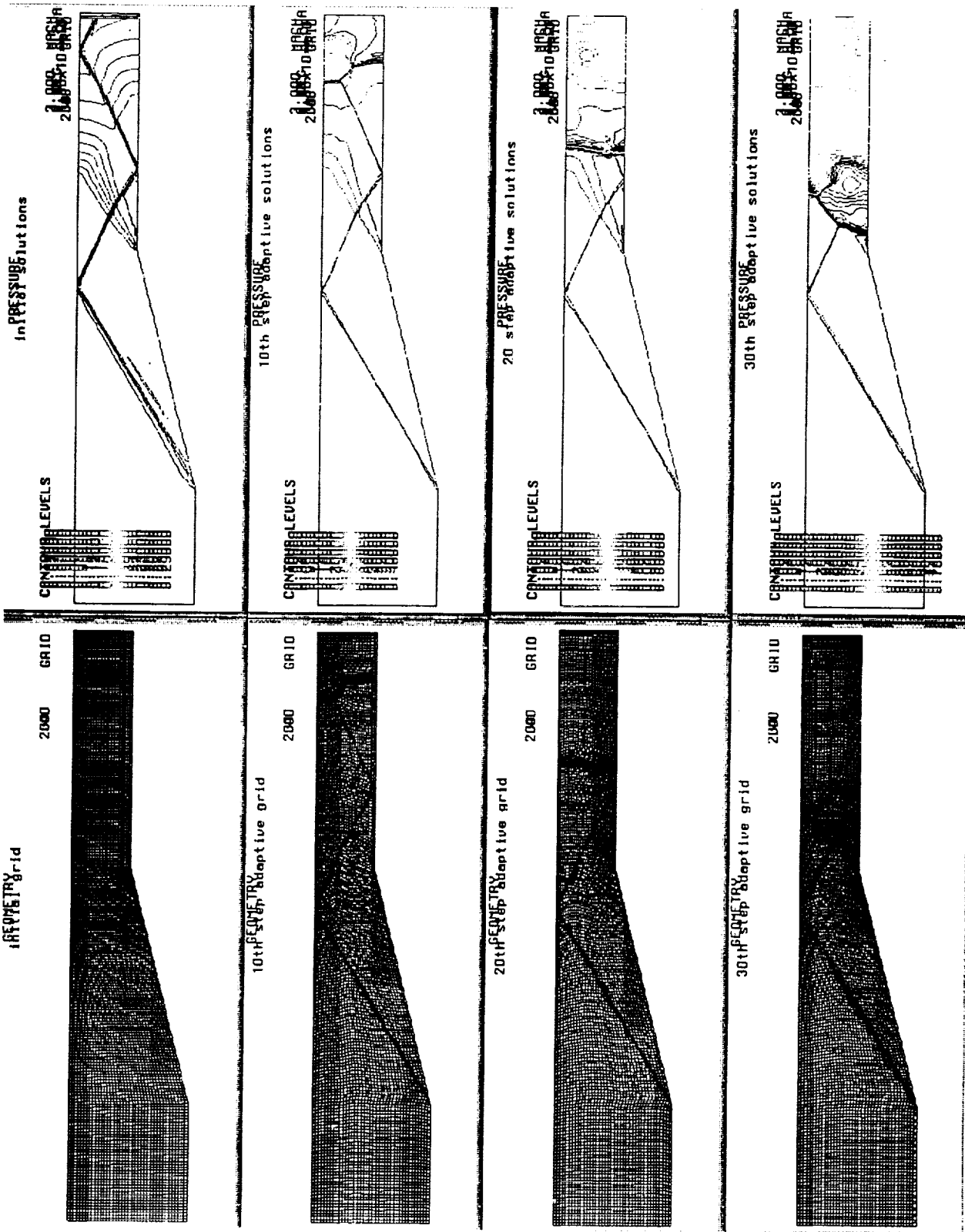


Figure 14. Adaptive grid for the moving shock in the converge inlet.

3-D Single Wedge Case

Grid Size : 80 X 50 X 11

Mach = 1.9

Flow Solver Applied : PARC3D



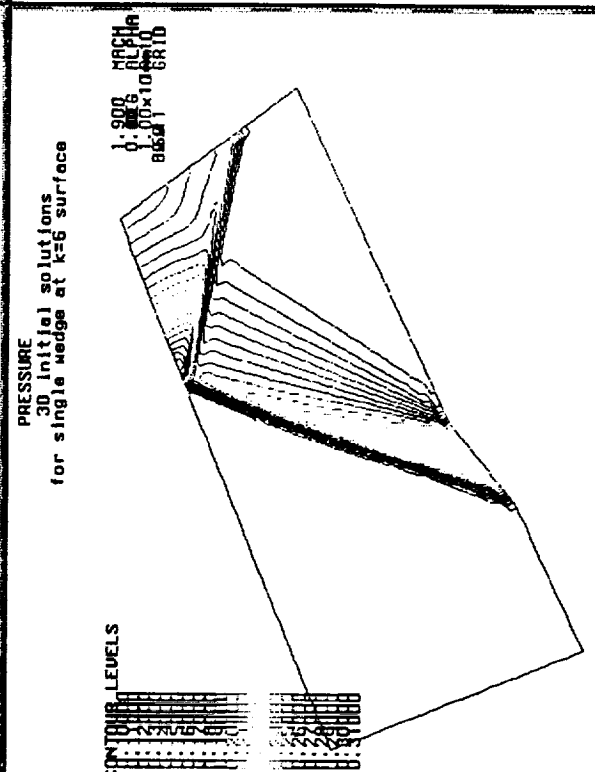
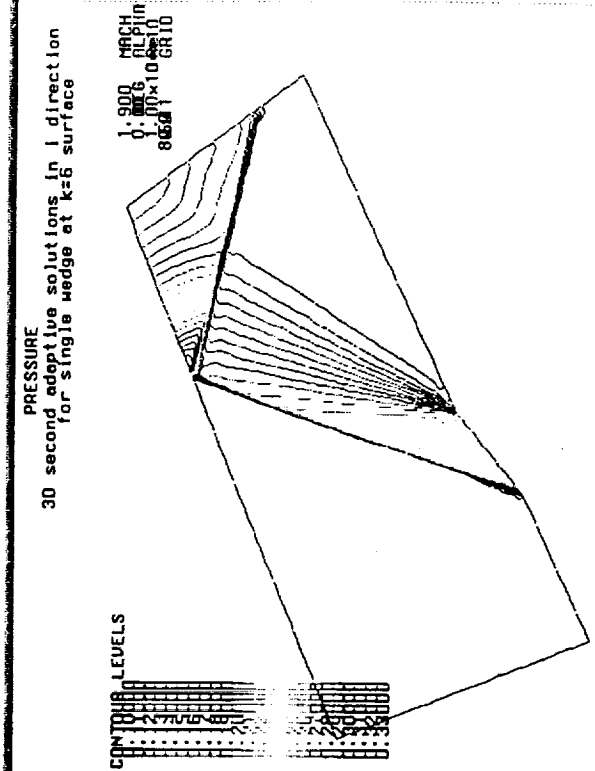
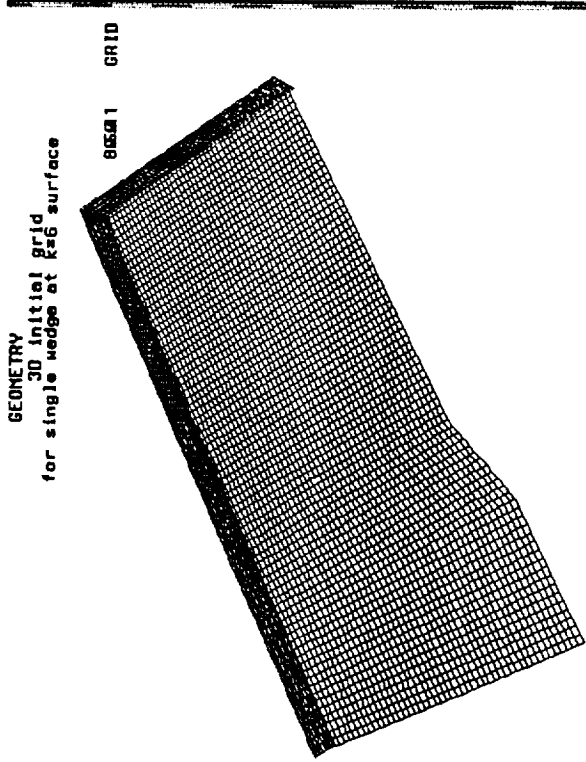
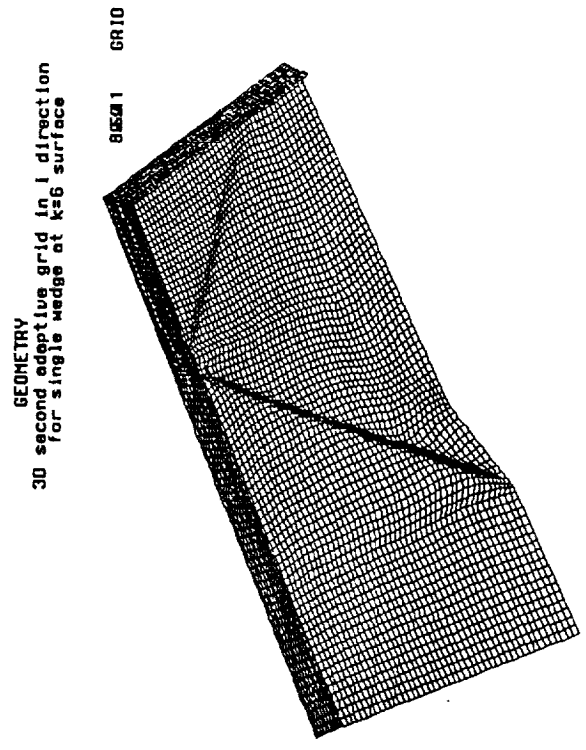


Figure 15.
3-D Single wedge, comparison of initial and adaptive grid & solution.

3-D Viscous Cone Case

Grid Size : 105 X 50 X 20

Mach = 3.0, Re = 4.9558×10^6

Flow Solver Applied : PARC3D



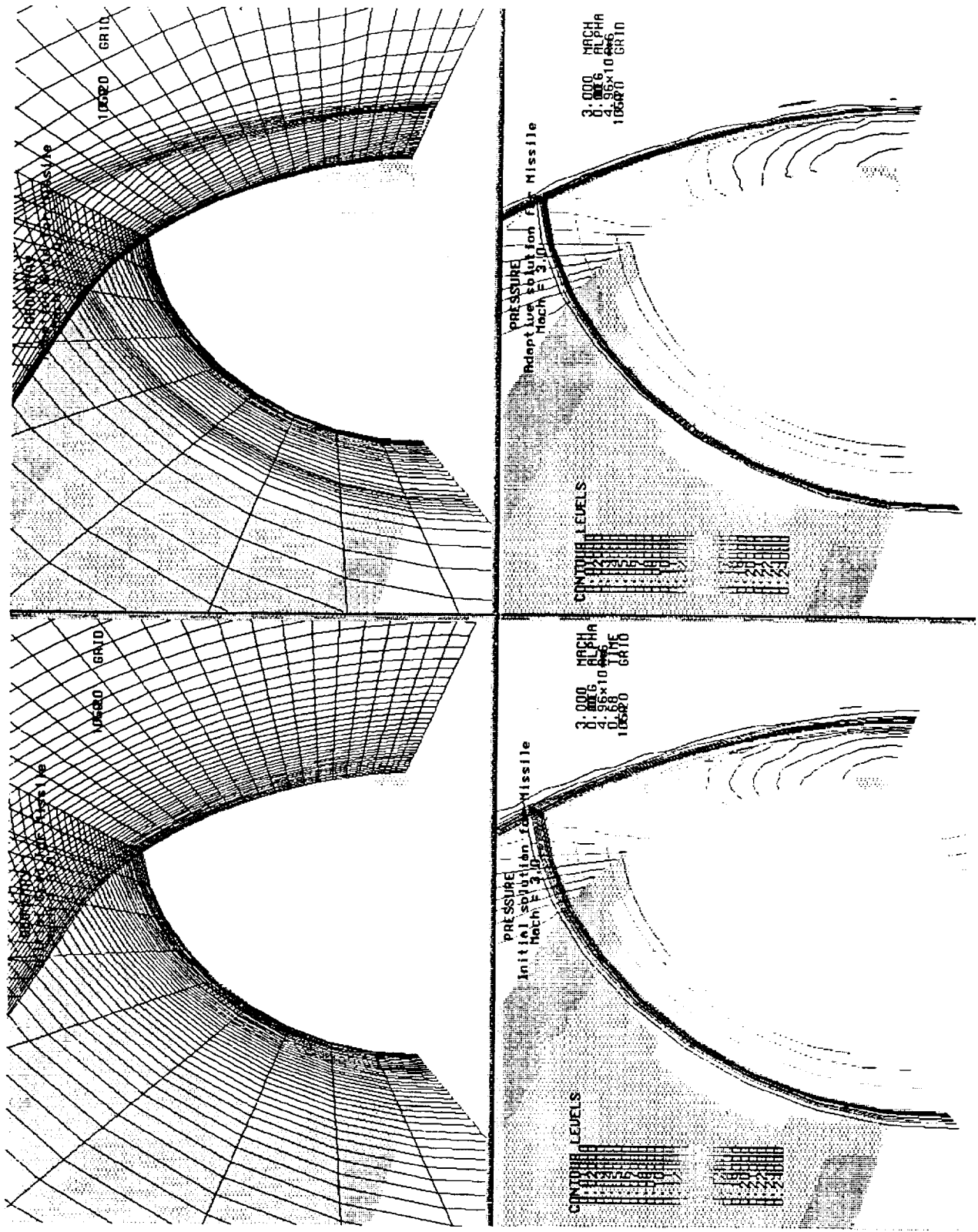


Figure 16.
3-D viscous cone case, bow shock in front of cone head.

3-D F-15 Body and Wing

Grid Size : 173 X 42 X 80

Mach = 1.5

Flow Solver Applied : PARC3D



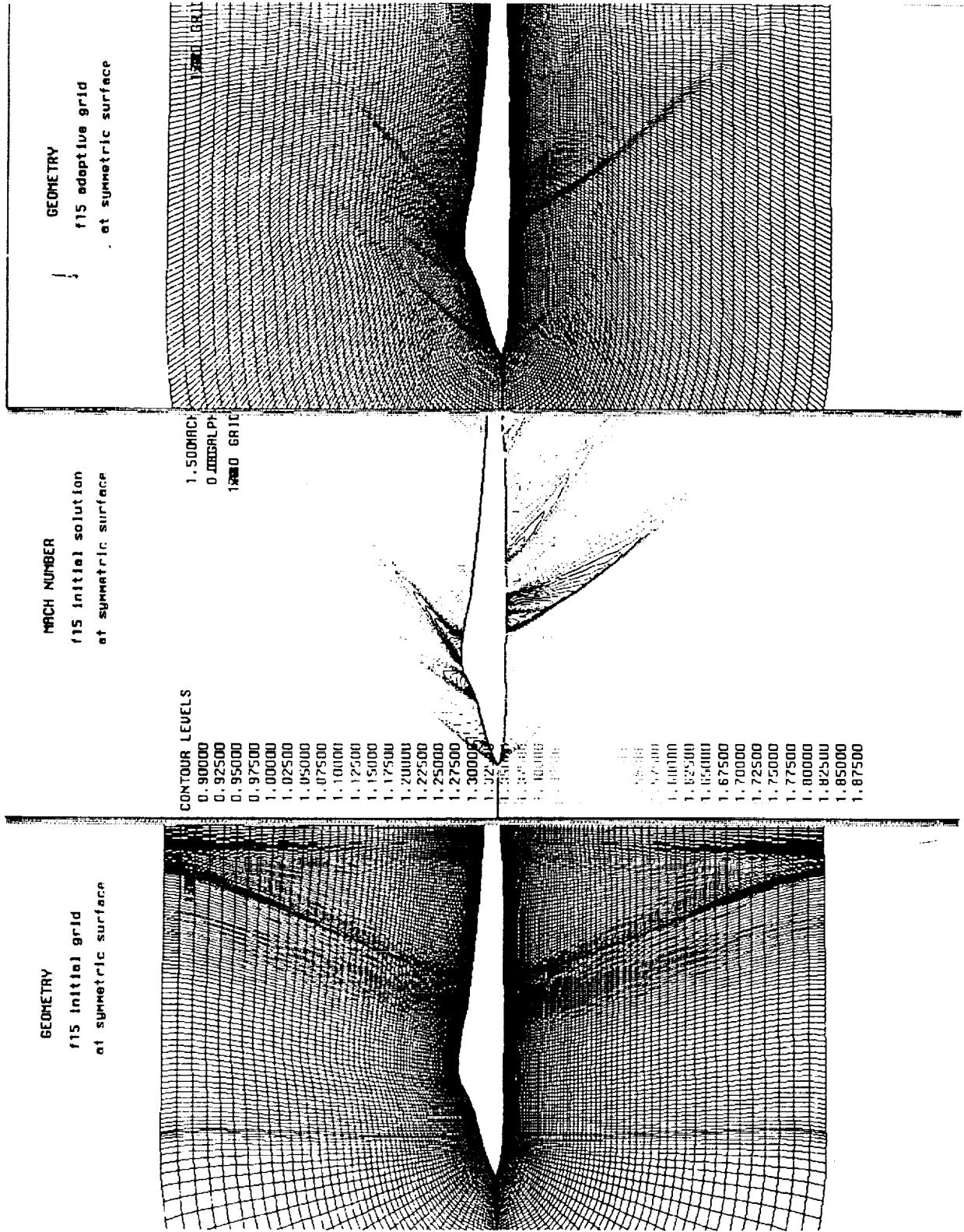


Figure 17.
3-D F-15 body and wing case, symmetric surface.

Helicopter Propeller Shock Prediction

Grid Size : Block 1 : 26 X 31 X 91
 Block 2 : 26 X 31 X 91

Flow Solver Applied : MSUTC



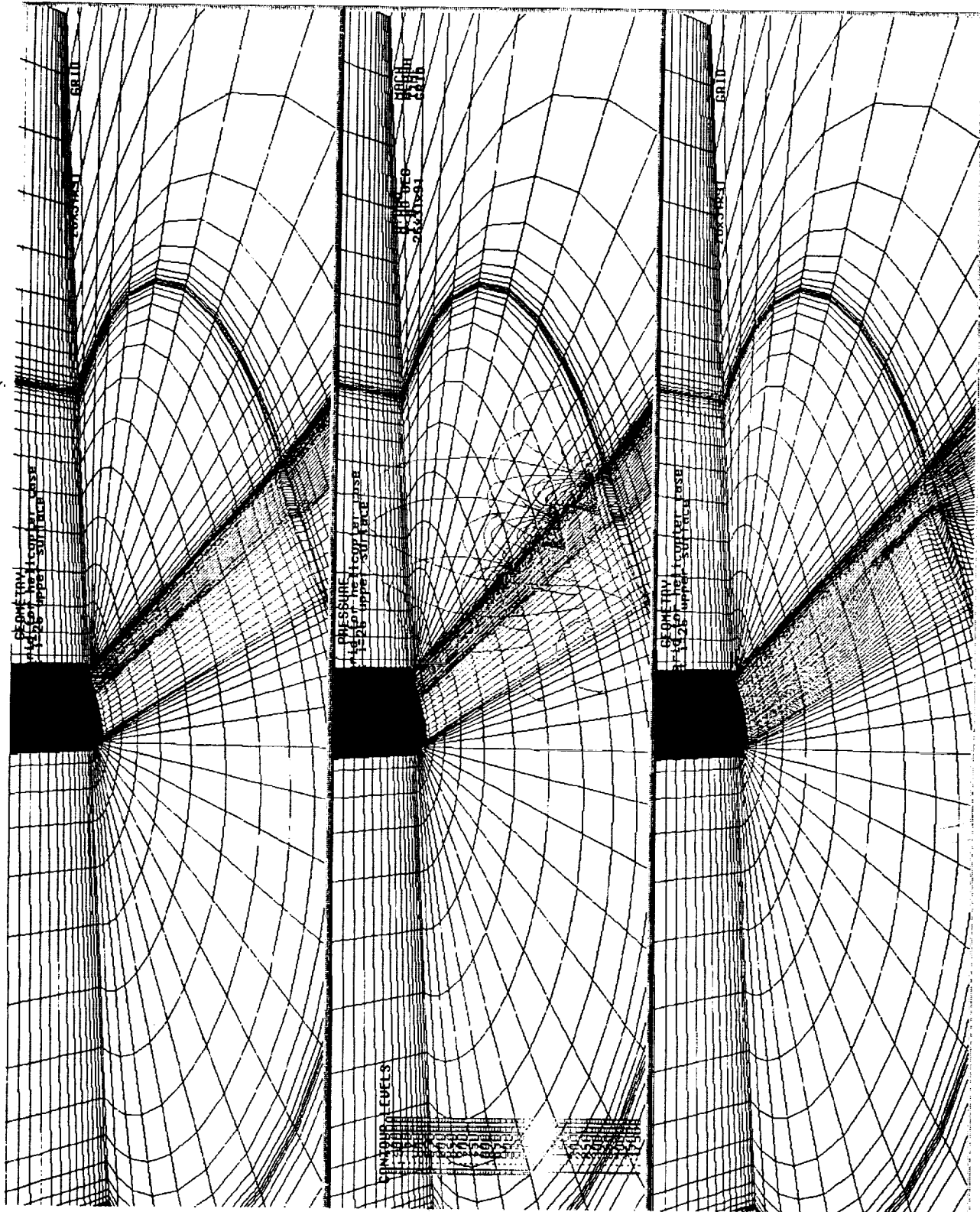


Figure 18.
3-D initial and adaptive grid for helicopter propeller.

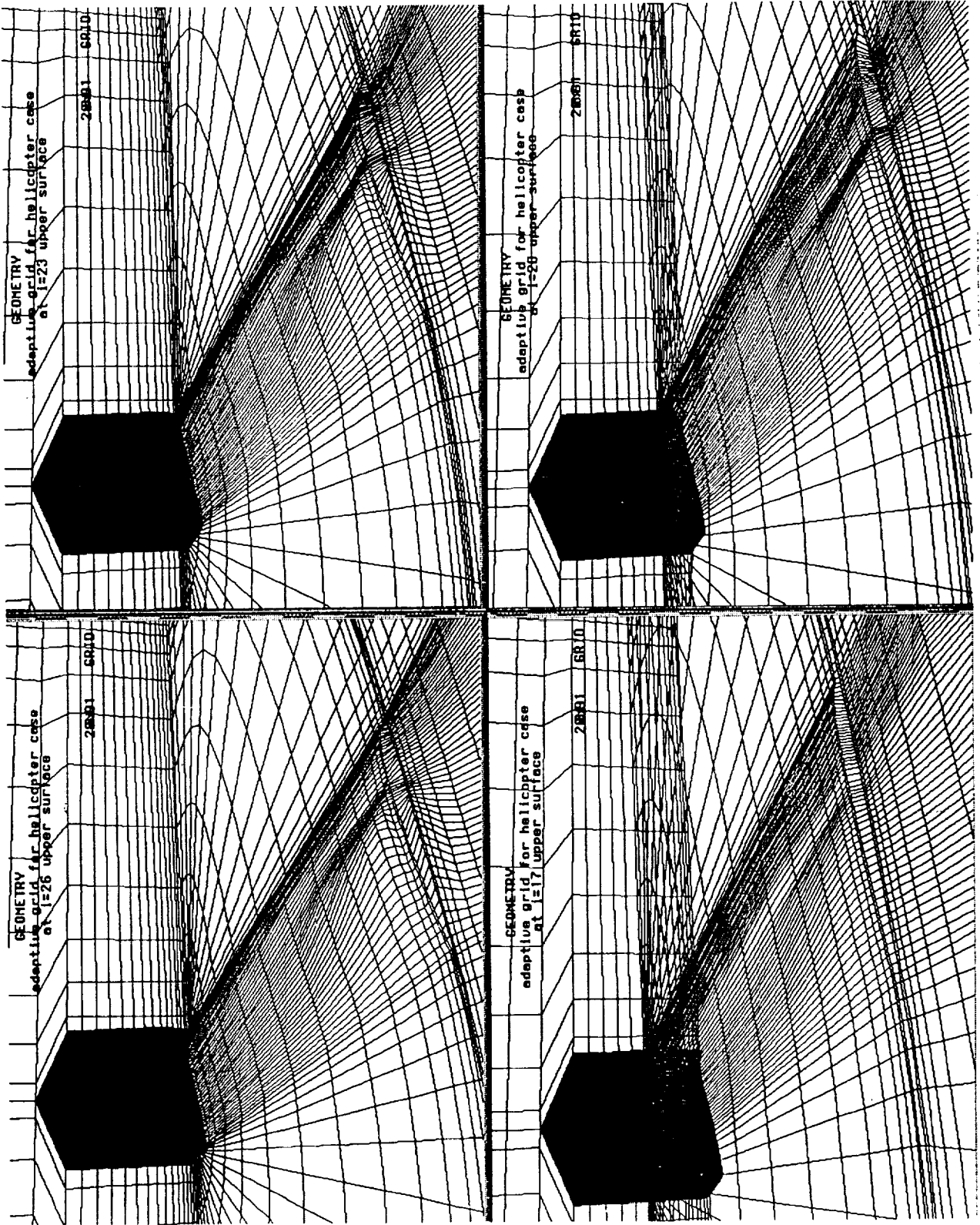


Figure 19.

3-D adaptive grid surfaces above the helicopter propeller.

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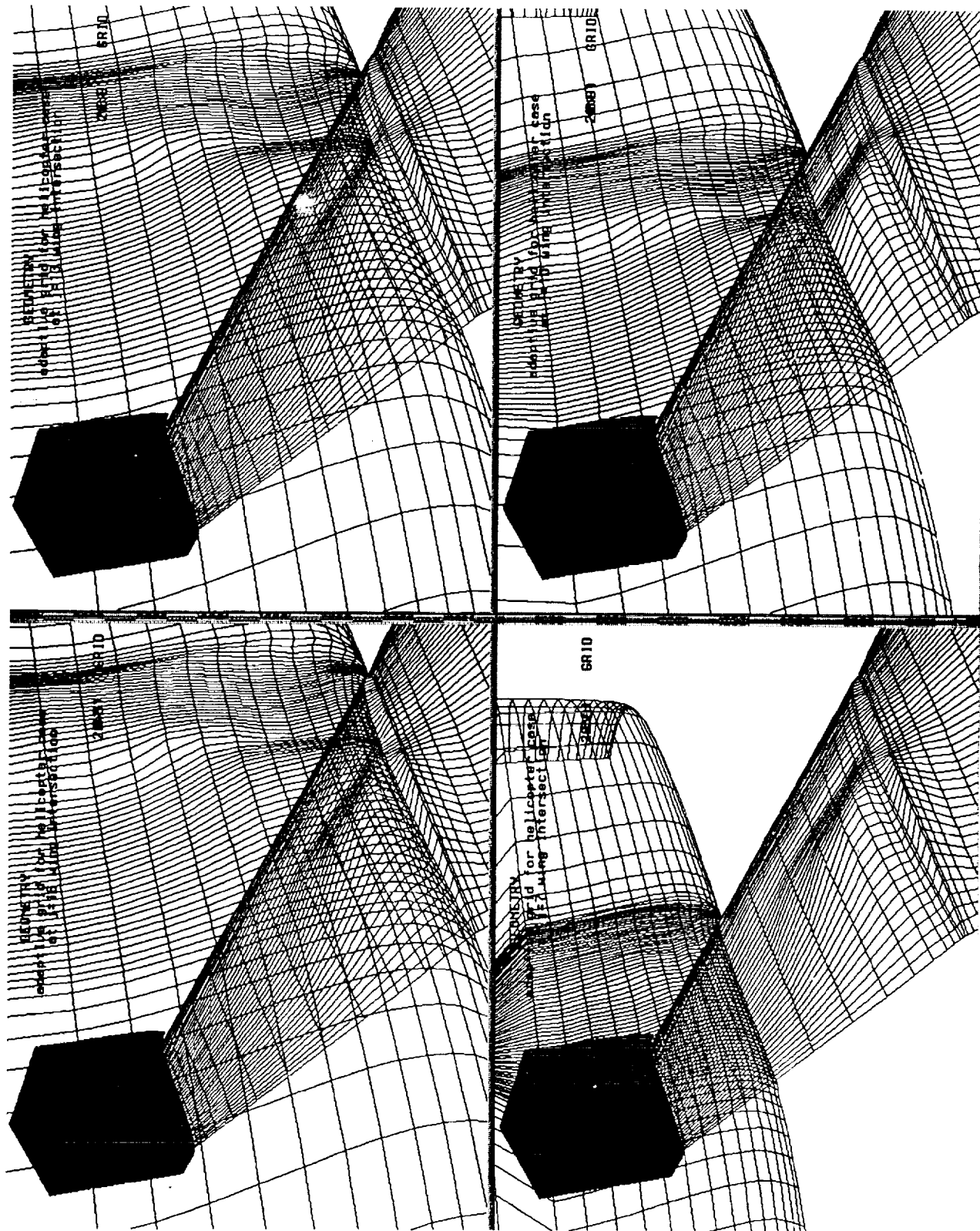


Figure 20.
3-D adaptive grid surfaces for the helicopter propeller intersection.



CONCLUSION

- . Algebraic Structured Adaptive Grid Generation is fast
- . NURBS makes the grid more smooth
- . Boolean sum allows an appropriate weight to the flow characteristics
- . More other flow characteristics can be added to the weight function

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