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STEADY POTENTIAL SOLVER FOR UNSTEADY AERODYNAMIC ANALYSES

D. Hoyniak
NASA Lewis Research Center
Cleveland, Ohio 44135

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Presentation Outline

- Description of flow solver, SFLOW
- Subsonic Calculations (Steady & Unsteady)
  - Compressor Cascade (10th Standard Configuration)
  - Turbine Cascade (4th Standard Configuration)
  - GE Low Speed Research Compressor
  - GE Low Speed Research Turbine
- Transonic Calculations (Steady)
  - Compressor Cascade (10th Standard Configuration)

Objective

Develop steady flow solver for use with LINFLO

- Compatible with LINFLO
- Composite Mesh
- Transonic Capability

Approach

- Steady flow potential equation written in nonconservative form
- Newton's Method
- Implicit, Least-Squares, Interpolation Method used to obtain finite difference expressions
- Matrix inversion routines from LINFLO

Differential Equations

Steady Flow

$$A^2\nabla^2\phi - (\gamma-1)\nabla^2\Phi\frac{\overline{D}\phi}{Dt} - \frac{\overline{D}^2\phi}{Dt^2} - \nabla\phi\cdot\frac{\nabla(\nabla\Phi)^2}{2}$$
$$= -A^2\nabla^2\Phi + \nabla\Phi\cdot\frac{\nabla(\nabla\Phi)^2}{2}$$

$$\frac{\overline{D}}{Dt} = \nabla\Phi\cdot\nabla$$

Unsteady Flow

$$A^2\nabla^2\phi - (\gamma-1)\nabla^2\Phi\frac{\overline{D}\phi}{Dt} - \frac{\overline{D}^2\phi}{Dt^2} - \nabla\phi\cdot\frac{\dot{\nabla}(\nabla\Phi)^2}{2} = 0$$

$$\frac{\overline{D}}{Dt} = i\omega + \nabla\Phi\cdot\nabla$$

Newton' Method

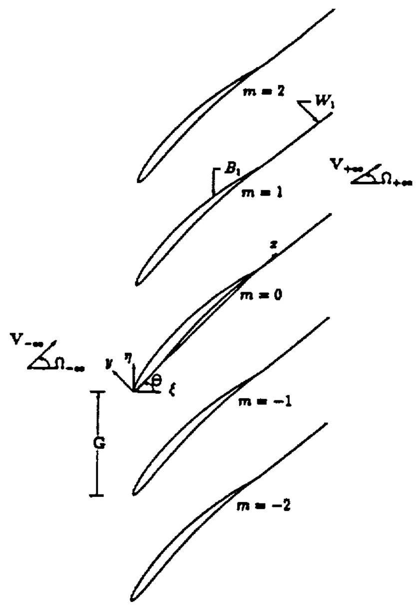
$$[A(\Phi)]\{\phi\} = \{b(\Phi)\}$$

$$\Phi(\vec{x})^{n+1} = \Phi(\vec{x})^n + \phi(\vec{x})^n$$

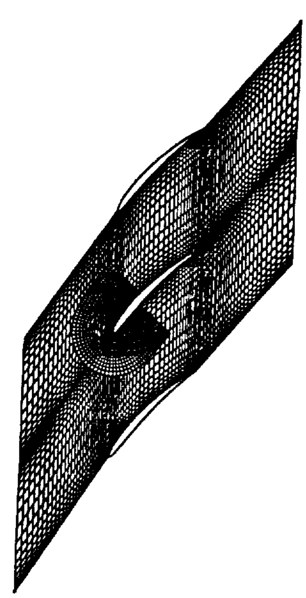
Convergence Criterion

$$\left|\phi(\vec{x})^n\right| < \varepsilon$$

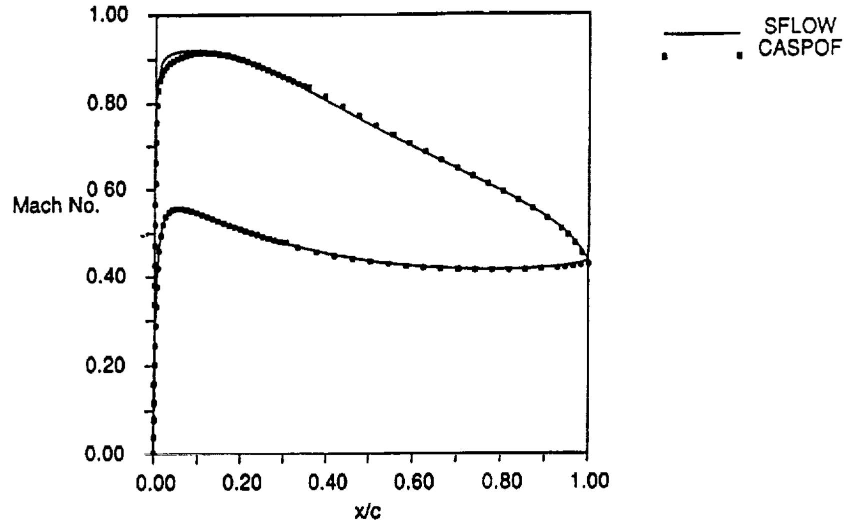
Cascade Geometry



Composite Mesh

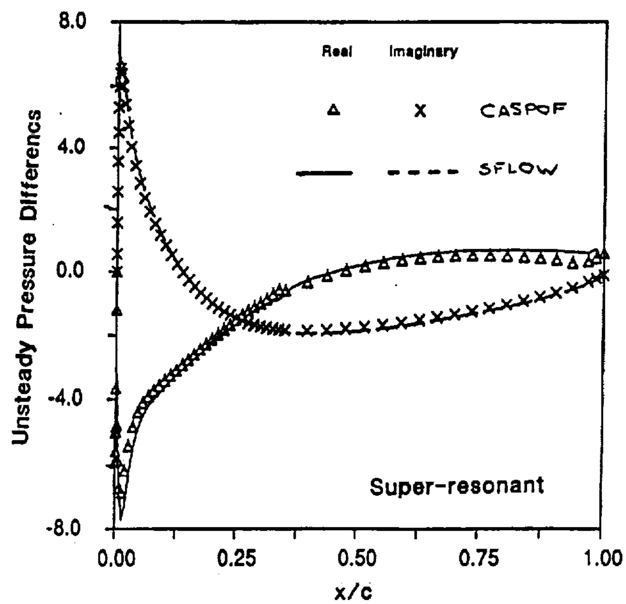


10th Standard Configuration, Subsonic Flow Conditions
Steady Mach Number Distribution
$M_{-\infty} = 0.7$, $\Omega_{-\infty} = 55$ deg



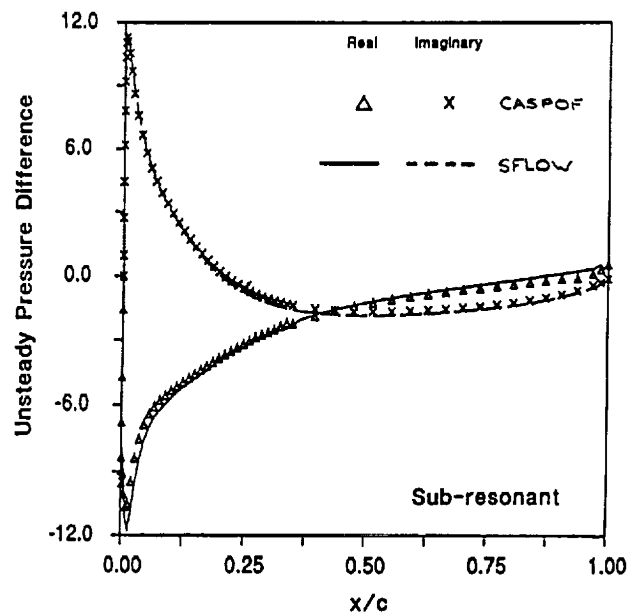
10th Standard Configuration, Subsonic Flow Conditions
Unsteady Torsion Mode Response

α = 1.0, ω = 0.24 σ = 30 deg

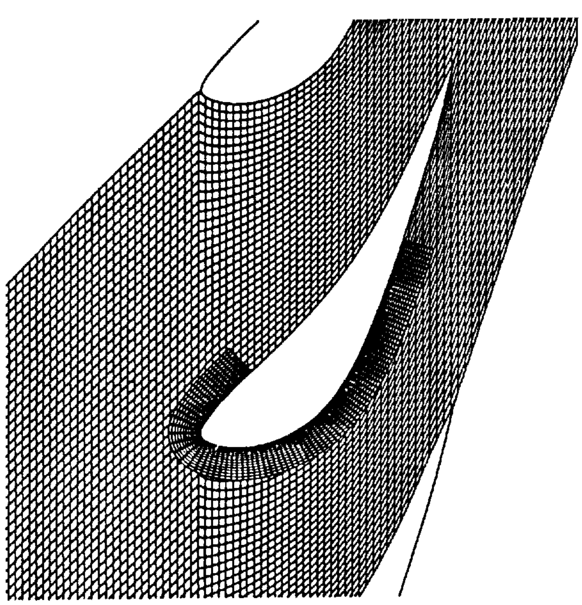


10th Standard Configuration, Subsonic Flow Conditions
Unsteady Torsion Mode Response

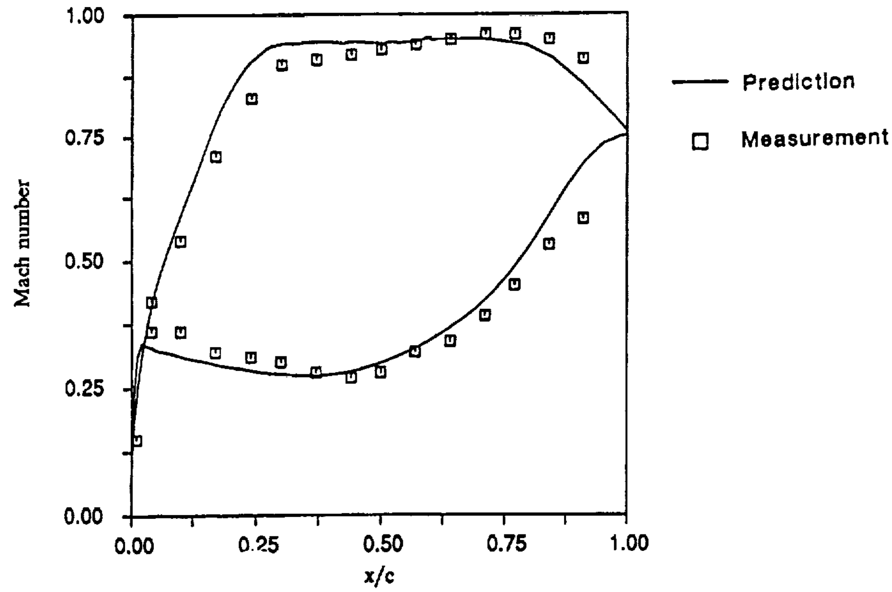
α = 1.0, ω = 0.24 σ = 180 deg



Standard Configuration Number 4
Turbine Cascade Composite Mesh

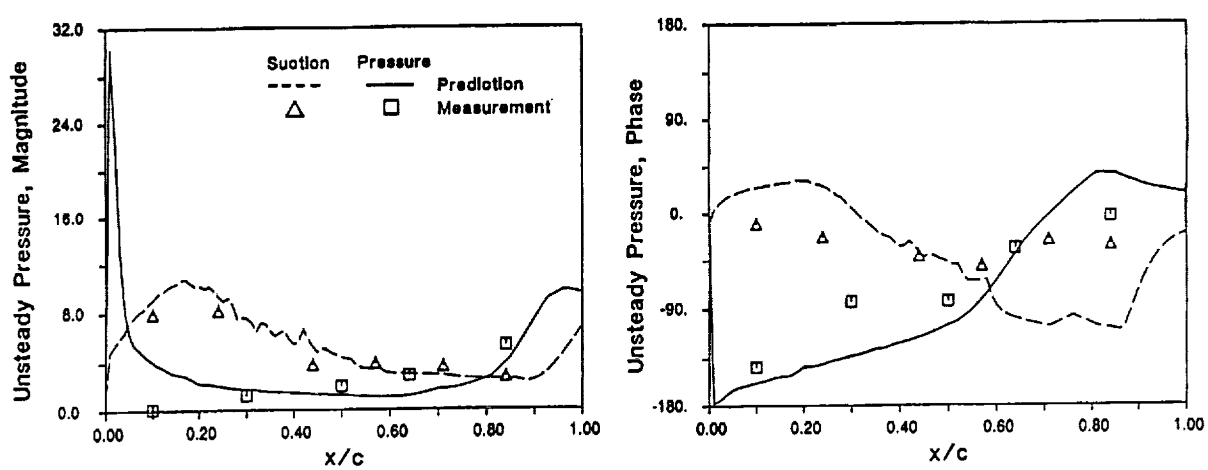


Standard Configuration Number 4
Steady Surface Mach Number Distribution



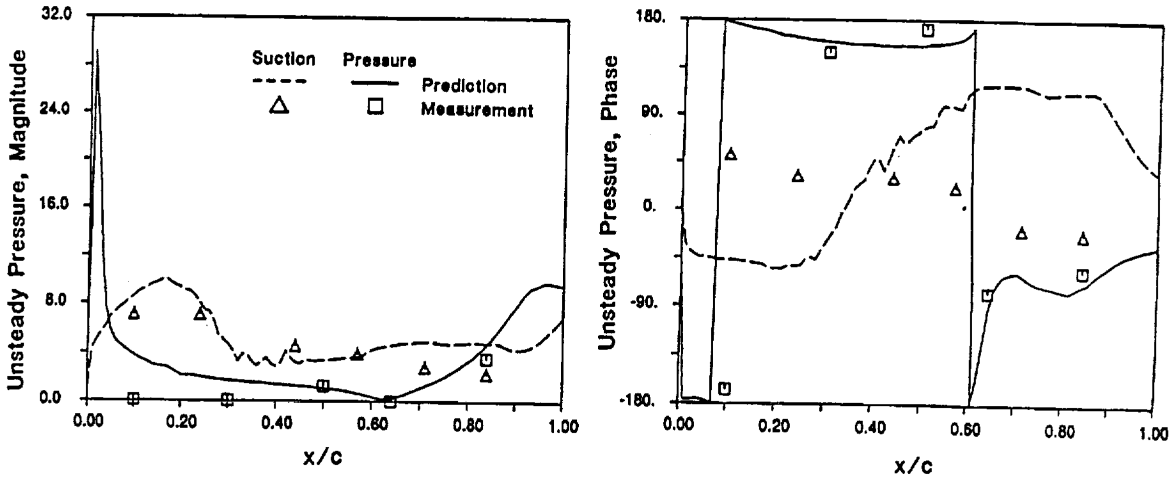
Standard Configuration Number 4
Unsteady Aerodynamic Response

h = (0.0016,0.0029), ω = 0.24, σ = -90 Deg

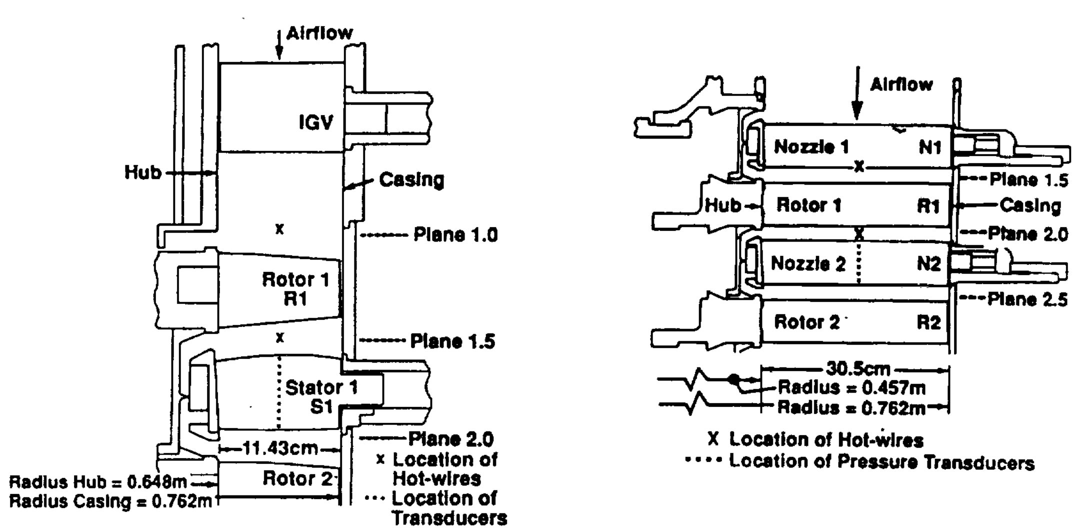


Standard Configuration Number 4
Unsteady Aerodynamic Response

h = (0.0016,0.0029), ω = 0.24, σ = 90 Deg



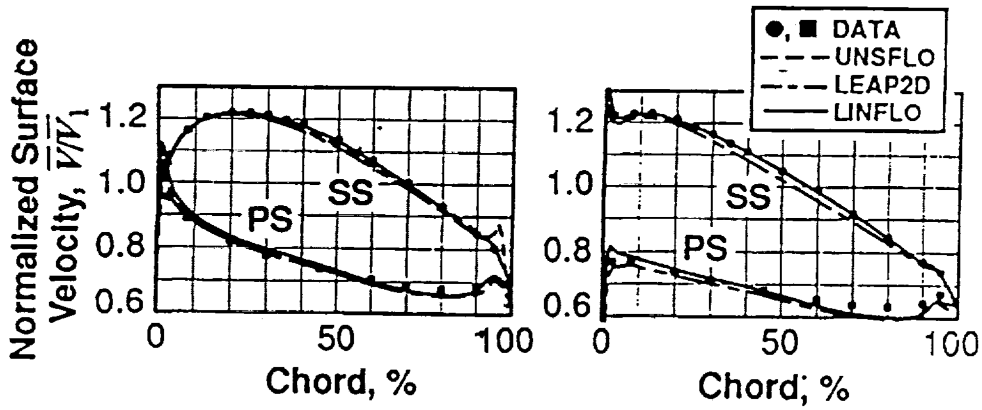
GE Low Speed Research Compressor & Turbine Configurations



Compressor Test Rig

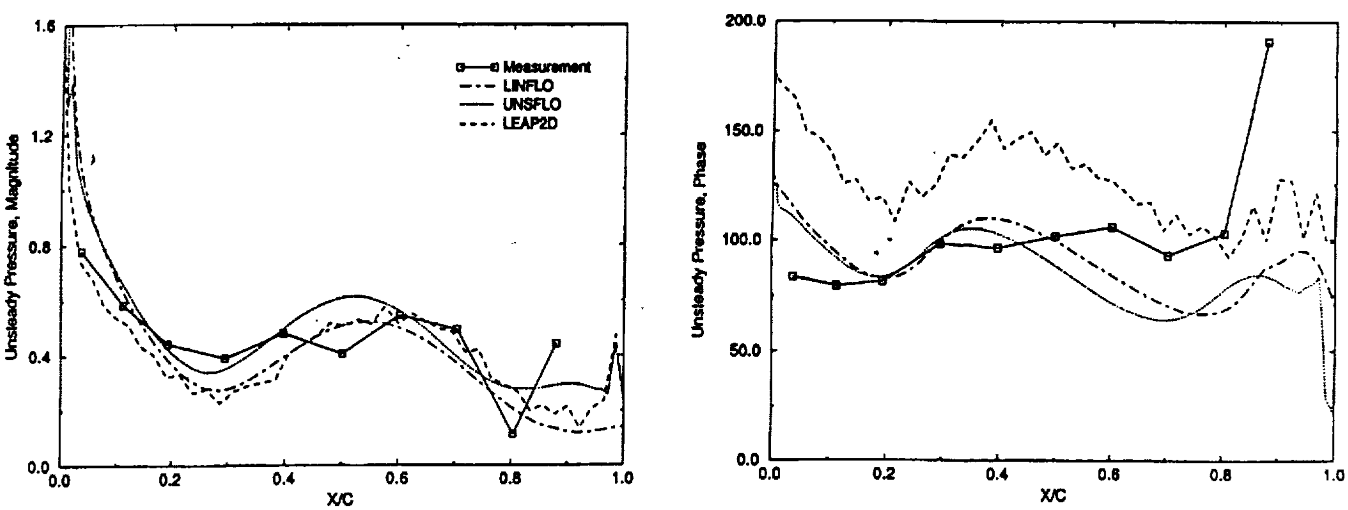
Turbine Test Rig

GE Low Speed Research Compressor
Steady Blade Loading

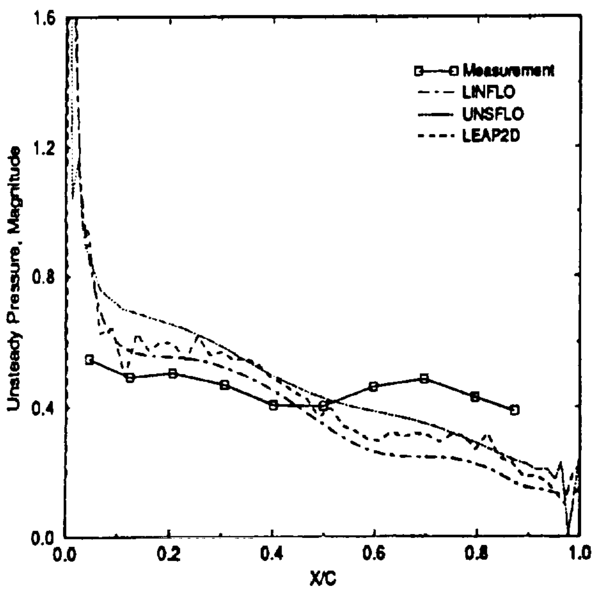


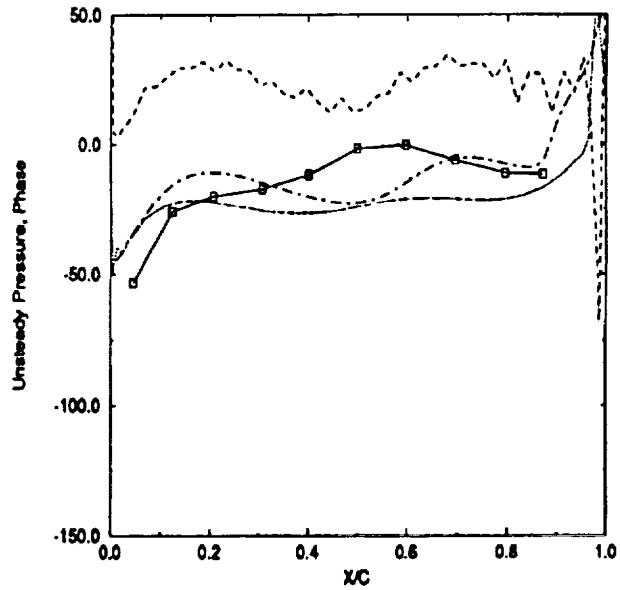
a) Design Point (DP) b) High Loading (HL)

GE Low Speed Research Compressor
Design Point, Suction Surface

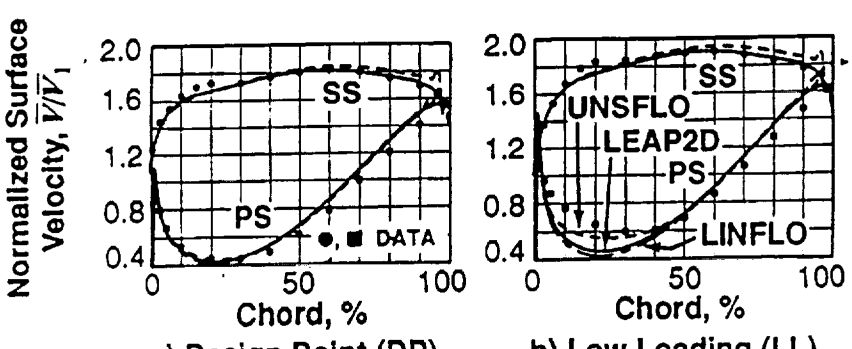


GE Low Speed Research Compressor
Design Piont, Pressure Surface

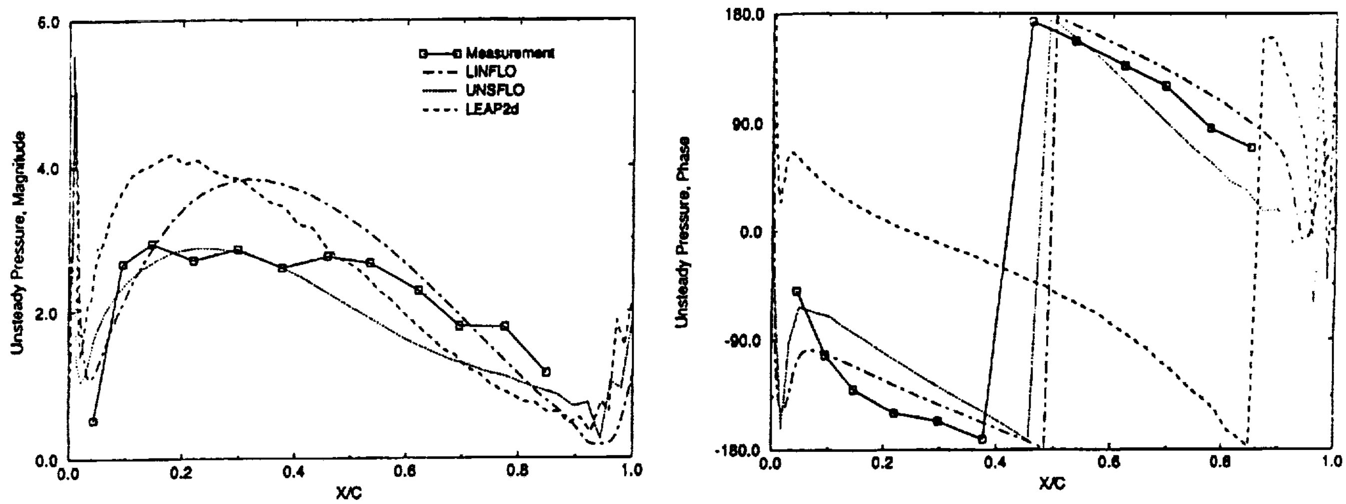




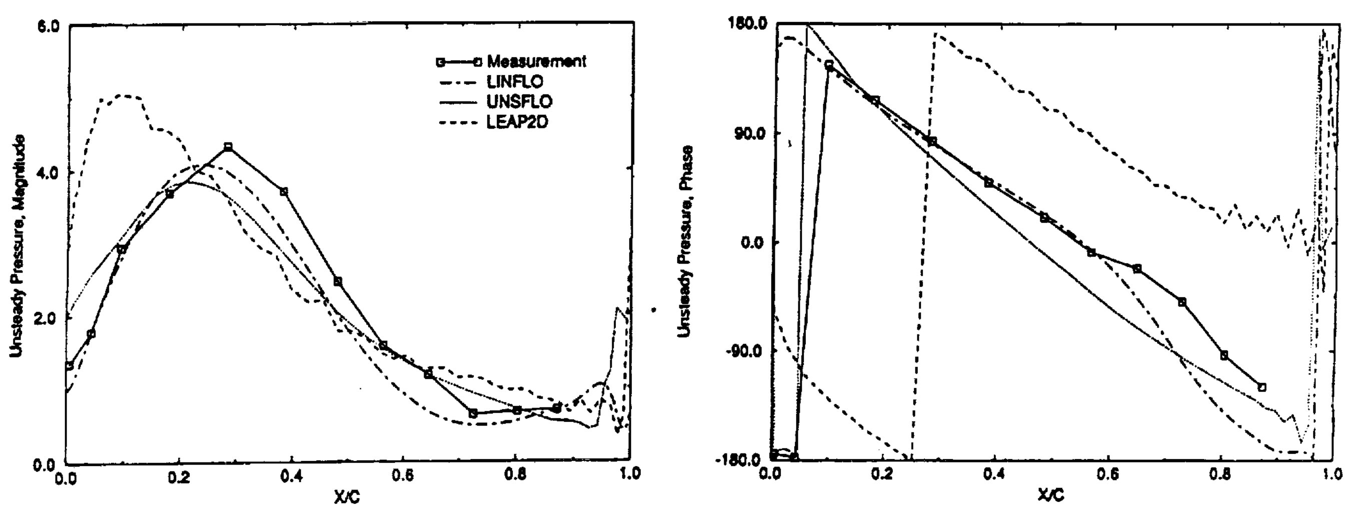
GE Low Speed Research Turbine
Steady Blade Loading



GE Low Speed Research Turbine
Design Point, Pressure Surface



GE Low Speed Research Turbine
Design Point, Suction Surface



Transonic Flow Calculations

- Artificial viscosity added using rotated difference scheme of Jameson
- Dissipation coefficient based on local Mach number
- Modified Newton's method used to solve resulting equations

Modified Newton' Method for Transonic Flow Calculations

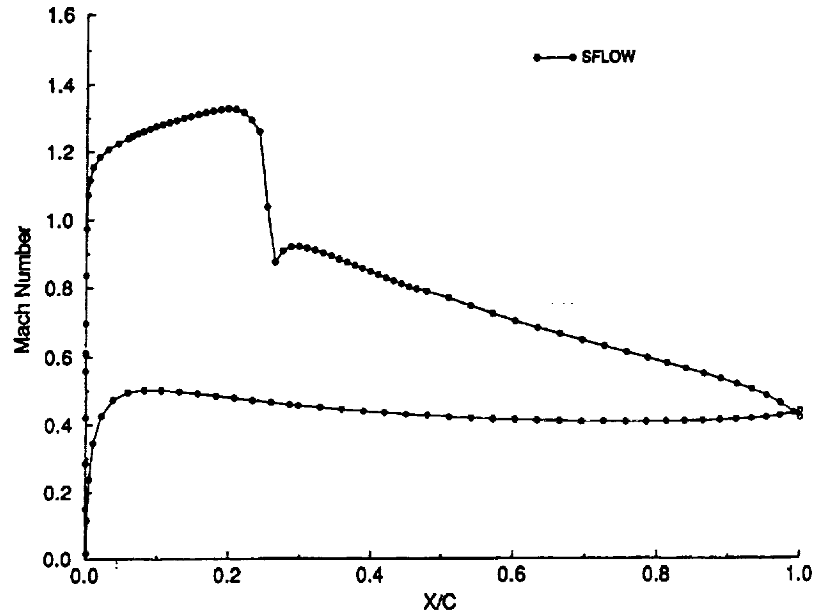
$$[A(\Phi)]\{\phi\} = \{b(\Phi)\}$$

$$\Phi(\vec{X})^{n+1} = \Phi(\vec{X})^{n} + \omega\phi(\vec{X})^{n}$$

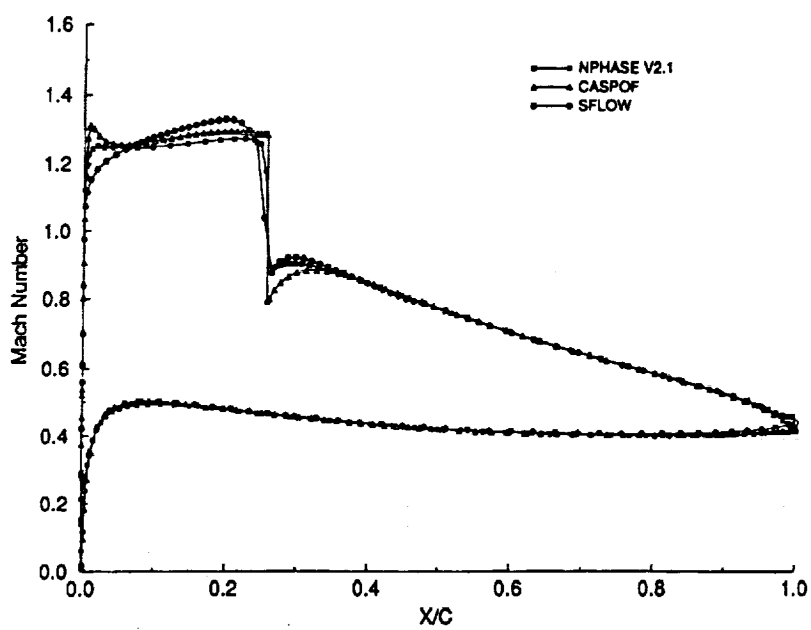
Convergence Criterion

$$|\phi(\vec{X})^{n}| < \varepsilon$$

10th Standard Configuration,Transonic Flow Conditions
$M_{-\infty}$= 0.8, $\Omega_{-\infty}$=58 deg.



10th Standard Configuration,Transonic Flow Conditions
Comparison with NPHASE & CASPOF Results
$M_{-\infty}$= 0.8, $\Omega_{-\infty}$=58 deg.



Summary

- 10^{th} standard configuration predictions show good agreement with other flow solvers
- 4^{th} standard configuration turbine predictions show good agreement with the magnitude of measured data, however there are some problems with phase near trailing edge on suction surface
- GE low speed research compressor and turbine predictions show reasonable agreement with magnitude and phase measurements
- Transonic solution progressing, needs better model for artificial viscosity near shock, and mesh clustering capability