

AERODYNAMIC DESIGN AND ANALYSIS OF A HIGHLY LOADED TURBINE EXHAUST VOLUTE MANIFOLD

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The aerodynamic design and analysis of a turbine exhaust volute manifold is described. This turbine exhaust system will be used with an advanced gas generator oxidizer turbine designed for very high specific work. The elevated turbine stage loading results in increased discharge Mach number and swirl velocity, which along with the need for minimal circumferential variation of fluid properties at the turbine exit, represent challenging volute design requirements. The design approach, candidate geometries analyzed, and steady state / unsteady CFD analysis results are presented.

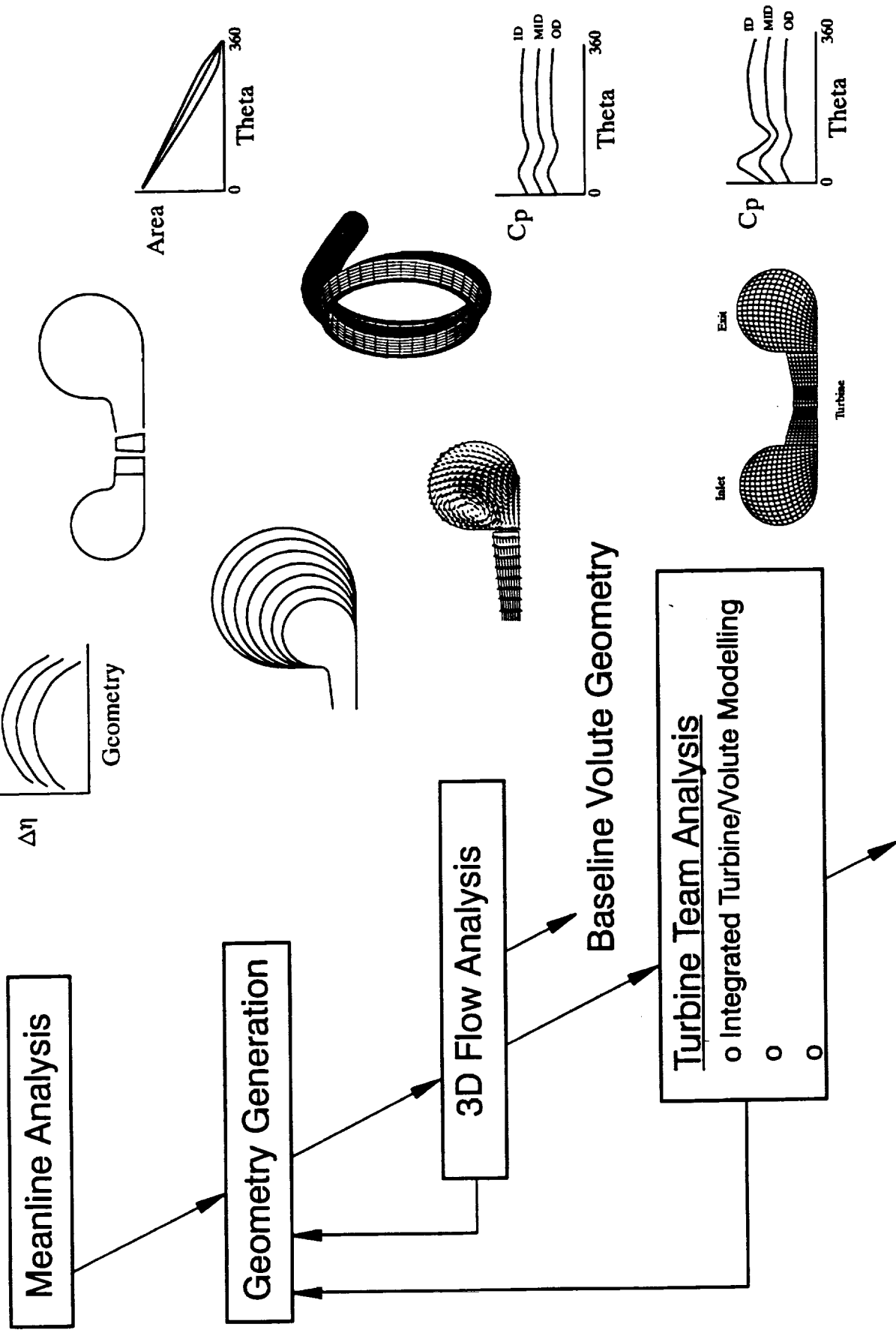
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MSFC Turbine Stage Technology Team

- **Team consisting of turbine specialists from government, industry, and universities committed to advancing the state-of-the-art of turbine design**
- **Effort directed at applying advanced computational fluid dynamics (CFD) codes and capability to the turbine design process**
- **Team focused on turbines meeting STME requirements**
- **Enhanced design / analysis tools available for future application**

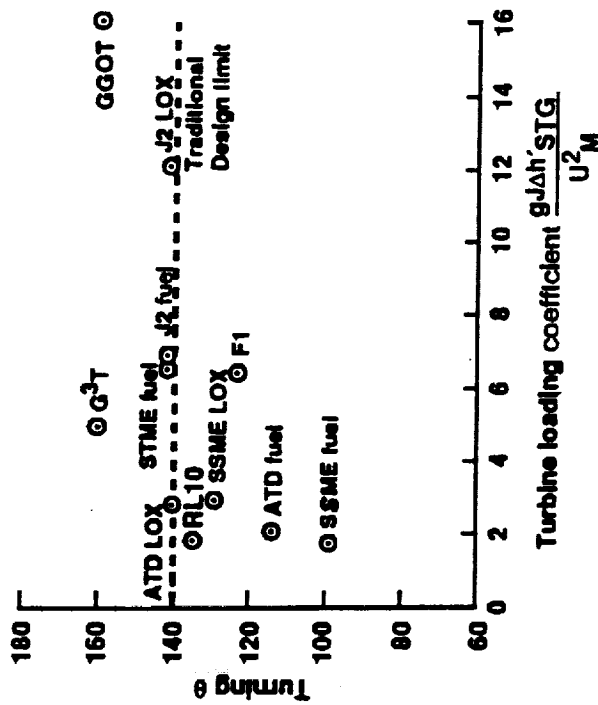
Volute Design Process Outline



Exhaust Volute Manifold Design Requirements

High Turbine Stage Loading Creates Challenging Goals

Turbine Stage Loading Summary



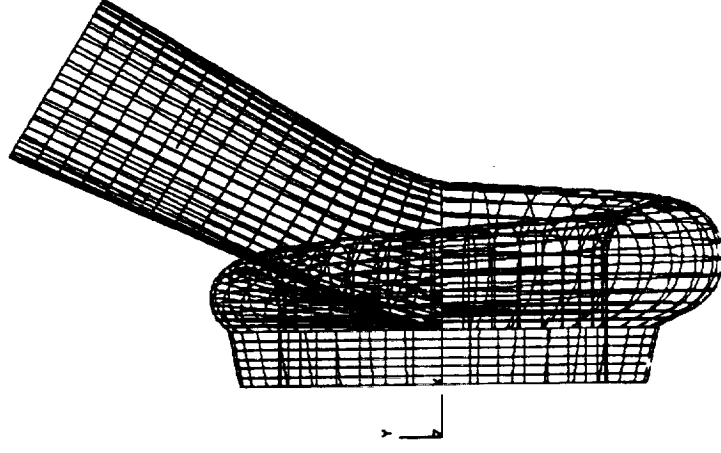
Exhaust Manifold Requirements

- Inlet Mach No. = 0.84
- Exit Mach No. = 0.3
- Minimize Transverse Press. Gradient
- Minimize Total Press. Loss

Meanline Analysis

First Pass Estimate of Geometry and Performance

- **Major Geometric Features Modeled**
 - **Distribution of Thru-Flow Area**
 - **Mean Flow Path Radius**
 - **Inlet and Exit Flow Paths**
 - **Surface Roughness**
- **Pressure Loss Estimate**
 - **Wall Friction**
 - **Secondary Flows in a Turning Passage**
 - **Diffusion**
 - **Tongue Incidence**
 - **Flow Path Dump**
- **Parametric Studies**
 - **Performance Optimization and Sensitivity**

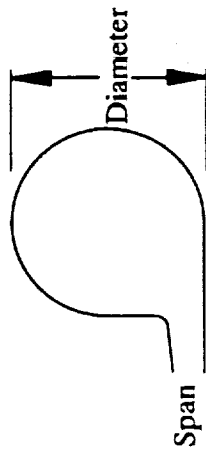


Geometry and Mesh Generation

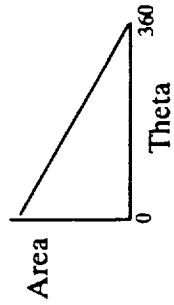
Rules Based Design Program Used To Create Volute Geometry

INPUT:

2D Definition



Area Distribution

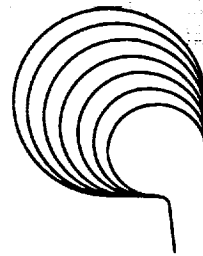


o Number of Sections Required

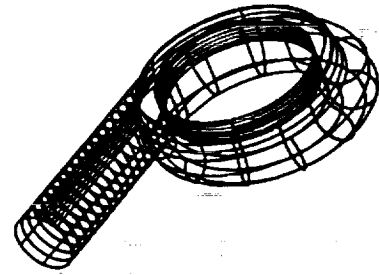
o CW/CCW Development

OUTPUT:

2D Contours

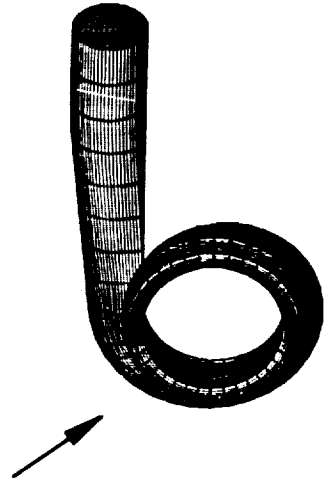


3D Surfaces



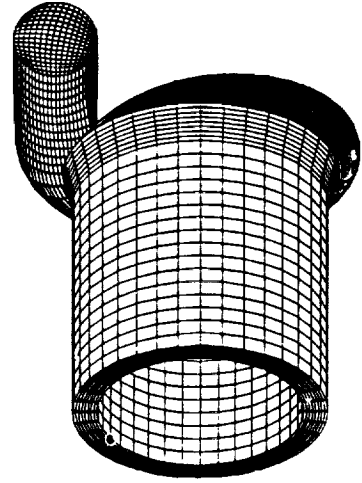
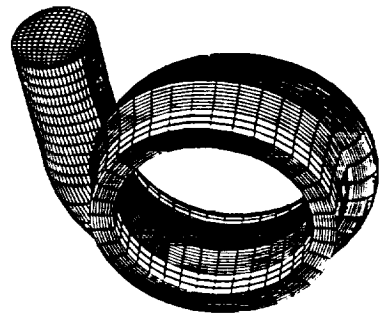
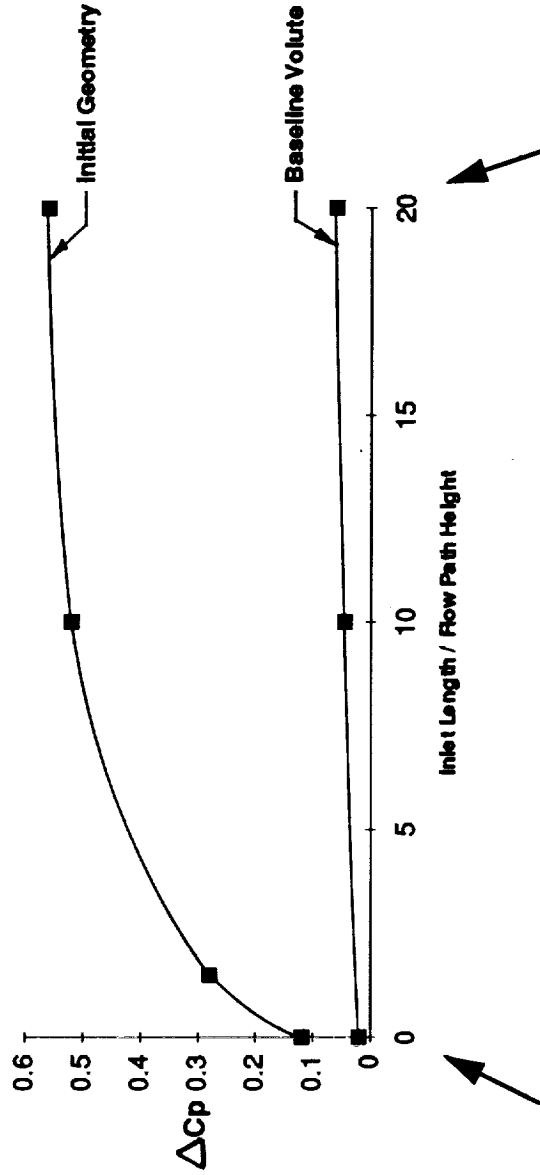
o CAD File for Geometry Enhancements

o Bulkpoint File For Mesh Generator



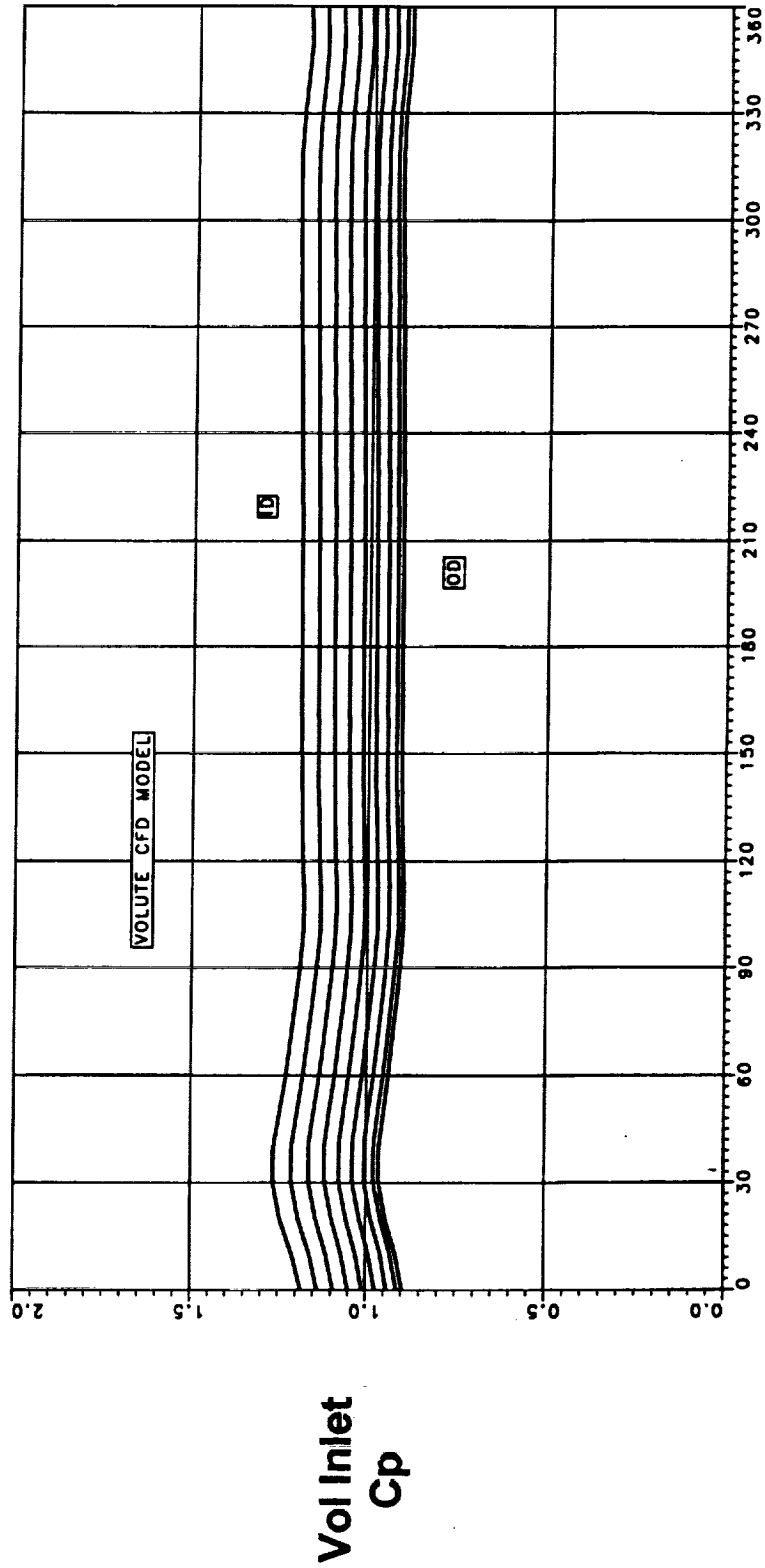
Exhaust Manifold 3D Flow Analysis Inlet Boundary Condition Sensitivity Assessment

Effect of Inlet Length on Calculated Transverse Gradient



Baseline Volute 3D Flow Analysis Circumferential Static Pressure Distribution

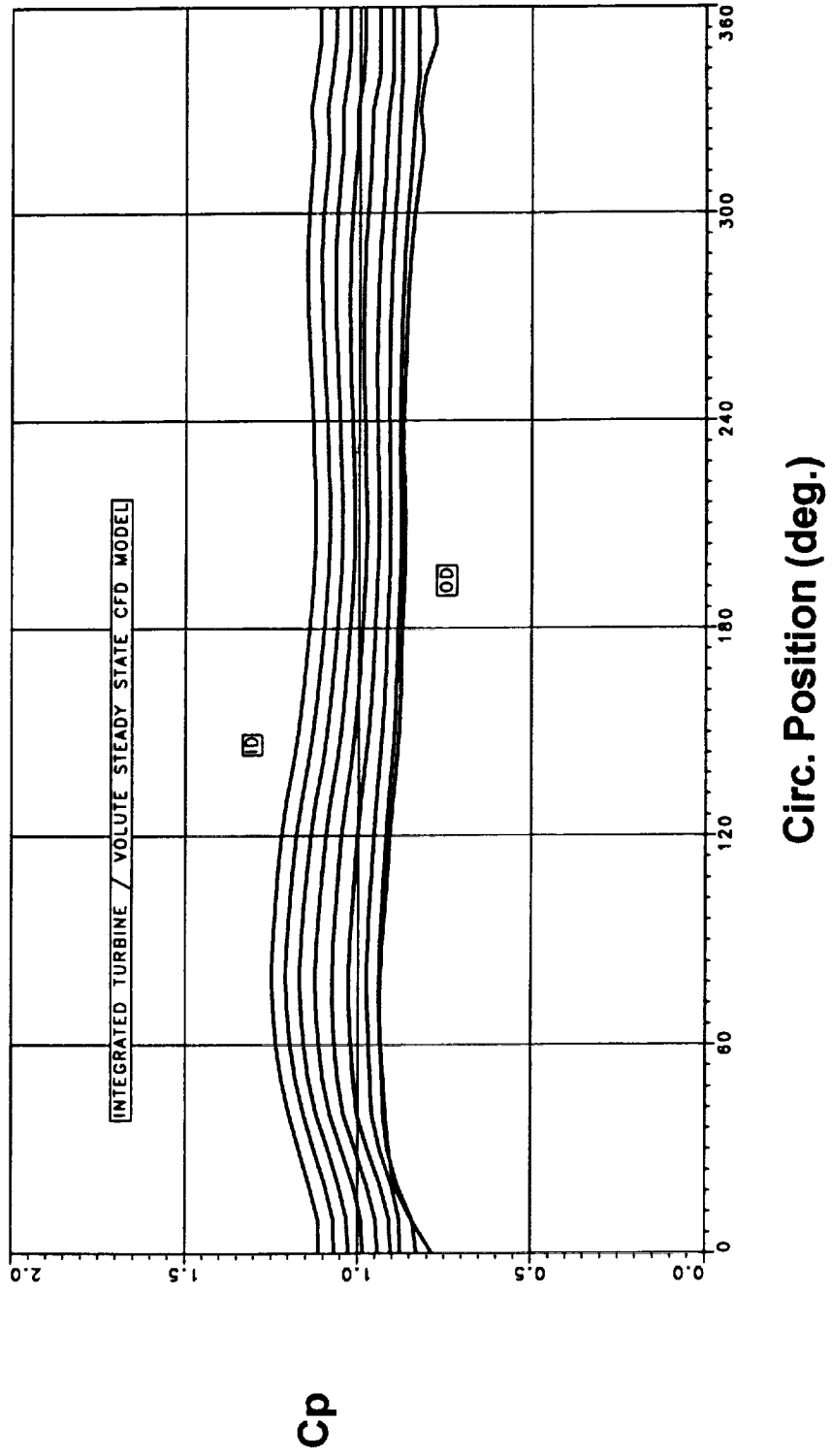
Steady State Model with 20:1 Inlet



Circ. Position (deg.)

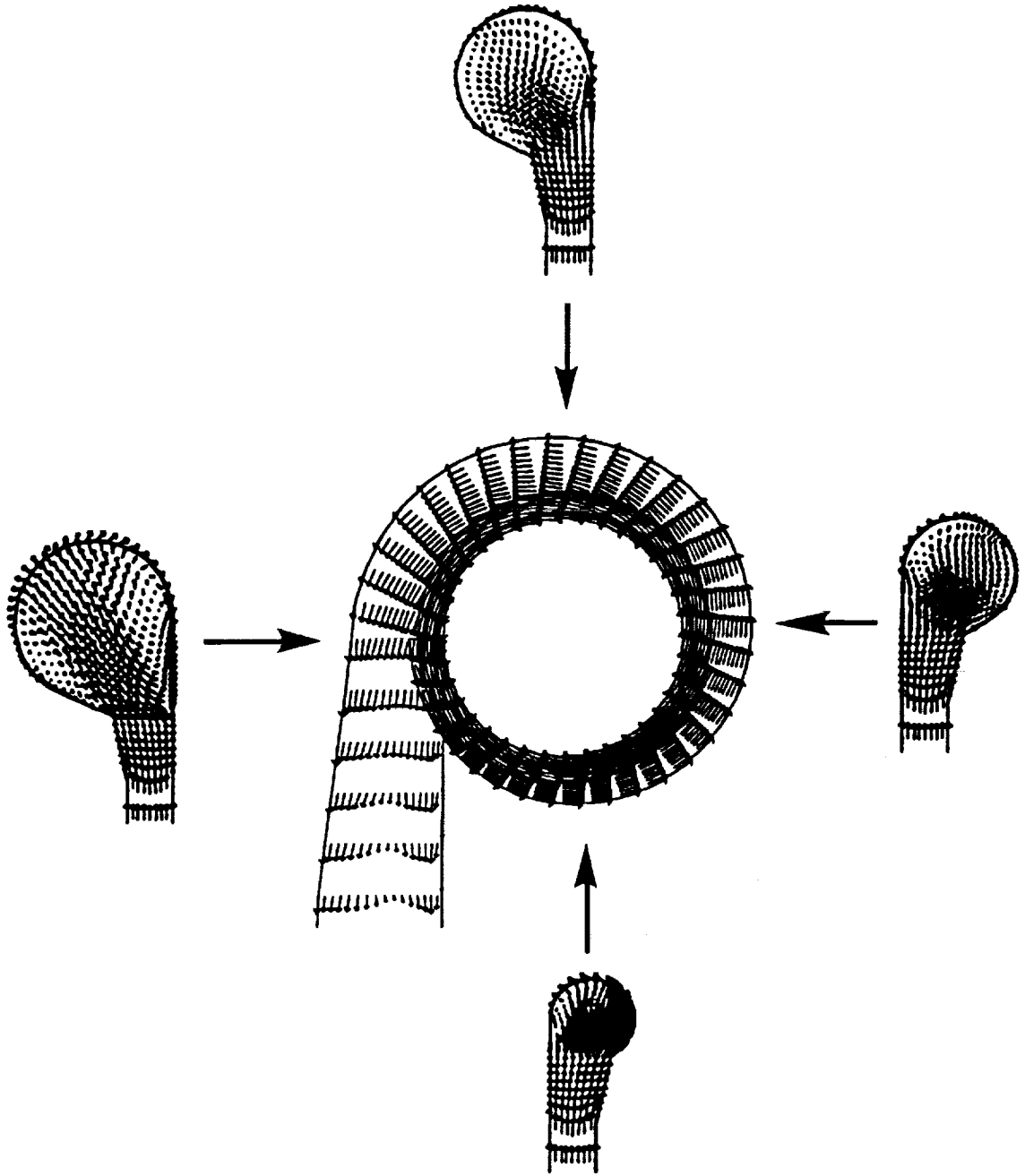
Integrated CFD Modeling of Components Circumferential Static Pressure Distribution at Turbine / Exhaust Man. Interface

Steady State Model of Inlet Volute, Turbine Stage and Exhaust Manifold

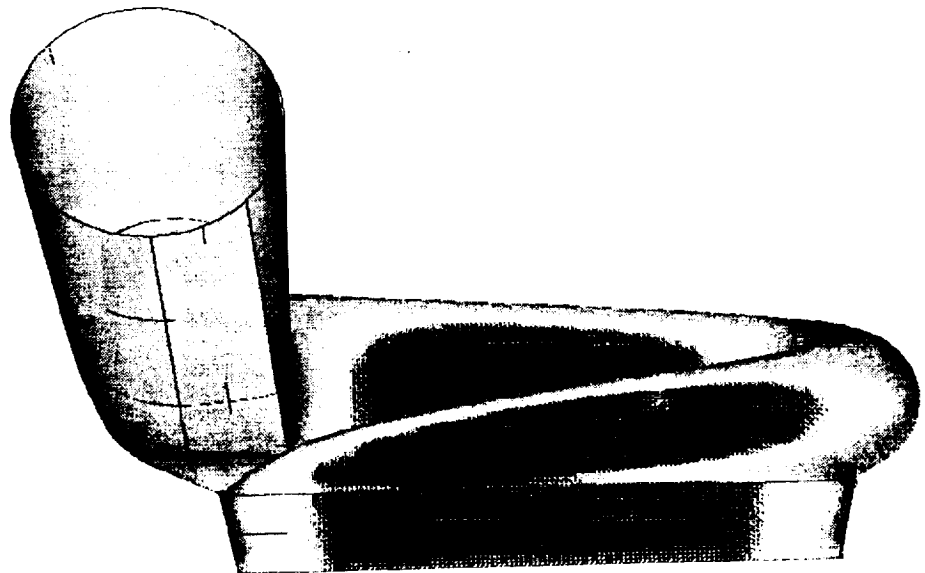
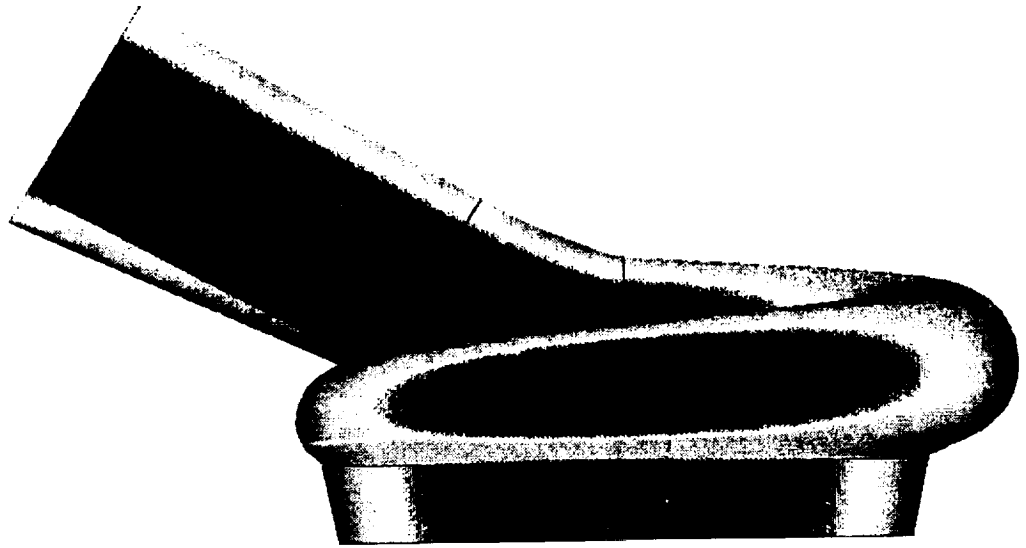


Exhaust Manifold 3D Flow Analysis

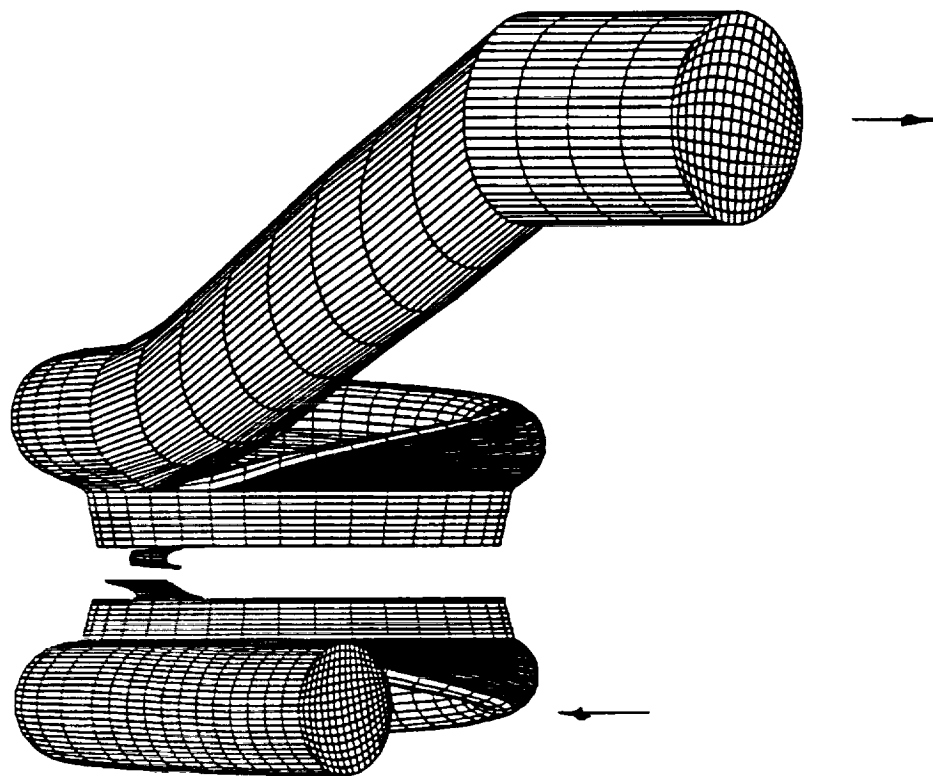
Baseline Volute Flow Vectors



Baseline Volute

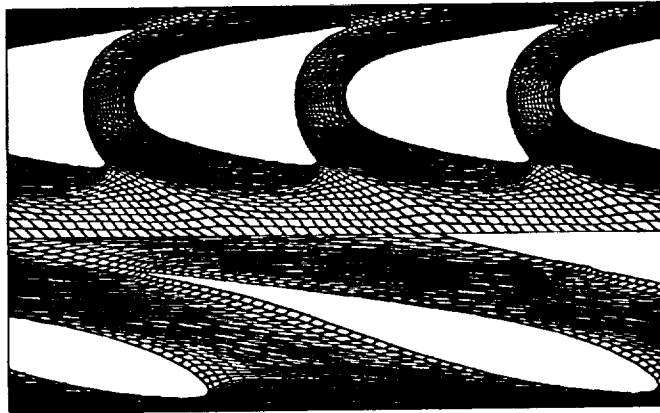


Integrated CFD Modeling of Components Computational Mesh for Inlet Volute, Turbine Stage and Exhaust Manifold

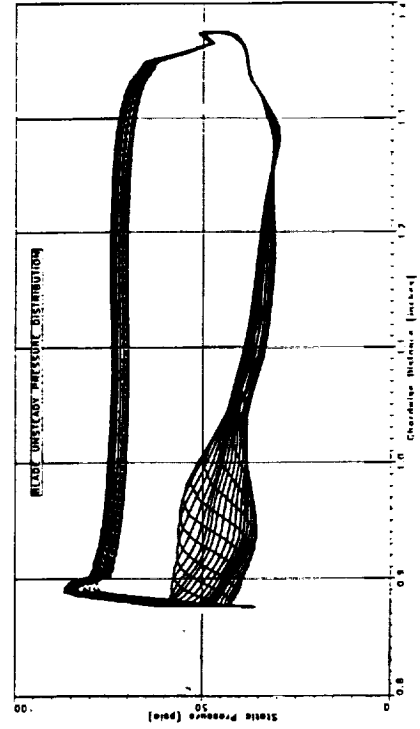
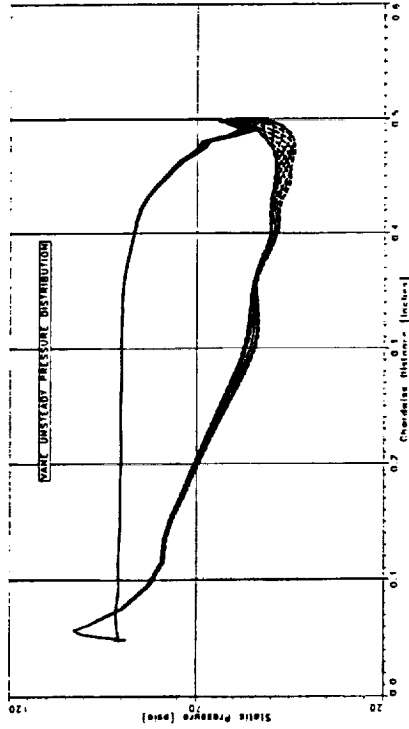


Time Accurate 3D Turbine Stage Flow Analysis Euler (w / shear), 20 Vanes, and 42 Blades

Computational Grid

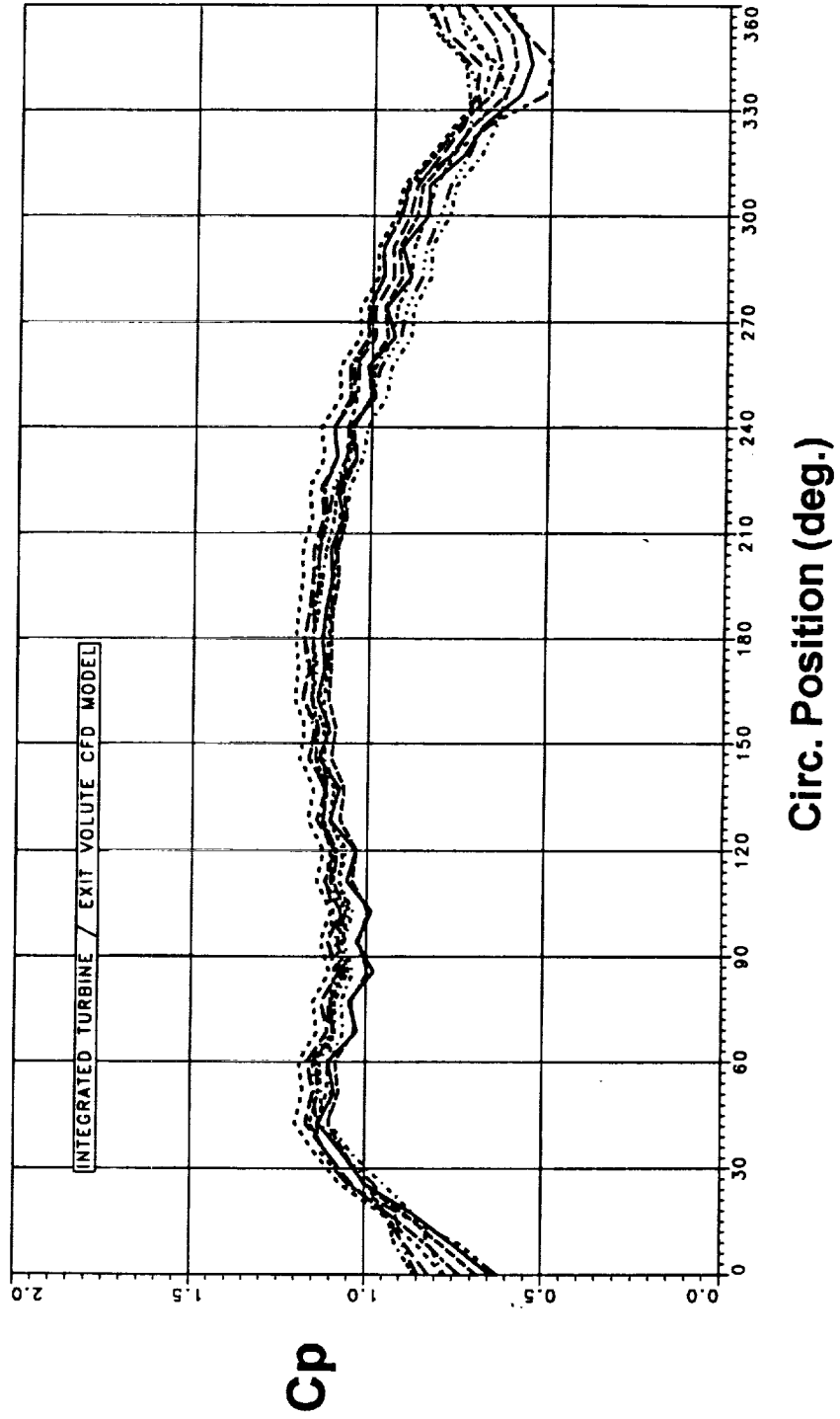


Unsteady Pressure Dist.



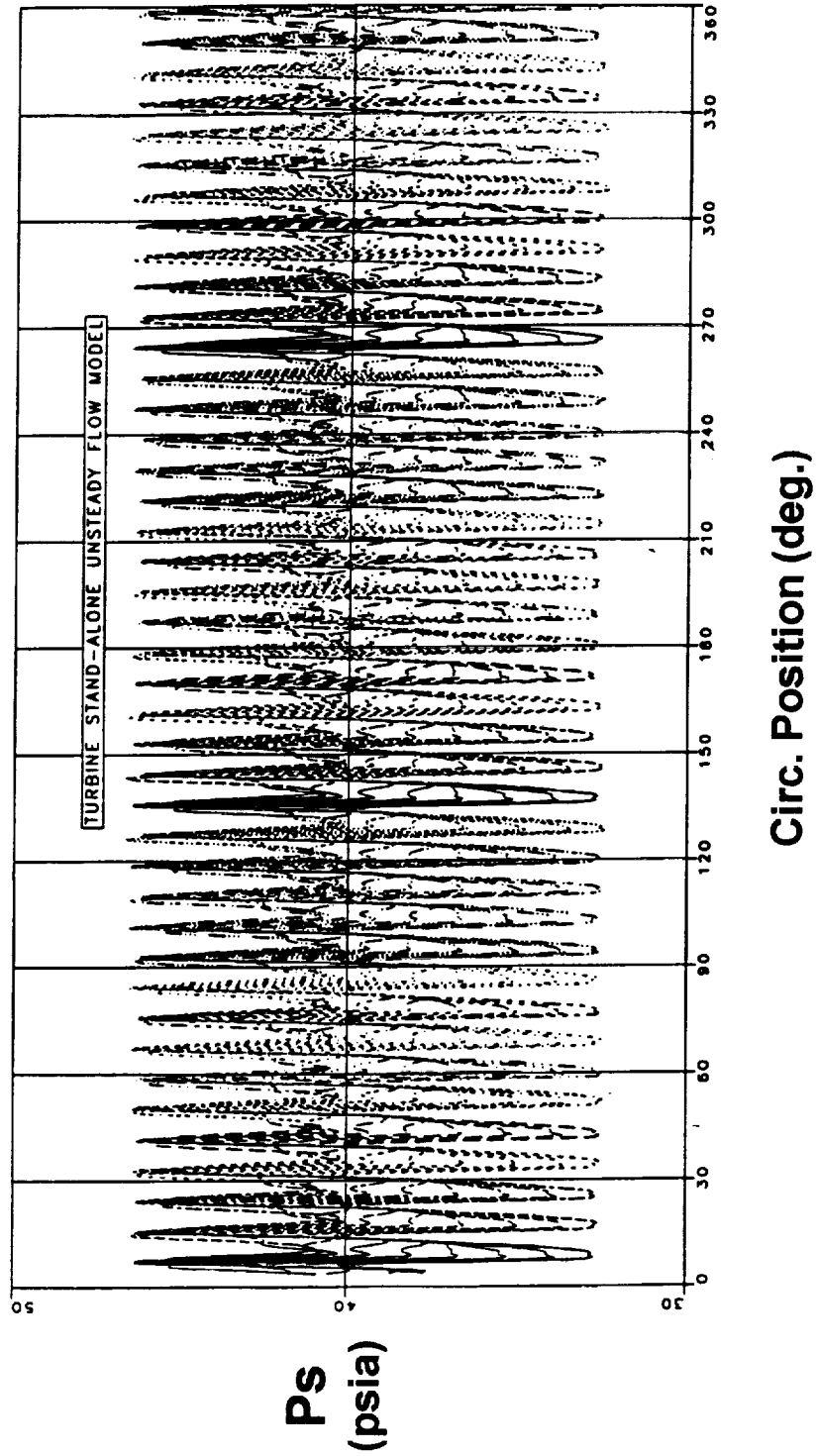
Integrated Time Accurate CFD Modeling of Components Turbine Stage (20 Vanes, 42 Blades) and Exhaust Manifold (42 Elements)

Time Averaged Circ. Static Pressure Distribution at Turbine Exit



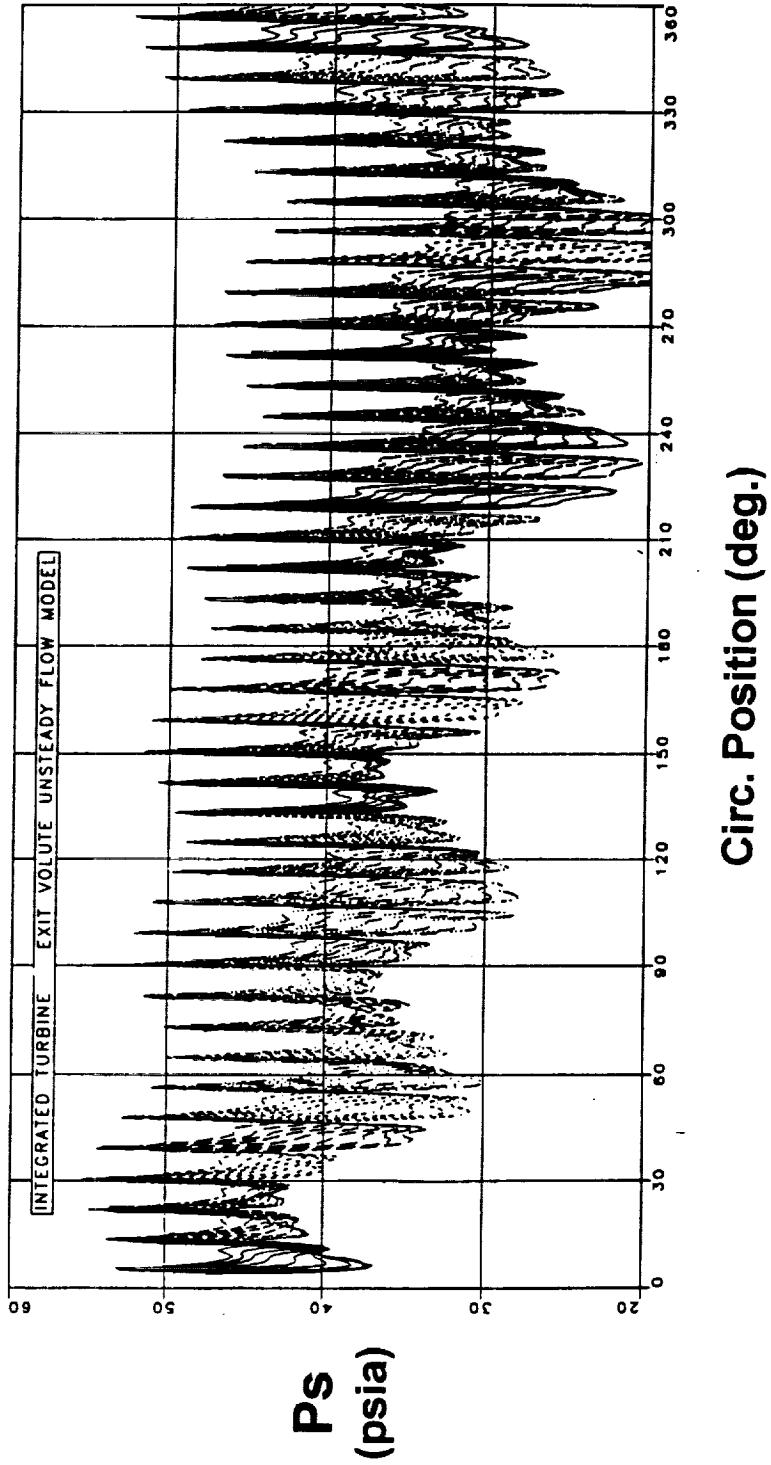
Time Accurate 3D Turbine Stage Flow Analysis Euler (w / shear), 20 Vanes, and 42 Blades

Instantaneous Circ. Static Pressure Distribution at Turbine Exit



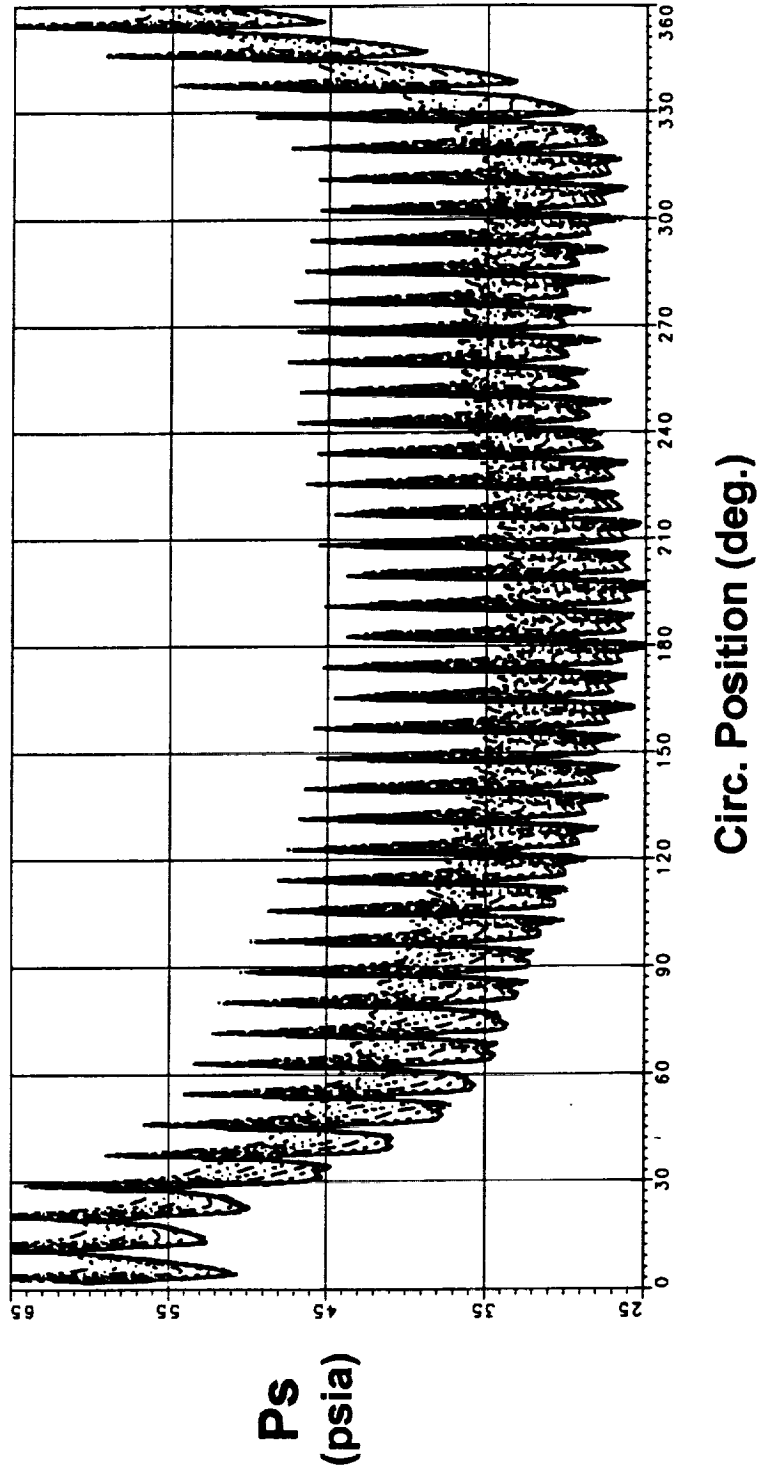
Integrated Time Accurate CFD Modeling of Components
Turbine Stage (20 Vanes, 42 Blades) and Exhaust Manifold (36 Elements)

Instantaneous Circ. Static Pressure Distribution at Turbine Exit



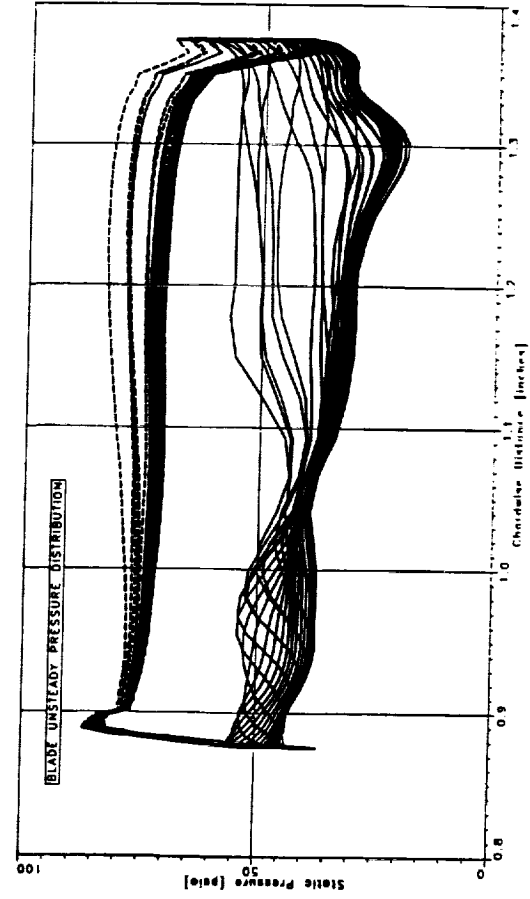
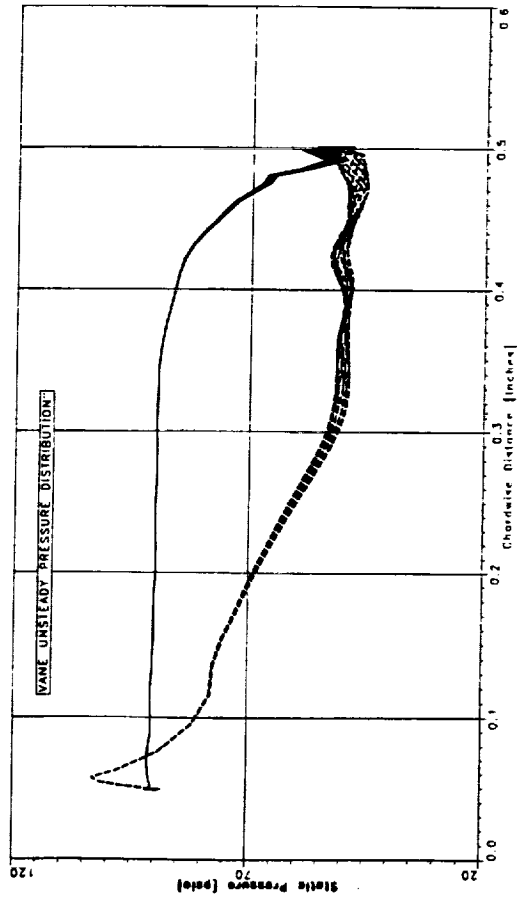
Integrated Time Accurate CFD Modeling of Components
Turbine Stage (20 Vanes, 42 Blades) and Exhaust Manifold (42 Elements)

Instantaneous Circ. Static Pressure Distribution at Turbine Exit



Integrated Time Accurate CFD Modeling of Components Turbine Stage (20 Vanes, 42 Blades) and Exhaust Manifold (42 Elements)

Unsteady Pressure Distributions



Aero Design and Analysis of a Highly Loaded Turbine Exhaust Volute Manifold

SUMMARY

- **Baseline Volute Geometry Defined - Performance Evaluation at MSFC**
- **Efforts Now Focused on Advanced Concepts for Volute Improvement**
- **Time Accurate 3D CFD Model of Turbine Stage / Exh. Volute Manifold Constructed & Running**
- **Early Results Show Large Turbine - Volute Interaction**
- **Results To Be Utilized In Advanced Concept Definition**

