

High Lift Aerodynamics

School of Aeronautics and
Astronautics

Purdue University

John Sullivan
Steve Schneider

N94-25268

Unclas

G3/05 0207527

Graduate Student

– Bryan Campbell

UnderGraduate Students

- Greg Bucci
- Rod Boone (Shaw University)
- Shad Torgerson
- Rick Erausquin
- Chad Knauer

(NASA-CR-195183) HIGH LIFT
AERODYNAMICS (Purdue Univ.) 46 p

High Lift Aerodynamics

**School of Aeronautics and
Astronautics**

Purdue University

John Sullivan

Steve Schneider

Graduate Student

- Bryan Campbell

Undergraduate Students

- Greg Bucci
- Rod Boone (Shaw University)
- Shad Torgerson
- Rick Erausquin
- Chad Knauer

• Sponsored by NASA AMES

- Project Monitor - Larry Erickson
- \$30,000

High Lift Aerodynamics

**School of Aeronautics and
Astronautics**

Purdue University

John Sullivan

Steve Schneider

Graduate Student

- **Bryan Campbell**

Undergraduate Students

- **Greg Bucci**
- **Rod Boone (Shaw University)**
- **Shad Torgerson**
- **Rick Erasquin**
- **Chad Knauer**

Impact of High Lift on Aircraft Performance

- **For a 150 Passenger Transport Aircraft**
 - **A 5% increase in Take-off L/D**
 - » **15% increase in Payload , or,**
 - » **11% increase in Range**
 - **A 5% increase in Max. Lift at Landing**
 - » **20% increase in Range**
 - » **3 Knot Decrease in Approach Speed**
- **Goal**
 - **Design of Optimum High Lift Systems with Minimum Complexity**

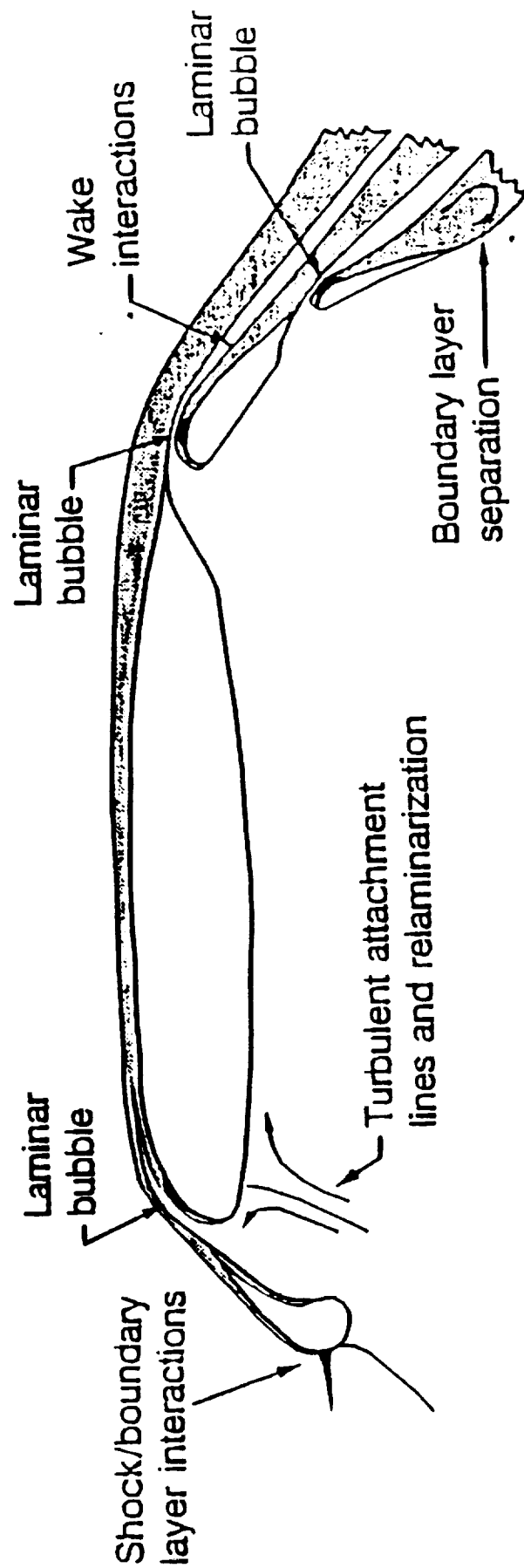


Figure 1. Flow on a Two-Dimensional High Lift Airfoil System

Objective of Current Program

- **Experimental Program Aimed at Providing a Physical Picture of the Flow Physics and Quantitative Turbulence Data of the Interaction of a High Reynolds Number Wake with a Flap Element**
- **Coordinate with Researchers Developing Computational Procedures**
 - **Stuart Rogers - NASA Ames**
 - **Kyle Anderson/Russ Rausch - NASA Langley**
 - **Mark Drela - MIT**
- **Coordinate with NASA Ames Experiments**
 - **Joe Marvin/George Meter**

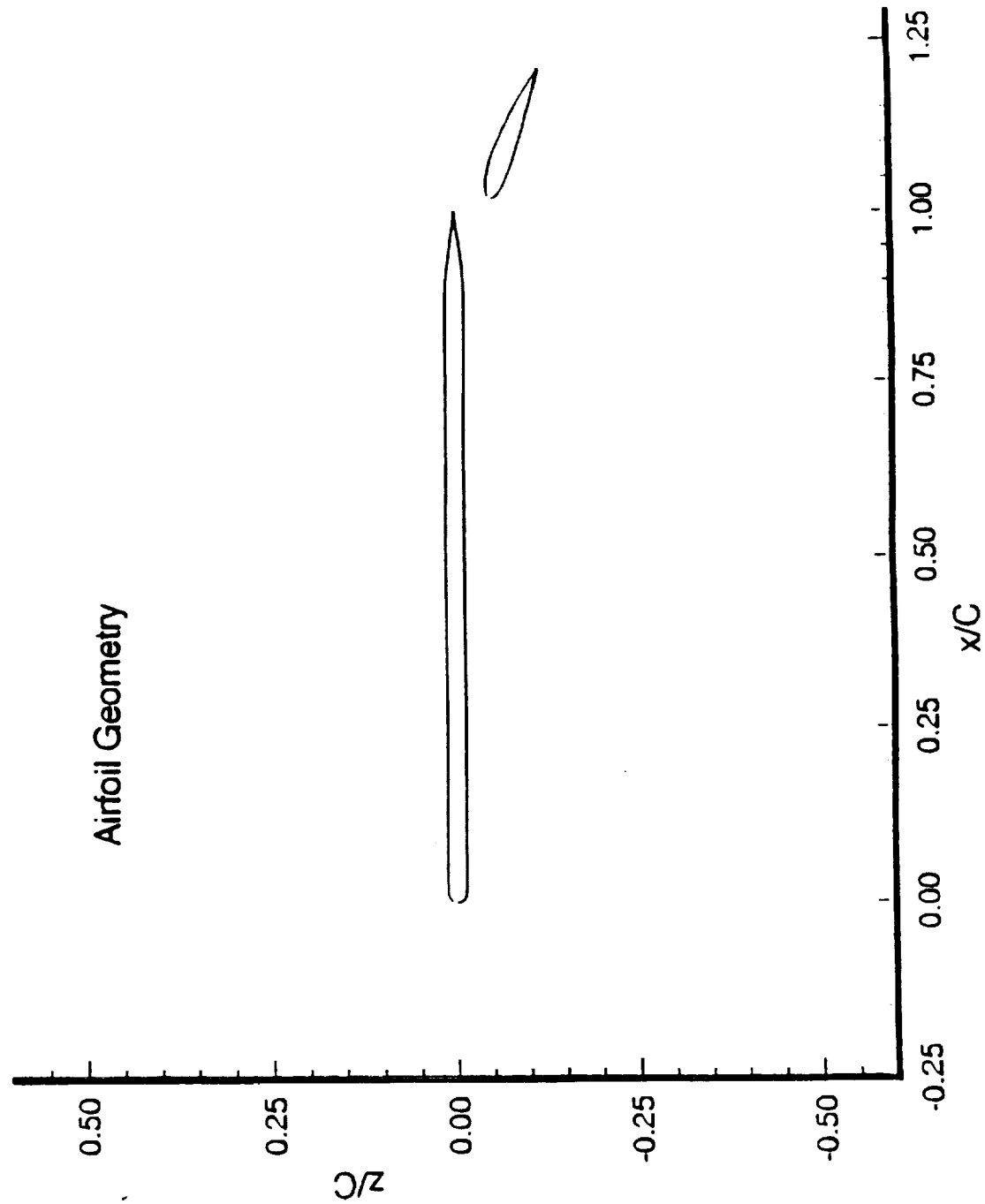


Figure 4. Two-Dimensional Model of Test Configuration

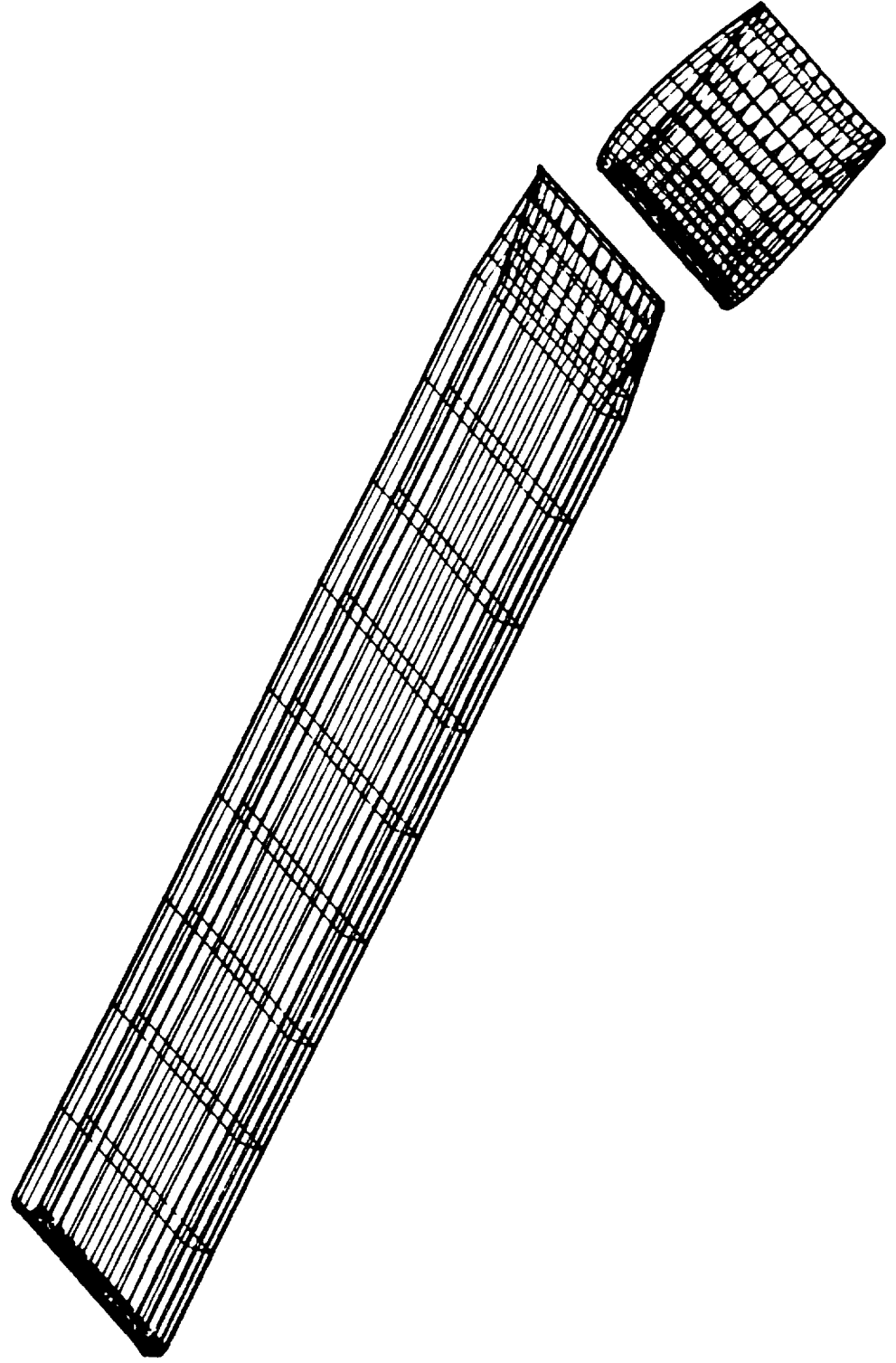


Figure 3. Panel Method Model of the Proposed Test Configuration

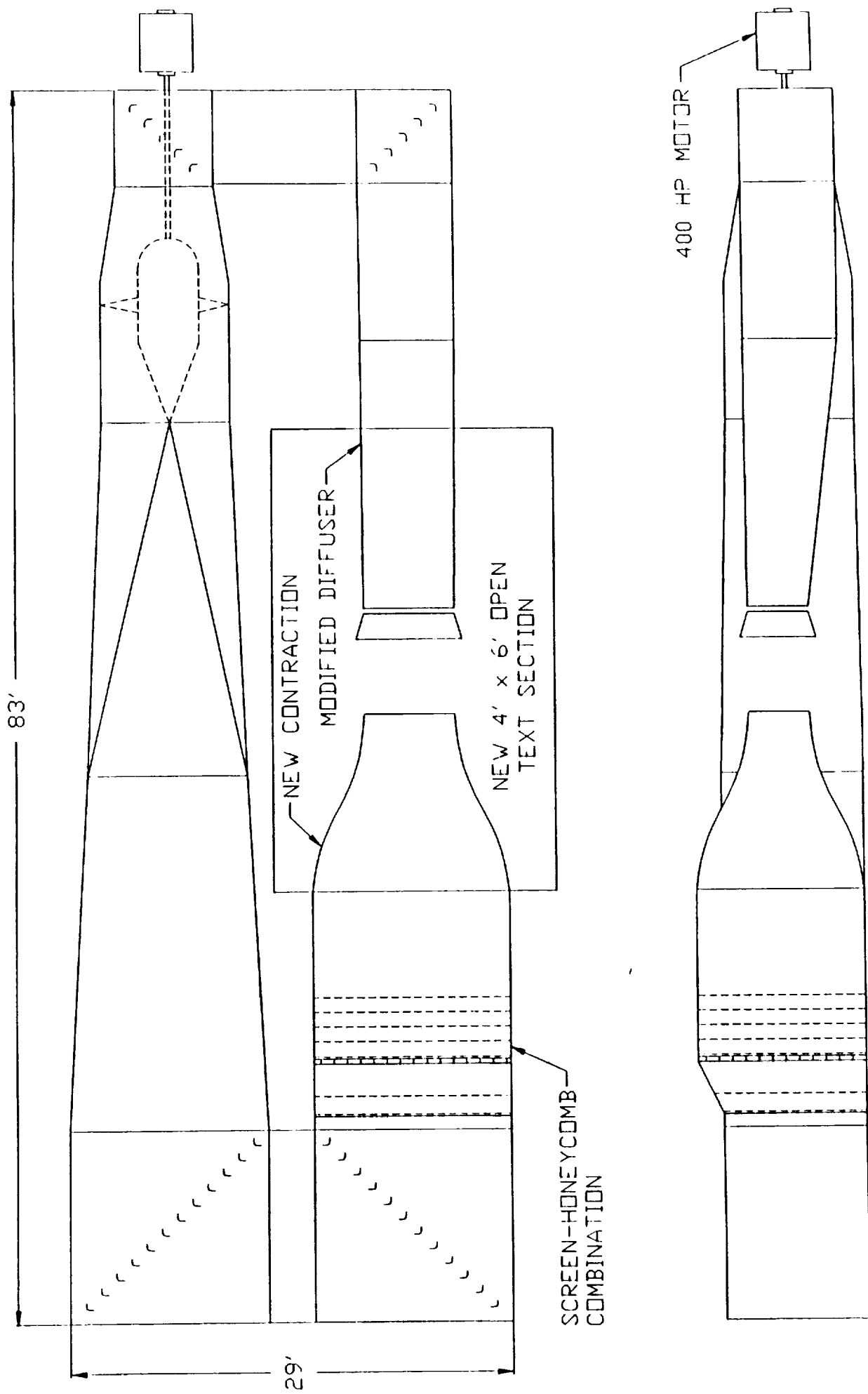
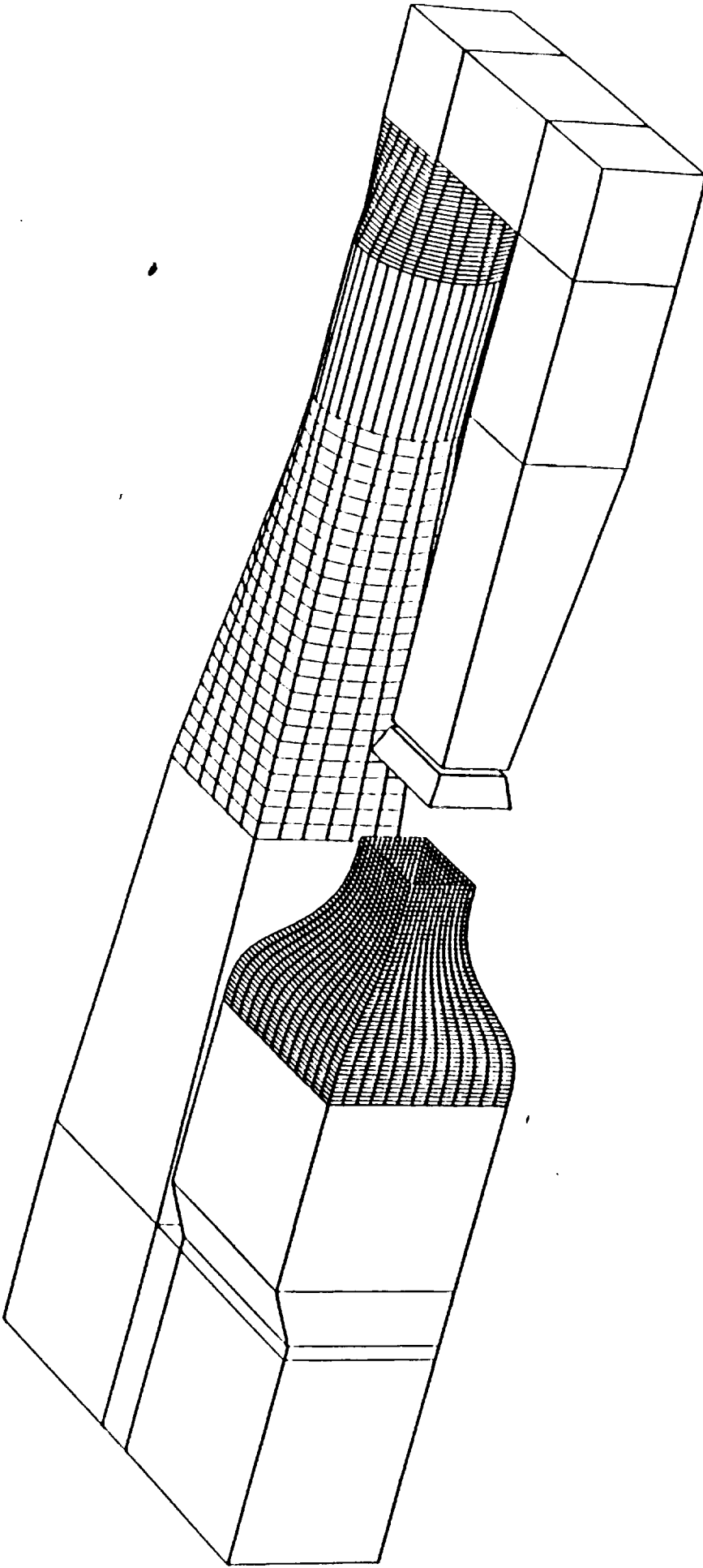


FIGURE #1: BEEING SUBSONIC WIND TUNNEL



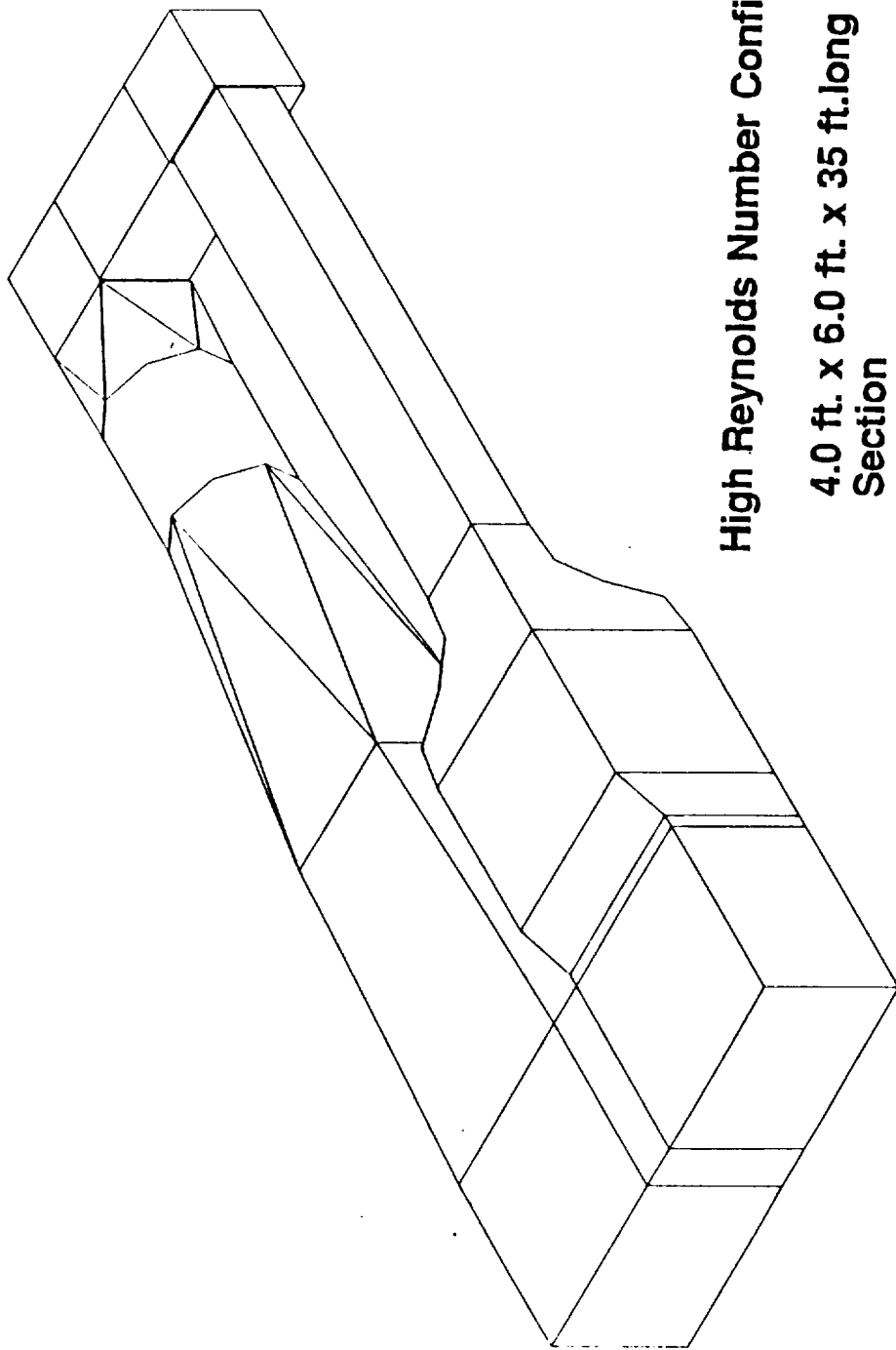
Standard Configuration

4.0 ft.x 6.0 ft. Test Section

Open Test Section (as shown)

Closed Test Section

Velocity - 200 mph.



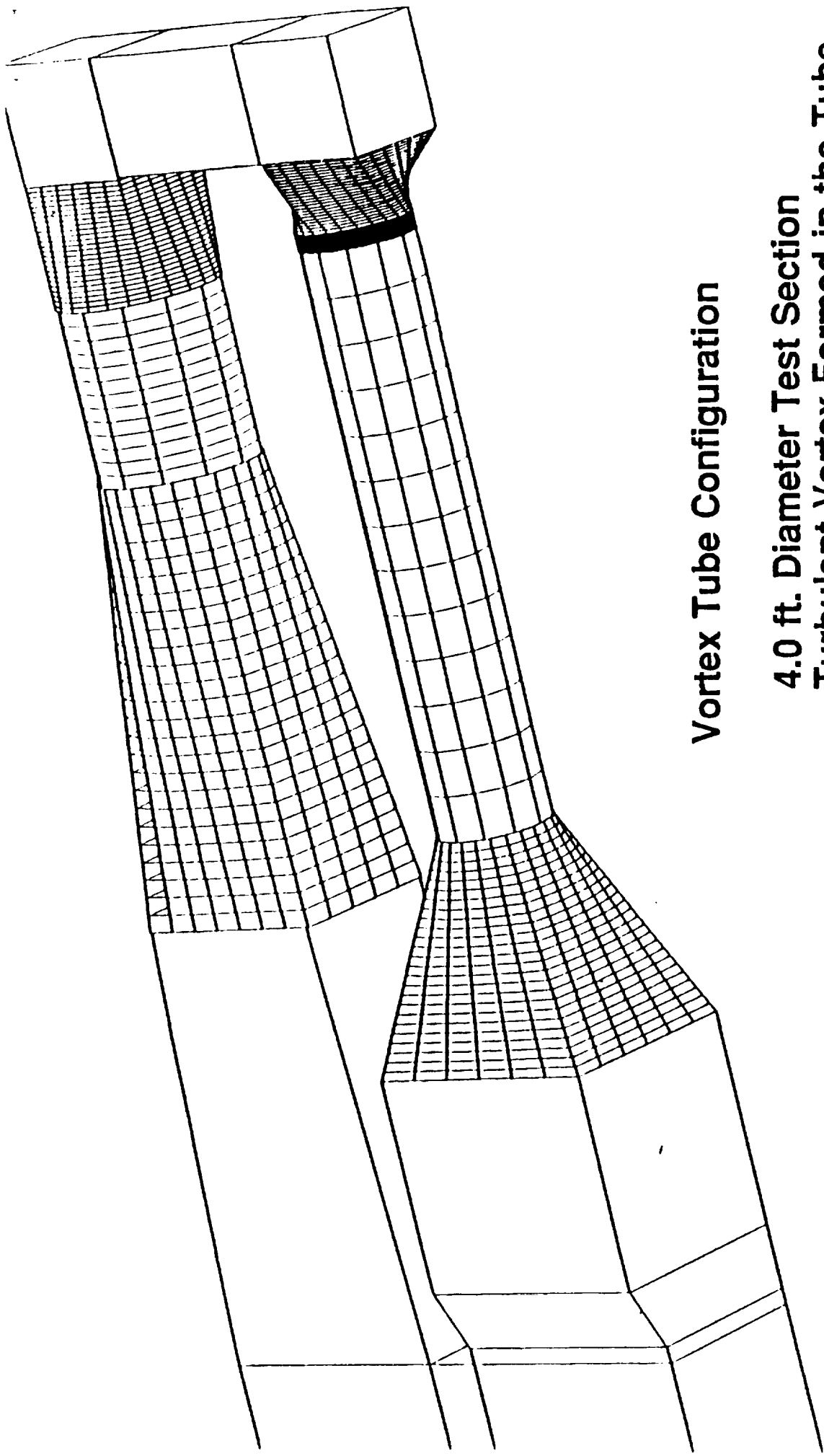
High Reynolds Number Configuration

**4.0 ft. x 6.0 ft. x 35 ft. long Test
Section**

Turbulent Boundary Layer on Walls

Reynolds Number = 40 million

**This is equivalent to the boundary
layer on the wing of a medium size
commercial aircraft (ie. 737)**



Vortex Tube Configuration

**4.0 ft. Diameter Test Section
Turbulent Vortex Formed in the Tube
Vortex Reynolds Number =
1.0 million**

**This is equivalent to the wing tip
vortex of a medium size commercial
aircraft (ie. Boeing 737)**

Instrumentation

- **Pitot Probe, 5 Hole Probe**
- **Hot Wire Anemometry**
 - 1, 2, 3 Component
- **LDV**
 - 1, 2 Component
- **PIV**
- **Flow Visualization**
 - Laser Sheet, Strobe Light

Design of the High Lift Experiment

- **2 - D**
 - X-Foil
 - MCARFA
- **3 - D**
 - PMARC

NACA 4415 Cross Section

(splines)

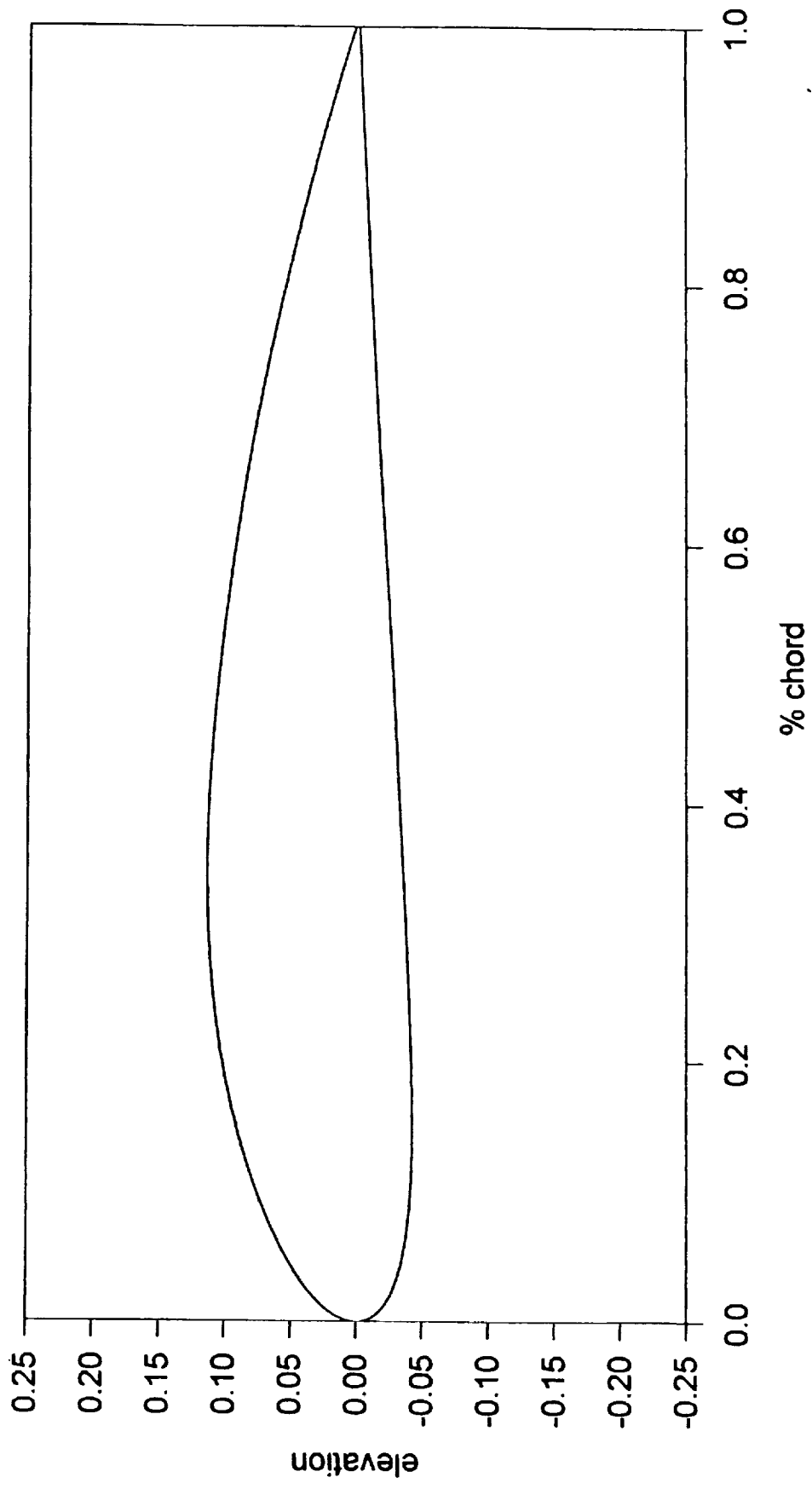
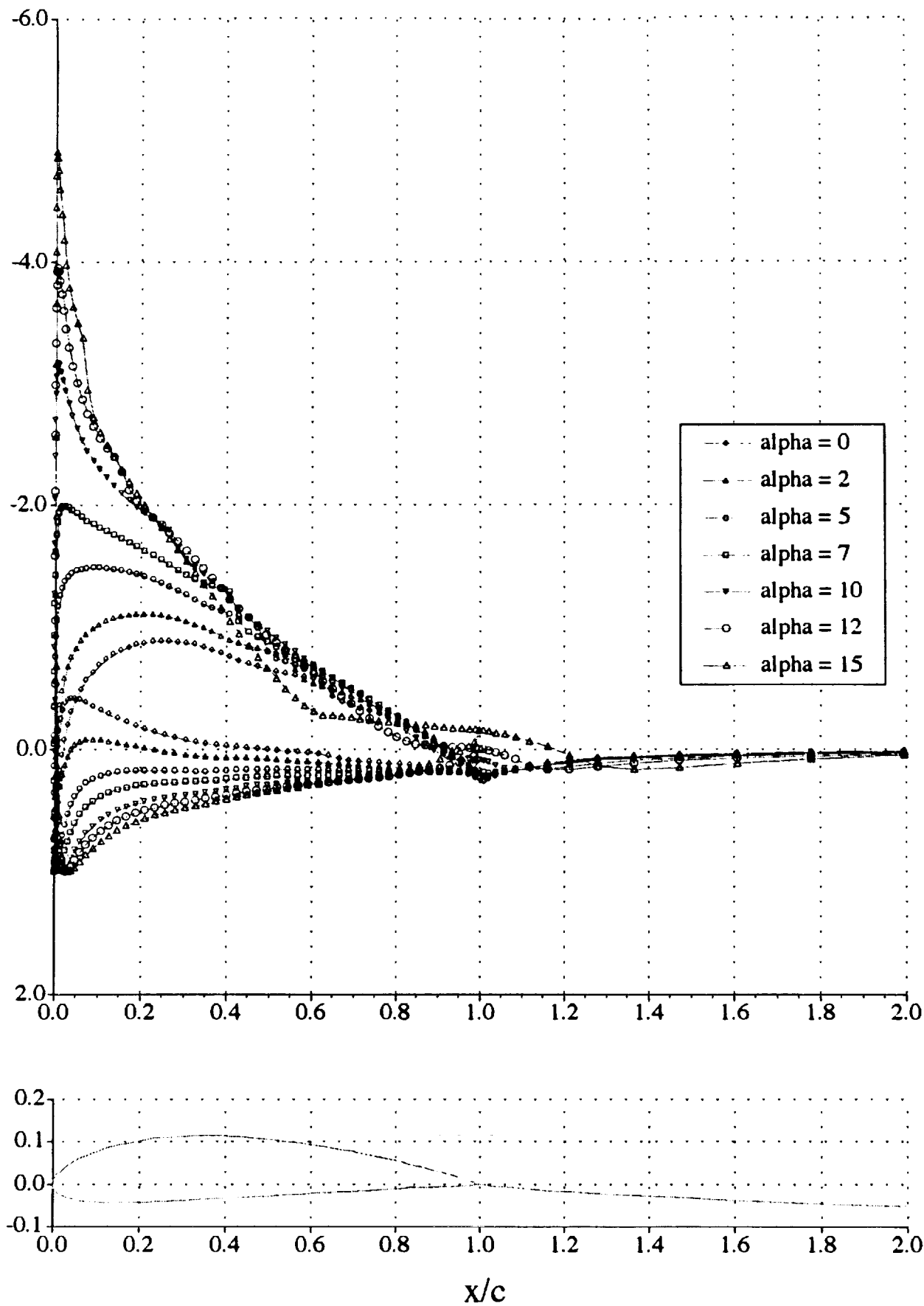


Figure 2(b): NACA 4415 - XFOIL pressure distributions
 $Re = 0.5 \times 10^6$

C_p



McDonnell Douglas Flap Geometry

~~(straight lines)~~ Splines.

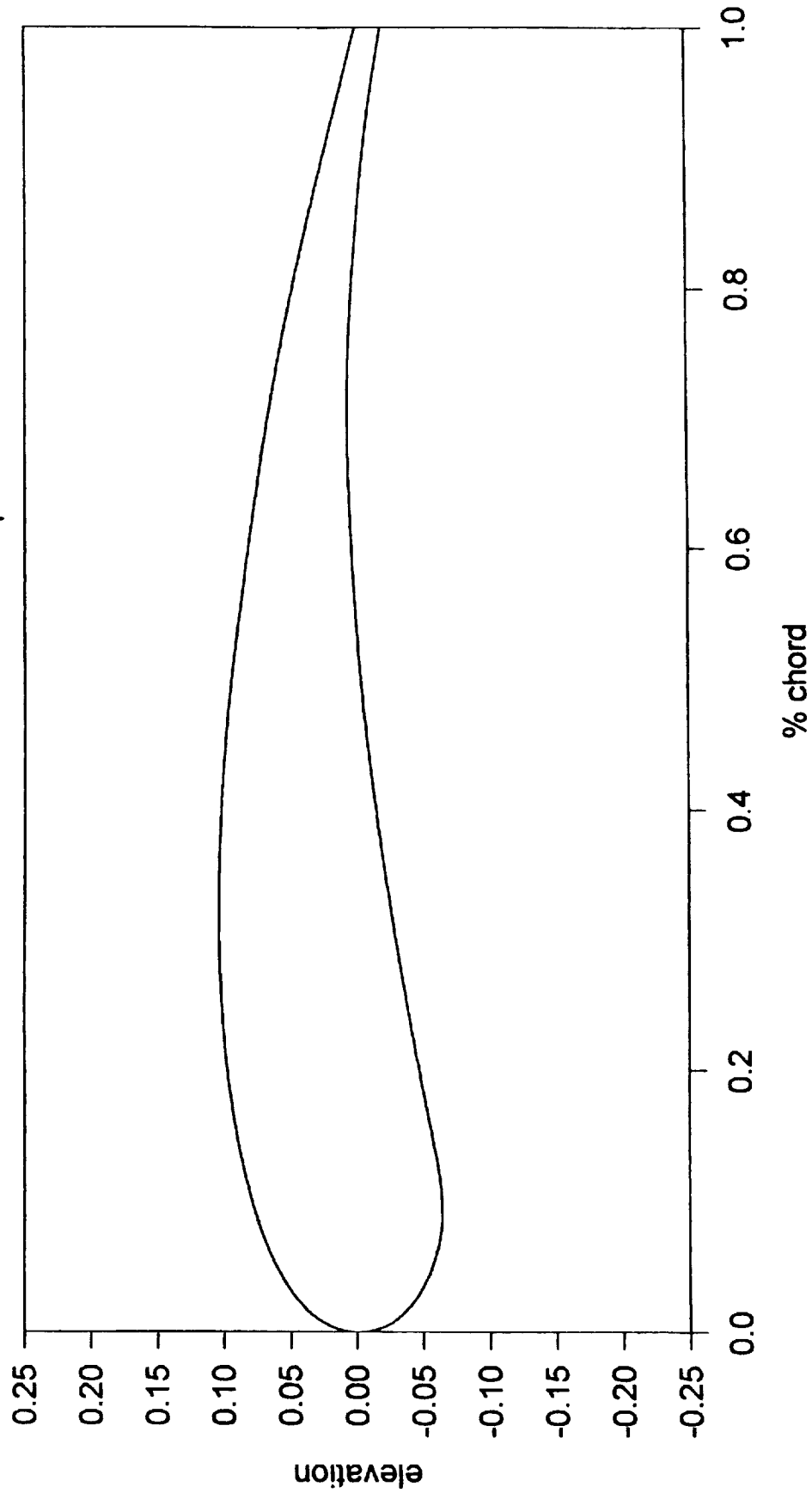
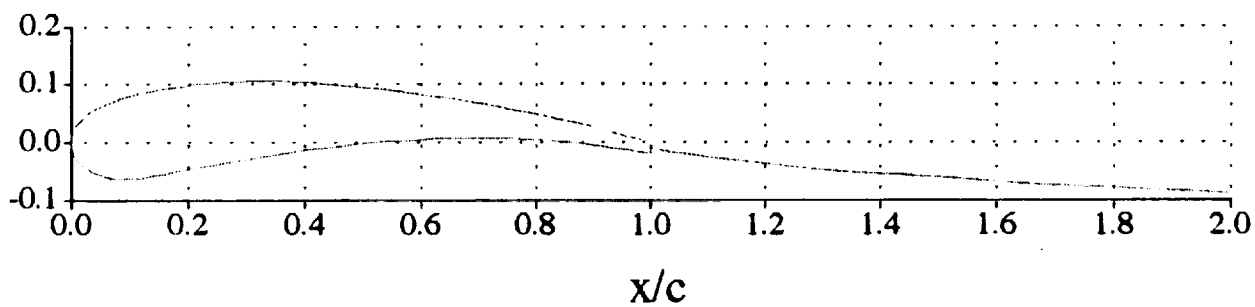
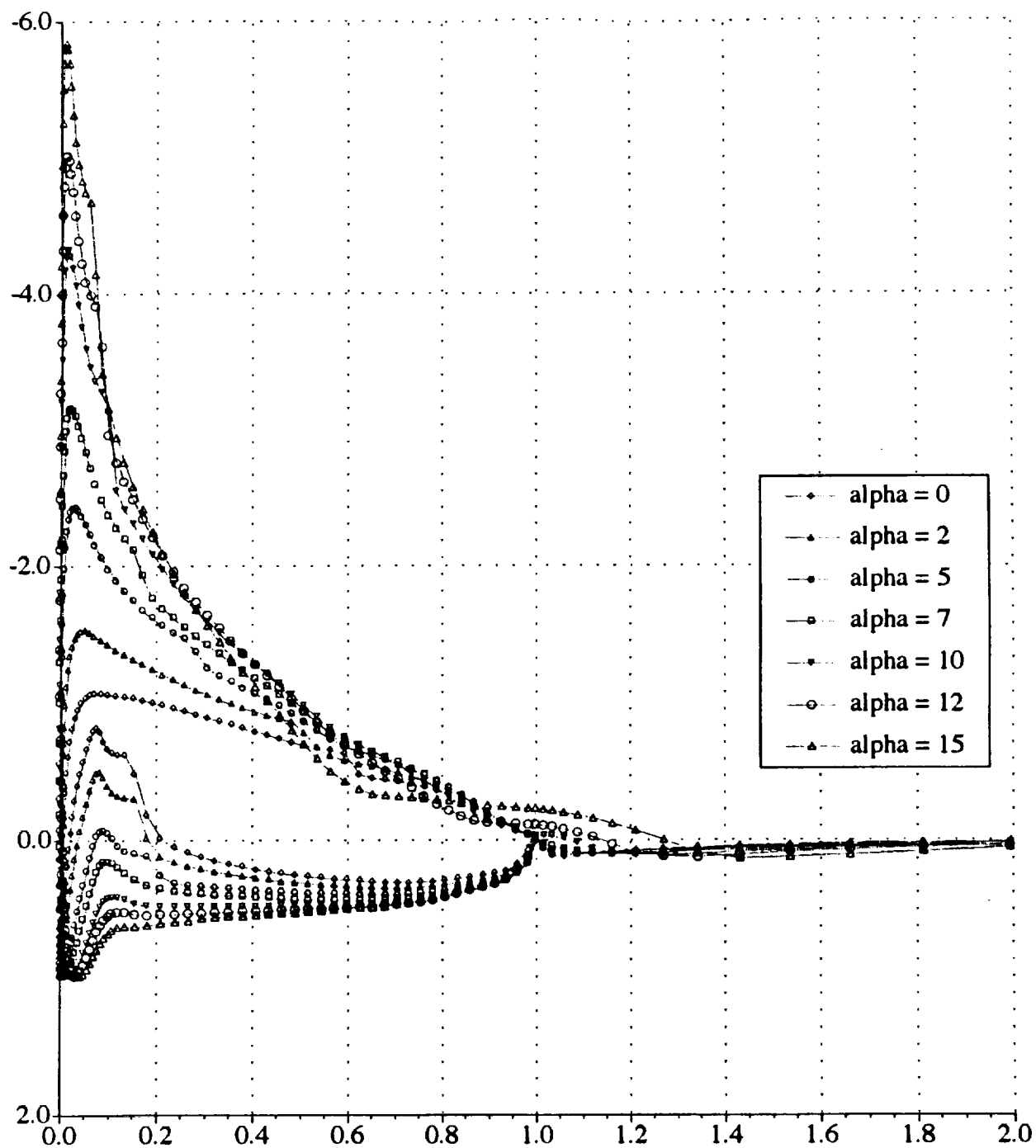


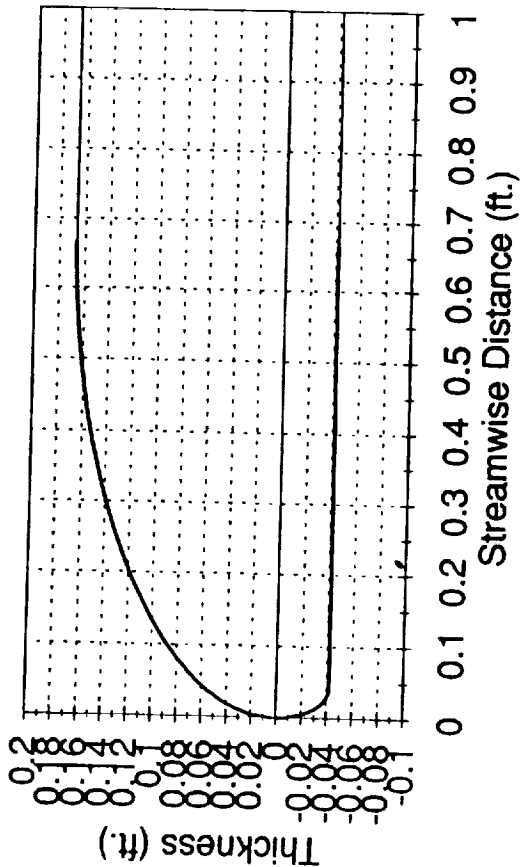
Figure 2(c): MD flap - XFOIL pressure distributions

$Re = 0.5 \times 10^6$

C_p



Nose of Flat Plate



Trailing Edge of Flat Plate

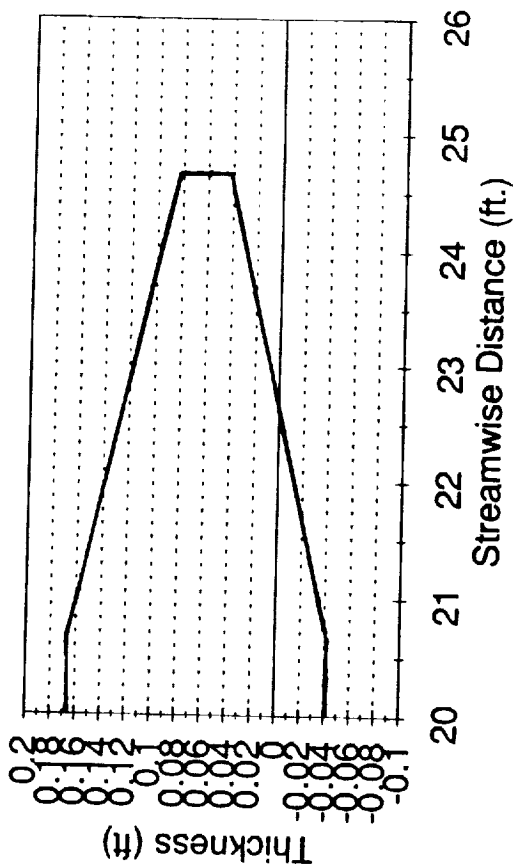


Figure 3(b): MCARFA pressure distributions for flat plate w/ NACA 4415 flap

$U_{\text{inf}} = 80 \text{ ft/s}$
 $x\text{-gap} = 0.0 \text{ ft}$ $y\text{-gap} = -0.46 \text{ ft}$

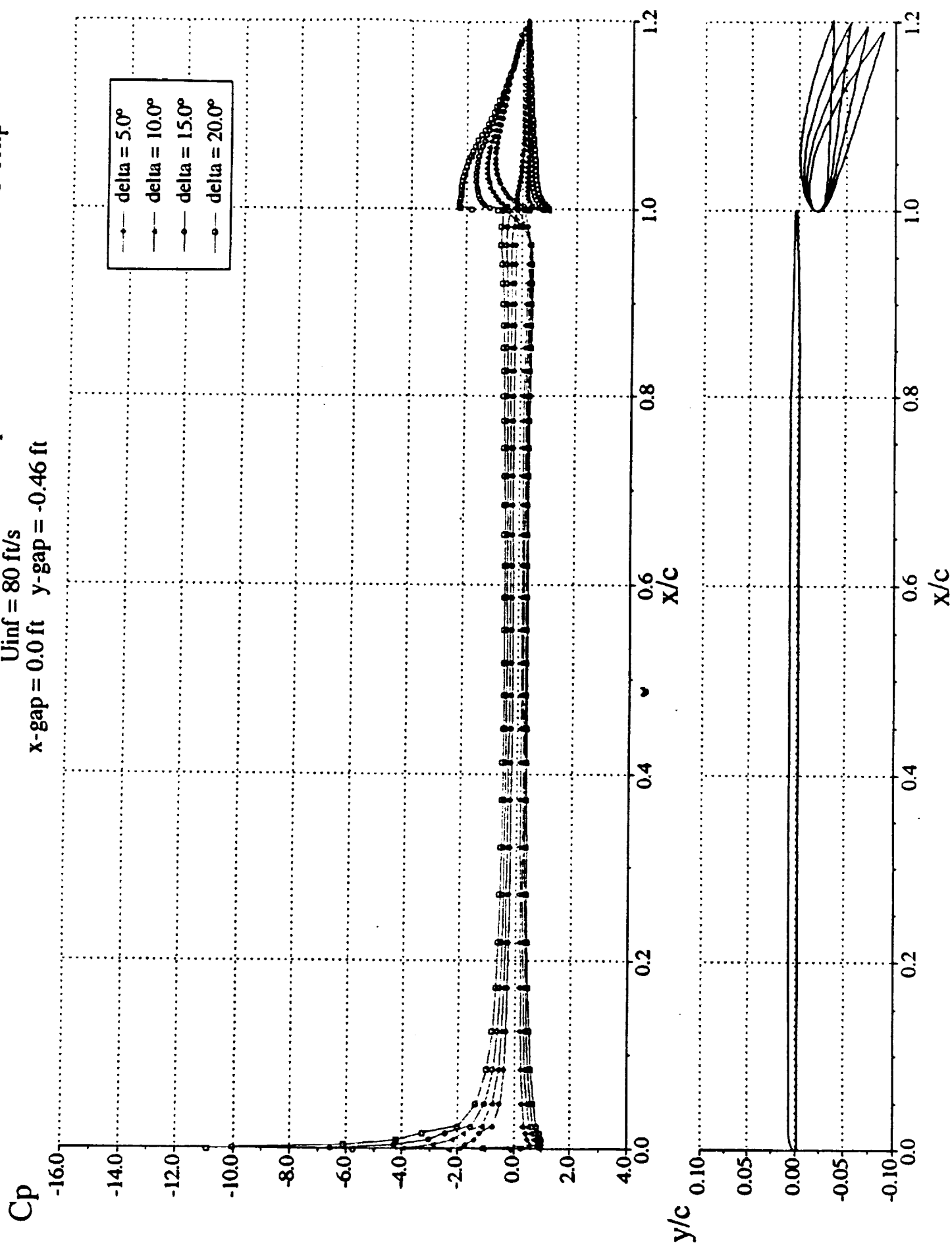


Figure 3(c): MCAKRA pressure distributions for flat plate w/ NACA 4415 flap
 $U_{\infty} = 80 \text{ ft/s}$
 $x\text{-gap} = 0.0 \text{ ft}$ $y\text{-gap} = -0.60 \text{ ft}$

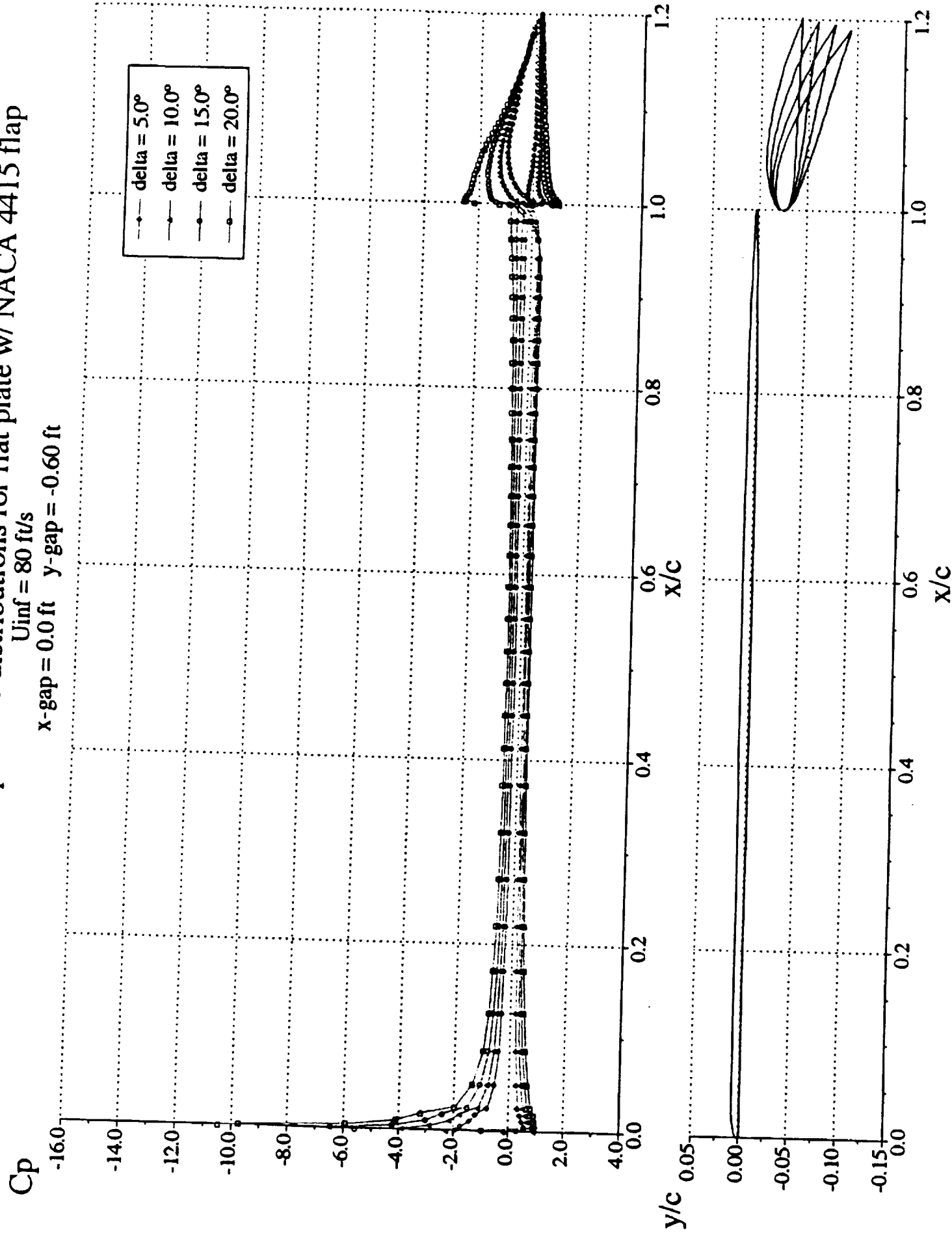


Figure 3(d): MCARFA pressure distributions for flat plate w/ NACA 4415 flap
 $U_{\text{inf}} = 80 \text{ ft/s}$
 $x\text{-gap} = 0.0 \text{ ft}$ $y\text{-gap} = -0.85 \text{ ft}$

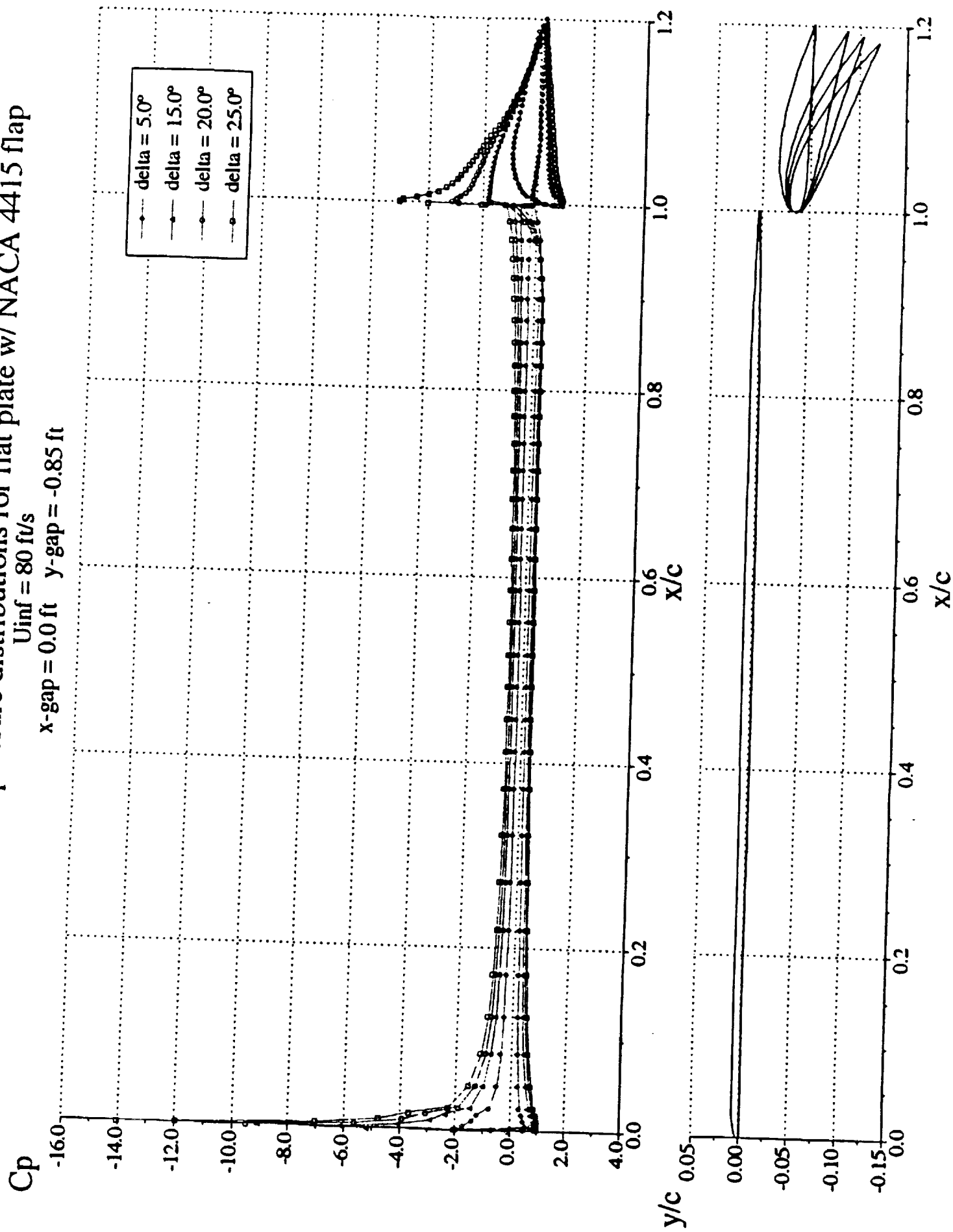


Figure 3(e): MCARFA pressure distributions for flat plate w/ M-D flap

$U_{\text{inf}} = 80 \text{ ft/s}$

$x\text{-gap} = 0.0 \text{ ft}$ $y\text{-gap} = -0.46 \text{ ft}$

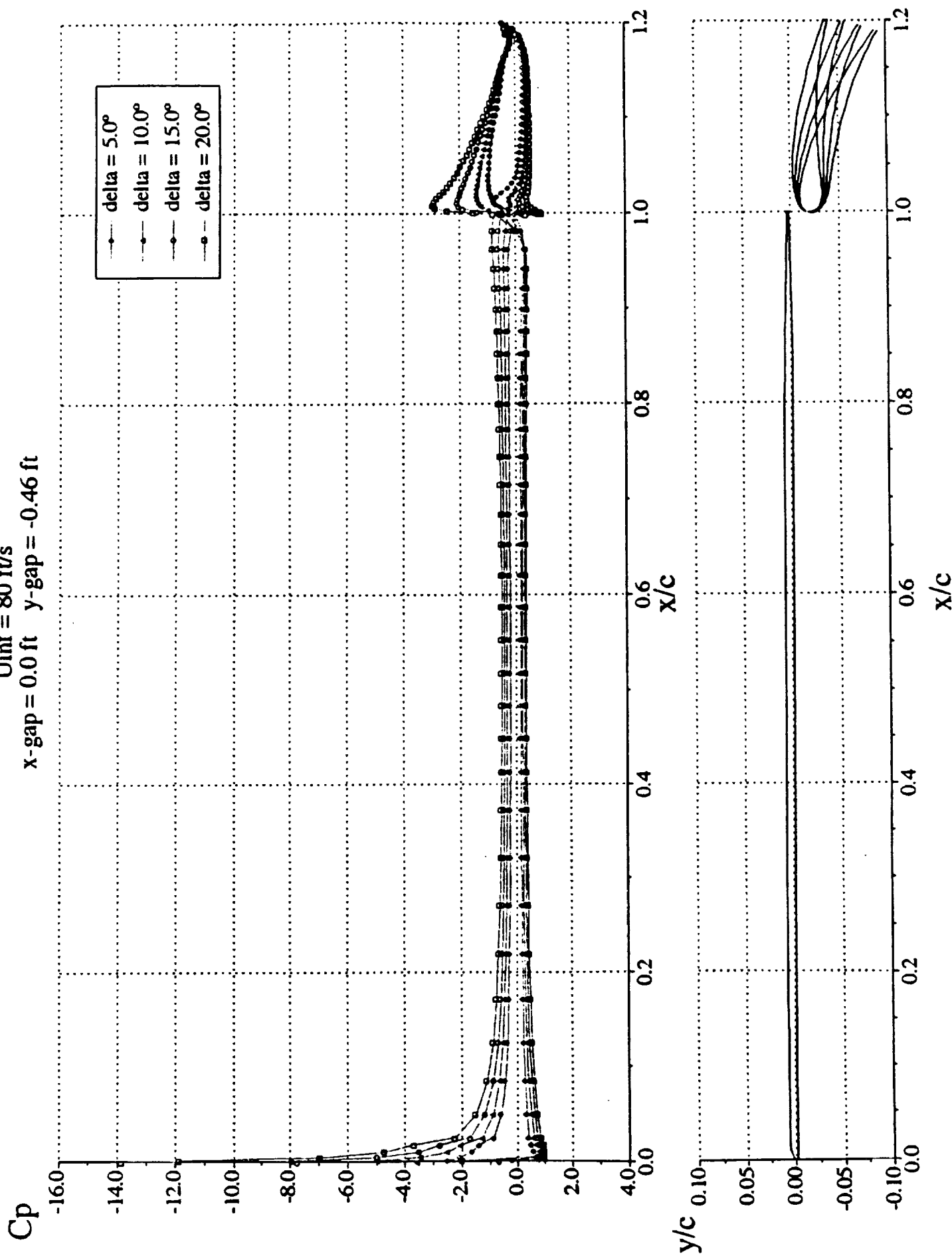


Figure 3(t): MCARFA pressure distributions for flat plate w/ M-D flap

$U_{inf} = 80 \text{ ft/s}$
 $x\text{-gap} = 0.0 \text{ ft}$ $y\text{-gap} = -0.60 \text{ ft}$

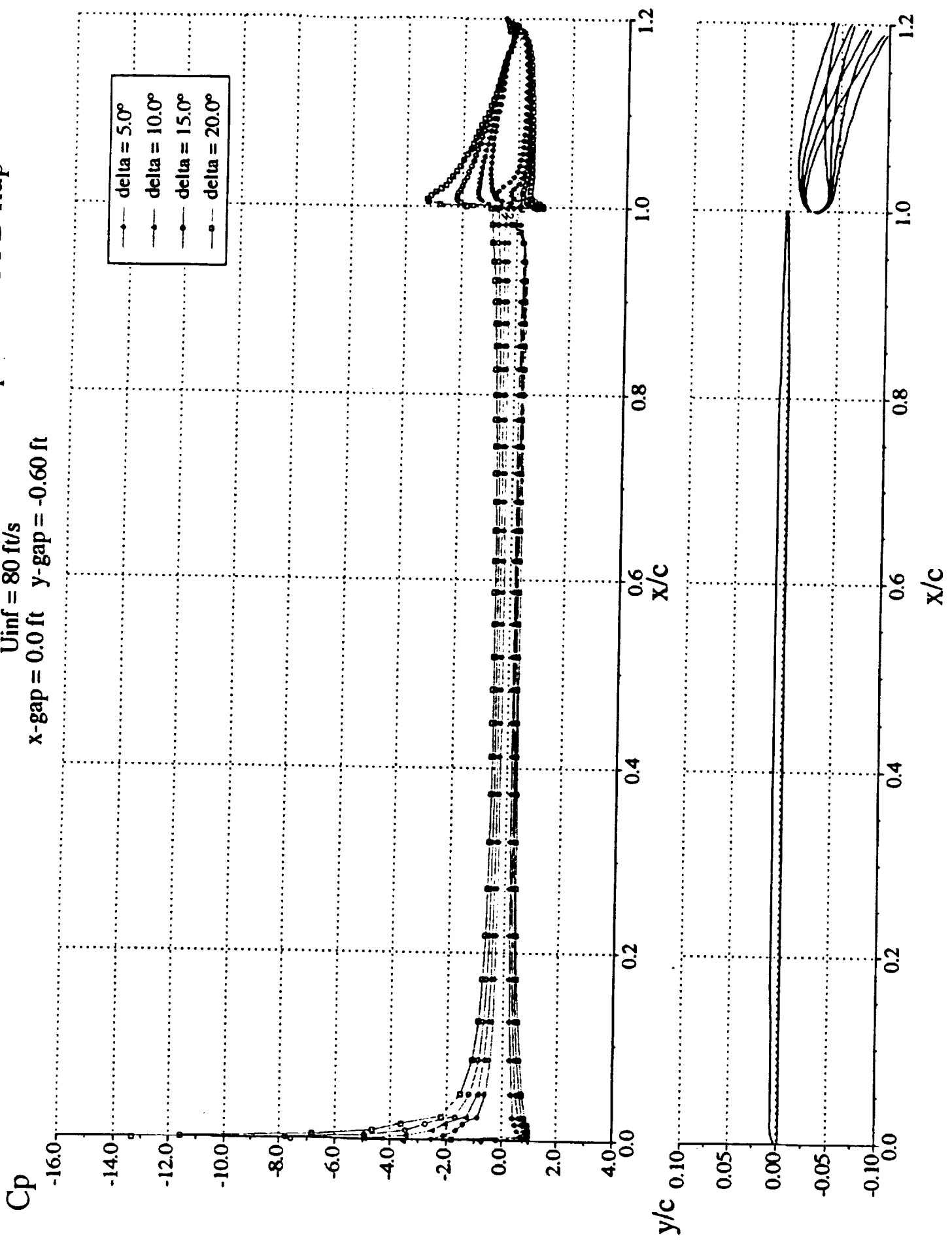
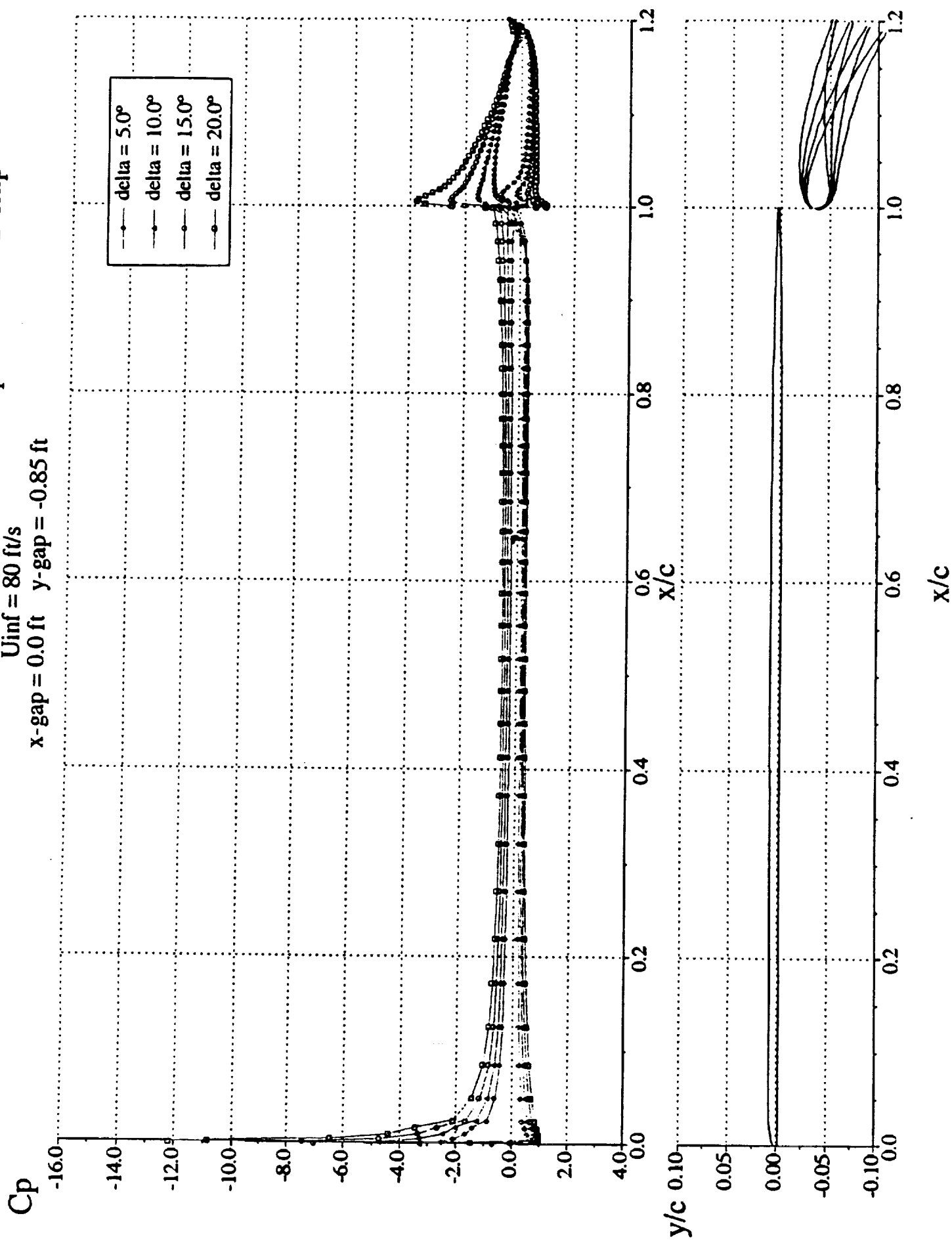


Figure 3(g): MCARFA pressure distributions for flat plate w/ M-D flap

$U_{\infty} = 80 \text{ ft/s}$
 $x\text{-gap} = 0.0 \text{ ft}$ $y\text{-gap} = -0.85 \text{ ft}$



Facilities

- **1/4 Scale (To Investigate 3-D effects)**
 - Tunnel Cross-Section (1 ft. x 1.5 ft.)
 - Flat Plate - $L = 8$ ft.
 - Flap Chord - $c = 1.2$ ft.
 - Reynolds Number Range (based on L)
 - » $Re = .5$ to 6.0 Million
- **Full Scale**
 - Tunnel Cross-Section (4 ft. x 6 ft.)
 - Flat Plate - $L = 24$ ft.
 - Flap Chord - $c = 5$ ft.
 - Reynolds Number Range(based on L)
 - » $Re = 2.0$ to 45.0 Million

1/4 Scale Facility Results

- **Pitot Probe Surveys**
- **PIV**

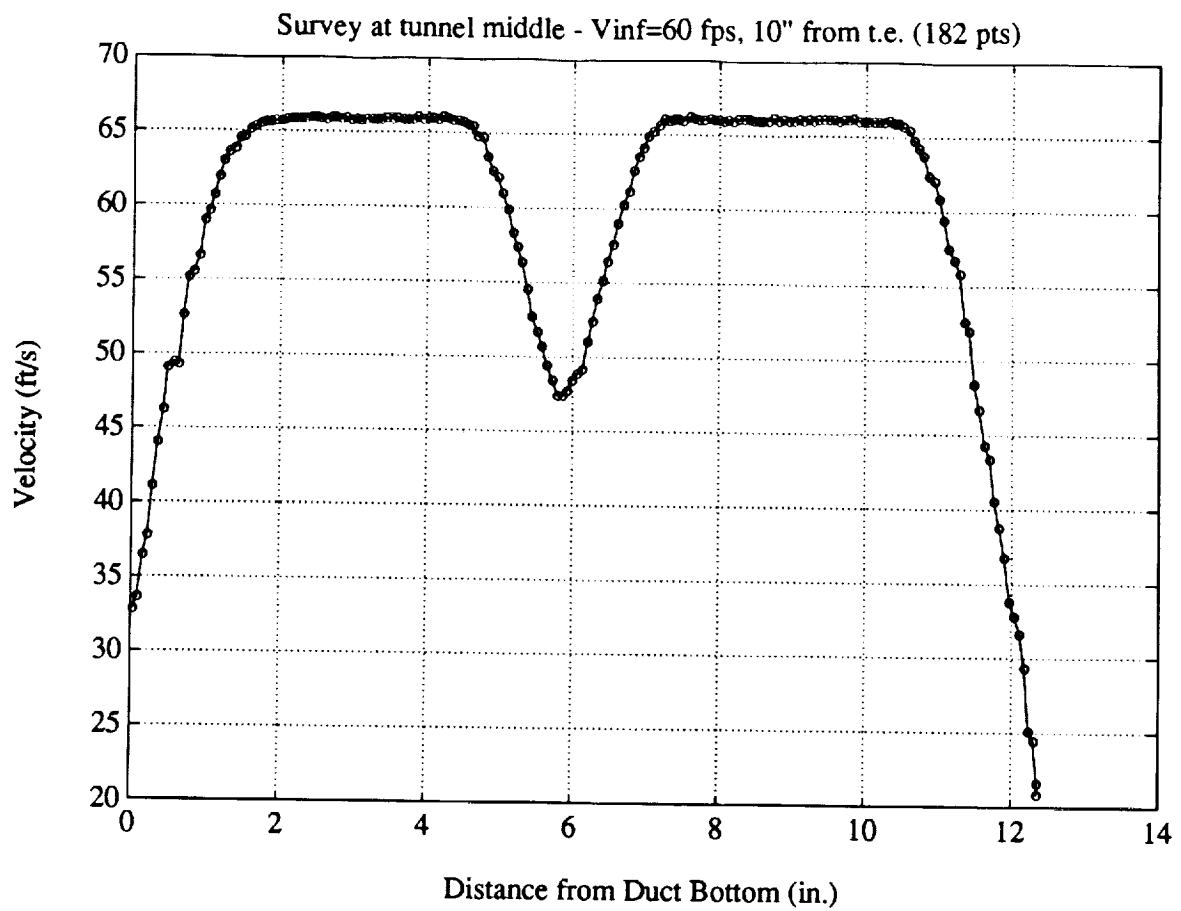


Fig. 4: Wake Survey (No Flap)

3D Wake Survey - 1/4 scale, $V_{\infty}=60$ fps, 10" from t.e.

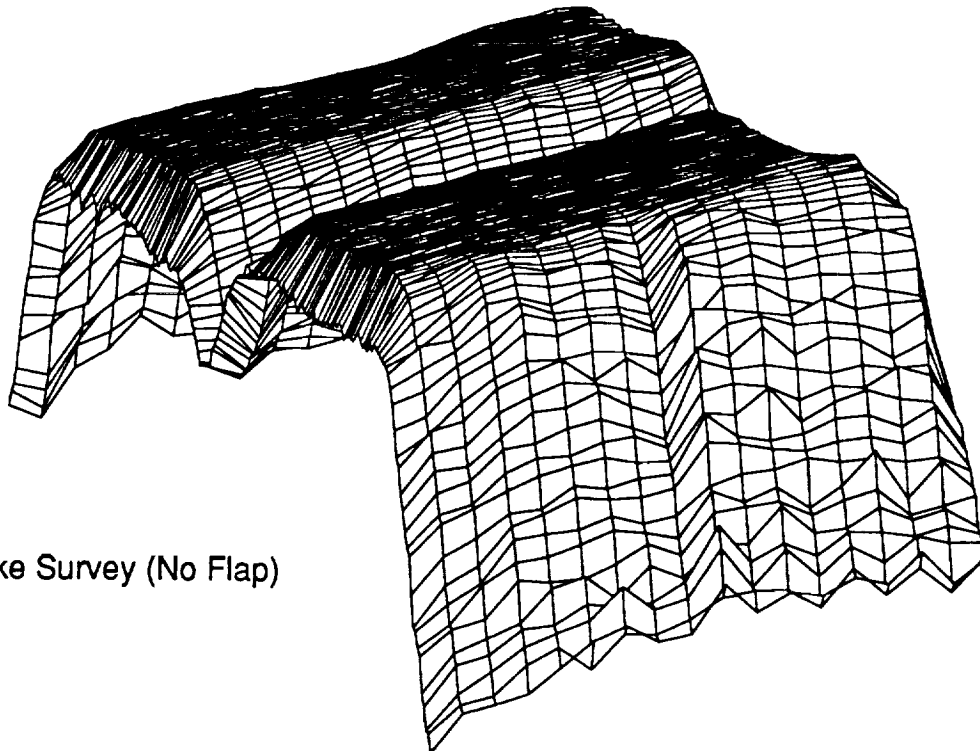
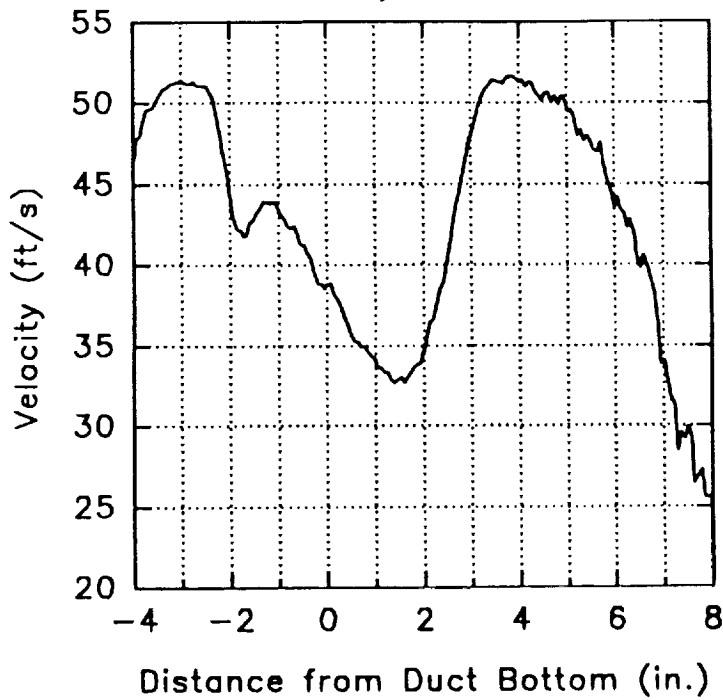


Fig. 5: Wake Survey (No Flap)

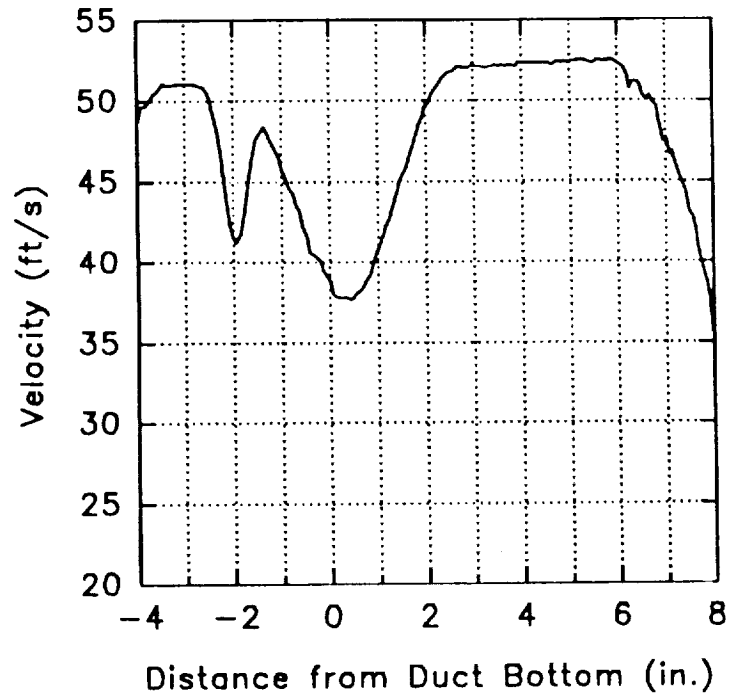
Wake Survey with Flap Deflected 25 deg
(probe aligned with freestream direction)

(10/26/93)

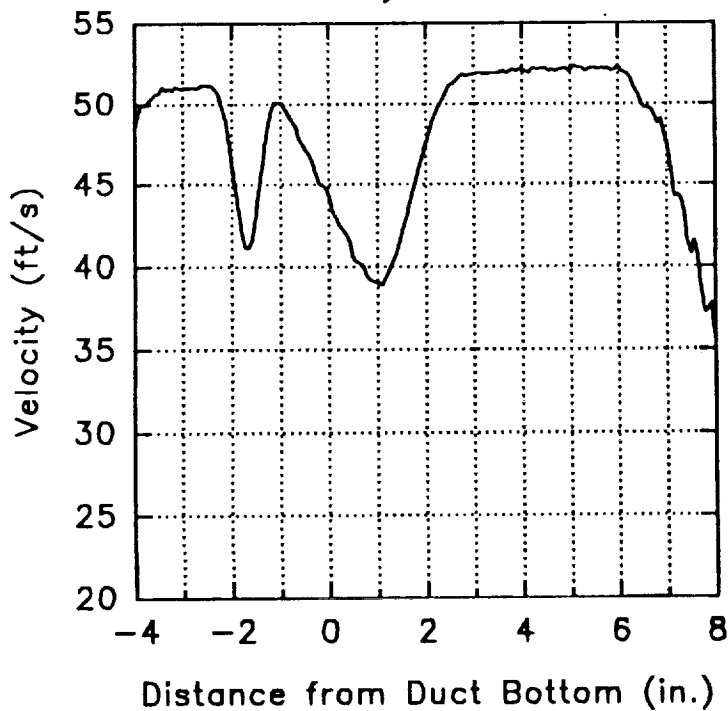
Survey at $x=2''$



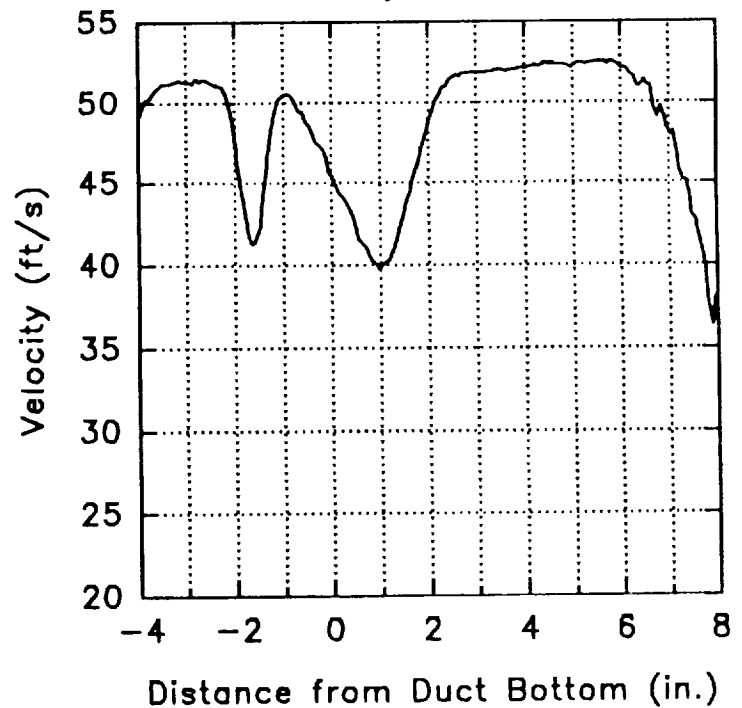
Survey at $x=4''$



Survey at $x=6''$



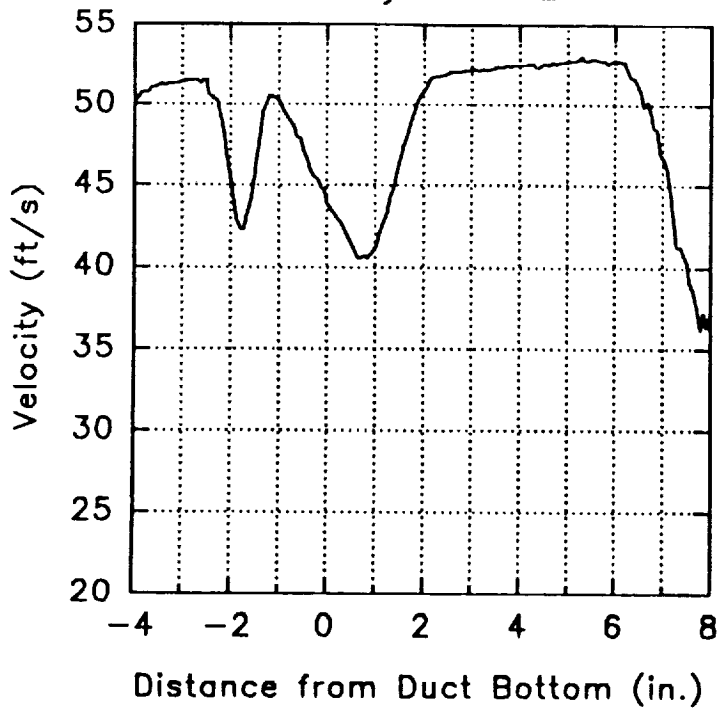
Survey at $x=9''$



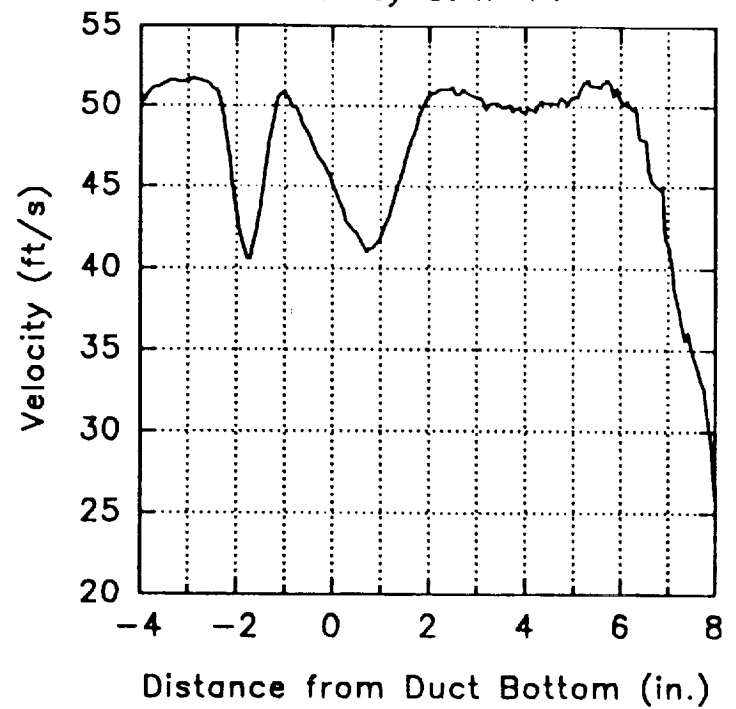
Wake Survey with Flap Deflected 25 deg
(probe aligned with freestream direction)

(10/26/93)

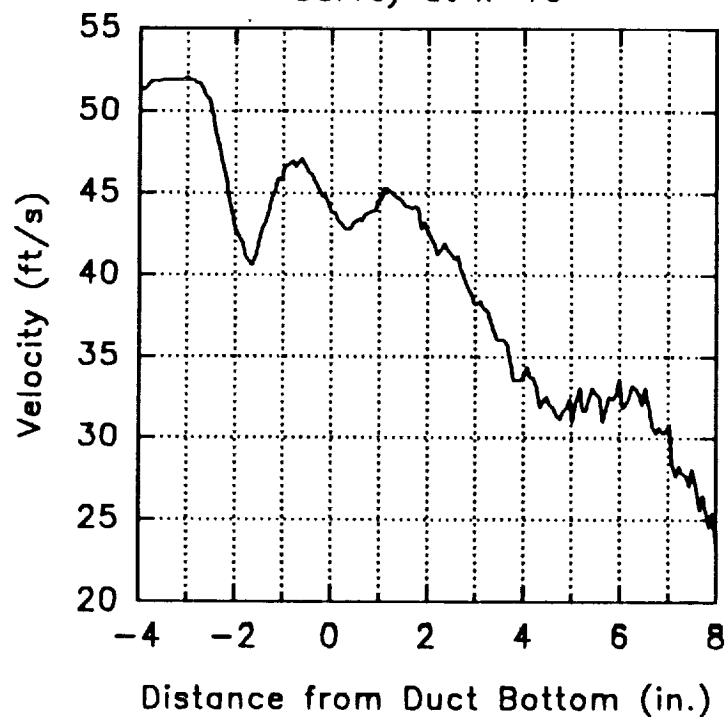
Survey at x=12"



Survey at x=14"



Survey at x=16"



Wake Survey with Flap Deflected 25 deg

(10/26/93)

(probe aligned with freestream direction)

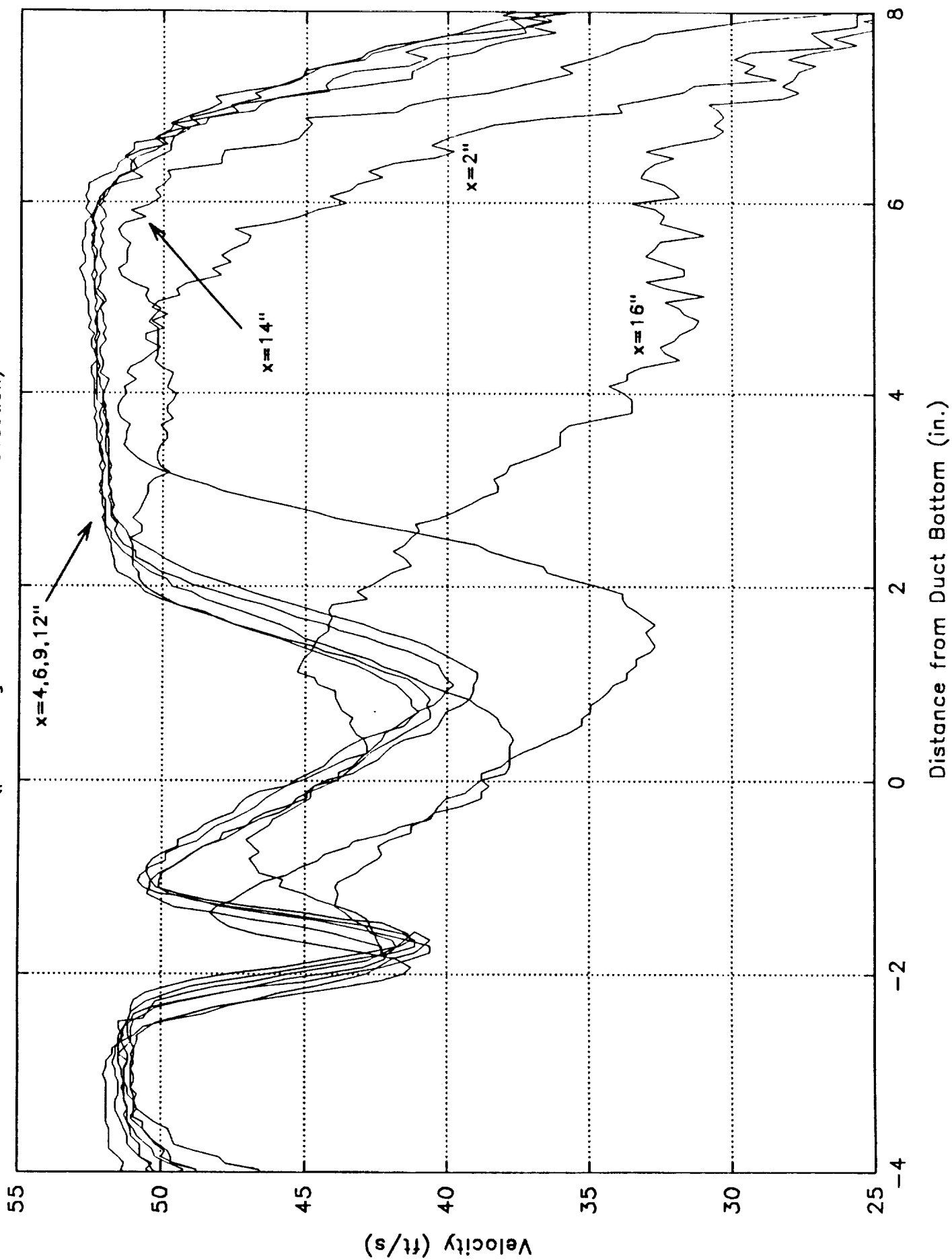


Figure 4(a)

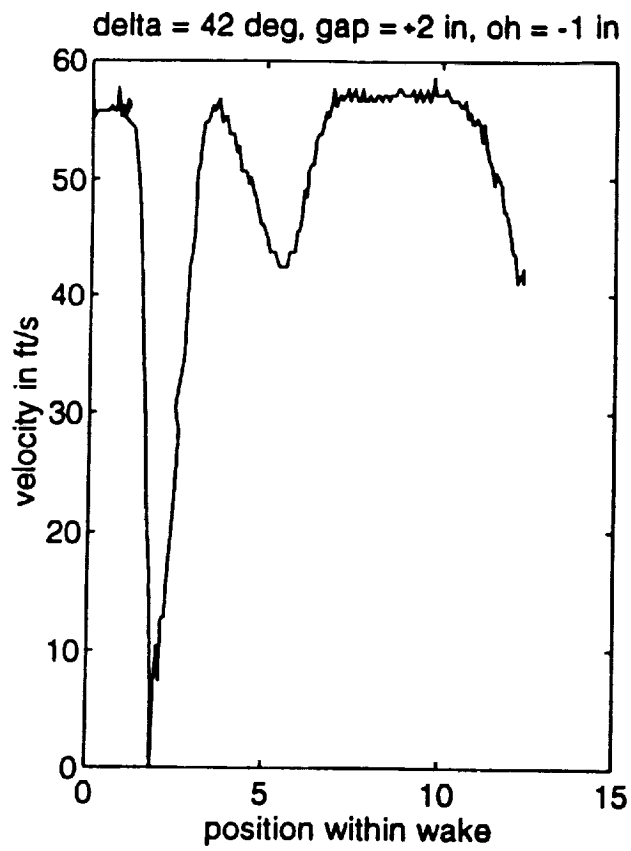


Figure 4(b)

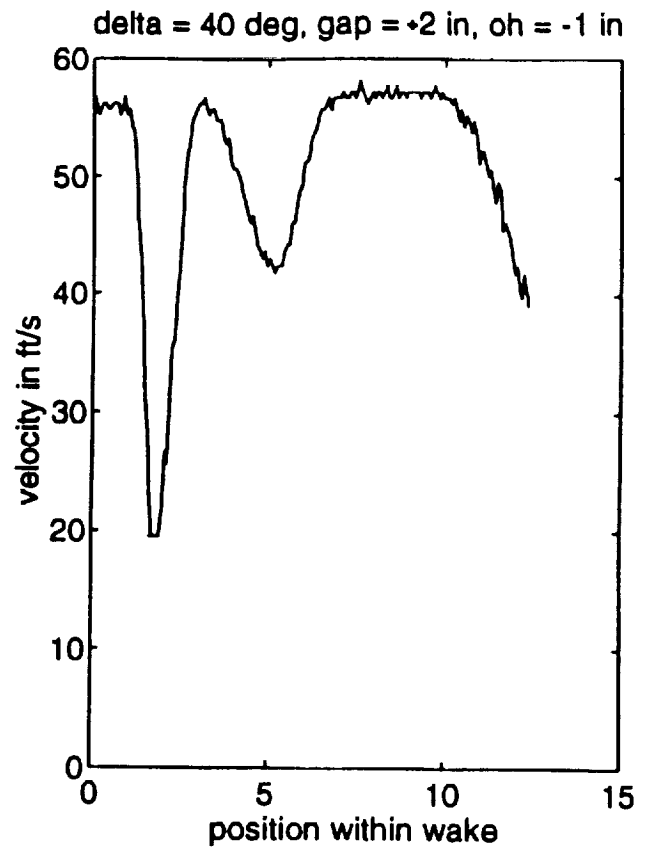


Figure 4(c)

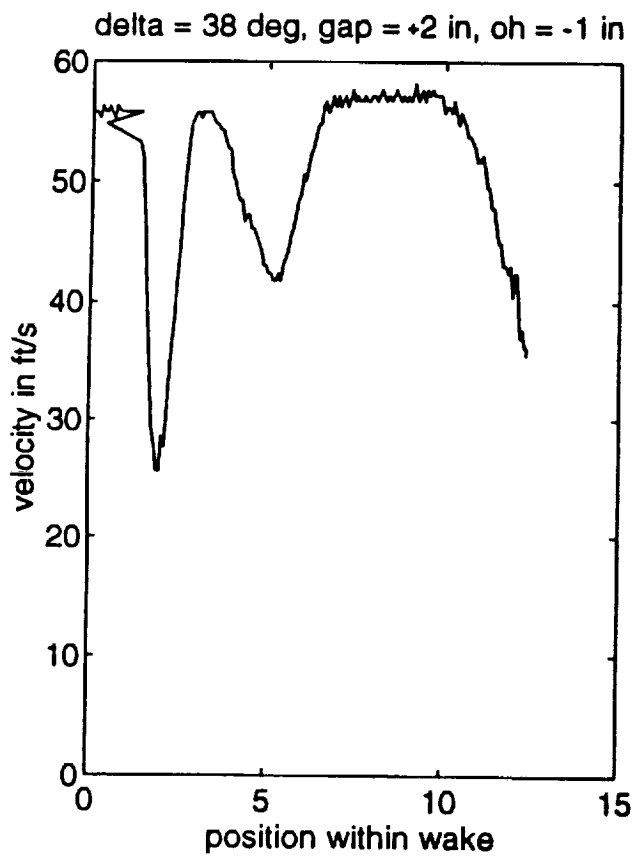


Figure 4(d)

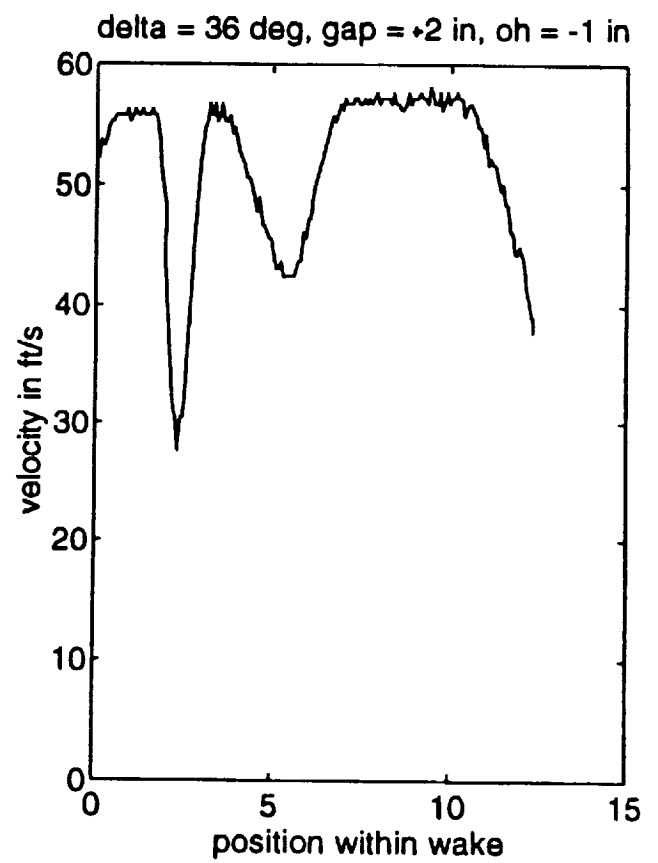


Figure 4(e)

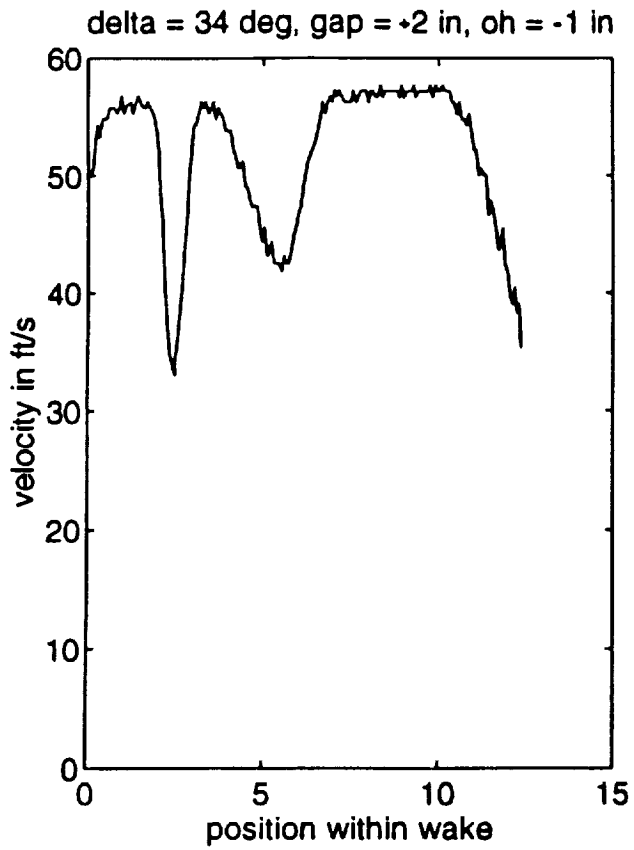


Figure 4(f)

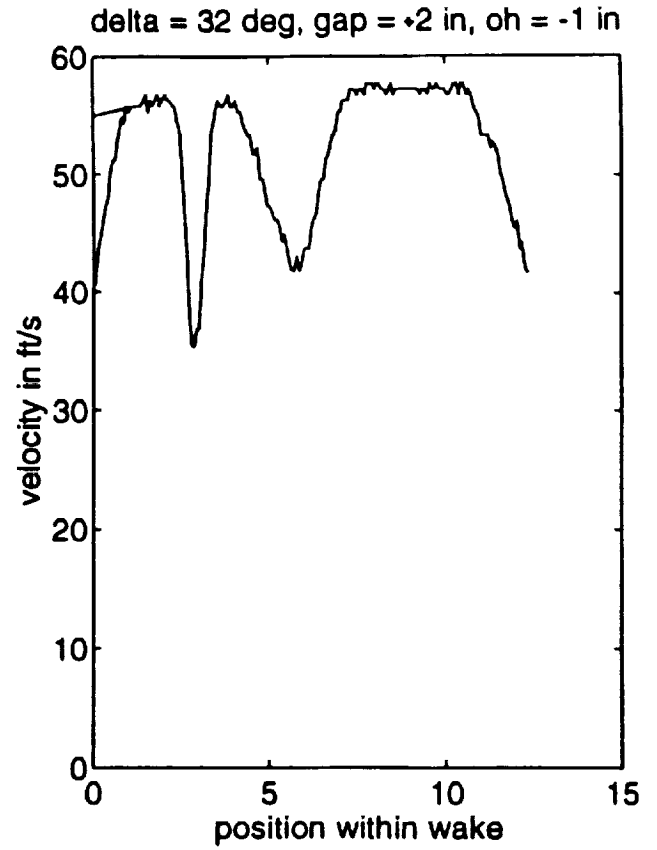


Figure 4(g)

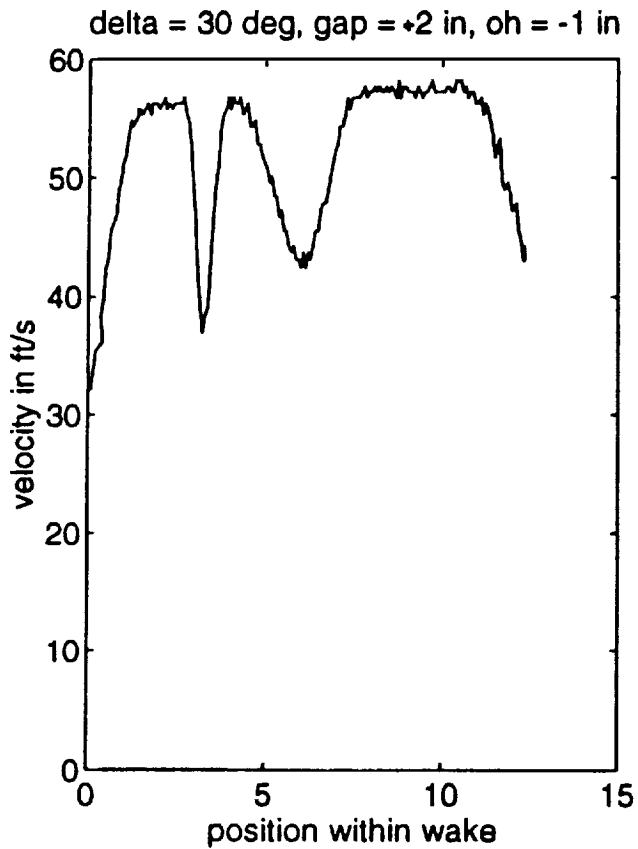
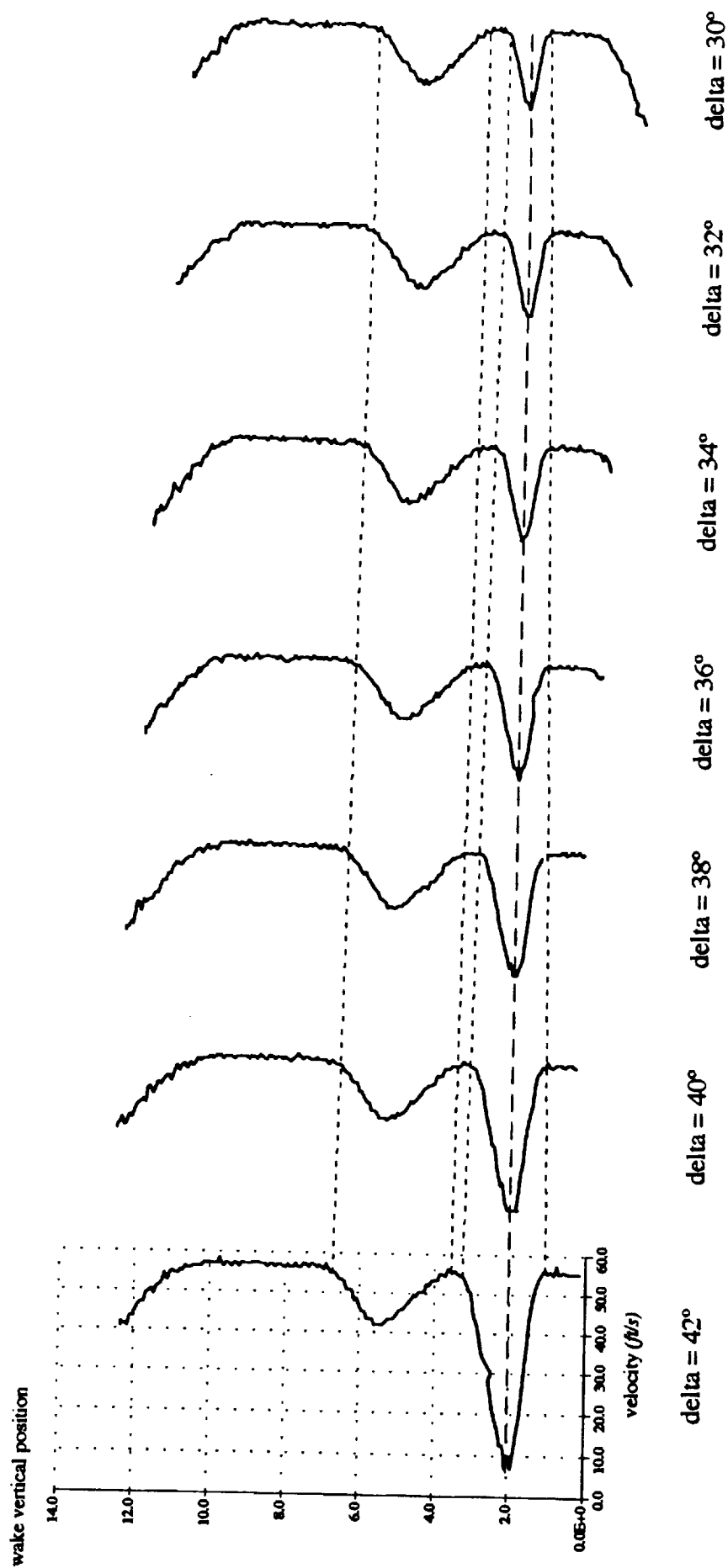
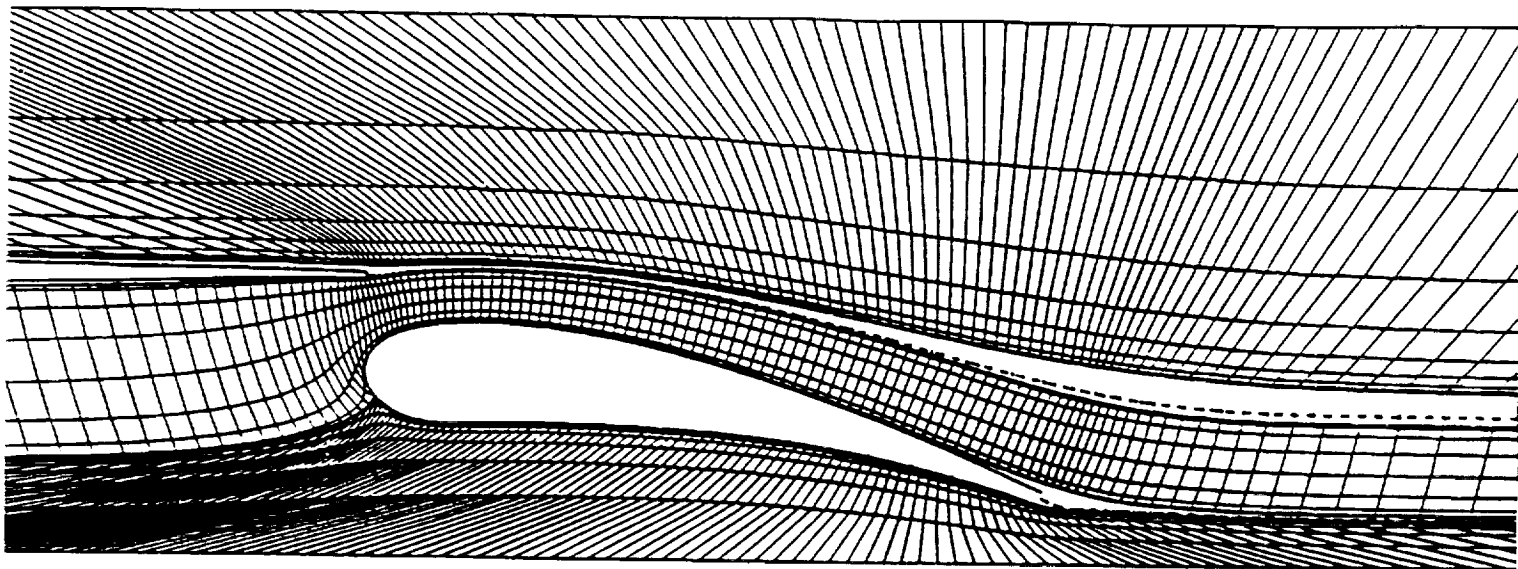


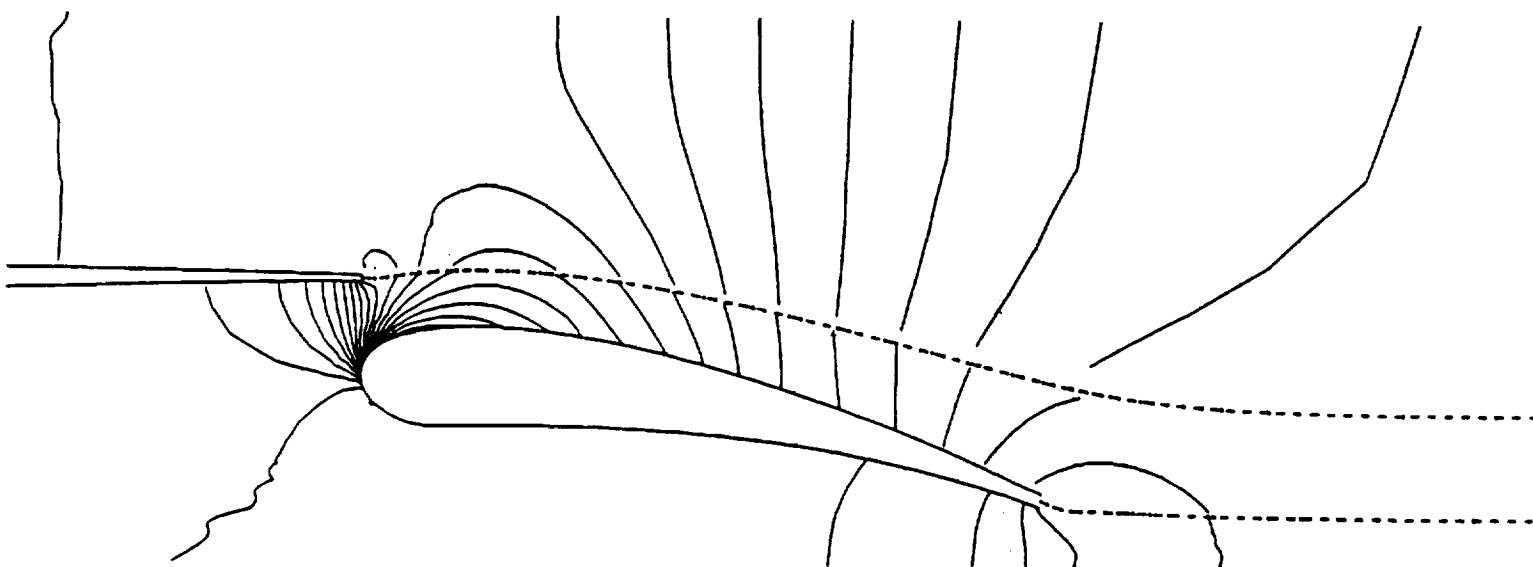
Figure 4(h): Comparison of wake profiles

$V = 50$ ft/s, gap = 2.0 inches, overhang = -1.0 inches, wake station = +3.0 inches aft of flap trailing edge

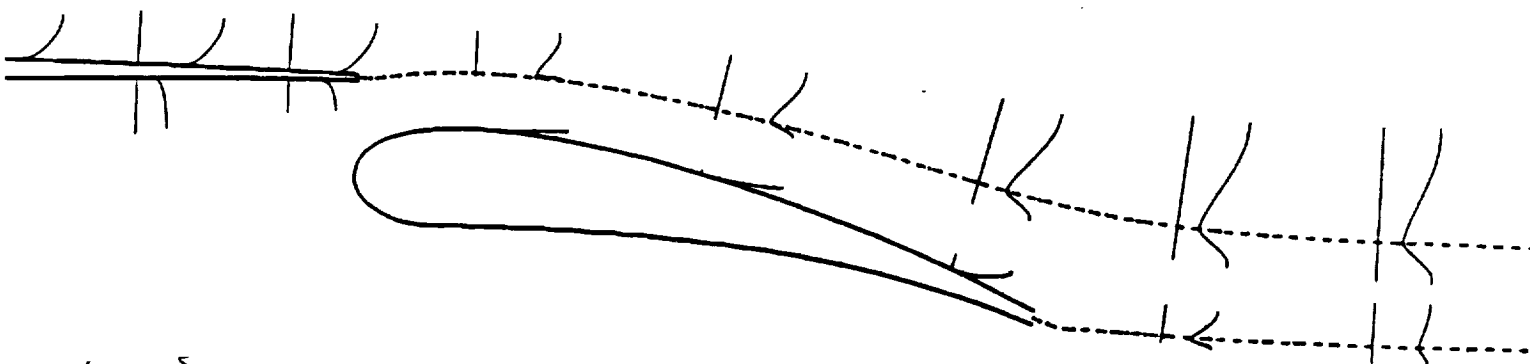




STREAMLINE GRID

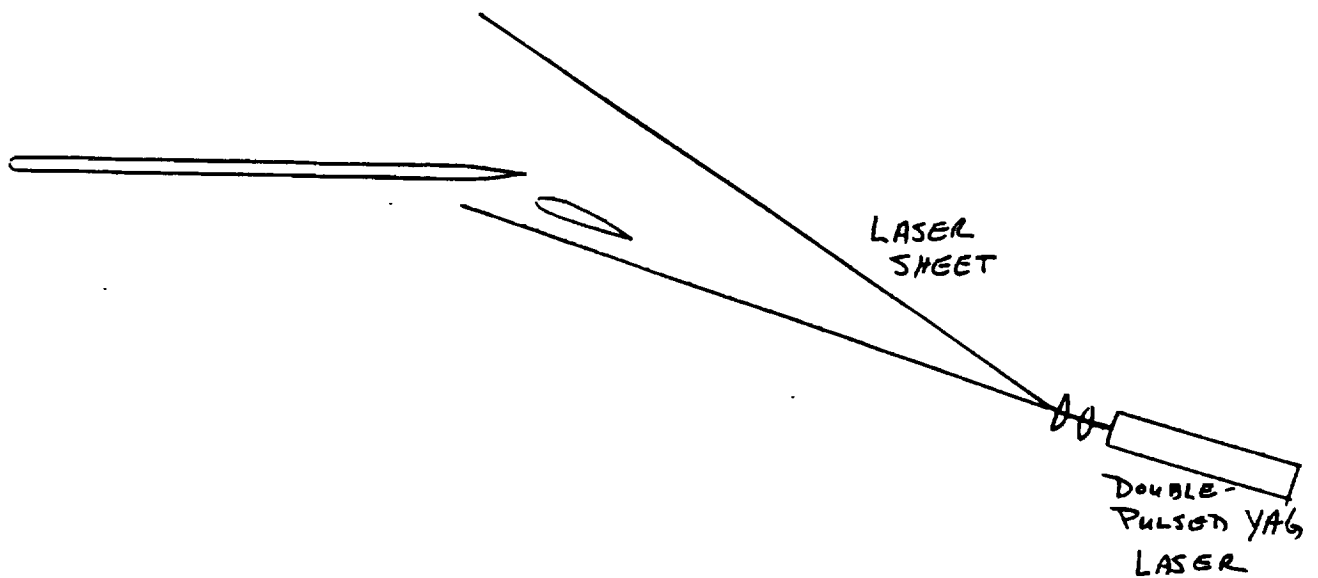


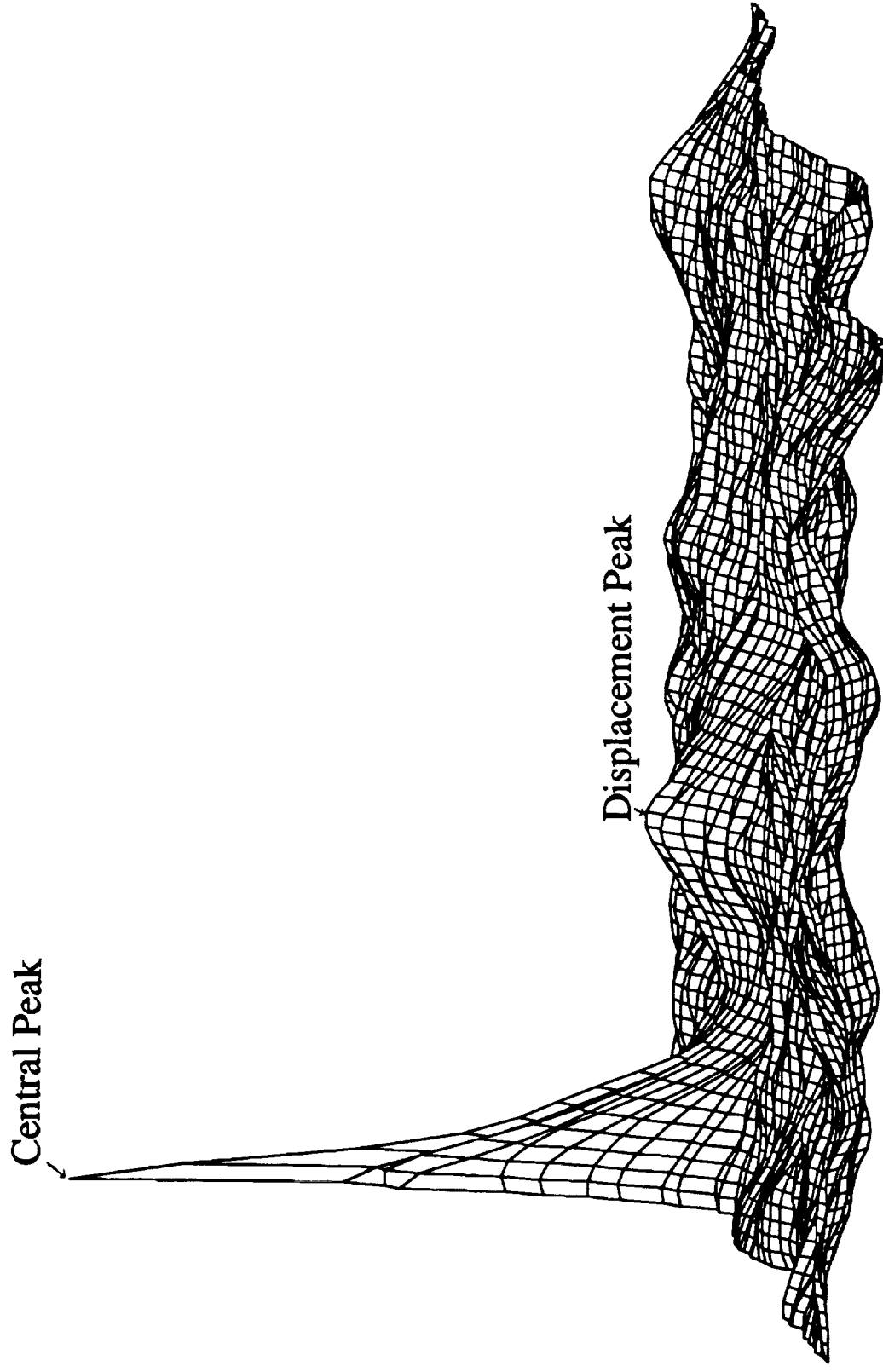
CONTOURS OF CP



MARK DRELA - MIT
MSES

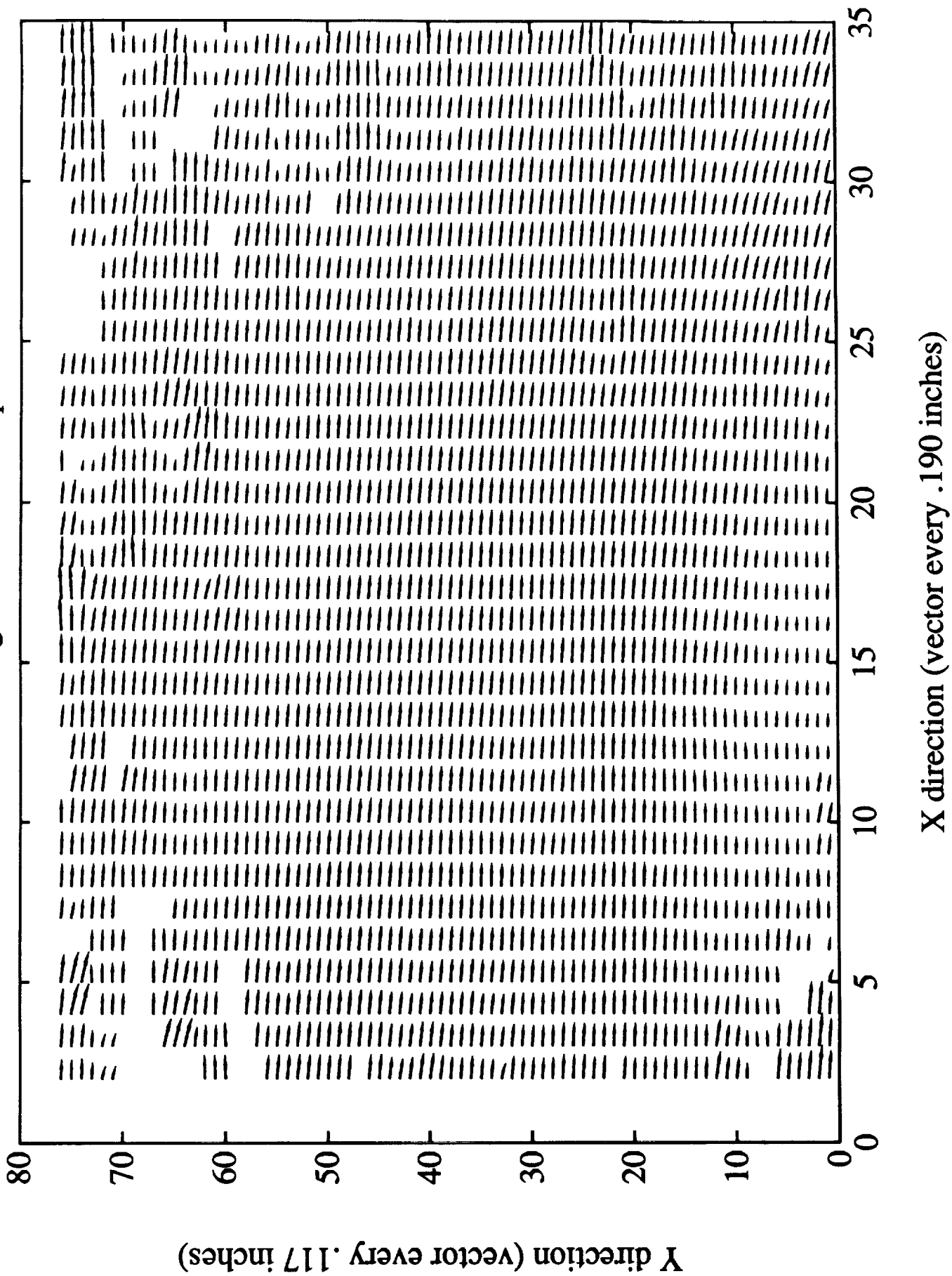
PIV 1/4 Scale Facility





Sample Autocorrelation Output

Vectors from image4.5.2 with low-pass filter



Velocity Profiles (128x128 regions)

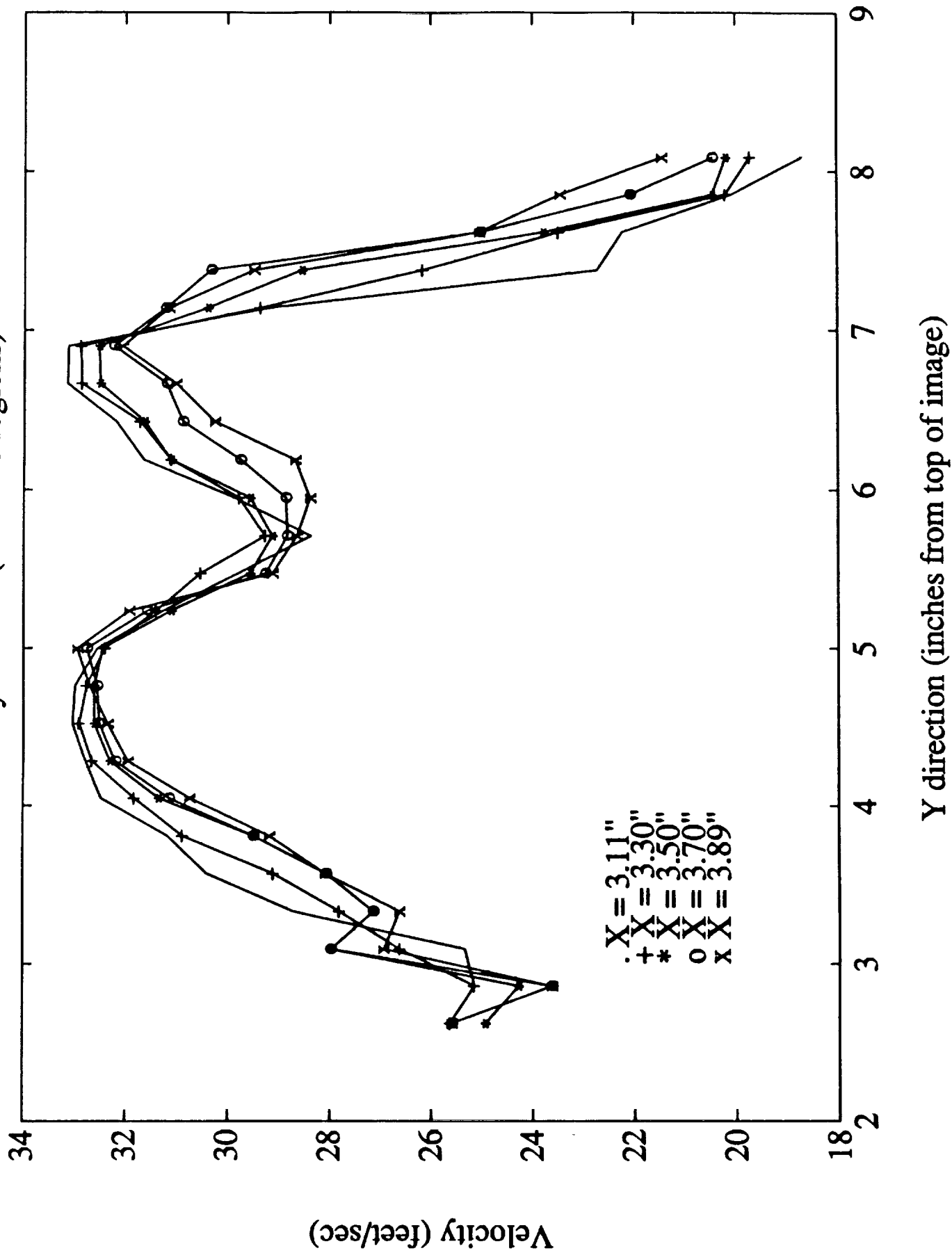
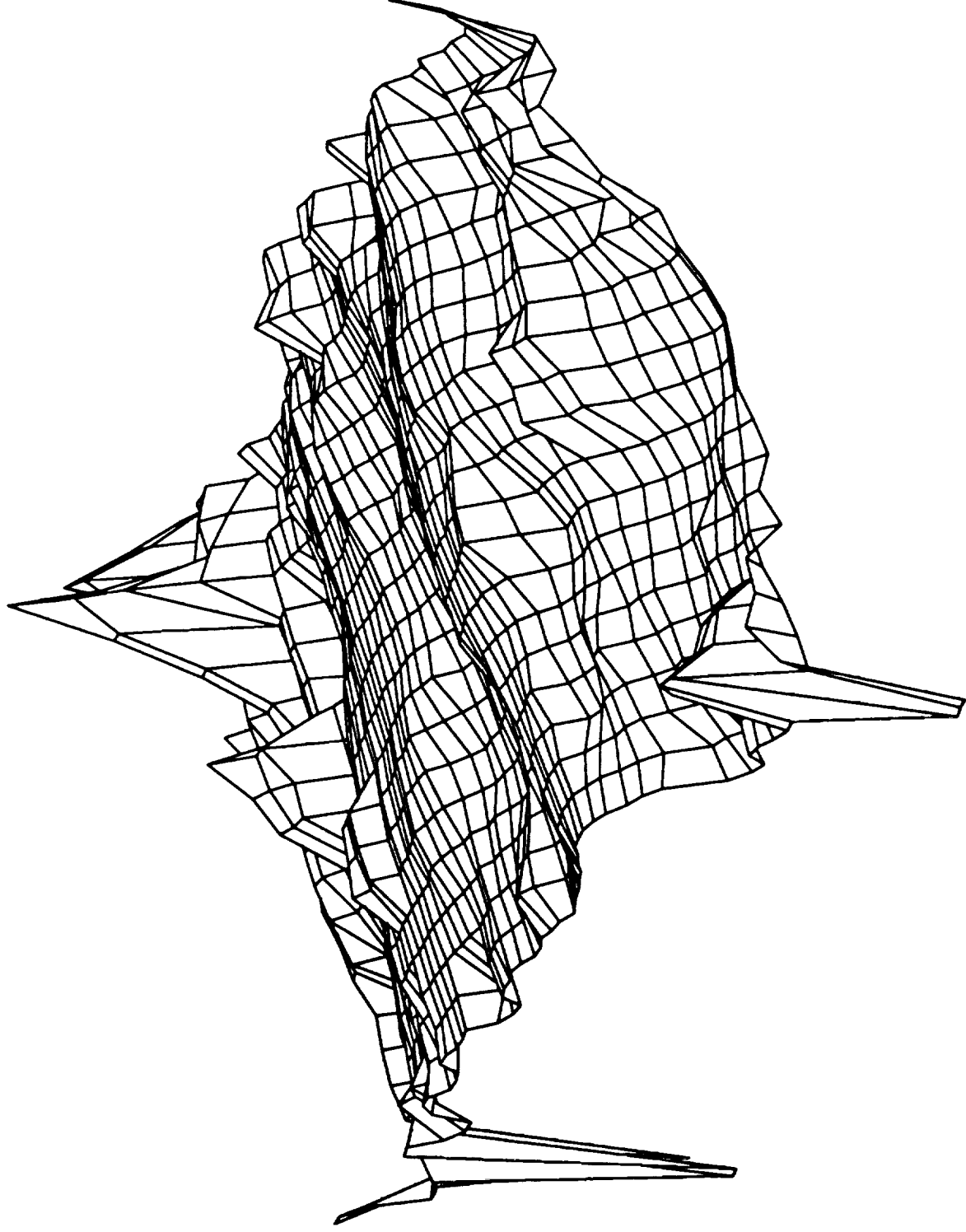


Image4.5.2

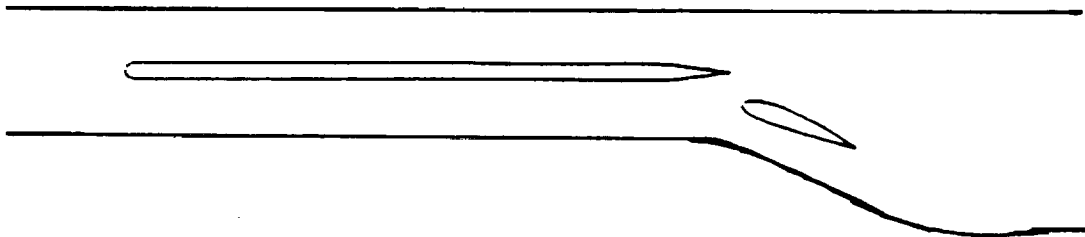


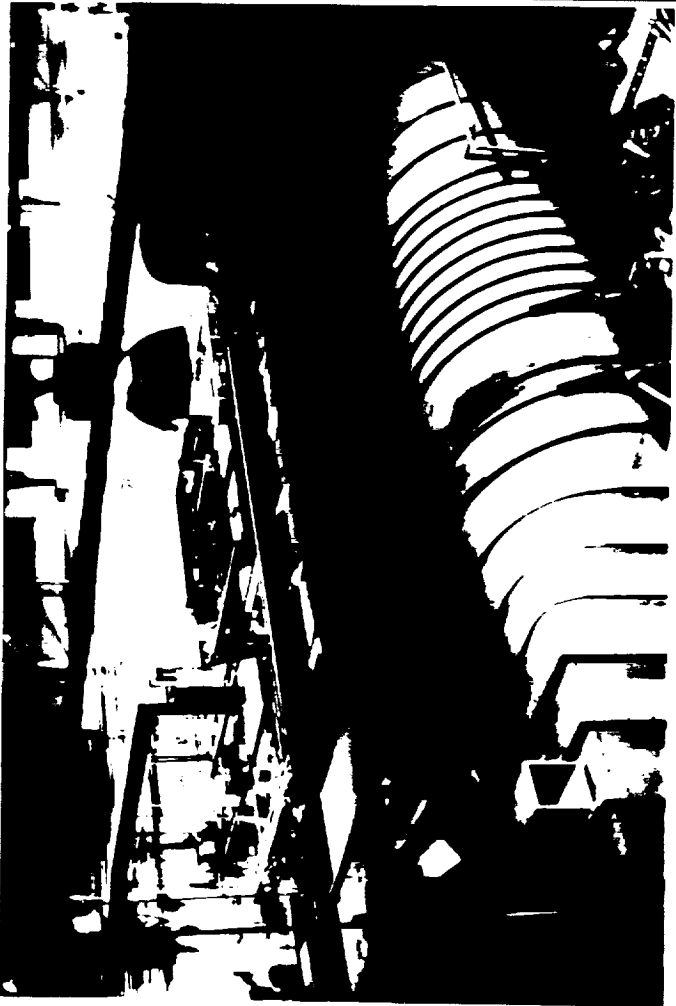
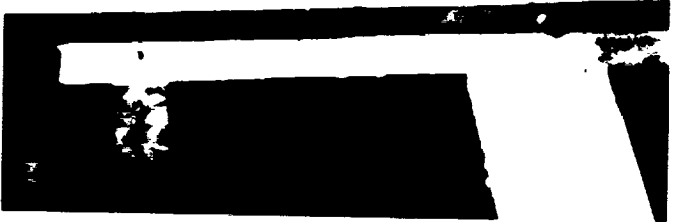
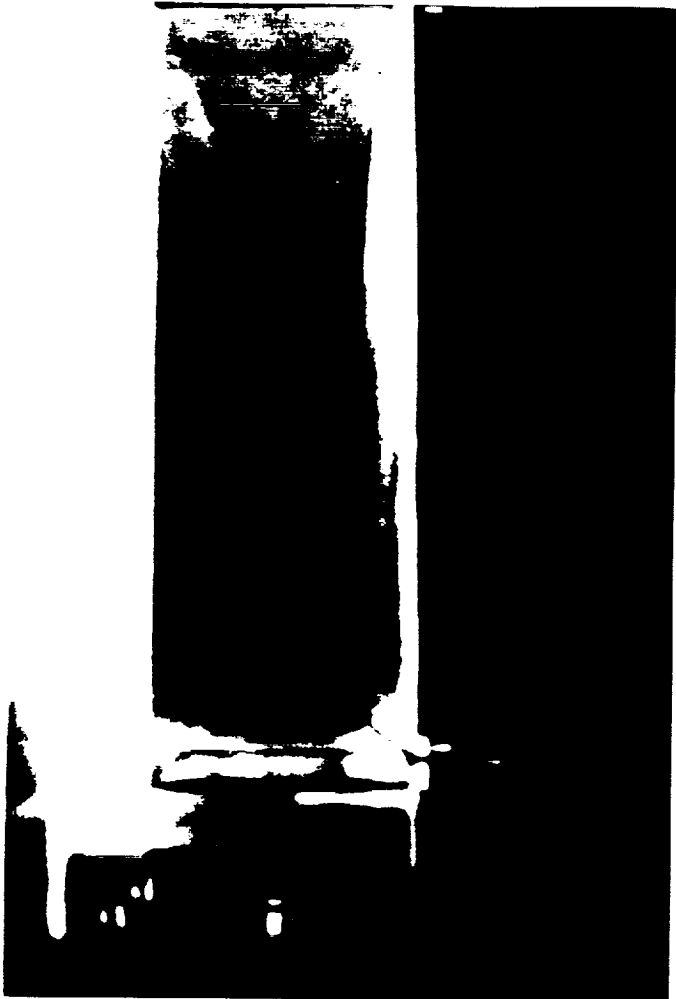
Mesh of velocity profile

Full Scale Facility

- **Status**

- **Construction Complete**
 - » **Foam-Fiberglass with Smooth Gel-Coat**
- **Pitot Probe Surveys**
- **Flow Visualization**

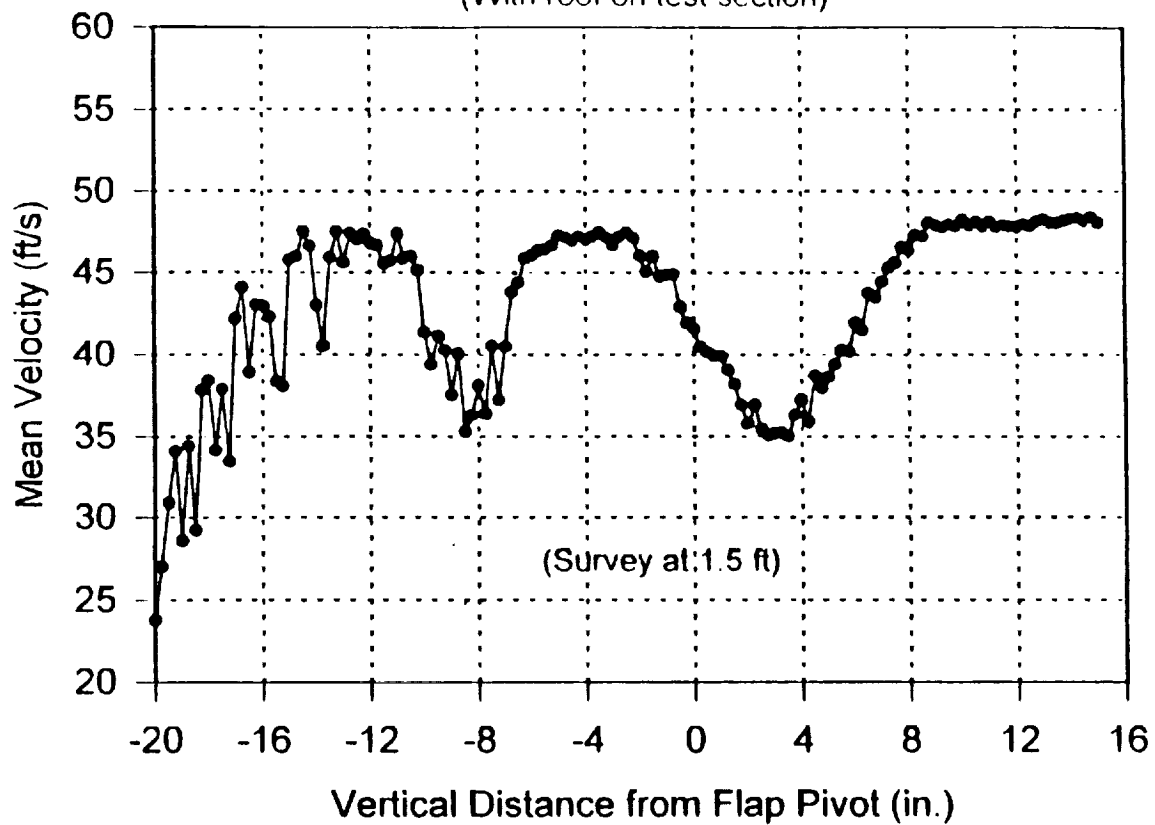






Mean Velocity Profile in Wake

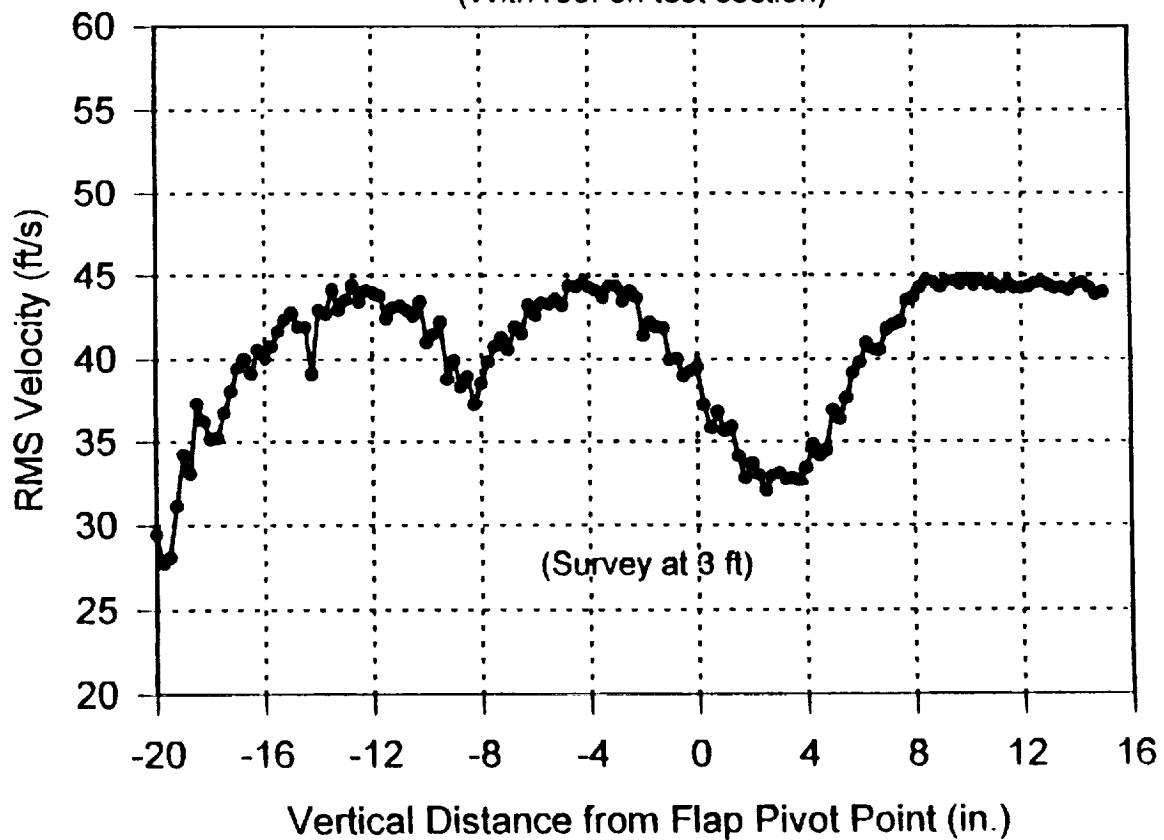
(With roof on test section)



(0.25" between data points)

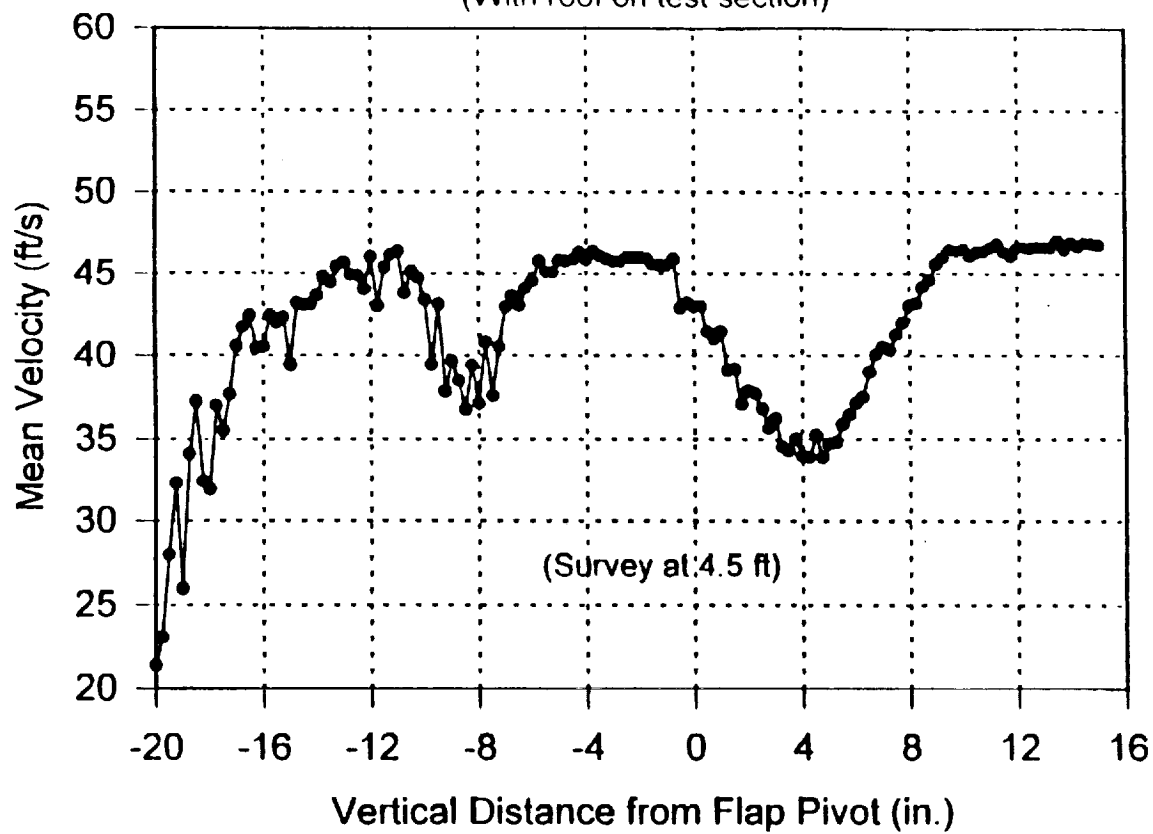
Mean Velocity Profile in Wake

(With roof on test section)



Mean Velocity Profile in Wake

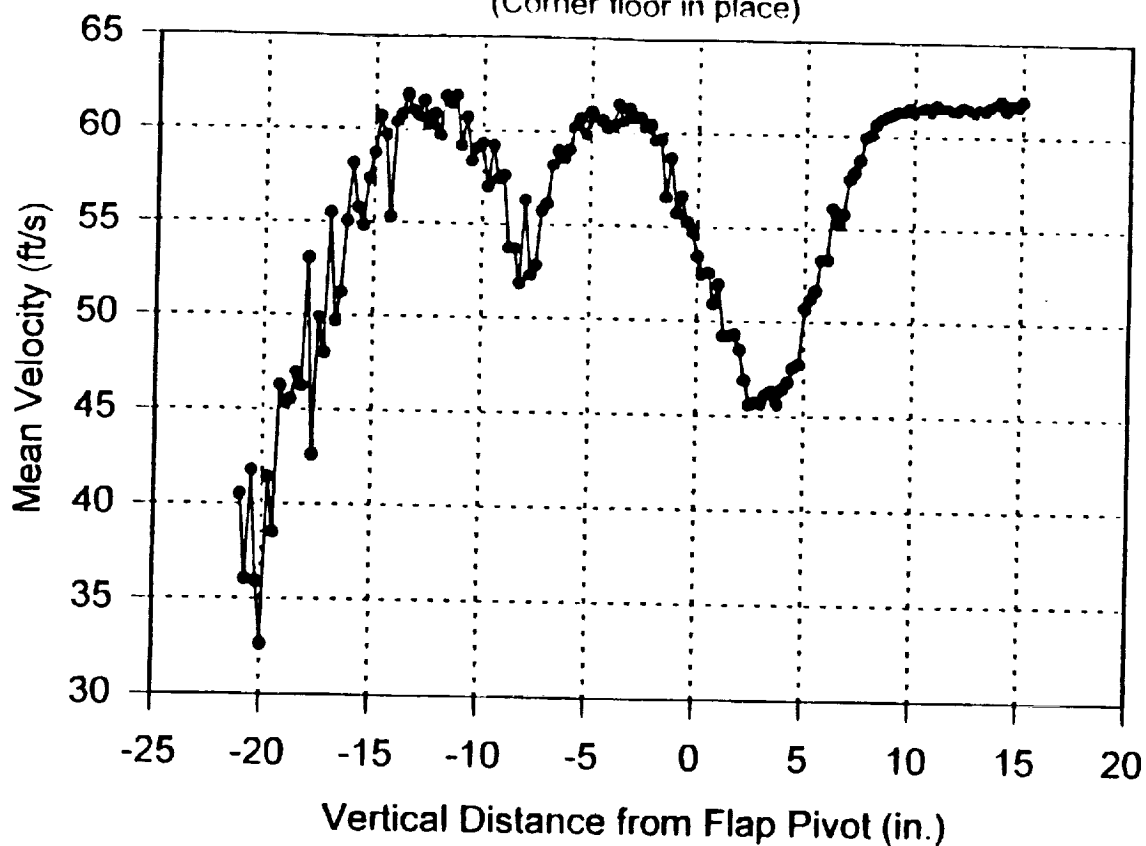
(With roof on test section)



(0.25" between data points)

Mean Velocity Profile in Wake (AOA=0 deg)

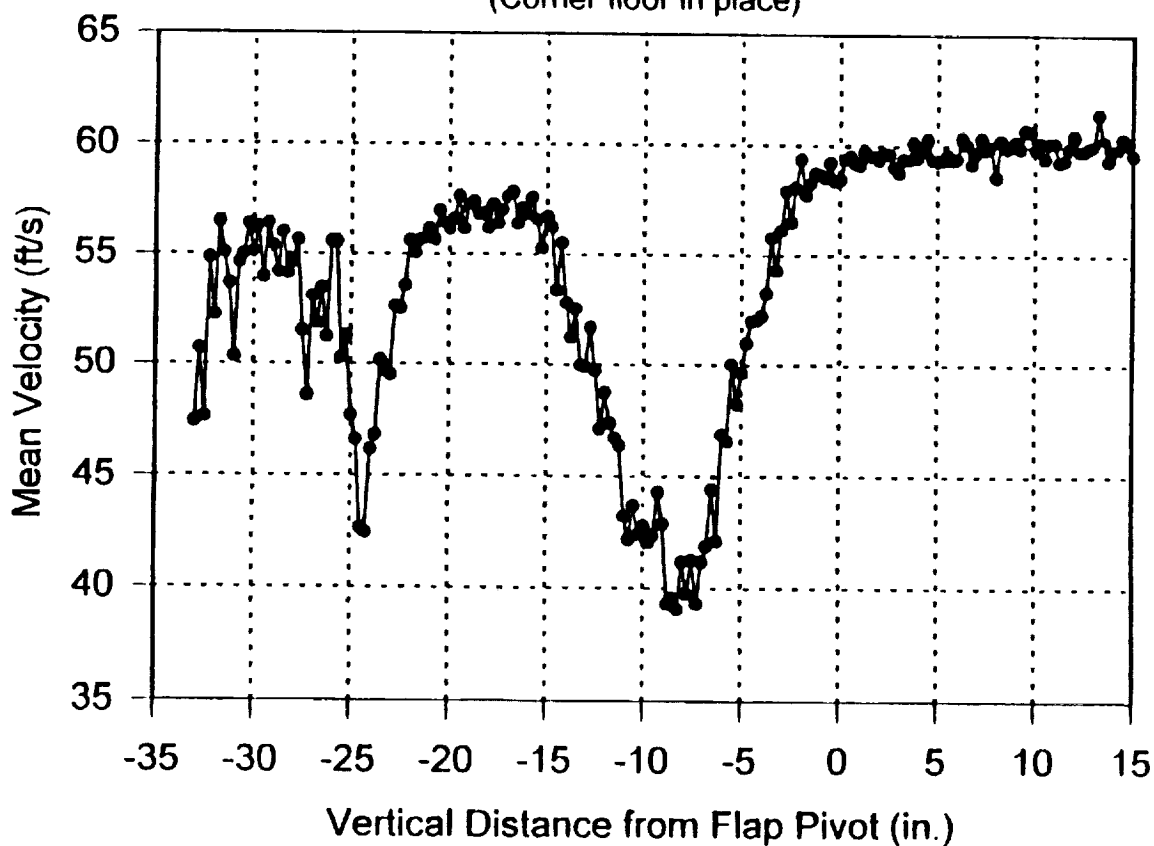
(Corner floor in place)



(0.25" between data points)

Mean Velocity Profile in Wake (AOA=10 deg)

(Corner floor in place)



(0.25" between data points)

Conclusions

- **1/4 Scale Facility**
 - Pitot Probe and PIV Data
 - Small 3-D Effects Up to Flap Stall
- **Full Scale Facility**
 - Operational
 - Preliminary Pitot Probe Data

Recommendations

- **Experiments in Full Scale Facility**
 - Work with Turbulence Modelers and CFD People to Develop Design Capability of High Lift Systems of High Reynolds Numbers
- **Issues**
 - Wake Structure
 - Wake Bursting
 - Coves
 - Trailing Edge Treatment
- **Facility Improvements**
 - Blowing in Flap/Side Wall Corner
 - » Higher Lift on Flap with 2-D Flow
 - Suction of Side Wall Boundary Layers