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COMPARISON BETWEEN PREDICTED AND EXPERIMENTALLY MEASURED FLOW FIELDS AT THE EXIT OF THE SSME HPFTP IMPELLER

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ABSTRACT

Validation of CFD codes is a critical first step in the process of developing CFD design capability. The MSFC Pump Technology Team has recognized the importance of validation and has thus funded several experimental programs designed to obtain CFD quality validation data. The first data set to become available is for the SSME High Pressure Fuel Turbopump Impeller. LDV Data was taken at the impeller inlet (to obtain a reliable inlet boundary condition) and three radial positions at the impeller discharge.

Our CFD code, TASCflow, is used within the Propulsion and Commercial Pump Industry as a tool for pump design. The objective of this work, therefore, is to further validate TASCflow for application in pump design. TASCflow was used to predict flow at the impeller discharge for flowrates of 80, 100 and 115 percent of design flow. Comparison to data has been made with encouraging results.

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Approach

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- Develop Computational Model
  - TRUEGRID
  - ICEM CFD

- Set Inlet Boundary Condition Based on Measured Inlet Conditions
  - LDV Measurements Obtained From Rocketdyne and NASA/MSFC at Q/Qd=0.8, 1.0, and 1.15

- Compute Flow for SSME HPFTP Impeller at Q/Qd=0.8, 1.0, and 1.15.
  - Computations Performed With ***TASCflow***

- Compare Predicted Exit Velocity Profiles to Measured
  - LDV Measurements Obtained From Rocketdyne and NASA/MSFC at Q/Qd=0.8, 1.0, and 1.15
  - Non-Dimensional Velocities (Vel/Utip)

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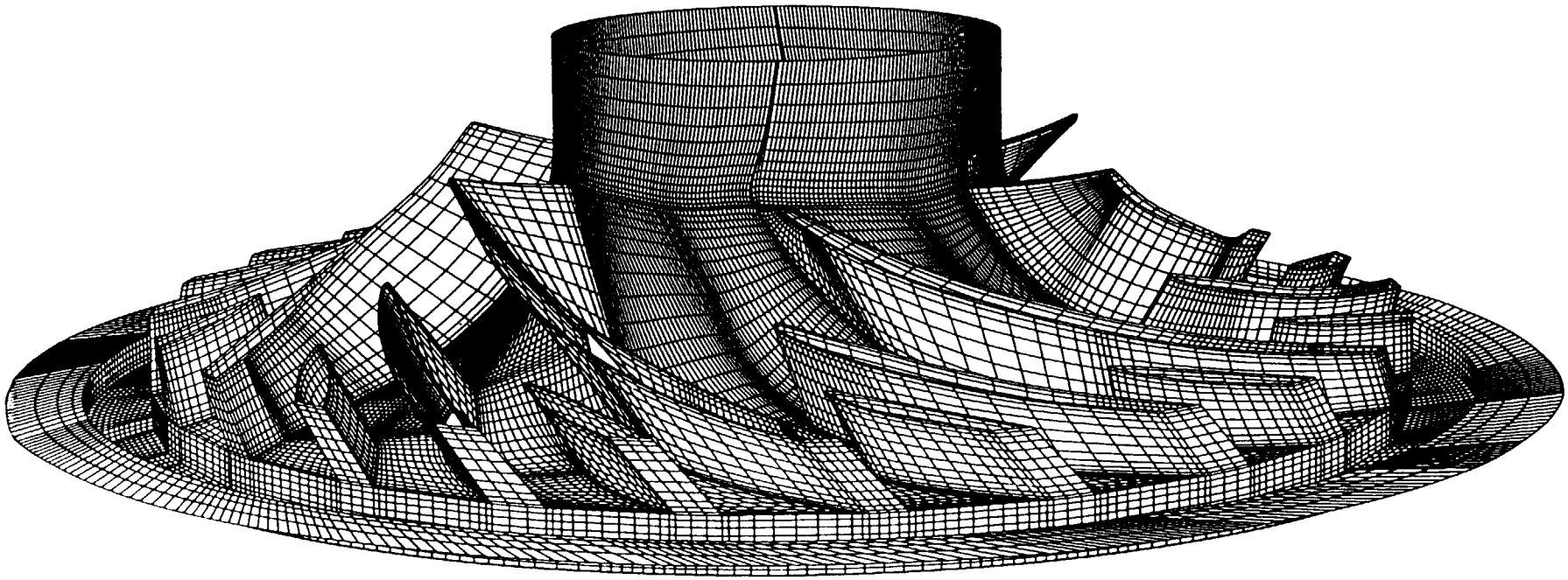
Computational Grid
89x29x60 (154860 Nodes)



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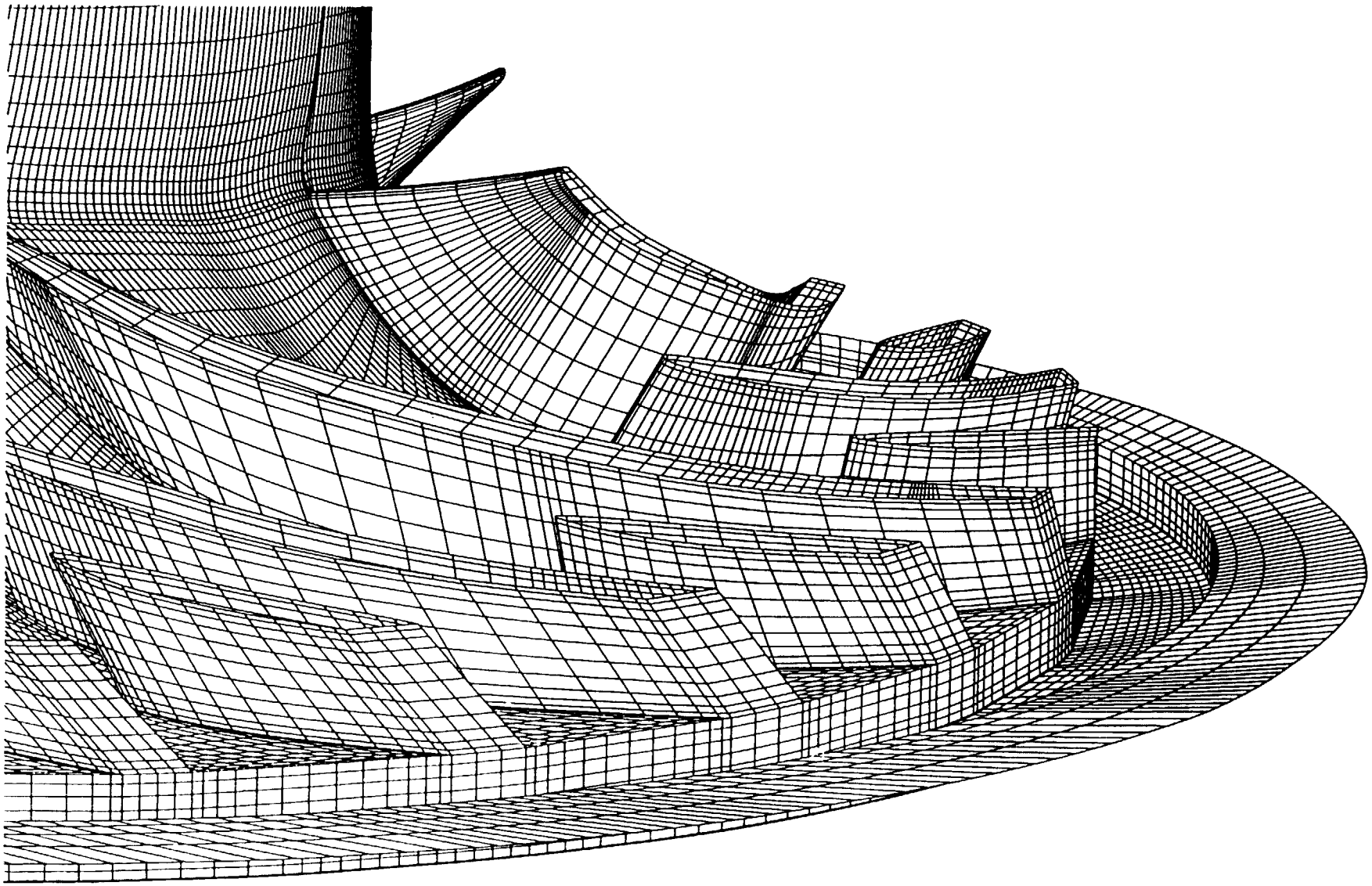

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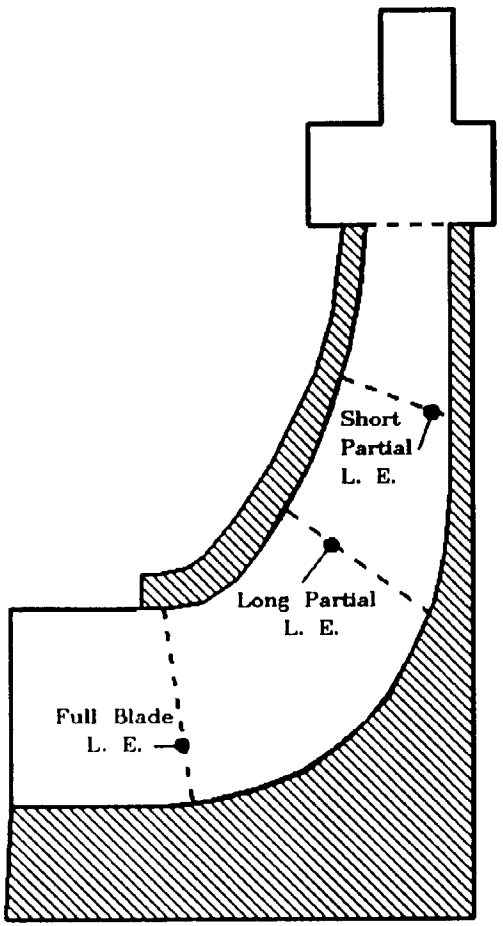
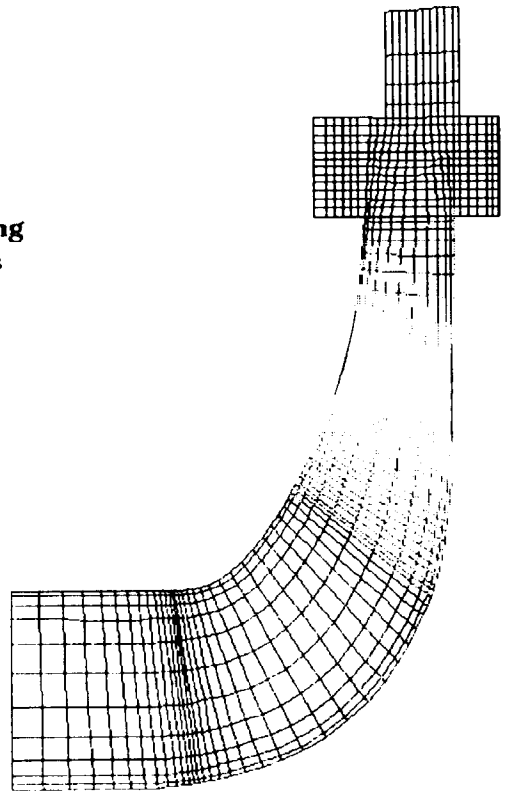
SSME HPFTP IMPELLER COMPUTATIONAL DOMAIN AND BOUNDARY CONDITIONS



— Inlet/Outlet

— Counter Rotating
Turbulent Walls

— Slip Walls



GRID COLORED BY PRESSURE

Collocated, Finite Volume, Primitive Variable

Incompressible - Subsonic - Transonic - Supersonic

Viscous - Laminar or Turbulent (k-e)

Steady or Unsteady

Stationary or Rotating Frame of Reference

Porous Media

Heat Transfer Including Conjugate Heat Transfer

Natural Convection

Species Transport

Chemical Reaction

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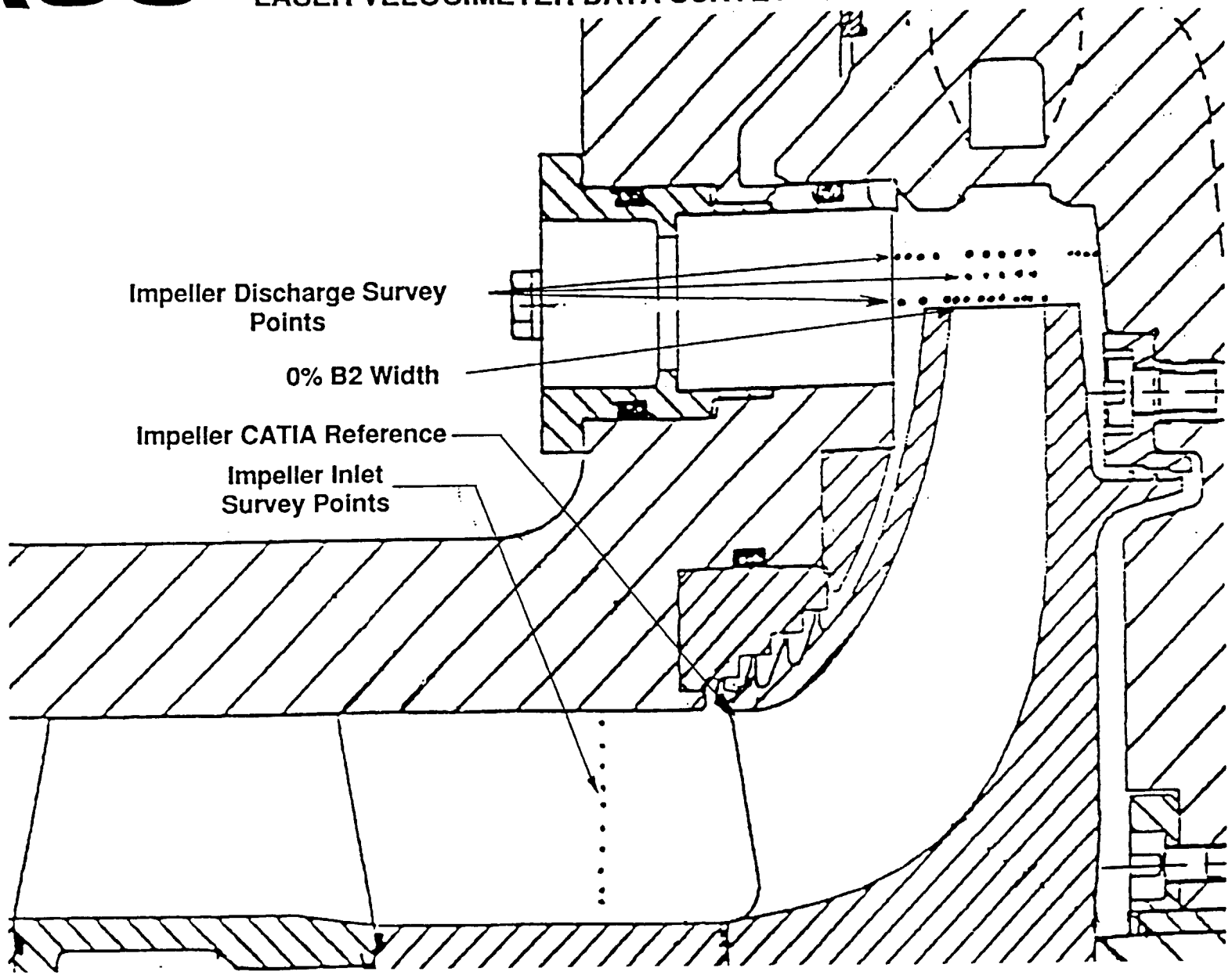
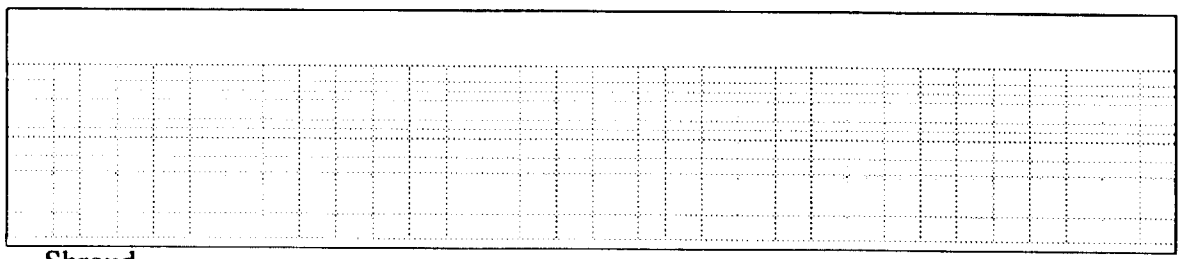
SSME HPFTP IMPELLER
LASER VELOCIMETER DATA SURVEY LOCATIONS



GRID STRUCTURE AT R/RTIP=1.013

EXPERIMENTAL DATA

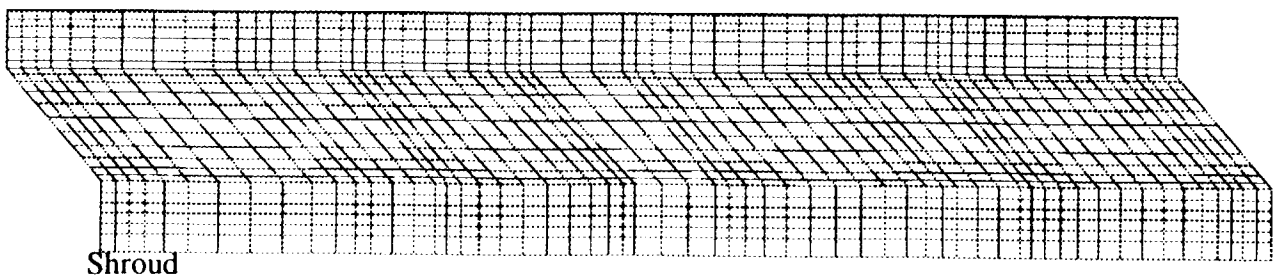
Hub



Shroud

TASCflow PREDICTION

Hub



Shroud

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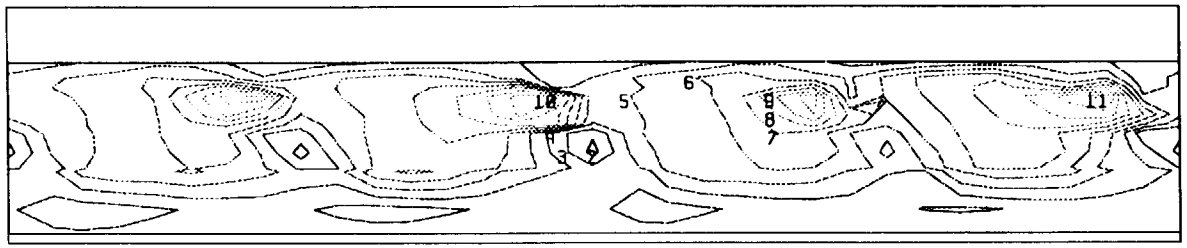
ABS. VELOCITY FOR Q/QD=1.0. R/RTIP=1.013

EXPERIMENTAL DATA

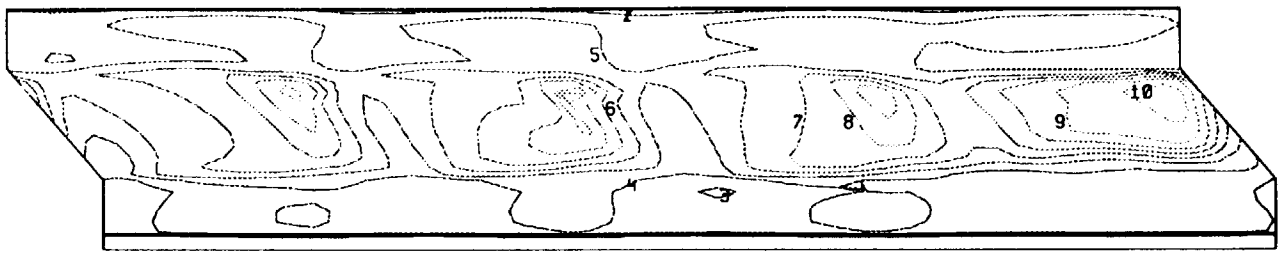
Hub



Shroud

TASCflow PREDICTION

Hub



Shroud

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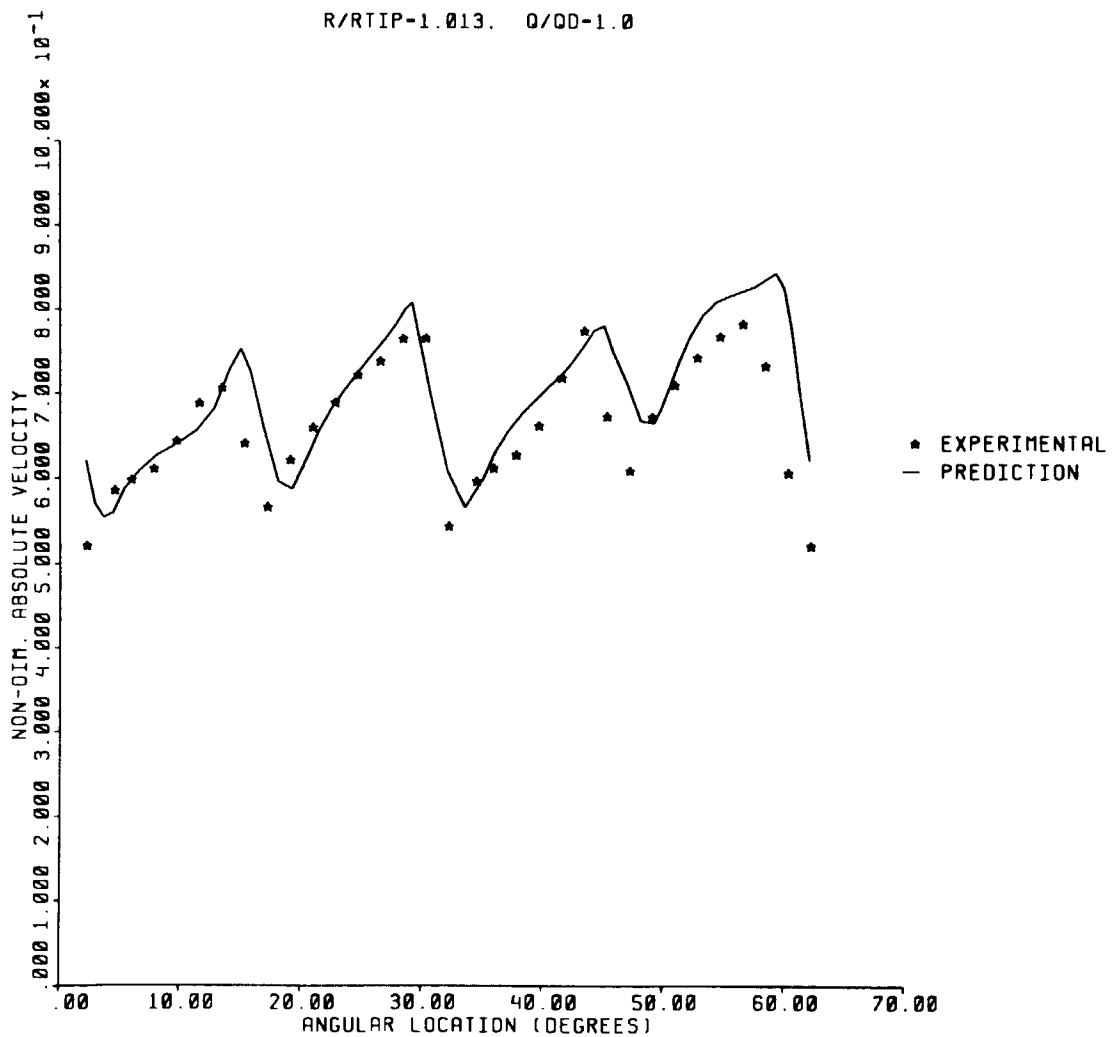
C	
12	9.500E-01
11	9.000E-01
10	8.500E-01
9	8.000E-01
8	7.500E-01
7	7.000E-01
6	6.500E-01
5	6.000E-01
4	5.500E-01
3	5.000E-01
2	4.500E-01
1	4.000E-01

ABSOLUTE VELOCITY, 50 PERCENT B2



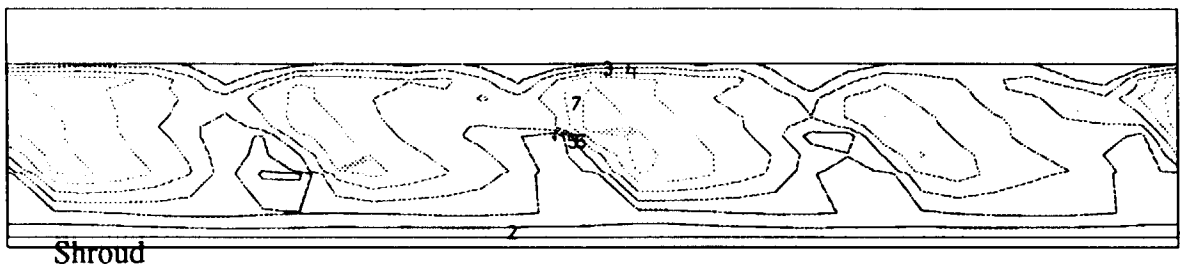
ABS. FLOW ANGLE FOR Q/QD=1.0. R/RTIP=1.013

ALPHA

8	3.000E+01
7	2.500E+01
6	2.000E+01
5	1.500E+01
4	1.000E+01
3	5.000E+00
2	0.000E+00
1	-5.000E+00

EXPERIMENTAL DATA

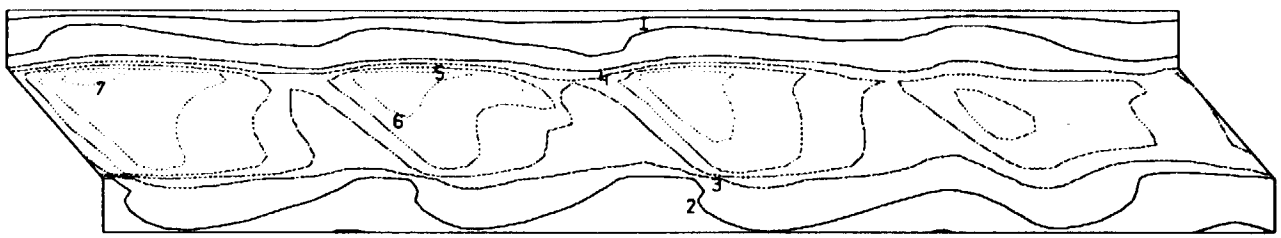
Hub



Shroud

TASCflow PREDICTION

Hub



Shroud

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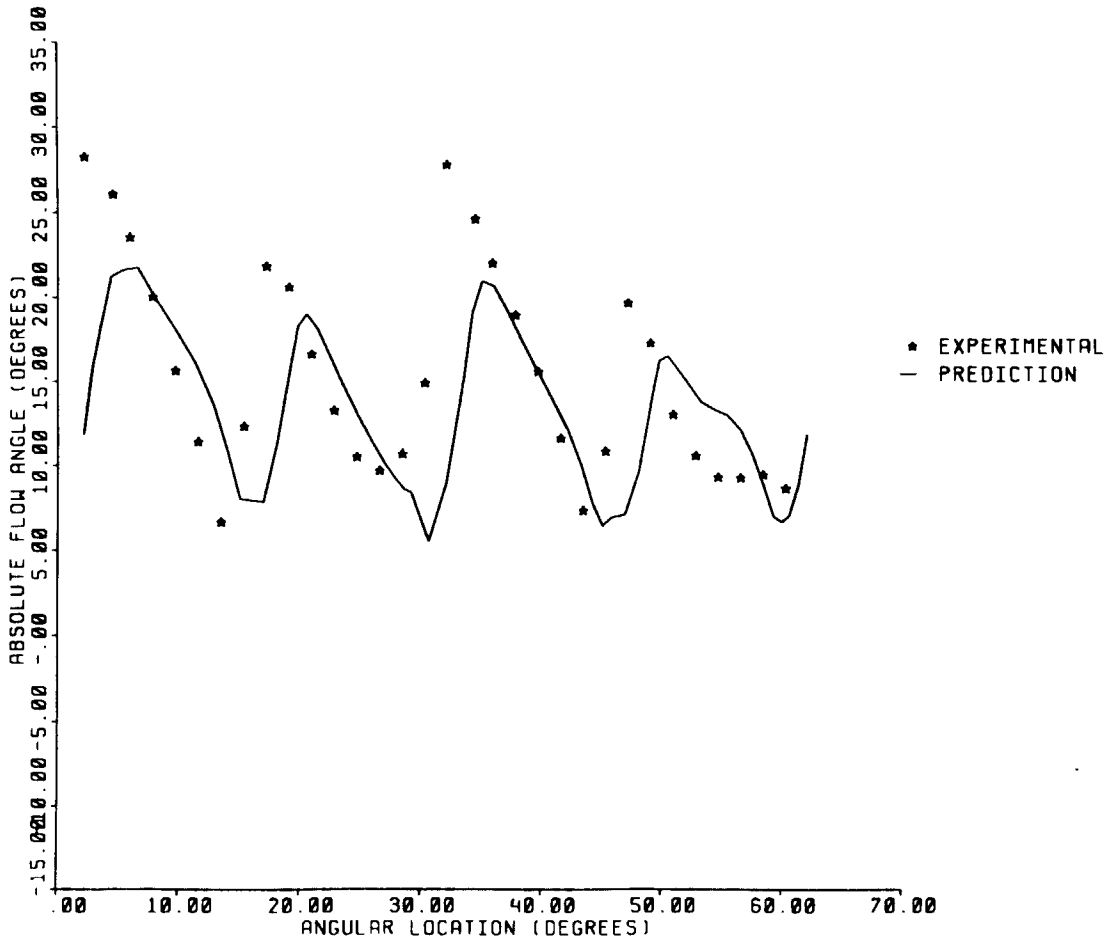
ABSOLUTE FLOW ANGLE, 50 PERCENT B2

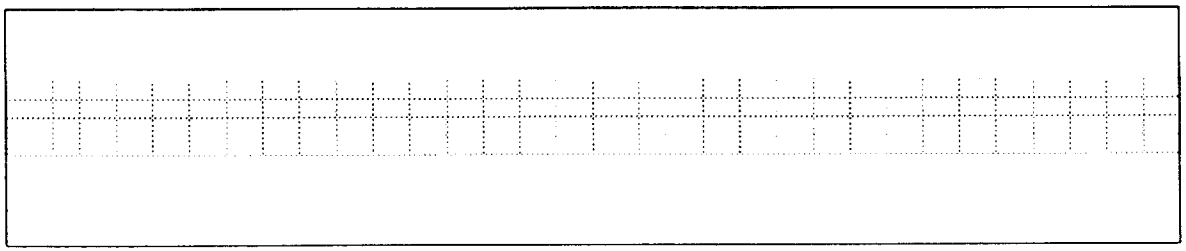
R/RTIP-1.013, Q/QD-1.0



GRID STRUCTURE AT R/RTIP=1.036

EXPERIMENTAL DATA

Hub



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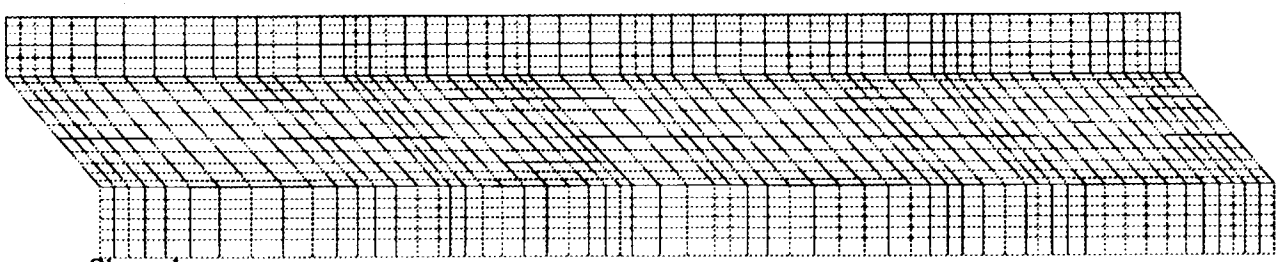
TASCflow PREDICTION

Hub



Shroud

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ABS VELOCITY FOR Q/QD=1.0. R/RTIP=1.036

C

9 9.000E-01

8 8.500E-01

7 8.000E-01

6 7.500E-01

5 7.000E-01

4 6.500E-01

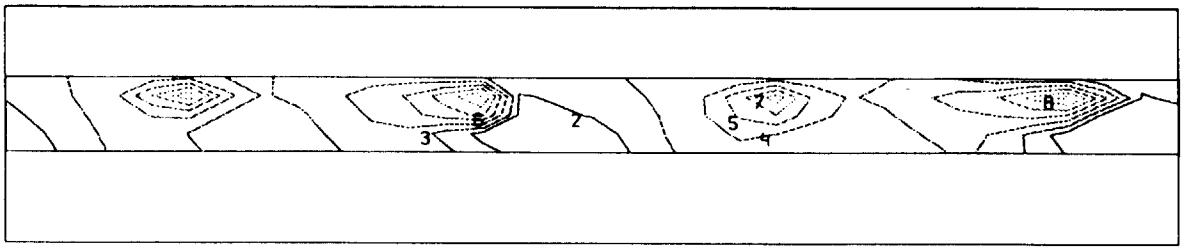
3 6.000E-01

2 5.500E-01

1 5.000E-01

EXPERIMENTAL DATA

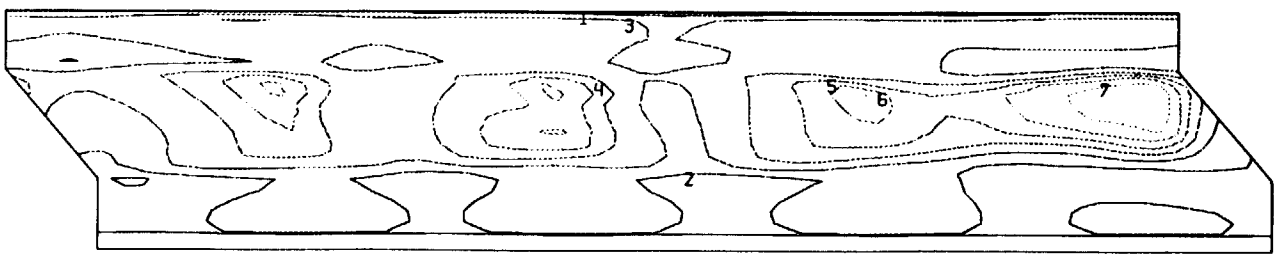
Hub



Shroud

TASCflow PREDICTION

Hub



Shroud

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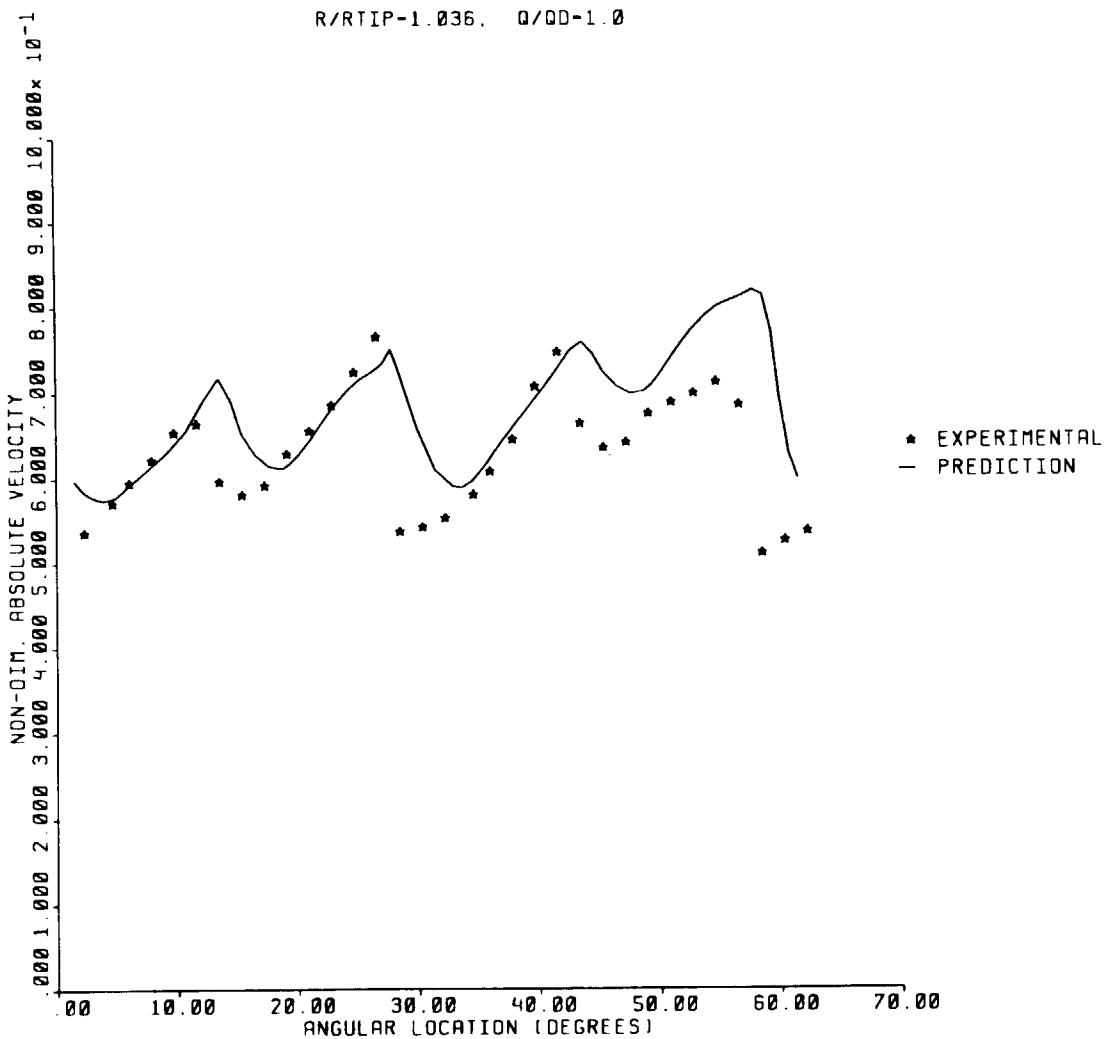
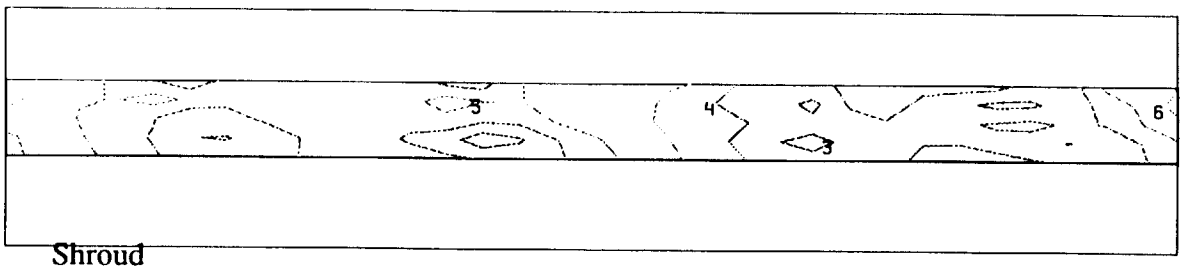
ABSOLUTE VELOCITY, 50 PERCENT B2



ABS. FLOW ANGLE FOR Q/QD=1.0. R/RTIP=1.036

EXPERIMENTAL DATA

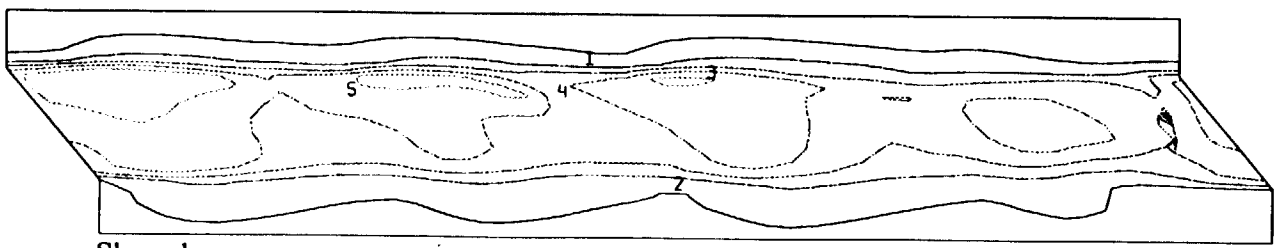
Hub



Shroud

TASCflow PREDICTION

Hub



Shroud

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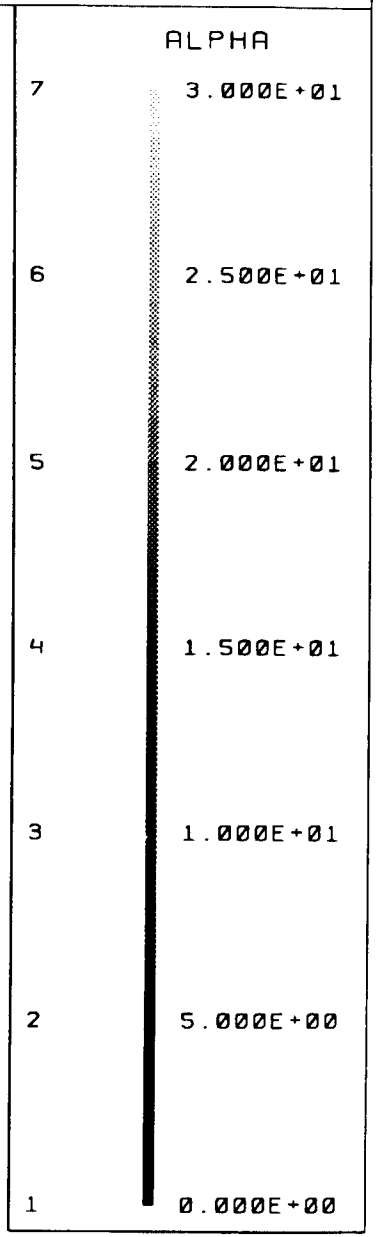
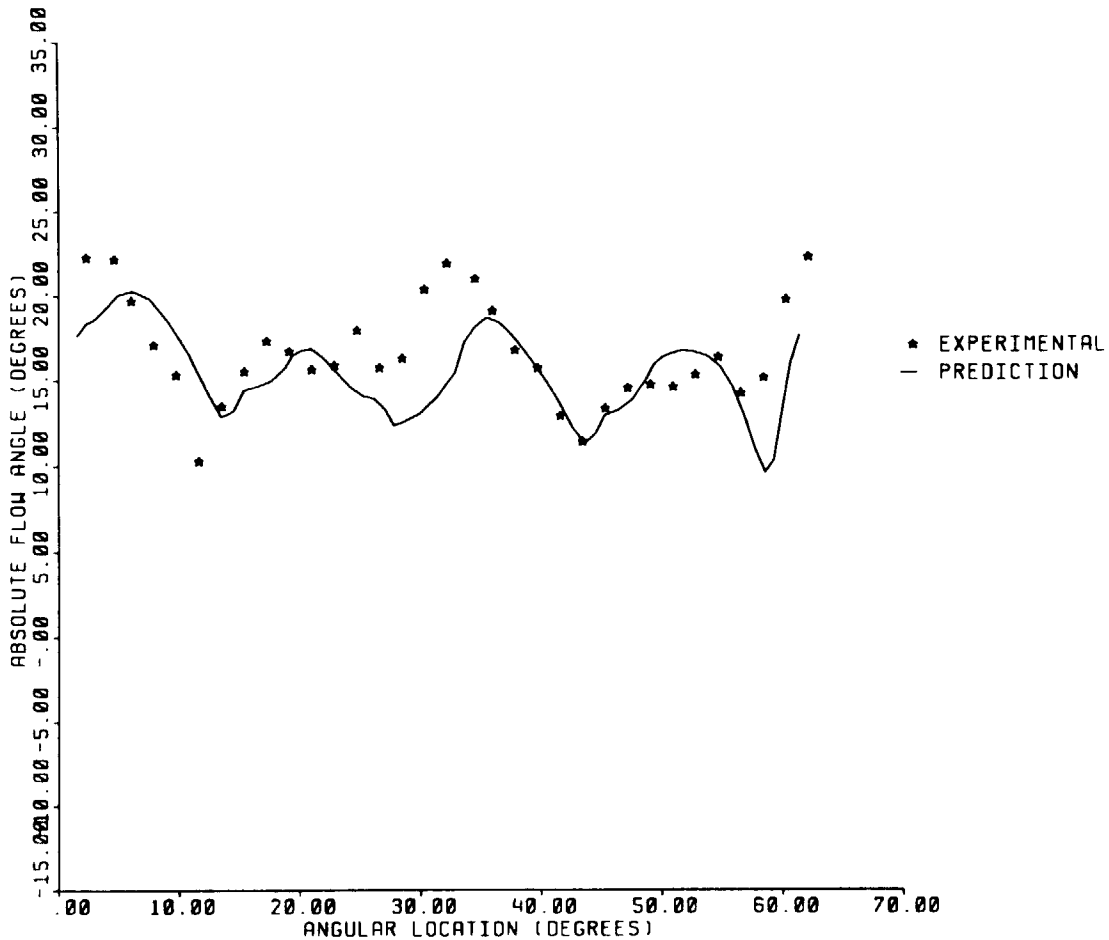


ABSOLUTE FLOW ANGLE, 50 PERCENT B2

R/RTIP-1.036. Q/QD-1.0

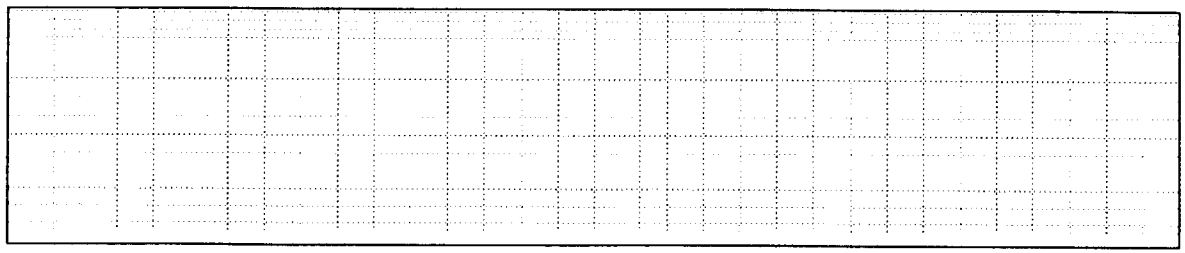


ASC

GRID STRUCTURE AT R/RTIP=1.060

EXPERIMENTAL DATA

Hub



Shroud

TASCflow PREDICTION

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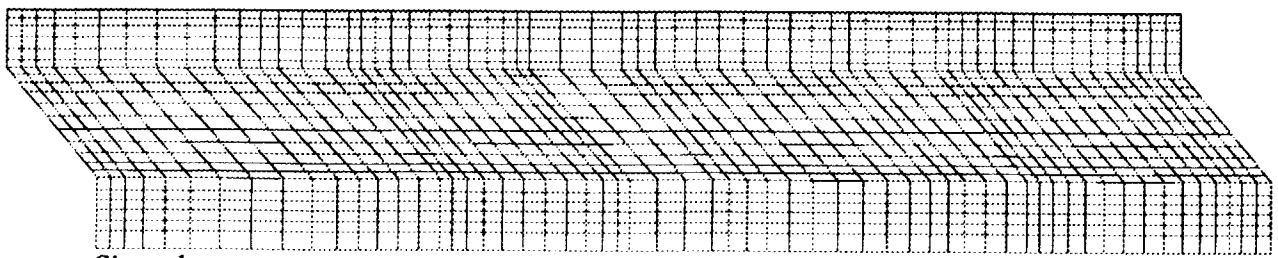

Shroud

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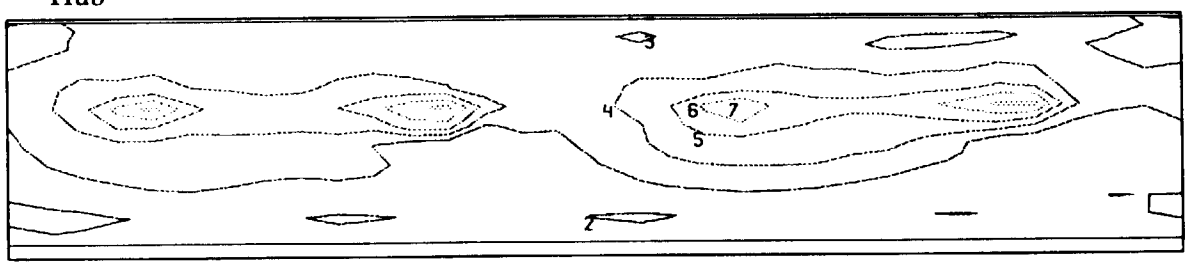
ABS. VELOCITY FOR Q/QD=1.0. R/RTIP=1.060

EXPERIMENTAL DATA

Hub



Shroud

TASCflow PREDICTION

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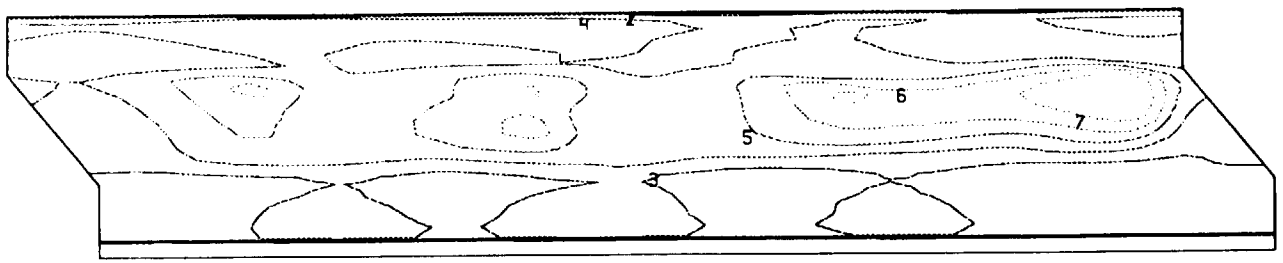

Shroud

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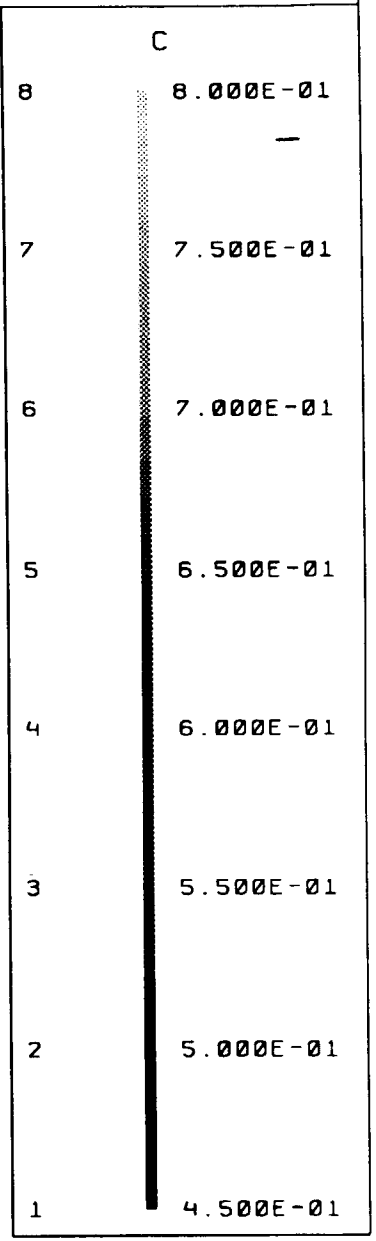
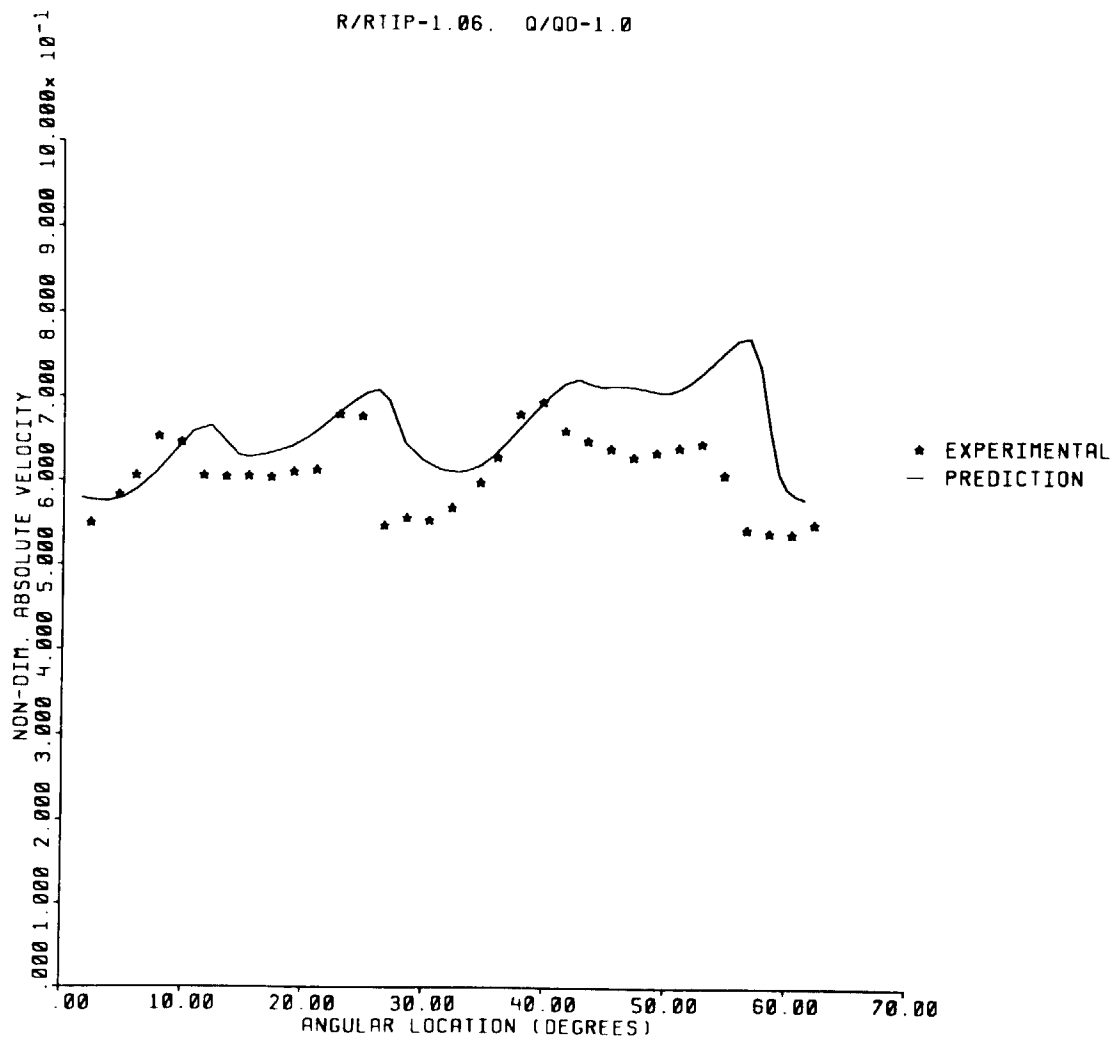


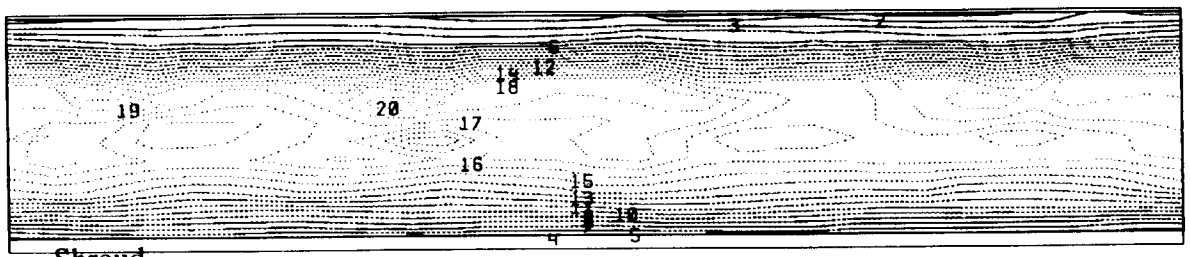
ABSOLUTE VELOCITY. 50 PERCENT B2



ABS. FLOW ANGLE FOR Q/QD=1.0, R/RTIP=1.060

EXPERIMENTAL DATA

Hub



Shroud

TASCflow PREDICTION

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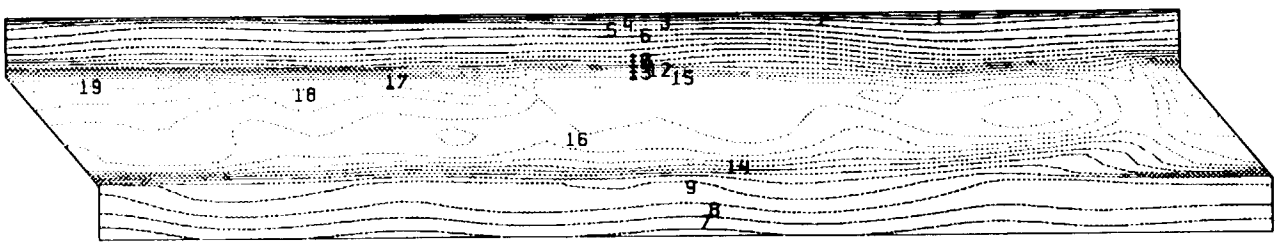

Shroud

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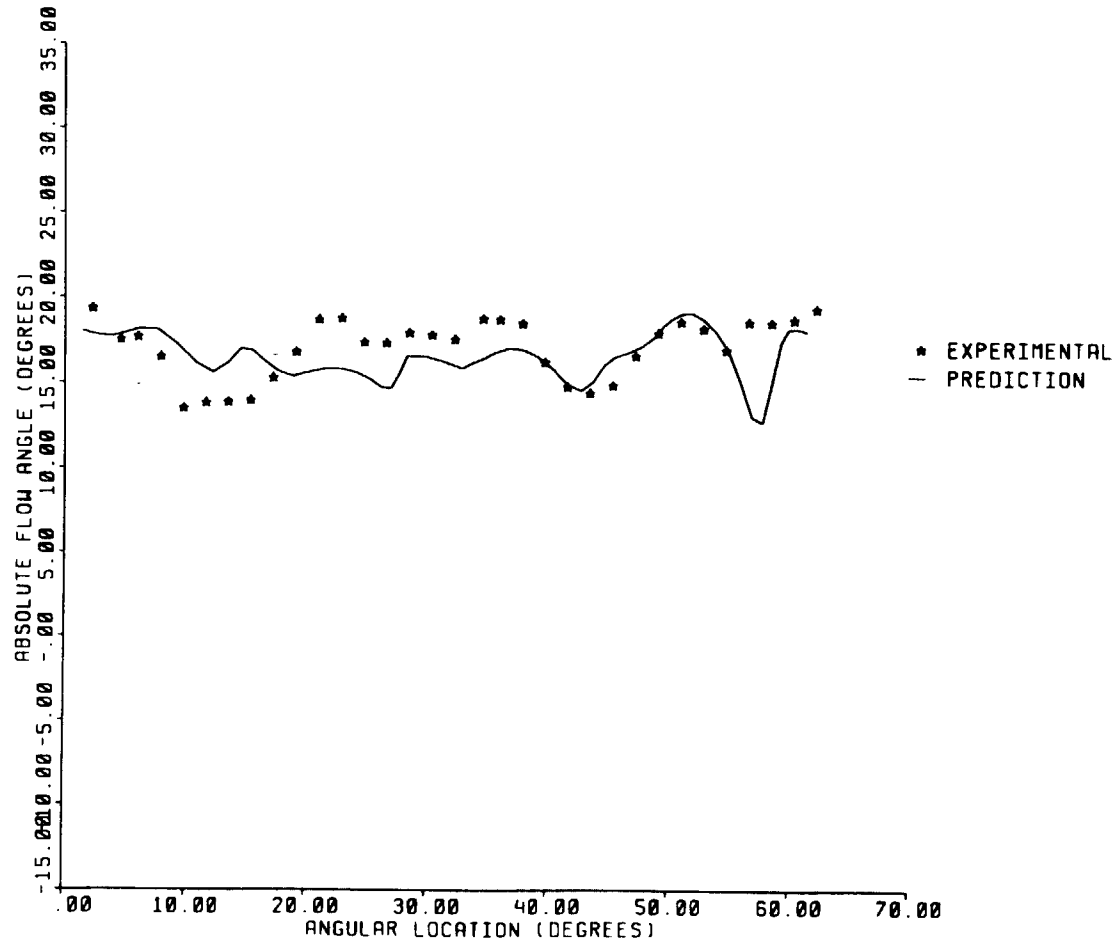
ALPHA	
20	2.400E+01
19	2.200E+01
18	2.000E+01
17	1.800E+01
16	1.600E+01
15	1.400E+01
14	1.200E+01
13	1.000E+01
12	8.000E+00
11	6.000E+00
10	4.000E+00
9	2.000E+00
8	0.000E+00
7	-2.000E+00
6	-4.000E+00
5	-6.000E+00
4	-8.000E+00
3	-1.000E+01
2	-1.200E+01
1	-1.400E+01

ABSOLUTE FLOW ANGLE, 50 PERCENT B2

R/RTIP-1.06. Q/QD-1.0



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Absolute Velocity (C/Utip) at Impeller Discharge

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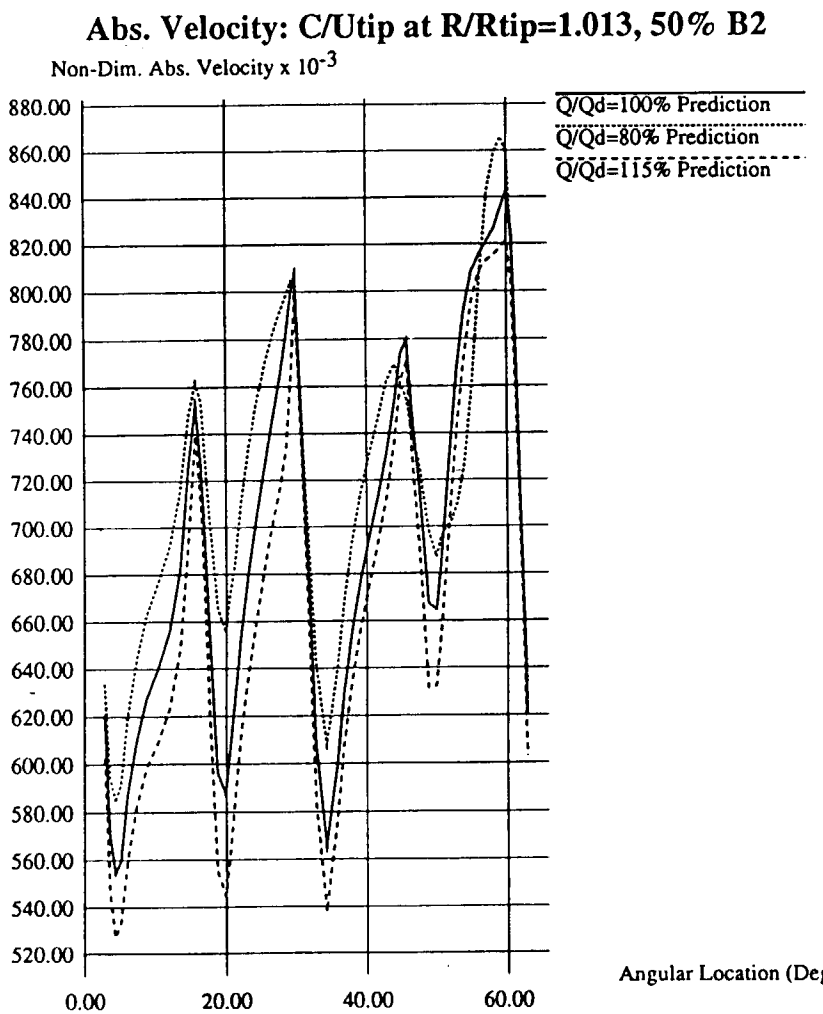
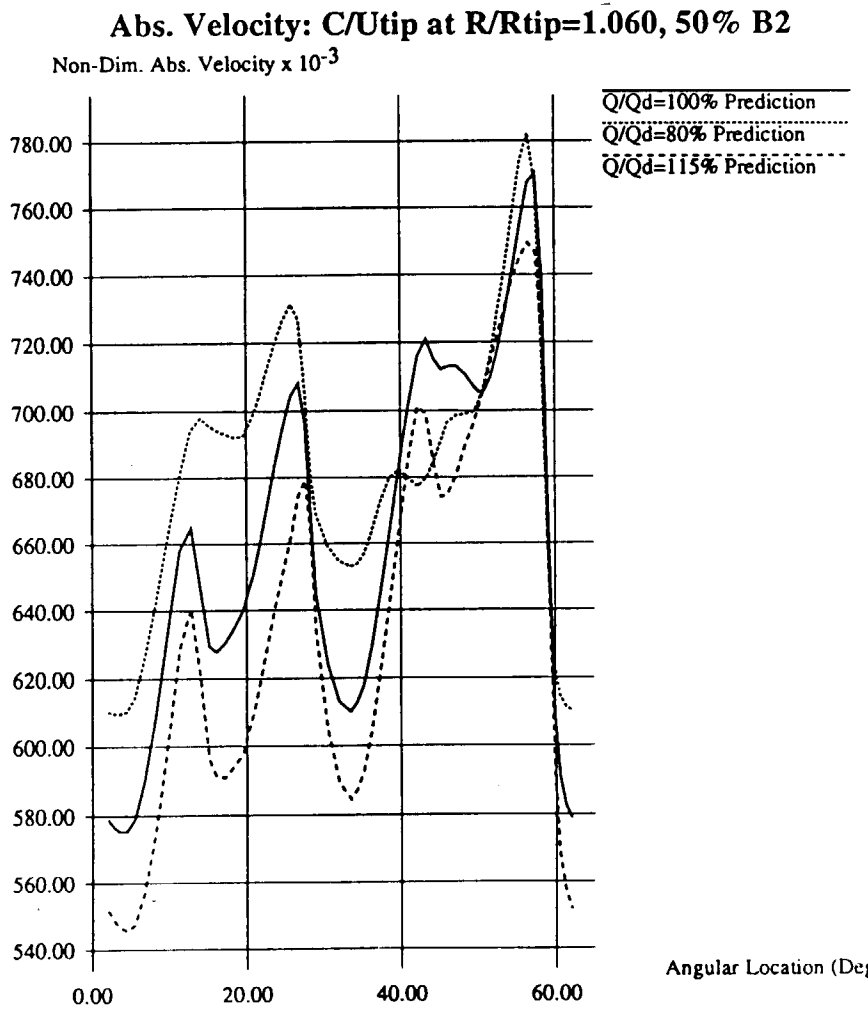
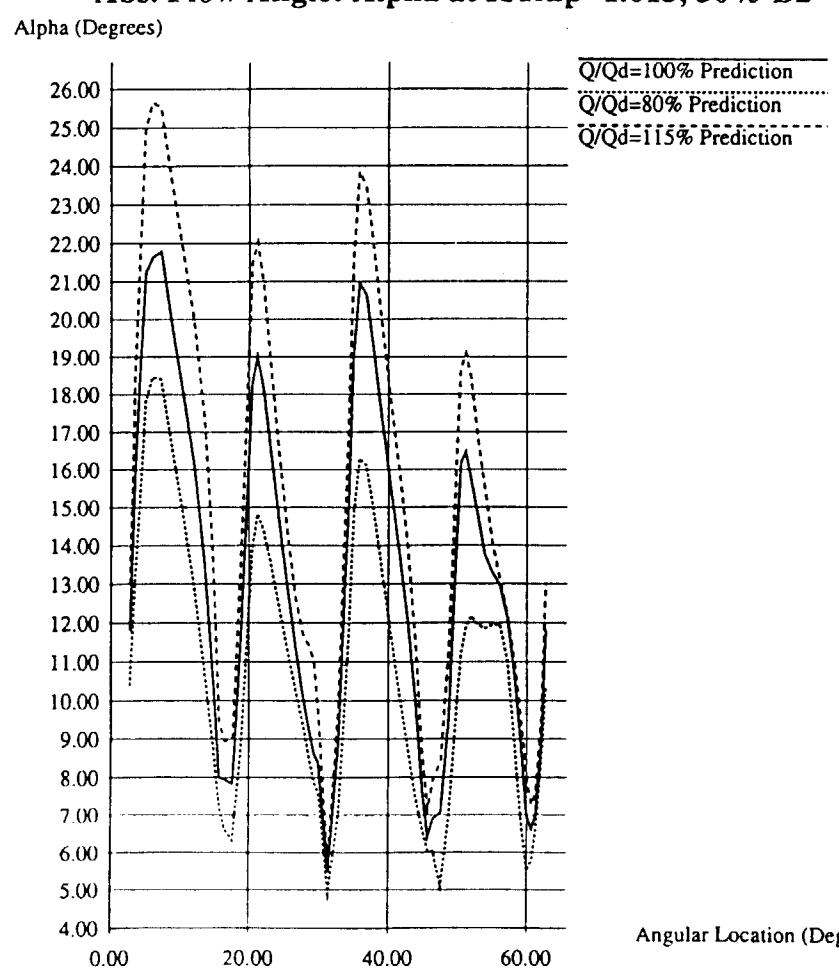
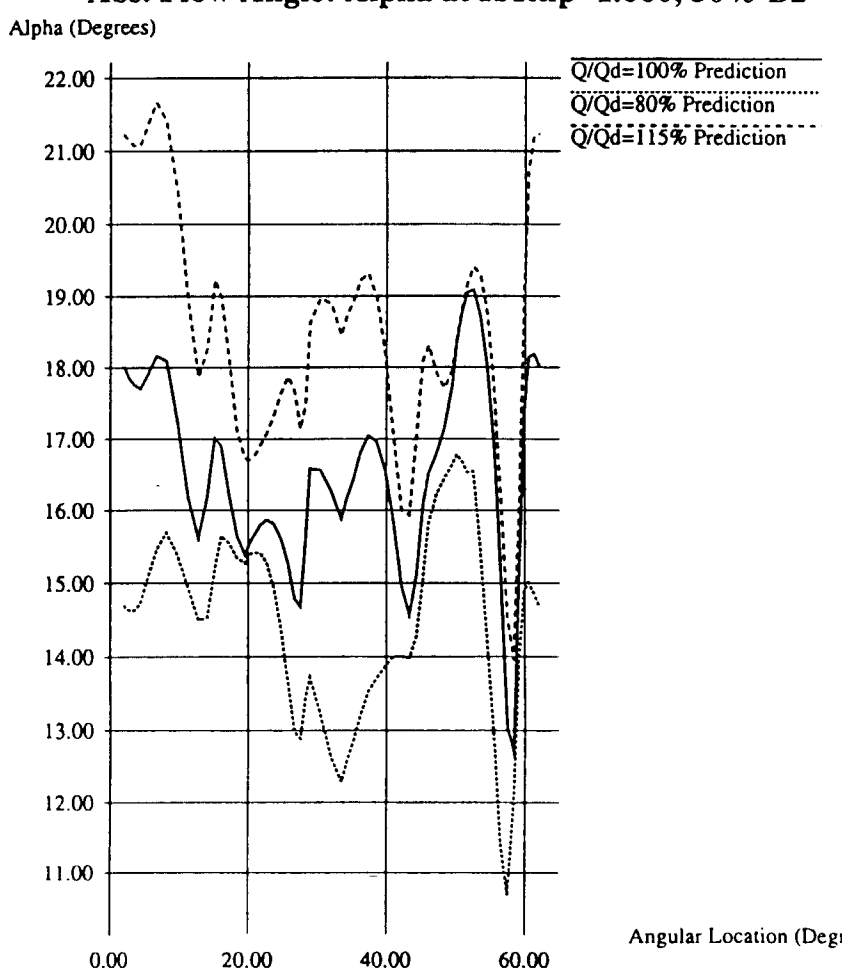





Abs. Flow Angle: Alpha at R/Rtip=1.013, 50% B2
Alpha (Degrees)
26.00
25.00
24.00
23.00
22.00
21.00
20.00
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
0.00
20.00
40.00
60.00
Angular Location (Degrees)
Q/Qd=100% Prediction
Q/Qd=80% Prediction
Q/Qd=115% Prediction


Abs. Flow Angle: Alpha at R/Rtip=1.060, 50% B2
Alpha (Degrees)
22.00
21.00
20.00
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
0.00
20.00
40.00
60.00
Angular Location (Degrees)
Q/Qd=100% Prediction
Q/Qd=80% Prediction
Q/Qd=115% Prediction