N91-10861

NAVIER-STOKES SOLUTIONS FOR FLOWS RELATED TO STORE SEPARATION

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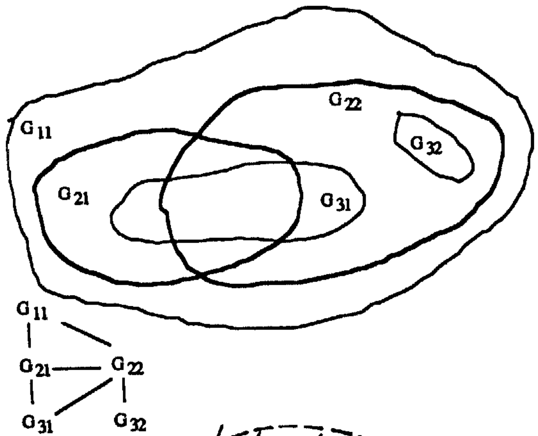
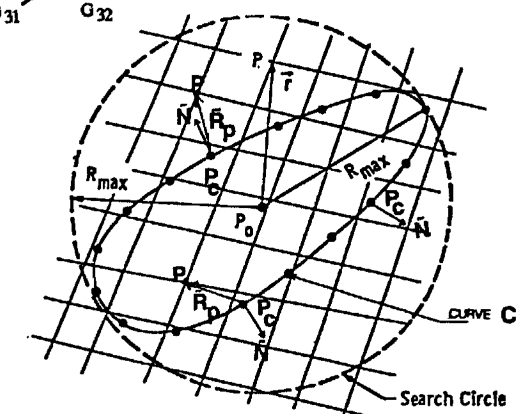
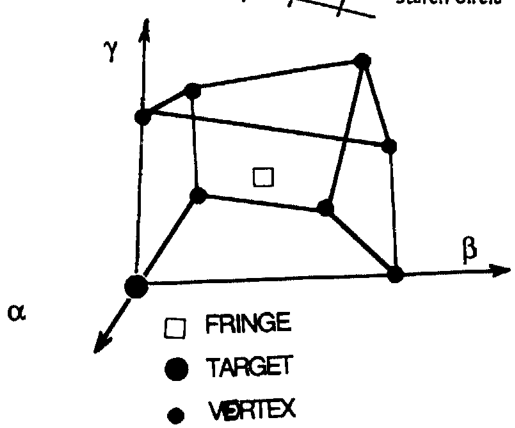
The objective is developing CFD capabilities to obtain solutions for viscous flows about generic configurations of internally and externally carried stores. The emphasis is placed on the supersonic flow regime with extensions being made to the transonic regime. The project is broken into four steps : (A) Cavity flows for internal carriage configurations; (B) High angle of attack flows, which may be experienced during the separation of the stores; (C) Flows about a body near a flat plate for external carriage configurations; (D) Flows about a body inside or in the proximity of a cavity. Three dimensional unsteady cavity flow solutions are obtained by an explicit, MacCormack algorithm, EMCAV3, for open, close, and transitional cavities. High angle of attack flows past cylinders are solved by an implicit, upwind algorithm. All the results compare favorably with the experimental data. For flows about multiple body configurations, the Chimera embedding scheme is modified for finite-volume and multigrid algorithms, MaGGiE. Then a finite volume, implicit, upwind, multigrid Navier-Stokes solver which uses on overlapped/embedded and zonal grids, VUMXZ3, is developed from the CFL3D code. Supersonic flows past a cylinder near a flat plate are computed using this code. The results are compared with the experimental data. Currently the VUMXZ3 code is being modified to accomplish step (D) of this project. Wind tunnel experiments are also being conducted for validation purposes.

ATTRIBUTES OF MaGGiE CODE







- SUBDOMAIN GRIDS GENERATED SEPARATELY AND INDEPENDENTLY.
- DISTANCE BETWEEN CELL CENTERS USED FOR INTERPOLATIONS.
- REGIONS OF A FINE LEVEL GRID COMMON TO OTHERS REMOVED **(HOLES).**
- REGIONS OF A COARSE LEVEL GRID OVERLAPPING SOLID SURFACES REMOVED (**ILLEGAL ZONES).**
- EDGES OF HOLES OR ILLEGAL ZONES ARE INTERGRID BOUNDARIES.
- 3-D VECTOR OPERATIONS TO LOCATE
  - CELLS IN A HOLE OR AN ILLEGAL ZONE.
  - CELLS OF OUTER BOUNDARY OF OVERLAP REGIONS **(FRINGE CELL).**
  - IMMEDIATE-NEIGHBOR CELLS OF A HOLE OR AN ILLEGAL-ZONE CELL (**FRINGE CELL**).
- **INFORMATION HEXAHEDRONS** AROUND FRINGE CELLS FORMED.
- CELLS IN A HOLE BUT NOT IN AN ILLEGAL ZONE UPDATED FROM | FINE LEVEL / EQUAL COARSE LEVEL | OF OTHER GRIDS
- COEFFICIENTS FOR TRILINEAR INTERPOLATIONS.
- VECTORIZED DATA STRUCTURES AS PREPROCESSOR FOR **VUMXZ3**
- DEVELOPED FROM CHIMERA.
- CHARACTERISTIC INTERGRID BOUNDARY CONDITIONS.

ATTRIBUTES OF VUMXZ3 CODE

- DEVELOPED FROM CFL3D CODE, HENCE INCLUDES ALL CFL3D ATTRIBUTES.
- ALL BUT CROSS-DERIVATIVE VISCOUS TERMS.
- BALDWIN-LOMAX TURBULENCE MODEL MODIFIED FOR VORTICAL FLOWS, MULTIPLE-WALLS, AND TURBULENT MEMORY RELAXATION FOR WAKES AND SHEAR LAYERS.
- BLOCK OR DIAGONAL INVERSIONS ACCOMODATE HOLES AND ILLEGAL ZONES FOR OVERLAPPED GRIDS.
- AVOIDS INFORMATION POLLUTION NEAR HOLES OR ILLEGAL ZONES FOR HIGHER ORDER SCHEMES.
- NULLIFIES WEIGHT OF CONTRIBUTIONS FROM ILLEGAL ZONES DURING 3-D MULTIGRID PROLONGATION.
- INTERGRID INFORMATION EXCHANGED BY TRILINEAR INTERPOLATIONS COUPLED WITH CHARACTERISTIC BOUNDARY CONDITIONS.
- COMBINED ZONAL AND OVERLAPPED EMBEDDING.
- DEMONSTRATIVE CASES :

SUPERSONIC FLOW PAST A BLUNT-NOSE CYLINDER (L/D=6.7)

AT 32°-ANGLE OF ATTACK ON

SINGLE C-O GRID.

C-O GRID EMBEDDED IN CARTESIAN GRID.

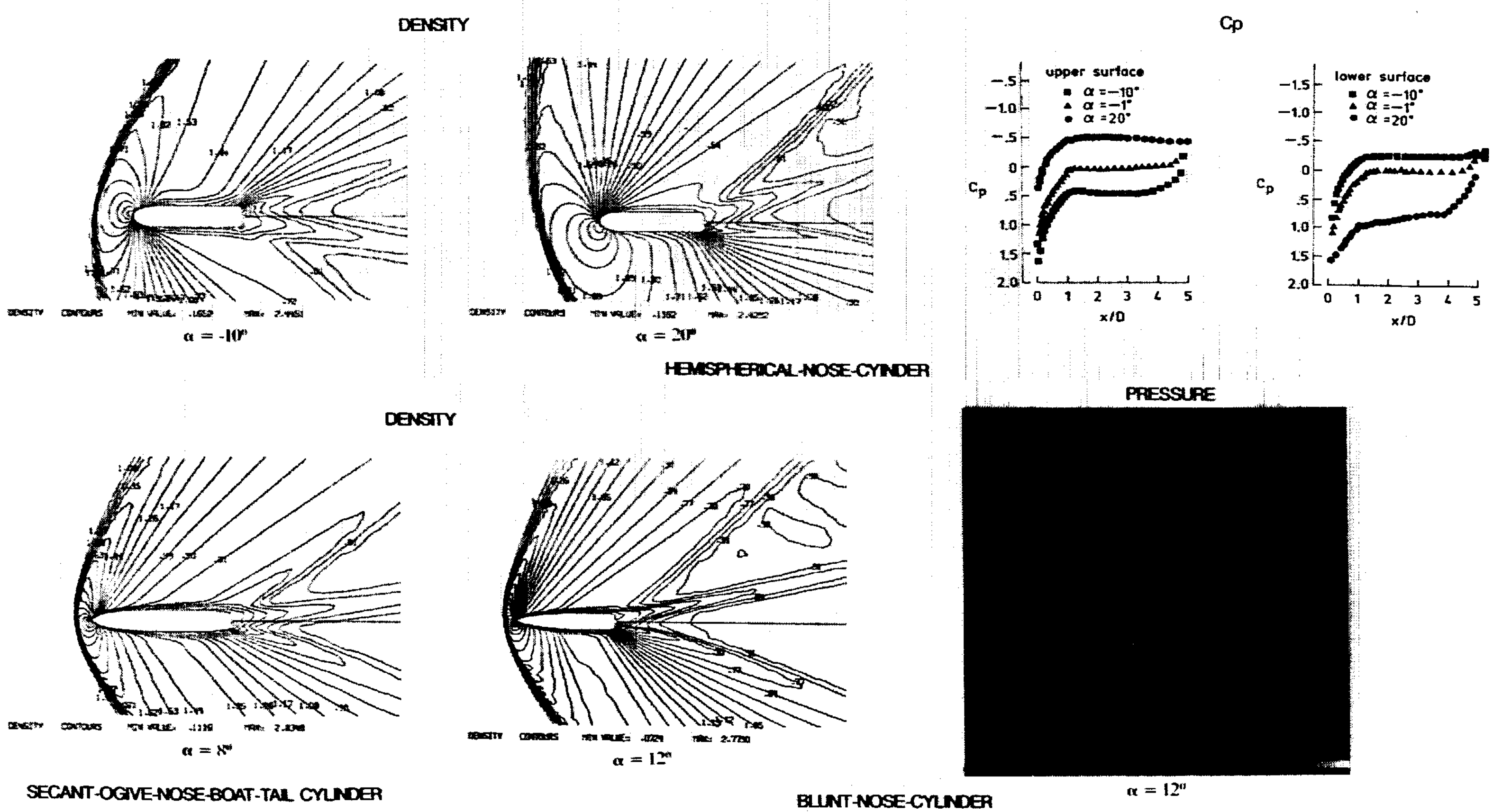
C-O GRID PATCHED TO H-O GRID.

SUPERSONIC FLOW PAST AN OGIVE-NOSE CYLINDER (L/D=18) NEAR

FLAT PLATE.

EFFECTS OF SHAPE AND INCIDENCE ON FLOW PAST A CYLINDRICAL SECTION

$M_\infty = 1.6 \quad Re_\infty = 2 \times 10^6$ / ft

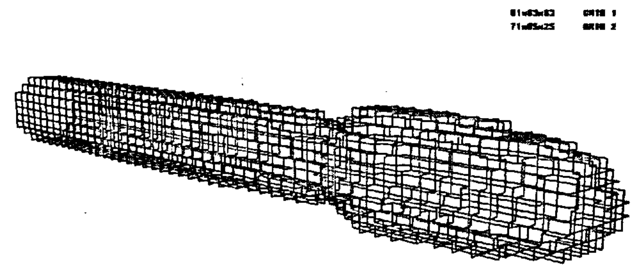


EMBEDDED GRIDS FOR BLUNT-NOSE-CYLINDER WITH STING

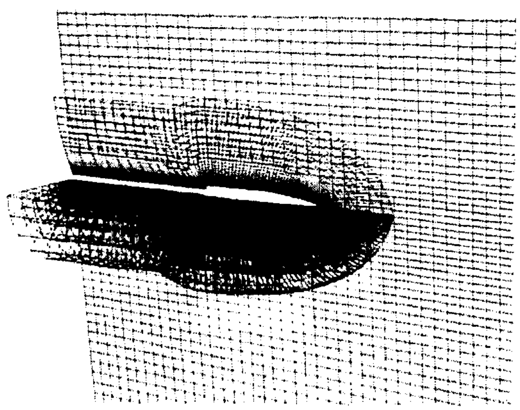
C-O GRID : 73x65x57

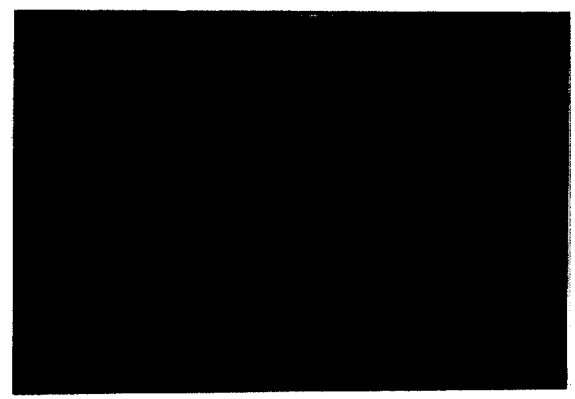
CARTESIAN GRID : 81x73x73

cartesian grid with hole

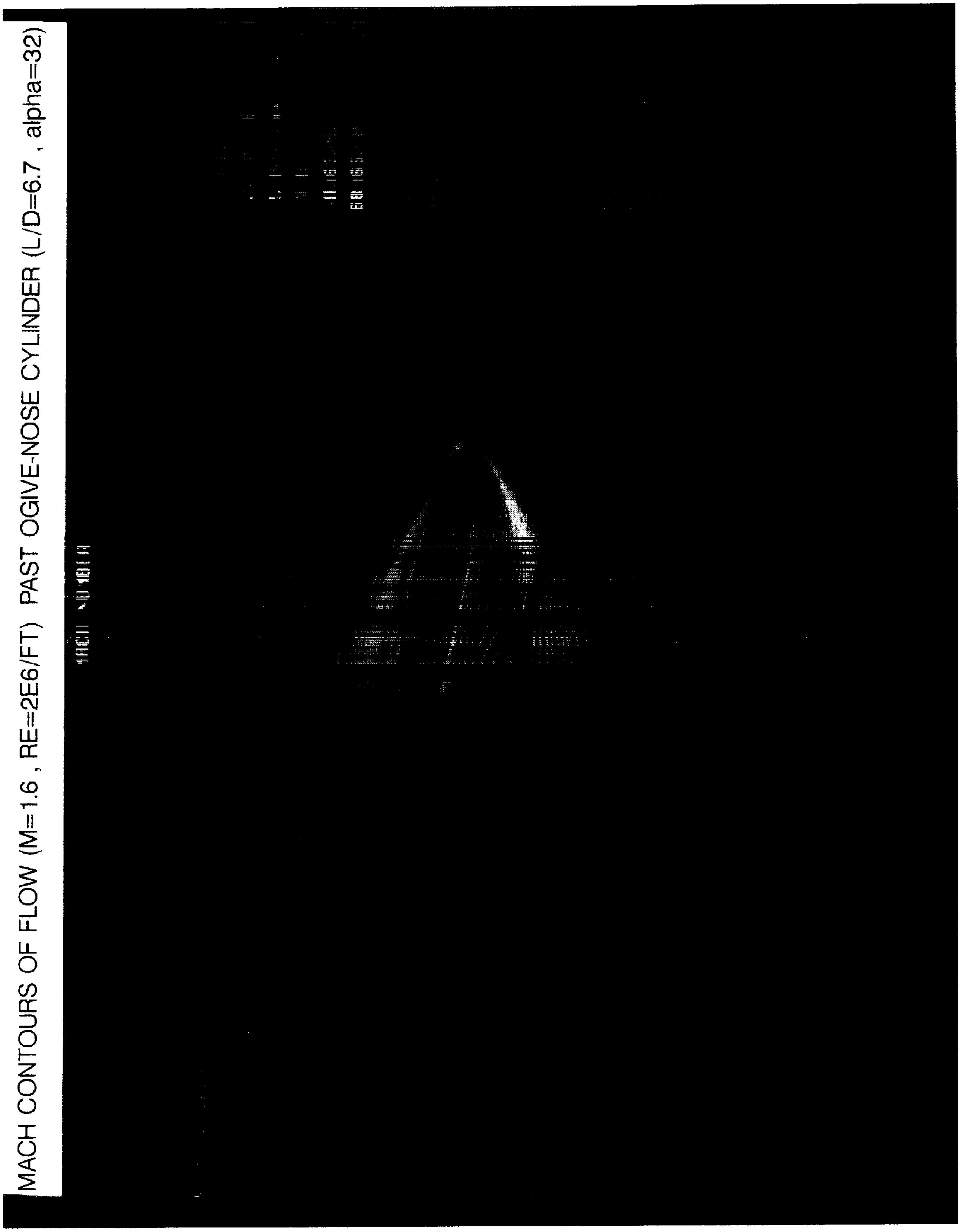


hole boundary cells





overlap of c-o with cartesian



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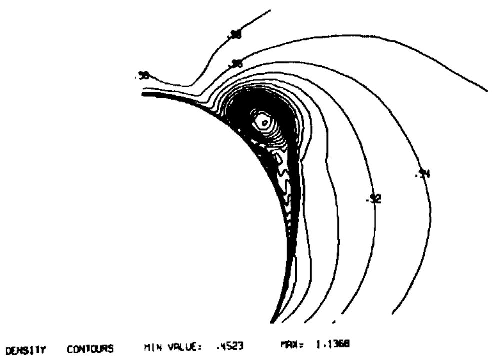
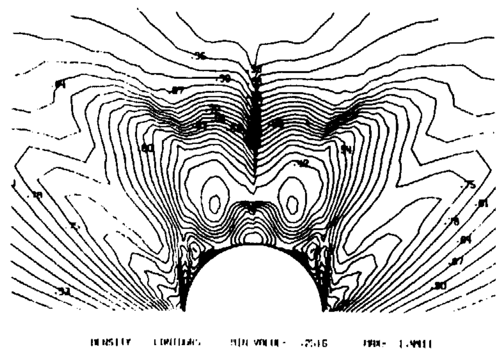
CROSSFLOW DENSITY CONTOURS OF FLOW PAST A BLUNT-NOSE-CYLINDER

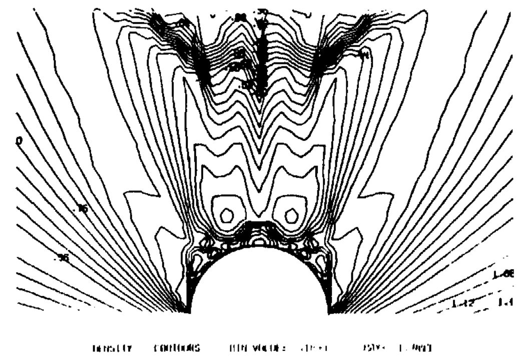
$M_\infty = 1.6 \quad Re_\infty = 2\times10^6$ / ft



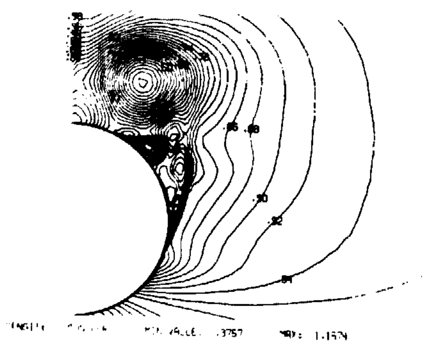
$\alpha = 12^\circ$



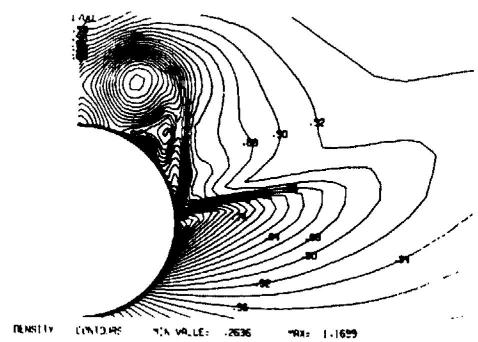
$\alpha = 32^\circ$



$\alpha = 44^\circ$



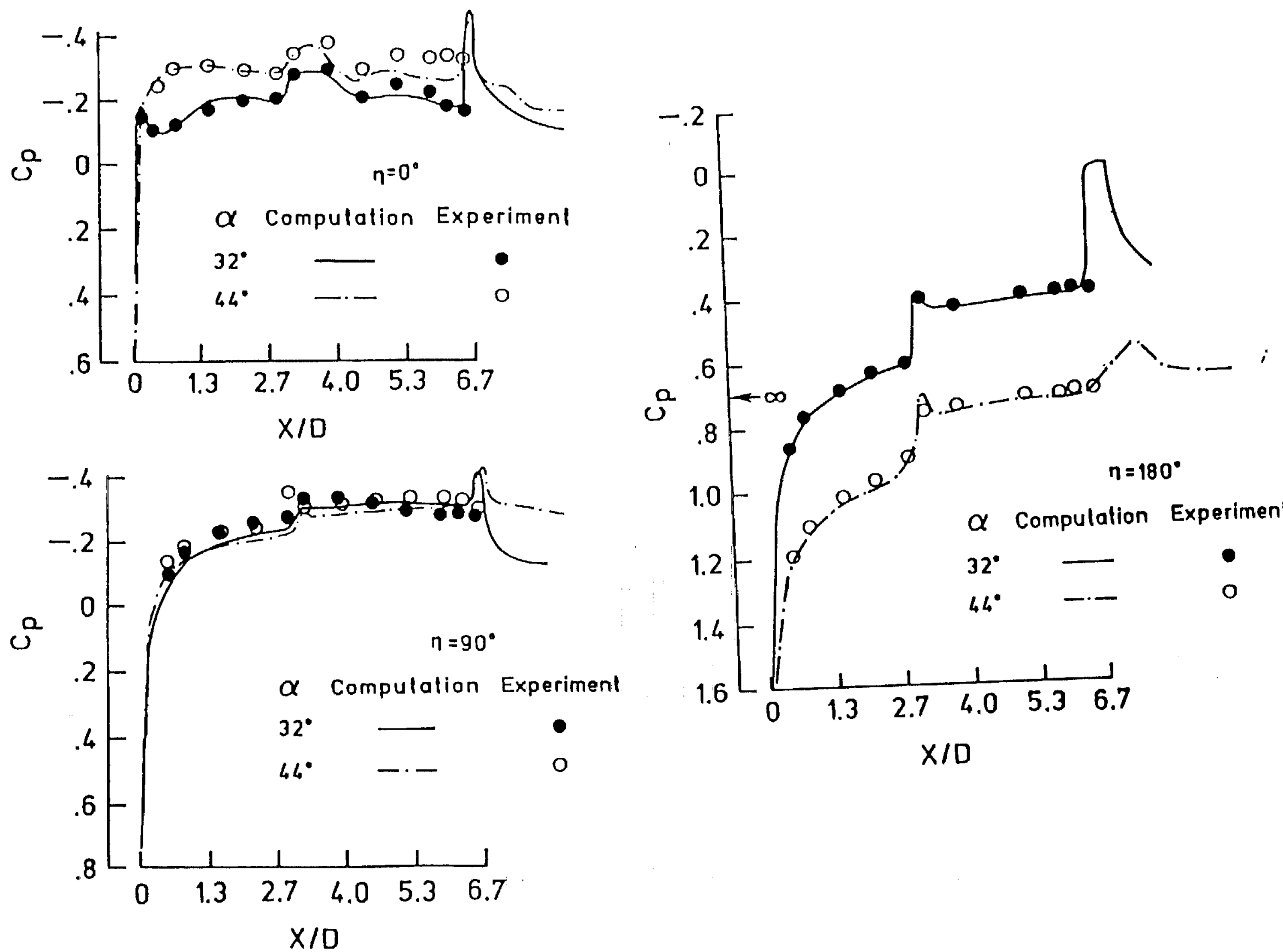
LAMINAR



TURBULENT

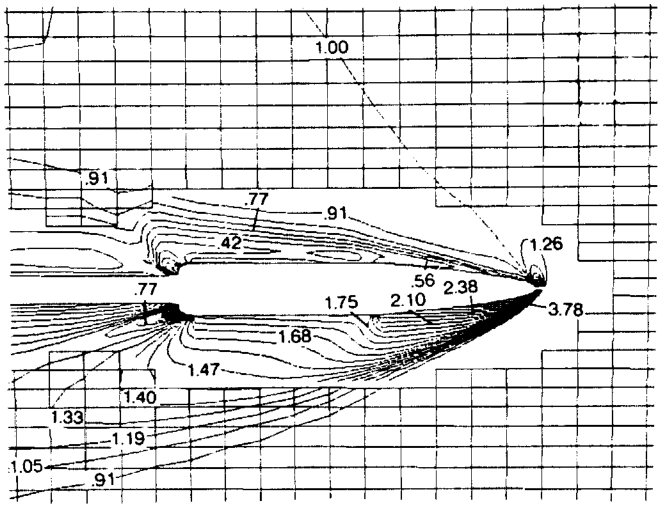
$\alpha = 20^\circ$

FLOW PAST A BLUNT-NOSE CYLINDER (L/D=6.7 , M=1.6 , Re=2E6/FT) η =0 LEESIDE, η=180 WINDSIDE

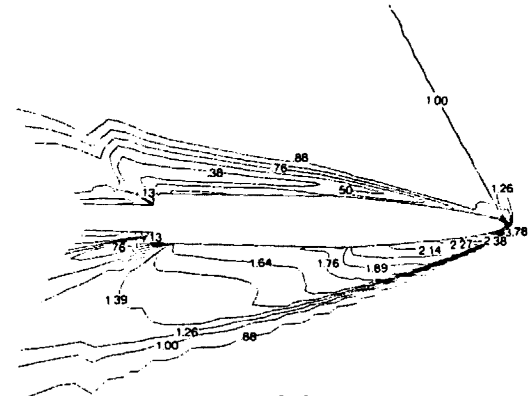


PRESSURE CONTOURS ON THE SYMMETRY PLANES OF BLUNT-NOSE-CYLINDER

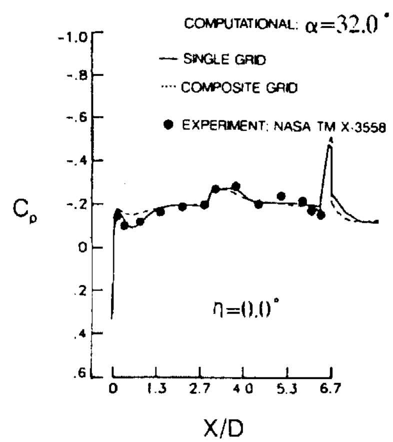
$M\infty = 1.6 \quad Re\infty = 2x10^6 / ft \quad \alpha = 32^0$



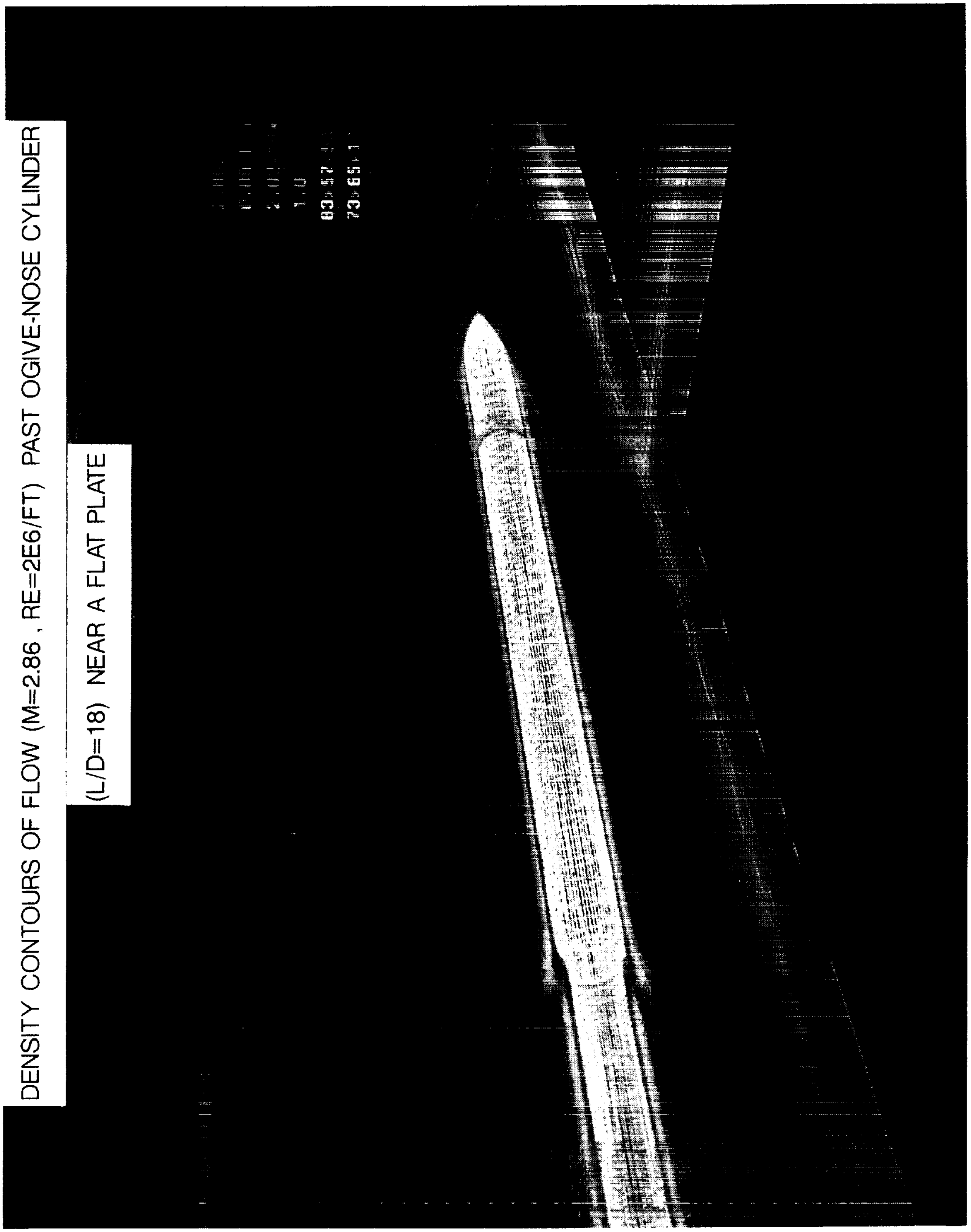
(a) composite grid



(b) single C-O grid



(c) Cp on leeside



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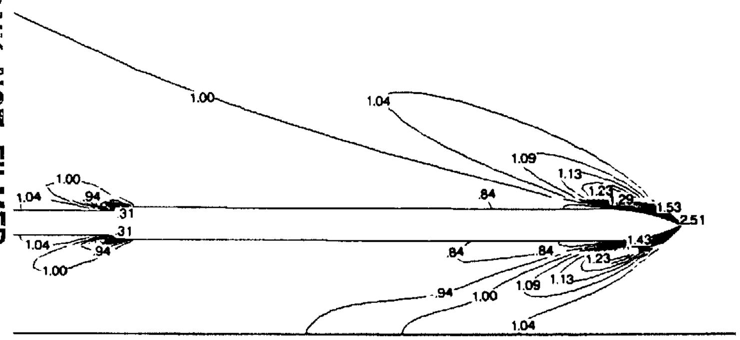
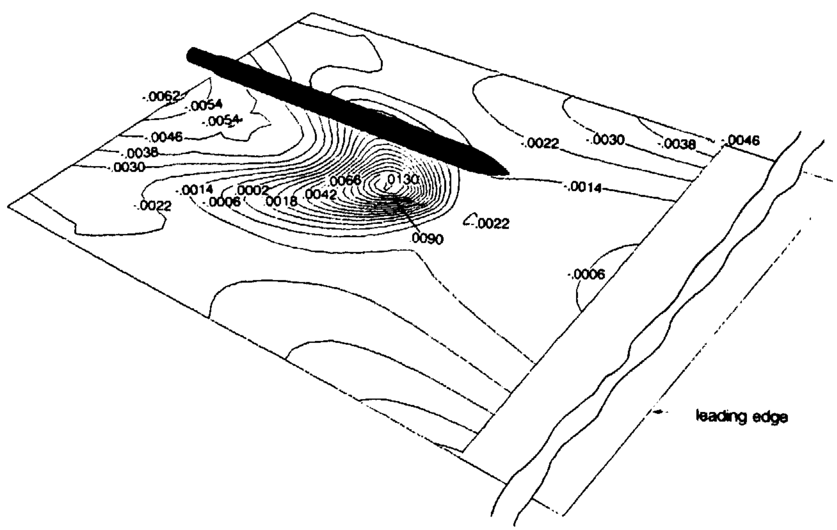
FLOW OVER OGIVE-NOSE-CYLINDER NEAR FLAT PLATE

$M\infty = 2.86 \quad Re\infty = 2x10^6 / ft \quad \alpha = 0^0$

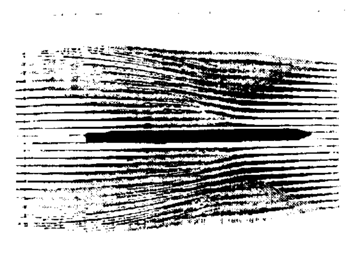
Pressure Contours on the Symmetry Plane of ONC



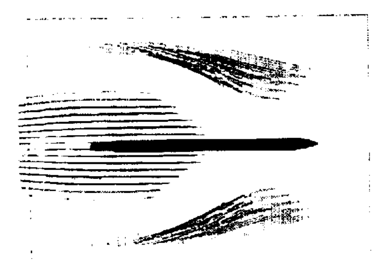
Pressure Coefficient Contours on the surface of the flat plate



Skin Friction Pattens near the flat plate surface



(a) two cells above the surface



(b) one cell above the surface

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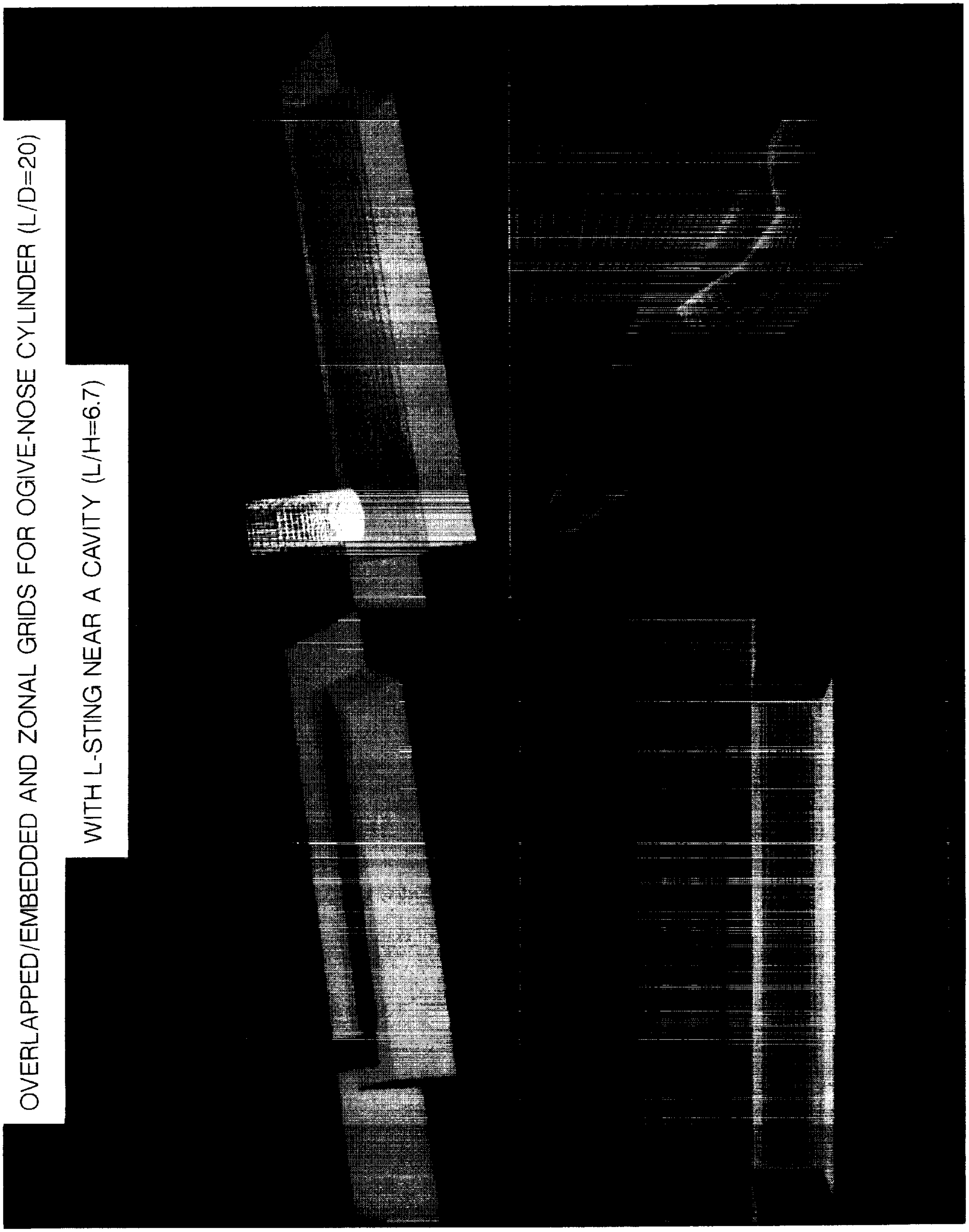

OVERLAPPED/EMBEDDED AND ZONAL GRIDS FOR OGIVE-NOSE CYLINDER (L/D=20)
WITH L-STING NEAR A CAVITY (L/H=6.7)

ATTRIBUTES OF EMCAV3

- 3-D REYNOLDS-AVERAGED NAVIER-STOKES EQUATIONS FOR UNSTEADY COMPRESSIBLE FLOW.
- EXPLICIT, UNSPLIT, PREDICTOR-CORRECTOR TIME INTEGRATION (MACCORMACK).
- FINITE DIFFERENCE SPATIAL DISCRETIZATION.
- SECOND ORDER ACCURATE IN TIME AND SPACE.
- VECTORIZED DATA STRUCTURE.
- DEVELOPED FROM SCRM32.
- ALGEBRAIC GRID GENERATOR.
- BALDWIN-LOMAX TURBULENCE MODEL MODIFIED FOR [VORTICAL FLOWS. / MULTIPLE WALLS. / TURBULENT MEMORY RELAXATION FOR SHEAR LAYER.]
- IMPLICIT MARCHING SOLUTION FOR 2-D COMPRESSIBLE BOUNDARY LAYER PROFILE.
- FOURIER TIME SERIES ANALYSIS FOR CAVITY ACOUSTICS.
- DEMONSTRATIVE CASES

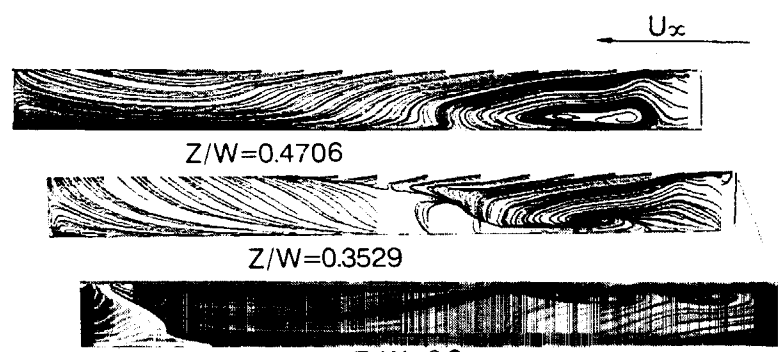
[2-D / 3-D] [SUBSONIC / TRANSONIC / SUPERSONIC] FLOWS AT [0° / 45°] YAW PAST [DEEP / TRANSITIONAL / SHALLOW] CAVITIES.

INSTANTANEOUS STREAMLINES OF FLOW PAST RECTANGULAR CAVITIES

$M_\infty=1.5$ L/D=6 Re=6.56×10^6/m

$M_\infty=1.5$ L/D=16 Re=6.56×10^6/m

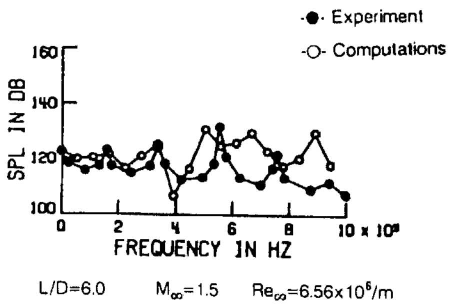
$M_\infty=0.9$ L/D=4.4 Re=5.35×10^6/m

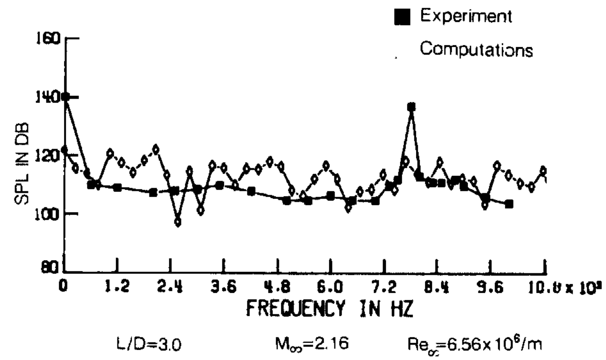


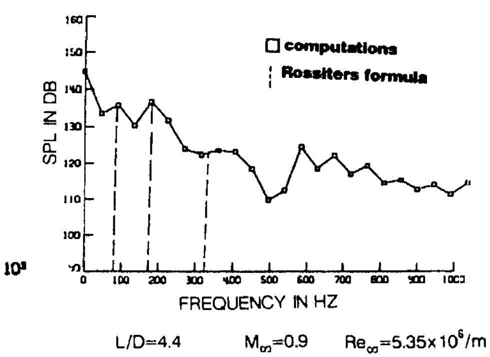
Z/W=0.0

$M_\infty=0.58$ L/D=11.7 Re=5.02×10^6/m

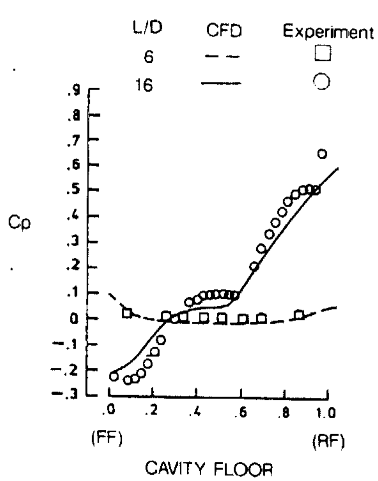
FREQUENCY SPECTRA OF SOUND PRESSURE LEVEL ON THE CAVITY FLOOR

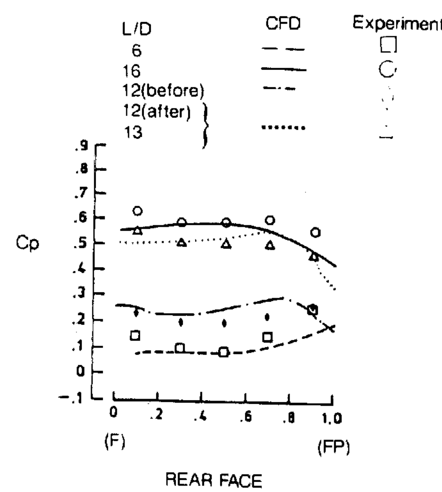






Cp FOR $M_\infty = 1.5$ $Re_\infty = 6.56 \times 10^6$/m FLOW





CONCLUSIONS

- 3-D CFD CAPABILITIES FOR UNSTEADY CAVITY FLOWS.
- TIME-AVERAGED AND TIME SERIES ANALYSES OF CAVITY FLOWS :

  EFFECTS OF LENGTH-TO DEPTH, FLOW REGIMES, YAW ANGLES.
- 2-D ANALYSES OF FLOWS PAST VARIOUS CYLINDRICAL SECTIONS AT VARIOUS ANGLES OF ATTACK.
- 3-D ANALYSES OF LAMINAR AND TURBULENT FLOWS PAST A BODY OF REVOLUTION

  AT VARIOUS ANGLES OF ATTACK.
- 3-D CFD CAPABILITIES DEVELOPED FOR VISCOUS FLOWS ABOUT

  COMPLEX AND/OR MULTICOMPONENT CONFIGURATIONS.
- COMBINED ADVANTAGES : GEOMETRICALLY CONSERVATIVE, MINIMALLY DISSIPATIVE

  : NUMERICALLY AND COMPUTATIONALLY EFFICIENT.

  : FLEXIBILITY IN BODY GEOMETRIES AND GRID TOPOLOGIES.
- FLUX CONSERVATION ACROSS INTERGRID BOUNDARIES NEED FURTHER STUDY.
- ANALYSES OF AERODYNAMIC INTERFERENCE OF A STORE NEAR A FLAT PLATE (EXTERNAL CARRIAGE).
- WORK-IN-PROGRESS : CFD SOLUTIONS FOR FLOWS PAST AN OGIVE-NOSE-CYLINDER WITH L-SHAPE

  STING NEAR A CAVITY AND CODE VALIDATATION WIND TUNNEL EXPERIMENTS.